Abstract

THE EFFECTS OF INJURY MANAGEMENT PROTOCOL IN COLLEGE ATHLETES WITH SPORTS-RELATED HEAD INJURY: EVIDENCE BASED RECOMMENDATIONS

By Shannon Lee Thomas

Many athletes do not realize when a concussion has occurred or the risk involved with contact sports. Athletes, coaches, trainers, and medical doctors must become aware of the effects and risks of sports-related concussion in order to decide when an injured player is ready to return-to-play. Research is still needed to effectively manage and treat sports-related concussion. This study investigated aspects of sports-related concussion including effective objective and subjective testing, average length of recovery time, and specific incidence across player position in football. Athletes were given pre-season neuropsychological testing to gather baseline data. The results indicated that subjective and objective testing are helpful in determining readiness for return-to-play after a concussion, however the tests are not the only factors to be used when determining readiness to play. The mean length of time needed for recovery after concussion was determined to be approximately seven days post-injury.
THE EFFECTS OF INJURY MANAGEMENT PROTOCOL IN COLLEGE
ATHLETES WITH SPORTS-RELATED HEAD INJURY:
EVIDENCE BASED RECOMMENDATIONS

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

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2004

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ACKNOWLEDGEMENTS

I would like to send my thanks to the members of my committee, Dr. Alice Kahn, Dr. Stephen Dailey, and Dr. Fofi Constantinidou. Without the support and cooperation of each committee member, this paper would not have been possible. I thank Dr. Kahn for being an excellent source of information about style and structure for the paper. My appreciation is extended to Dr. Dailey, without whom I would not have been able to organize the athletes’ participation in the study. My sincerest gratitude goes to Dr. Constantinidou who not only encouraged me to challenge myself with this project, but also provided in depth knowledge to enhance every aspect of my thesis.

I would also like to acknowledge all of the athletes who completed both baseline testing and returning to the clinic to undergo testing post-injury. If these athletes had not agreed to participate in the study, I truly would have not have been able to complete the project.

Gratitude must also be extended to the graduate students in the Speech Pathology and Audiology Department who each tested athletes for baseline data. This would have been an impossible task if not the generosity of their time and effort. A special thanks goes to my office mates, Kate Laske and Taniesha Avery for supporting me throughout the project and aiding me whenever necessary.

Lastly, I would like to acknowledge my family and friends for supporting and assuring me through the completion of this project. Without everyone’s encouragement, I would not have been capable of challenging myself to write this thesis.
Chapter I

Introduction

*Incidence and Effects of Concussion in Sports*

An estimated 300,000 brain injuries occur in the United States each year in sports-related events. Most of these brain injuries are of mild severity and therefore classified as concussions. Contact sports place athletes at risk for concussion. In fact, football players have an approximated 19% chance of suffering a concussion while on the field (Lovell, Bradley, Collins, & Burke, 2003). Each year, 250,000 of the estimated 300,000 incidences of concussion are reported from football alone (Dodick, 2001). Because concussion can occur with a either a blow to the head or a traumatic jarring of the body, an estimated 34% of football players at the collegiate level have sustained one concussion and 20% have sustained two or more concussions (Lovell et al., 2003).

Sports-related concussion can lead to acute psychological, cognitive, and motor difficulties. These impairments can be immediate or gradual in onset and may include confusion, amnesia, vacant stare, delayed verbal or motor responses, disorientation of time and place, uncoordination, incoherent speech, alteration of consciousness deficits in memory, attention, concentration, reasoning, balance, and coordination (Reichenecker, 1998; Dodick, 2001). Symptoms can persist for days, weeks, or even months if an athlete returns to play before the symptoms have subsided. Persistent symptoms can cause the athlete to have difficulty with academics, activities of daily living, and emotional well being. Complete recovery from concussion is possible if proper management occurs. However, some athletes experience persistent symptoms which include headaches, dizziness, lightheadedness, blurred vision, fatigue, irritability, depression, unusual
sensitivity to environment, impaired concentration, and/or memory loss (Dodick, 2001). Additionally, an athlete is more likely to sustain a second concussion in the first few days after the original injury. A second concussion could have catastrophic effects such as second impact syndrome (SIS). SIS has been associated with 26 deaths in the United States since 1984 (Maroon, Lovell, Norwig, Podell, Powell, & Hartl, 2000). These difficulties may not be identified until the athlete encounters environments that require the usage of cognitive functions (Sohlberg & Mateer, 1989).

Assessment

Proper identification of sports-related concussion is essential for assessing readiness for return to play, preventing unfavorable consequences, and avoiding the potential long-term effects of frequent brain injury. Return-to-play decisions are often difficult without baseline testing. While neuropsychological tests have been determined to be sensitive to subtle cognitive changes after concussion, the effectiveness of such tests is thoroughly enhanced with established baseline data. Repeated testing can follow injury to determine when the player returns to baseline and henceforth can be used as factor to determine readiness to return to play (Ravdin, Barr, Jordan, Lathan, & Relkin, 2003).

The use of symptoms as an assessment tool is problematic as symptoms may not occur consistently across all situations and environments. Symptoms may also be delayed in onset and therefore not begin until the return to play decision has already been made. In addition, many individuals associated with competitive sports believe that symptoms of concussion will eventually subside even if the athlete continues to play while experiencing the post-concussive symptoms. This furthers the evidence that making
return to play decisions based on reported symptoms is not the most effective or safe route to take for the best interests of the injured athlete (Lovell & Collins, 1998).

Statement of the problem

Currently, there are more than 17 different sets of guidelines for concussion, which include different grading of concussion and criteria for return to play readiness (Lovell et al., 2003). The most popular guidelines in usage are the American Academy of Neurology (AAN) guidelines for the Sideline evaluation and the Standardized Assessment of Concussion (SAC) for sideline use. The AAN guidelines are the most commonly used tool for determining return to play readiness and concussion severity. While these guidelines are very widely used, studies have revealed that they are not effective in detecting the effects of mild concussion (McCrea, Kelly, Kluge, Ackley, & Randolph, 1997). Consequently, sports-related concussion can be overlooked or misdiagnosed leading to grave consequences including death.

Neuropsychological baseline assessment of athletes participating in high impact sports can prove helpful in managing concussion. Athletes sustaining a concussion can be re-assessed and monitored until his or her performance returns to the baseline. This comparison to baseline along with the presence of symptoms can provide useful information in the return to play decision.

Purpose of the study

The purpose of this study was threefold: 1) To determine the sensitivity of a neuropsychological test battery in detecting concussion in athletes, 2) To assess time required for an injured athlete to return to baseline neuropsychological and post-
concussion symptom scores, 3) To compare the incidence of mild traumatic brain injury across player positions in football.
Chapter II

Review of the Literature

Concussion in Sports

Definition

The Committee of Head Injury Nomenclature of the Congress of neurological Surgeons first defined concussion in 1966 as ‘a clinical syndrome characterized by immediate and transient impairment of neural functions, such as alteration of consciousness, disturbance of vision, equilibrium, etc. due to mechanical forces’. However, this definition is limited as it does not mention common symptoms associated with concussion. By omitting the symptoms, this definition does not account for minor injuries that can cause the onset of cognitive and/or physical symptoms. Currently, the most widely used definition was written by Kelly, Nichols, Filley, Lillehei, Rubenstein, and Kleinschmidt (1991) and says concussion is “a trauma induced alteration in mental status that may or may not involve loss of consciousness”. This definition clearly states that loss of consciousness is not necessary for concussion to occur, but omits information about symptoms associated with concussion other than loss of consciousness. In an attempt to create an all encompassing definition, the Concussion in Sport Group (CISG) developed a new definition of concussion. This definition states, “Concussion is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces” (Aubry, Cantu, Dvorak, Graf-Baumann, Johnston, Kelly et al., 2002). As shown in Table 1, this definition includes “several common features that incorporate clinical, pathological, and biomechanical injury constructs that may be used in defining the nature of a concussive head injury” as well (Aubry et al., 2002).
Table 1. Common Features Used for Defining Concussion

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.

1. Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously.

2. Concussion may result in neurological changes but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury.

3. 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.

