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Abstract

A controversial issue is whether TBI is a necessary precursor to the development of PTSD symptoms, or if the two variables are mutually exclusive. Recent rodent-models reveal that a stressful environment cannot cause PTSD symptoms directly without TBI, yet it is unknown if PTSD symptoms can develop following a TBI. This study provides a potential analogue to study this relationship by evaluating the effects of sports-related concussion. **Purpose:** This study investigated two questions, 1) Is there a significant difference in the frequency of PTSD symptoms reported by athletes at baseline (BL) testing and post-concussion (PC) testing over time? 2) Is there a significant difference in the frequency of PTSD symptoms in a more severely concussed and less severely concussed group of athletes in the acuity stage? **Method:** Athlete participants, both male and female, ages 17-28, were administered the ImPACT test, self-reported PTSD symptoms and levels of fear, stress, and anxiety in sports, at BL, PC1 (48-72 hours post-injury), PC2 (7-10 days) and PC3 (1-month). Non-concussed (n=365) and concussed (PC1 n= 98; PC2 n= 22; PC3 n=19) athletes were extracted from a pre-existing database. PTSD symptoms were evaluated across groups, and within individual athletes (n=37) post-injury. Groups of less severely concussed (n=23) and more severely concussed (n=27) athletes were evaluated at PC1. Athletes (n=45) self-reported the level of fear, stress, and anxiety that they experience in sports on a 7-point scale. **Results:** Multiple independent t-tests showed a statistically significant difference between PTSD symptoms at PC1 (M=1.58) and PC2 (M= 0.55) compared to the non-concussed (M= 0.18) group. At 1-month post-injury PTSD symptoms had decreased (M=0.37) showing no significant differences from BL. The same pattern of recovery was seen in a group of individual athletes (n=37). More severely concussed athletes reported more PTSD symptoms (M= 1.81) than the less severely concussed group (M= 0.96), with no significant difference. At BL, athletes experience anxiety (M=0.49), stress (M=0.93), and fear (M=0.49) at a minimal level (ratings of less than 1 out of 6). The major finding of this study is that concussed athletes report a statistically significant increase in PTSD symptoms following a sports-related concussion in the acuity stage, with a decrease in symptoms for 1-month post-concussion.

Keywords: mTBI, sports-related concussion, PTSD symptoms, ImPACT, severity, fear, stress, anxiety

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Chapter 1: Introduction

1.1 Rationale for Investigation

A current health issue is the reported increase in the diagnosis of Post-traumatic stress disorder (PTSD) in soldiers returning from Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF). The question that has been raised is whether mild traumatic brain injury (mTBI), also referred to as a concussion, can contribute to the development of PTSD symptoms. Several investigators have attempted to determine the relationship between mTBI and PTSD, as they are common diagnoses in OEF/OIF soldiers. Unfortunately separating the variables of stress, fear, and anxiety from TBI is problematic in this population due to the high levels of stress, fear, and anxiety in a war environment. A potential analogue to study the relationship between TBI and PTSD is sports-related concussion. The purpose of the present study is to investigate the contribution of mTBI in the development of PTSD symptoms in the absence of a heightened fearful environment, by using athletes as participants. Looking at sports-related concussion may provide insight into the relationship between mTBI and PTSD symptomatology.

1.2 Defining mTBI & Neurocognitive Testing

The United States Centers for Disease Control and Prevention (CDC) estimates that 1.6 to 3.8 million concussions occur in sports and recreational activities annually. However, these figures vastly underestimate the total TBI burden because many individuals suffering from mild or moderate TBI do not seek medical advice (Langlois, Rutland-Brown & Wald, 2006, 375-378). Another limiting factor is that a consensus definition of concussion has not been agreed upon, as shown in Table 1. Agreeing upon a consensus definition of concussion is a difficult task because loss of consciousness (LOC) and posttraumatic amnesia (PTA) were once sole identifiers of concussion. For instance, the definition proposed by the American Congress of Rehabilitation

Medicine includes associated diminished or altered state of LOC for less than 30 minutes and PTA, or memory disruption for less than 24 hours, and a Glasgow Coma Scale (GCS) score of 13 (Kay, Harrington, Adams, Anderson, Berrol, Cicerone, Dahlberg, Gerber, Goka, Harley, Hilt, Horn, Lehmkuhl & Malec, 1993).

However recent research has revealed that 90% of concussions result in no loss of consciousness (McCrea, 2008, 154) and suggests that LOC, amnesia, and confusion cannot identify or predict severity of a concussion (McCrea, 2008, 24). In this paper, concussion/mTBI is defined as, "a disturbance in brain function that occurs following either a blow to the head or as a result of the violent shaking of the head" (Immediate Post-Concussion Assessment and Cognitive Testing, 2014). For athletes, the injury can be sustained by a direct hit or jarring motion when hitting the ground. The injury may also occur from a pressure wave from close-range explosive blasts in soldier populations.

Functional recovery after mTBI follows a course similar to that of symptom and neuropsychological recovery. The overwhelming majority of mTBI patients return to normal independent, social, and to work, within a period of days to weeks after injury (patients with mTBI typically recover within 7-10 days). Similar to the studies on cognitive and symptoms recovery, non-injury-related factors often play a significant role in functional outcome. That is, mTBI patients with preexisting medical or psychological problems, high levels of psychosocial stress at time of injury, and poor social support systems after injury are potentially at risk of poorer functional outcomes associated with mTBI (McCrea, 2008, 132).

Table 1. Concussion defined within commonly used scales from Puga, 2011	
Scale Name	Definition
SCAT-Standardized Concussion Assessment Tool	Sports concussion is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces. Several common features that incorporate clinical, pathological, and biomechanical injury constructs that may be utilized in defining the nature of concussive head injury.
*ImPACT-Immediate Post Concussion Assessment and Cognitive Test	A concussion is a disturbance in brain function that occurs following either a blow to the head or as a result of the violent shaking of the head.
AAN- American Academy of Neurology	Concussion is a traumatic-induced alteration in mental status that may or may not involve loss of consciousness. Confusion and amnesia are the hallmarks of concussion.
GCS- Glasgow Coma Scale	Assessment of gross neurological status across three core areas of motor function, verbal reasoning, and the patient's ability to open the eyes voluntarily or in response to external commands and stimuli.
CDC-Heads Up Center for Disease Control and Prevention	Concussion is a type of traumatic brain injury or TBI, caused by a bump, blow, or jolt to the head that can change the way your brain normally works. Concussions can also occur from a fall or a blow to the body that causes the head and brain to move quickly back and forth.
SAC-Standardized Assessment of Concussion	Concussion is a trauma-induced alteration in mental status that may or may not involve loss of consciousness. Confusion and amnesia are the hallmarks of concussion.
UIL-University Interscholastic League	Traumatic brain injury occurs when an outside force impacts the head hard enough to cause the brain to move within the skull or if the force causes the skull to break and directly hurts the brain.

The Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) is a computerized neuropsychological screening battery designed specifically for assessing sport-related concussion. The ImPACT consists of six individual test modules that measure aspects of cognitive functioning including attention, memory, reaction time, impulse control and processing speed (Iverson, Lovell & Collins, 2003, 461). The sixth module is the Post-Concussion Symptom Scale developed by Pardini (2004) which consists of 21 commonly reported symptoms grouped

into four symptom clusters (See Table 2). The dependent measure is the total score derived from this 21- item symptom scale. The ImPACT is a reliable battery that was used as a primary assessment tool in this study.

Table 2. Post-Concussion Symptom Scale, grouped into four symptom clusters from Lau et al., 2012

Concussion Symptom Clusters:	
Migraine	Headaches, Visual Problems, Dizziness, Noise/Light Sensitivity, Nausea/Vomiting, Balance Problems, Numbness/Tingling
Cognitive	Fatigue, Fogginess/Drowsiness, Difficulty Concentrating/Remembering, Cognitive slowing
Sleep	Difficulty falling asleep, sleeping less than usual, sleeping more than usual
Neuropsychiatric	More emotional, sadness, nervousness, irritability

1.3 Defining PTSD

According to the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (DSM-V), diagnostic criteria for PTSD include a history of exposure to a traumatic event that results in symptoms from four symptom clusters: intrusion, avoidance, negative alterations in cognition/mood, and alterations in arousal/reactivity. Other factors include duration of symptoms, the individual's functioning, and ruling out a substance or co-occurring medical condition. The specifications of delayed expression and a dissociative subtype of PTSD are also noted. If a person meets DSM-V criteria after 1-month post event, PTSD is diagnosed. Symptom onset typically occurs in the first 24 hours for most people. Clinicians should be

cautious in diagnosing PTSD in a person who has sustained an mTBI if that person does not exhibit prominent symptoms in the initial days post-injury (North, Nixon, Shariat, Mallonee, McMillen, Spitznagel & Smith, 1999, 755-762).

Table 3. PTSD Criteria from American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (2013)

Criterion A: Stressor	The person was exposed to: death, threatened death, actual or threatened serious injury, or actual or threatened sexual violence, as follows: **(one required)**: Direct exposure; Witnessing, in person; Indirectly, by learning that a close relative or close friend was exposed to trauma. If the event involved actual or threatened death, it must have been violent or accidental; Repeated or extreme indirect exposure to aversive details of the event(s), usually in the course of professional duties (e.g., first responders, collecting body parts; professionals repeatedly exposed to details of child abuse). This does not include indirect non-professional exposure through electronic media, television, movies, or pictures.
Criterion B: Intrusion symptoms	The traumatic event is persistently re-experienced in the following way(s): **(one required)** Recurrent, involuntary, and intrusive memories. Traumatic nightmares. Dissociative reactions (e.g., flashbacks) which may occur on a continuum from brief episodes to complete loss of consciousness. Intense or prolonged distress after exposure to traumatic reminders. Marked physiologic reactivity after exposure to trauma-related stimuli.
Criterion C: Avoidance	Persistent effortful avoidance of distressing trauma-related stimuli after the event: **(one required):** Trauma-related thoughts or feelings. Trauma-related external reminders (e.g., people, places, conversations, activities, objects, or situations).
Criterion D: Negative Alterations in cognitions and mood	Negative alterations in cognitions and mood that began or worsened after the traumatic event: **(two required)** Inability to recall key features of the traumatic event (usually dissociative amnesia; not due to head injury, alcohol, or drugs). Persistent (and often distorted) negative beliefs and expectations about oneself or the world (e.g., "I am bad," "The world is completely dangerous"). Persistent distorted blame of self or others for causing the traumatic event or for resulting consequences. Persistent negative trauma-related emotions (e.g., fear, horror, anger, guilt, or shame). Markedly diminished interest in (pre-traumatic) significant activities. Feeling alienated from others (e.g., detachment or estrangement). Constricted affect: persistent inability to

	experience positive emotions.
Criterion E: Alterations in arousal and reactivity	Trauma-related alterations in arousal and reactivity that began or worsened after the traumatic event: **(two required).** Irritable or aggressive behavior. Self-destructive or reckless behavior. Hypervigilance. Exaggerated startle response. Problems in concentration. Sleep disturbance.
Criterion F: Duration	Persistence of symptoms (in Criteria B, C, D, and E) for more than one month
Criterion G: Functional	Significant symptom-related distress of functional impairment (e.g.,

Specify if: With dissociative symptoms.

