Research has shown possible risk factors associated with a greater incidence of sports-related concussion and varying recovery patterns. This study examined athletic positions, gender, and previous history of concussion to investigate the risk factors of sustaining a concussion and of affecting an athlete’s recovery. Results are as follows: football players in offensive positions have a greater risk for sustaining a concussion than those in defensive positions; there is no difference in the severity of the concussions or in the rate of recovery between offensive and defensive football players; athletes in non-contact sports are more at risk for a concussion than those who participate in contact sports; each concussion an athlete sustains increases the risk of sustaining a future concussion by 50%; if an athlete has sustained three or more prior concussions, it is probable that more symptoms will accompany each subsequent concussion; male athletes have more symptoms than female athletes.
ASSESSMENT OF RISK FACTORS IN SPORTS-RELATED CONCUSSION:
INCIDENCE RATE AND RECOVERY PATTERNS

A Thesis
Submitted to the
Faculty of Miami University
in partial fulfillment of
the requirements for the degree of
Masters of Arts
Department of Speech Pathology and Audiology
by
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Miami University
Oxford, Ohio
2007

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ACKNOWLEDGMENTS

I would like to extend my thanks to Dr. Constantinidou for being an outstanding advisor, teacher, and friend when guiding and supporting me through not only this project, but also my academic career at Miami University. I began my research career four years ago with Dr. Constantinidou and she has continually challenged me and encouraged me to stretch my limits.

I would also like to thank the readers on my committee, Dr. Brett Massie and Mrs. Anne Marie Kubat. Without the support and cooperation of each committee member this thesis would not have been possible. I thank Dr. Massie for his eagerness to participate in this project as well as for providing excellent suggestions on the topic of sports concussions. My appreciation is extended to Mrs. Kubat who provided support, encouragement, and insight throughout this process.

I must express my gratitude to all of the athletes who participated in this study, especially to those who underwent multiple assessments due to sustaining concussions. A special thanks goes to the graduate students in the Speech Pathology and Audiology Department who contributed to this study by assessing the athletes for baseline data.

Lastly, I would like to sincerely thank my family and friends for supporting me throughout my entire graduate school career, which has been by far my most challenging journey yet.
ASSESSMENT OF RISK FACTORS IN SPORTS-RELATED CONCUSSION:
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Chapter 1
Introduction and Review of the Literature

Incidence of Sports-Related Concussion

An approximate 300,000 sports-related traumatic brain injuries occur in the United States each year. Most of these traumatic brain injuries are of mild severity and therefore are classified as concussions (Lovell, Bradley, Collins, & Burke, 2003). Worldwide, competitive sports participation has increased, and approximately 5-10% of athletes are sustaining concussions annually (Zillmer, Schneider, Tinker, & Kaminaris, 2006). Conversely, anyone associated with the athletic field knows that the “true” rate of concussion is much higher. Zillmer et al. (2006) found that when asked, 70% of athletes report having experienced concussion symptoms. The incidence of concussion is high in sports; however, risk factors such as history of concussion, gender, and field position are associated with higher rates of concussion.

Symptoms of Concussion

Acute psychological, cognitive, and motor difficulties often result from sports-related concussions. These impairments may have an immediate or gradual onset and can include deficits in coordination, balance, reasoning, concentration, attention, and memory. Other symptoms of mild traumatic brain injury can be confusion, amnesia, vacant stare, delayed verbal or motor responses, disorientation of time and place, incoordination, incoherent speech, and alterations of consciousness (Dodick, 2001). Athletes may experience anywhere from a few mild symptoms to many severe symptoms, but the bottom line is that athletes can present with any combination of these symptoms. Some symptoms may be delayed in onset, such as depression, fatigue, sleep disturbance, irritability, and feeling mentally “foggy” (Maroon et al., 2000).

Collectively, any symptoms experienced after a concussion have been termed postconcussion syndrome (Zillmer et al., 2006). Complete recovery from concussion is possible if proper management occurs. However symptoms can persist for days, weeks, or even months if an athlete returns to play before the symptoms have subsided. Symptoms of concussion can cause an athlete to struggle with academics, activities of
daily living, and emotional welfare. If a structured and supervised rehabilitative protocol is conducted, and the right precautions are taken, an athlete who sustains a sports concussion can have a successful return to play (Solomon, Johnston, & Lovell, 2006).

**Definition of Concussion**

Concussion is the behavioral consequence of a traumatic brain injury (TBI) or closed head injury. Approximately 90% of sport-related concussions are mild and therefore referred to as mild traumatic brain injuries (mTBI) (Solomon et al., 2006). There has been no universal agreement on the definition of concussion and many definitions have been proffered through the years by neurosurgeons, neurologists, orthopedic surgeons, and multidisciplinary groups. Although many of the definitions have been similar, some researchers have viewed the lack of agreement on a definition as a barrier to more progress in this area (Solomon et al., 2006). Many professionals are working on formulating a complete consensus definition of concussion because the definition impacts identification, diagnosis, case conceptualization, treatment, recommendations, and research (Ruff & Jurica, 1999).

At the First International Symposium on Concussion in Sport, physicians, therapists, allied health professionals, coaches, and others involved in the care of injured athletes met to provide recommendations for the improvement of safety and health of athletes. This conference was held in Vienna, Austria, and the outcome of the conference was a document that proposed a consensus definition. Aubry et al. (2002) defined concussion as follows:

Sports concussion is defined as 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 the following:

1. Concussion may be caused by a direct blow to the head, face, neck, or elsewhere on the body with an “impulsive” force transmitted to the head.
2. Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously.
3. Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury.

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.

5. Concussion is typically associated with grossly normal neuroimaging studies (McCrory et al., 2005, p. 196).

In 2004 the Second International Symposium on Concussion in Sport was held in Prague, Czech Republic. No changes were made to this definition by the Prague Group beyond noting that post-concussive symptoms may be prolonged or persistent in some cases (McCrory et al., 2005).

Although the above definition is often recommended as the most current and agreed upon by many in the sports medicine field, there are numerous other definitions that appear in the professional literature. Many people agree that Gronwall (1991) expressed the full concept of concussion well when he stated:

- Basically, however, an MHI [minor head injury] is defined negatively; it is one that is not severe, that is at the opposite end of the continuum from the very serious. It is also an injury in which head trauma is not followed by abnormal neurological signs, though it can be and often is followed by complaints of headache, poor memory, impaired concentration, vertigo, irritability, sensitivity to light and noise, and easy fatigue (p. 254).

Webbe agreed with the above definition, but new information about concussion has been exposed since Gronwall proposed his definition. Webbe (2006) and his colleagues developed a working definition that reads as follows:

- Cerebral concussion is a closed head injury that represents a usually transient alteration in normal consciousness and brain processes as a result of traumatic insult to the brain. The alterations may include loss of consciousness, amnesia, impairment of reflex activity, and confusion regarding orientation. Although most symptoms resolve within a few days in the majority of cases, some physical symptoms such as headache, and cognitive symptoms such as memory dysfunction, may persist for an undetermined time (p. 48).
This definition includes the fact that physiological and morphological changes may continue for many days or weeks following a concussion.

**Historical Perspective of Concussion**

Since the beginning of sport there has always been serious risk of head injury, but the effects of concussion have not always been recognized. Mythological literature and ancient medical reports reference head injury numerous times. Homer’s *Iliad* and *Odyssey* both include characters who died following head injuries. There are accounts of athletic head injuries from the ancient Greek and Roman culture, through the middle ages, 18th, 19th, and 20th centuries up until the present (Zillmer et al., 2006). It was in the 20th century when the vast frequency of head-to-head collisions between football players called into question the safety of the sport and highlighted an awareness of head injuries in sports.

