Predicting Concussion Symptoms: The Impact of Pre-Injury Risk Factors on Post-Concussion Symptom Severity in Football Players

by

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Abstract

This thesis explores how pre-existing mental health factors—anxiety, depression, concussion history, learning disorders, and ADHD—affect post-concussion outcomes in Canadian Football League (CFL) athletes. The study addresses a gap in the literature by investigating whether baseline mental health risks predict post-concussion symptom severity, offering insights for improved concussion management and athlete welfare. Using a longitudinal repeated measures design, baseline data from 793 CFL athletes, collected during 2017-2018 pre-season medical evaluations, were analyzed. Participants completed SCAT3 and BSI-18 assessments to measure concussion history and mental health variables. Pearson correlations, t-tests, and stepwise regression analyses assessed relationships between pre-injury mental health factors and post-concussion outcomes. Results showed significant increases in somatization and depression post-concussion, while anxiety remained stable. SCAT symptom severity emerged as a key predictor of post-injury psychological outcomes, with pre-injury anxiety and somatization influencing post-injury anxiety. These findings underscore the importance of assessing baseline mental health to better manage post-concussion symptoms and guide personalized interventions.

Preface

This thesis is an original work by Ryan White. This study was a part of a broader research project from which this thesis was developed. Data for this study was collected from the Active Rehabilitation Project conducted by the co-principle investigators Dr. Mrazik and Dr. Naidu. The Active Rehabilitation study was granted ethics approval prior to the beginning of this study (Pro00073481) by the Research Ethics Board at the University of Alberta. The research conducted for this thesis was supervised by Dr. Martin Mrazik at the University of Alberta.

Dedication

This thesis is dedicated to my family, especially my mother, Jackie, who has always inspired me to aim high and work diligently to achieve my goals. I extend heartfelt thanks to my Poppy for teaching me the importance of not taking life too seriously and for encouraging me to find joy in every moment. Nanny, thank you for reminding me to hold on to hope and faith, as things always have a way of working out. My deepest gratitude goes to Robert for our insightful conversations on philosophy, history and psychology, Shannon for guiding me through the complexities of statistics, Kelly for supporting my physical health and wellness with her expertise, and Haley for her unwavering and unconditional love, support, and encouragement every step of the way.

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Chapter - 1 Introduction

Over the last 25 years, the issue of sport-related concussions has garnered increasing concern due to their frequency, immediate effects, and the potential for long-term neurological consequences (DeKosky, Ikonomovic, & Gandy, 2010; Kelly, 1999; Langlois, Rutland-Brown, & Wald, 2006; McCrory et al., 2005, 2009). The relationship between concussion risk factors mental health and injury, particularly in sports like football with concussions, is complex. Psychological models, such as the biopsychosocial model, cognitive appraisal theory, social support theory, and the health belief model, highlight how mental health influences the body's immune and neuroendocrine systems, impacting injury healing/recovery and potentially injury severity or symptom expression as a whole. Poor mental health not only jeopardizes physical health but can also lead to unhealthy behaviours and potential side effects from mental health medications.

The bidirectional influence between mental and physical health emphasizes the need for an integrated treatment approach. Poor mental health can prolong injury recovery, affecting athletes' functionality, performance, and long-term outcomes. The relatively high prevalence of sports-related concussions (SRCs), particularly in American football, underscores the global importance of understanding and managing these injuries. Research by Zuckerman et al. (2015) from the NCAA Injury Surveillance Program for the 2009-2010 to 2013-2014 academic years revealed an average concussion recurrence rate of 13.9% for men's sports and 10.3% for women's sports across 17 sports. Men's ice hockey had the highest recurrence rate at 20.1%, while men's baseball showed a 0.0% recurrence rate (Hootman, Dick, & Agel, 2007). In women's sports, soccer had the highest recurrence rate at 12.5%, and volleyball had the lowest at

5.4% (Zuckerman et al., 2015). Among NFL players from 2015 to 2019, the risk of sustaining a second concussion within a year of the first was between 5.3% and 8.3%, which is comparable to the 6.7% rate of same-year repeat concussions in adolescent athletes (Cools et al., 2022).