In addition to meeting criteria for diagnosis, an individual experiences high levels of either of the following in reaction to trauma-related stimuli:

Depersonalization: experience of being an outside observer of or detached from oneself (e.g., feeling as if "this is not happening to me" or one were in a dream).

Derealization: experience of unreality, distance, or distortion (e.g., "things are not real").

Specify if: With delayed expression.

Full diagnosis is not met for at least six months after the trauma(s), although onset of symptoms may occur immediately.

It is crucial to keep in mind that the investigators in this study do not diagnose PTSD; rather we are investigating athletes' self-reported PTSD symptoms. The DSM-V PTSD diagnostic criteria are listed in Table 3 to demonstrate the complexity of PTSD, and how symptoms of the disorder overlap with mTBI symptoms. If compared to Table 2, one can see how the symptoms of PTSD and mTBI overlap in the areas of concentration, increased arousal, irritability, re-experiencing the event and avoidance of the harmful event.

Table 4. PTSD Symptom Clusters from American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders (2000).

PTSD SYMPTOM CLUSTERS	**SPECIFIC SYMPTOMS**
Traumatic event is persistently re-experienced	(a) Intrusive and distressing recollections of the event including visual images, thoughts, or perceptions; (b) distressing dreams (nightmares), (c) acting or feeling as if the traumatic event was happening again (e.g., dissociative flashbacks); (d) intense psychological distress when exposed to things (e.g., thoughts or external visual reminders) that symbolize or resemble an aspect of the traumatic event
Persistent avoidance of things associated with the event and a numbing of general responsiveness	(a) avoiding thoughts, feelings, or conversations associated with the event; (b) avoiding activities, places, or people that stimulate thoughts of memories of the event; (c) feeling detached or estranged from others; or (d) having a sense of foreshortened future (e.g., not expecting to have a career, marriage, children, or a normal life span)
Increased arousal	(a) difficulty falling or staying asleep; (b) irritability or outbursts of anger; (c) difficulty concentrating; (d) hypervigilance; and (e) an exaggerated startle response

The National Co-morbidity Survey (NCS) report states that based on the general adult population, the estimated lifetime prevalence of PTSD among adult Americans is 7.8 percent, with women (10.4 percent) twice as likely as men (5 percent) to have PTSD at some point in their lives. This represents a small proportion of those who have experienced a traumatic event at some point in their lives. In the general adult population in the United States, 60.7 percent of men and 51.2 percent of women reported experiencing at least one traumatic event. These

statistics show that a traumatic, stressful event does not always lead to PTSD, for the percentage of people who have experienced a traumatic event is much higher than the actual prevalence of Americans with PTSD. The most frequently experienced traumas listed in the NCS report were: witnessing someone being badly injured or killed; being involved in a fire, flood or natural disaster; being involved in a life-threatening accident; combat exposure. The majority of this population had experienced two or more traumatic events; more than 10 percent of males and 6 percent of females reported four or more types of trauma during their lifetimes.

The types of trauma that were most associated with PTSD in men were rape, exposure to combat, neglect, and physical abuse during childhood years. For women, the most associated events with PTSD were rape, sexual molestation, a physical attack, abuse during the childhood years, and being threatened with a weapon. The NCS report explains that, none of these events invariably produced PTSD in those exposed to it, and a particular type of traumatic event does not necessarily affect different sectors of the population in the same way. The NCS report concluded, "PTSD is a highly prevalent lifetime disorder that often persists for years…and many report the occurrence of quite a few such events during their lifetimes."

1.3.1 Cognitive Theories of PTSD Manifestation

The literature provides three cognitive accounts of PTSD development. The first postulates that the traumatic experience is represented by storing information about what is threatening and what should be escaped or avoided. This theory proposes that the fearful information about the trauma results in intrusive recollections of the event, which in turn causes physiological reactions (Chemtob, Roitblat, Hamada, Carlson & Twentyman, 1988; Creamer, Burgess & Pattiston, 1992; Foa & Kozak, 1986). The second, principled by social-cognitive theorists, emphasizes the wider meaning of the trauma. The intrusive images and nightmares are said to result from the incompatibility between information previously stored in memory (e.g. the world is meaningful; personal vulnerability; viewing the self as worthy and positive)

and the new information provided by the trauma. The inadequately or partially integrated memories are thought to result in PTSD (Harvey, Brewin, Jones & Kopelman, 2003, 664). The dual representation theory of PTSD was proposed by Brewin (2001; Brewin & Joseph, 1996). According to this theory, many of the features and details of some traumatic event (e.g. the sounds, smells, and sights) are initially retained in episodic memory. Individuals then experience intrusive images and flashbacks, which are hallmarks of PTSD. A meta-analysis conducted by Ozer, Best, Lipsey, and Weiss (2003) showed that dissociation shortly after the traumatic event, called peritraumatic dissociation, was highly predictive of subsequent PTSD. Factors before or months after the traumatic episode were not as predictive of PTSD.

1.4 Similarities Between mTBI and PTSD Symptoms

Information about concussion mainly comes from studies within the civilian sector, such as sports-related concussion (McCrea, 2008; McCrea, 2005). Most civilians who sustain mTBI recover completely by 1-week to 3-months after injury (Binder, Rholing &Larrabee, 1997; Belanger & Vanderploeg, 2005; Iverson; 2005), with one to five percent complaining of persistent post-concussive symptoms (PCSs) months or years after injury (McCrea, 2008). This minority expresses a variety of physical (e.g. headache, tinnitus), emotional (e.g. irritability), or cognitive symptoms (e.g. diminished concentration or memory ability) that are directly attributed to the previous concussion (Ruff, 2007). However, PCSs are highly nonspecific. Researchers have shown that PCSs are frequent among healthy adults and clinical groups without a history of concussion (Paniak, Reynolds, Phillips, Toller-Lobe, Melnyk, & Nagy, 2002; Iverson & Lange, 2003). PCSs significantly overlap with depression, PTSD, and chronic pain (McCrea, 2008).

Individuals with PTSD often report the same symptoms as patients who have sustained mTBIs. Schneiderman et al. (2008) surveyed over 2200 post-deployment veterans and reported that the most commonly occurring symptoms in both concussion and PTSD were sleep disruptions and increased irritability. Hoge, Goldberg and Castro (2009) suggested that the symptoms post-injury may be related to acute stress, sleep deprivation, or other injuries, and

indicated that the symptoms attributed to mTBI deficits may be more closely related to PTSD or depression. In a sample of 128 patients with PTSD, 89 percent reported irritability, 56 percent reported memory problems, 92 percent reported concentration problems, and 90 percent reported difficulty sleeping, (Foa, Cashman, Jaycox & Perry, 1997, 445-451) which all overlap with symptoms post-concussion**.**

1.5 The Paradox of PTSD and mTBI Coexistence

The controversial issue is whether a person who sustains a TBI develops PTSD symptoms, or if TBI and PTSD symptoms are mutually exclusive. There are several reasons to suggest that PTSD suffered after mTBI may not be identical to these conditions when they occur in the absence of TBI (Bryant & Harvey, 1999, 16). In patients with mTBI they could have LOC, organic damage, and post-concussive symptoms such as irritability, concentration deficits, agitation, and insomnia (Alexander, 1995). The post-concussive symptoms described are hallmarks of PTSD, as well. Gil, Caspi,, Zilberman Ben-Ari, Koren, & Klein (2005) explain that traumatic events involving TBI have a reduced prevalence of PTSD since amnesia of the traumatic event may play a protective role (Mayou, Bryant & Duthie, 1993; Sbordone, & Liter, 1995). Other studies have shown that PTSD is prevalent among patients with TBI, supporting the view that TBI and PTSD are not mutually exclusive (Bryant, & Harvey, 1998; Ohry, Rattok, & Solomon, 1996).

Klein, Caspi & Gil (2003) presented a critical review of the literature assessing the relationship between TBI and PTSD with memory of the traumatic event as a critical factor. A significant proportion of the studies indicate that PTSD and TBI are mutually exclusive, especially when there is no memory of the traumatic event. Yet none of these studies carefully addressed memory for the traumatic event as an important variable that differentiates people with TBI, nor adequately addressed the degree to which victims of TBI actually remember the

traumatic event (Klein et al., 2003, 30-31). Other studies show that PTSD occurs in patients with head injury, suggesting that PTSD may develop in TBI survivors, even in those who cannot remember the traumatic event (Klein, Caspi & Gil, 2003, 28). The issue is inconclusive.

Gil et al. (2005) provided a well-controlled study to directly assess the relationship between explicit memory of the traumatic event and subsequent development of PTSD in participants who had experienced a traumatic event associated with TBI. The authors' goal was to investigate if not remembering the event is a protective factor against subsequent PTSD. Participants included 120 accident victims who had an mTBI and who were hospitalized right after their trauma. The patients were evaluated for PTSD at 24 hours post-injury, 1-week, 3-months, and 6-months. Overall, 14 percent of the mTBI participants met full criteria for PTSD at six months. Subjects with memory of the traumatic event were significantly more likely to develop PTSD than those without memory of the traumatic event. At-risk variables included having a prior psychiatric disorder, memory of the traumatic event, and development of major symptoms within the first 24 hours or 1-week post injury. A portion of persons with mTBI developed PTSD and met criteria 6-months post-injury (Gil et al., 2005, 963-967). The exclusion criteria in the present study, was developed based on the risk factors indicated by Gil et al, 2005.

The evidence to support the argument that lack of lack of memory of the trauma leads to reduced LOC and PTA, recent research shows that LOC and PTA are not necessary to diagnose mTBI. According to McCrea (2008), "fewer and fewer mild and moderate TBI patients are hospitalized, with more triaged in the emergency department or treated in ambulatory/outpatient settings, so the true incidence of all severity TBI is severely underestimated" (p. 3). Individuals who do not experience LOC or PTA after an mTBI rarely seek medical attention and for this reason the prevalence of mTBI is drastically underestimated (McCrea, 2008, 4).