4. Concussion is typically associated with grossly normal structural neuroimaging studies.” (Aubry et al, 2002)

Historical Overview of Concussion in Sports

Injuries in sports began to gain notoriety in 1904, when President Theodore Roosevelt threatened to ban American football. When this threat occurred, football came under great media and medical scrutiny as being a dangerous sport, for no other organized sport has been associated with as many deaths. Nineteen football players were paralyzed or killed in 1904 which spurred the birth of the National Collegiate Athletic Association (NCAA) to establish guidelines for safer athletic competition. In 1954, sports-related deaths reached an all time high in American football at 30 athletes. American football was associated with 819 deaths from concussion or cervical spine
injury between 1931 and 1986. In the ten 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).

Rule changes, equipment standards, better conditioning, and better on-field medical care have dramatically reduced the number of concussion related deaths since the 1970’s. The 1970’s brought the realization that more subtle forms of brain injury could follow concussion. While death or serious injury due to concussion has decreased significantly, spinal cord injuries causing quadriplegia have not been significantly reduced. This could possibly be attributed to a lack of equipment capable of preventing this type of injury (Cantu, 1997).

*Incidence of Sports-Related Concussion*

The reported incidence of concussion has decreased significantly and caused inconsistencies in the literature regarding high school football over the past twenty years. These inconsistencies may result from changes in rules of the game, techniques, and equipment. For example, many football players used to use 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, Gerberich, Priest, Boen, Staub, and Maxwell found that 24% of all football injuries were classified as concussion and that 19 out of 100 high school football players would sustain a concussion each season. When these figures were expanded to the larger picture, it was approximated that 200,000 concussions would occur per season in high school football.
This figure was reduced in 1999, when Powell and Barber-Foss reported only an approximated 40,000 concussions would occur per high school football season. This figure was modified again in 2003 as the University of Pittsburgh reported one in ten high school athletes would receive a concussion while playing a contact sport. This number expands to approximately 62,000 concussions expected each year in all high school athletic events with 63% of the concussions occurring in football players.

*Incidence of Concussion According to Player Position in Football*

While football is considered a high-risk sport for concussion and many studies have sought to find the overall incidence of concussion in football players, there is little information targeting incidence according to player position. Such an analysis would be informative as logic dictates that some positions in the sport are more prone to concussions than others. Delaney, Lacroix, Leclerc, and Johnston (2000) reported that during the 1997 season of the Canadian Football League, there were differences in the percentage of players with concussion per position. The results of this study indicated the players with the highest chances of experiencing concussion were quarterbacks who played in all games during the season and had a history of at least one previous concussion sustained while playing football. The percentage of players from each position who experienced at least one concussion during the 1997 season are listed in Table 2.
Table 2. Primary Position of Players with at least One Concussion

<table>
<thead>
<tr>
<th>Primary Position</th>
<th>Percentage (No.) with concussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarterback</td>
<td>71.4% (5/7)</td>
</tr>
<tr>
<td>Running back</td>
<td>58.3% (7/12)</td>
</tr>
<tr>
<td>Defensive Lineman</td>
<td>54.2% (13/24)</td>
</tr>
<tr>
<td>Linebacker</td>
<td>47.6% (10/21)</td>
</tr>
<tr>
<td>Wide receiver/ slot back</td>
<td>47.1% (8/17)</td>
</tr>
<tr>
<td>Cornerback/ safety</td>
<td>42.9% (12/28)</td>
</tr>
<tr>
<td>Offensive Lineman</td>
<td>34.6% (9/26)</td>
</tr>
<tr>
<td>Special teams player</td>
<td>28.6% (4/14)</td>
</tr>
<tr>
<td>Punter/ kicker</td>
<td>25.0% (1/4)</td>
</tr>
<tr>
<td>Tight end</td>
<td>0.0% (0/1)</td>
</tr>
</tbody>
</table>

In a pilot study investigating university football players, Delaney, Lacroix, Gagne, and Antoniou (2001) also demonstrated a distinction among player position and occurrence of concussion. Similarly to the previously mentioned study, running backs and quarterbacks were the positions where the highest percentage of players suffered a concussion. This research also found that players who had suffered at least one previously recognized concussion had a higher risk of suffering another concussion. The percentage of players from each position who suffered at least one concussion in this study is listed in Table 3.

Table 3. Primary Positions of Players that Suffered at least One Concussion

<table>
<thead>
<tr>
<th>Primary Position</th>
<th>Percentage (No.) with concussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running back</td>
<td>100% (1/1)</td>
</tr>
<tr>
<td>Quarterback</td>
<td>83.3% (5/6)</td>
</tr>
<tr>
<td>Offensive Lineman</td>
<td>60.0% (3/5)</td>
</tr>
<tr>
<td>Cornerback/Safety</td>
<td>50.0% (4/8)</td>
</tr>
<tr>
<td>Defensive Lineman</td>
<td>50.0% (3/6)</td>
</tr>
<tr>
<td>Wide receiver/ slot back</td>
<td>25.0% (2/8)</td>
</tr>
<tr>
<td>Linebacker</td>
<td>0.0% (0/7)</td>
</tr>
<tr>
<td>Special teams player</td>
<td>0.0% (0/2)</td>
</tr>
</tbody>
</table>
In contradiction to the previous two studies, the follow-up study in 2002 (Delaney, Lacroix, Leclerc, & Johnston) examining at university football players did not find quarterbacks and running backs to be the positions reporting the highest incidence of concussion. In this study, tight ends and defensive linemen represented the highest percent of players to suffer at least one concussion. The percentage of players from each position who suffered at least one concussion in this study is listed in Table 4. This research revealed nine different positions all reporting more than 50% of players experiencing at least one concussion.

Table 4. Primary Position of Players who Suffered at least One Concussion

<table>
<thead>
<tr>
<th>Primary Position</th>
<th>Percentage (No.) with concussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tight end</td>
<td>100.0% (6/6)</td>
</tr>
<tr>
<td>Defensive Lineman</td>
<td>80.9% (38/47)</td>
</tr>
<tr>
<td>Special Teams player</td>
<td>80.0% (12/15)</td>
</tr>
<tr>
<td>Wide receiver/ slot back</td>
<td>77.3% (34/44)</td>
</tr>
<tr>
<td>Cornerback/ safety</td>
<td>70.6% (36/51)</td>
</tr>
<tr>
<td>Linebacker</td>
<td>70.4% (31/44)</td>
</tr>
<tr>
<td>Offensive Lineman</td>
<td>69.1% (38/55)</td>
</tr>
<tr>
<td>Running back</td>
<td>65.7% (23/35)</td>
</tr>
<tr>
<td>Quarterback</td>
<td>52.4% (11/21)</td>
</tr>
<tr>
<td>Punter/kicker</td>
<td>0.0% (0/6)</td>
</tr>
</tbody>
</table>

The differences seen in the incidence of players with concussion per position could be due in part to the varying sample sizes of each position represented in the respective studies. Delaney et al. (2002) included many more quarterbacks in the sample population than Delaney et al. (2001). Many more linebackers were included in Delaney et al. (2000) and (2002) than in Delaney et al. (2001) study. The larger study, Delaney et al. (2002) may also include players who do not play on a regular basis and are therefore
not at as likely to sustain a concussion. This would impact the results by lowering the actual likelihood of sustaining a concussion at a given position.

As detailed above, the literature is inconsistent regarding percentage of players with concussion per position. However, there is a trend to indicate a distinction in the incidence of concussion per player position.

Assessment of Concussion in Sports

Neuropsychological Assessment of Sports-Related Concussion

Neuropsychological testing has become a cornerstone in successful evaluation of concussion. Since it has been found 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 post-injury has been shown to be 89.5% effective in determining injured athletes versus normal controls at 24 hours post-injury (Collins et al., 1999). Neuropsychological testing is a major contributing factor to understanding sports-related concussion as well as proper management of the injured athlete in terms or return to play readiness.

Neuropsychological testing should include assessment of information processing speed, planning, memory, and mental flexibility. Various forms of neuropsychological testing are currently being used which include tests given on paper, abbreviated batteries, extensive batteries administered by neuropsychologists, and computer-based tests (Aubry et al., 2002).

