ABSTRACT

SELF-ASSESSMENT OF COGNITIVE DEFICITS AND PREDICTION OF PERFORMANCE ON IMPACT TESTING IN COLLEGE ATHLETES FOLLOWING CONCUSSION

by Amy Nicole Frazer

This study sought to examine how effectively concussed college athletes are able to predict the effects of their concussion on their neuropsychological testing performance. Performance prediction tasks are often used to assess an individual’s level of self-awareness, an area of deficit that has commonly been noted following more severe forms of traumatic brain injury. Little research has been conducted on the effects of sports-related concussion on an athlete’s self-awareness. Surveys were administered to athletes before and after neuropsychological testing to assess an athlete’s awareness of any deficits since their concussion and whether the athlete expected their concussion to affect their testing performance. Results indicate that athlete report of symptoms is most likely not a good indicator of when an athlete can be safely returned to play following a concussion due to inconsistent report of symptoms and the possible presence of impaired self-awareness or denial.
SELF-ASSESSMENT OF COGNITIVE DEFICITS AND PREDICTION OF PERFORMANCE ON IMPACT TESTING IN COLLEGE ATHLETES FOLLOWING CONCUSSION

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CHAPTER I  
Introduction

Athletes may participate in a variety of sports at the collegiate level, many involving high-impact force to an athlete’s body during practices and games. Contact with opponents, game equipment, or the playing surface can lead to a range of injuries that may require the removal of the athlete from play for a period of time to allow for recovery. A sports-related injury that has been an important topic of research in the last decade is sports-related concussion, a form of mild traumatic brain injury (MTBI).

Concussion has been defined as a complex pathophysiological process caused by direct or indirect traumatic biomechanical forces on the brain (Centers for Disease Control and Prevention, 2007). Concussion can result in a variety of cognitive, somatic, emotional, and sleep-related impairments (Reddy & Collins, 2009). Duration of these impairments can be brief, but can also last from several minutes to days, weeks, or months after injury (Reddy & Collins, 2009).

Self-awareness refers to an individual’s ability to perceive themselves and their capabilities and to consider such perceptions in relatively objective terms. Research has shown that self-awareness can be impaired by moderate and severe traumatic brain injury (Sherer et al., 2005; Flashman & McAllister, 2002; Port, Wilmott, & Charlton, 2002; Roberts, Rafal, & Coetzer, 2006; Cheng & Man, 2006). Impaired self-awareness results in a decreased ability to consider one’s deficits as a result of the injury and how such deficits will affect one’s performance. This can lead to delayed recovery and return to everyday activities.

While evidence of impaired self-awareness has been noted following more severe traumatic brain injuries, little is known about how self-awareness is affected by sports-related concussion. A major challenge to such research is the difficulty in separating the effects of possible impaired self-awareness in athletes from denial of deficit due to the pressure to return to play. It is important to obtain more information on self-awareness following sports-related concussion in order to assess how accurately an athlete can consider his or her deficits and report them to medical and athletic personnel. If concussed athletes suffer impaired self-awareness, they may not accurately perceive and convey the symptoms they experience. This could lead to a return to play when the athlete has not truly recovered, resulting in an increased risk of further head injury. This research is designed to serve as a pilot study on impaired self-awareness in
college athletes following concussion. Athletes were asked to predict their performance on neuropsychological testing following concussion in comparison to their baseline scores. Impaired prediction of performance may indicate an impairment in self-awareness.
Review of the Literature

Research Population

College athletes are male and female college students that range in age from approximately 18-23 years old. These athletes may play any one of a variety of sports, such as baseball, basketball, football, ice hockey, soccer, softball, and volleyball. There are currently more than 375,000 student athletes participating in sanctioned sports at the collegiate level. This represents roughly 5 percent of all students enrolled in college (Rosandich, 2002). The overall number of athletes at the average National Collegiate Athletic Association (NCAA) member university has risen dramatically since the early 1980s. More than 217,000 male student athletes were enrolled in NCAA member schools during the 2003-2004 academic year, an increase of 28% from 1981-1982. Women’s collegiate sport participation has risen even more dramatically with approximately 163,000 female student athletes during the 2003-2004 academic year, a 120% increase from 1981-1982 (Dick, Agel, & Marshall, 2007).

Athletes participating in sports programs may be at risk of injury. A study conducted by the NCAA over a 16 year time period (from 1988-89 through 2003-04) reported a total of 182,000 injuries over the course of the study. Sports that are typically associated with player contact, such as football and men’s ice hockey, reported dramatically higher injury rates during games than during practices. The authors attributed this finding to curtailed contact during practices. Sports that restrict player contact, such as basketball and soccer, still had a majority of their game injuries associated with player contact, but did not display dramatic differences between practice and game injury rates (Hootman, Dick, & Agel, 2007). A greater number of injuries were reported during preseason practices than during in-season and postseason practices. The authors speculated that this was due to poorly conditioned athletes during the preseason and the fact that preseason practices often last longer than in-season or postseason practices. Player contact accounted for 41.6% of injuries during practices and 58% of injuries during games. Football had the highest injury rates during both practices and games out of the 15 sports sampled. Men’s baseball had the lowest rates of injury during practice for men’s sports. For women’s sports, soccer had the highest rate of game injury while softball had the lowest.

Another factor in risk of athletic injury is the fact that athletes in many sports have displayed increases in height, weight, and body mass index. This rate of increase is dramatically higher than that of the secular trend. In a study on the trends of body size in college athletics
from the period of 1950 to 2008, increases in height, weight, and body mass index were noted in football, basketball, baseball, and men’s and women’s tennis players for most positions. The greatest increases were observed in football offensive and defensive linemen. Increased mass allows for increased strength and greater area for player contact. This can result in higher rates of athletic injury (Yamamoto, Yamamoto, Yamamoto, & Yamamoto, 2008).

Athletes may also be at risk of injury due to their position or the type of play being carried out. For instance, a kicker for a football team has less of a chance of bodily contact than a running back or offensive lineman. A goalie for a hockey team has less of a chance of sustaining bodily contact or contact with the playing surface and surrounding walls than a center.

**Defining Concussion**

Traumatic brain injury (TBI) is one type of injury that can occur during athletic play. TBIs are typically classified as mild, moderate, or severe. Mild traumatic brain injury (MTBI) is generally synonymous with concussion in the medical literature (Kushner, 2001). Sports-related concussions can be caused by contact with an opponent, a teammate, the ground, or a piece of equipment or object in the playing area (Gessel, Fields, Collins, Randall, Dick, & Comstock, 2007).

The Third International Conference on Concussion in Sport held in Zurich in 2008 provided a definition and guidelines for concussion in their consensus statement. Concussion was classified as “a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces” (McCrory et al., 2009). Five primary points related to concussion are also outlined, including: (i) a concussion may be caused by direct or indirect forces to the head, (ii) concussion generally results in a short period of impaired neurologic function that resolves spontaneously, (iii) concussion symptoms largely reflect a functional rather than a structural disturbance, (iv) loss of consciousness may or may not occur, and (v) no abnormality is generally seen on standard structural neuroimaging following a concussion (McCrory et al., 2009).

Prior to this conference, there had been several definitions of concussion proposed. The most commonly cited definition was put forward by the Committee of Head Injury Nomenclature of the Congress of Neurological Surgeons in 1966 (LeClerc, Lassonde, Delaney, Lacroix, & Johnston, 2001). This committee classified concussion as ‘a clinical syndrome
characterized by immediate and transient impairment of neural functions, such as alteration of consciousness and disturbance of vision or equilibrium due to brainstem involvement’ (Committee on Head Injury Nomenclature, 1966, p. 386). Those who opposed this definition note that it does not address loss of consciousness (LOC) and implies that all symptoms of concussion are immediate and last only a brief period of time (LeClerc et al., 2001). The International Conference on Concussion in Sport addressed these concerns in their definition mentioned above. However, some debate still exists on the true definition of concussion and how it is manifested in athletes.

Due to the wide range of symptom severity and duration following concussion, many medical associations and professionals have created grading scales to express concussion severity and to provide guidelines for return to play following concussion. The three most common concussion-grading scales are the Cantu scale, the scale created by the Colorado Medical Society, and the scale of the American Academy of Neurology (Kushner, 2001). All three of these scales separate concussions into three grades of severity based on loss of consciousness (LOC), posttraumatic amnesia (PTA), confusion, and duration of symptoms immediately following the injury event. All three of the scales agree that grade 1 concussions have no LOC (Kushner, 2001). Grade 1 concussions are commonly referred to as “dings” or “having one’s bell rung,” and are often the most difficult to discern because the athlete does not lose consciousness and may experience only mild symptoms (Cobb & Battin, 2004). In a national survey of high school and collegiate athletic trainers, grade 1 concussions were the most common type (88.9%), grade 2 were the second most common (10.6%), and grade 3 occurred the least (0.4%) (Guskiewicz et al., 2000).

**Risk Factors of Concussion**

Several studies have been conducted on the variety of factors that place an athlete at risk of concussion and its ensuing symptoms. Chief among the risk factors examined have been sex, age, sport and position played, and concussion history. Some studies have found that female athletes generally report a greater number of symptoms following a concussion and have a worse outcome following MTBI (Covassin, Swanik, Sachs, 2003; Dick, 2009). However, it has been suggested that this may simply be due to the fact that females are more honest in reporting their symptoms following a concussion (Dick, 2009). Researchers have found that high school
and division III college athletes more commonly suffer concussions than division I and II college or professional athletes. This difference was attributed to increased exposure (athletes playing both offense and defense), quality and condition of protective equipment, and the skill level of players (Guskiewicz et al., 2000). The type of sport played influences the risk for concussion. One study found that football results in the greatest number of concussions, with those on the offensive line being most at risk (Schulz et al., 2004). However, other authors have found that male and female lacrosse, male and female soccer, and female basketball are at the highest risk (Covassin et al., 2003). The type of play being carried out may also increase the risk of concussion. In a study of 40 college football players, those performing running plays were found to have the greatest risk of sustaining a concussion. Seventy five percent of concussions reported in this study occurred while the athlete was in an offensive position (Bennington, 2009). Several sports that require the use of protective equipment still have a high rate of concussion incidence. It has been hypothesized that the use of protective equipment during play leaves athletes feeling a false sense of security and therefore playing more aggressively in a way that leads to injury (Covassin et al., 2003). Finally, Guskiewicz et al. (2000) found that those athletes who have suffered concussions in the past are three times more likely to suffer another concussion during the same season.

Neurological Effects of Concussion on the Brain

Concussion is a result of acceleration/deceleration forces that occur in a linear or rotational acceleration pattern (Biasca, Wirth, Maxwell, & Simmen, 2005). An acceleration/deceleration injury occurs when a player’s head strikes another player, athletic equipment, or a surface in the play area. This impact stops the movement of the head so quickly that the brain does not have time to stabilize within the cerebrospinal fluid of the skull, causing it to collide with the skull’s inner surface. This injury can occur even when the head is not impacted directly, such as when a football player is tackled on the lower body and sustains whiplash when the head is pulled back suddenly with the rest of the body. A linear acceleration pattern occurs when the head is struck at midline and the brain moves in a forward-backward movement within the skull (Biasca et al., 2005). An example of this would be two soccer players who jump to head a ball during a game and strike foreheads. Upon impact, the brain remains still within the moving skull until it collides with the inside of the frontal part of the skull. The brain
is then forced to the back of the skull, causing a second impact site. The first site of impact is known as a coup injury and the secondary site of impact is known as a contre coup injury. These injuries can cause focal damage to the meninges, cortex, and subcortical structures, with the basal portion of the brain in the frontal and temporal lobes especially prone to damage (Biasca et al., 2005). An angular or rotational acceleration injury occurs when a force strikes the head off-center, causing the head to rotate away from the blow. Again, the rapid impact forces the head to the side while the brain remains still. When the skull stops moving, the brain continues its movement, causing further injury (Biasca et al., 2005).

The primary pathologic feature of TBI at all levels of severity is diffuse axonal injury, also known as axonal shearing (Kushner, 2001). Axons within the brain are long, thin nerve fibers that often extend across different layers of the brain, for example, from the outer gray matter of the cerebral cortex into the subcortical white matter deep inside the brain. Because these layers have different densities and are located at different distances from the center of a given rotation, they accelerate and decelerate at different speeds when the head is impacted or whiplash occurs. This can cause different layers of the brain to slide across each other, putting stress on the thin fibers of the axons. The acceleration/deceleration forces discussed above result in flexion-extension movement of the neck, causing stretching, twisting, and shearing damage to these nerve fibers in widespread areas of the brain’s white matter (Biasca et al., 2005).