Epidemiological studies show that traumatic events, or repeated stress, can result in PTSD, a chronic condition, (Woon, Sood, Hedges, 2010) although not all individuals exposed to traumatic events develop PTSD (Gross and Hen, 2004). Despite the claims that LOC at the time of trauma impedes encoding of the traumatic event, there is increasing evidence that PTSD is a prevalent problem after mTBI (Bryant & Harvey, 1999, 16). Well-controlled studies indicate that the incidence of PTSD after mTBI is between 17 and 33 percent in hospitalized patients (Bryant & Harvey, 1998; Ohry et al., 1996; Rattock & Rose, 1993, 243).

Bryant and Harvey (1999) have put forth a rationale for how PTSD could emerge in a patient with a brain injury. Their study compared PTSD symptom profiles in motor vehicle accident (MVA) survivors who sustained an mTBI (n=79) or no TBI (n= 92). The adult patients were assessed within 1-month of their trauma and were reassessed at 6-months for PTSD. Results showed that the mTBI group had more post-concussive symptoms than did the non-TBI group. The mTBI group reported fewer intrusive memories, fear, and helplessness in response to the trauma compared to the non-TBI patients in the acute phase and at 6-months post-trauma. These findings suggest that, whereas impaired consciousness at the time of the trauma may reduce the frequency of traumatic memories in the initial month, mTBI does not result in a different profile of longer-term PTSD (Bryant & Harvey, 1999, 15). Overall, we know that in MVA patients there is a positive correlation of post-concussion symptoms and PTSD symptoms (Bryant et al., 1999). The investigators also found that other psychiatric disorders such as depression can amplify post-concussive symptoms after an mTBI and complicate recovery, which is consistent with the reports previously described by Gil et al., 2005.

More recently, Brandes, Ben-Schachar, G., Gilboa, A., Bonne, O., Freedman, S., & Shalev, A.Y (2002), stated that “the association between cognitive impairment and early PTSD

symptoms is unknown, yet such association may lead to poorer processing of traumatic memories and thereby contribute to subsequent PTSD" (p. 1). Their study evaluated the relationship between PTSD symptoms and cognitive functioning within 10 days of traumatic events within a group of 48 recent trauma survivors. The results suggest that lower IQ and impaired attention are associated with early PTSD and depressive symptoms, and poorer attention may have a role in shaping traumatic memories.

1.6 Overview of Physiological Processes

TBI involves rotational and acceleration-deceleration forces that put the brain in motion. These forces may result in intra-axonal changes leading to disconnection, deafferentation and loss of synaptic boutons (Blumbergs, Scott, Manavic, Wainwright, Simpson & McLean, 1995; Povlishock & Christman, 1995). Parts of the limbic system are susceptible to damage in TBI. If during a traumatic event, limbic structures are damaged, which are important in regulating emotion and memory, (LeDoux, 1999), the individual may be more susceptible to subsequent PTSD. Brewin (2001) highlights that the hippocampus is important in the extinction of conditioned. An individual with a damaged hippocampus might exhibit persistently excessive fear responses to general trauma-related cues (a definitive characteristic of PTSD) (Harvey et al., 2003, 666). This issue was further investigated in recent literature using rodent-models, as described next.

1.7 Differentiating the Effects of Stress and TBI Using Rodent-Models

Two groups of investigators have studied rodent-models in the past few years to determine the relationship between the variables of fear, stress, and anxiety and TBI. In the first study, Kwon, Kovesdi, Gyorgy, Wingo, Kamnaksh, Walker, Long & Agoston (2011) explain that psychological stress and brain injury can both lead to lasting neurobehavioral abnormalities.

PTSD and blast-induced traumatic brain injury (bTBI) have become the most significant health issues in current military conflicts. It is important to note that military bTBI occurs in stressful environments that place the brain in a heightened state of fear. Blast injury occurs when individuals are in close proximity to explosive devices, and therefore, result in neurocognitive and memory impairment, mood disorders, and attention deficits.

The purpose of the study by Kwon et al. (2011) was to use a rodent-model to determine long-term consequences of stress with and without the exposure to blast. In their experiment, the authors assessed anxiety and spatial memory of rats at different points in time after repeated exposure to stress alone or in combination with a single mild blast. The dependent variables included locomotor activity, anxiety, spatial learning, and memory. These variables were used to measure differences in stressed-injured rodents (SI), and stressed (blast) sham injured (SS) rodents, as compared to a control group (C).

When evaluating locomotor activity 24 hours after exposure to a blast, the SI group spent significantly more time in the periphery and significantly less time in the center, compared to C and SS animals. Then, 4 hours after the blast (or sham) injury, the SI rats traveled significantly shorter distances than C animals. SI animals exhibited raised anxiety by spending less time in the open arms and more time in the closed arms. A Barnes maze (BM), which is a maze in which the rodent is placed and is trained to locate the escape chamber, was used to measure spatial learning and memory. At baseline (BL), all rodents had no latency responses in trying to find the escape chamber. The results showed that the SI rats performed very poorly on day 64. Deficits included increased latency times similar to those measured in the first BM session, indicating lasting memory impairment caused by the blast. On all of these previously mentioned measured of behavioral effects, no significant differences were seen between the SS and C behaviors.

When rodents in this study were exposed to stress only, the rodents displayed an increase in anxiety with no cellular or molecular abnormalities. When rodents were exposed to repeated stress with blast, lasting behavioral, molecular, and cellular abnormalities (characterized by memory impairment, neuronal and glial cell loss, inflammation, and gliosis) were observed (Kwon et al, 2011, 5). In the rodent-model, a stressful environment cannot cause PTSD symptoms alone without TBI (Kwon et al., 2011, 1).

Due to the experimental setup in the Kwon et al. (2011) study they were unable to determine the effect of blast injury alone because handling and transporting the rodents resulted in a significant amount of stress. In the present study we attempt to control for this limitation and assess the impact of TBI on PTSD symptom development directly in athletes, based on an environment with limited anxiety/stress.

In the following year, Reger, Poulos, Buen, Giza, Hovda & Fanselow (2012), presented a different rodent-model of mTBI induced PTSD-like symptoms. Reger et al. (2012) explain that there is a high correlation between diagnoses of mTBI and PTSD. The current increase in soldiers exposed to active combat has generated further interest in this dual diagnosis as a public health problem (Tanielian & Jaycox, 2008; Kennedy et al., 2007; Hoge et al., 2008). There has been controversy surrounding this co-morbidity. Symptoms of mTBI may be subtle and largely transient, which have led some to argue that patients' lasting symptoms stem from PTSD alone (Hoge et al., 2008). The simple rodent model developed in this study addresses these clinical questions by showing that PTSD symptoms can be modeled with Pavlovian fear conditioning acutely after mTBI (Reger et al., 2012, 2).

In their study, rats were trained with one of the five fear-conditioning procedures (n = 105) two days after concussive brain trauma. Fear learning was assessed over subsequent days

and chronic changes in fear learning and memory circuitry were assessed by measuring *N*-methyl-D-aspartate (NMDA) receptor subunits and GAD-67 protein levels in the hippocampus and basolateral amygdala complex (BLA) (Reger et al., 2012, 1). The injured rats exhibited an overall increase in fear conditioning and appeared to over generalize learned fear to both conditioned and novel stimuli. The injury resulted in a significant upregulation of excitatory NMDA receptors in the BLA, and decreased GABA related inhibition (GAD-67) in the BLA and hippocampus. Similar to PTSD, a disorder that produces exaggerated fear conditioning, this data suggests that concussion can produce a state whereby fear conditioning is enhanced in stressful situations (Reger et al., 2012, 7).

Reger et al. (2012) concluded that mTBI predisposes the brain toward heightened fear learning during stressful post-injury events and provides a potential molecular mechanism by which this occurs. This data represents a novel rodent-model that can help advance the neurobiological and therapeutic understanding of the co-morbidity of PTSD and TBI. Since mTBI results in cognitive and emotional dysfunction, these injuries are a significant risk factor for the development of anxiety disorders, including PTSD. However, because physically traumatic events typically occur in a highly emotional context, it is unknown whether TBI itself is a cause of augmented fear and anxiety (Reger et al., 2012).

The rodent-models described have found that TBI increases fear conditioning, predisposes the brain toward heightened fear learning during stressful post-injury events, and is a significant risk factor for the development of anxiety disorders.

1.8 Effects of Blast Injury in Relation to PTSD

Nearly two million troops have been deployed to Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) since 2001. Due to high levels of combat exposure, there has

been increased risk of blast injury and post-deployment mental and physical health problems (Hoge, Castro, McGurk, Cotting, & Koffman, 2004; Vasterling, Verfaellie, &Sullivan, 2009; Hoge et al., 2008). Due to exposure to improvised explosive devices (IED), TBI has been described as a "signature injury" of OEF/OIF (DePalma, Burris, Champion, & Hodgson, 2005, 1335).

The incidence of mTBI sustained in current conflicts is unclear, in part because of varying screening strategies (Iverson, Langlois, McCrea, & Kelly, 2009, 1299). Initial estimates suggest that 11 to 22 percent of OEF/OIF soldiers may sustain mTBI during their service (Hoge et al., 2008; Terrio, Brenner, Ivins, Cho, Helmich, Schwab, Scally, Bretthauer & Warden, 2009). Rates of combat-related PTSD among returning OEF/OIF veterans has also been a concern. Consistent with estimates from previous conflicts (Dohrenwend, Turner, Turse, Adams, Koenen & Marshall, 2007), the prevalence of PTSD among soldiers deployed to OEF/OIF ranges from 10 to 17 percent (Sundin, Fear, Iversen, Rona, & Wessley, 2010).

Polusny, Kehle, Nelson, Erbes, Arbisi, & Thuras (2011) investigated the relationship between mTBI, PTSD, and post-deployment health outcomes by determining if PTSD is a mediating or confounding variable. Mediation implies a temporal sequence from the risk factor (mTBI) to the dependent variable (postdeployment health outcomes) via a mediating variable (PTSD). Confounding implies that the relationship between the risk factor (mTBI) and the dependent variable (post-deplyoment health outcomes) is non-causal and results from the causal variable (PTSD) (Polusny et al., 2011, 80).