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 comparison for each athlete when he or she becomes injured. This is especially important as the qualities which make an athlete good at his or her sport, make his or her baseline scores better than national norms. Therefore, comparison to national norms would be inaccurate.

The CISG recommended that all sports organizations utilize the benefits of neuropsychological baseline and follow-up testing (Aubry et al., 2002). Collecting baseline data for neuropsychological and post-concussion symptom scores provides an estimation of cognitive and psychosocial function which can then be used to determine recovery from effects of concussion (Echemendia & Julian, 2001).

Problems associated with neuropsychological testing include the possibility of practice or learning effects with serial testing. Players may return to baseline scores even if symptoms persist, and the inconsistent ability of the tests to detect neuropsychological and cognitive differences caused by concussion. Tests such as the Trail Making Test (TMT), Digit Span, and Grooved Pegboard have been found to be subject to practice effect (Lovell & Collins, 1998).

Despite these problems, some research has examined the sensitivity of specific tests in the neuropsychological battery. Collins et al (1999) reported that Trails B and Symbol Digits (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 as control at 2 hours and 48 hours post-injury with the Hopkins Verbal Learning Test (HVLT), SDMT, Controlled Oral Word (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, Barth, Alves, Rimel, and Jane, (1996) noted the TMT was sensitive to the mild effects of concussion, as it denoted subtle impairments in injured athletes.

In contrast, some research has indicated no differences between the scores of injured athletes and controls at 1 day, 3 days, 5 days, and 10 days post-injury and the TMT, Digit Span, and the HVLT. (Gusiewicz, Riemann, Perrin, & Nashner, 1997). Similarly, no difference post-injury was observed at any interval post-injury between contact and non-contact sports athletes regardless of concussion history and the control group on COWAT or digit span (International Symposium on Concussion in Sport, 2001) as well as no differences at any interval post-injury between concussed and non-injured Australian football players on the TMT (International Symposium on Concussion, 2001).

Ravdin et al. (2003) proposed that studies comparing injured athletes to controls and not to baseline are more accurate as baseline testing is often completed after training for the season has commenced and therefore, is slightly skewed by confound variables such as fatigue. Because of the contradictory results of these prior studies, further investigation is necessary to determine the practical application of these tests in determining the subtle effect of concussion.

Medical Diagnosis of Concussion

Neuroimaging

Concussions imply a mild brain injury with normal neuroimaging findings. Neuroimaging studies are not routinely conducted with all concussed athletes. However, neuroimaging tests are recommended for athletes who exhibit loss of consciousness or
disturbance of conscious state, seizures, or persistent symptoms as there may be a structural lesion associated with these signs of concussion (Aubry et al., 2002).

The future of medical diagnosis of concussion seems promising as there are several new, more specific neuroimaging techniques such as PET scans, SPECT tests, and fMRI’s which may be able to detect minor abnormalities currently not detected with traditional MRI and CT scans (Johnston, Ptito, & Chankowsky, 2001). The fMRI is a non-invasive test that monitors cerebral blood flow and metabolic changes in the brain when an athlete completes various activities of physical and cognitive nature. This test can then determine if there is an abnormality in the activation of different brain functions. However, there is not an abundance of research to determine the effectiveness of these techniques with concussion. Also, the lack of baseline neuroimaging could inhibit the usefulness of these techniques. (University of Pittsburgh, 2002).

Other Medical Diagnoses

Several methods of medical diagnosis of concussion other than neuroimaging are being introduced to the field. Electrophysiological recording (ERP, EEG) and balance testing have both been shown to detect abnormalities in brain function following concussion. It has also been proposed that cell damage after concussion can be detected with biochemical serum markers such as S-100, NSE, and MBP (Aubry et al., 2002).

As well as the aforementioned theories, neurochemical and metabolic changes are believed to occur up to 10 days after a concussion. These changes can increase the vulnerability of brain cells by increasing the demand for glucose even though there is a reduction of cerebral blood flow to deliver the glucose. Henceforth, demand for glucose
is greater than the supply, so the brain cannot return to normal neurochemical homeostasis (Hovda, Prins, Becker, Lee, Bergsnider, & Martin, 1999).

**Symptom Based Assessment of Concussion**

An athlete can experience numerous signs and symptoms following concussion. Symptoms such as loss of consciousness, tinnitus, lightheadedness, poor muscle coordination, headache, nausea, and vomiting can be indicative of brainstem dysfunction. In contrast, symptoms such as confusion, disorientation, amnesia, decreased information processing and memory impairment are usually indicative of damage to the cerebral cortex. In addition, symptoms such as depression, fatigue, sleep disturbance, irritability, and feeling “foggy” are often delayed in onset. (Maroon et al., 2000).

The CISG describes three categories of symptoms indicating concussion: cognitive features, typical symptoms, and physical signs (Appendix A).

Cognitive features indicating a concussion include periods of confusion or amnesia, loss of consciousness for any length of time, and/or an inability to answer questions regarding orientation such as the date, time, or location (Aubry et al., 2002). Typical symptoms of concussion include headache, dizziness, nausea, a loss of balance, tinnitus, diplopia, sleepiness, or sleep disturbance. If any of these symptoms are present in the setting of an impact, concussion is suspected (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 cognitive symptoms include loss of consciousness, poor concentration, slowness to answer questions or follow directions, and inappropriate playing behavior such as running the wrong the direction on the playing field. Psychological symptoms of a
concussion encompass laughing and crying inappropriately and/or personality changes. Medical symptoms of a concussion include concussive convulsions, nausea, vomiting, and vacant stare. Motor deficits often considered to be physical signs of concussion are poor coordination, unsteady walking, and slurred speech (Aubry et al., 2002).

Typically, many athletes under-report symptoms as the nature of competitive sports pushes athletes to play at all costs. If a player is suspected of suffering a concussion, but reports no symptoms, sideline testing should take place and the player should be closely monitored for the delayed presence of signs and symptoms (Leclerc, Lassonde, Delaney, Lacroix, & Johnston, 2001).

Sideline testing is a brief assessment procedure that should include tasks to evaluate an athlete’s higher level cognitive functioning such as orientation, memory, problem solving, and ability to learn new information. Appropriate questions to include in a sideline evaluation can be found below in Table 5 (Leclerc et al., 2001; Reichenecker, 1998).

Table 5. Questions to be Included in Sideline Evaluation

<table>
<thead>
<tr>
<th>Which team did we play last week?</th>
<th>Which team scored last?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did we win last week?</td>
<td>Which team are we playing today?</td>
</tr>
<tr>
<td>How far into the quarter is it?</td>
<td>Which quarter is it?</td>
</tr>
</tbody>
</table>

These brief evaluations can also detect signs that are often observed on the sidelines and may indicate a concussion include: confusion, dazed appearance, uncertainty of environment, clumsiness, slow to answer questions, loss of consciousness, personality change, and amnesia (Field, Collins, Lovell, & Maroon, 2003). Standardized
assessment tools such as the Standardized Assessment of Concussion (SAC) (Appendix B) can be used to test for the previously mentioned signs of concussion (Kelly, 2000).

If a player presents with any one of these symptoms, a concussion should be suspected and proper management procedures should be implemented immediately. Loss of consciousness is not necessary for an athlete to be considered having sustained a concussion.

Return-To-Play Assessment

Currently 17 different sets of guidelines have been devised to assess return to play readiness in athletes who have sustained a concussion. These guidelines have played a large role in aiding coaches, doctors, and trainers who lack background in sports-related concussion by creating a heightened awareness of the importance of the return to play decision. (Echemendia & Julian, 2001).

Even with the heightened awareness, the guidelines are consistently under scrutiny for inappropriately assessing readiness for return to play. Until recently, these guidelines have considered loss of consciousness to be the only indicator of severe brain injury. Therefore, athletes not experiencing loss of consciousness were determined ready to return to play before their recovery was complete, which put them at increased risk for cumulative or persistent effects of concussion (Lovell et al., 2003).

