THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF KINESIOLOGY

RETURN TO CLASSROOM: EFFECTS OF MILD TRAUMATIC BRAIN INJURY ON ACADEMIC PERFORMANCE

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ABSTRACT

Mild traumatic brain injuries (mTBI), often called concussions, are a growing concern for children, adolescents, and all athletes participating in contact sports, as studies show that the damage caused by a brain injury can be more serious and have a longer lasting impact than first thought. Recent lawsuits involving professional athletes have resulted in multi-million dollar settlements and new guidelines for returning a concussed athlete to sport (Strachan 2015). However, little attention has been paid to the effect of concussions on a student-athlete's return to academics. This preliminary study of Grade Point Averages (GPA) from a cohort of 26 Penn State Division I varsity student-athletes shows that mTBI has a significant impact ($p=0.03$) on GPA. Specifically, it was observed that despite a change in study habits and increase in study time, there was an average decrease of 0.25 (on a 4.0 scale) in GPA from the semester prior to mTBI compared to the semester of injury. The student-athletes' GPAs tended to rebound the semester following mTBI, but the trend showed that the GPAs did not quite return to pre-concussive levels. All subjects were cleared to return to play 7-10 days post injury, but it can take more than twice that amount of time to return to school (Master 2012). Hence, return to play does not equate to return to academic rigor, and ignoring this fact with premature return to school could lead to compounding effects, longer lasting impacts, and increased deficits in not only the student-athletes current grades, but also their lives beyond sport.

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Chapter 1

Introduction

Background:

When people think of serious sports injuries, they typically picture fractured bones, sprained ligaments, and strained muscles. Recently, however, public attention is increasingly focusing on a sports injury that is nearly epidemic in the United States: concussions. It is estimated that up to 1.7 million children and adolescents in the United States suffer from concussions annually. A concussion is a type of Traumatic Brain Injury (TBI) induced by an impulsive force transmitted to the brain resulting from a direct or indirect impact to the head, face, neck, or elsewhere (Daneshvar 2011). More broadly, a concussion is a brain injury incurred by an external force leading to a hindrance in proper brain function (Mayo Clinic 2014). Concussions are just as serious, if not more serious, than orthopedic injuries, because they affect the body's control center.

Recent lawsuits from the National Football League Players Association (NFLPA) against the NFL have brought the significance of concussions to light. The NFL is close to a nearly $1 billion settlement involving approximately 4,500 former professional football players, who sustained brain injuries while playing in the league (Strachan 2015). There is strong data supporting the NFLPA's case that under current conditions, the NFL puts their professionals at greater risk than first thought. A study done on 79 deceased professional football players concludes that 76 of those former professionals were found to have evidence of degenerative brain disease. Even though this sample of professionals represents a predisposed population, due to their status as high profile athletes who

agreed to have their brains studied posthumously, the study has brought the severity of the effects of concussions into the spotlight (Breslow 2014).

Concussion symptoms can vary, depending on the severity of the injury, and can include headaches, fatigue, dizziness, nausea, and vomiting (Starkey 2013). In addition, severe concussions can cause the person to become sensitive to noise or light, cause a loss of balance or double vision, or even lose consciousness (AANS 2015). Less obvious is the effect of the concussion on the person's memory, concentration, coordination, processing speed, and reaction time (Sady 2011). Repeated concussions, such as those suffered by professional football players, are suspected of causing other, serious disorders such as Amyotrophic Lateral Sclerosis (ALS, or Lou Gehrig's disease), Alzheimer's Disease, Parkinson's Disease, Dementia, and Chronic Traumatic Encephalopathy (CTE) (Healy 2010). Not all head trauma leads to CTE, a progressive degenerative disease of the brain found in people with a history of repetitive brain trauma, although nearly all of the deceased NFL professional football players in the study showed evidence of this disease (Breslow 2014).

Unfortunately, because concussions occur quite frequently, they are often waived off and considered as more of an annoyance than serious injury. As a result, many athletes return to play too quickly, which can lead to more serious repercussions such as second-impact syndrome, resulting in death (Mayo Clinic 2014). Various sports organizations such as the National Football League (NFL), the National Hockey League (NHL) the Fédération Internationale de Football (FIFA), and even President Barack Obama are paying attention to the serious consequences of concussions (Klayman 2015). The NFL recently established concussion standards, following the class action

lawsuit brought by retired football players. The NHL has also been sued by former players, and has received negative publicity following the tragic deaths of several young hockey players who were known to have suffered numerous concussions (Branch 2014). Likewise, bad publicity following high profile concussive injuries at the 2014 World Cup prompted soccer's governing body, FIFA, to establish new concussion protocols (FIFA 2014). Expressing concern about the risks concussions pose to young athletes, President Obama convened a national summit to encourage research into the issue (Farrey 2015).

Clearly the NFL, NHL, and FIFA all have a vested interest in preventing concussions and getting star athletes back onto the field as soon as possible, so that they can win games and make money for their teams and the league. It stands to reason that most of the research thus far has focused on returning to sport after a mild traumatic brain injury (mTBI). By contrast, the effect of concussions on the return to academics has been vastly understudied, despite evidence that concussions have both a direct and indirect impact on learning (Sady 2011).

Purpose:

The purpose of this study was to examine the effect of a concussion on a student's return to academic rigor. The overall goal of my research was to determine if student-athletes' academics are negatively impacted by concussions, both in the short term (semester of concussion) and in the longer term (semester post-concussion), and whether the concussion has a more pronounced impact on certain subjects' academic abilities (concentration, information recall, reaction time, memory, and attention span).

Hypothesis:

Concussions and other traumatic brain injuries have a deleterious impact on academic progress and success. The physical symptoms that a concussed athlete may experience, such as headache, fogginess, dizziness, and sensitivity to light, and the cognitive impairment caused by the concussion, including mental fatigue, decreased attention span, and impaired concentration, make it hard to focus on academics. Due to the direct negative influence that concussions have on the student's ability to concentrate, memorize, and be attentive, the Grade Point Average (GPA) of the scholar-athlete will decline. It is predicted that the focus, memory retention, and ability to focus will decline at the time of concussion, and will improve with recovery, but not reach pre-concussion levels.

Chapter 2

Literature Review

The brain is the most complex organ; it acts as the command center of the central nervous system. Ironically, the brain is the primary system used by humans to gain knowledge, but there is still so much about the brain that is not understood. Due to the fact that the brain is not fully understood, the effects of concussions are also not completely appreciated.