The impact to the head that results in a concussion initiates a destructive neurometabolic sequence of events (Giza & Hovda, 2001). Excitatory neurotransmitters are released, resulting in cellular membrane disruption and ionic imbalances. Greater amounts of adenosine triphosphate (ATP) are required to correct these imbalances. This results in an increase in glucose metabolism within the first 24 hours after concussion. This increased metabolism and an initial decrease in cerebral blood flow causes an imbalance between the energy required and what is actually available to brain structures. The increase in glucose metabolism is followed by a period of reduced glucose uptake and metabolism that may last for as long as one month. Because exercise alters glucose uptake in the brain and increases cortisol in a dose-dependent manner, continued physical activity immediately or shortly following a concussion could worsen the neuronal energy imbalance after concussion. While this sequence of events has primarily been noted in animal studies, research has indicated that it can be generalized to humans considering that postconcussive activity has been clinically noted to worsen concussion symptoms and cognition.
(Daalsgaard et al., 2004; Majerske et al., 2008). This is why it is important to identify a concussion when it occurs and remove the athlete from play to prevent further neurologic damage.

Neuroimaging techniques such as computer tomography or magnetic resonance imaging are commonly used to show the areas of the brain that have been damaged by TBI. Concussion, however, generally results in limited structural axonal injury. This means that though damage may have occurred due to injury, it may be confined to a smaller area or may have resulted in only functional rather than axonal damage. Limited structural axonal injury is typically not visible through standard structural neuroimaging (Kushner, 2001). This is due to the fact that damage at the axonal level is below the detection threshold of current neuroimaging technologies (Kelly, 2000).

Second-Impact Syndrome (SIS)

The occurrence of a second head injury within hours to days after the first concussion has been found to lead to a rare condition known as second-impact syndrome (SIS) in teenage athletes (Byard & Vink, 2009). This syndrome arises when a concussion is sustained while an athlete is still experiencing symptoms from an earlier concussion, resulting in progressive cerebral edema (Kushner, 2001). This may occur if an injury is not recognized as a concussion during play or if an athlete is returned to play prior to full recovery. Following the second injury, the athlete may appear confused, but is usually able to walk off the field or court on their own. However, the second injury results in a loss of the brain’s ability to autoregulate blood flow (Piebes, Gourley, & Valovich McLeod, 2009). This can lead to vascular engorgement, diffuse brain swelling, and increased intracranial pressure. Within minutes, the athlete may collapse and suffer loss of eye movement, rapidly dilating pupils, respiratory failure, coma, and potentially death. SIS has been found to occur predominantly with teenage athletes. Though very few cases have been confirmed in medical literature, it has been estimated that the syndrome kills four to six people under the age of 18 each year (Bach, 2007). All documented cases have occurred in people under the age of 20 except in boxing (Herring et al., 2005).

The Frontal Lobes

Impairments that occur as a result of concussion are often caused by functional damage to the frontal lobes (Bigler & Orrison, Jr., 2004). Functions of the frontal lobes include: i)
maintaining attention, ii) executive functions such as volition, planning, organization, and self-monitoring, iii) working, prospective, and long-term memory, iv) information retrieval, v) prosodic features of language and planning of verbal output, vi) affect, mood, and personality, and vii) self-awareness and theory of mind (Chayer & Freedman, 2001). Impairments in these areas may occur due to the nature of sports concussion. In a large number of cases of sport-related concussion, the primary impact is to the front of the head as athletes are most commonly running forward and are therefore most likely to have the front of their head collide with an opponent or an object on the playing field (Bigler & Orrison, 2004). Concussion results mainly in functional rather than structural impairments, meaning that while brain structures typically remain intact and may appear undamaged, the functions that those structures are responsible for may be impaired (Ptito, Chen, & Johnston, 2007). Impaired frontal lobe functions can result in decreased executive functioning skills, such as motivation, planning, utilizing responses, carrying out intended activities, selection of realistic goals, and impaired prediction of performance (Sohlberg & Mateer, 1989). All of these skills are important for carrying out everyday activities.

**Symptoms of Concussion**

Diagnosis of concussion is complicated due to the variety of symptoms that may present in an athlete and the fact that some symptoms may not present until several hours or days after the concussion occurrence (Eckner & Kutcher, 2010). Three characteristics that may immediately present following neurological impairment during athletic play are loss of consciousness (LOC), post-traumatic amnesia (PTA), and confusion (Reddy & Collins, 2009). While LOC has been linked with neuropsychological outcome (Kelly, 2001), it often does not occur with a concussion. Greater than 90% of concussive injuries have no LOC (Cobb & Battin, 2004). PTA, on the other hand, has been found to co-occur with a greater number of symptoms, longer symptom duration, and greater impairments on neuropsychological testing (Erlanger et al., 2003). PTA generally involves loss of memory for the traumatic event as well as impaired recall of events immediately before or after the injury. Athletes may be unable to recall details about a recent play in the game or well-known current events in the news. Confusion is another potential indicator of severity and often presents immediately or shortly after injury occurrence. An athlete with post-traumatic confusion may present with a vacant stare, disorientation, delayed ability to
follow instructions or answer questions, and poor concentration and attention. Athletes may also experience a loss of sense of time or place, often indicated by the athlete walking in the wrong direction on the playing field or lining up with the wrong team. Confusion is commonly a sign that leads fellow players to realize that an athlete has been injured (Collins, Stump, & Lovell, 2004). The duration of the above-listed symptoms has also been found to be an indicator of concussion severity (Erlanger et al., 2003; Collins, Stump, & Lovell, 2004). Other symptoms that have been noted by athletes and medical and athletic personnel immediately following concussion include headache, dizziness, nausea or vomiting, slurred or incoherent speech, sensitivity to bright lights, and imbalance or incoordination (Kushner, 2001; Cobb & Battin, 2004). Cognitive, somatic, emotional, and sleep-related impairments have been noted in the hours, days, and weeks following a concussion.

Cognitive symptoms are those that relate to disorders in thought processes, such as learning, memory, comprehension, reasoning, judgment, abstract thought, and self-awareness. These symptoms can include concentration and attention deficits, mental fogginess, confusion, disorientation, amnesia or memory impairments, and delayed processing speed (Reddy & Collins, 2009; Guskiewicz et al., 2000). Memory and attention problems have been found to be the most persistent cognitive impairments following concussion (Webbe & Barth, 2003). These impaired cognitive skills can affect the athlete both on and off the playing field.

Somatic symptoms are those that manifest as a physical ailment. Somatic symptoms of concussion include headache, dizziness, blurred vision, neck pain, nausea, vomiting, photophobia, fatigue, and sleepiness (Guskiewicz et al., 2000). In one study, headache was found to be the most commonly reported symptom in high school and collegiate athletes, with 86% of athletes in a nationwide survey citing it as a symptom (Guskiewicz et al., 2000).

Emotional changes may also be noted in athletes following a concussion. Depression and emotional lability have been reported (Ryan & Warden, 2003). Many athletes find themselves to be more irritable in the days shortly following their injury. Athletes have also reported feeling much more fatigued than usual and having a general feeling of detachment from their lives following injury (McIntosh, 1997).

Sleep-related symptoms of concussion that have been reported by athletes include hypersomnia, insomnia, and general sleep disturbances. Following injury, athletes may have difficulty staying awake or falling asleep and may report less restful sleep than prior to
concussion (Breed, Flanagan, Watson, 2004). One research study sampled athletes with a history of multiple concussions and compared their subjective and objective reports of sleep quality with those of a control group with no concussion history. Athletes were monitored for two consecutive nights in a laboratory and for ten minutes of wakefulness. They also completed questionnaires related to sleep quality and symptoms. Concussed athletes were found to report more symptoms and worse sleep quality than control athletes, but no between group differences were noted on polysomnographic or quantitative EEG variables. Concussed athletes did, however, show significantly more delta activity and less alpha activity during wakefulness than control athletes. This indicates that concussions may be more associated with wakefulness problems than with sleep disturbances (Gosselin et al., 2009).

Most deficits associated with concussion have been found to resolve in the first several days following injury (Bleiberg et al., 2004; Bruce & Echemendia, 2003). One meta-analysis that included 9 studies found that the effects of sports-related concussion within the first 24 hours include mild-to-moderate neuropsychological impairments in several areas. Relatively large impairments in global functioning, memory acquisition, and delayed memory were noted. This acute effect resolved within seven days post-injury (10 days for delayed memory) (Belanger & Vanderploeg, 2005). Neurocognitive function has been found to return to baseline levels within five to seven days (McCrea et al., 2003). However, several studies on subjects following MTBI have found that up to 15% are at risk of developing persistent post-concussion symptoms (PCSs), which may delay return to normal school/work functioning (Alexander, 1995; Bernstein, 1999; Dikmen, McLean, & Temkin, 1986).

Concussion diagnosis is complicated by several factors. A concussed athlete may present with any or all of the potential symptoms outlined above. Internal and external pressures may lead an athlete to downplay their symptoms in order to return to play. The athlete may not want to disappoint their team members or coaches by admitting they need time off from play until they have recovered (Granito, Jr., 2001). They may also not want to risk losing their position on the team to an uninjured player (Tracey, 2003). Coaches or parents may inadvertently pressure an athlete to return to play when they feel the impairments have resolved (Granito, Jr., 2001). These pressures can lead an athlete to underreport their symptoms, potentially resulting in a return to play before complete recovery.
Management of the Concussed Athlete

The 3rd International Conference on Concussion in Sport (McCrory et al., 2009) outlined the steps for on-field or sideline assessment of acute concussion. First, the athlete should be evaluated using standard emergency management principles, and special care should be taken to rule out a cervical spine injury. The athlete’s disposition must be deemed appropriate by a medical professional in a timely manner. If no medical professional is available, the athlete should be removed from play and urgent referral to a physician should be made. Once first aid issues have been addressed, an assessment of the concussive injury should be conducted using a respected testing instrument such as the SCAT2 or the Sideline ImPACT. An athlete should not be left alone following an injury and should be monitored for any deterioration in status in the hours following the injury. Any player diagnosed with concussion should generally not be allowed to return to play on the day of injury. However, this may be permitted for some adult athletes if sufficient immediate resources to assess concussion presence and severity are available. There is evidence that some professional American football players are able to return to play more quickly without risk of injury recurrence (Pellman et al., 2005). However, data has shown that for those athletes at the collegiate and high school levels, same day return to play can result in neuropsychological deficits post-injury that may not be evident on the sidelines immediately following injury. These athletes are more likely to have delayed onset of symptoms (Guskiewicz et al., 2004; Johnston et al., 2004).

Despite the potential dangers of a premature return to play, many athletes are returned to play prior to full recovery. This may be due to a variety of factors. Coaches may feel that a player’s skills are too important to lose during a close game situation. Athletes may feel pressure to underreport their symptoms in order to meet the expectations of their coach, teammates, family, and friends. Athletes may also have the mentality of “no pain, no gain” and convince themselves that any symptoms they may be experiencing are unimportant. In a national survey of high school and collegiate football players, 30.8% of injured players returned to play on the same day of injury, with a mean recovery time of only 13 minutes. The remaining two thirds of players return to play an average of 4 to 8 days after injury (Guskiewicz et al., 2000).

It is now common practice for most high school, university, and professional level athletic programs to obtain baseline neuropsychological scores for each athlete prior to the start
of the season (McCrory, 2009). The Immediate Post-concussion Assessment and Cognitive Testing (ImPACT), developed by Lovell and associates in 2000, is now the most widely used neuropsychological test in sports (Schatz, Pardini, Lovell, Collins, & Podell, 2006). It is used by the National Football League, National Hockey League, and many Major League baseball and National Basketball Association teams. ImPACT has also been used for sports-related concussion management at high schools and universities spread throughout all of the fifty states. If a player sustains a head injury during play, they are retested to assess for any change in cognitive performance compared to their baseline scores. Excessive physical activity should be avoided during recovery time, as this has been found to slow the recovery process (Majerske et al., 2008). Activities requiring concentration and attention such as scholastic work, video games, and text messaging may worsen symptoms when performed shortly after injury occurrence (Logan, 2009). The athlete is permitted to return to play when they no longer report symptoms and they have returned to their baseline neuropsychological performance (McClincy, Lovell, Pardini, Collins, & Spore, 2006).

Assessment of Concussion

One of the most significant developments in the field of concussion management has been the growing use of neuropsychological testing mentioned above to diagnose and track recovery from concussion. The use of neuropsychological testing as a tool for concussion management was first formally recognized as a “cornerstone” of injury assessment, management, and return-to-play decision making by the First International Conference on Concussion in Sport held in Vienna in 2001. The most recent assembly of this conference upheld this ruling, but stated that neuropsychological testing should not be used alone, but in conjunction with clinical perceptions and investigative results (McCrory et al., 2009). Neuropsychological testing can be conducted by paper and pencil or by computer and generally tests domains such as verbal and visual memory, complex attention, reaction time, and processing speed (Reddy & Collins, 2009).