Although the sport had its beginnings in 1869, football helmets weren’t available until 1893, and when first provided were not particularly effective (Zillmer et al., 2006; Cantu & Mueller, 2003). President Theodore Roosevelt had threatened to ban American football in 1904 because of its harsh brutality and because no other sport had been associated with so many deaths. In 1904 nineteen football players were paralyzed or killed, and that spurred the birth of the National Collegiate Athletic Association (NCAA) to establish guidelines for safer athletic competition (Cantu, 1997). In 1931 the American Football Coaches Association started the annual Football Fatality Report (Clarke, 1998). Between the years 1931 and 1975 there was still an average of 18.9 fatal football brain injuries per year (Zillmer et al., 2006). Even with the decrease of football fatalities, in the 10 year span between 1973 and 1983, concussion-related deaths in American football were greater in number than the combination of all other competitive sports (Cantu, 1997).

Through the years there has been an increased awareness of the potential long-term effects of sports concussions. This increased awareness has resulted in greater emphasis on providing better protection to athletes. Protection includes rules and regulations, as well as specific equipment standards, resulting in improved helmets, mouth-guards, and other face and head protection to reduce the transfer of kinetic energy to the head during an athletic contest (Zillmer et al., 2006). In addition, improved
conditioning and better on-field medical care have dramatically reduced the number of concussion-related deaths since the 1970s (Cantu, 1997).

It wasn’t until the mid 1980s that the perception of sports-related mild traumatic brain injury began to change and the potential severity of mild traumatic brain injury was truly discovered (Lovell, Echemendia, Barth, & Collins, 2004). The interest in sports-related brain injury rapidly emerged in the 1990s because sports concussion forced several prominent athletes into retirement, which in turn received media exposure. Consequently, the sports community began raising concerns about player safety. This caused professional leagues such as the National Hockey League (NHL) and National Football League (NFL) to take a serious interest in sports-related cerebral concussions. The interest at the professional level has cascaded down to the collegiate programs, high school programs, and even recreational programs (Echemendia, 2006b). Neuropsychology has just recently become involved in sports-related cerebral injuries, but neuropsychological evaluation has quickly become the standard for the assessment and management of sports-related concussions.

**Sport-Specific Concussion Incidence Rate**

The incidence rate of concussion does not appear consequential when looking at the total of all athletic injuries sustained during practice and competition. Covassin, Swanik, and Sachs (2003) researched data compiled by the National Collegiate Athletic Association Injury Surveillance System (NCAA-ISS) database over a 3-year period and found that only 6.2% of all college injuries were concussions. Powell and Barber-Foss (1999) completed a similar study using the National Athletic Trainer Association injury surveillance system, and that study found that 5.5% of all injuries in high school athletes were concussions. These two studies represent high school and college Division I, II, and III athletes that participate in football, soccer (men and women), baseball, basketball (men and women), and wrestling as well as several other sports. The relatively low incidence of concussion may explain the lack of surveillance systems and the fact that athletic trainers are not consistently formally and extensively educated in the diagnosis and treatment of concussion (Macciocchi, 2006). However, the rates of concussions vary across sports.
Football

The reported incidence of concussion has decreased significantly and caused inconsistencies in the literature regarding football over the past twenty years (Macciocchi, 2006). These inconsistencies may result from changes in the rules, techniques, and better equipment. For example, many football players previously used the head as the initial point of impact, however now the players are instructed to use the shoulders and chest as the point of contact with another player.

In 1983 researchers found that 24% of all football injuries were classified as concussion, which indicated approximately 200,000 concussions would occur per season in high school football (Gerberich, Priest, Boen, Staub, & Maxwell, 1983). In 1999 Powell and Barber-Foss reported a significantly smaller incidence when they published that an approximate 40,000 concussions would occur per high school football season.

A large scale ($N = 2,300$) study of concussion in college football players found that over a 4-year period the single concussion rate was 7.9% and increased slightly to 8.4% when multiple concussions were included (Macciocchi, Barth, Alves, Rimel, & Jane, 1996). A more recent study including 2,385 high school and college football players revealed a lower rate of concussion with the annual concussion rate at 3.8% (McCrea, Kelly, Randolph, Cisler, & Berger, 2002). Powell and Barber-Foss (1999) conducted a study examining concussion in multiple high school sports and found that football-related concussions account for 63.4% of all concussions. This same study documented the football players’ risk for concussion during any given season to be 3.66%.

A recent study using the NCAA-ISS database supported the notion that football-related concussion rates may be relatively stable rather than increasing (Covassin et al., 2003). In this same study the investigators found that the risk of concussion varies from 6.0% to 7.2% during practice and from 6.7% to 9.3% in actual games. This investigation found that players competing in games had a 10 time greater risk of sustaining a concussion (Covassin et al., 2003).

Soccer

There is no question surrounding the fact that head-to-head, head-to-ground, and head-to-goalpost contact can be the cause of concussion in soccer players. Controversy does however surround the notion that heading a soccer ball can cause a head injury.
There are currently arguments for and against heading as a source of injury (McCrory, 2003). Another issue surrounding concussion in the sport of soccer is that the incidence rate and risk factor for sustaining a concussion may vary depending on gender. This issue is discussed below in the section titled risk factors for concussion.

The same incidence trend of a higher rate of concussions sustained during games rather than practices found in football was found to be true for soccer. Covassin et al. (2003) found that the risk of concussion for practice to be 1.7% annually compared to 7.6% annually in games. The NCAA-ISS found differing concussion rates in games for men soccer players (7%) and women soccer players (11%) (Brooks, 2004).

Hockey

Although the sport of hockey had its beginning in the 1870s, hockey players didn’t begin wearing helmets until the 1970s, consequently reducing the rate of concussions sustained (Davidson & Steinbreder, 1997). However, incidence rates of concussion in professional hockey appear to have increased dramatically over the past five years. Statistics comparing the incidence rates of concussion in male and female hockey players show that, overall, men and women have similar rates of injury (Macciocchi, 2006).

A 3-year prospective study of a Swedish hockey team found that there is concussion risk of 5.3% annually (Lorentzon, Wedren, & Pietila, 1988). In a similar study the annual concussion rate in the same population was found to be 5.0% (Tegner & Lorentzon, 1996). As observed in most other sports, the concussion rate is higher for games as opposed to practice. Covassin et al. (2003) found NCAA hockey players to be 15 times more likely to experience a concussion during a game than during practice. While the concussion rates in hockey players appear to vary between 3% and 5% annually, the use of selected samples and differing reporting formats complicates the interpretation of concussion rates in hockey players (Macciocchi, 2006).

Basketball

In general, the number of studies investigating the incidence of concussion in basketball is limited. The two documented studies in this area indicate that basketball results in a lower rate of concussion than football. Furthermore, Macciocchi (2006) reported a low risk for concussion in both women and men basketball athletes (1.04
concussions per 100 player season exposures and 0.29-0.61 concussions per 100 player season exposures respectively). Consistent with other sports, both men and women basketball players are significantly more likely to sustain concussions during a game than during practice (Macciocchi, 2006).

Risk Factors for Concussion

In the recent years, sports medicine has made a consistent effort to identify risk factors for concussion. The identification of these factors is important to the design of improved protective equipment and to the formulation of regulations that help prevent injuries. In addition, identification of certain risk factors can help to facilitate recovery from injury.

Gender

Despite the lack of research on female athletes, evidence has shown that female athletes are at higher risk for injury than males (Zillmer et al., 2006). One study using the NCAA-ISS found that women were more at risk for concussion than men when playing the game of soccer (Covassin et al., 2003). Another study used Canadian university soccer players to report findings that females are associated with a higher risk for concussion than males (Delaney, Lacroix, Leclerc, & Johnston, 2002). The NCAA-ISS data reported the relative risk per 1,000 athletic exposures (games and practices) for men to be 0.35 and for women to be 0.62. All of these studies add to the hypothesis that women are at greater risk of sustaining a concussion than men (Solomon et al., 2006).

Covassin et al. (2003) state that female athletes are consistently found to be at higher risk for sustaining concussions than male athletes across all sports and all ages because women athletes are not being provided with the quality of protective equipment that men athletes are (Zillmer et al., 2006). For example, men lacrosse players are required to wear helmets where-as female lacrosse players typically do not have that option.