Although much of the media attention has focused on concussions in male professional athletes, they are far from the only victims of this injury. In a comprehensive evaluation of concussive injuries, the prevalence rates of concussions between ice hockey, soccer, and basketball players were compared and gender of the athlete who suffered the concussion was noted. This study found that ice hockey players yielded the most concussions, followed by soccer, then basketball. Also, there was found to be a gender difference in the rate of concussions. Overall, females were more likely to suffer a concussion than males (Dick 2009). Moreover, according to the Centers for Disease Control and Prevention; there are more than three million concussions that occur in the United States annually, with 135,000 or more resulting from sports or recreation-related injuries for children from 5-18 years of age (US HHS & CDC 1997). Bakhos et al. (2010) reported that concussions have doubled in the past 10 years for young athletes who are between 8 and 13 years old, and has increased by more than 200% for 14-19 year olds during that same time period. Sport-related head injuries comprised 18.2% of head injuries in children less than 10 years of age, 43.2% of head injuries in children 10 to14

years of age, 53.4% of head injuries in 15 and 16 year olds, and more than 70% of head injuries in college-aged (ages 17 to 22 year old) students (Kelly 2001).

Concussion is the most common form of TBI, with up to 70% to 90% of injuries being classified as mild (Cassidy 2004). Whether mild, moderate, or severe, a concussion is a brain injury. Concussions affect proper brain function. In examining the physiological mechanisms that cause this to occur, Smayda, (1999) described a concussion as an immediate, yet reversible, traumatic paralysis of the nervous function of the brain.

For many, the physical symptoms of a concussion subside approximately three months after injury; but for other individuals, the physical, cognitive, and emotional symptoms persist more than a year after the time of injury (Witt 2010). The time it takes for mTBI symptoms to be resolved varies significantly. Slobounov et al. (2011) reported that an athlete's brain may remain injured even after the symptoms of a recent concussion have disappeared, and that these injuries are undetectable by commonly used neuropsychological tests.

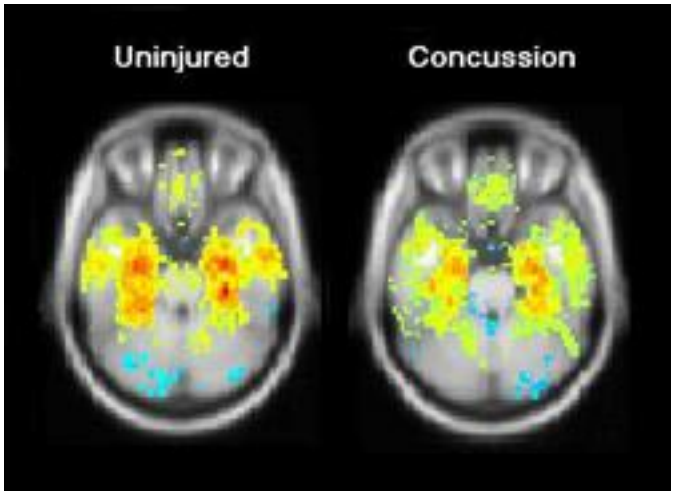

Figure 1: Uninjured versus recently concussed human

Figure 1 is from a Slobounov study on advanced brain scanning techniques utilizing resting state functional magnetic resonance imaging (Thomas 2011). The figure shows an uninjured participant and the damaging effects of concussion on a recently concussed participant.

Although concussion and TBI are used interchangeably at times, concussion is only one of several types of TBI. The brain can suffer different, distinct kinds of injuries based upon the sort and amount of force influencing the head. Depending on the type of injury suffered, only a single functional area, several functional areas, or all functional areas of the brain may be affected by the force. There are six functional areas of the brain including those dealing with focus, memory, attention, speed/reaction time, flexibility, and creativity. In addition to concussion, other TBI categories include contusion, coup-countercoup, diffuse axonal, and penetration (Zasler 2012).

A TBI can be classified into three separate levels, based on characteristics, intensity, and duration of the impact on the brain. The three different kinds of TBIs include mild TBI (mTBI), moderate TBI, and severe TBI. Mild TBI's are the least intense, as well as most common type of TBI (Zasler 2012). They are usually the result of direct impact on the head from some external object, but can also be elicited by rapid acceleration/deceleration of the head without impact. The effect of this impact may or may not result in a loss of consciousness. Testing of the brain may yield normal scans. A change in mental status (i.e. person is dazed, confused, or loses consciousness) at the time of injury is used as an indicator of mTBI. Moderate TBIs occur due to a non-penetrating blow to the head, and/or a violent shaking of the head. A TBI is considered moderate when there is a loss of consciousness for a few minutes to several hours,

confusion expands over a few days to weeks, and physical or cognitive impairments last for months or become permanent (Zasler 2012). The most intense form of TBI is severe TBI. Severe injuries of the head are most often caused from crushing blows or penetrating wounds to the head. The aforementioned injuries crush, rip, and shear the delicate brain tissue. Severe TBI is the most life threatening of the three TBIs, and the most intractable type of injury to the brain (Zasler 2012). Most concussions fall within the mild TBI level, which is why it stands to reason that mild TBI and concussion are used synonymously. According to a report from the Centers for Disease Control (2003), approximately 75 percent of concussions suffered each year are categorized as "mild."

Any concussion, whether the result of a loss of consciousness or not, is the result of rotational movements of the brain inside the calvaria, which refers to the cranium as a whole, minus the facial bones, as well as the shearing forces affecting the upper reticular formation that create torque. These internal forces also cause the brain to move in a spinning manner. While the brain is whipping around in the inner regions of the skull, it suffers direct impact with the inner prominences, most notably the petrous and orbital ridges, as well as the wings of the sphenoid (Smayda 1999). Basically, upon the force of impact, the brain knocks into the inner part of the head, where it bumps on one side, and then the other, of the bony makeup of the head known as the skull. This rumbling motion of the brain on the sides of the skull leads damaging bruises at two sites in the brain that are affected, called the coup and the countercoup. Such injuries can cause a number of short term and long-term effects (Smayda 1999; Davis 2013).

As noted earlier, short-term effects and symptoms stemming from this bouncing around of the brain include, but are not limited to headaches, dizziness, blurred vision,

coma, and seizures. More common long-term effects that can emerge include memory issues, lack of inhibition, intensified anger or aggression, significant personality changes, inability to focus attention, lack of concentration, problems organizing, planning, or problem solving, and in some cases, language impairment (UT Dallas 2015). Both the short and long term effects from mTBI vary in intensity based upon the severity of the concussion and from one individual to the next. According to the Centers for Disease Control, TBI is a leading cause of death and disability among children in the United States (Thurman 2014).