Recently, the CISG published a stair step process as an outline to assist the return to play determination (Table 6). With this stepwise progression, the athlete should only move on to the next level when he or she is asymptomatic at the present level. If any symptoms occur at any level, the athlete should go back to the previous level for another full day and then attempt to progress again the next day (Aubry et al., 2002).
Table 6. CISG Stair Step Process to Determine Readiness for Return to Play

<table>
<thead>
<tr>
<th>Step</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No activity, complete rest. Once asymptomatic, proceed to level 2.</td>
</tr>
<tr>
<td>2</td>
<td>Light aerobic exercise such as walking or stationary cycling</td>
</tr>
<tr>
<td>3</td>
<td>Sport specific training- for example, skating in hockey, running in soccer.</td>
</tr>
<tr>
<td>4</td>
<td>Non-contact training drills.</td>
</tr>
<tr>
<td>5</td>
<td>Full contact training after medical clearance.</td>
</tr>
<tr>
<td>6</td>
<td>Game play” (Aubry et al, 2002).</td>
</tr>
</tbody>
</table>

While these are excellent guidelines for the return-to-play decision, the authors did not mention the appropriate amount of time an athlete should be asymptomatic at each level before progressing to the next step. This would be a pertinent piece of information in determining the status of the athlete’s recovery process. Therefore, further information is needed in addition to these guidelines to confidently make a return-to-play decision.

Effects of Sports-Related Concussion

Cumulative Effects of Sports-Related Concussion

Various studies have examined the statistics describing the cumulative effects of concussion in both college and high school athletes. The statistics include chances of multiple concussion, chances of experiencing loss of consciousness, and chances of experiencing decreased cognitive functioning. However, there is little evidence that examines sports-related concussion in sports other than football.
Football players with history of concussion are three to six times more likely than players without history of concussion to sustain a subsequent concussion. Cognitive symptoms such as amnesia, loss of consciousness, and confusion have been noted to occur more often in athletes with a history of two or more concussions. Collins, Lovell, Iverson, Cantu, Maroon, and Field (2002) found that athletes with a history of three or more concussions are almost seven times more likely to experience loss of consciousness than athletes without history of concussion. Athletes with two or more concussion are also at risk of suffering decreased speed of processing and executive function difficulty than those with no prior concussion (Collins et al., 2002; Collins et al., 1999)

*Second Impact Syndrome*

Sports such as football, soccer, and hockey put players at an increased risk for sustaining multiple concussions (University of Pittsburgh, 2002). Athletes who return to play before completely recovering from the first concussion are at increased risk for sustaining a second concussion from even a minor collision. This second concussion can disturb blood supply to the brain causing cerebral swelling and deterioration of cells which leads to cognitive disability and even death (Kelly, 2000; McCrory & Berkovic, 1998).

This process is referred to as “Second Impact Syndrome” (SIS). While some studies report as many as 17 cases of SIS since 1992 (Harmon, 1999), others report that as few as five of these cases are actually representative of SIS (McCrory & Berkovic, 1998). Regardless of incidence, SIS is a very serious issue and needs to be considered when decisions regarding readiness for return to play (Maroon et al., 2000).
Neuropsychological and Cognitive Impairment from Concussion

Numerous studies have indicated the cognitive and neurobehavioral outcomes of sports-related concussion. Concussion reportedly results in decreased cognition in the areas of orientation, immediate memory, concentration, and delayed recall (McCrea, Kelly, Randolph, Cisler, and Berger, 2002). Information processing speed, attention, executive functioning, visuomotor speed, and auditory attention have also been noted to be impaired following concussion (Macciocchi et al 1996; Collins et al., 1999).

Neurobehavioral outcomes have been documented to include dizziness, irritability, headache, fatigue, depression, anxiety, sensitivity to light, and sensitivity to noise (Ferguson, Mittenberg, Barone, & Schneider, 1999; Gaetz, Goodman, & Weinberg, 2000). One study investigating the effectiveness neuropsychological assessment in detecting the deficits associated with concussion has suggested that impairments detected for 2-3 days following concussion were equivalent to those detected with a blood alcohol level of .10% and a period of sustained wakefulness of 24 hours. (International Symposium for Concussion in Sport, 2001).

Cognitive and Neurobehavioral effects of sports-related concussion can be short or long-term and immediate or delayed in onset. This variation causes many concussions to be misdiagnosed or mismanaged possibly leading to further injury.

Post-Concussion Syndrome

Post-concussion syndrome (PCS) is characterized by the development of symptoms such as headache, dizziness, nausea, disorientation, and impaired motor control after an athlete sustains a concussion (Slobounov, Sebastianelli, & Simon, 2002).
An estimated 50 to 80% of individuals who suffer a concussion can be affected by PCS at approximately three months post-injury.

Symptoms must persist for a minimum of three months before PCS can be diagnosed, and neuropsychological changes must accompany the presence of physical symptoms for the entire three month period of time before diagnosis (American Psychiatric Association (DSM-IV), 1994). While these requirements are applicable with severe brain injuries, they are problematic in mild concussions associated with sports injuries. Research regarding mild concussion has repeatedly shown that neuropsychological symptoms are typically resolved within days of the injury.

Many theories address the possible causes of PCS. The DSM-IV suggests that underlying cerebral dysfunction and structural anomaly are the causes of PCS, while other sources indicate psychosocial factors are main contributors to the materialization of PCS (World Health Organization (ICD-10), 1992).

**Motor Deficits**

Motor deficits include gross and fine motor skills. Following concussion, transient functional changes are believed to occur in motor areas of the brain resulting in impaired motor coordination and control.

Motor speed is often affected by sports-related concussion. This deficit is manifested in increased reaction time which becomes prominent in tests that require choice with timed reactions (International Symposium of Concussion in Sports, 2001).

Motor imprecision is also noted with concussion. Responses to motor tasks have been documented with increased occurrence of error following concussion due to imprecise movements (Slobounov et al., 2002). Imprecision is also noted with gait as
players are often unsteady and need help to walk after sustaining a concussion (McCrory & Berkovic, 2000).

*Recovery after Sport-Related Concussion*

Recovery is a highly debated, very important part of sport-related concussion. Controversy surrounds the most effective scale by which injury is measured to be used, the post-concussion symptoms score or the score achieved on the neuropsychological battery of tests, to determine when an athlete’s recovery from concussion is complete. There is also a wide discrepancy among studies to suggest approximately how long an athlete is expected to need for recovery to be complete. Currently, the estimated time for recovery is anywhere from 48 hours to 14 days with some studies reporting athletes require up to three months of recovery after concussion.

McCrea et al., (2002) suggest recovery is gradual and complete within two days post-injury regardless of loss of consciousness or amnesia immediately after injury. However, some studies report that athletes do not return to baseline until approximately 10 days post-injury, regardless of improved symptom reports (Lovell et al., 2003). In addition, some research indicates the most athletes return to baseline functioning between seven and fourteen days following a concussion (Enchemendia et al., 2001).

Age may have an impact on the recovery period. High school athletes may experience post-concussion symptoms up to four days longer than college athletes. In one study, high school athletes needed seven days post-injury to compare with non-injured, age-matched controls on tasks of cognitive functioning whereas the college athletes displayed data similar to the age-matched controls within three days after sustaining a concussion (Field et al., 2003).
**Management of Concussion in Sports**

Management of concussion in sports should include three basic elements: an educational component, a program of cognitive rehabilitation, and a common set of management rules that should be followed for each player.

The educational component should address the athlete’s knowledge of physical, cognitive, and emotional symptoms that he or she is likely to encounter after sustaining a concussion. The athlete’s family and team should also be educated about the possible symptoms the athlete could experience.

A cognitive rehabilitation program should include areas such as memory training, organizational training, and attention training. This rehabilitation should be implemented for athletes who have persistent cognitive deficits beyond the expected recovery time period. Emotional and psychological effects of sports-related concussion should also be addressed and dealt with appropriately as many of the athletes who are in this position are devastated at the prospect of not being able to participate in his or her sport (Echemendia & Julian, 2001).