Broshek et al. (2005) report that morphological, physiological, and hormonal factors can predict differential outcomes of concussion in males and females. Examples of cortical differences that may affect concussions are that cortical neuronal densities are greater in males, while neurophil count (neuronal processes) is greater in females. Studies
have shown that female brains may have higher cortical metabolic demands, therefore producing a more intense and prolonged symptom response to mild TBI (Webb, 2006).  

History of Concussion

Macciocchi (2006) documented that football players with histories of multiple concussions (greater than three) were much more likely to sustain another concussion during the season than players with two or fewer previous concussions. Pardini and Collins (2006) state that concussion history is predictive of a lower threshold for subsequent concussions as well as a worse outcome when compared to athletes with no history of concussion. Furthermore, the significance of prior concussion history appears to become more relevant for athletes who have sustained three or more previous concussions. There is increasing evidence that a prior history of three or more concussions is associated with long-term changes in neurophysiology, which in turn results in a decline in neuropsychological test performance in some athletes. In addition, athletes with three or more concussions are at increased risk of sustaining a future concussion, typically have worse on-field presentations of their next concussion, have greater acute changes in memory performance, and are more likely to have longer recovery periods. The findings to date on three or more concussions should be considered preliminary (Iverson, Brooks, Lovell, & Collins, 2006). Collins et al. (1999) found significant long-term reductions in processing speed and executive functions in United States football players with histories of two or more concussions. While there is an inconsistency as to the number of previous concussions necessary to affect a player’s risk of receiving another concussion and exhibiting long-term cognitive decline, the evidence suggests that it is important to assess each athlete’s history of concussion, and those athletes who have previously sustained concussions should be managed more conservatively.

Position

Thus far there has been little research pertaining to the correlation of offensive and defensive positioning to the risk of concussion. Theoretically, the risk factor of offensive and defensive positioning will vary from sport to sport and there are some sports, such as basketball, that do not have primarily offensive and defensive positions.
There have been a few studies researching the rates of concussion according to player position in football, but they lack information on the generality of incidence rate for offense versus incidence rates for defense. Delaney, Lacroix, Leclerc, and Johnston (2000) found quarterbacks (an offensive position) to have the highest risk of experiencing a concussion. Delaney, Lacroix, Gagne, and Antoniou (2001) found similar results, reporting that players who suffer the highest percentages of concussions are running backs and quarterbacks. Another study Delaney, Lacroix, Leclerc, & Johnston (2002) conducted showed contradicting results to the previous studies. In this study, tight ends and defensive lineman were the players more likely to suffer at least one concussion.

Assessment of Concussion in Sports

Neuropsychological Assessment

During the past 10 years neuropsychology has become increasingly involved in the prevention and management of sports concussions. This has lead to the development of sports neuropsychology. Neuropsychological assessment has quickly become an integral component for the assessment and management of sports-related concussions. Professional leagues like the National Hockey League and the National Football League as well as many collegiate organizations such as the NCAA now use neuropsychological testing as the standard for concussion management. In view of the fact that recovery from concussion can occur before or after the athlete’s clinical symptoms resolve, neuropsychological testing should play an important role in assessing return to play readiness (Aubry et al., 2002). Neuropsychological testing can provide information regarding an athlete’s processing speed, planning, memory, and mental flexibility. Various forms of neuropsychological testing, ranging from paper tests and abbreviated batteries to computer-based tests and extensive neuropsychological batteries, are currently being used (Collins, Echemendia, & Lovell, 2004).

The extreme increase in interest in neuropsychological testing has resulted in the development of sophisticated neuropsychological test instruments. The traditional paper-and-pencil tests are fairly labor intensive and limit the widespread use of neuropsychological assessment. Recent development of computer-based neuropsychological testing instruments has expanded, and will continue to expand, the involvement of neuropsychology at all levels of competition (Lovell, 2006).
ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing) is one of the newest computerized neuropsychological assessments. It was developed during the late 1990s to address some of the limitations of traditional neuropsychological testing. The development of ImPACT allows for randomization of stimuli, accurate and reliable measures of variables such as reaction time and processing speed, and fast, reliable scoring. ImPACT contains five sections: demographics and history, concussion symptom inventory, computerized neuropsychological testing modules, current concussion details, and a comment section. All of these sections take approximately 30 minutes to administer (Lovell, 2006).

Bigler & Orrison (2004) claim that even the best neuroimaging methods may result in a false negative concussion diagnosis, and neuropsychological testing is used because of its sensitivity to the outward manifestation of the actual underlying neuropathology. Imaging techniques such as CT scans and MRI are typically insensitive in measuring the subtle effects of concussion. However, neuropsychological testing has been shown to be 89.5% effective in detecting injury in athletes 24 hours post-injury (Collins et al., 1999). Neuropsychological testing is not used to diagnose concussion. Instead, it shows the effects of the concussion by highlighting the neurocognitive changes present in an athlete following concussion (Echemendia & Cantu, 2003).

While neuropsychological testing provides an abundance of information after an athlete sustains a concussion, the usefulness of such testing is enhanced with the presence of baseline data for each athlete. Baseline data provides a direct comparison for each athlete when he or she becomes injured. Athletes sustaining a concussion can be reassessed and monitored until his or her performance returns to the baseline. This comparison to baseline, along with the evaluation of symptoms, can provide useful information in the return to play decision. It is recommended that all sports organizations utilize the benefits of neuropsychological baseline and follow-up testing by setting up a concussion management program (Aubry et al., 2002). Collecting baseline data for neuropsychological and postconcussion symptom scores provides an estimation of cognitive and psychosocial function that can then be used to determine the recovery from a concussion (Echemendia & Julian, 2001). While neuropsychological baseline
assessment is helpful, empirical data have yet to determine how far above or below baseline a player should perform before returning to play (Echemendia & Cantu, 2003).

Neuropsychological testing is a vital instrument for concussion management, but one of the problems associated with it is the possibility of learning effects as a result of serial testing. Players who learn the test may return to baseline scores even if symptoms of the concussion persist and full recovery has not been made. Tests such as the Trail Making Test (TMT), Digit Span, and Grooved Pegboard have been found to be subject to the practice effect (Lovell & Collins, 1998). There is also an inconsistency in the tests’ capacities to detect neuropsychological and cognitive differences caused by concussion.

Researchers have examined the sensitivity of specific tests in the neuropsychological battery. Collins et al. (1999) reported that TMT B and the Symbol Digits Modalities Test (SDMT) were both sensitive to those athletes with a history of two or more concussions. Likewise, Echemendia, Putukia, Mackin, Julian, and Shoss (2001) found significant differences between concussed athletes and athletes involved in non-contact sports, such as swimming (used as a control), at 2 hours and 48 hours post-injury when evaluated by the Hopkins Verbal Learning Test (HVLT), SDMT, Controlled Oral Word Association Test (COWAT), and the TMT. The concussed group of athletes continued to have significantly different scores than the control group on the SDMT at 1 month post-injury. Macciocchi et al. (1996) noted the TMT was sensitive to the mild effects of concussion, as it denoted subtle impairments in injured athletes.

Some studies have contradicted the research cited above, reporting no differences between the scores of injured athletes and controls at 1 day, 3 days, 5 days, and 10 days post-injury on the TMT, Digit Span, and the HVLT (Guskiewicz, Riemann, Perrin, & Nashner, 1997). Similarly, no differences were observed at any interval post-injury between contact and non-contact sport athletes and the control group, regardless of concussion history, on COWAT or digit span. Aubry et al. (2002) discovered no differences at any interval post-injury between concussed and non-injured Australian football players on the TMT. It can be speculated that the severity of concussions tested could have differed in these studies, producing different results. It is also likely that some subjects had experienced the learning effect, therefore creating an inconsistency among the studies.
Neuroimaging

Concussion implies a mild brain injury, in general, with normal neuroimaging findings. For sports-related concussion, neuroimaging of any type is typically not performed, rather medical decisions are made by the athlete’s clinical presentation (Bigler & Orrison, 2004). There are some situations in which neuroimaging is recommended for athletes, and that is those in which there is extended loss of consciousness, seizures, or persistent symptoms that suggest a structural cerebral lesion (Aubry et al., 2002). While neuroimaging is not used routinely to diagnose a concussion, new brain-imaging technologies such as gradient echo, perfusion, and diffusion weighted imaging, which all have greater sensitivity for structural abnormalities, are on the horizon and could revolutionize the diagnosis, care, and management of sports-related concussion (Bigler & Orrison, 2004; McCrory et al., 2005).