The objective of their study was to assess longitudinal associations between mTBI and PTSD symptoms reported in theater and long-term psychosocial outcomes in combat-deployed National Guard soldiers (n=953) (Polusny et al., 2011, 79). Participants were surveyed for mTBI

and PTSD in Iraq 1-month before returning home (time 1) and 1-year later (time 2). The results showed that the rate of self-reported mTBI during deployment was 9.2 percent at time 1 and 22 percent at time 2. Time 1 PTSD symptoms more strongly predicted post-deployment symptoms and outcomes than did mTBI history. Therefore, although PTSD was strongly associated with post-concussive symptoms and psychosocial outcomes at 1-year post-deployment, once PTSD was accounted for mTBI history did not have a long-term impact (Polusny et al., 2011, 79).

Swick, Honzel, Larsen, Ashley & Justus (2012) performed a study in which a key cognitive control function, inhibition performance, was examined in correlation with severity of PTSD symptoms to determine a specific correlation between severity of concussion and PTSD symptoms. Veterans with a diagnosis of PTSD (n=40) and age-matched control veterans (n=33) self-reported PTSD and depressive symptoms on questionnaires. The results showed that PTSD patients showed a significant deficit in response inhabitation, and higher levels of PTSD and depressive symptoms were associated with higher error rates; re-experiencing was the strongest predictor of performance. Swick et al. (2012) claim that, additional studies are needed to verify that these findings are independent of mTBI, since the variables of mTBI and fear, stress, anxiety during the traumatic event overlap in a war environment. A limitation of this study is that TBI never occurs without exposure to psychological stress in soldiers so it is difficult to know how the variables of stress and TBI affected one another.

A recent study by Cifu, Taylor, Carne, Bidelspach, Sayer, Scholten & Campbell (2013), determined the prevalence of TBI, PTSD, and pain (head, neck, back) in veterans from Operation OIF/OEF and Operation New Dawn (OND) using ICD-9 codes. Veterans who received any inpatient or outpatient care from Veterans Health Administration (VHA) facilities from 2009 to 2011 at least once were included as participants. The results indicated that in any 1-year TBI

prevalence was 7 percent, when data was pooled from 3-years TBI diagnoses increased to 9.6 percent. PTSD prevalence was 29.3 percent, and 40.2 percent were diagnosed with pain. Six percent of individuals were diagnosed with all three (Cifu et al., 2013, 1169). The results showed that increasing numbers (over 40%) of veterans from OIF/OEF/OND accessed VHA from 2009 to 2011. Among those with a TBI diagnosis, the majority also had a mental health disorder, with approximately 50 percent having both PTSD and pain.

Exposure to mild blast poses especially difficult challenges because the immediate symptoms are not life-threatening but 6-9 months later soldiers develop memory impairment, anxiety, and mood disorders (Belanger, Vanderploeg, Curtiss & Warden, 2007, 5; Brenner, Vanderploeg & Terrio, 2009, 239). These symptoms indicate damage to the hippocampus and the prefrontal cortex, which are also neuroanatomical substrates of PTSD (Jaffee and Meyer, 2009). This overlap in PTSD and post-concussive symptoms, and common neuroanatomical substrates make it difficult to differentiate the effects of the two variables.

Virtually no TBI occurs on the battlefield without the exposure to psychological stress. PTSD is frequent among soldiers. About 14 percent of soldiers suffer from PTSD-like symptoms compared to 4 percent of the U.S. adult civilian population (Keane, Marshall & Taft, 2006; Richardson, Frueh & Acierno, 2010). Therefore, understanding the mechanisms of what makes PTSD manifest differently in soldiers compared to the civilian population is crucial.

1.9 Sports-related Concussion: Model Used to Determine mTBI Effects

The ImPACT is used to evaluate sports-related concussion through a careful determination of change or decline in functioning that can be attributed to a brain injury. Sports neuropsychology is relatively unique in that cognitive assessment often occurs over very brief retest intervals to facilitate decisions regarding return to practice and competition (Iverson,

Lovell & Collins, 2003, 460). The ImPACT can be used to determine pre-season baseline scores (BL) of a non-concussed group of athletes, identify concussion and track recovery. The assessment intervals are, Post-Concussion Assessment 1 (PC1; 2-3 days post-injury), Post-Concussion Assessment 2 (PC2; 7-10 days post-injury), and Post-Concussion Assessment 3 (PC3; 1 month post injury).

Fjordbak, Salvatore & Bene (2011) presented four studies at the American Speech-Language-Hearing Association (ASHA) convention regarding the relationship between concussion and PTSD symptoms between athletes and soldiers. In the first study, the investigators collaborated with the research team at the William Beaumont Army Medical Center, assessing cognitive function in post-deployment Soldiers (n=16) experiencing chronic headache as a result of IED blast at 12-months post-injury, or later. A PTSD questionnaire that asked the same questions as the current study's questionnaire (i.e. Are you having nightmares; flashbacks; trouble keeping thoughts of the incident out of your head; feeling numb or detached; avoiding similar situations; having difficulty sleeping). The results displayed a mean score of 3.75 PTSD symptoms and a standard deviation of 2.05, when assessed at least 1-year post-injury.

Fjordbak et al. (2011) described a descriptive study which compared soldiers (n=7) from the previous cohort to concussed athletes (n=9) in the acuity stage. The groups were matched based on age, gender, and education. The ImPACT test was administered to the athletes, and a military version was administered to the soldiers. The group of athletes (n=9) assessed at 2-weeks post-concussion or less (M= 7.2 days) performed better on the neurocognitive assessment overall than the soldiers who were assessed at more than 1-year post-concussion (M= 14.4 months). The soldiers demonstrated impairments in cognitive-linguistic function and higher ratings on the total

symptom scale than did athletes. Athletes demonstrated better verbal (79.56% > 67.43%) and visual memory (64.33% > 58.43%), a quicker reaction time (.63 seconds < .66 seconds), and a significantly lower total symptom score (19.9 < 53.3) compared to the soldiers.

In a third investigation by Fjordbak et al. (2011), the same questionnaire was administered to a group of athletes (n=145) at baseline to provide insight into the frequency of PTSD symptoms in a non-concussed group of athletes. The athletes reported an average of less than 1 positive response to the six PTSD questions (M= .28, SD= .93, Range 0-6), indicating a low frequency of "free floating" PTSD symptoms.

In a fourth study by Fjordbak et al. (2011), the investigators collected BL data and conducted follow-up testing post-concussion to monitor recovery and decisions regarding return to play-decisions. The results showed that athletes' PTSD symptoms increased immediately after sustaining a concussion (M=1.3), but over time the self-reported PTSD symptoms diminished from PC1 to PC3. The athletes showed an increase in self-reported PTSD symptoms after concussion from BL (M=.44) to PC1 (M=1.3). As a point of comparison, soldiers reported a mean of 3.35 PTSD symptoms at 1-year post-concussion.

Overall, Fjordbak et al. (2011) found that when comparing soldiers and athletes diagnosed with concussion, the manifestations are substantially different. The differences between the two populations include cause of the injury (hit versus blast), the etiological and localization manifestations (focal versus global), history of previous concussion/mTBI, and the context within which the injury was sustained (sport versus war). BL data shows that athletes present with few pre-morbid signs of PTSD symptoms do not persist post-injury. The comparison between these two populations shows that even being away from the battlefield for

more than 12 months, soldiers continue to present with cognitive-linguistic deficit profiles that were still more impaired than athletes seen in the acuity stage post-injury.

The co-morbidity of PTSD and concussion remains unresolved. The limitations of Fjordbak et al. (2011) was the time of assessment between groups, small sample sizes, and lack of comparable BL data for both samples. The present study furthers the studies by Fjordbak et al. (2011) by expanding the sample size of athletes, and by providing strict exclusion criteria to isolate the independent variable, concussion.

1.10 Purpose of Present Study

The contribution of physiological brain injury is difficult to parse out since an injury happens in the context of a heightened stressful environment for soldiers exposed to a blast or closed head injury. Athletes, on the other hand, are emotionally involved in their athletic game and are supposedly enjoying themselves prior to being exposed to brain trauma. Stress is not a factor in sports, although adrenaline levels are increased, and there may be some anxiety present, the environment is not life-or-death as it is for soldiers in war. Athletes are virtually functioning normally, and factors such as intense fear and sleep deprivation are not present in athletes, as they are reported in soldiers. In an attempt to separate the variables of emotion and trauma, we investigated how athletes' neurocognitive functioning and self-reported PTSD symptoms change prior from baseline to after experiencing a brain injury.

To determine if the variables of fear, stress, and anxiety are required to PTSD symptoms in humans, we ruled out pre-morbid psychiatric disorders, substance abuse, attention deficit hyperactive disorder (ADHD) and history of concussions (< 12 months ago) in the selected participants. A self-reported Level of fear/stress/anxiety protocol was administered for athletes to indicate the level of these variables they experience in sports. We hypothesized that sports do

not result in a heightened level of fear/stress/anxiety, but only produce mild anxiety; that would isolate the effects of mTBI on athletes' psychological functioning.

In order to investigate the contribution of mTBI to the development of PTSD symptoms, the two research questions posed in this study are,

1. Is there a significant difference in the frequency of PTSD symptoms reported by athletes at baseline testing and post-concussion testing over time?
2. Is there a significant difference in the frequency of PTSD symptoms in a more severely concussed and less severely concussed group of athletes in the acuity stage?

The following hypotheses are proposed in response to the research questions,

1. The concussed group at post-concussion evaluation 1 (PC1) will present a higher number of PTSD symptoms compared to the non-concussed group at baseline testing (BL).
2. Athletes' PTSD symptoms will decline after PC2 (7-10 days post-concussion) mirroring the pattern of post-concussion symptoms that usually resolve within 7-10 days post-injury.
3. Athletes with a more severe concussion will present a higher number of PTSD symptoms and will rate those symptoms as more severe, compared to the less severely concussed group.

Concussion is currently a prominent issue in both the media and literature, especially in relation to the soldiers returning from OEF/OIF, as well as sports-related concussion at all levels of play (e.g. especially repeated hits to the head in football). The main issue in the context of war is differentiating how mTBI, and PTSD, affect veterans' daily functioning. If the results indicate that the resolution of self-reported PTSD symptoms is consistent with the resolution of post-concussion symptomatology when measured over time, then clinicians could use the PTSD symptom clusters to predict recovery post-concussion. This study has the potential to identify a cause-effect relationship between mTBI and PTSD symptoms, thereby indicating that treatment

for mTBI may aid in resolving PTSD symptoms in athletes. Overall, this study provides insight into how PTSD develops in a context absent of heightened fear, as well as provides awareness of the effects of TBI on athletes' psychological functioning.