In addition to the direct short-term and long-term concussion effects discussed above, there are also immediate and residual impacts of brain injuries. The immediate impact, known as the primary injury, includes the gamut of the short-term effects categorized into three different domains including physical, emotional, and cognitive. Examples of physical short-term effects may involve headaches, confusion or foggy feeling, vertigo, lightheadedness, tinnitus (ringing in ears), fatigue, blurred vision/seeing stars, being dazed, nausea/vomiting, difficulty with mobility or coordination, and temporary loss of consciousness. Some emotional short-term effects may include frustration, irritability, crankiness, feeling helpless, having fear of future harm, anxiety, feeling easily overwhelmed, and mood swings. Cognitive impairment that is considered a short-term effect from concussion is partial or total memory loss, loss of concentration, slow reaction time, difficulty talking and communicating (Smayda 1999; Mayo Clinic 2014).

Many symptoms however, are not experienced immediately. These undesirable neurophysiological responses, called secondary injuries, do not occur at the time of the

injury, but emerge a few hours or days following a concussion. Secondary injuries include tissue damage can result in long-term effects. Such effects include coma, cognitive deficits (long-term/permanent), psychosocial, behavioral and emotional changes, as well as bodily damage and biochemical changes at the cellular level (Smayda 1999). Because of these residual effects, returning to academic work too soon after suffering a concussion should not be advised. All the symptoms may not have yet presented themselves, thus returning too quickly could exacerbate the problem. It is paramount for physicians to oversee the patient very closely after a concussion (Hunt & Asplund 2010).

When a brain is injured, it cannot be casted or reset like a fracture or dislocation. Currently, the most common remedy for a concussion is rest. The amount of rest needed post-concussion varies for each individual. According to the NCAA protocol, the rehabilitation plan for concussions includes avoiding potential stressors such as schoolwork, video games, reading, texting, or watching television (NCAA 2013).

Recent studies have clearly documented that student-athletes suffering from concussion may experience persistent post-concussive symptoms including somatic, cognitive, physical, psychological, and/or behavioral changes lasting more than 1 month following injury (Cantu 2011; Zemek 2013). It is important to stress that the majority of concussed athletes are cleared for sports participation within 7-10 days post-injury and return to the classroom within 3 days post-injury. It is believed that this rapid return to academics is not conducive to complete healing and may contribute to other significant cognitive deficits (Sady 2011).

Persistent concussive symptoms may impact the affected individual's quality of life through impaired cognition, memory, and attention, thereby affecting academic performance, mood, and social engagement (Zemek 2013). Since these attributes are critical centerpieces of human development, there can be significant temporary and enduring difficulties in cognitive processing following sports-related concussions (Sady 2011).

Concussive injury can cause a variety of neurochemical abnormalities. Both the physical and intellectual demands placed on athletes in a school environment can exacerbate the burden on the brain and may cause the concussive symptoms to re-emerge or worsen (Giza 2001). Thus, premature return-to-sport and return-to-academics after concussion may put student-athletes not only at greater risk for additional and more severe concussions, but also may cause persistent academic problems or even permanent learning disabilities (Guzkiewicz 2011). Hunt and Asplund (2010) emphasize the consequences of suffering a concussion from both academic and athletic perspective by asserting that the "effects of a concussion can have severe negative effects on athletes' scholastic abilities and can sometimes end a career."

Research indicates that history of concussion, especially multiple concussions, may affect academic progress of student-athletes (McGrath 2010). It has been reported that student-athletes aged 17 to 22 years old with multiple concussions may have lingering memory deficits that may result in academic problems (Iverson 2012). Beers et al. (1994) reported that students with history of concussion performed poorly on linguistically oriented psycho-educational tests. Moreover, concussed students showed cognitive deficits in visual-spatial skills and in the areas of attention, memory, and novel

problem solving (Beers 1994). In studies involving pediatric athletes, it appears that younger athletes take longer to recover from the cognitive injuries than older athletes (McCrory 2009; Meehan 2011). For example, Meehan cited a study demonstrating that the difference in recovery time between high school athletes and professional athletes was startling. Nearly 23% of high school athletes showed cognitive difficulties 3 weeks after the concussive injury, while only 1.6% of concussed NFL players took more than 14 days to recover (2011). This may be due to biomechanical differences between adults and children, such as the relative size of the head compared with the rest of the body, brain water content, vasculature, degree of myelination, and the shape of the skull (Meehan 2011). In addition, the longer recovery period may be due to brain development. Younger brains are designed for rapid learning and may suffer greater harm from a concussive injury than a more fully developed brain (Meehan 2011). Studies also suggest that early TBI may negatively affect the ability to learn cognitive skills later on, and the earlier the TBI, the more significant its impact on cognition (Meehan 2011).

Although the majority of scientific study has focused on developing guidelines for the safe return to the athletic field rather than the safe return to rigorous academics, the National Collegiate Athletic Association (NCAA) has created some guidelines for returning to academic work following a concussion. Among the recommendations that the NCAA has made are to approach return to school in a step-wise program that matches the needs of the unique concussed individual (NCAA 2013). Because recovery time from a concussion varies based on many factors, such as the severity of the concussion and the individual, recommendations are very general at this juncture in time. These guidelines

are based on the patient's tolerance for focused concentration and memory, rather than a standard and rigid set of parameters. The following recommendations provided are from NCAAs "Return-To-Learn" initiative:

- If the student-athlete cannot tolerate 30 minutes of light cognitive activity, he or she should remain at home or in the residence hall.
- Once the student-athlete can tolerate 30-45 minutes of cognitive activity without return of symptoms, he/she should return to the classroom in a step-wise manner. Such return should include no more than 30-45 minutes of cognitive activity at one time, followed by at least 15 minutes of rest.
- The levels of adjustment needed should be decided by a multi-disciplinary team that may include the team physician, athletic trainer, faculty athletic representative or other faculty representative, coach, individual teachers and psychologist. The level of multi-disciplinary involvement should be made on a case-by-case basis (NCAA 2013).

A recent report from the Coalition on Intercollegiate Athletics Subcommittee on Concussion specifically noted that: (a) "There is a notable absence of any unified system of concussion management"; (b) "…no formal return-to classroom protocol after concussion...this is an area that we believe should be of concern to faculty"; and (c) "overreliance on ImPACT technology" (adopted by NCAA as a primary concussion assessment tool) that is shown to lack the required specificity and sensitivity (COIA 2014). There have been some findings, although inconclusive, that preventative measures can be taken to limit the negative effects of a concussion. Research has led to the belief that antioxidant therapy could be used as a proactive measure to counteract the

production of free radicals and in turn avoid the potential for extensive damage of brain cells (Hunt & Asplund 2010). In animal studies involving physical, cognitive, and affective tests, Hunt and Asplund demonstrated that antioxidant therapies produce many beneficial and protective properties post-injury. To date, however, no human trial has successfully demonstrated efficacy (Hunt & Asplund 2010).

Chapter 3

Methods

Subjects

The subjects in this medical and academic review study consist exclusively of Pennsylvania State University student-athletes (n=26) who have been diagnosed with a concussion while enrolled at the university. Following approval by the Pennsylvania State University Institutional Review Board (IRB), each student-athlete voluntarily gave their informed consent to obtain information from both their medical records and academic record.