Symptom Based Assessment

There are four general symptom categories in identifying a concussion: typical symptoms, cognitive symptoms, physical symptoms, and medical symptoms. Typical symptoms of concussion include headache, dizziness, nausea, loss of balance, tinnitus, diplopia, sleepiness, or sleep disturbance. If any of these symptoms are present following an impact, concussion is suspected (Aubry et al., 2002). Cognitive symptoms indicating concussion include periods of confusion or amnesia, loss of consciousness for any length of time, poor concentration, slow processing time, and/or an inability to answer questions regarding orientation such as the date, time, or location. Psychological symptoms of a concussion encompass laughing and crying inappropriately and/or personality changes (Aubry et al., 2002). Physical signs of concussion can be mild or severe in nature and can include different aspects of cognitive, psychological, medical, and motor functioning. Physical symptoms include loss of consciousness, slowness in answering questions or following directions, and inappropriate playing behavior such as running the wrong direction on the playing field. Motor deficits often considered to be physical signs of concussion are poor coordination, unsteady walking, and slurred speech (Aubry et al., 2002). Medical symptoms of a concussion include concussive convulsions, nausea, vomiting, and vacant stare (Aubry et al., 2002).
The different clusters of symptoms can suggest a location in the brain in which an injury occurred. Symptoms such as loss of consciousness, tinnitus, lightheadedness, poor muscle coordination, headache, nausea, and vomiting can be indicative of brainstem dysfunction. Damage to the cerebral cortex can produce symptoms such as confusion, disorientation, amnesia, decreased ability to process information, and memory impairment (Maroon et al., 2000).

Return to Play Assessment

The return to play (RTP) decision is not a simple one; rather it is a complex and dynamic decision-making process. While this decision is a difficult one, there is a possibility that this process could be made easier with knowledge of the major risk factors for incidence rate and recovery patterns. For example if a concussed athlete has a high risk for sustaining another concussion or is “at risk” for a longer recovery period, the RTP decision should be a more conservative one.

The team physician typically manages the RTP decision, but it is a collaborative and cooperative decision-making process that includes an entire concussion management team. It is the role of the physician to evaluate the athlete and talk with Certified Athletic Trainers and other professionals, including a neuropsychologist if available, and then make a decision based on the comprehensive information. Frequently, Certified Athletic Trainers make the immediate RTP decision on the sidelines. Certified Athletic Trainers should have extensive training in recognition of the signs and symptoms of concussion, so that they are able to make the RTP decision on the spot (Echemendia, 2006a).

The goal of the RTP decision is to return the player to competition at a point when it is most safe for the player, but not to restrict the player from competition unnecessarily. Historically, this decision has been based on a series of guidelines that were developed to match classification schemes used to rate the severity of the concussion. Collins et al. (1999) documented 14 different classification systems. Although they were useful in standardizing RTP, these guidelines lacked empirical support (Echemendia, 2006a).

The summary and agreement statement published after the First International Symposium on Concussion in Sport recommended that the existing RTP guidelines be abandoned in favor of individualized RTP decisions (Aubry et al., 2002). This statement further recommended that a concussed athlete should rest with no activity until
postconcussion symptoms are not present, and neurological and cognitive evaluations return to normal. Once asymptomatic, the athlete should begin a graded, medically supervised process beginning with light aerobic exercise, eventually progressing to full-contact training and game play (Echemendia, 2006a).

The summary and agreement statement published after the Second International Conference of Concussion in Sports, held in Prague, endorsed the use of individually tailored RTP, but also downplayed the role of neuropsychology in managing simple concussions. This view of neuropsychology is inconsistent with the existing literature, which documents that cognitive symptoms may persist beyond the resolution of physical symptoms and that neuropsychology plays an important role in managing concussion (Echemendia, 2006a). The summary and agreement statement also provided a useful tool for evaluating the signs and symptoms of concussion. It is a two-sided card that is referred to as the Sport Concussion Assessment Tool (SCAT). The SCAT contains basic concussion information, the Postconcussion Symptom Scale, and a sideline evaluation protocol that assesses orientation, symptoms, five-item word recall, digits backward (or months in reverse), and neurological screening. Lastly, McCrory et al. (2005) included a useful guideline of the graded return to play process:

1. Rest until asymptomatic (physical and mental rest)
2. Light aerobic exercise (e.g. stationary cycle)
3. Sport-specific training
4. Non-contact training drills (start light resistance training)
5. Full contact training after medical clearance
6. Return to competition (game play)

There should be approximately 24 hours (or longer) for each stage and the athlete should return to stage 1 if symptoms recur (p. 199).

The RTP decision is a complex and dynamic one. Although there has been an exponential increase of research in the diagnosis and management of sports-related concussions during the past decade, the RTP decision remains a largely clinical venture.
without firm empirically based guidelines (Echemendia, 2006a). What professionals do recognize is that the RTP decision should be individualized to each athlete and that the decision needs to be a collaborative one. The RTP decision is significant because of the detrimental effects a second concussion can have on an athlete who prematurely returns to play.

_Section Impact Syndrome._

Second Impact Syndrome (SIS) occurs when a second concussion is sustained before the signs and symptoms of the first have resolved. This is a rare, but potentially deadly syndrome. SIS occurs when the brain has already endured trauma and, therefore, has increased vulnerability (Bender, Barth, & Irby, 2004). Twenty-six documented deaths have resulted from SIS since 1984. Even the slight possibility of SIS emphasizes the importance of conservative RTP criteria and neurocognitive assessment to be sure that full recovery has taken place (Bender et al., 2004).

The pathophysiology of SIS is not clearly understood. The limited evidence available suggests that the first impact results in subcortical edema and increased intracranial pressure, which make the brain susceptible to further injury. Significant intracranial pressure following the second impact hinders blood flow, causing severe tissue damage that leads to cognitive disability (Bender et al., 2004).

_Concussion Management_

One of the most challenging topics facing medical and paramedical professionals is the difficulty of concussion management. The accurate identification of a concussion and, once identified, the care and management, as well as the RTP decision are all complex issues. One challenge in the identification of concussion is assessing the signs and symptoms that may or may not be present (Bender et al., 2004). The immediate symptoms may disappear promptly or they may remain for hours, days, weeks or months, and new symptoms may appear at any time. Cognitive deficits may or may not be present in a concussed athlete, and the same goes for behavioral changes (Bender et al., 2004). Having to contend with the uncertainty of diagnosing a concussion is difficult enough, but in addition, it is also common for athletes to underreport their symptoms due to their motivation to return to play (Lovell et al., 2004).
Once the injury is identified as a concussion and the athlete has been given appropriate medical care, the RTP decision becomes the next challenge. Documentation of baseline neuropsychological performance, signs and symptoms, and behavior are key to making this decision (Bender et al., 2004). Although there are still many uncertainties regarding the diagnosis, management, and RTP decision, concussion management programs, such as the Miami University Concussion Management Program used in this study, are organized ways to effectively control the concussion management process. These programs have become more important, as concussion has recently been recognized as a major public health issue (Pardini & Collins, 2006).

Statement and Significance of the Problem

Evidence has shown that there may be particular risk factors that are associated with a greater incidence of concussion and/or associated with a slower recovery or an incomplete recovery from a concussion. While there is evidence to support the notion of certain “risk factors,” there has been little research conducted in this specific area. If there are set risk factors for sustaining a concussion or producing a prolonged recovery period, these factors could be taken into consideration when RTP decisions are being made. If an athlete is more “at risk” due to a history of multiple concussions, playing in a risky position, or from being a specific gender, the concussion management team making the RTP decision may decide to make a more conservative decision so as not to make the athlete susceptible to another concussion that may yield a more serious result.