Although soldiers are not used as participants in this study, the results are compared to previous data collected by Fjordbak et al. (2011). Since athletes and soldiers display differences in PTSD symptomatology over time, factors such as what context the athletes/soldiers were exposed to after their injury are crucial. Athletes at the University of Texas at El Paso's Concussion Management Clinic who are diagnosed with a concussion are recommended to follow a Rest Protocol. The literature on soldiers at war explains that soldiers are not provided with a period of rest post-injury, and are continually exposed to blasts and stress in their work environment. This study has the potential for providing evidence for the use of a rest protocol for managing PTSD symptoms in both athlete and soldier populations post-concussion.

Chapter 2: Method

2.1 Participants

Participants include middle school, high school, collegiate, and semi-professional athletes, both male and female, ages 17-28, and of any ethnicity, from the El Paso community. Demographic information from the ImPACT test was used to select participants based on the following exclusion criteria; they are an athlete, no history of concussion or concussion occurred at least 12 months prior to BL testing, no history of substance abuse, and never been diagnosed with a psychiatric disorder. Prior BL and PC participants were extracted from the pre-existing database, and incoming athletes were also recruited as participants. Participants were either referred to the Concussion Management Clinic (CMC) by their physician or by a school administrator, or assessed on-sight at their school's location by UTEP's CMC team.

2.2 Procedure

During the orientation process, age-appropriate informed consent forms were administered to all athletes. This form was previously approved by UTEP's Institutional Review Board (IRB). Athletes who were over 18 years of age signed for themselves, and those 17 years of age or younger were required to have parental consent to participate in the study, or to receive any testing from UTEP's CMC team. Consent forms and the ImPACT test are available in English and Spanish to account for cultural differences.

In order to maintain confidentiality, the CMC keeps all patients' information private and confidential based on the Health Insurance Portability and Accountability Act (HIPPA) and UTEP regulations. The results of any assessments, including data collected for research, are stored in a password protected file in which the clinic founder and director, Dr. Salvatore can only permit access. Any printed information in patient files is locked in a filing cabinet inside

the CMC, which is also locked and only accessed by Concussion Management Team members. The only risk that this study may pose to participants is the loss of confidentiality of their responses, but the previously mentioned precautions are taken to ensure confidentiality. Other sites relevant to this research include middle schools, high schools, El Paso Community College, UTEP, the Rhino's hockey team, the Diablo's baseball team, and any other sports teams in the El Paso community.

A standard group research design was used in the present study. The independent variable, mTBI/concussion, was used to determine which group the participants would be assigned to (concussed vs. non-concussed). The dependent variable is the self-reported PTSD symptoms. To answer the first research question, is there a difference in the frequency of PTSD symptoms between a concussed and non-concussed group of athletes over time, an inter-subject analysis using an independent samples t-test was performed. To analyze the pattern of PTSD symptoms across groups of athletes over time, the groups include a BL sample (n=365), PC1 sample (n=98), PC2 sample (n=22) and PC3 sample (n=19). An intra-subject analysis was performed on athletes (n=37) post-concussion, using a Pairwise Comparison. To answer the second research question, is there a significant difference in the frequency of PTSD symptoms in a more severely concussed (n=27) and less severely concussed (n=23) group of athletes in the acuity stage, a two-tailed independent samples t-test was used to compare the means of both groups.

2.3 Instrumentation

The two instruments used in this study are the ImPACT and athletes' self-reported PTSD symptoms. A yes/no checklist was developed based on the DSM-IV PTSD criteria, which is governed by three symptom clusters. These include re-experiencing the traumatic event,

persistent avoidance of things associated with the event and a numbing of general responsiveness, and persistent symptoms of increased arousal. This protocol, The Post-Concussion Assessment Questionnaire, was used to record self-reported PTSD symptoms by asking the athlete to "Check yes or no if you are experiencing any of these symptoms." The six PTSD symptoms listed in the questionnaire are, having nightmares, having flashbacks, having trouble keeping thoughts of an incident out of the head, feeling numb/detached, avoiding similar situations, and having difficulty sleeping. A yes response equals a score of 1 for the specific question. Standardized instructions were also provided verbally to each participant to ensure that they answered the questions under the same impressions. At BL, the athletes were told that the questions were non-specific to concussion because the group of participants for this study had never experienced a concussion before. In reference to the terms "the incident" or "similar situations" in two of the questions, it was explained, "For example, if you were in a car accident, a fight, or any traumatic event please check yes/no to these symptoms in relation to that event." During PC testing, the questions were specific to the athletes' recently experienced concussion.

The ImPACT test is composed of three main sections; demographic information, six neurocognitive tests of memory, learning, reaction time across printed words and symbols and self-reported post-concussion symptoms. The post-concussion symptom ratings are based on how the athlete is feeling at that current moment and within the past 24 hours. Lovell and Collins' (1998) Graded Symptom Checklist was used as the basis of the present checklist. The concussed group's PC1 evaluation was conducted within 48-72 hours of their concussion, the PC2 evaluation was conducted within 7-10 days of their concussion, and the PC3 evaluation was conducted at approximately 1-month post-injury. The ImPACT test was used to identify a concussion based on the reliable change difference scores (Iverson et al., 2003, 461) on five

composite measures of verbal memory, visual memory, reaction time, processing speed, and the post-concussion symptom scale.

The ImPACT test was also used in this study to determine the severity of a concussion, since LOC, amnesia, and confusion cannot identify concussion nor predict the severity of a concussion (McCrea, 2008, 24). The CMC emphasizes the use of the ImPACT test as a reliable method of test-retest differences were therefore used to identify concussion based on individual performance. This method does not limit the sample of participants to those who have sought medical attention based on LOC or PTA. If the ImPACT detects a reliable change in test performance from BL to PC1, PC2, and PC3 on any of the five composite scores, then the coefficient for a particular composite score is highlighted in red on the ImPACT report. The red test-retest coefficients, on any of the five composite scores, were used to rate the severity of concussion. Those with 1 or more red coefficients were rated as "more severely concussed" and those with no red test-retest coefficients were rated as "less severely concussed."

The Level of Fear Questionnaire was used to investigate the level of fear, stress, and anxiety that the athletes' experience when playing their sport on a 7-point scale. The participants were asked to rate the level of fear, stress, and anxiety that they experience when stepping onto the court/field to play their sport. The following definitions were provided on the questionnaire. Fear is defined as, "I experience a feeling of unease or apprehensiveness in response to a real and *imminent danger that is present."* Stress is defined as, "I experience a bodily response to danger or stress-provoking events and experience associated *symptoms."* Anxiety is defined as, "I experience feelings of unease or apprehensiveness when *no danger is imminently present."* In statistical analysis of the 7-point scale, a rating of zero represents non-experiencing of the

variable, 1-3 represents mildly experiencing the variable, and 4-6 represents severely experiencing the variable.

2.4 Analysis

The data from the Post-Concussion Assessment Questionnaire, ImPACT test, and Level of Fear Questionnaire were coded by the CMC team in Statistical Package for Social Sciences (SPSS). Once all information was entered into the dataset, the CMC team cleaned and checked the datasets to avoid data processing errors. The data was analyzed using SPSS Statistics Student Version 17.0 to calculate the frequency counts including the mean, and some median scores for data that were scored using a nominal scale, as well as the percentages for ratio/continuous data. Using an alpha level of .05, multiple independent samples t-tests were used to compare PTSD symptoms over time (BL→PC1, BL→PC2, BL→PC3, PC1→PC2, PC1→PC3, PC2→PC3). A Pairwise Comparison was also used to investigate the pattern of self-reported PTSD symptoms in individual athletes (n=37) from the acuity stage (PC1) post-injury, to approximately 1-month post-injury (PC3). An independent samples t-test was used to determine the difference in PTSD symptoms in a more severely concussed group (n=27) and a less severely concussed group (n= 23) at the acuity stage (PC1). Descriptive statistics, such as the mean and standard deviations, were gathered to determine the average level of fear, stress, and anxiety that non-concussed athletes experience in sports (n=45). A One-Sample Test was also conducted to determine any significant differences between the variables of fear, stress, and anxiety.

Chapter 3: Results

3.1 The Effects of Concussion During the Acuity Stage

The first research question posed was, is there a significant difference in the frequency of PTSD symptoms reported by athletes at baseline testing and post-concussion testing over time? The investigators hypothesized that the concussed group at PC1 will present a higher number of PTSD symptoms compared to the non-concussed group at BL.

The two groups included 365 non-concussed athletes and 98 concussed athletes. An independent samples t-test was conducted to compare the number of reported PTSD symptoms for the two groups of athletes. The t-test showed a statistically significant difference between the non-concussed group (M= .18, SD= .631) and the concussed group's (M=1.5816, SD=1.711) PTSD symptoms at PC1; t= -7.994, p = .0001. The concussed group reported more PTSD symptoms (M= 1.58) than did the non-concussed group (M=.18) in the acuity stage. This parametric statistical analysis supports the statistical findings without exception. Overall, there is a statistically significant difference between self-reported PTSD symptoms in a non-concussed group and self-reported PTSD symptoms after a concussion, with an increase in PTSD symptoms post-injury in the acuity stage.

Table 5. Inter-subject group statistics of athletes' self-reported PTSD symptoms from baseline testing (BL) to PC1evaluation (2-3 days post-concussion)

		N	Mean	Std. Deviation	Std. Error Mean
PTSD Total Symptom Score	BL	365	.18	.631	.033
	PC1	98	1.58	1.711	.173

The table below provides more description of the paired two-tailed independent t-test, using an alpha level of 95%. Since $p < 0.05$ reveals a statistically significant difference between groups, the results shown below reveal that there was a statistically significant difference between the PTSD symptom scores at BL and PC testing. With $p = 0.0001$, the equal variances not assumed would be evaluated, showing that $t = -7.994$, $df = 104.172$, the mean difference is -1.40629, and the standard error of the difference is -1.75515. The lower interval is -1.75515, and the upper interval is -1.05743.

Table 6. Independent samples t-test of athletes' self-reported PTSD symptoms from baseline testing (BL) to PC1 evaluation (2-3 days post-concussion)

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PTSD Total Symptom Score	Equal variances assumed	219.643	.000	-12.819	461	.000	-1.406	.110	-1.622	-1.191
	Equal variances not assumed			-7.994	104.172	.000	-1.406	.176	-1.755	-1.057

3.2 PTSD Symptomatology Over Time: Inter-subject Data

A second hypothesis proposed was, athletes' PTSD symptoms will decline after PC2 (7-10 days post-concussion) mirroring the pattern of concussion symptoms that usually resolve within 7-10 days post-injury. Independent sample t-tests were conducted on a group of athletes (n=98) at PC1 (2-3 post-injury) and a group of athletes (n=22) at PC2 (7-10 days post-injury). The t-test showed a statistically significant difference between the self-reported PTSD symptoms of the concussed group of athletes at PC1 (M= 1.58, SD= 1.711) and group of athletes at PC2 (M=0.55, SD=1.143); t= 3.468, p = .003. The group of athletes at PC1 reported more PTSD

symptoms (M= 1.58) than did the group of athletes at PC2 (M= 0.55). This parametric statistical analysis supports the statistical findings without exception. Overall, there is a statistically significant difference between self-reported PTSD symptoms post-concussion at 2-3 days post-injury and 7-10 days post-injury, with a decrease in symptoms during this time period; indicating a pattern of recovery over time.