After giving consent for the objective information required for this study, the participants were asked to fill out a survey. This survey consisted of questions concerning the physical and emotional symptoms of the subjects, the time spent studying/completing classwork prior to and following the concussion, as well as the specific subject matter that provided biggest challenge for the subjects post-injury.

The subjects represented a range of Penn State University sports. There were 26 total subjects in the study. The subjects were active Penn State University Athletics members of fencing (1), gymnastics (6), rugby (8), soccer (5), swimming and diving (2), volleyball (3), and wrestling (1).

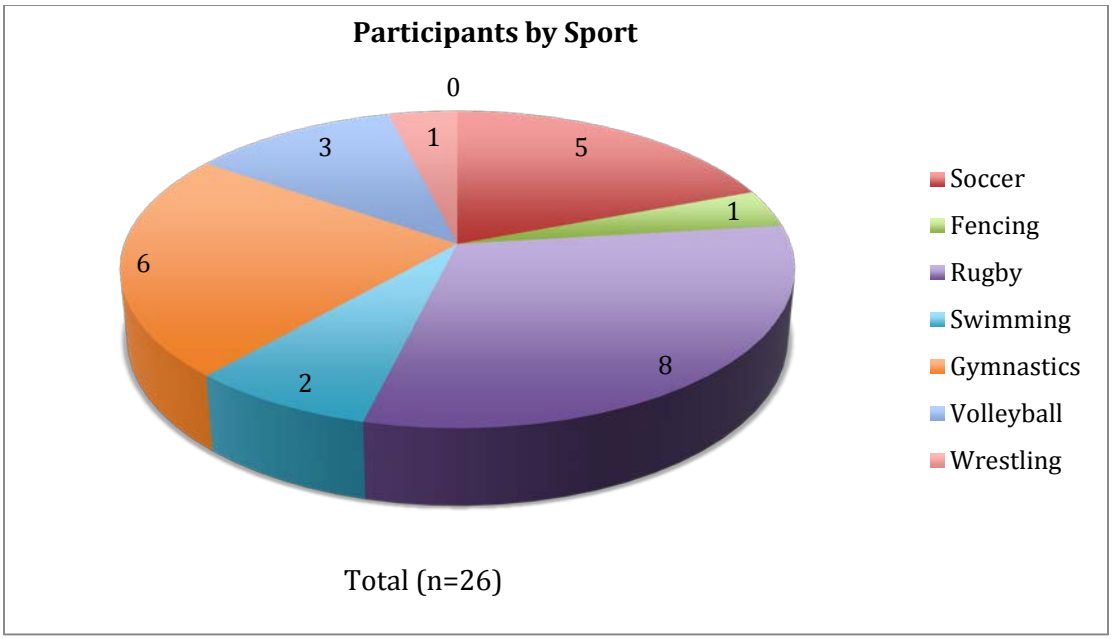

Figure 2: Participants by Sport

There were nearly an equal number of male and female subjects in the study. Twelve male subjects and 14 female subjects participated in the study.

Gender	Number of Subjects
Male	12
Female	14
Total	**26**

Table 1: Number of subjects based off gender

Experimental Procedure

Following approval by the Penn State IRB, the next step was athlete identification. At this point, Penn State student-athletes that had a concussion while attending Penn State University were identified using a variety of methods, including reviewing previous concussion lab participants, word of mouth, and speaking with known affected individuals. Once identified, the student-athlete participants were given

thorough explanations regarding the medical release and academic record release forms in which they voluntarily agreed to sign.

After an adequate number of participants was identified and consented, the medical record information was obtained from Penn State Hershey Medical Group on Benner Pike in State College, PA. A form was created to collect the necessary information. The form used a subject number and the two corresponding identifiers: the subject's names (the first identifier) and the subject's date of birth (the second identifier), and requested five data points. The data points included date of injury, symptoms reported during the injury, the length of time the symptoms lasted, how long it took the athlete to return to class, and the amount of time before the athlete began participating in their sport following injury.

Using the form, staff from the Penn State Hershey Medical Group gathered the available medical information for all 26 student-athletes. Not all of the data points were available for each participant. For example, for some participants, the symptoms resolved or they were released to return to classes or play before the next medical appointment, or they did not have a follow up appointment.

The next step was to obtain the student-athletes' academic information to determine whether the concussive brain injury affected academic performance. To obtain the academic information, a list of subject numbers and identifiers, along with the date the student-athletes suffered the brain injury was provided to the Director of the Morgan Academic Support Center for Student Athletes at the Pennsylvania State University. The Director provided the Grade Point Averages (GPA) for the student-athletes for the semester prior to the concussion, the semester the student-athlete suffered the concussion,

and the semester following their injury. All 26 participants had GPA data for the semester of the concussion. Post-concussion semester GPA data was available for 18 of the participants (Table 2).

After the medical and academic results were gathered, a final piece of subjective information was collected. An academic subject information form was sent out to all participants. This questionnaire sought subjective information regarding how the concussion affected the student-athlete's cognitive skills

Analysis

This study involved an examination of the academic performance of 26 Penn State student-athletes who have suffered concussions. The student-athletes' academic performance was measured by evaluating their pre-concussion, semester of injury, and post-concussion semester Grade Point Average (GPA) to determine if the subjects' academic performance decreased due to the concussion.

Chapter 4

Results

The study involved 26 Penn State student-athletes who suffered concussions while at Penn State. Using medical and academic records from the University and its affiliated sports medicine practice, the study compared the student-athletes' GPA for the semester prior to the concussion, with the semester concussed, and the semester following the concussion. The overall trend supported the hypothesis that the concussion negatively affected the student-athletes' GPA during the semester of the concussion, compared to the semester prior to the concussion (Table 4).

Of the 22 students whose academic records had GPA data for both the semester before the concussion and the semester of the concussion, 17 (77.3%) showed a reduction in their GPA in the semester of the concussion. Using a two-tailed t-test, the study indicated that the results were statistically significant with a p-value of 0.034, which confirmed the hypothesis. The differences in GPA ranged from an average prior semester GPA of 3.20 to an average concussed semester GPA of 2.95 (Table 3). This shows a decrease of 7.8%. The standard deviation for the prior semester GPAs was 0.394 with variance of 0.16; for the concussed semester GPAs, the standard deviation was 0.603 with variance of 0.36.

In the semester following the concussion, the average GPA was 3.10, showing a 4.8% rebound from the concussed semester, but still 3.1% less than the pre-concussion semester average GPA of 3.20. The standard deviation for the GPA in the semester following the concussion was 0.54 with variance of 0.29. Thus, the data showed a trend

that the concussion had a somewhat residual effect on the GPA in the semester following the concussion, but the results did not show statistical significance (Table 3).