Purpose of the Study

The purpose of this study is to look at offensive and defensive positions, gender, and previous history of concussion in order to gain knowledge as to the major risk factors affecting an athlete’s full recovery and of sustaining a concussion in the first place.

Research Questions and Hypotheses

This study will be testing four hypotheses:

1) Does athletic positioning (offense vs. defense) affect the incidence of concussions in athletes? It is hypothesized that athletes in offensive positions sustain more concussions than those in defensive positions.
2) Does gender affect the length of recovery time from concussion? It is hypothesized that females require a longer period of time to fully recover than males.

3) Do previous concussions make an athlete more susceptible to sustaining another concussion? It is hypothesized that a history of three or more concussions makes an athlete more susceptible to sustaining another concussion.

4) Do previous concussions affect the amount of time it takes to recover from a concussion? It is hypothesized that athletes who have sustained three or more previous concussions require a longer recovery period than those with two or fewer previous concussions.
Chapter II
Methods

Subjects

The Miami University Concussion Management Program is a collaborative effort between the Department of Speech Pathology and Audiology and the Intercollegiate Athletics program at Miami University. Subjects included in this study were college age male and female athletes from Miami University. All freshman and transfer students on the varsity football, hockey, men’s and women’s basketball, and women’s soccer teams received baseline neuropsychological testing, prior to the onset of pre-season training, in order to assess their non-injured cognitive functioning.

The data used in this study was collected from athletes who participated in sports seasons from 1999 to 2006. During this time period baseline data was collected from 379 athletes and injury data was collected from 71 athletes.

Procedures

This study implemented the procedures outlined in the Miami University Concussion Management Program. Upon sustaining a sports concussion, athletes were referred to the Miami University Speech and Hearing Clinic, ideally within 48 hours, but no later than 5 days after their injury. Injured athletes were administered the same neuropsychological test battery initially completed to obtain scores that are compared to their baseline data. If a decline in performance was found in the testing, or if concussion symptoms were reported by the athlete, an additional follow-up assessment would be scheduled 4-8 days after the injury and weekly thereafter until that athlete had minimal postconcussion symptoms and the test scores fell within one standard deviation of the baseline or normative test scores.

The assessment that was used for each athlete in this study was the Pittsburgh Steelers Neuropsychological Battery (PSNB) (Brandt, 1991). Table 1 lists the tests administered to the athletes and the abilities that each test evaluates. Each athlete was given the entire PSNB in private therapy rooms at the Miami University Speech and Hearing Clinic. The neuropsychological test battery was administered by trained graduate students in the Department of Speech-Language Pathology under the supervision of Fofi Constantinidou, Ph.D.
Prior to the start of administering the PSNB, each athlete was provided with an informed consent form (Appendix A), a questionnaire to fill out that provided the examiner with that athlete’s prior concussion history (Appendix B), and a Postconcussion Rating Scale (Appendix C). The persons administering the assessments were present while the athletes filled out these forms to clarify meanings and answer questions. Completion of the paperwork and the PSNB took approximately one hour for each athlete.

Table 1
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>Memory for words (verbal memory)</td>
</tr>
<tr>
<td>Trail Making Test</td>
<td>Visual scanning, mental flexibility</td>
</tr>
<tr>
<td>Controlled Oral Word Association Test</td>
<td>Word fluency and retrieval</td>
</tr>
<tr>
<td>Digit Span (from Wechsler Memory Scale-Revised)</td>
<td>Attention span</td>
</tr>
<tr>
<td>Symbol Digits Modalities</td>
<td>Visual scanning, visual motor speed</td>
</tr>
<tr>
<td>Grooved Pegboard Test</td>
<td>Motor speed/coordination</td>
</tr>
<tr>
<td>Delayed Recall (from Hopkins Verbal Learning Test)</td>
<td>Delayed memory for previously learned word list</td>
</tr>
</tbody>
</table>

Data Gathering

Concussion Questionnaire

In addition to the PSNB, the athletes completed the Concussion Questionnaire (Appendix B) to obtain information regarding the athletes’ previous concussion histories. The questionnaire consisted of 28 questions that were modified from Geffen, Hinton-Bayre, and Geffen (1998). The original questionnaire was used to study the incidence of concussion in rugby players in Australia and provides a standardized procedure to survey a player’s history of concussion.

Postconcussion Rating Scale

The Postconcussion Rating Scale (PCRS) (Appendix C) modified by Lovell and Collins (1998) was used to rate physical, emotional, and cognitive symptoms of
The PCRS provides a standardized procedure to organize a player’s subjective symptoms after concussion. The rating scale used in the present study consists of 21 symptoms associated with concussion. Subjects rated their symptoms using a 7-point scale with possible scores ranging from 0 (i.e. symptom not present) to 6 (i.e. symptom is severe).

Null Hypotheses

There were four null hypotheses:

1) It is hypothesized that athletes in offensive and defensive positions have similar rates of concussion.

2) It is hypothesized that the length of recovery after a concussion does not differ between males and females.

3) It is hypothesized that the number of previous concussions has no effect on making an athlete more susceptible to sustaining another concussion.

4) It is hypothesized that the length of an athlete’s recovery period has no correlation with the number of previous concussions sustained.

Statistical Analysis

Data analyses were performed using the Statistical Package for the Social Sciences (SPSS) 15.0. A variety of statistical analyses were performed at $\alpha = .05$ in order to address the hypotheses in this study.
Chapter III  
Results

The primary objective of this study was to research offensive and defensive positions, gender, and previous history of concussion in order to gain knowledge as to the major risk factors of sustaining a concussion and affecting an athlete’s full recovery. A variety of statistical analyses were performed at $\alpha = .05$ to gain insight into these major risk factors. A total of 71 concussed athletes, listed by sport in Table 2, were used in this study. From these 13 sports, the mean age of injured athletes that participated was $19.8028, SD = 1.3376$.

Table 2  
Concussed Athletes Delineated by Sport and Gender

<table>
<thead>
<tr>
<th>Sport</th>
<th>Gender</th>
<th>$n$</th>
<th>% of injured athletes</th>
<th>Type of sport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Football</td>
<td>Male</td>
<td>29</td>
<td>40.84%</td>
<td>Contact</td>
</tr>
<tr>
<td>Ice Hockey</td>
<td>Male</td>
<td>10</td>
<td>14.08%</td>
<td>Contact</td>
</tr>
<tr>
<td>Basketball</td>
<td>Female</td>
<td>9</td>
<td>12.68%</td>
<td>Contact</td>
</tr>
<tr>
<td>Soccer</td>
<td>Female</td>
<td>7</td>
<td>9.86%</td>
<td>Contact</td>
</tr>
<tr>
<td>Field Hockey</td>
<td>Female</td>
<td>3</td>
<td>4.22%</td>
<td>Contact</td>
</tr>
<tr>
<td>Track</td>
<td>Male</td>
<td>3</td>
<td>4.22%</td>
<td>Non-contact</td>
</tr>
<tr>
<td>Track</td>
<td>Female</td>
<td>2</td>
<td>2.82%</td>
<td>Non-contact</td>
</tr>
<tr>
<td>Cheerleading</td>
<td>Female</td>
<td>2</td>
<td>2.82%</td>
<td>Non-contact</td>
</tr>
<tr>
<td>Volleyball</td>
<td>Female</td>
<td>2</td>
<td>2.82%</td>
<td>Non-contact</td>
</tr>
<tr>
<td>Volleyball</td>
<td>Male</td>
<td>1</td>
<td>1.41%</td>
<td>Non-contact</td>
</tr>
<tr>
<td>Baseball</td>
<td>Male</td>
<td>1</td>
<td>1.41%</td>
<td>Non-contact</td>
</tr>
<tr>
<td>Softball</td>
<td>Female</td>
<td>1</td>
<td>1.41%</td>
<td>Non-contact</td>
</tr>
<tr>
<td>Broomball</td>
<td>Male</td>
<td>1</td>
<td>1.41%</td>
<td>Contact</td>
</tr>
</tbody>
</table>
Research Question 1: Does athletic positioning (offense vs. defense) affect the incidence of concussions in athletes?