A recommended protocol for the management of sports-related concussion includes four steps to be followed to ensure appropriate actions are taken following a concussion. Table 7 shows these four steps.
Significance of the Study

The present study investigated many aspects of sports-related concussion with administration of a neuropsychological battery of tests, post-concussion symptoms scores, and a concussion survey at Miami University of Ohio. The collegiate sports represented in the study include football, soccer, basketball, and ice hockey. The athletes provided information on the number of concussions and the position they were playing when a concussion was sustained. Athletes reporting prior concussions provided information about changes in neuropsychological abilities and post-concussive symptoms experienced after injury.

The present study provides information regarding the incidence and recovery of concussion collegiate sports, and identifies risk factors associated with initial and multiple concussions including specific player position. Furthermore, this study examines the sensitivity of each test included in the neuropsychological battery of tests to the cognitive decline following concussion. Findings could be of value to the athletes,
coaches, trainers and team physicians in planning how to reduce the risk, manage appropriately, and prevent subsequent concussions.

Research Questions and Hypotheses

1. Is the brief neuropsychological battery used in this study sensitive in detecting cognitive decline immediately following mild traumatic brain injury? It is hypothesized that certain tests in the battery will be more sensitive to cognitive decline exposed after injury based on prior testing of these standardized tests.

2. How long does it take for neuropsychological and post-concussion symptom scores to recover after sports-related mild traumatic brain injury? It is hypothesized that neuropsychological and post-concussion symptom scores return to baseline approximately 7 to 10 days post-injury.

3. Is there a difference in the incidence of mild traumatic brain injury according to player position in football? It is hypothesized that individuals who play certain positions in football are more likely to suffer a concussion.
Chapter III

Methods

Subjects

The study included data collected in seasons 1999-2003 from athletes of five varsity sports at Miami University. The sports represented in the study were football, hockey, men’s and women’s basketball, and women’s soccer. Baseline data was collected for all athletes new to the university. The examination was administered by trained graduate students in the Department of Speech-language Pathology under the supervision of Fofi Constantinidou, Ph.D.

Procedures

Data was collected at the Miami University Speech and Hearing Clinic for all collegiate athletes. The experimenter sat with each athlete in an adult therapy room. Each athlete was given an Informed Consent Form, the Survey, and a Post-Concussion Rating Scale. If the athletes did not understand a question on the survey, the experimenter was present to answer any questions. The athletes turned in their survey directly to the experimenter. After these forms were completed by the athletes, a neuropsychological test battery was given to collect baseline data for each athlete. Completion of the paperwork and test battery took approximately one hour.

The experimental tasks for the present study included the Pittsburgh Steelers Neuropsychological Battery (PSNB)(Brandt, 1991). The PBSN was used in this experiment to gather baseline data of cognitive functioning as well as follow-up serial testing after injury. Prior research has demonstrated that this battery is sensitive to the mild effects of sports-related concussion. Table 8 lists each test in the battery and the
neuropsychological area associated with each test (Lovell & Collins, 1998). In addition to the PSNB, a Post-Concussion Questionnaire was administered to identify athletes at Miami University with a history of concussion and to obtain baseline neurobehavioral symptoms. Each test was administered using standardized directions therefore inter-rater reliability was believed to be adequate.

Table 8. Pittsburgh Steelers Neuropsychological Battery

<table>
<thead>
<tr>
<th>Test:</th>
<th>Ability Evaluated:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hopkins Verbal Learning Test (HVLT)</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>

Confidentiality of Records

All subjects were provided with an informed consent form which they read and signed. Participation in this study was voluntary and subjects could withdraw from the study at any time. No payment or other form of compensation was provided for the subjects’ participation. Subjects were assigned a subject number (first initial of last name plus the four digits of their birth month and day) which was used for baseline and injured data purposes. The surveys were stored in a locked filing cabinet in a locked office and were only be used for data collection.
Data Gathering

Questionnaire

The questionnaire used in the present study was modified from Geffen, Hinton-Bayre, and Geffen (1998) (Appendix C). The original questionnaire by Geffen et al. (1998) was used to study the incidence of concussion in rugby players in Australia. It provides a standardized procedure to survey a player’s history of concussion. The questionnaire used in the present study consisted of 28 questions regarding the participant’s history of concussion.

Post-Concussion Rating Scale

The post-concussion rating scale used in the present study was modified from Lovell and Collins (1998) (Appendix D). It provides a standardized procedure to organize a player’s subjective symptoms after concussion. The rating scale used in the present study consisted of 21 symptoms associated with concussion

Research Hypotheses

1. Certain tests in the neuropsychological battery will be more sensitive to cognitive decline exposed after injury.

2. Neuropsychological and post-concussion symptom scores return to baseline approximately 7 to 10 days post-injury.

4. Individuals who play certain positions in football are more likely to suffer a concussion.
Statistical Analysis

Data analyses was performed using the Statistical Package for the Social Sciences (SPSS) (2001). Descriptive statistics, t-test comparisons, and χ² analyses was conducted at α= .05.
Chapter IV

Results

Subjects

The subjects in this study were both male and female athletes from Miami University. Females represented 25.1 percent of the subjects with baseline data and 43.2 percent of the injured athletes. Males comprised the remaining 74.9 percent of the athletes with baseline data and 56.8 percent of the injured athlete data. The age range was 16-22 years with a mean of 18.4 years. Data was collected from injured athletes between 4 hours and 68 days post-injury with a mean time of 7.3 days for the first testing post-injury (T1) and 13.9 days for the second testing post-injury (T2).

Data Analysis

Data analyses are presented according to the research questions. Descriptive analyses are presented first, followed by inferential statistics when applicable.

RQ1. Is the brief neuropsychological battery used in this study sensitive in detecting cognitive decline immediately following mild traumatic brain injury? A t-test of related measures was performed at $\alpha = .05$. To determine the large scale effectiveness of the neuropsychological battery, the injured athletes were divided into two groups based on their performance at T1 post-injury. Group one ($n=31$) consisted of the athletes who showed a decline in at least one test in the battery as compared to their baseline performance. Group two ($n=8$) consisted of the athletes who did not show a decline in any of the individual tests. Eighty percent of the injured athletes showed a decline. A $\chi^2$ analysis was performed to determine if there was a significant difference in the number of athletes between the two groups at T1 post-injury. The $\chi^2$ was significant, $\chi^2(1) = 13.564,$
p=.000 indicating that the neuropsychological battery is sensitive in detecting cognitive decline immediately following concussion because a significant number of athletes performed lower than their baseline performance.

Figure 1 shows the percentages of athletes who showed a cognitive decline at T1 anytime post-injury, T1 within 48 hours of injury (T1≤ 2 days), and T1 at three to four days post-injury (T1= 3-4 days), T1 at five or more days post-injury (T1≥ 5 days).

Figure 1. Percent of Athletes with Post-Injury Cognitive Decline in at least One Test.

To look at the effectiveness of individual tests within the battery, the group means of the athletes’ baseline (B) neuropsychological scores were compared to the group mean neuropsychological score obtained at T1 and the second testing following the injury (T2). If the T1 or T2 score was significantly lower than B, then it was concluded that the test was sensitive in detecting cognitive decline following concussion. The post-concussion survey score, t(14)= -2.34, p=.035, was found to be significant in determining a cognitive decline after injury when compared to baseline. In addition, even though the difference was not statistically significant, cognitive decline was detected in the Hopkins Verbal Learning Test Trial 1, t(20)=1.72, p=.101 which assesses verbal memory.
Certain tests were also found to be significant in determining cognitive decline depending on the interval at which the athletes were tested post-injury. The Trail Making Test A, $t(10)= -2.734$, $p=0.021$ was found to be statistically significant in denoting cognitive decline when the athletes were tested within 48 hours of the injury as well as when the athletes were more than five days post-injury, $t(3)=3.703$, $p=0.034$. However, when athletes were tested at three to four days post-injury, the Trail Making Test A was not significant, while Grooved Pegboard dominant, $t(5)=2.703$, $p=0.043$ was significant in showing a decline in ability.