In addition, the study also analyzed the physical, emotional, and cognitive effects reported in the student-athlete's medical records at the time of the concussion (Figure 5). Of those, headaches were the most commonly reported effect of the concussion. The student-athletes also reported perceived concussion symptoms as they related to their cognitive skills (Figure 4).

The subjects in this pilot study suffered concussive injuries during different semesters and points in their scholastic career. Subjects received their concussion from the first semester enrolled at Penn State to their ninth semester of enrollment.

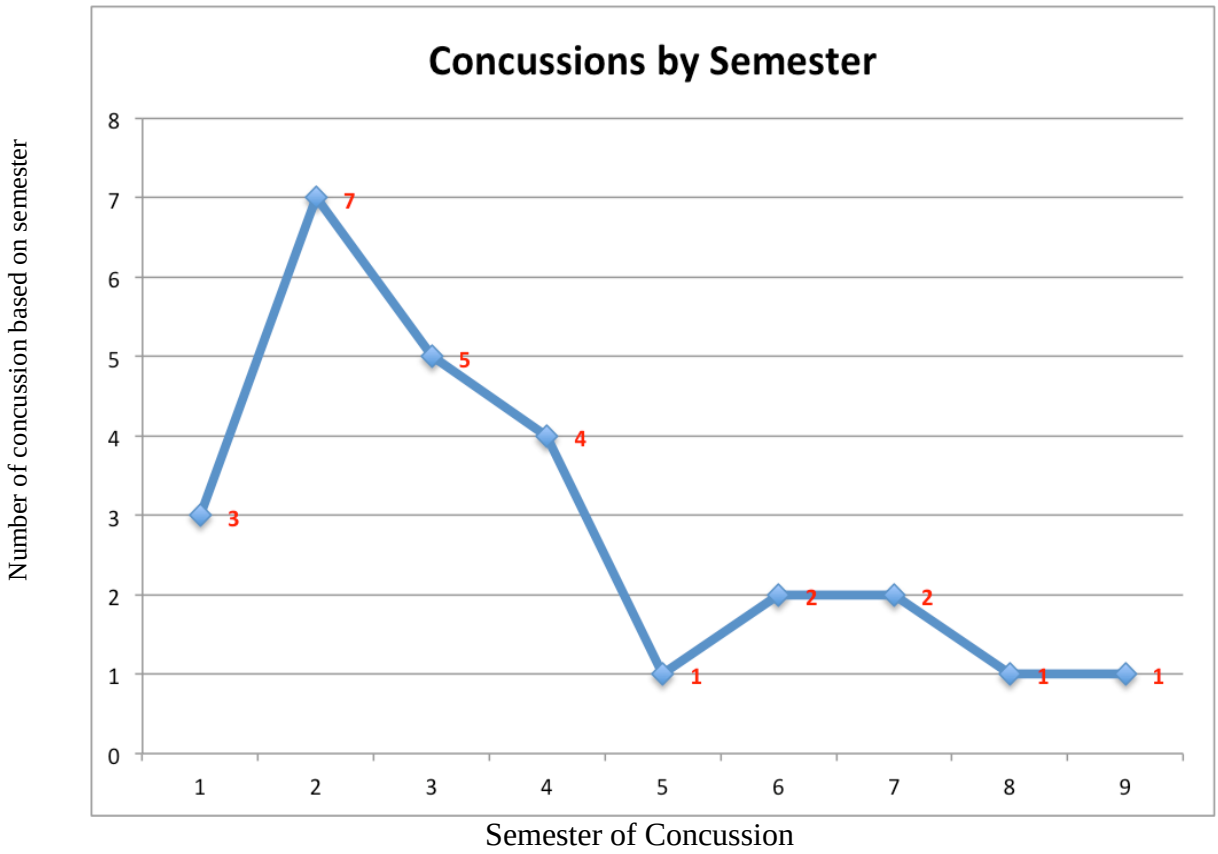

Figure 3: Number of concussions per semester of enrollment at Penn State

Figure 3 shows that a majority of the concussions suffered by the subjects occurred during the first four semesters (19) of participation in the sport compared to the last four or five semesters (7) enrolled as a student-athlete. The breakdown of concussions were three during the first semester, seven during the second semester, five during the third semester, four during the fourth semester, one during the fifth semester, two during both the sixth and seventh semester, and one in both the eighth and ninth semester of enrollment.

Subject Number	GPA (semester Prior)	GPA (semester Of)	GPA (semester After)
1	3.36	3.57	3.59
2	n/a	2.74	3.29
3	3.23	2.88	n/a
4	2.75	3.28	3.38
5	3.09	2.23	2.40
6	2.84	1.67	n/a
7	3.04	1.64	2.56
8	3.55	3.28	3.53
9	n/a	3.07	3.02
10	3.67	3.17	n/a
11	3.08	2.82	n/a
12	3.40	3.33	n/a
13	2.89	3.93	2.00
14	n/a	3.48	3.20
15	n/a	3.27	2.90
16	4.00	3.54	3.81
17	2.89	2.71	n/a
18	3.43	2.84	2.69
19	3.44	1.90	2.96
20	2.74	2.67	2.33
21	3.39	3.44	3.67
22	3.29	3.26	3.83
23	2.31	2.17	n/a
24	2.87	3.08	3.18
25	3.41	3.13	n/a
26	3.77	3.60	3.58

Table 2: Individual Grade Point Averages for each subject for the semester prior to concussion, the semester concussed and the semester following the concussion, with green representing an increased GPA, and red indicating a decreased GPA

Table 2, above, matches each subject with their respective GPA for the semester prior (when available), semester of, and semester after concussion (when available). The GPAs in green represent the GPA increasing from the previous semester, whereas the GPAs in red show the GPA decreasing from the subject's previous semester.

	Semester Prior	Semester of Concussion	Semester Following
Average Semester GPA	3.20	2.95	3.11
Standard Deviation	0.39	0.60	0.54
Variance	0.16	0.36	0.29

Table 3: Trends of each semester GPA, as well as the standard deviation and variance of each semester measured

Statistical analysis was performed for the student-athletes' average semester GPAs, as well as the corresponding standard deviations, and variance.

GPA (semester Prior)	GPA (semester of Concussion)
3.36	3.57
n/a	2.74
3.23	2.88
2.75	3.28
3.09	2.23
2.84	1.67
3.04	1.64
3.55	3.28
n/a	3.07
3.67	3.17
3.08	2.82
3.40	3.33
2.89	3.93
n/a	3.48
n/a	3.27
4.00	3.54
2.89	2.71
3.43	2.84
3.44	1.90
2.74	2.67
3.39	3.44
3.29	3.26
2.31	2.17
2.87	3.08
3.41	3.13
3.77	3.60
p-value = 0.034	

Table 4: 2-tailed t-test of GPAs from the semester before compared to semester of the concussion

Table 4 shows a 2-tailed t-test of GPAs from the semester before compared to semester of the concussion. This confirms statistical significance (p-value < 0.05). The statistically significant p-value of 0.03 supports the hypothesis that concussion negatively affects the student-athletes' GPA during the semester of the concussion, compared to the semester prior to the concussion.