Paper and pencil tests are conducted by trained professionals and are completed manually by the athlete. Such tests generally have research-based assessment and standardized norms for comparison. This is also true for computer-based assessments, but these are completed at the computer using the keyboard and mouse to input the athlete’s answers. Both types of tests can be administered at the beginning of the season and following the occurrence of a concussion.
Computerized neuropsychological testing has many advantages within the collegiate athletic system. First, preseason baseline testing of a large number of athletes is possible with minimal human resource demands. Computer administration allows for randomization of test stimuli to decrease practice effects. Computers provide more sensitive measurements of reaction time to 1/100 of a second, while traditional testing measures accuracy to 1-2 seconds (Reddy & Collins, 2009). Finally, computerized neuropsychological testing provides new avenues for research in the field of concussion assessment and management.

ImPACT is currently the most widely used computerized neuropsychological test for athletic programs. The ImPACT consists of three main parts: demographic data, neuropsychological tests, and the Post-Concussion Symptom Scale (PCSS). The demographic section provides data on sport, medical, and concussion history. There are six neuropsychological tests, which target various aspects of cognitive functioning including attention, memory, processing speed, and reaction time. Four separate composite scores are obtained from these six tests: Verbal Memory, Visual Memory, Visuomotor Speed, and Reaction Time (Majerske et al., 2008).

The Post-Concussion Symptom Scale (PCSS) is a part of the ImPACT that can be used to track concussion symptoms as reported by the athlete. It is made up of a checklist which asks the athlete to rate 21 symptoms on a seven-point scale, with zero indicating no experience of a symptom and six indicating a very severe symptom (Lovell, 1999; Lovell & Burke, 2002). The PCSS is easily understood by athletes as it utilizes common terms to describe symptoms rather than medical terminology (eg. sensitivity to light rather than photophobia) (Schatz et al., 2006). As this scale is based solely on self-report of symptoms by the athlete, it is difficult for the athletic or medical professional to ensure that this subjective report is an accurate representation of the symptoms the athlete is actually experiencing. However, research has found an inverse relationship between post-concussion symptom scores and several neuropsychological subtests. High symptom scores have also been found to predict fMRI blood oxygen level-dependent signal changes in cerebral prefrontal regions (Chen, Johnston, Collie, McCrory, & Ptito, 2006).

Empirical research has shown that ImPACT can effectively determine if there has been a change in cognitive function compared to baseline and can indicate when athletes have returned to baseline performance following injury (Iverson et al., 2004; Iverson et al., 2005; Schatz et al., 2006). It has been found that ImPACT does not have the large practice effects often seen on
paper and pencil tests (Iverson, Lovell, & Collins, 2003). Lovell et al. (2003) followed concussed high school athletes for 1-week post-injury, comparing them to age-matched control participants. Control group scores examined did not increase with multiple testing opportunities. Concussed athletes were found to perform much lower on the Verbal Memory test at 36 hours, 4, and 7 days post-injury compared to their baselines. When these athletes were separated by severity of concussion, the more severe group (retrograde amnesia, anterograde amnesia, or disorientation for >5 minutes) showed larger decreases from baseline scores and took longer to return to baseline than those in the less severe group. In studies to examine the validity of ImPACT, decreased performance on the Symbol Digit Modalities Test significantly correlated with ImPACT Processing Speed and Reaction time Indices (Iverson et al., 2004). Symptoms reported following a concussion were also significantly correlated to decreased performance on ImPACT Reaction Time, Verbal Memory, and Processing Speed Indices (Iverson et al., 2004). Schatz et al. (2006) found that the combined sensitivity of ImPACT and the PCSS (the probability of a positive test result when a concussion is present) is 81.9%, and the specificity (the probability of a negative test when a concussion is not present) is 89.4%.

One weakness of the ImPACT and similar computerized neuropsychological tests that has been suggested is how an athlete’s level of effort or motivation may affect test results (Bailey, Echemendia, & Arnett, 2006; Echemendia & Cantu, 2003; Echemendia & Julian, 2001; Hunt, Ferrara, Miller, & Macciocchi, 2007). Hunt et al. (2007) found that those athletes from their sample who were found to exert poor effort on neuropsychological testing had significantly lower test performance than those athletes who exerted adequate effort. Level of effort in this study was assigned using brief effort tests, which are not normally included in neuropsychological testing following concussion. Based upon their results, the researchers suggested that an effort test be included in all neuropsychological tests, however, this instrument has not yet been added to the ImPACT. Bailey et al. (2006) found that concussed athletes placed in a ‘suspect motivation at baseline’ group demonstrated significantly improved neuropsychological performance during post-injury testing over the ‘high motivation at baseline’ group. This means that those athletes who were judged to have lower levels of motivation at baseline testing showed greater improvement on post-injury testing than those athletes who displayed strong motivation during baseline testing. Researchers concluded that this was a result of obtaining incorrect baseline scores for those athletes with low motivation, indicating that level
of motivation affects test results. Athletes may not be highly motivated to put forth their best effort during baseline testing, but are more likely to do so when their return to play is dependent upon their test scores. This situation could lead to a premature return to play of an athlete who is not fully recovered from concussion, resulting in increased risk of repeat injury.

**Recovery from Concussion**

If an athlete with a concussion is managed appropriately, prognosis for recovery is good. Based on neuropsychological tests, neurocognitive function has typically been found to return to baseline levels within five to seven days (Majerske et al., 2008). This recovery can be slowed by continued physical and cognitive activity immediately after the concussion has occurred.

The primary requirement in concussion recovery is physical and cognitive rest in the hours, days, and potentially weeks following a concussion (McCrory et al., 2009). As mentioned above, the majority of concussion symptoms will spontaneously resolve within several days following injury, so little additional medical intervention is typically required. During this period of recovery, the athlete should be told to limit both excessively physical and cognitive activities to diminish the risk of delayed recovery. Such activities may need to be modified to avoid slowing recovery. This may include reducing an athlete’s coursework, shortening the school day, rescheduling examinations, etc. following concussion. Additional research is needed on the effects of other cognitive rehabilitation interventions on concussion recovery (Majerske et al., 2008).

Even if an athlete is given adequate time to recover from a concussion, cumulative effects of multiple concussions may occur (Cobb & Battin, 2004). Several studies have found that those athletes who have suffered multiple concussions often have a longer recovery and are at an increased risk for future injury (Reddy & Collins, 2009). Both high school and college athletes with a history of three or more concussions have been found to have a more severe on-field presentation of concussion (Collins et al., 2002). Such athletes were also more likely to report headache at baseline neuropsychological testing (Register-Mihalik, Mihalik, & Guskiewicz, 2008). Cumulative effects of concussion may present through symptoms that persist in a chronic manner, hindering an athlete in his or her academic and personal life and decreasing their quality of life (Piebes et al., 2009).
Return to Play

Once neuropsychological test results indicate that a player has returned to baseline, the player no longer reports symptoms, and a physician’s approval is obtained, the player may be returned to play (McCrory, 2009). Some guidelines for return to play support a graduated stepwise progression, easing the athlete back into physical activity. Others simply provide guidelines for how long an athlete should typically be withheld from play depending on concussion severity (Cobb & Battin, 2004). The consensus statement of the 3rd International Conference on Concussion in Sports supports a progressive return to play in which the athlete progresses through activity stages as their concussion resolves: no activity, light aerobic exercise, sport-specific exercise, non-contact training drills, full contact practice, and return to play (McCrory et al, 2009). The American Academy of Neurology provides return to play guidelines that are based more on what grade of severity has been assigned to the concussion and the duration of time that the athlete has been asymptomatic, with those having sustained multiple or more severe concussions being withheld from play for a longer period of time (Cobb & Battin, 2004).

Prevalence of Concussion

Determining the incidence of concussion is difficult due to the variety of potential symptoms, unrecognized concussions, and athletes who may not report their symptoms. However, according to data collected by the National Collegiate Athletic Association Injury Surveillance System, approximately 135, 901 U.S. collegiate athletes sustained a concussion in 2005 (Gessel et al., 2007). Occurrence rates of 0.5 to 3.0 injuries per 1,000 athlete exposures at the collegiate level has also been suggested, but self-report data suggests a significantly higher incidence (Gessel et al., 2007). In collegiate football alone, reported occurrence rates range from 4% to 5% of all collegiate football players (Guskiewicz et al., 2000), with the rate of game day concussions showing a steady increase from 1987 to 2003 (Dick, Agel, & Marshall, 2007). Concussions have been reported in nearly all sports, including football, basketball, baseball, softball, soccer, boxing, ice hockey, volleyball, field hockey, rugby, lacrosse, and cheerleading (Guskiewicz et al., 2000). The highest rates of concussion for both high school and collegiate athletes generally occur in soccer due to heading the ball and in football due to tackling and being tackled (Gessel et al., 2007).
Defining Self-Awareness

Metacognition has been defined as “thinking about thinking” and includes self-awareness, self-monitoring, and self-control (Kennedy & Coelho, 2005). Prigatano and Schachter (1991) defined self-awareness as “the capacity to perceive the ‘self’ in relatively ‘objective’ terms, while maintaining a sense of subjectivity. It is a natural paradox of human consciousness” (p. 13). Sense of self is an important aspect of self-awareness. One’s sense of self is the collection of self-reflecting judgments regarding one’s abilities, traits, and attitudes that guides one’s behaviors, choices, and social interactions (Johnson et al., 2002). This sense of self may be accurate, meaning that a person would have generally good self-awareness, or it could be incorrect or impaired in a way that causes one’s level of self-awareness to decrease.

Developmental researchers have theorized that a sense of self begins to form in early childhood and is altered and further defined through experiences and perceptions throughout childhood and adolescence before gaining permanence in early adulthood (Miller et al., 2001; Zeman, 2001). Maintaining an accurate sense of self, and therefore strong self-awareness, requires metacognitive self-reflection throughout the lifespan as one grows and changes as a result of life experience. Such self-reflection is especially important when performing an unfamiliar or complex cognitive or physical task, as these require an individual to monitor their progress, comparing their actual performance with the expected performance goal (Kennedy & Coelho, 2005). If their performance is found to be lacking, a person with strong self-monitoring skills would most likely change their behaviors in order to achieve a more positive result. In this way, self-awareness and its many aspects are largely responsible for self-control and the alteration of behavior to properly adapt to each situation, specifically those in which an unfamiliar or complex task is being performed.

Self-Awareness in the Brain

In the late 19th century, Hughlings Jackson suggested that a sense of self relies upon the evolutionary development of the prefrontal cortex (Meares, 1999). Studies conducted on brain lesions have generally supported this theory. Impaired self-awareness has been noted in individuals with damage to the anterior and medial prefrontal regions (Damasio, Tranel, & Damasio, 1990) and anterior temporal regions (Prigatano, 2005). These individuals displayed impaired awareness in relation to appropriateness of social interactions, judgment, planning
difficulties (Prigatano & Schacter, 1991; Stuss, 1991), and awareness of the mental states of others (theory of mind) (Stone, Baron-Cohen, & Knight, 1998; Stuss, Gallup, & Alexander, 2001).

Functional imaging (fMRI and PET) studies conducted on subjects with no neurologic disorder have indicated that self-awareness may be controlled by several cerebral areas. Similar to the studies conducted on those with impaired self-awareness, some of these studies have noted activation in frontal lobe structures, specifically in the medial frontal lobe areas (Gusnard et al., 2001; Johnson et al., 2002; Kelley et al., 2002) during introspective thinking tasks, but with varying activation patterns from one study to another. Activation outside the frontal lobes within the posterior parietal lobe (Kjaer et al., 2002), temporal lobes (Kjaer et al., 2002; Vogeley et al., 2001), and cingulate area has also been noted in individuals completing tasks requiring self-reflection or self-monitoring. Specifically, the anterior cingulate and paracingulate regions (Frith & Frith, 1999) and posterior cingulate (Johnson et al., 2002) have shown patterns of activation during self-reflective tasks.

Posterior cingulate activation has been found in several studies of episodic autobiographical memory retrieval (Maddock, 1999; Maddock, Garrett, & Buonocore, 2001). This area has connections to several other memory areas, including the prefrontal cortex, the hippocampus, and the thalamus (Duvernoy, 1998; Morris, Petrides, & Pandya, 1999; Mesulam, 2000). Memory plays a role in self-awareness and self-monitoring in that one must have the ability to recall past experiences and how they shaped one’s thoughts and behaviors. For example, if a student athlete did poorly during their first game of the season, they might recall this when practicing and preparing for the next game and alter their playing methods for better sports performance.