Mental health in athletes is intertwined with the stressors of training, injuries, and performance evaluations, emphasizing the interconnected nature of physical and psychological challenges. Despite these perspectives, persistent barriers to mental health support exist, with historical stigma and perceived weakness hindering athletes in seeking help. Acknowledging the complex interplay between mental and physical well-being is crucial for promoting optimal injury avoidance, symptom severity reduction and recovery outcome variables in athletes.

This study explores the impact of pre-existing risk factors/predictors including anxiety, depression, previous concussions, learning disorders, and ADHD on mental health symptoms or the outcome variables in Canadian Football League (CFL) athletes. Current research indicates that athletes experiencing elevated stress levels may be more prone to getting injured, experiencing more severe symptoms or outcome variables and encountering difficulties in recovering and prolonged recovery times from SRCs and other injuries, but a significant gap exists in the literature regarding the severity of concussion outcome variables for athletes with pre-existing risk factors. To address this gap, our study investigates concussion outcome variables in CFL athletes, focusing on baseline or pre-concussion risk factors. Our objective is to evaluate the correlation between these pre-concussion demographics and The Brief Symptom Inventory (BSI) risk factors and determine if they can predict the severity of outcome variables following a concussion.

The current study utilizes data from Register-Mihalik et al.'s (2019) Active Rehab Study (ARS) on CFL players. By employing the Sport Concussion Assessment Tool (SCAT3) and the

BSI-18, this research investigates the link between subjective mood symptoms on the SCAT3 and comprehensive mental health screening during baseline testing. The BSI-18 has been validated as a reliable tool for assessing psychological symptoms, particularly somatization, depression, and anxiety. Research demonstrates its effectiveness in capturing overall psychological distress, with anxiety often a key contributor. This aligns with the study's findings that SCAT Symptom Severity Scores correlate with increased psychological distress (Frankie., 2017). The BSI-18's psychometric properties, such as internal consistency, further support its clinical use, especially when comprehensive assessments are unavailable. Similarly, the BSI's role in screening psychological symptoms is well-documented. Studies highlight its utility when comprehensive tools like PROMIS 29 are inaccessible, mirroring the thesis findings where SCAT scores predicted broader psychological symptoms, including anxiety and depression (Drobnjak, 2013).

These tools enable clinicians to screen athletes for mental health concerns when more detailed diagnostics are unavailable. The primary objective is to assess the relationship between pre-concussion risk factors and post-concussion symptom severity over time.

Chapter 2: Literature Review

To date, few studies have examined the specific relationship between pre-injury mental health and post-injury outcomes among athletes. In this respect, we aim to contribute practical implications around mental health as a critical factor in injury reduction and recovery. This study is important because it helps fill the gap in the literature on both aspects by focusing on individuals who are at an elevated risk for injury/elevated outcome variables and whose careers hinge on their mental and physical health. This research provides valuable insights that can inform preventative measures and enhance athlete welfare. This study highlights the importance

of risk factors as early predictors for acute injury characteristics and symptom severity or outcome variables, supporting the need for improved clinical assessment methods, psychoeducation, proactive treatment (addressing risk factors early), and proper rehabilitation. Future research should strive to develop predictive algorithms for identifying more severe outcome variables and prolonged recovery, as well as further investigate these risk/vulnerability factors and predictors in diverse populations.

Mental Health

In recent years, mental health in Canada has exhibited significant trends and challenges. Statistics Canada (2023) reported that over 5 million Canadians were diagnosed with mood, anxiety, or substance use disorders in 2022, indicating a considerable increase over the past decade. The prevalence of generalized anxiety disorder among Canadians aged 15 and older increased from 2.6% in 2012 to 5.2% in 2022. Similarly, major depressive episodes rose from 4.7% to 7.6%, and bipolar disorder cases increased from 1.5% to 2.1% during the same period (Statistics Canada, 2023). Throughout their lifetime, approximately 3.5 million Canadians will meet the criteria for a mood disorder (Pearson et al., 2013). Specifically, around 3.2 million Canadians are expected to experience a major depressive episode, and 2.4 million will meet the criteria for generalized anxiety disorder (Pearson et al., 2013). Moreover, among those with generalized anxiety disorder, 54% also meet the criteria for depression. The literature identifies anxiety and depression as common co-occurring conditions (Belzer & Schneier, 2004; Nguyen et al., 2005).