Table 7. Inter-subject group statistics of athletes' self-reported PTSD symptoms from PC1 evaluation (2-3 days post-concussion) to PC2 evaluation (7-10 days post-concussion)

		N	Mean	Std. Deviation	Std. Error Mean
PTSD Total Symptom Score	PC1	98	1.58	1.711	.173
	PC2	22	.55	1.143	.244

The table below provides more description of the paired two-tailed independent t-test, using an alpha level of 95%. Since $p < 0.05$ reveals a statistically significant difference between groups, the results shown below reveal that there was a statistically significant difference between the PTSD symptom scores at PC1 and PC2 testing. With $p = 0.003$, the equal variances not assumed would be evaluated, showing that $t = 3.468$, $df = 44.949$, the mean difference is 1.036, and the standard error of the difference is 0.299. The lower interval is 0.434, and the upper interval is 1.638.

Table 8. Independent samples t-test of athletes' self-reported PTSD symptoms from PC1 evaluation (2-3 days post-concussion) to PC2 evaluation (7-10 days post-concussion)

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PTSD Total Symptom Score	Equal variances assumed	9.261	.003	2.704	118	.008	1.036	.383	.277	1.795
	Equal variances not assumed			3.468	44.949	.001	1.036	.299	.434	1.638

To further analyze the recovery of athletes over time an independent samples t-test was performed between the same group of athletes at PC2 (7-10 days post-injury) and a group of athletes at PC3 (1 month post-injury). The two groups included 22 athletes tested at PC2 and 19 athletes tested at PC3. The t-test showed a difference, but not a significant difference, between the self-reported PTSD symptoms of the group of athletes at PC2 (M= 0.55, SD= 1.143) and group of athletes at PC3 (M=0.37, SD=0.831); t= 0.559, p = 0.488. The group of athletes at PC2 reported more PTSD symptoms (M= 0.55) than did the group of athletes at PC3 (M= 0.37). This parametric statistical analysis supports the statistical findings without exception. Overall, there is not a statistically significant difference between self-reported PTSD symptoms post-concussion at 7-10 days post-injury and 1-month post-injury, with a decrease in symptoms during this time period; indicating a pattern of recovery over time.

Table 9. Inter-subject group statistics of athletes' self-reported PTSD symptoms from PC2 evaluation (7-10 days post-concussion) to PC3 evaluation (1-month post-concussion)

		N	Mean	Std. Deviation	Std. Error Mean
PTSD Total Symptom Score	PC2	22	.55	1.143	.244
	PC3	19	.37	.831	.191

The table below provides more description of the paired two-tailed independent t-test, using an alpha level of 95%. Since $p < 0.05$ reveals a statistically significant difference between groups, the results shown below reveal that there is no statistically significant difference between the PTSD symptom scores at PC2 and PC3 testing. With $p = 0.488$, the equal variances assumed would be evaluated, showing that $t = 0.559$, $df = 39$, the mean difference is 0.177, and the standard error of the difference is 0.317. The lower interval is -0.464, and the upper interval is 0.818.

Table 10. Independent samples t-test of athletes' self-reported PTSD symptoms from PC2 evaluation (7-10 days post-injury) to PC3 evaluation (1-month post concussion)

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PTSD Total Symptom Score	Equal variances assumed	.491	.488	.559	39	.579	.177	.317	-.464	.818
	Equal variances not assumed			.572	37.968	.571	.177	.309	-.449	.803

The investigators then conducted an independent samples t-test comparing the means of athletes' PTSD symptoms at PC1 to PC3 to determine how significant the athletes' recovery was from the acuity stage to 1 month post-injury. The two groups included 98 athletes tested at PC1

and 19 athletes tested at PC3. The t-test showed a statistically significant difference between the athletes' self-reported PTSD symptoms at PC1 (M= 1.58, SD= 1.711) and at PC3 (M=0.37, SD=0.831); t= 4.716, p = 0.0001. The group of athletes at PC1 reported more PTSD symptoms (M= 1.58) than did the group of athletes at PC3 (M= 0.37). This parametric statistical analysis supports the statistical findings without exception. Overall, there is a statistically significant difference between self-reported PTSD symptoms post-concussion from 2-3 days post-concussion to 1-month post-concussion, with a decrease in symptoms during this time period; indicating a significant pattern of recovery over time.

Table 11. Inter-subject group statistics of athletes' self-reported PTSD symptoms from PC1 evaluation (2-3 days post-concussion) to PC3 evaluation (1-month post-concussion)

		N	Mean	Std. Deviation	Std. Error Mean
PTSD Total Symptom Score	PC1	98	1.58	1.711	.173
	PC3	19	.37	.831	.191

The table below provides more description of the paired two-tailed independent t-test, using an alpha level of 95%. Since $p < 0.05$ reveals a statistically significant difference between groups, the results shown below reveal that there is a statistically significant difference between the PTSD symptom scores at PC1 and PC3 testing. With p = 0.0001, the equal variances not assumed would be evaluated, showing that t = 4.716, df = 53.104, the mean difference is 1.213, and the standard error of the difference is 0.257. The lower interval is 0.697, and the upper interval is 1.729.

Table 12. Independent samples t-test of athletes' self-reported PTSD symptoms from PC1 evaluation (2-3 days post-concussion) to PC3 evaluation (1-month post-concussion)

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PTSD Total Symptom Score	Equal variances assumed	13.546	.000	3.015	115	.003	1.213	.402	.416	2.010
	Equal variances not assumed			4.716	53.104	.000	1.213	.257	.697	1.729

Overall, there was a statistically significant difference between the non-concussed group of athletes at BL and group of concussed athletes at PC1, with an increase in PTSD symptoms in the acuity stage. There was a statistically significant difference between the groups of athletes' PTSD symptoms at PC1 and PC2, showing a significant decrease in symptoms between the acuity stage and 7-10 days post-injury. There was not a significant different in reported PTSD symptoms from PC2 to PC3, but there was still an observed decrease in the reported symptoms. There was a statistically significant difference between the groups of athletes' PTSD symptoms from PC1 to PC3, showing that athletes' PTSD symptoms significantly decreased over the course of 1-month post-injury.

3.3 PTSD Symptomatology Over Time: Intra-Subject Data

To further investigate athletes' PTSD symptomatology over time, intra-subject analysis data was collected on a group of athletes (n= 37) who had self-reported PTSD symptoms at PC1, PC2, and PC3. Descriptive Statistics of Measure 1 (PTSD Symptoms) were collected. At PC1 athletes (M=1.70, SD= 1.777) reported the most symptoms, with a decline in symptoms at PC2 (M= 0.97, SD=1.518) and PC3 (M=0.70; SD= 1.331).

Table 13. Intra-subject descriptive statistics of a group of individual athletes' self-reported PTSD symptoms at post-concussion evaluations (PC1 2-3 days post-concussion; PC2 7-10 days; PC3 1-month)

	Mean	Std. Deviation	N
PC1 total PTSD score	1.70	1.777	37
PC2 total PTSD score	.97	1.518	37
PC3 total PTSD score	.70	1.331	37

Table 14. Intra-subject estimates of a group of individual athletes' self-reported PTSD symptoms at post-concussion evaluations

PC	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	1.703	.292	1.110	2.295
2	.973	.250	.467	1.479
3	.703	.219	.259	1.146

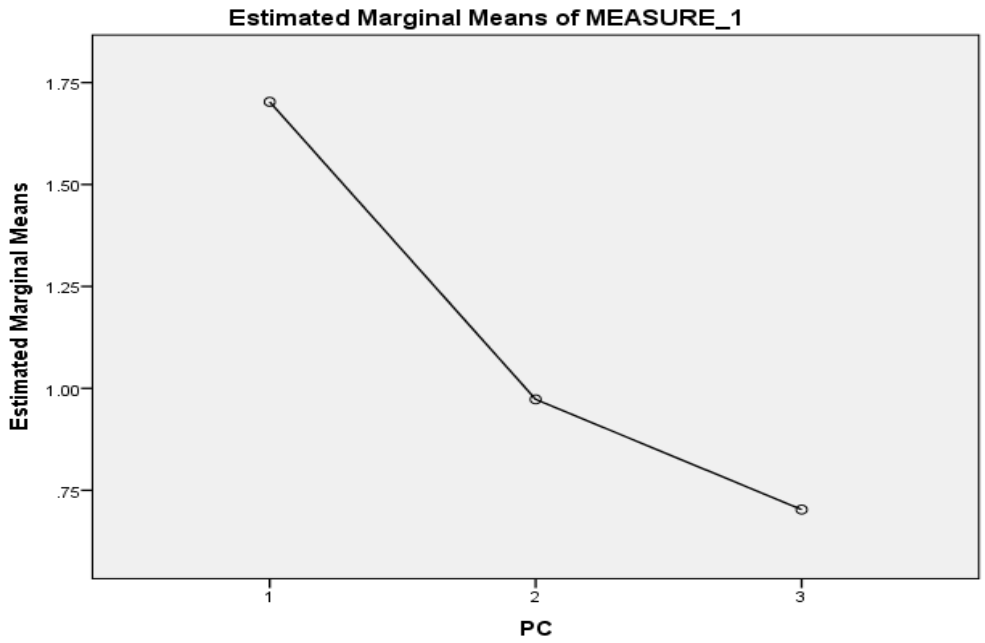

Figure 1. Estimated marginal means of concussed athletes' self-reported PTSD symptoms across time: PC1 (2-3 days post-concussion); PC2 (7-10 days post-concussion); PC3 (1-month post-concussion)

The table below shows a Pairwise Comparison between PC1, PC2, and PC3. Since $p < 0.05$ reveals a statistically significant difference between variables, the results shown below reveal that there was a statistically significant difference between the PTSD symptom scores at PC1 and PC2 testing. From PC1 to PC2, $p = 0.003$, the mean difference is 0.730, and the standard error of the difference is 0.204. The lower interval is 0.218, and the upper interval is 1.241. From PC2 to PC3, $p= 0.401$, the mean difference is 0.270, and the standard error of the difference is 0.176. The lower interval is -0.172, and the upper interval is 0.712. From PC1 to PC3, $p= 0.001$, the mean difference is 1.000, and the standard error of the difference is 0.239. The lower interval is 0.400, and the upper interval is 1.600.