Performance on many tests at T2 showed significant impairment as compared to the first testing after injury. The Post-concussion scale, $t(27)=3.78$, $p=0.001$, Trail Making Test A $t(27)=3.67$, $p=0.001$ and Trail Making Test B, $t(27)=2.13$, $p=0.042$, COWAT, $t(27)=-5.00$, $p=0.000$, Digit Span $t(27)=-2.37$, $p=0.025$, Symbol Digits, $t(27)=-3.615$, $p=0.001$, Grooved Pegboard dominant $t(27)=3.61$, $p=0.001$ and non-dominant $t(27)=3.15$, $p=0.004$ at T2 were all statistically significantly better than T1 indicating improvement in cognitive ability with increased time post-injury. The data also indicates that Symbol Digits, $t(12)=-4.38$, $p=0.001$, Grooved Pegboard (dominant), $t(13)=2.815$, $p=0.015$ were significantly better at T2 than baseline.

Some research supports the use of control data versus baseline comparisons. The rationale behind this notion relates to levels of fatigue during pre-season testing that can alter test results. Therefore, independent samples t-tests were also performed between data taken post-season as a measure for comparison to baseline and T1. This independent samples t-test indicated that Symbol Digits, $t(73)=1.99$, $p=0.050$, was very effective in determining a decline in neuropsychological function at T1 post-injury.
Qualitatively, the PBSN was very useful in determining cognitive decline after concussion. Table 9 lists the means and standard deviations of testing at baseline (B), within one to seven days after injury (T1), and five to ten days after injury (T2). Appendix E lists each athlete and the tests within the battery that showed cognitive decline at T1 and T2 for that athlete.

Table 9. Means and Standard Deviations of Tests at B, T1, and T2.

<table>
<thead>
<tr>
<th>Test</th>
<th>Baseline</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Post-Concussion Scale</td>
<td>12.80</td>
<td>12.74</td>
<td>25.56</td>
</tr>
<tr>
<td>HVLT Trial 1</td>
<td>7.14</td>
<td>1.82</td>
<td>6.28</td>
</tr>
<tr>
<td>HVLT Delayed Recall</td>
<td>9.01</td>
<td>2.03</td>
<td>8.56</td>
</tr>
<tr>
<td>Trail Making Test A</td>
<td>22.28</td>
<td>6.68</td>
<td>22.14</td>
</tr>
<tr>
<td>Trail Making Test B</td>
<td>48.81</td>
<td>20.02</td>
<td>51.03</td>
</tr>
<tr>
<td>COWAT</td>
<td>43.71</td>
<td>7.37</td>
<td>41.71</td>
</tr>
<tr>
<td>Digit Span</td>
<td>17.71</td>
<td>3.37</td>
<td>18.57</td>
</tr>
<tr>
<td>Symbol Digits</td>
<td>57.65</td>
<td>9.98</td>
<td>61.00</td>
</tr>
<tr>
<td>Grooved Pegboard (Dominant)</td>
<td>93.28</td>
<td>10.62</td>
<td>90.20</td>
</tr>
<tr>
<td>Grooved Pegboard (Non-dominant)</td>
<td>98.38</td>
<td>14.24</td>
<td>100.69</td>
</tr>
</tbody>
</table>

Note: T1 = 1-7 days post-injury; T2 = 5-10 days post-injury

An in-depth look at the individual symptoms listed on the post-concussion rating scale revealed results that are useful in determining the most subjective symptoms of a concussion. Some research suggests that several of the symptoms included on this list may be felt on any given day and may not be a result of a concussion. Therefore, paired-samples t-tests were performed between group means for each symptom reported at baseline and group means reported for each symptom immediately after injury, T1, and
T2 post-injury. Several symptoms were found to be reported significantly more severe immediately after the injury and at T1 than baseline. Headache, t(12)=4.693, p=.001, dizziness, t(12)= 4.938, p=.000, fatigue, t(12)=2.582, p=.024, sleeping more than usual, t(12)=2.796, p=.016, drowsiness, t(12)=3.125, p=.009, sensitivity to light, t(12)=3.075, p=.010, sensitivity to noise, t(12)=3.709, p=.003, irritability, t(12)=2.466, p=.030, feeling mentally “foggy”, t(12)=5.196, p=.000, and difficulty concentrating, t(12)=3.333, p=.006 were the symptoms likely to be rated more severely immediately after injury than at baseline. Likewise, headache, t(14)= -3.165, p=.007, dizziness, t(14)= -2.523, p=.024, sleeping more than usual, t(14)= -2.16, p=.048, drowsiness, t(14)= -2.87, p=.012, sensitivity to light, t(14)= -1.936, p=.007, feeling mentally “foggy”, t(14)= -3.603, p=.003, and difficulty concentrating, t(14)= -2.827, p=.013 were all significantly more severe at T1 than baseline.

In addition to the statistical significance among the symptoms listed above, the post-concussion scale was very useful qualitatively. Table 10 lists the means and standard deviations for each symptom as well as percentage of players reporting certain symptoms at baseline, immediately after injury, T1, and T2. The symptoms reported by more than 50% of the athletes at baseline testing were fatigue and feeling slowed down. Immediately after injury, more than 50% of the athletes reported symptoms of headache, nausea, balance problems, dizziness, fatigue, sleeping more than usual, drowsiness, sensitivity to light, sensitivity to noise, numbness or tingling, irritability, feeling slowed down, feeling mentally “foggy”, difficulty concentrating, and difficulty remembering. The symptoms reported by more than 50% of athletes at T1 were headache, dizziness, fatigue, drowsiness, sensitivity to light, feeling slowed down, feeling mentally “foggy”,
and difficulty concentrating. Headache and difficulty concentrating were the only two symptoms to be reported by more than 50% of the athletes tested at T2. Figure 2 shows the percentage of players to report each symptom at baseline, immediately after injury, T1, and T2.

Table 10. Means and Standard Deviations for Each Symptom and Percentage of Players Reporting Certain Symptoms at B, Immediately After Injury, T1, and T2.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>B</th>
<th>Immediately</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>%age reporting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headache</td>
<td>.600</td>
<td>1.30</td>
<td>3.61</td>
<td>2.17</td>
</tr>
<tr>
<td>Nausea</td>
<td>.133</td>
<td>.352</td>
<td>1.81</td>
<td>2.13</td>
</tr>
<tr>
<td>Vomiting</td>
<td>.067</td>
<td>.258</td>
<td>.613</td>
<td>1.45</td>
</tr>
<tr>
<td>Balance problems</td>
<td>.400</td>
<td>1.30</td>
<td>2.29</td>
<td>1.90</td>
</tr>
<tr>
<td>Dizziness</td>
<td>.467</td>
<td>.915</td>
<td>3.29</td>
<td>1.66</td>
</tr>
<tr>
<td>Fatigue</td>
<td>1.33</td>
<td>1.54</td>
<td>2.45</td>
<td>2.05</td>
</tr>
<tr>
<td>Trouble falling asleep</td>
<td>.933</td>
<td>1.67</td>
<td>1.03</td>
<td>1.76</td>
</tr>
<tr>
<td>Sleeping more than usual</td>
<td>.267</td>
<td>.799</td>
<td>2.13</td>
<td>2.25</td>
</tr>
<tr>
<td>Sleeping less than usual</td>
<td>1.00</td>
<td>1.36</td>
<td>.742</td>
<td>1.41</td>
</tr>
<tr>
<td>Drowsiness</td>
<td>.200</td>
<td>.561</td>
<td>2.51</td>
<td>1.98</td>
</tr>
<tr>
<td>Sensitivity to light</td>
<td>.333</td>
<td>.899</td>
<td>2.29</td>
<td>2.19</td>
</tr>
<tr>
<td>Sensitivity to noise</td>
<td>.067</td>
<td>.258</td>
<td>2.06</td>
<td>2.06</td>
</tr>
<tr>
<td>Irritability</td>
<td>.733</td>
<td>.961</td>
<td>1.81</td>
<td>2.04</td>
</tr>
<tr>
<td>Sadness</td>
<td>.667</td>
<td>1.40</td>
<td>.807</td>
<td>1.40</td>
</tr>
<tr>
<td>Nervousness</td>
<td>.867</td>
<td>1.25</td>
<td>.903</td>
<td>1.47</td>
</tr>
<tr>
<td>Feeling more emotional</td>
<td>1.00</td>
<td>1.36</td>
<td>1.42</td>
<td>1.78</td>
</tr>
<tr>
<td>Numbness</td>
<td>.200</td>
<td>.414</td>
<td>1.35</td>
<td>1.87</td>
</tr>
<tr>
<td>Feeling slowed down</td>
<td>1.13</td>
<td>1.64</td>
<td>2.29</td>
<td>1.70</td>
</tr>
<tr>
<td>Feeling mentally “foggy”</td>
<td>.600</td>
<td>1.28</td>
<td>3.23</td>
<td>1.69</td>
</tr>
<tr>
<td>Difficulty concentrating</td>
<td>.667</td>
<td>1.04</td>
<td>3.23</td>
<td>1.52</td>
</tr>
<tr>
<td>Difficulty remembering</td>
<td>.733</td>
<td>1.44</td>
<td>2.42</td>
<td>2.25</td>
</tr>
</tbody>
</table>
Figure 2: Percentage of Athletes Reporting each Symptom at B, immediately after injury, T1, and T2.
RQ2. How long does it take for neuropsychological and post-concussion symptom scores to recover after sports-related mild traumatic brain injury? The average length of time required for recovery was calculated by determining the number of days needed for the injured athlete’s score to return to baseline or national means (if baseline was not available). The mean length of time for recovery was 10.07 days (n= 38) with a standard deviation of 9.59. However, isolating the athletes with baseline data from those who were compared to national norms, the mean length of time to return to baseline was 7.36 (n=21) days with a standard deviation of 5.29. While 47.4% of the patients with baseline data returned to baseline within 7.36 days, 52.6% of the athletes required more time.