GPA (semester of concussion)	GPA (semester after)
3.57	3.59
2.74	3.29
2.88	n/a
3.28	3.38
2.23	2.40
1.67	n/a
1.64	2.56
3.28	3.53
3.07	3.02
3.17	n/a
2.82	n/a
3.33	n/a
3.93	2.00
3.48	3.20
3.27	2.90
3.54	3.81
2.71	n/a
2.84	2.69
1.90	2.96
2.67	2.33
3.44	3.67
3.26	3.83
2.17	n/a
3.08	3.18
3.13	n/a
3.60	3.58
p-value = 0.688	

Table 5: 2 tailed t-test using the semester of concussion and semester after concussion

Table 5 shows 2 tailed t-test using the semester of concussion and semester after concussion, which yielded a p-value of 0.69. The study did not demonstrate statistical significance between the semester where the student-athlete was concussed and the semester following the concussion.

GPA (semester prior)	GPA (semester after)
3.36	3.59
n/a	3.29
3.23	n/a
2.75	3.38
3.09	2.40
2.84	n/a
3.04	2.56
3.55	3.53
n/a	3.02
3.67	n/a
3.08	n/a
3.40	n/a
2.89	2.00
n/a	3.20
n/a	2.90
4.00	3.81
2.89	n/a
3.43	2.69
3.44	2.96
2.74	2.33
3.39	3.67
3.29	3.83
2.31	n/a
2.87	3.18
3.41	n/a
3.77	3.58
p-value = 0.272	

Table 6: 2 tailed t-test was performed for the semester prior to the concussion and the semester after the concussion

Table 6 compared the GPAs for the semester before the concussion to the semester after the concussion to determine if there was a change in subjects' GPAs from before their concussion to after their concussion. A p-value of 0.27 determined that there was not a significant decrease in GPA from the semester before the concussion to the semester after the concussion.

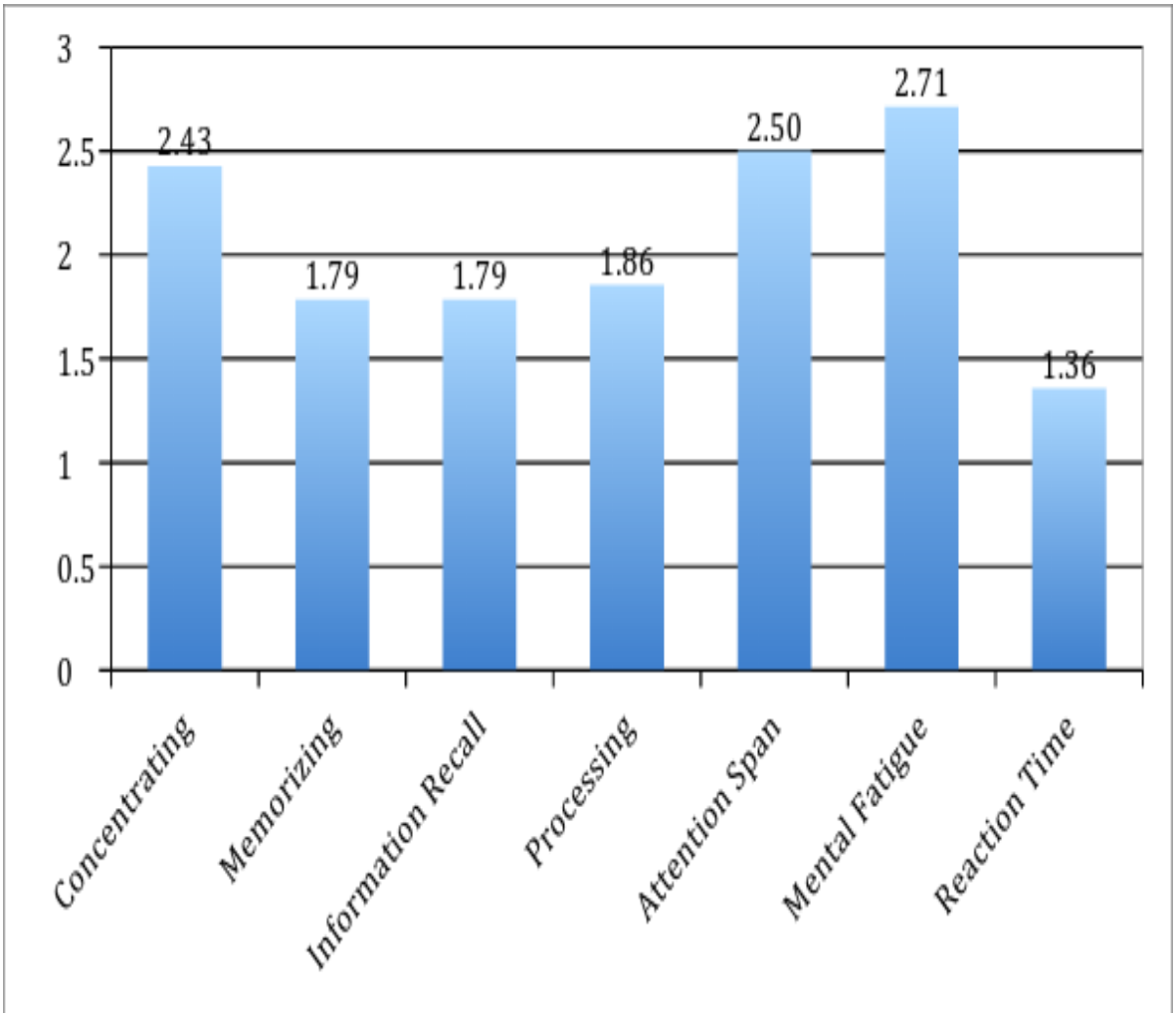

Figure 4: Mean values for key attributes affected by concussion

In Figure 4, the subjects self-reported and ranked the effect of the concussion on these attributes, using a 0-5 scale, with 0 being not affected at all and 5 being completely compromised.