Along with playing a role in memory function, the posterior cingulate region seems to be responsible for the perception and evaluation of the emotional component of incoming stimuli. Maddock (1999) found that the posterior cingulate is the most frequently activated area when subjects were evaluating the emotional relevance of a particular stimulus. This led Maddock to hypothesize that the posterior cingulate may act as a go-between for memory retrieval and emotion. This means, for example, that the posterior cingulate is responsible for the emotion one might associate with the smell of baking chocolate chip cookies because it evokes memories of baking at one’s grandmother’s house. In relation to self-awareness, this mediating role between
memory and emotion of the posterior cingulate may play a part in the presentation of denial following injury, which will be discussed in a later section.

Due to the variety of activation patterns seen among neuroimaging research, there is still some debate over what area of the brain controls self-awareness. This variety could be largely due to differences in the tasks performed. Despite the activation seen in other areas of the brain during self-awareness tasks, self-awareness is generally considered to be a frontal lobe function (Kennedy & Coelho, 2005).

**Self-Awareness in Healthy Individuals**

Even individuals with no neurological insult have varying levels of self-awareness and may engage in inaccurate self-representation at times, whether deliberately or subconsciously (Flashman & McAllister, 2002). These cognitive misrepresentations are thought to represent a normal pattern of functioning, and have been positively associated with a sense of well-being, positive effectivity, and self-esteem (Tournois, Mesnil, & Kop, 2000). Positive forms of self-deception have been found to help direct an individual towards favorable future goals (Flashman & McAllister, 2002). Research has indicated that self-deception is most likely to occur when there is a lack of concrete information, or the motivation to self-deceive is high (Flashman & McAllister, 2002). A lack of information may occur when an individual must make predictions about the future or recall specific past information. One’s motivation to self-deceive might be high if one wishes to make a good impression on someone or believes strongly in one’s capabilities. In a study conducted by Sackeim and Wegner (1986), subjects with no neurological insult were found to utilize “self-serving biases” when evaluating their behaviors and outcomes. These biases were characterized as follows: “If an outcome is positive, I controlled it, I should be praised, and the outcome was very good. If an outcome is negative, I did not control it (as much), I should not be blamed, and it was not so bad anyway (Sackeim & Wegner, 1986, p. 559). While individuals with TBI may also use such biases, their decreased level of self-awareness may also be attributed to the neurological insult rather than “healthy” inaccurate self-representation.
Impaired Self-Awareness Following Traumatic Brain Injury

Impaired self-awareness is commonly noted in individuals who have sustained a TBI. Anosognosia is a term often used in relation to impaired self-awareness. While originally used to refer to the unawareness of hemiplegia in stroke patients (Babinski, 1914), the term anosognosia now encompasses all forms of a patient’s unawareness of deficits resulting from a brain injury (Ries et al., 2007). This unawareness may be as severe as not recognizing one’s limb as one’s own following neurological insult or may present in a milder form as is the case with those who do not acknowledge potential cognitive effects that an injury may have caused and how such deficits will influence their performance. Such unawareness of deficit may extend to a variety of sensory, motoric, and higher cognitive deficits (Ries et al., 2007). Sherer et al. (2005) found that greater injury severity was associated with a greater degree of impaired self-awareness. The number of brain lesions on neuroimaging tests was found to be predictive of the degree of impaired self-awareness, however, lesion volume and location were not. Results of this study led the authors to speculate that, if self-awareness is controlled by a widely distributed neural network, then a lesion in a specific region may be less relevant than damage across multiple regions (Sherer et al., 2005). As has been mentioned earlier, such diffuse damage is common with TBIs.

The cause of impaired self-awareness following brain injury has been a subject of debate for several years. In 1955, Weinstein and Kahn argued that impaired self-awareness following injury is primarily psychologically motivated. They suggested that the denial of deficit following brain injury is an adaptive strategy to aid the individual in familiarizing the situation by imposing personal meaning onto the unfamiliar experience of neurological insult (Weinstein & Kahn, 1955). However, since that time, neuroimaging has revealed several brain areas that are activated during tasks involving self-reflection. In sharp contrast to Weinstein and Kahn’s argument, Levine (1990) suggested that the interruption of afferent sensory or cognitive systems leads to an immediate unawareness of resulting deficits. This theory seems to attribute impaired self-awareness following injury entirely to the neurological insult and does not acknowledge any psychological or emotional factors.

Impaired awareness has been described as a schema with three distinct dimensions (Flashman, Amador, & McAllister, 1998). The first dimension is whether or not an individual is able to identify a specific deficit or difficulty he or she is experiencing. Some individuals
following TBI may accurately identify their deficits while others will argue that they are no different than prior to their injury, despite obvious evidence to the contrary. The second dimension concerns the emotional response an individual has to his or her deficits. This emotional response can range from indifference to major complaint in those aware of their deficits and indifference to angry denial in those who are unaware of any deficit. The third dimension involves an individual’s ability to comprehend the impact of a deficit on his or her everyday life. Some individuals following TBI may admit they have a deficit, but still believe that they can function at their previous level. To have full awareness of deficit following injury, an individual must realize that their difficulties are a direct result of the brain injury. Some individuals acknowledge their deficits, but claim they are the result of being overly stressed or attribute them to normal aging (Flashman & McAllister, 2002).

Whether the cause of impaired self-awareness is purely a protective psychological response, an interruption in a vital neural network due to injury, or some combination of the two, impaired self-awareness following TBI has been found to result in poorer short- and long-term outcomes in patients with moderate to severe TBIs (Lam, McMahon, Priddy, & Gehred-Schultz, 1988; Sherer et al., 1998; Sherer et al., 2003). Little research has been conducted on the effects of impaired self-awareness on recovery outcome in the MTBI or concussion population.

**Assessment of Self-Awareness**

It is very difficult to measure an individual’s level of self-awareness because it cannot be measured directly, but must be inferred (Sohlberg, Mateer, Penkman, Glang, & Todis, 1998). Also, many studies have found that individuals who have sustained a TBI commonly under-report their cognitive, behavioral, and emotional symptoms (Allen & Ruff, 1990; Newman, Garmoe, Beatty, & Ziccardi, 2000; Prigatano, Altman, & O’Brien, 1990; Sherer et al., 1998). Researchers have used a variety of methods to attempt to quantify an individual’s level of self-awareness following TBI.

One method that has proven effective in assessing self-awareness is the predicted performance method, which allows a comparison between an individual’s predicted performance with their actual performance on a particular task (Gauggel, Hoop, & Werner, 2002). Deficits in self-awareness may be indicated by a higher prediction than actual performance. Individuals who have sustained a moderate to severe TBI have been noted to have decreased self-awareness, and
therefore often overestimate their performance on a cognitive or physical task (Fischer, Trexler, & Gauggel, 2004). Performance prediction and how it is affected by sports-related concussion has not yet been examined in the college athlete population.

Assessment of impaired self-awareness is also complicated by the fact an individual may display a variety of deficits in awareness. Three types of deficits in awareness have been identified (Crosson et al., 1989): (i) intellectual awareness deficits in which an individual is unable to understand that a function is impaired, (ii) emergent awareness deficits in which an individual is unable to recognize a problem while it is occurring, and (iii) anticipatory awareness deficits in which the individual is unable to anticipate that a problem will occur as a result of a deficit. Level of impaired awareness may also vary by how much an individual is able to acknowledge the effects of a deficit on their daily function and whether they correctly attribute the deficit to their injury.

Many individuals with TBI may acknowledge that they have a deficit, but do not realize how it will affect their daily functioning (Flashman & McAllister, 2002). Without the ability to consider their deficits in relation to their required level of daily functioning, individuals with traumatic brain injury have an increased chance of being unsuccessful during tasks because they do not consider how the deficit will affect their performance or use strategies to compensate for the deficit.

As the results of several neuroimaging studies have suggested, self-awareness is largely controlled by the frontal lobes. These areas also play a critical role in the monitoring of social skills and behaviors. (Port et al., 2002). This connection may explain emotional and behavioral impairments, such as apathy, irritability, lowered affect, disinhibition, and emotional lability commonly seen in individuals following traumatic brain injury. The presence of such emotional and social deficits may negatively impact the individual’s recovery and make return to everyday activities more difficult.

*Impaired Self-Awareness or Denial?*

Today’s college athletes are under a large amount of pressure to demonstrate their best performance during all competitions. While any injury can be an obstacle to such efforts, concussion may be especially difficult for an athlete due to the fact that there is generally no outward sign that an injury has been sustained, as is the case with a torn rotator cuff or broken or
sprained bones. Having been labeled “a silent epidemic” (Landau & Hissett, 2008), there is a lack of education among the general public that a concussion even constitutes a brain injury (Lash, McMorrow, Tyler, & Antoinette, 2004). Along with the fact that concussed athletes generally show no outward physical signs of injury, they are often put under intense pressure to make a quick return to play, both from their own internal urges and from external sources such as coaches, parents, and teammates. In a national survey of college athletes, about fifty percent reported having suffered an injury in the past year, and a large number of these athletes stated that they were put under intense pressure to ignore their injuries (American Institutes for Research, 1988). Curry (1993) described the normalization of injury for athletes through traditional role socialization, in which athletes learn to see pain and injury as a normal part of athletic play through interaction with coaches and successful athletes who have sustained injuries in their own careers. These role models for younger, less experienced athletes support conformity to a demanding sports ethic – one which may lead to serious injury during athletic play and mental toughness which inhibits the acknowledgement of the injury severity (Curry, 1993).

Clough, Earle, & Sewell (2002) discussed mental toughness in athletes as characterized by four factors: (i) control: feeling and acting as though one is influential, (ii) commitment: tending to involve oneself in an encounter rather than being alienated from it, (iii) challenge: believing that life is changeable and seeing this an opportunity rather than a threat, (iv) confidence: high sense of self-belief in oneself and one’s performance. While mental toughness in an athlete can be related to improved performance in sport (Golby & Sheard, 2004), it has also been identified as a personality characteristic that leads to increased risk of stress and athletic injury (Williams & Anderson, 1998). Athletes judged to have high mental toughness were found to perceive their injuries as less threatening and less susceptible to further injury than lower mentally tough peers (Levy, Polman, Clough, Marchant, & Earle, 2006). Though this led researchers to state that athletes of high mental toughness coped better with pain during the recovery process, it may also be that such a downplaying of the importance of injury could be a result of denial, which could lead to a disregard for symptoms and questionable compliance with recovery guidelines.

Myles (2004) discussed what he termed a “loss of sense of self” following brain injury as involving the survivor making negative evaluations about post-injury changes in his or her
functioning. The pre-injury personality type of the injured person seems to play a part in these evaluations, with those who previously had very positive perceptions of their functioning being more likely to make negative self-evaluations (Miller, 1993). These negative evaluations often lead to emotional distress which increase the chance of denial of changes in functioning post-injury (Nochi, 1998; Prigatano, 1986). Denial is considered to be a protective psychological response that may develop as an injured individual becomes emotionally distressed by the increasing recognition of their deficits following an injury. It is an attempt to protect the idea of the pre-injury conceptualized self to avoid emotional distress by rejecting knowledge of changes in functioning that do not correspond to that conceptualization (Myles, 2004). Prigatano (1999) states that this form of denial due to loss of sense of self is distinct from denial that results from impaired self-awareness. While those with impaired self-awareness seem to be genuinely unaware of changes in their functioning, those with denial as a result of loss of sense of self are aware of the changes, but avoidant of the emotional distress that comes with such awareness. Myles (2004) states that even mild brain injuries, such as concussion, often result in cognitive impairments, making immediate functioning at pre-injury levels unfeasible.

The self-regulation theory proposed by Leventhal, Meyer, and Nerenz (1980) has been used to explain the cognitive precursors of coping responses and emotional and functional outcome in injured athletes. Though this theory was originally developed in the context of chronic illness, it has been adapted to the realm of sports injury (Leventhal et al., 1980). The theory states that athletes form a representation of their condition based upon three sources: lay information regarding the condition, expert sources such as trainers and physicians, and current and past experience with the condition. This representation has both cognitive and emotional aspects. If this representation is considered especially threatening by an individual, he or she will adopt active (behavioral) and passive (psychological) coping procedures against the perceived threat (Hagger, Chatzisarantis, Griffin, & Thatcher, 2005).