RQ3. Is there a difference in the incidence of mild traumatic brain injury according to player position in football? A $\chi^2$ analysis was performed with data from the football athletes reporting having had a prior concussion and the position each athlete played. Out of 127 football athletes included in the study, 34 had sustained a prior concussion. There were a total of 11 different possible football positions. Due to this large number of possibilities, and only a 34 athletes meeting the aforementioned criteria, there was not a statistically significant result found $\chi^2(9)=9.53, p=.390$. Table 11 lists the positions and observed number of players reporting a prior concussion for each position. The positions were then separated into two categories: offensive (n=21) and defensive (n=12) and the analysis was performed again. While still statistically insignificant, there was a trend to indicate offensive players are at greater risk for sustaining a concussion $\chi^2(1)=2.45, p=.117$. With a larger sample, perhaps this trend will become significant.
Table 11. Primary position of players with at least one concussion

<table>
<thead>
<tr>
<th>Position</th>
<th>Percentage with concusion</th>
<th>Number with concussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarterback</td>
<td>62.5 %</td>
<td>5/8</td>
</tr>
<tr>
<td>Safety</td>
<td>50.0%</td>
<td>1/2</td>
</tr>
<tr>
<td>Linebacker</td>
<td>40.0%</td>
<td>6/15</td>
</tr>
<tr>
<td>Offensive Lineman</td>
<td>30.0%</td>
<td>6/20</td>
</tr>
<tr>
<td>Wide Receiver</td>
<td>28.6%</td>
<td>4/14</td>
</tr>
<tr>
<td>Running Back</td>
<td>23.5%</td>
<td>4/17</td>
</tr>
<tr>
<td>Tight end</td>
<td>22.2%</td>
<td>2/9</td>
</tr>
<tr>
<td>Punter/ kicker</td>
<td>20.0%</td>
<td>1/5</td>
</tr>
<tr>
<td>Defensive Lineman</td>
<td>15.8%</td>
<td>3/19</td>
</tr>
<tr>
<td>Defensive Back</td>
<td>12.5%</td>
<td>2/16</td>
</tr>
<tr>
<td>Long Snapper</td>
<td>0.0%</td>
<td>0/2</td>
</tr>
</tbody>
</table>

Qualitatively, there was a difference noted between the percentages of players at several positions reporting having sustained at least one prior concussion. Quarterbacks reporting the highest percentage of players having had a concussion (62.5%) followed by those playing in the safety (50%) and linebacker (40%) positions.
Chapter V
Discussion

This study compared the sensitivity of each neuropsychological test in the current research battery to the effects of concussion, to assess time required for an injured athlete to return to baseline neuropsychological and post-concussion scores, and compared the incidence of concussion across player position in football. These issues were studied to further modify the current battery so it can be fully effective in determining when an injured athlete is ready to return to play.

Sensitivity of Neuropsychological Test Battery

Overall, the use of the neuropsychological battery and the monitoring protocol of injured athletes were effective in identifying decline following concussion, with 80% of the athletes showing a decline in cognitive abilities and/ or reporting significantly more severe symptoms at T1 post-injury as compared to baseline testing. Considering the remaining 20% of athletes who reported experiencing no symptoms and showed no deviation from baseline scores at T1 post-injury, three possible conclusions can be indicated: 1) the athlete was never truly concussed, 2) the athletes was concussed, but had largely recovered by the time of testing, or 3) neither the neuropsychological battery nor the post-concussion rating scale were sensitive enough to detect a decline.

Upon review of individual tests of the battery, the post-concussion rating scale and the Trail Making Test were found to be the most effective when testing occurred within 48 hours post injury. These results agree with Echemendia et al (2001), Macciocchi, et al (1996), and Collins et al (1999) who also indicated statistical differences between the baseline scores of injured athletes and scores on the TMT at 24-
48 hours post-injury. Other tests such as the HVLT and the Grooved Pegboard (dominant trial) showed descriptive trends but were not statistically significant. As the database grows to include more injured athletes with available baseline scores, it is expected that the descriptive trends will become statistically significant.

When compared to normative data (vs. baseline scores), the SDMT showed sensitivity. Both the TMT and SDMT require speed of processing, mental flexibility, and throughput. These findings suggest that these skills may be most affected by concussion. This agrees with prior research presented by the International Symposium of Concussion in Sports (2002) which indicates increased reaction time is observed in athletes following a concussion. Slobounov et al. (2002) also indicated that increased occurrence of error on the tests involving speed of processing and mental flexibility could be attributed to motor movements becoming more imprecise for athletes post-injury as compared to baseline testing. Future studies may want to obtain normative data to compare the database of injured athletes to a group of control athletes as in the present study, the performance on two T2 tests (SDMT and Grooved Pegboard dominant trial) was higher than the baseline performance. Ravdin et al. (2003) indicated baseline testing may not be as accurate due to the fact that it is collected after the athletes have begun pre-season training and fatigue as well as to adjustment issues relating to college lifestyle may contribute to a lower baseline performance. This factor was found to be true in the present study as the athletes largely reported being fatigued and feeling slowed down at the baseline testing.

Performance on T2 post-injury was on average 9.88 days after concussion. Performance on some tests at T2 was found to be significantly higher than performance at B and T1 on some of the tests. Therefore, this indicates that recovery could possibly be
determined when scores on the PBSN not only return to baseline, but exceed the initial scores collected during pre-season training to ensure that complete neuropsychological and neurobehavioral functioning has returned. Alternatively, the improvement between T1 and T2 post-concussion scores suggests that the tests in the neuropsychological battery do indicate cognitive decline immediately after injury (T1). However, one cannot rule out the effects of practice on these tests in the absence of a control group at both T1 and T2. Lovell and Collins (1998) indicate practice effects should be considered for tests including TMT, Grooved Pegboard, and Digit Span.

The symptoms listed in the post-concussion rating scale were also found to be significantly different at B, immediately after injury, T1, and T2. As mentioned previously, the athletes reported being fatigued at baseline testing. However, athletes at baseline did not report classic post-concussion symptoms such as headache, difficulty concentrating, dizziness, sensitivity to light, and drowsiness, which were reported immediately and at T1. Most of these symptoms resolved by T2, which is consistent with the athletes’ neurological performance. The different symptoms indicate that the post-concussion rating scale symptoms are very effective in determining the presence of a concussion. This result is very interesting and revealing as it has often been disputed that athletes will not accurately report symptoms because they tend to be highly motivated to return to play and will therefore underreport the subjective symptoms of concussion (Lovell, Echemendia, Barth, & Collins, 2004). The present results indicate the athletes were likely to report their post-concussion symptoms more accurately than originally thought by other researchers. Perhaps this is because athletes were assessed by clinicians
in the Miami University clinic versus trainers or coaches and felt more comfortable disclosing symptoms.