Football is the only sport included in the Miami University Concussion Management Program in which an athlete clearly played an offensive or defensive position. Therefore, the results relating to athletic positioning reflect only what has been found in offensive and defensive positioning in football.

A $\chi^2$ analysis was performed to determine if there was a significant difference between the overall number of offensive and defensive athletes who received baseline testing. A total of 182 non-injured athletes were included, 100 in the offensive position and 82 in the defensive position. The $\chi^2$ analysis showed no significant difference, $\chi^2(1) = 1.780$, $p = 0.182$. Another $\chi^2$ analysis was performed to determine if there was a significant difference between the number of concussed offensive and defensive athletes. There were 15 offensive athletes with concussions and 10 defensive athletes with concussions, totaling 25 athletes. The $\chi^2$ analysis showed that the number of concussed athletes in offensive positions was significantly higher than the number of concussed athletes in defensive positions, $\chi^2(2) = 11.615$, $p = 0.003$. Table 3 lists the percentages of injured subjects delineated by football positions, as well as the number of athletes in each position who had positive concussion histories.

Table 3

Concussed Athletes Broken Down by Football Position

<table>
<thead>
<tr>
<th>Position</th>
<th>Percentage of injured athletes</th>
<th>Number with positive concussion history</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running Back (O)</td>
<td>20.69%</td>
<td>3/6</td>
</tr>
<tr>
<td>Offensive Lineman (O)</td>
<td>13.79%</td>
<td>1/4</td>
</tr>
<tr>
<td>Defensive Lineman (D)</td>
<td>13.79%</td>
<td>2/4</td>
</tr>
<tr>
<td>Linebacker (D)</td>
<td>13.79%</td>
<td>2/4</td>
</tr>
<tr>
<td>Wide Receiver (O)</td>
<td>10.34%</td>
<td>2/3</td>
</tr>
<tr>
<td>Tight End (O)</td>
<td>6.90%</td>
<td>2/2</td>
</tr>
<tr>
<td>Defensive Back (D)</td>
<td>6.90%</td>
<td>1/2</td>
</tr>
<tr>
<td>Long Snapper (S)</td>
<td>6.90%</td>
<td>1/2</td>
</tr>
<tr>
<td>Category</td>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>---------------------------------------------------</td>
<td>-----</td>
<td>--------</td>
</tr>
<tr>
<td>Recovery time (in days) for offensive football players</td>
<td>12</td>
<td>8.1667</td>
</tr>
<tr>
<td>Recovery time (in days) for defensive football players</td>
<td>8</td>
<td>6.0000</td>
</tr>
</tbody>
</table>

An independent $t$-test was performed to determine if the number of symptoms or total scores on the Postconcussion Rating Scale differed depending on athletic positioning at Time 1 (first consultation, postconcussion). It was found that there is not a significant difference between the number of symptoms, $t(23) = -0.401, p = 0.692$, or the PCRS scores for offensive and defensive football players, $t(23) = -0.253, p = 0.803$.

While football was the only sport for which offense vs. defense could be analyzed for risk of concussion, a logistic regression analysis was completed to determine the risk of being concussed when playing a contact sport (refer to Table 2 for listing of contact sports). The other predictors included in this analysis were being male and the number of

Note. O = Offensive position; D = Defensive position; S = Special teams
concussions an athlete sustained prior to attending Miami University (MU). A $G$-statistic analysis tested the utility of this logistic regression model to predict $P(\text{concussed at MU})$. For this analysis, $G = 24.237, p < 0.001$, indicating that there is sufficient evidence that at least one of the predictors is a significant risk factor for sustaining a concussion. An odds ratio of 0.29 indicates the significant and unexpected result that the probability that a subject will be concussed as a result of moving from a non-contact sport to a contact sport ($z = -2.77, p = 0.006$) is decreased by 71% ($0.29 – 1$).

**Research Question 2: Does gender affect the length of recovery time from concussion?**

Independent $t$-tests were performed to determine if there is a difference between male and female athletes in the number of days it takes to recover. It was found that there was not a significant difference in the number of days it takes males to recover when compared to the number of days it takes females to recover within any of the sample groups. Among athletes for whom baseline data was gathered, there was not a significant difference between genders when comparing the time it took to return to one score or less below their original baseline performance, $t(43) = -.0212, p = 0.833$. There was also no significant difference between genders when comparing the time it took for athletes who did not have baseline data to return to the national average of the standardized neuropsychological assessments, $t(14) = -.0489, p = 0.632$. Among athletes who sustained two concussions, and who were tracked through the Miami University Concussion Management Program, there was no significant difference between genders in recovery time after a second injury, $t(6) = 1.502, p = 0.184$.

A mixed model of multivariate analysis of variance (MANOVA) was used to compare the PCRS scores across genders. Baseline PCRS scores and PCRS scores at Time 1 (postconcussion) were compared. See Table 5 for PCRS score means and standard deviations. The MANOVA revealed a significant change in the overall scores from baseline to Time 1, $F(1,39) = 12.066, p = 0.001$, but there was no significant difference when comparing genders and performance across PCRS scores, $F(1,39) = 0.411, p = 0.525$. However, upon examination of the average scores, males showed a higher baseline score than females. Therefore, an independent t-test assuming unequal variances was conducted. $T$-test results indicate that the male baseline PCRS score is significantly higher than the female score, $t(34.824) = 2.264, p = 0.030$. The PCRS scores
at Time 1 were similar between groups, $t(69) = -0.617, p = 0.539$. See Table 6 for the means and standard deviation of the number of PCRS symptoms across genders.

Table 5
Postconcussion Rating Scale (PCRS) Scores at Baseline and Time 1

<table>
<thead>
<tr>
<th>Score</th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male Baseline PCRS Score</td>
<td>30</td>
<td>13.1000</td>
<td>12.5461</td>
</tr>
<tr>
<td>Female Baseline PCRS Score</td>
<td>11</td>
<td>6.3636</td>
<td>6.2972</td>
</tr>
<tr>
<td>Male Time 1 PCRS Score</td>
<td>30</td>
<td>24.5500</td>
<td>22.5604</td>
</tr>
<tr>
<td>Female Time 1 PCRS Score</td>
<td>11</td>
<td>23.0000</td>
<td>20.1891</td>
</tr>
</tbody>
</table>

Table 6
Number of Postconcussion Rating Scale (PCRS) Symptoms at Time 1 Categorized by Gender

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male: Time 1 PCRS Symptoms</td>
<td>45</td>
<td>9.0222</td>
<td>6.3657</td>
</tr>
<tr>
<td>Female: Time 1 PCRS Symptoms</td>
<td>26</td>
<td>9.9231</td>
<td>5.0669</td>
</tr>
</tbody>
</table>

The same logistic regression analysis that was mentioned above was used to determine the effect being male had on sustaining a concussion at Miami University. The estimated coefficient of $-0.3365$ for male represents the change in the log of $P($concussed at MU$)/P($not concussed at MU$)$ when moving from females to males. This result is insignificant ($z = -1.09, p = 0.275$).

Research Question 3: Do previous concussions make an athlete more susceptible to sustaining another concussion?

A logistic regression was used to investigate the effects of prior history of concussion on sustaining another concussion while playing a sport at Miami University. An estimated coefficient of $0.4036$ for number of concussions sustained prior to attending
MU represented the change in the log of $P(\text{concussed at MU})/P(\text{not concussed at MU})$ for each additional concussion experienced prior to the athlete attending MU. The odds ratio of 1.50 indicated that the probability that an athlete will be concussed at MU increases by 50% (1.50-1) for each additional concussion experienced prior to attending MU. This result is significant ($z = 3.38, p = 0.001$), suggesting that each prior concussion increases an athlete’s risk of a future concussion by 50%. A measure of association was also completed to determine the number and percentage of concordant, discordant, and tied pair associations. The predictors used for finding the likelihood of being concussed at MU were being a male, number of concussions sustained prior to attending MU, and playing a contact sport. Sixty-eight athletes with concussions and 279 athletes who weren’t concussed were compared, resulting in $68 \times 279 = 18,972$ pairs with different response values. A pair is considered concordant if an athlete who sustained a concussion at MU had a higher predicted probability of being concussed at MU, discordant if the opposite is true, and tied if the probabilities are equal. This analysis resulted in 55.9% of pairs being concordant and 23.4% of pairs being discordant. These results suggest that this measure of association does a fair job of predicting the likelihood of being concussed at MU based on the three predictors listed above. Although, when the other analyses completed in this study are taken into consideration, it can be concluded that prior history of concussion is the biggest predictor of the three.