Collegiate athletes have been found to demonstrate the greatest amount of mood disturbance in the initial phase of the injury (Heil, 1993; Leddy, Lambert, & Ogles, 1994). At this time, athletes can experience many emotions, including anxiety, fear, anger, confusion, frustration, depression, isolation, boredom, shock that an injury actually occurred, and lowered self-esteem.
Tracey (2003) created an integrated model depicting the psychological response to injury and the recovery process as a flow chart with personality, history of stressors, coping resources, interventions, personal and situational factors, behavioral and emotional responses, and cognitive appraisal of injury all playing a role in an athlete’s overall response to injury. Her qualitative research found that injured athletes reported such internal worries as time lost from training and participating, what the injury meant to their athletic season, how the injury might influence future plans, injury effects on social relationships with teammates, concern for comparison to other athletes, and fear of being labeled as “damaged goods” by the coach. Upon return to sport following injury recovery, athletes have been found to have several stressors: fear of losing playing time compared to pre-injury, re-injury anxiety, attempting to achieve or surpass pre-injury skill level, meeting coach and teammate performance standards, and a general decline in their confidence in their athletic abilities. With tunnel vision becoming more likely when an athlete is subjected to stress (Nideffer & Sagal, 2001), such stressors as those listed can increase the athlete’s risk of re-injury once they return to play.

Brewer (2007) found that psychosocial factors play a considerable role in the onset, rehabilitation, and return to play following injury. Accepting and taking responsibility for an injury has been identified as an integral part of the coping and recovery process (Bianco, Malo, & Orlick, 1999; Brewer, Linder, & Phelps, 1995; Udry, 1997). Interviews have indicated that athletes believe a key aspect in successful injury recovery and return to sport is creating realistic expectations of post-injury performance (Podlog & Eklund, 2009). Research has shown that returning athletes often tend to have unrealistic performance expectations and may find it extremely discouraging to be beaten by previously weaker competitors (Bianco et al., 1999; Podlog & Eklund, 2007).

Along with an athlete’s internal emotional response to injury, athletic personnel, teammates, and parents play a major role in response to injury and satisfaction with recovery. While coaches have been found to be significantly more knowledgeable about concussion than the general public and 70-95% of coaches report that they would consult a healthcare professional before allowing a player to return to action (Guilmette, Malia, & McQuiggan, 2007), studies have shown that a player’s status or athletic skill level, game situation, and the importance of upcoming competitions influenced coach decisions to return the athlete to play. Higher-level athletes had a greater likelihood of being returned to competition (Flint & Weiss,
In interviews with collegiate athletes, six out of seven athletes stated that they felt pressure from parents concerning their recovery from injury (Granito, 2001). Athletes also commented on how their teammates could either support them through their injury and the recovery process or create more pressure that could delay their healing and recovery process (Granito, 2001).

Athletes stated that positive feedback to and from coaches and trainers both during recovery and after return to play, learning about their injury and how to cope, having a feeling of contributing to the team’s success, and positive support from teammates were key factors in a satisfactory return to play following injury (Podlog & Eklund, 2009). Interviewed athletes also indicated that time pressures (the urge to be recovered for a particular competition) and internal and external pressures from themselves, athletic personnel, teammates, and parents made creating realistic return to play goals difficult, which in turn decreased their feelings of success (Podlog & Eklund, 2009). This suggests the need to minimize external pressures to return to play in order to aid athletes in creating realistic post-injury goals.

Statement and Significance of the Problem

College athletes are at risk of sustaining a concussion during practice and game play. The frontal lobes of the brain, largely responsible for self-awareness and self-reflection, are especially vulnerable to damage from concussion due to the nature of a concussive injury. Research has shown that moderate to severe brain injury can result in impaired self-awareness, however, little research exists on the effects of mild traumatic brain injury, specifically concussion, on an individual’s level of self-awareness. Denial of deficits and the tremendous pressure put on college athletes to return to play are other important factors to consider in assessment of concussion. Unfortunately, it is very difficult to differentiate between what may be the result of impaired self-awareness and what is the result of personal and external pressures on the athlete to downplay their symptoms in order to return to play. The presence of impaired self-awareness in athletes, denial of deficits, or a combination of the two following concussion could lead an individual to overestimate their abilities following their injury, resulting in a heightened chance for failure and risk of re-injury. This inability to accurately assess deficits and their effect on daily function could have negative implications for an athlete in several areas, including in the social, school, and work environments.
Purpose of the Study

The purpose of this study is to gain insight into how college athletes assess their own cognitive deficits following sports-related concussion and how these deficits may affect their performance on standardized neuropsychological assessment. A primary consideration is how impaired self-awareness, as a result of injury, denial of deficits due to pressure to return to play, or a combination of these factors, impacts an athlete’s acknowledgement of symptoms following a concussion and their ability to predict their performance on neuropsychological testing. It will explore how such self-assessment corresponds to athletes’ performance on follow-up ImPACT testing. The effects of repeated sports-related concussions will be assessed in any participating athletes with a history of multiple concussions.

Research Questions and Hypotheses

This study seeks to answer the following questions:

1) Does an athlete’s self-assessment of their deficits prior to post-injury ImPACT testing correlate with his or her actual performance on the assessment? It is hypothesized that concussed athletes will demonstrate impaired self-awareness or denial of deficits indicated by performance prediction that does not correspond with their actual ImPACT performance.

2) How accurately are athletes able to predict their performance on post-injury ImPACT testing? It is hypothesized that concussed athletes will have lower accuracy in predicting their performance on ImPACT testing than non-concussed control athletes. Control athletes are expected to accurately assess their performance on follow-up ImPACT testing.

3) Are athletes more aware of deficits after taking the post-injury ImPACT Test? It is hypothesized that concussed athletes will become more aware of deficits after having taken the test. This will be indicated by changed responses on the post-ImPACT test survey. Control athletes are expected to maintain the same responses from pre- to post-ImPACT surveys.

4) Is a history of multiple concussions related to degree of impaired self-awareness or denial of deficits and lower ImPACT scores? It is hypothesized that those athletes
with a history of multiple concussions will have decreased self-awareness, greater
denial of deficits, and lower ImPACT scores than control athletes and those athletes
with a history of only one concussion.
CHAPTER II

Methods

Participants

Miami University maintains a Concussion Management Program in which the Speech Pathology and Audiology Department and the Intercollegiate Athletics program collaborate to obtain baseline neuropsychological testing scores for athletes using the ImPACT program. Miami University athletes from the varsity football, hockey, basketball, women’s softball, women’s field hockey, and women’s soccer teams complete baseline ImPACT testing prior to beginning pre-season training their freshman year.

Participants of this study were made up of Miami University athletes participating in the following sports during the Fall 2009 season: football, men’s ice hockey, and women’s basketball. A total of 14 athletes served as research subjects. Seven of these participants sustained a concussion during the Fall 2009 season, while the other seven served as non-concussed controls for each concussed athlete. All participating concussed athletes were required to have completed computerized baseline ImPACT testing and sustained a concussion during practice or game time play during the Fall 2009 athletic season. All participating control athletes were required to have completed computerized baseline ImPACT testing and have no history of concussion during the Fall 2009 athletic season.

Procedures

All procedures utilized in this research were approved by the Miami University Institutional Review Board. Prior to the start of the Fall 2009 athletic season, athletic trainers for all participating teams were emailed by the principal investigator to inform them of this research and the need for participants. Trainers were to inform athletes of the study and the possibility of their participation and provide them with a flyer attached to the email, which briefly outlined the research and their potential to serve as a research subject. Any athlete who did not wish to participate returned a decline to participate form to the principal investigator.

This study utilized procedures outlined in the Miami University Concussion Management Program. Athletes who sustained a concussion during practice or game time during the Fall 2009 season were referred to the Miami University Speech and Hearing Clinic for post-injury ImPACT testing by their coach or athletic trainer. All participating athletes had completed
baseline ImPACT testing at the start of their freshman year or at the start of their first year as a transfer student. The athletes were generally referred to the clinic for testing within 48 hours of injury, however, this was not always the case as some athletes did not report experiencing symptoms until several days later. ImPACT was administered in a private testing room by one of three randomly assigned trained speech pathology graduate students. Athletes who displayed a decline in performance greater than one standard deviation from their baseline scores in any area tested on the post-injury assessment or athletes who still reported symptoms of a concussion were scheduled for a reassessment within 4-8 days. It was recommended that these athletes not be permitted to return to play until their ImPACT scores returned to baseline.

Upon entering the testing room and prior to the athlete beginning ImPACT, the principal investigator met with each concussed athlete to briefly present this research and to request their participation. Athletes were informed that their participation would require them to fill out two surveys, one immediately prior to taking the ImPACT test and one immediately after the test. The athletes were told that these surveys were meant to collect information on their experience of any concussion symptoms and if they had noticed any areas of deficit since the concussion. The surveys also asked them to consider how any noted deficits might affect their performance on the ImPACT and to predict their performance considering these deficits. A copy of these two surveys can be found in Appendix 1. If athletes agreed to participate in the research, they signed three informed consent forms, which described the research, their rights as a research participant, and provided the principal investigator with permission to access their baseline and post-injury ImPACT results. Each athlete was provided with a copy of these signed consent forms and a packet further detailing the goals and procedures of this research. After signing these documents, the athlete was given the first survey to complete before the graduate assistant entered the room to begin the testing. Athletes were informed that their coaches and trainers would not be provided with their answers to these surveys and were encouraged to be as honest as possible in their answers.

In order to attempt to control for the influence of athlete motivation during testing, the principal investigator observed the athlete for the duration of ImPACT testing and while the athlete completed both pre- and post-ImPACT surveys. Athletes were not informed that they were being observed while taking the test as this may have altered their natural behavior. The athlete was viewed from an observation room and rated on a six-point scale ranging from zero...
(test not completed) to five (best effort exerted). This scale can be found in Appendix 4. As mentioned earlier, some research has indicated that an athlete’s level of effort can influence performance results.

Prior to beginning computer testing, athletes responded to a concussion questionnaire asked by the graduate assistant to obtain information regarding their concussion history. Each athlete was asked to complete the Postconcussion Rating Scale in which they rate their present physical, emotional, and cognitive symptoms on a 7 point scale ranging from 0 (symptom not present) to 6 (severe symptom). Any athlete who rated any symptoms on this scale above 0 was considered to have failed the test and were required to return to the clinic for reassessment within 4-8 days.

After the athlete completed the ImPACT test, the principal investigator reentered the room to provide the second survey. Athletes were again observed completing this survey from an observation room. Upon their departure, athletes were provided with the copies of their consent forms and an information packet on this research.

The recruitment of controls was carried out with the help of the athletic trainers of each participating sport. The principal investigator contacted the athletic trainer of a particular sport each time that one of their athletes sustained a concussion. An email was sent to the athletic trainer reminding them of this research, providing information on the age and position played of the athlete who sustained a concussion, and requesting that the trainer suggest a player of similar age and position to the concussed athlete who had no history of concussion during the Fall 2009 season. A player of similar age was requested in order to attempt to equalize the amount of time that had passed since last taking the ImPACT test and a player of a similar position was requested in order to have an athlete with a similar athletic experience and risk of injury as that of the concussed athlete. The trainers provided the contact information of potential control athletes to the principal investigator. These athletes were then contacted by the principal investigator to request that they participate in this research as a control subject. All control subjects were emailed, informed of the purpose and procedures of this research, and asked to come to the clinic to complete ImPACT testing. All control athletes who agreed to participate in this research received 25 MU bucks as compensation for their involvement (as approved by the Miami University NCAA representative).
Similar procedures to those used with concussed athletes were conducted for control subjects. Testing was conducted in a private room by one of the three trained speech pathology graduate assistants who also conducted testing for concussed athletes. Each control subject met with the principal investigator prior to testing to be further informed of this research and to sign the three consent forms. They were informed that their participation would require them to complete two surveys, one immediately before ImPACT testing and one immediately after. The goal of these surveys was to obtain information on an uninjured athlete’s ability to predict their performance (an indication of self-awareness) on the ImPACT and to compare this to their concussed counterparts. These surveys can be found in Appendix 3. The control athlete was then left alone to complete the initial survey. Controls were also observed by the principal investigator during ImPACT testing and while completing both surveys, and their level of effort was rated using the six point scale. Following completion of testing, the principal investigator reentered the room to provide the second survey. The principal investigator viewed the athlete completing the survey from the observation room, and then provided the athlete with copies of their signed consent forms and an information packet on this research upon their departure.
CHAPTER III
Results

Statistical Analysis

Data analysis was conducted using Minitab data analysis software. Several descriptive statistical analyses were utilized to obtain results. Fisher’s Exact Test was used to examine the significance of the association between the results of several of the questions asked on the surveys and the athletes’ ImPACT performance. Fisher’s Exact Test is a statistical significance test used in the analysis of contingency tables when a sample size is small, as is the case with this research. The Wilcoxon Rank-Sum Test was used to examine the significance of the association between the number of symptoms an athlete admitted he or she was experiencing and the athlete’s accuracy in predicting their ImPACT performance; this test is a non-parametric assessment of whether two independent samples of observations come from the same distribution. The Kendall Rank Correlation Coefficient, commonly known as a tau test, was used to examine the significance of the association between the athlete’s level of effort rating and the level of effort rating of the principal investigator. This test was also used to examine the significance of the association between inconsistent athlete report of symptoms and an athlete’s accuracy in predicting their ImPACT performance. The tau test is a measure of rank correlation, or the similarity of the orderings of the data when ranked by each of the quantities. A binomial test of significance was utilized to examine the significance of difference between changes in prediction from pre- to post-ImPACT surveys between concussed and control athletes. This test is used to examine the distribution of a single dichotomy when the researcher has a small sample.