Overall, the findings showed a statistically significant difference between PTSD symptoms at PC1 and PC2, with a decrease in symptoms over time. There was not a significant difference between symptoms at PC2 and PC3. There was a statistically difference from the

acuity stage (PC1) to 1-month post-injury (PC3). These results are consistent with the inter-subject results discussed previously between the groups of athletes over time.

Table 15. Pairwise comparisons of a group of individual athletes' self-reported PTSD symptoms at post-concussion evaluations (PC1 2-3 days post-concussion, PC2 7-10 days, PC3 1-month)

PC		Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	.730*	.204	.003	.218	1.241
	3	1.000*	.239	.001	.400	1.600
2	1	-.730*	.204	.003	-1.241	-.218
	3	.270	.176	.401	-.172	.712
3	1	-1.000*	.239	.001	-1.600	-.400
	2	-.270	.176	.401	-.712	.172

3.4 Athletes' Recovery to Baseline

The findings led the investigators to ask, at what point do athletes recover post-concussion, in relation to their baseline symptoms? Two independent samples t-test were performed between a group of non-concussed athletes' PTSD symptoms and two points post-concussion (7-10 days and 1-month) to determine when the athletes, as a group, had recovered.

An independent samples t-test was performed between the non-concussed group at BL and the group of athletes at PC2 to determine if the athletes had significantly recovered by 7-10 days. The t-test showed no statistically significant difference between the non-concussed (n= 365) group (M= .18, SD= 0.631) and the concussed (n=22) group's (M=0.55, SD=1.143) PTSD symptoms at PC2; t= -1.505, p = .001. The PC group reported more PTSD symptoms (M= 0.55) than did the non-concussed group (M=0.18) 7-10 days post-injury. This parametric statistical analysis supports the statistical findings without exception. Overall, there is not a statistically

significant difference between self-reported PTSD symptoms in a non-concussed group and self-reported PTSD symptoms after a concussion, yet still an increase in PTSD symptoms from BL to 7-10 days post-injury. This finding indicates that athletes have recovered by 7-10 days post-concussion, because there is still no statistically difference in symptomatology from baseline.

Table 16. Inter-subject group statistics of athletes' self-reported PTSD symptoms from baseline testing (BL) to PC2 evaluation (7-10 days post-concussion)

		N	Mean	Std. Deviation	Std. Error Mean
PTSD Total Symptom Score	BL	365	.18	.631	.033
	PC2	22	.55	1.143	.244

The table below provides more description of the paired two-tailed independent t-test, using an alpha level of 95%. Since $p < 0.05$ reveals a statistically significant difference between groups, the results shown below reveal that there was not a statistically significant difference between the PTSD symptom scores at BL and PC2 testing. With $p = 0.001$, the equal variances not assumed would be evaluated, showing that $t = -1.505$, $df = 21.777$, the mean difference is -0.370, and the standard error of the difference is 0.246. The lower interval is -0.881, and the upper interval is 0.140.

Table 17. Independent samples t-test of athletes' self-reported PTSD symptoms from baseline testing (BL) to PC2 evaluation (7-10 days post-concussion)

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PTSD Total Symptom Score	Equal variances assumed	11.920	.001	-2.521	385	.012	-.370	.147	-.659	-.081
	Equal variances not			-1.505	21.777	.147	-.370	.246	-.881	.140

assumed									

An independent samples t-test was then performed between the non-concussed group at BL and the group of athletes at PC3 to determine if the athletes had significantly recovered by 1-month, in relation to their BL performance. An independent samples t-test showed an increase in reported PTSD symptoms between the non-concussed (n= 365) group (M= 0.18, SD= 0.631) and the concussed (n= 19) group at 1-month post-concussion (M=0.37, SD=0.831); t= -1.279, p = 0.038. The group at 1-month post-concussion reported more PTSD symptoms (M= 0.37) than did the non-concussed group (M=0.18), but not a statistically significant difference. This parametric statistical analysis supports the statistical findings without exception. Overall, there is not a statistically significant difference between self-reported PTSD symptoms in a non-concussed group and self-reported PTSD symptoms at 1-month post-injury. This finding indicates that the athletes are recovered from the concussion by 1-month post-injury, with no significant difference from BL.

Table 18. Inter-subject group statistics of athletes' self-reported PTSD symptoms from baseline testing (BL) to PC3 evaluation (1-month post-concussion)

		N	Mean	Std. Deviation	Std. Error Mean
PTSD Total Symptom Score	BL	365	.18	.631	.033
	PC3	19	.37	.831	.191

The table below provides more description of the paired two-tailed independent t-test, using an alpha level of 95%. Since $p < 0.05$ reveals a statistically significant difference between groups, the results shown below reveal that there was no statistically significant difference between the PTSD symptom scores at BL and PC3 testing. With p = 0.038, the equal variances assumed would be evaluated, showing that t = -1.279, df = 382, the mean difference is -0.193,

and the standard error of the difference is 0.151. The lower interval is -0.490, and the upper interval is 0.104.

Table 19. Independent samples t-test of athletes' self-reported PTSD symptoms from baseline testing (BL) to PC3 evaluation (1-month post-concussion)

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PTSD Total Symptom Score	Equal variances assumed	4.326	.038	-1.279	382	.202	-.193	.151	-.490	.104
	Equal variances not assumed			-.998	19.095	.331	-.193	.193	-.598	.212

Overall, there not a statistically significant difference between self-reported PTSD symptoms in a non-concussed group at BL to a group of athletes 7-10 days post-injury. This finding indicates that athletes have recovered by 7-10 days post-concussion, because there is not a statistically significant difference in symptomatology from their initial BL. Furthermore, there was no statistically significant difference in PTSD symptoms from BL to 1-month post-injury. This finding indicates that the athletes are recovered from the concussion by 1-month post-injury, with no significant differences from reported BL symptoms.

3.5 Concussion Severity and PTSD Symptom Development

The second research question posed was, is there a significant difference in the frequency of PTSD symptoms in a more severely concussed and less severely concussed group of athletes in the acuity stage? The investigators hypothesized that athletes with a more severe concussion

will present a higher number of PTSD symptoms, and will rate those symptoms as more severe, compared to the less severely concussed group.

The two groups included 23 less severely concussed athletes and 27 more severely concussed athletes. A two-tailed independent samples t-test showed a statistically significant difference between the more severe group (M= 1.81, SD= 1.942) and the less severe group's (M=0.96, SD=1.147) PTSD symptoms in the acuity stage; t= -1.859, p =0.083. The more severe group reported more PTSD symptoms (M= 1.81) than did the less severe group (M=0.96) at PC1. This parametric statistical analysis supports the statistical findings without exception. Overall, there was not a statistically significant difference between self-reported PTSD symptoms in a more severely concussed and less severely concussed group of athletes; yet more PTSD symptoms were reported in the more severe group.

Table 20. Inter-subject group statistics of self-reported PTSD symptoms between a group of more severely concussed and less severely concussed athletes at PC1 evaluation (2-3 days post-concussion)

	TBI Status at PC1	N	Mean	Std. Deviation	Std. Error Mean
PTSD Symptoms at PC1	Less Severe Concussion	23	.96	1.147	.239
	More Severe Concussion	27	1.81	1.942	.374

The table below provides more description of the paired two-tailed independent t-test, using an alpha level of 95%. Since $p < 0.05$ reveals a statistically significant difference between groups, the results shown below reveal that there is not a statistically significant difference between the PTSD symptom scores of the more severe and less severe groups. With p =0.083, the equal variances assumed would be evaluated, showing that t = -1/859, df = 48, the mean

difference is -0.858, and the standard error of the difference is 0.462. The lower interval is -1.786, and the upper interval is 0.070. Overall, concussion severity did not play a significant role in the development of PTSD symptoms in the acuity stage, based on these small samples of athletes. The more severely concussed group reported more PTSD symptoms in the acuity stage compared to the less severe group.

Table 21. Independent samples t-test of self-reported PTSD symptoms between a group of more severely concussed and less severely concussed athletes at PC1 evaluation (2-3 days post-concussion)

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PTSD Symptoms at PC1	Equal variances assumed	3.133	.083	-1.859	48	.069	-.858	.462	-1.786	.070
	Equal variances not assumed			-1.934	43.113	.060	-.858	.444	-1.753	.037

3.6 Context of Fear, Stress, and Anxiety in Sports

A group of athletes (n=45) self-reported the level of fear, stress, and anxiety that they experience in playing their sport, on a scale of 0-6 (least to greatest). In statistical analysis of the 7-point scale, a rating of zero represents non-experiencing of the variable, 1-3 represents mildly experiencing the variable, and 4-6 represents severely experiencing the variable. Descriptive statistics, such as the mean and standard deviations, were gathered to determine the average level of fear, stress, and anxiety that a group of non-concussed athletes experiences in their sport (n=45).

The table below shows that athletes experience fear (M= 0.49; SD= 1.014), stress (M= 0.93; SD= 1.355), and anxiety (M= 1.02; SD= 1.617) in their sport at mild levels. The athletes

reported experiencing all three variables "mildly" based on the scale, since all three averages fall within the 1-3 point range out of 6 total ratings. The results, therefore, support the hypothesis that sports-related concussion does not occur in a heightened fearful environment.