**Research Question 4: Do previous concussions affect the amount of time it takes to recover from a concussion?**

It was hypothesized that, the more previous concussions an athlete has had, the longer it will take that athlete to recover from a concussion. A Pearson Correlation showed no relationship between the number of days it took an athlete to recover and the number of previous concussions sustained by the athlete. Similar results were obtained for athletes who returned to one score or less below their baseline data, $r = -0.170, p = 0.132$, and for athletes with no baseline data that returned to one score or less below the national average, $r = -0.191, p = .257$.

Nine athletes had a history of 3 or more concussions, while 23 athletes had a history of one prior concussion (see Table 7). At Time 1, athletes with 3 or more concussions reported significantly more symptoms than athletes with one prior
concussion. An independent $t$-test showed that there is a significant difference in the number of PCRS symptoms between those athletes with one previous concussion and those with three or more previous concussions, $t(30) = -3.265, p = 0.003$.

Table 7
Number of Postconcussion Rating Scale (PCRS) Symptoms at Time 1 Categorized by Number of Previous Concussions

<table>
<thead>
<tr>
<th>Number of Concussions</th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Previous Concussion: Time 1 PCRS Symptoms</td>
<td>23</td>
<td>6.8261</td>
<td>4.8209</td>
</tr>
<tr>
<td>Three or More Previous Concussions:</td>
<td>9</td>
<td>13.2222</td>
<td>5.4032</td>
</tr>
<tr>
<td>Time 1 PCRS Symptoms</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Chapter IV
Discussion

This study researched offensive and defensive positions, gender, and previous history of concussion in order to gain knowledge into the factors affecting the risk of an athlete sustaining a concussion and into the major risk factors affecting an athlete’s full recovery from a concussion. While the rate of concussion among college athletes is high, preventive measures could be taken to decrease the incidence of concussion. Identifying definite risk factors for incident rate of concussion and elements that affect recovery time when concussions do occur would be a beginning step to a reduced rate of concussion among college athletes.

Athletic Positioning

This study intended to compare offensive vs. defensive positioning in multiple sports, but there was not enough positioning data to justify analyzing sports other than football. In several sports such as soccer, basketball and ice hockey, the boundaries between offensive and defensive play are not as clearly delineated as in football. The results obtained from this study concluded that football players in an offensive position are more at risk for sustaining a concussion than football players in a defensive position. The majority of concussed athletes in this study were found to be running backs, an offensive position. This result is similar to the findings of Delaney, Lacroix, Gagne, and Antoniou (2001) who also found that running backs and quarterbacks suffer the highest percent of concussions. Delaney, Lacroix, Leclerc, and Johnston (2000) reported that quarterbacks (an offensive position) have the highest risk of sustaining a concussion. From these studies, it appears that offensive football players are at higher risk for sustaining concussions than their defensive counterparts. However, one specific offensive position has yet to be identified as having the highest risk of sustaining a concussion. There have also been studies that show the contradicting result that defensive football positions hold the highest risk for the sustaining of a concussion (Delaney et al., 2002).

While football players in offensive positions were at a greater risk for concussion, the reported symptomology associated with offensive and defensive players on the PCRS was similar. In addition, the rate of recovery between offensive and defensive players was similar. These findings suggest that while offensive players get injured more
frequently, the severity of the injury is not different than that of defensive players. In the present study severity was measured based on neuropsychological test results and reported post concussion symptoms. These measures might be more sensitive than the sideline concussion rating, neuroimaging studies, or traditional measures of brain injury due to the mild nature of sports concussions. Macciocchi and Barth (2004) stated that the severity of concussions is difficult to measure because most grading systems used to rate concussion severity recommend using presence and duration of unconsciousness and posttraumatic amnesia, but these guidelines may not reliably predict the severity of neuropsychological impairment following the injury.

The present results indicate that non-contact sport athletes are concussed more frequently than contact sport athletes. These results were unexpected due to the physical nature of contact sports. A possible explanation for this is that participants in contact sports wear more protective equipment, thus lowering their risk of concussion, whereas athletes participating in non-contact sports typically wear no protective equipment. This unanticipated research finding provides reason for further research in the area of concussions in non-contact sports. Thus far the majority of studies researching sports concussion have focused solely on contact sports.

**Gender**

In the present study, the major gender difference was found to be the presence of symptoms at the time of baseline. A possible explanation could be a difference between the male and female sports teams in the degree of physical contact included in preseason training. The baseline testing was typically completed in the midst of preseason training camp for football, where the freshman players were new to college, their sleep patterns were disturbed, and the athletes were not used to physical contact at the collegiate level. While the same might be true for female athletes, it is thought that female basketball players and soccer players do not experience the same amount and intensity of physical contact as male football players do during preseason training. Another theory is that males “play through” more injuries than females possibly due to the male ego or the cultural stigma of “boys don’t cry”. Therefore, males report more symptoms at baseline because of previous unreported injuries that have lingering effects.
**Prior History of Concussion**

The present study yielded results concluding that, at the collegiate level, each concussion an athlete sustains prior to competing in collegiate athletics increases the risk of sustaining a future concussion by 50%. This reveals that the prior number of concussions an athlete has sustained is important information to obtain in order to assess what type of risk that athlete has for sustaining another concussion. Pardini and Collins (2006) found similar results, stating that concussion history is predictive of a lower threshold for future concussions. This data implies that it is important to assess athletes’ history of concussions, and that those athletes who have a history of prior concussions should be managed more conservatively.

The results in this study show that prior history of multiple concussion results in increased PCRS scores at Time 1. This reveals that, while athletes with differing concussion histories may take similar amounts of time to recover from concussions, a concussion sustained by an athlete with three or more prior concussions is initially more severe than a concussion sustained by an athlete without such a significant concussion history. These findings add to the increasing evidence that a prior history of three or more concussions is associated with long-term changes in neurophysiology, which in turn results in a decline in neuropsychological test performance in some athletes (Iverson, Brooks, Lovell, & Collins, 2006).

**Conclusions**

This study has led to the following general conclusions:

1. Football players in an offensive position have a greater risk for sustaining a concussion than football players in a defensive position.

2. There is no difference in the severity of the concussions (according to the PCRS) or in the rate of recovery between offensive and defensive football players.

3. Athletes in non-contact sports are also at a great risk for sustaining a concussion and in some cases at a greater risk than those who participate in contact sports.

4. Each concussion an athlete sustains prior to competing in collegiate athletics increases the risk of sustaining a future concussion by 50%.
5. If an athlete has sustained three or more prior concussions, it is probable that the next concussion will present with more symptoms, and will therefore be more severe.

6. Male athletes have significantly more PCRS symptoms than female athletes. Therefore baseline symptom testing in addition to the neuropsychological data is important.

Clinical Implications

If specific risk factors for incidence rates and recovery patterns of concussions can be identified, revisions of rule, protective equipment, and concussion management approaches could be altered accordingly to decrease the occurrence, severity, and lasting effects of sports concussions. This study supports the need for more education surrounding the overall realm of sports concussions, including formal and extensive training for athletic trainers in the diagnosis and treatment of concussions and more surveillance systems to appropriately manage concussed athletes.

This study displays the importance of using a pre-post concussion tracking system such as the Miami University Concussion Management Program in order to better protect athletes at all levels of competition. The collaboration between the speech-language pathology and athletic department ensured that each concussed athlete at Miami University was monitored physically, behaviorally, and cognitively to determine the appropriate recovery time before returning to play. Given the information that research is uncovering about the devastating effects of concussion, it is apparent that safety must be the top priority of a concussion management program such as the one referenced in this study.