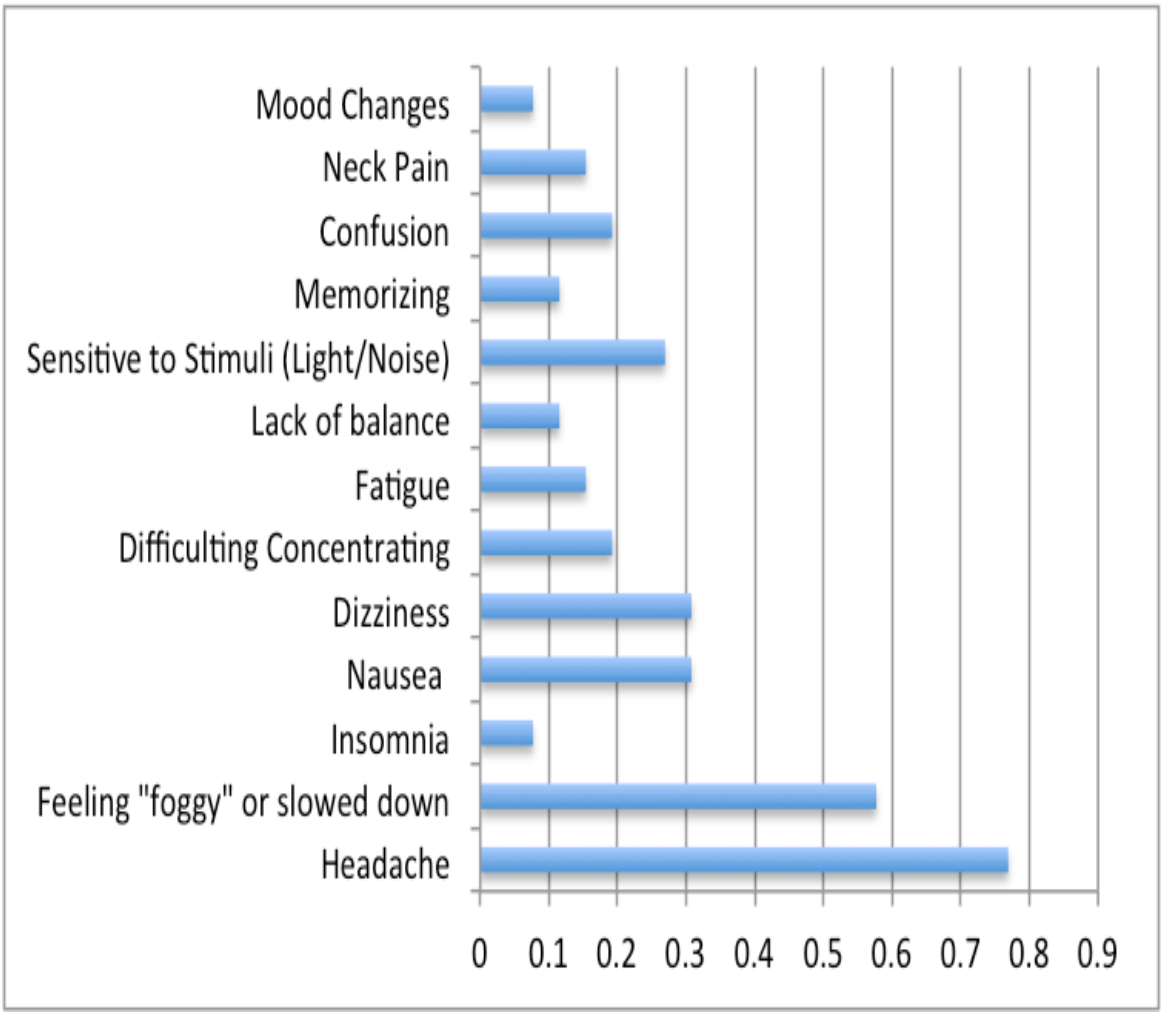

Figure 5: Frequency of symptoms reported at the time of injury

Using medical records, the study analyzed the types of symptoms reported by the student-athletes at the time of the injury.

Chapter 5

Discussion

This medical and academic review study consisted of twenty-six (26) Pennsylvania State University student-athletes from a variety of sports, each of whom suffered and were diagnosed with a concussive injury while attending the University. All 26 student-athletes gave their signed consent to obtain information in their medical records pertaining to their specific mTBI, as well as their academic records. From the medical records, data points were acquired, including the date of injury and the symptoms reported during the injury. When available in the medical record, data was also collected regarding the length of time the symptoms lasted, how long it took the athlete to return to class, and the amount of time before the athlete began participating in their sport following injury, however, the volume of this data was insufficient to measure for this study. After the medical records were obtained, the academic records were reviewed to obtain the student athlete's GPA for the semester prior to the injury, the semester of, and the semester following the concussion.

The purpose of this study was to examine concussive effects on a student's return to academic rigor, a topic that has not been widely studied. The overarching intent of this research was to determine if student-athletes' academic performance was negatively impacted by concussions, both in the short term (semester of concussion) and in the longer term (semester post-concussion). A secondary goal was to determine whether the concussion had a more pronounced impact on certain academic attributes (concentration, reaction time, mental fatigue, information recall, memory, and attention span) but insufficient data was available to perform this analysis.

It was my assertion that concussions and other mild traumatic brain injuries have a deleterious impact on academic progress and success. Due to the direct negative influence that concussions have on the student's ability to concentrate, memorize, and be attentive, I hypothesized that after suffering a concussion, a scholar-athlete's GPA would decline. In addition, I predicted that the focus, memory retention, and ability to pay attention, as reflected in the GPA, would be at their worst at the time of concussion, and would improve with time, but not reach pre-concussion levels.

The medical and academic review study format was chosen for its non-invasive nature, while still providing an abundance of insight into how a concussion affects academic progress and success. This study not only revealed significant findings in grade point averages from the unaffected prior semester to the affected concussed semester, but also dove deeper in trying to understand why grade point averages are affected by mTBI.

The statistically significant difference between the pre-mTBI semester and the semester during which the mTBI occurred (p-value of <0.03) suggests that the subjects suffered short-term cognitive impairment, such as that identified by Smayda (1999). A decrease (an average of 0.25 on a 4.0 scale) in GPA the semester of concussion when compared to GPA prior to concussion may seem rather inconsequential, if it is viewed as an isolated incident. However, the complexity of mTBI is not adequately reflected by these few numerical values. The data tended to show that the subjects' GPA rebounded in the semester following the injury, but not all the way back to pre-concussive levels, which raises the question as to whether the mTBI might have longer lasting effects than was observed in this study, or whether subsequent mTBIs have a greater or longer lasting impact on cognitive function. As Zemek noted, persistent postconcussive symptoms

(PCSs) can last more than 1 month following concussion, and can negatively impact school performance (2013).