Table 22. One-sample statistics from level of fear/stress/anxiety questionnaire, non-concussed athletes' self-reported ratings of stress, fear, anxiety in playing their sport

	N	Mean	Std. Deviation	Std. Error Mean
Experience fear in sport	45	.49	1.014	.151
Experience stress in sport	45	.93	1.355	.202
Experience anxiety in sport	45	1.02	1.617	.241

Table 23. One-sample test from level of fear/stress/anxiety questionnaire, non-concussed athletes' self-reported ratings of stress, fear, anxiety in playing their sport

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Experience fear in sport	3.234	44	.002	.489	.18	.79
Experience stress in sport	4.620	44	.000	.933	.53	1.34
Experience anxiety in sport	4.242	44	.000	1.022	.54	1.51

Table 24. Frequencies of non-concussed athletes' self-reported level of fear in playing their sport:
Severity ratings on scale of 0-6 least to greatest

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no	33	71.7	73.3	73.3
	less severe 1	6	13.0	13.3	86.7
	less severe 2	4	8.7	8.9	95.6
	less severe 3	1	2.2	2.2	97.8
	more severe 5	1	2.2	2.2	100.0
	Total	45	97.8	100.0	
Missing	System	1	2.2		
Total		46	100.0		

Table 25. Frequencies of non-concussed athletes' self-reported level of stress in playing their sport:
Severity ratings on scale of 0-6 least to greatest

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no	25	54.3	55.6	55.6
	less severe 1	9	19.6	20.0	75.6
	less severe 2	5	10.9	11.1	86.7
	less severe 3	2	4.3	4.4	91.1
	more severe 4	3	6.5	6.7	97.8
	more severe 5	1	2.2	2.2	100.0
	Total	45	97.8	100.0	
Missing	System	1	2.2		
Total		46	100.0		

Table 26. Frequency table of non-concussed athletes' self-reported level of anxiety in playing their sport: Severity ratings on scale of 0-6 least to greatest

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no	26	56.5	57.8	57.8
	less severe 1	9	19.6	20.0	77.8
	less severe 2	2	4.3	4.4	82.2
	less severe 3	3	6.5	6.7	88.9
	more severe 4	2	4.3	4.4	93.3
	more severe 5	2	4.3	4.4	97.8
	more severe 6	1	2.2	2.2	100.0
	Total	45	97.8	100.0	
Missing	System	1	2.2		
Total		46	100.0		

Chapter 4: Discussion

A controversial issue is whether TBI is a necessary precursor to the development of PTSD symptoms, or if TBI and PTSD symptoms are mutually exclusive. Recent research using rodent-models have revealed that a stressful environment cannot cause PTSD symptoms directly without TBI. Furthermore, it is unknown if PTSD symptoms can develop following an TBI.

This study investigated two questions, 1) Is there a significant difference in the frequency of PTSD symptoms reported by athletes at baseline testing and post-concussion testing over time? 2) Is there a significant difference in the frequency of PTSD symptoms in a more severely concussed and less severely concussed group of athletes in the acuity stage?

The purpose of this study was to determine if there is a significant difference between the frequencies of PTSD symptoms reported at baseline testing and the frequency of PTSD symptoms reported during post-concussion testing. The major finding of this study is that concussed athletes report a statistically significant increase in PTSD symptoms following a sports-related concussion in the acuity stage (2-3 days post-injury). The sample of 365 athletes at BL testing averaged 0.1753 PTSD symptoms, and the sample of 98 athletes at post-concussion testing averaged 1.5816 PTSD symptoms in the acuity stage. The results of this study revealed a statistically significant difference in PTSD symptoms from BL testing to PC1 testing, demonstrating the effects that a concussion has in the development of PTSD symptoms.

The findings also showed that there was no statistically significant difference between self-reported PTSD symptoms in a non-concussed group at baseline to a group of athletes at PC2 (7-10 days post-injury). This finding indicates that athletes have recovered by 7-10 days post-concussion, because there is not a statistically significant difference in symptomatology from their initial BL. Furthermore, there was no statistically significant difference between self-

reported PTSD symptoms in a non-concussed group and self-reported PTSD symptoms at PC3 (1-month post-injury). Therefore, the reported PTSD symptoms at 1-month-post injury are still higher than reported symptoms at BL testing, but the difference is not significant. This finding indicates that the athletes are recovered from the concussion by 7-10 days post-concussion and remain recovered 1-month post-injury, with no significant differences from reported BL symptoms.

The second research question was, is there a significant difference in the frequency of PTSD symptoms in a more severely concussed and less severely concussed group of athletes in the acuity stage? To evaluate how severity of concussion effects PTSD symptom development, a group of less severely concussed athletes (n=23) and more severely concussed athletes (n=27) were evaluated at PC1. Severity was determined using reliable-change indices from the ImPACT neurocognitive examination. The results revealed that the more severely concussed group reported more PTSD symptoms (M= 1.81) than the less severely concussed group (M= 0.96), yet had no significant difference between groups. Therefore, based on the methodology used in this study, severity did not cause a statistically significant difference in the self-reporting of PTSD symptoms. Concussion severity based on reliable change indices of the ImPACT test may predict PTSD symptom development in a larger sample size, since there was a difference noted between groups.

Previous researchers who have analyzed the effects of mTBI have used soldiers as participants. Soldiers experience mTBI in the context of a heightened fearful environment in war where it is difficult to sparse out the variables of mTBI and fear/stress/anxiety. Therefore, one cannot tell if the fear induced environment or mTBI is the casual factor in the resulting PTSD symptoms. The current study used athletes as participants based on the rationale that

athletes experience concussion in a context is absent of heightened fear/stress. The results from the Level of Fear Protocol revealed that non-concussed athletes experience anxiety (M=0.49), stress (M=0.93), and fear (M=0.49) at a minimal level (rating of less than 1 out of 6), supporting the hypothesis that sports-related concussion does not occur in a heightened fearful environment.

4.1 Athlete vs. Soldier PTSD Symptom Recovery

As a point of comparison, soldiers report a mean of 3.35 PTSD symptoms at 1-year post-concussion (Fjordbak et al. 2011), indicating that mTBI recovery is different in the context of heightened fear for soldiers. The current study showed that athletes, who are not in a heightened fearful environment, return to the baseline symptomatology at 1-month post-concussion. Overall, the timeline for recovery between these two populations is very different.

As previously discussed, the context of the environment is a major contributing factor to the development of PTSD symptoms based on rodent-models in the acuity stage. This sports-related concussion model has also isolated the mTBI variable and has shown the direct effects in the acuity stage, showing an increase in PTSD symptoms 2-3 days post-injury.

Another factor to consider when evaluating symptomatology over time is what context the participants go into post-injury. In UTEP's CMC, athletes who are evaluated and diagnosed with a concussion are recommended to follow a full Rest Protocol until they return to BL performance on a series of neurocognitive examinations. Typical athletes who are compliant with the Rest Protocol show no signs/symptoms within 10-14 days post-injury and return to sports/school within 1-month of the injury (the time that PTSD symptoms in this study resolved). The results found in this study show that the athletes' PTSD symptoms parallel post-concussion symptoms in terms of recovery and the Rest Protocol appears to be a main contributing factor to this difference.

On the other hand, soldiers rarely receive the opportunity for rest following a concussion and this may be an additional reason soldiers' symptoms continue to persist for years post-injury. When the brain is in a concussive state, its energy is diverted to basic functioning. Therefore, the energy the brain has for filtering or censoring is limited. For example, a concussed person thereby experiences the hypersensitivity to sound, light, or noise. Healing requires energy that is only gathered from rest. Since soldiers are continually exposed to blasts and stressful environments, the brain fatigues and symptoms are exemplified. Further research should be done in the population of soldiers to determine how rest protocols can improve neurocognitive and emotional symptoms long-term after a concussion.

4.2 Limitations

Factors that may have affected the results could include gender, in which both male and female participants were included, as well as levels of education since middle school, high school, collegiate, and semi-professional athletes, were all used as participants. A limitation of this study is the difference in sample size between the groups over time. The sample sizes could have been much larger but exclusion criteria such as no prior history of concussion, no history of substance abuse, and no history of psychiatric disorders, were used in this study to control for extraneous variables that may have influenced the development of PTSD symptoms nonspecific to concussion. The main limitation of this study is that all PTSD symptoms and reports of fear, stress, anxiety experienced are self-reported.

4.3 Controls

Exclusion criteria included history of substance abuse, history of psychiatric disorders, history of concussion, and diagnosis of Attention-deficit disorder. Participants were not included if they had experienced a concussion within the past 12 months. The ImPACT test which was

used to identify concussion, based on test-retest reliability scores, uses baseline performance to do so. Baseline data served as a major control in this study. The level of fear questionnaire was utilized to control for the level of stress, fear, and anxiety in athlete participants to support our claim that the independent variable was isolated.

4.4 Clinical Implications

Concussion is currently a prominent issue in both the media and literature, especially in relation to the soldiers returning from OEF/OIF, as well as sports-related concussion at all levels of play (e.g. especially repeated hits to the head in football). The main issue in the context of war is trying to differentiate the effects that mTBI and PTSD have on veterans' daily functioning. The present study provides a potential analogue to determine the direct effects that mTBI has on athletes developing PTSD symptoms. In the present study, the resolution of self-reported PTSD symptoms is consistent with the resolution of post-concussion symptomatology when measured over time. Therefore, clinicians can utilize PTSD symptom clusters to determine concussion recovery. This study also identifies a cause-effect relationship between mTBI and PTSD symptoms, due to the absence of a heightened fearful/stressful environment and the control mechanisms implemented. This may indicate that treatment for mTBI should be the focus in resolving PTSD symptoms in athletes (ex. Rest protocol). Although soldiers are not used as participants in this study, the results could influence clinical decision making for this population, as well. Further research should be done in the population of soldiers to determine how Rest protocols can improve neurocognitive and emotional symptoms long-term after a concussion. Overall, this study provides insight into how PTSD develops in a context absent of heightened fear, as well as provides awareness of the effects of TBI on athletes' psychological functioning.

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Appendix A
Post-Concussion Assessment Questionnaire

Answer the following questions.	**Athlete's Response**		
What is your name?			
What is your birthdate?			
What is your address?			
Where are you now?			
What date of the month is it?			
What month are we in?			
What year are we in?			
What day of the week is it?			
Can you recall how you got the injury? Circle one of the following.	YES	NO	N/A
Can you recall the events immediately before the accident?	YES	NO	N/A
Are there are details that you cannot remember before the accident?	YES	NO	N/A
Are there are details that you cannot remember after the accident?	YES	NO	N/A

Check *Yes* or *No* to the following questions.

Are you…	**No**	**Yes**
having nightmares?		
having flashbacks?		
having trouble keeping thoughts of incident out of head?		
feeling numb/detached?		
avoiding similar situations?		
having difficulty sleeping?		

Appendix B

Level of Fear Questionnaire

Please note that this information will not affect your return to play process, but is solely for research purposes and is completely anonymous.

Please rate the level of fear/stress/anxiety that you experience in playing your sport, by circling the related severity score. If you do not experience one of the listed psychological states circle no; if you do experience a state please circle a level of severity from 1-6 (1= least severe; 6= most severe).

Level of…	**Definition**	**No**	**Yes**
Fear	I experience a feeling of unease or apprehensiveness in response to a real and *imminent danger that is present.*	0	1 2 3 4 5 6
Stress	I experience a bodily response to danger or stress-provoking events and experience associated *symptoms*	0	1 2 3 4 5 6
Anxiety	I experience feelings of unease or apprehensiveness when *no danger is imminently present.*	0	1 2 3 4 5 6

Vita

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