Results

The purpose of this study was to examine the level of self-awareness of deficits in college athletes following sports-related concussion. Self-awareness was assessed through the use of a performance prediction task. By examining how an athlete’s prediction of neuropsychological performance is affected by concussion, the results can be used to aid athletic and medical personnel in gaining more knowledge on viability of athlete report of symptoms following head injury in sports. A total of 14 collegiate athletes participated in the study, seven as concussed athletes, and seven as non-concussed controls. Tables 1 and 2 provide demographic information on all research participants, both concussed and controls.
Table 1
Concussed Athlete Participants

<table>
<thead>
<tr>
<th>Athlete Number</th>
<th>Sex</th>
<th>Age</th>
<th>Class Standing</th>
<th>Sport</th>
<th>Athletic Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Male</td>
<td>20</td>
<td>Junior</td>
<td>Football</td>
<td>Linebacker</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>20</td>
<td>Sophomore</td>
<td>Football</td>
<td>Linebacker</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>19</td>
<td>Freshman</td>
<td>Football</td>
<td>Tight end</td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>21</td>
<td>Sophomore</td>
<td>Football</td>
<td>Tight end</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>20</td>
<td>Junior</td>
<td>Hockey</td>
<td>Left wing</td>
</tr>
<tr>
<td>6</td>
<td>Female</td>
<td>19</td>
<td>Freshman</td>
<td>Basketball</td>
<td>Guard</td>
</tr>
<tr>
<td>7</td>
<td>Female</td>
<td>20</td>
<td>Junior</td>
<td>Basketball</td>
<td>Guard</td>
</tr>
</tbody>
</table>

Table 2
Non-concussed Control Athlete Participants

<table>
<thead>
<tr>
<th>Athlete Number</th>
<th>Sex</th>
<th>Age</th>
<th>Class Standing</th>
<th>Sport</th>
<th>Athletic Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Male</td>
<td>20</td>
<td>Junior</td>
<td>Football</td>
<td>Linebacker</td>
</tr>
<tr>
<td>9</td>
<td>Male</td>
<td>20</td>
<td>Sophomore</td>
<td>Football</td>
<td>Linebacker</td>
</tr>
<tr>
<td>10</td>
<td>Male</td>
<td>19</td>
<td>Freshman</td>
<td>Football</td>
<td>Tight end</td>
</tr>
<tr>
<td>11</td>
<td>Male</td>
<td>19</td>
<td>Sophomore</td>
<td>Football</td>
<td>Tight end</td>
</tr>
<tr>
<td>12</td>
<td>Male</td>
<td>21</td>
<td>Sophomore</td>
<td>Hockey</td>
<td>Rt. forward</td>
</tr>
<tr>
<td>13</td>
<td>Female</td>
<td>19</td>
<td>Freshman</td>
<td>Basketball</td>
<td>Guard</td>
</tr>
<tr>
<td>14</td>
<td>Female</td>
<td>21</td>
<td>Junior</td>
<td>Basketball</td>
<td>Forward</td>
</tr>
</tbody>
</table>

Research Question 1: Does an athlete’s self-assessment of their deficits prior to post-injury ImPACT testing correlate with his or her actual performance on the assessment?

The Fisher’s Exact Test was used to examine the association between a concussed athlete’s prediction on the pre-ImPACT survey as to whether or not their concussion would affect their performance on ImPACT and whether an athlete passed or failed the test. This analysis produced a probability (p) value of 0.4286, which indicates no statistically significant
association. All four concussed athletes who stated on the pre-ImPACT survey that their concussion would affect ImPACT performance failed the test. Table 3 presents the statistical results and athlete distribution for this analysis.

**Table 3**

**Concussed Athlete Pre-ImPACT Survey Performance Prediction and ImPACT Pass/Fail Rate**

<table>
<thead>
<tr>
<th>Will concussion affect performance?</th>
<th>Did athlete pass or fail ImPACT?</th>
<th>Pass</th>
<th>Fail</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td></td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Percent</td>
<td></td>
<td>0.00</td>
<td>57.14</td>
<td>57.14</td>
</tr>
<tr>
<td>Row Percent</td>
<td></td>
<td>0.00</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>Column Percent</td>
<td></td>
<td>0.00</td>
<td>66.67</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Percent</td>
<td></td>
<td>14.29</td>
<td>28.57</td>
<td>42.86</td>
</tr>
<tr>
<td>Row Percent</td>
<td></td>
<td>33.33</td>
<td>66.67</td>
<td></td>
</tr>
<tr>
<td>Column Percent</td>
<td></td>
<td>100.00</td>
<td>33.33</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>14.29</td>
<td>85.71</td>
<td>100.00</td>
</tr>
</tbody>
</table>

The Fisher’s Exact Test was also used to examine the association between a concussed athlete’s prediction of how their post-injury ImPACT scores would compare to their baseline and whether the athlete passed or failed the test. The choices for the prediction of how their post-injury score would compare to baseline were originally ‘a lot worse,’ ‘a little worse,’ ‘same,’ ‘a little better,’ and ‘a lot better’. These options were condensed into two options for statistical analysis, the ‘same or better than baseline’ and ‘worse than baseline,’ due to small sample size. This analysis indicated that no statistically significant association exists between an athlete’s ability to predict difference from baseline testing and actual ImPACT performance in this sample. Results for this analysis are displayed in Table 4.
Table 4

Concussed Athlete Pre-ImPACT Survey Prediction of how Performance will Differ from Baseline and ImPACT Pass/Fail Rate

<table>
<thead>
<tr>
<th>How will performance be different from baseline?</th>
<th>Did athlete pass or fail ImPACT?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pass</td>
</tr>
<tr>
<td>Frequency</td>
<td></td>
</tr>
<tr>
<td>Worse</td>
<td>0</td>
</tr>
<tr>
<td>Percent</td>
<td>0.00</td>
</tr>
<tr>
<td>Row Percent</td>
<td>0.00</td>
</tr>
<tr>
<td>Column Percent</td>
<td>0.00</td>
</tr>
<tr>
<td>Frequency</td>
<td></td>
</tr>
<tr>
<td>Same or better</td>
<td>1</td>
</tr>
<tr>
<td>Percent</td>
<td>14.29</td>
</tr>
<tr>
<td>Row Percent</td>
<td>25.00</td>
</tr>
<tr>
<td>Column Percent</td>
<td>100.00</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>14.29</td>
</tr>
</tbody>
</table>

Research Question 2: How accurately are athletes able to predict their performance on post-injury ImPACT testing?

The Fisher’s Exact Test was utilized to examine the association between athlete accuracy of performance prediction and whether athletes passed or failed the ImPACT test. Prediction accuracy for the concussed group was based on whether the athlete stated that their concussion would or would not affect their ImPACT performance. If the athlete incorrectly stated whether their concussion would affect their ImPACT performance on either the pre- or post-ImPACT survey, they were coded as having incorrect performance prediction. For the concussed group, this analysis resulted in a p-score of 0.4286, indicating that no statistically significant association exists between accuracy of performance prediction and actual test performance. Four of the
seven concussed athletes incorrectly predicted their performance on ImPACT on either the pre-or post-ImPACT survey. Table 5 provides the results of this analysis.

**Table 5**

**Concussed Athlete Accuracy of Performance Prediction Overall and ImPACT Pass/Fail Rate**

<table>
<thead>
<tr>
<th>Did athlete correctly predict ImPACT performance?</th>
<th>Did athlete pass or fail ImPACT?</th>
<th>Pass</th>
<th>Fail</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Yes</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Percent</td>
<td></td>
<td>14.29</td>
<td>28.57</td>
<td>42.86</td>
</tr>
<tr>
<td>Row Percent</td>
<td></td>
<td>33.33</td>
<td>66.67</td>
<td></td>
</tr>
<tr>
<td>Column Percent</td>
<td></td>
<td>100.00</td>
<td>33.33</td>
<td></td>
</tr>
<tr>
<td>Frequency No</td>
<td></td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Percent</td>
<td></td>
<td>0.00</td>
<td>57.14</td>
<td>57.14</td>
</tr>
<tr>
<td>Row Percent</td>
<td></td>
<td>0.00</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>Column Percent</td>
<td></td>
<td>0.00</td>
<td>66.67</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>1</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14.29</td>
<td>85.71</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Prediction accuracy for the non-concussed control group was based on whether an athlete correctly predicted that they would do ‘worse’ or ‘the same or better’ than their baseline on follow-up ImPACT testing. For the non-concussed control group, this analysis resulted in a $p$-score of 0.0476, indicating that there is a statistically significant association between accuracy of performance prediction and actual test performance for controls. Five of the seven controls correctly predicted that their follow-up ImPACT performance would be the same or better than baseline. Table 6 presents the statistical results of this analysis for non-concussed controls.
Table 6  
Control Athlete Accuracy of Performance Prediction Overall and ImPACT Pass/Fail Rate

<table>
<thead>
<tr>
<th>Did athlete correctly predict ImPACT performance?</th>
<th>Did athlete pass or fail ImPACT?</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pass</td>
<td>Fail</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
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<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Percent</td>
<td>71.43</td>
<td>0.00</td>
<td>71.43</td>
<td></td>
</tr>
<tr>
<td>Row Percent</td>
<td>100.00</td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Column Percent</td>
<td>100.00</td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>No</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Percent</td>
<td>0.00</td>
<td>28.57</td>
<td>28.57</td>
<td></td>
</tr>
<tr>
<td>Row Percent</td>
<td>0.00</td>
<td>100.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Column Percent</td>
<td>0.00</td>
<td>100.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>2</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>71.43</td>
<td>28.57</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>

*Research Question 3: Are athletes more aware of deficits after taking post-injury ImPACT than prior to taking post-injury ImPACT?*

The Fisher’s Exact Test was used to examine the association between whether an athlete believed that their concussion affected their ImPACT performance after having taken the test and whether that athlete passed or failed the test. This analysis found that no statistically significant association exists between these two variables. Statistical results and athlete distribution for this analysis can be found in Table 7.
Table 7

Concussed Athlete Post-ImPACT Survey Performance Prediction and ImPACT Pass/Fail Rate

<table>
<thead>
<tr>
<th>Did concussion affect performance?</th>
<th>Did athlete pass or fail ImPACT?</th>
<th>Pass</th>
<th>Fail</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td></td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Percent</td>
<td>Yes</td>
<td>0.00</td>
<td>28.57</td>
<td>28.57</td>
</tr>
<tr>
<td>Row Percent</td>
<td></td>
<td>0.00</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>Column Percent</td>
<td></td>
<td>0.00</td>
<td>33.33</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>No</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Percent</td>
<td></td>
<td>14.29</td>
<td>57.14</td>
<td>71.43</td>
</tr>
<tr>
<td>Row Percent</td>
<td></td>
<td>20.00</td>
<td>80.00</td>
<td></td>
</tr>
<tr>
<td>Column Percent</td>
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<td>100.00</td>
<td>66.67</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
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<td>6</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14.29</td>
<td>85.71</td>
<td>100.00</td>
</tr>
</tbody>
</table>

The two athletes who changed their prediction from pre- to post-ImPACT survey both ultimately failed the test. These athletes originally stated on the pre-ImPACT survey that their concussion would affect their performance, but then stated on the post-ImPACT survey that their concussion did not affect their performance. These 2 athletes were more correct in predicting that their performance would be affected by their concussion prior to taking ImPACT. Results on all concussed athletes for this analysis are provided in Table 8.
<table>
<thead>
<tr>
<th>Athlete Number</th>
<th>Will concussion affect performance (before taking ImPACT?)</th>
<th>Did concussion affect performance (after taking ImPACT)?</th>
<th>Did athlete change or maintain prediction from pre- to post-ImPACT survey?</th>
<th>Passed or failed ImPACT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>No</td>
<td>Changed</td>
<td>Failed</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
<td>No</td>
<td>Maintained</td>
<td>Failed</td>
</tr>
<tr>
<td>3</td>
<td>No</td>
<td>No</td>
<td>Maintained</td>
<td>Passed</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>No</td>
<td>Changed</td>
<td>Failed</td>
</tr>
<tr>
<td>5</td>
<td>No</td>
<td>No</td>
<td>Maintained</td>
<td>Failed</td>
</tr>
<tr>
<td>6</td>
<td>Yes</td>
<td>Yes</td>
<td>Maintained</td>
<td>Failed</td>
</tr>
<tr>
<td>7</td>
<td>Yes</td>
<td>Yes</td>
<td>Maintained</td>
<td>Failed</td>
</tr>
</tbody>
</table>

A binomial test of significance was utilized to examine the association between whether concussed athletes versus non-concussed controls changed their prediction from pre- to post-ImPACT survey. The z value produced for this binomial test was 0.764, indicating that there is no statistically significant difference in prediction change between the two groups. Two of the seven concussed athletes changed their prediction from pre-to post-ImPACT survey. All seven non-concussed controls stated that they would do the same or better as baseline on follow-up ImPACT testing and maintained this prediction across both surveys.