In addition to the significant impact on academic performance, there are many more profound impacts from repetitive sub-concussive blows and mTBIs. It is well documented that sub-concussive and mTBI injuries can lead to Chronic Traumatic Encephalopathy, as shown in a study on NFL players (Breslow 2014). Multiple sub-concussive hits and concussions can have severe degenerative consequences and can lead to emotional hardships like depression, anger, anxiety, and aggression (McKee 2009). Student-athletes are usually allowed to return to full sport participation within 7-10 (when symptoms usually recede), but residual effects on return to academics are seen more than two times longer than the return to play timeline suggests (Master 2012). Thus, return to play must not equate to return to the classroom. This misconception, along with the evidence from this review study, indicates that physicians, coaches and schools should consider changing the approach to returning concussed students to the classroom until further analysis is completed.

It is not surprising that the test demonstrated statistical significance from the pre-concussion semester to the concussed semester, especially when this data is supported by the symptoms reported in the medical record. Approximately 75% of the subjects reported having headaches and nearly 60% complained of feeling “foggy” or slowed down. In addition, approximately 30% of the subjects indicated that the concussion left them feeling dizzy and nauseous (Figure 5). These symptoms are likely to interfere with the learning process, which could result in a lower GPA.

The subjects were also asked to self-report the effect of the concussion on such attributes as concentration, memorization, information recall, processing, attention span, mental fatigue, and reaction time. On a scale of 0 to 5, with 0 showing no effect and 5 being completely impaired, the subjects rated mental fatigue as the most affected attribute, with a mean score of 2.71, followed by attention span, with a mean score of 2.50 and concentration, with a mean score of 2.43. The subjects rated reaction time as the least affected attribute with a mean score of 1.36. For college students, particularly athletes, increased mental fatigue and impaired attention spans would be likely to negatively impact academic performance due to lack of stamina to attend to lecture or perform work. Moreover, student-athletes experiencing these cognitive changes may suffer a decrease in confidence of their academic abilities, which could cause a ripple effect for future semesters. If the symptoms persist, or are exacerbated by future mTBIs, this may prevent the student from reaching their full academic potential, which can affect the student's plans for graduate school or their professional careers. In other words, life after school can be gravely transformed due to mTBI.

There are a number of confounding variables which could have affected the results of the study and also explain some of the results. Participating in Division 1 athletics is both stressful and time consuming, two factors that could have a negative impact on academic success and GPA, regardless of the mTBI. While the study did not confirm whether the concussions occurred during the athlete's sport season, it is likely that the vast majority of concussions did, which might also explain the drop in the mean GPA score for the concussed semester. In addition, the difficulty of the coursework

inherently fluctuates each semester. Changes in difficulty might account for some of the individual scores decreasing, or increasing, from semester to semester.

Confounding variables, which might have affected the post-concussion GPAs could include the increased time spent studying following the concussion when sport participation may have been medically prohibited. Similarly, not being able to participate in the sport or other extra-curricular activities might have given the subjects more time and energy for schoolwork both during the time of concussion and after the concussive symptoms resolved. Interestingly, academic records for five subjects actually showed an increase in GPA during the semester of concussion, which was not anticipated.

Inherent weaknesses in this study are the paucity of subjects and the lack of a control group. Being a preliminary study, there were a limited number of subjects (n=26). Adding a control group would be important in future research to compare concussed athletes with student-athletes with no history of concussion. To be most accurate, it would be helpful to compare those who are in the same semester and have the same major as the concussed athletes.

Another limitation that arose was the number of concussions the subjects suffered, how they were spaced out over time, and how these variables could affect results. It is believed that up to 50% of concussions go unreported, and the effects of sub-concussive injury are still being studied (Harmon 2013). Given the prevalence of concussion in athletics, it is possible, and perhaps likely, that the subjects suffered more than one concussion. With a larger group of subjects, it may be possible to stratify those who are suffering their first reported concussion with those who have had multiple concussive injuries.

This study did not measure other variables such as whether the concussions occurred during the subjects' sport seasons; something that should be considered in future studies. Although the study included both male and female athletes, future studies might break out the results along gender lines, known as the gender effect. It might also be important to consider whether the concussion had a greater effect on certain types of courses or majors, such as those requiring verbal skills versus math skills. It would also be interesting to study the differences between concussed Division 1 athletes and students who are not participating in a varsity sport at the collegiate level. Further, results from this study could be compared to a separate study that measures the effects of concussion on the GPAs of college student-athletes, who have more developed brains, versus the still developing high school student-athletes who also suffered mTBI.

In the future, I plan to continue this research by comparing the academic records of 26 student-athletes without history of concussion to the 26 student-athletes who have been diagnosed with concussion. Separately, I would like to compare concussed athletes to concussed non- athletes, to rule out sport as a variable. Ultimately, additional studies should be used to develop guidelines for student and student-athlete's return to academic work following a concussion, so that the brain has sufficient time to recover before the student returns to academic rigor.

In conclusion, the study showed a statistically significant impact ($p=0.03$) on the student-athletes' GPA in the semester in which the athletes suffered a mild traumatic brain injury compared to the semester before the injury occurred. The average GPA decreased 7.8% or 0.25 on a 4.0 GPA scale in the concussed semester as compared to the prior semester. The data tended to show a slight lingering impact on the average GPA in

the semester following the concussion, but it was not statistically significant. This suggests the need to consider developing guidelines for a student-athlete's return to academics following a concussive injury, giving the brain time to heal before being subjected to a rigorous academic schedule. It must be understood that being cleared to return to sport participation does not equate to being cleared for academic resumption and student-athletes could suffer lasting impacts if this evidence is overlooked.

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WORK EXPERIENCE

Vietnam Medical Project **May-June 2015**

- Observed a gamut of medical pathologies and assisted in surgeries De Nang, VN

Concussion Labratory at The Pennsylvania State University **February 2014-2016**

- Laboratory Supervisor: Semyon Slobounov
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Shadowed at Mount Nittany Medical Center **June-August 2014**
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- Observed physicians for sixty hours with involvement in family medicine, sports medicine and surgery
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Penn State Men's and Women's Soccer Camp Counselor **Jan. 2012-Present**
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- Adapted teaching style of soccer fundamentals to varying age groups
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ACADEMIC:

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- Assist in medical work in Vietnam associated with lower extremity surgery

PanHellenic/IFC Penn State Dance Marathon (THON) **2012-Present**
State College, PA

- Raised over five-thousand dollars to help in the fight against Pediatric Cancer
- Participated as a THON Dancer entailing no sleeping or sitting for forty-six straight hours
- Dancer Relations Committee Member creating emotional and physical support to those THON weekend. Served as Volunteer Committee Chair
- Played a role in both Make-a-wish, Athlete Hour and Pep Rally to boost morale of those on the floor and in the stands

Mack Brady Memorial Soccer Clinic

- Provide free assistance open to public soccer community celebrating the life of Mack Brady, a young soccer player who lost his life.
- Raises over two hundred and fifty thousand dollars in scholarships each year

Special Olympics **2014-2015**

- Worked as a sports volunteer State College, PA
- Volunteered at the annual Beaver Stadium 5K Run/Walk