Time for Recovery from Concussion

The mean length of time for recovery from concussion in this study was 10.07 days. Twenty-one of the 38 athletes required less than 10 days to recover and 17 athletes required more than 10 days to recover to baseline scores or national norms. The mode of the group was also 10 days, which indicates the mean is a good representation of the entire group. This data agrees with the seven to fourteen day recovery period suggested by Echemendia et al. (2001).

Incidence of Concussion According to Player Position

There were a total of 11 different possible football positions. Upon examination of the percent of injuries, certain positions seem to increase the players risk for concussion. These include: quarterback, safety, linebacker, and offensive lineman. Furthermore, offensive positions resulted in nearly twice as many concussions as compared to defensive positions. In agreement with Delaney et al. (2000), quarterbacks reported the highest incidence of concussion with 62.5% reporting having experienced a prior mild brain injury. Additionally, Delaney et al. (2000) presented similar percentages of players in the safety, linebacker, and offensive lineman positions as the present study. Players in these positions also reported a prior history of at least one concussion.

Conclusions

The present study has lead to the following general conclusions:

1. The neuropsychological battery is an effective method to monitor performance in athletes who sustain concussions.
2. Most athletes recover from a concussion between seven and ten days.

3. The post-concussion rating scale provides useful subjective information for injured athletes.

4. There is a qualitative difference in the incidence of concussion per player position in football that needs to be examined further as the injured athlete database grows in numbers.

Efficacy Based Recommendations for Improving the Concussion Management Protocol at Miami University

1. Injured athletes should be tested within 24-48 hours post-injury.

2. The Athletic Department and the Speech Pathology and Audiology Department at Miami University should consider conducting baseline testing prior to pre-season training.

3. Consider developing a control group using Baseline, T1, and T2 repeated testing for additional comparison.

4. Baseline data is helpful in determining return to play readiness, but should not be the only determining factor.

5. Athletes in certain high risk positions should be counseled regarding their risk and potential effects of multiple concussions.

Clinical Implications for Related Fields

Information from the present study can be very useful for clinical practices. The survey used in the present study can be used to identify athletes with a history of concussion and help educate these athletes on the potential risks of sustaining multiple mild brain injuries. The present research supports the need for education and counseling
regarding the effects of concussion as well as a program that monitors football players in specific positions very closely as these positions are more likely to sustain a concussion.

The importance of using post-concussion symptoms in addition to scores on the neuropsychological tests can be provide additional information in determining when athletes are ready to return-to-play following a concussion. This study intensifies the need for both objective and subjective measures to be analyzed prior to determining the overall recovery from concussion.

The collaboration between the areas of speech-language pathology and athletics will ensure that each athlete sustaining a concussion is monitored physically, psychologically, academically, and behaviorally to determine the appropriate recovery time before returning to play. According to the Concussion in Sports Group (2001) neuropsychological testing is the “cornerstone” of sports concussion management. With these considerations each athlete’s safety becomes the top priority and treated as an individual. This can be a very important factor in the competitive arena of athletics.

**Limitations**

The primary limitation of this study was that only 21 injured athletes have available baseline data. Because of the small sample size, there is a issue of statistical power presented. As the database continues to grow, it is expected that power will no longer be a limitation and significant results will be produced.

Additional limitations of the study include difficulty retesting an injured athlete within an appropriate time frame immediately after injury. Retesting was sometimes difficult due to the weekend competitions, away games, or the athlete and the clinician’s schedules. Time 1 testing should take place within 24-48 hours post-injury in order to test
the immediate effects of concussion. Time 1 testing in some athletes did not take place until several days post-injury. By then, the athletes could have returned to baseline which can contribute to the lack of statistical significance on some tests at T1.

*Implications for Future Research*

Concussion in sports is a growing field of research. Future research should continue to focus on determining the effectiveness of neuropsychological testing and post-concussion symptoms in determining time for recovery following a concussion. Future research should use baseline data collected during the off-season as well as a control group to determine benchmarks for helping to make the return-to-play decision. Control data should be collected at repeated intervals similar to T1 and T2 testing to account for the possible presence of practice effects.

Future research should also continue to examine the differences in incidence of concussion among player position in football. If it can be determined that certain player positions are more susceptible to concussion, player specific helmets could possibly be implemented. With considering each position separately, each group of players can be informed of the risk for concussion and be educated on recovery processes accordingly.
Appendix A: Concussion in Sport Group’s (CISG) Three Categories of Symptoms to Indicate Concussion

1) Cognitive features

Unaware of period, opposition, score of game

Confusion

Amnesia

Loss of consciousness

Unaware of time, date, place

2) Typical symptoms

Headache

Dizziness

Nausea

Unsteadiness/loss of balance

Feeling “dinged” or stunned or “dazed”

“Having my bell rung”

Seeing stars or flashing lights

Ringing in the ears

Double vision

Other symptoms such as sleepiness, sleep disturbance, and a subjective feeling of slowness and fatigue in the setting of an impact may indicate that a concussion has occurred or has not resolved.

3) Physical signs

Loss of consciousness/impaired conscious state
Poor coordination or balance

Concussive convulsion/impact seizure

Gait unsteadiness/loss of balance

Slow to answer questions or follow directions

Easily distracted, poor concentration

Displaying unusual or inappropriate emotions, such as laughing or crying

Nausea/vomiting

Vacant stare/glassy eyed

Slurred speech

Personality changes

Inappropriate playing behavior- for example, running in the wrong direction

Appreciably decreased playing ability
Appendix B: Standardized Assessment of Concussion (SAC)

**Orientation** (1 point each)  
**Immediate Memory** (1 point each)  

<table>
<thead>
<tr>
<th>Month</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>Word 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day of the week</td>
<td>Word 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>Word 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time (within 1 hour)</td>
<td>Word 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Word 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Orientation Score: 5  Immediate Memory Score: 15

**Concentration:**
Reverse digits: (Go to next string length if correct on first trial. Stop if incorrect on both trials. 1 point for each string length)

- 3-8 -2  5-1-8
- 2-7-9-3  2-1-6-8
- 5-1-8-6-9  9-4-1-7-5
- 6-9-7-3-5-1  4-2-8-9-3-7

Months of the year in reverse order: (1 point for entire sequence correct)
- Dec-Nov-Oct-Sep-Aug-Jul
- Jun-May-Apr-Mar-Feb-Jan

Concentration Score: 5

**Delayed Recall:** (approx 5 minutes after Immediate Memory. 1 point each)
- Word 1
- Word 2
- Word 3
- Word 4
- Word 5

Delayed Recall Score: 5

Summary of total Scores:
- Orientation: 5
- Immediate Memory: 15
- Concentration: 5
- Delayed Recall: 5

Total Score: 30

The following may be performed between the Immediate Memory and Delayed Recall portions of the assessment when appropriate:

**Neurologic Screening:**
- Recollection of the injury
- Strength
- Sensation
- Coordination

**Exertional Maneuvers:**
- 1 40-yard sprint
- 5 sit-ups
- 5 push-ups
- 5 knee bends
Appendix C: Concussion and Sports Related Head Injuries Survey

**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. List any additional medical conditions: ________________________________

13. How old were you in your first concussion? ______

14. Do you have any additional medical conditions? ______________

15. How many times have you been concussed? ______

16. How many times have you been knocked unconscious? ______

17. Is there a long history of your head being hurt? __________

18. How many times have you had a memory loss? ______

19. Have you had any previous concussions? __________

20. Is there a history of your family having had head injuries? ______
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.

<table>
<thead>
<tr>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

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 D: Postconcussion Scale (Lovell and Collins, 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>
<tr>
<td>Total Score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix E: Tests within the battery that showed cognitive decline for each subject.

<table>
<thead>
<tr>
<th>Sub</th>
<th>T1</th>
<th>T2</th>
<th>Sub</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HVLT, COWAT, TMT</td>
<td>HVLT, TMT, Grooved Peg</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>TMT</td>
<td>HVLT, Grooved Peg</td>
<td>21</td>
<td>HVLT</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Grooved Peg, TMT, HVLT</td>
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