**Research Question 4: Is a history of multiple concussions related to degree of impaired self-awareness or denial of deficits and lower ImPACT scores?**

The Fisher’s Exact Test was utilized to examine the association between number of previous concussions and whether athletes passed or failed the ImPACT test. This analysis resulted in a p-score of 0.5714, indicating that there is no statistically significant association
between these two variables. All athletes who reported a history of prior concussions failed ImPACT. Results of this analysis can be found in Table 9.

### Table 9

**Concussed Athlete Number of Previous Concussions and ImPACT Pass/Fail Rate**

<table>
<thead>
<tr>
<th>How many concussions prior to current one?</th>
<th>Did athlete pass or fail ImPACT?</th>
<th>Pass</th>
<th>Fail</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency 0</td>
<td></td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Percent</td>
<td></td>
<td>14.29</td>
<td>14.29</td>
<td>28.57</td>
</tr>
<tr>
<td>Row Percent</td>
<td></td>
<td>50.00</td>
<td>50.00</td>
<td></td>
</tr>
<tr>
<td>Column Percent</td>
<td></td>
<td>100.00</td>
<td>16.67</td>
<td></td>
</tr>
<tr>
<td>Frequency 1</td>
<td></td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Percent</td>
<td></td>
<td>0.00</td>
<td>42.86</td>
<td>42.86</td>
</tr>
<tr>
<td>Row Percent</td>
<td></td>
<td>0.00</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>Column Percent</td>
<td></td>
<td>0.00</td>
<td>50.00</td>
<td></td>
</tr>
<tr>
<td>Frequency 2</td>
<td></td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Percent</td>
<td></td>
<td>0.00</td>
<td>28.57</td>
<td>28.57</td>
</tr>
<tr>
<td>Row Percent</td>
<td></td>
<td>0.00</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>Column Percent</td>
<td></td>
<td>0.00</td>
<td>33.33</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>1</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14.29</td>
<td>85.71</td>
<td>100.00</td>
</tr>
</tbody>
</table>

The Fisher’s Exact Test was also utilized to examine the association between number of previous concussions and accuracy of performance prediction. This analysis resulted in a *p*-score of 0.6571, indicating that no statistically significant association exists between these variables for this sample. Table 10 provides the results of this analysis.
Table 10
Concussed Athlete Distribution of Number of Previous Concussions and Accuracy of Performance Prediction

<table>
<thead>
<tr>
<th>Athlete Number</th>
<th>Number of concussions previous to current one</th>
<th>Accuracy of performance prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>Inaccurate</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>Inaccurate</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>Accurate</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>Inaccurate</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>Inaccurate</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>Accurate</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>Accurate</td>
</tr>
</tbody>
</table>

*Report of Symptoms*

The Wilcoxon Rank-Sum Test was utilized to examine the association between the number of symptoms reported by concussed athletes on the pre-ImPACT survey and athletes’ accuracy of performance prediction. This analysis resulted in a \(p\)-score of 0.8454, indicating that no statistically significant association exists between these two variables.

The Kendall Rank Correlation Coefficient, or tau test, was utilized to examine the association between inconsistently reported symptoms from pre- and post-ImPACT surveys to the PCSS of the ImPACT and accuracy of performance prediction. The symptoms examined for consistency were fatigue, concentration, and irritability, as these symptoms appear on both the pre-ImPACT survey and the Post-Concussion Symptom Scale (PCSS) of the ImPACT. The PCSS is given prior to the athlete beginning ImPACT testing on the computer and asks the athlete to rate a number 21 symptoms on a seven-point scale, with zero indicating that they are not experiencing the symptom and six indicating that the symptom is severe. This analysis resulted in a coefficient of 0.2034, indicating that there is not a statistically significant association between these two variables. Table 11 displays the athlete distribution of symptoms inconsistently reported of the three symptoms examined and accuracy of performance prediction.
Table 11
Concussed Athlete Inconsistently Reported Symptoms
and Accuracy of Performance Prediction

<table>
<thead>
<tr>
<th>Athlete Number</th>
<th>Symptoms reported on pre-ImPACT survey</th>
<th>Symptoms reported on Post-concussion Symptom Scale of ImPACT</th>
<th>Accuracy of performance prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fatigue, difficulty concentrating</td>
<td>None of 3</td>
<td>Inaccurate</td>
</tr>
<tr>
<td>2</td>
<td>None of 3</td>
<td>None of 3</td>
<td>Inaccurate</td>
</tr>
<tr>
<td>3</td>
<td>Fatigue</td>
<td>None of 3</td>
<td>Accurate</td>
</tr>
<tr>
<td>4</td>
<td>None of 3</td>
<td>Fatigue, difficulty concentrating, irritability</td>
<td>Inaccurate</td>
</tr>
<tr>
<td>5</td>
<td>Fatigue, difficulty concentrating, irritability</td>
<td>None of 3</td>
<td>Inaccurate</td>
</tr>
<tr>
<td>6</td>
<td>Fatigue, difficulty concentrating, irritability</td>
<td>Fatigue, difficulty concentrating, irritability</td>
<td>Accurate</td>
</tr>
<tr>
<td>7</td>
<td>None of 3</td>
<td>Fatigue</td>
<td>Accurate</td>
</tr>
</tbody>
</table>

Level of Effort

The Fisher’s Exact Test was utilized to examine the association between the level of effort a concussed athlete reported they exerted on ImPACT testing to predict whether an athlete passed or failed the test. This analysis resulted in a p-score of .5714, indicating that no statistically significant difference exists between these two variables. All non-concussed controls reported putting forth their best effort, thus, no statistically significant association was found between these two variables for the control group. The results of this statistical analysis are outlined in Table 12.
Table 12

Concussed Athlete Level of Effort Rating and ImPACT Pass/Fail Rate

<table>
<thead>
<tr>
<th>Level of Effort Rating</th>
<th>Pass</th>
<th>Fail</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Average effort</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Percent</td>
<td>0.00</td>
<td>42.86</td>
<td>42.86</td>
</tr>
<tr>
<td>Row Percent</td>
<td>0.00</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>Column Percent</td>
<td>0.00</td>
<td>50.00</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Did my best</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Percent</td>
<td>14.29</td>
<td>42.86</td>
<td>57.14</td>
</tr>
<tr>
<td>Row Percent</td>
<td>25.00</td>
<td>75.00</td>
<td></td>
</tr>
<tr>
<td>Column Percent</td>
<td>100.00</td>
<td>50.00</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>6</td>
<td>100.00</td>
</tr>
<tr>
<td></td>
<td>14.29</td>
<td>85.71</td>
<td></td>
</tr>
</tbody>
</table>

The Kendall Rank Correlation Coefficient, or tau test, was utilized to examine the association between athlete level of effort rating and the level of effort rating of the principal investigator who observed each athlete as they completed the ImPACT. This analysis between concussed athletes’ level of effort rating and that of the principal investigator resulted in a coefficient of 0.7083, indicating that there is no statistically significant agreement between these two variables. All level of effort ratings for non-concussed controls were the same (best effort), resulting in a 1-to-1 correlation. Table 13 presents the statistical results of these two variables for the concussed athlete group.
| Kendall Tau b Correlation Coefficients, N=7 | Prob>|tau| under H0: Tau=0 | Concussed athlete’s level of effort rating | Principal investigator’s level of effort rating for concussed athletes |
|---------------------------------------------|--------------------------|------------------------------------------|---------------------------------------------|
| Concussed athlete’s level of effort rating  | 1.00000                  |                                           | 0.7083                                      |
| Principal investigator’s level of effort rating for concussed athletes | 0.14434                  |                                           | 1.00000                                    |
|                                             | 0.7083                   |                                           | 0.14434                                    |
CHAPTER IV
Discussion

The objective of this research was to explore how self-awareness is affected by sports-related concussion in college athletes. More severe forms of traumatic brain injury have been found to result in decreased self-awareness (Ries et al., 2007; Sherer et al., 2005), however, there are currently very few studies that have examined how self-awareness is affected by concussion. Self-awareness is an important consideration in management of concussed athletes, as a large component of an athlete being restricted from or returned to play is self-report of symptoms. In the absence of any obvious loss of consciousness, amnesia, or post-traumatic confusion, it is often up to the athlete to report any symptoms they may be experiencing in order to be referred for post-injury medical care and neuropsychological testing. The results of this research will add to the limited information in this area and perhaps encourage further study.

Awareness of Deficits Prior to and Following ImPACT

One factor that seemed to play a role in accuracy of performance prediction and self-awareness is the gender of an athlete. Only one of the five concussed male athletes correctly predicted the effects of their concussion on their ImPACT performance as compared to two of the two concussed female athletes. The two female participants were the only concussed athletes to state that their concussion would affect their ImPACT performance on both the pre- and post-ImPACT surveys. Table 14 below summarizes the gender distribution for several of the research questions. This data suggests that female athletes may be more apt to acknowledge and report that a concussion has affected them and may therefore be more accurate in predicting their neuropsychological performance. Female athletes have been found to report significantly more symptoms than males both at baseline and post-injury (Covassin et al., 2006; Broshek, 2005; Kontos, 2002). Another reason for this difference in report could be that females have been found to be more frequently cognitively impaired than males following sports-related concussion. Broshek et al. (2005) studied 155 concussed high school and collegiate female athletes and found that female athletes had significantly greater declines in simple and complex reaction times compared to baseline levels, and they reported more post-concussion symptoms compared to age-matched concussed males. Some possible reasons that have been suggested for this inequity are the fact that females have weaker neck muscles than males (Barnes et al., 1998).
and less head/neck mass overall, allowing greater linear and angular acceleration of the skull upon impact (Tierney et al., 2005). Cultural tendencies are another factor that may play a role in greater report of symptoms in female athletes. Vertinsky (1994) concluded that U.S. society is more protective of female athletes than of male athletes. Male athletes are often encouraged to play despite injuries and may not report symptoms in order to avoid being removed from play (Lovell et al., 2002). Granite and Carroll (2002) found that female athletes were more concerned about the effects of an injury on their future health, may be more honest in reporting their symptoms, and are not as upset as male athletes when told they are being removed from play.

When examining the relationship between whether an athlete believed that their concussion affected their ImPACT performance after having taken the test and whether that athlete passed or failed the test, a gender difference was again noted. The data for this analysis is presented in Table 7 above. The only two concussed athletes to report that their concussion would affect their ImPACT performance on the post-ImPACT survey were the two females. These results again support the research discussed above that females may experience more severe symptoms than males following concussion or may be more likely to report symptoms. Both of the male athletes who changed their prediction failed the test, and were therefore more accurate in predicting their performance prior to taking the test. This was the opposite of what had been hypothesized, as one would generally expect a person to be more accurate in predicting their performance on a task after rather than prior to completing it. Interestingly, these two athletes admitted experiencing two of the highest number of symptoms (five and six) and were inconsistent in reporting two out of three and three out of three symptoms from the survey to the PCSS. This data is presented in Table 14.
### Table 14
Self-Awareness/Performance Prediction Summary for Concussed Athletes

<table>
<thead>
<tr>
<th>Athlete Number</th>
<th>Athlete Gender</th>
<th>Will concussion affect performance (Response on pre-ImPACT survey)?</th>
<th>Did concussion affect performance (Response on post-ImPACT survey)?</th>
<th>Did athlete pass or fail ImPACT?</th>
<th>Accuracy of performance prediction</th>
<th>Number of symptoms reported on pre-ImPACT survey (11 possible)</th>
<th>Inconsistently reported symptoms between pre-ImPACT survey and PCSS (out of 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Male</td>
<td>Yes</td>
<td>No</td>
<td>Failed</td>
<td>Inaccurate</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>No</td>
<td>No</td>
<td>Failed</td>
<td>Inaccurate</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>No</td>
<td>No</td>
<td>Passed</td>
<td>Accurate</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>Yes</td>
<td>No</td>
<td>Failed</td>
<td>Inaccurate</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>No</td>
<td>No</td>
<td>Failed</td>
<td>Inaccurate</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Female</td>
<td>Yes</td>
<td>Yes</td>
<td>Failed</td>
<td>Accurate</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>Female</td>
<td>Yes</td>
<td>Yes</td>
<td>Failed</td>
<td>Accurate</td>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>

This data indicates that inconsistent report of symptoms and greater number of symptoms reported may be related to decreased levels of anticipatory and emergent awareness. Not surprisingly, none of the non-concussed controls changed their predictions from the pre- to post-ImPACT surveys, with all predicting that they would perform the same or better on the test. However, two of the seven control athletes performed significantly below their baseline performance for at least one composite score (Table 6 above). This would have resulted in them failing the test and having to repeat it until returning to baseline levels had they had a concussion. The reason for this occurrence is unknown, however, past research has concluded that non-concussed athletes taking the ImPACT generally do not show a significant change in score from initial to follow-up testing when no concussion has occurred (Lovell et al., 2003). ImPACT has also been found to have a high specificity rate (the probability of a negative test when a concussion is not present). In a study of 132 athletes, 89% of non-concussed controls were correctly identified based on ImPACT performance (Schatz et al., 2006). A number of
factors may have influenced these control athletes’ performance, including minimal sleep the night before testing or being overly stressed.