The Mental Health and Access to Care Survey (2022) revealed that approximately 48.8% of individuals diagnosed with mood, anxiety, or substance use disorders sought help from health professionals. Therapy was the most common form of support, utilized by 43.8% of individuals,

followed by medication (36.5%) and informational resources (32.0%) (Statistics Canada, 2023). Psychologists play a crucial role in addressing a wide range of mental health concerns, often engaging in direct clinical care, leadership, and research (Gray et al., 2015). Research indicates that most individuals prefer psychologists over psychiatrists, likely due to a preference for psychotherapy over psychotropic medications (Angermeyer et al., 2013; Qahar et al., 2020). Psychologists possess diverse skills that are beneficial across various populations, including psychiatric patients, children, and athletes. Despite available resources, barriers such as stigma, concerns about confidentiality, and the perception of mental health issues as a sign of weakness hinder many Canadians in seeking help (Gulliver et al., 2012).

Athlete Mental Health

The World Health Organization (WHO) defines health as the favourable state of an individual's physical, mental, and social well-being, which collectively contribute to their overall functioning (World Health Organization, 2016). On a global scale, health is used to evaluate an individual's resilience when experiencing physical, mental, or social challenges (Schnike et al., 2021). It is crucial to comprehend the interconnected nature of physical and psychological challenges concerning athletes within the context of this definition. Mental health in athletes has become an increasingly important area of focus, with research highlighting various mental health challenges and their implications. Athletes are subject to unique stressors such as intense training regimens, performance pressure, and injury recovery, which can contribute to mental health issues like depression, anxiety, and eating disorders (Reardon & Factor, 2010; Rice et al., 2016 Schnike et al., 2021).

Reardon and Factor (2010) discuss the prevalence of mental health disorders in athletes, noting that athletes may experience these issues at similar or higher rates compared to the

general population. Factors contributing to these mental health challenges include the pressure to perform, injuries, and the transition out of sports. Additionally, Rice et al. (2016) conducted a systematic review of mental health outcome variables in elite athletes and found that the prevalence of mental health issues such as anxiety and depression is significant. The study emphasizes the need for better mental health support and resources tailored specifically for athletes. Moreover, when an athlete experiences a decline in physical health, such as through injuries, it can lead to psychological complications, including relational issues, anxiety, depression, eating disorders, and heightened aggression (Castonguay & Oltmanns, 2013). To grasp the holistic ramifications of athlete health, one must recognize the significance of obstacles in the diagnosis and management of mental health.

Historically, mental health has been characterized as either high functioning or poor functioning (Schnike et al., 2021). This implies that athletes seeking assistance for their mental health symptoms would be evaluated as either having a disease or a disordered state or not (Murphy, 2012). This binary classification leaves considerable space for misconceptions that may hinder athletes from seeking assistance. Gulliver et al. (2012) highlight barriers to seeking help among athletes, including stigma, concerns about confidentiality, and the belief that mental health issues are a sign of weakness. These barriers can prevent athletes from accessing necessary care and support. Given the existing trend of both youth and adults historically avoiding seeking help for their mental health issues, it is unsurprising that athletes, in particular, have demonstrated a lower tendency to seek help compared to the general population (Sawyer et al., 2001; Gulliver et al., 2012). Among the obstacles identified by athletes, current reports highlight issues such as limited mental health literacy, individual characteristics, and attitudes

(Gulliver et al., 2010). Of these challenges, the most prevalent barrier consistently documented in the literature is the stigma associated with mental health.