Limitations

The PCRS is a valuable diagnostic tool, yet as is the case with any survey, it poses limitations. The use of baseline data for a subjective measure, such as the PCRS, allowed for more powerful comparisons when looking at PCRS symptoms and scores.

Another limitation experienced in this study was the number of subjects. Although 379 athletes is a fairly large number of subjects, there were only 71 athletes who sustained concussions and were referred for postconcussion testing while attending Miami University. When the subjects were broken down and analyzed even further, some
of the groups were then too small to analyze with any statistical power. For example, analysis focusing on the number of prior concussions was limited because there was a small number of athletes with three or more concussions to substantially fill that category.

Lastly, as with any study that spans several years, it was difficult to obtain data that wasn’t originally collected. Including information on athletic positioning affecting sports other than football would have been valuable information that could have provided significant results. However, the majority of injury reports generated through the Miami University Concussion Management Program did not include exact details, such as athletic positioning, with regard to how the concussions occurred.

**Future Research**

Concussion research in sports is a growing field of investigation. Future research should continue to delve into particular risk factors that can be used to determine an athlete’s likelihood of sustaining a concussion, and, if an athlete sustains a concussion, into risk factors for more severe concussions and prolonged recovery periods. In general, larger subject pools in the future would yield stronger results.

Some analyses in this study yielded results that contradicted previous research, such as how athletic positioning affected concussion incidence rates. Research has shown contradicting findings, and, with the sports medicine field growing, more research, for instance research into concussion in non-contact sports, should add valuable information to the discourse of sports concussions. For example, there are studies that further break down offensive and defensive positions according to sport and specify which exact player positions are associated with greater risk of sustaining concussion. This study included a breakdown of player position, but the subject number was low in this area. Because there have been contradicting findings when attempting to decipher whether the offense or defense as a whole is more at risk, looking for specific positions that show significantly higher incidence rates of concussion will lead to more conclusive results.

The sample used in this study was comprised solely of collegiate athletes at Miami University, Oxford, OH. Further research should include more diverse samples with regard to age and level of competition. It is possible, for instance, that high school athletes have very different risk factors for concussion incidence rate and recovery
patterns than professional athletes. Research in these areas is much needed in order to optimize the protection against concussion for all athletes.
Appendix A: Informed Consent

Informed Consent for College Athletes:

1. 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, Dr. Fofi Constantinidou at (513) 529-2507, 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

_____________________________ __________________________
Subject’s or legal guardian's Signature indicating consent Date

_____________________________ __________________________
Investigator's Signature Date
Appendix B: Concussion Questionnaire

Name: _______________ Date: __________

Concussion and Sports-Related Head Injuries

Subject Code: (First initial of last name plus the 4 digits of the month and day of your birthday. For instance John Smith born on March 5 would be written as S0305): ______

Age: ___ Birthday: __________

Name of primary sport you play: ______________

What position do you play in your primary sport? ______________

List any additional sports you participate in: ________________________________

Year in School: freshman sophomore junior senior other __________

List any existing medical conditions: ________________________________________

Explanation of the term “concussion”:

Concussion can result from a direct blow to the head or even from the heavy contact of bodies, without actual head contact. You may have been concussed if you were knocked unconscious or if you were unable to remember part of a game clearly (that is, you had a gap in your memory). You may have just been confused or disoriented for a period of time. After a concussion you may have experienced headaches, blurred vision, nausea, dizziness, tiredness, irritability, loss of coordination, or difficulty concentrating or remembering things.

Over your athletic career have you ever been concussed during a game, meet, or practice? _______ If NO, please go to question #17.

1. What position were you playing when you were concussed? __________________

2. What is the approximate date of your most recent concussion? Month___ Year_____

3. Were you knocked unconscious? If YES, how long were you unconscious? ________

4. Was there a period of time when you were confused or disoriented? If YES, how long did this period last? ____________

5. Did you have gap in your memory? If YES, how long was the gap? ______________
6. Who diagnosed your concussion? ____________________________________________

7. Were you counseled regarding the effects of your concussion at the time your concussion was diagnosed? __________

8. How many times have you been concussed? ______ If only once, go to question 14

9. How many times have you been knocked unconscious? __________

10. What was the longest period of time you were knocked unconscious? __________

11. How many times have you had a memory gap after a concussion? __________

12. What was the longest gap in your memory after a concussion? __________

13. When did each of your concussions occur?
   1st: month____ year____;
   2nd: month____ year____;
   3rd: month____ year____;
   4th: month____ year____;
   5th: month____ year____;
   Additional_____________________________________________.

14. How many games does your team play in a season? _______.
How many games do you usually participate in per season? ______
Have you missed any games due to a concussion? ______ If YES, how many? ______

15. Have you ever been off work or other activities because of a concussion?________
If YES, how long?___________________________________________________________

16. Do you believe you have changed in any of the following ways as a result of your head injuries? Please use the rating scale below to answer.

   None        Mild         Moderate       Severe
   0         1           2           3           4           5           6

   a._______ Mental-attention, memory, decision making, follow conversation, detailed instructions fatigue easily.

   b._______ Physical-fatigue more easily, increased sleep.

   c._______ Emotional-depressed, anxious, irritable more easily

   d._______ Social-enjoy leisure activities, relationships, friends, family commitments
e. ______ Work - maintaining workload, increasing productivity

f. ______ Playing Ability - fatigue, decision, speed, reaction time, skills under pressure

Re-start here if no previous sports-related concussion:

17. Over your career how many non-head injuries have you had that required you to miss a game? (i.e.: broken bone, sprain, etc.) ____________________________

18. How many games have you missed due to these non-head injuries? ____________

19. Have you ever received a head injury outside of a competitive contact sport? ______
   If NO, please stop here.
   If YES, please explain ______________________________________________________
   __________________________________________________________________________

20. Were you knocked unconscious after a non-sport related head injury?
   If YES, how long were you unconscious? ______

21. Was there a period of time when you were confused or disoriented after a non-sport related head injury? If YES, how long did this period last? ______________

22. Did you have gap in your memory after a non-sport related head injury?
   If YES, how long was the gap? ____________

23. Who diagnosed your concussion after a non-sport related head injury? ______________

24. Were you counseled regarding the effects of your concussion at the time your concussion was diagnosed? ____________

25. How many times have you been concussed after a non-sport related head injury? __

26. How many times have you been knocked unconscious after a non-sport related head injury? ______

27. What was the longest period of time you were knocked unconscious after a non-sport related head injury? ______

28. How many times have you had a memory gap after a non-sport related concussion? ____________

29. What was the longest gap in your memory after a after a non-sport related concussion? ________________
### Appendix C: Postconcussion Rating Scale

**Postconcussion Rating Scale (Rosenthal & Mayer, 1998)**

Please rate each symptom on a scale of 0 to 6 with 0 meaning you do not have the symptom, 1 meaning you have the symptom mildly, 3 meaning you have the symptom moderately and 6 meaning you have the symptom severely.

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Baseline Date:</th>
<th>____ hours/days after concussion Date:</th>
<th>____ days after concussion Date:</th>
<th>____ days after concussion Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Headache</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>2. Nausea</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>3. Vomiting</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>4. Balance problems</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>5. Dizziness</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>6. Fatigue</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>7. Trouble falling asleep</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>8. Sleeping more than usual</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>9. Sleeping less than usual</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>10. Drowsiness</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>11. Sensitivity to light</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>12. Sensitivity to noise</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>13. Irritability</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>14. Sadness</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>15. Nervousness</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>16. Feeling more emotional</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>17. Numbness/ Tingling</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>18. Feeling slowed down</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>19. Feeling mentally “foggy”</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>20. Difficulty concentrating</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
<tr>
<td>21. Difficulty remembering</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
<td>0 1 2 3 4 5 6</td>
</tr>
</tbody>
</table>

**Total Score**
References