**Accuracy of Performance Prediction**

No statistically significant association was noted between accuracy of performance prediction and whether an athlete passed or failed ImPACT. However, some interesting points were noted in the data. This information is displayed in Table 8 above. Of the three athletes who correctly predicted their performance on both the pre-ImPACT and post-ImPACT surveys, one (male) passed and two (females) failed. Of the four males who incorrectly predicted their performance, either on the pre- or post-ImPACT survey, all failed. This seems to suggest that even if males are experiencing deficits that may lead them to fail neuropsychological testing, they are either unaware of the effects those deficits might have or are hesitant to admit that they are experiencing such effects. This raises the question of whether their inaccurate prediction was a result of truly impaired self-awareness or psychological denial of deficit.

As was discussed in an earlier section, Crosson et al. (1989) identified three types of deficits in awareness: (i) intellectual awareness deficits in which an individual is unable to understand that a function is impaired, (ii) emergent awareness deficits in which an individual is unable to recognize a problem while it is occurring, and (iii) anticipatory awareness deficits in which the individual is unable to anticipate that a problem will occur as a result of a deficit. Considering this schema when analyzing the data from this research may aid in identifying in what ways self-awareness is affected by sports-related concussion.

Those concussed athletes who incorrectly predicted their ImPACT performance on both pre- and post-ImPACT surveys seem to be experiencing deficits in all three of these areas. These athletes did not acknowledge that any cognitive functions were impaired or stated that even in the presence of impaired cognitive functions, their ImPACT performance would be unaffected. Even in considering their deficits prior to taking ImPACT (anticipatory) and then completing ImPACT (emergent), they were unaware of or denying that any cognitive impairments they were experiencing would negatively affect their neuropsychological performance. The presence of impaired awareness in these athletes is supported by research that has found that deficits in self-awareness may be indicated by a higher prediction than actual performance. Individuals who have sustained more severe TBI have been noted to have decreased self-awareness, and therefore
often overestimate their performance on a cognitive or physical task (Fischer, Trexler, & Gauggel, 2004). This could also be the case with these athletes. If denial was the reason for these athletes’ incorrect performance predictions, it would indicate that, though they are intellectually aware of the presence of cognitive deficits, they are unwilling to acknowledge how those deficits will affect their performance. This is an attempt to avoid the emotional distress that would come with such acknowledgement of deficit.

Those concussed athletes who correctly predicted their performance prior to ImPACT seem to have intact intellectual and anticipatory awareness, but are experiencing emergent awareness deficits. Prior to taking ImPACT, these athletes acknowledged that they were experiencing cognitive impairments (intellectual) and that these impairments might negatively affect their ImPACT performance (anticipatory). However, they were unable to recognize during ImPACT (emergent) that they were experiencing difficulty. Again, denial may play a part in this, but this would raise the question of why an athlete would acknowledge an impairment and its potential negative consequences prior to the task, but then deny that those impairments had any negative effect after having completed the task.

Finally, those athletes who correctly predicted their ImPACT performance on both pre- and post-ImPACT survey seem to have all three types of self-awareness intact or are not exhibiting denial in response to any cognitive impairments they are experiencing. One of these athletes passed ImPACT and therefore may have genuinely not been experiencing any cognitive impairments. The other two athletes who correctly predicted their performance were the two female participants. They were the only two athletes of the total six who failed ImPACT to acknowledge their deficits and that they would negatively affect their performance. As the results above have supported, women athletes have been found to experience more severe cognitive symptoms than male athletes following concussion. This indicates two possibilities for interpretation of the gender differences noted in this research. Females may be more likely to acknowledge impairments and their negative effect on task performance simply because they are experiencing more severe symptoms than males or because females are less likely than males to exhibit denial of deficit following injury. The latter possibility is supported by research that has shown that female athletes are not as upset as male athletes when told they are being removed from play (Granite & Carroll, 2002). This would suggest that male athletes experience greater
emotional distress in response to acknowledgement of impairments, and are therefore more likely than female athletes to exhibit denial in order to avoid such distress.

Previous Concussions and Impaired Awareness

Results of this research suggest that a history of concussion may result in a higher chance of failing ImPACT post-injury. Tables 9 and 10 above display this information. All concussed athletes who reported having had previous concussions failed the test. No statistically significant association was found between number of previous concussions and accuracy of performance prediction, yet neither of the two male athletes who reported having had 2 prior concussions accurately predicted their ImPACT performance. These two athletes were the only 2 who changed their performance prediction from pre- to post-ImPACT survey, and both admitted to experiencing some of the highest numbers of symptoms (five and six checked). This suggests that a history of multiple concussions may result in not only a greater number of symptoms following concussion, but also a greater decrease in intellectual, anticipatory, and emergent awareness. Athletes with a history of two or more previous concussions have been found to have long-term deficits in executive function, processing speed, and self-reported symptom severity (Collins et al., 2006). The two control athletes who failed ImPACT reported no prior history of concussions. Neither rated any symptoms on the PCSS and both reported getting approximately eight hours of sleep the night before.

Report of Symptoms

This research also explored the relationship between the number of symptoms an athlete reported they were experiencing and the athlete’s accuracy of performance prediction. Of the five athletes who checked five or more symptoms, four stated in the pre-ImPACT survey that their concussion would affect their performance, and all five ultimately failed. These results can be seen in Table 14 above. This seems to indicate that a greater acknowledgement and consideration of symptoms and deficits may lead an athlete to predict a decrease in performance. Considering that the survey asking for symptoms the athlete was experiencing and the PCSS were both given near the beginning of testing, it could be that an athlete is more likely to acknowledge that a concussion may affect their neuropsychological performance when confronted with a list of the potential concussion symptoms. Through confrontation with these
symptoms on the pre-ImPACT survey and PCSS, athletes were more likely to exhibit accurate intellectual and anticipatory awareness prior to ImPACT. However, by the time the athlete had completed computerized testing approximately 45 minutes later, these symptoms may have been put out of mind, allowing a false sense of confidence in one’s performance and resulting in a change in performance prediction. Thus, emergent awareness deficits may still be present.

**Level of Effort**

Level of effort was not found to significantly correlate with whether an athlete passed or failed ImPACT for this sample (Tables 12 and 13). However, individual composite scores were not compared between those who were reported to have higher versus lower levels of effort. Hunt et al. (2007) found that those athletes who exerted poor effort on ImPACT had significantly lower scores than those with high levels of effort.

**Conclusions**

This research raised several important questions regarding the effect of sports-related concussion on self-awareness, as outlined in the discussion section. However, due to small sample size, statistical analysis in this research had little statistical power. Based upon the analysis of the data, no conclusive evidence has been found indicating that sports-related concussion has an effect on an athlete’s self-awareness.

**Limitations**

The primary limitation in this research study was the number of participants. With seven concussed athletes and seven non-concussed control athletes, this research was largely inadequately powered for statistical analysis. Another weakness of this research is that two of the seven control athletes failed ImPACT. Such an occurrence might be avoided in future research with the use of more survey questions to control athletes about other potential influences of neuropsychological performance. Another weakness is that all of the participants were Miami University athletes. A sample including athletes from universities across the nation would provide results that can be generalized to a larger population. An additional limitation is the fact that the symptoms included on the pre-ImPACT survey for concussed participants were not the same as those symptoms on the PCSS of the ImPACT. Having a greater number of symptoms to
compare and test for consistency in athlete report may have increased the chance that a statistically significant association could be found. Finally, the questions on the surveys provided to concussed and control athletes were limited in their ability to determine an athlete’s level of self-awareness and to conclusively identify whether inaccurate performance prediction was a result of impaired self-awareness or denial of deficits. No questions were asked to athletes regarding whether they had ever downplayed the symptoms of an injury in the past or if they felt they were experiencing internal or external pressures to return to play that might lead to denial of deficit.

**Future Research**

Sports-related concussions and how they affect an athlete’s self-awareness continues to be an important topic for further research. Future research should focus on exploring the effects of concussion on self-awareness in a larger sample size and with athletes of a variety of ages and athletic skill. If ImPACT is used again as a basis for performance prediction, more symptoms should be examined for consistency in athlete reporting. Though level of effort was not found to have significant influence on ImPACT performance in this research, based on past research attempts should be made to control for athlete level of effort on ImPACT, and to explore the role this factor might have in consistency of test performance. Further research could also be conducted on self-awareness in athletes using other types of performance prediction tasks or methods of assessment for self-awareness. Researchers should attempt to further identify how intellectual, anticipatory, and emergent awareness are affected by sports-related concussion. Research should also explore the reasons for athlete denial of symptoms and attempt to discover whether inaccurate prediction of performance is a result of decreased self-awareness or athlete denial due to the desire to return to play.
References


metabolism and not accumulation of lactate within the human brain. *Journal of Physiology, 554*, 571–578.


Meares, R. (1999). The contribution of Hughlings Jackson to an understanding of


Appendices

Appendix 1

Survey #1: Post-injury Pre-ImPACT testing

Name:

Age:

Sport played:

1) When did you have your concussion?

2) Have you had any previous concussions?

3) Please list the approximate dates of your concussion(s).

4) Please check any of the following cognitive areas that you feel have been affected by your concussion.

Attention
Concentration
Processing speed- how quickly you can think through a problem
Reaction time- how quickly you can react to a stimuli (ex. delayed reaction to ball thrown to you)
Reasoning
Problem solving
Planning
Organization
Visuospatial skills
Sense of time
Fatigue
5) Do you think that your irritability level has changed since your concussion occurred?
Lot more irritable  Little more irritable  Same  Little less irritable  Lot less irritable

6) Do you think your concussion will affect your ImPACT performance?
Yes  No

7) Do you expect your performance on the ImPACT test to be different than the first time you took it?
Significantly lower  A little lower  Same  A little better  A lot better

8) How do you expect to perform on the ImPACT test today?
Very poor  Poor  Average  Good  Excellent

MU IRB Approval #09-013
Survey #2: Post-injury Post-ImPACT testing

Name:

Age:

Sport played:

1) Do you think that your concussion affected your performance on ImPACT testing?
   Yes  No

2) How do you think you performed on the ImPACT test today?

   Very poor  Poor  Average  Good  Excellent

3) Please rate your level of effort on the ImPACT test.

   Didn’t try at all  Tried a little  Average effort  Did my best

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Appendix 2
Survey #3: Pre-ImPACT testing for Control Subjects

Name:

Age:

1) Have you had any injuries to your head during the course of the semester?
   Yes          No

2) If so, do you think these injuries might have an effect on your ImPACT performance?
   Yes          No          No injuries

3) Do you expect your performance on the ImPACT test to be different than the first time you took it?
   Significantly lower   A little lower   Same   A little better   A lot better

4) How do you expect to perform on the ImPACT test today?
   Very poor   Poor   Average   Good   Excellent

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Survey #4: Post-ImPACT Testing for Control Subjects

Name:

Age:

1) Do you think that your initial prediction (from the earlier survey) for how you would perform on the test was accurate? Yes No

2) How do you think you performed on the ImPACT test today?
   Very poor Poor Average Good Excellent

3) Please rate your level of effort on the ImPACT test.
   Didn’t try at all Tried a little Average effort Did my best

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Appendix 3

Subject’s Level of Effort on ImPACT Scale

*As rated by principal investigator

5: Subject is observed to be fully focused for duration of ImPACT Test, with no instances of acting distracted or overly bored.

4: Subject is observed to have occasional instances of distraction, but overall behavior indicates best effort.

3: Subject is observed to have several instances of distraction and behavior that will most likely detract from test performance.

2: Subject seems to put forth minimal effort, working impulsively through test, slumped in chair, just trying to get it over with, etc.

1: Subject is unable/refuses to complete ImPACT test.