Athletes, historically idealized for centuries and regarded as physically superior to the general population (Bär & Markser, 2013), encounter this pervasive stigma that can impede their mental health-seeking behavior. Athletes, both historically and presently, have been instructed to surmount mental and physical obstacles to attain peak performance, earning admiration for their resilience (Bär & Markser, 2013). This prevailing narrative reinforces the perception that athletes are either impervious to mental illness or possess the ability to triumph over it. Consequently, the stigma attached to mental health issues, coupled with the heightened pressure on athletes to exhibit no signs of vulnerability, may act as a deterrent to seeking help. This delay in seeking support has the potential to allow deteriorating mental health functioning to progress to clinically diagnosable levels without timely intervention (Watson, 2005). The influence of stigma on athletes' willingness to seek help is evident in a study conducted by Gulliver and colleagues (2012). This research explored the hurdles perceived by adolescent elite athletes when seeking assistance for their mental health. The findings indicated that more than 40% of the barriers identified by participants were associated with stigma and embarrassment. This suggests that athletes may harbour elevated levels of self-stigmatizing attitudes, aligning with prior research findings (Van Raalte et al., 1992).

Injuries and Mental Health

Injury can significantly affect an individual's mental health, often leading to conditions such as depression, anxiety, and substance use disorders. Studies have shown that athletes and other individuals involved in high-risk activities are particularly vulnerable to mental health issues following injuries due to the physical and psychological demands of their activities.

Injuries can disrupt an athlete's identity and career, leading to significant emotional distress and challenges in mental health (Reardon et al., 2019). For instance, the prevalence of mood disorders among injured individuals is notably higher compared to the general population, underscoring the need for comprehensive mental health support post-injury (Reardon et al., 2019).

Research shows that psychological factors play a role in the recovery process from sports injuries. For athletes, injuries can be life-altering, leading to significant mental health challenges (Barker, 2021). Athletes often face stressors that can impede their recovery, such as worries about eligibility, academic responsibilities, and relationship issues. These stressors can affect their physical recovery by causing stress-related symptoms such as digestive issues and a reduced ability to rest and heal. It is important for athletes to address these stressors rather than ignore them (Cleveland Clinic, 2023). Research has identified the importance of treating the psychological impact of an injury as well as the physical injury for the best outcome.

History of Sport-Related Concussions

The term "concussion" derives from the Latin "concutere" (agitation or shaking) and "commotio cerebri" (brain shaking or temporary loss of consciousness), first described by Hippocrates in the 5th century BCE (Townsend, 2021). This concept was expanded by Celsus and Galen in the 2nd century CE and further refined by the Persian physician Razes in the 9th century, who distinguished concussion as a functional injury separate from severe structural trauma (Mettler, 1947; Rhazes, 1548).

Contemporary Definitions

The definition of sport-related concussion (SRC) has evolved since its initial proposal by the Concussion in Sport Group (CISG) in 2001 (McCrory et al., 2017). The most recent update

occurred at the Amsterdam CISG meeting in 2022 where the Scientific Committee reviewed and modified the Berlin definition (Patricios et al., 2023). The accepted definition, although it did not reach an 80% consensus, states that *SRC is a traumatic brain injury caused by a direct blow to the head, neck, or body, resulting in an impulsive force transmitted to the brain during sports and exercise-related activities.* This triggers a neurotransmitter and metabolic cascade, potentially causing axonal injury, altered blood flow, and inflammation. Symptoms may appear immediately or evolve over time, typically resolving within days but sometimes persisting longer. Standard structural neuroimaging (CT or MRI) usually shows no abnormalities, though research settings may detect changes in functional, blood flow, or metabolic imaging (Patricios et al., 2023).

Prevalence of Sports-Related Concussions (SRCs)

Coined as a silent epidemic by Goldstein in 1990, sports-related concussions (SRCs) have been a concern for athletes since the inception of organized individual sports in 776 BC (Echemendia, 2006). The Center for Disease Control and Prevention (CDC) has provided alarming estimates, suggesting that in the United States alone, approximately 1.6-3.8 million athletes of all ages suffer from SRCs annually (Langlois et al., 2006). Specifically focusing on the younger demographic, Bryan and colleagues (2016) projected that 1.1 to 1.9 million athletes under the age of 18 experience SRCs each year. Notably, these estimates, while indicative of the widespread issue, do not delineate which sports contribute most significantly to the incidence of SRCs.

Concussion Risk and Symptom Severity Factors

To mitigate concussive injuries, recent research has emphasized the identification of individual-level concussion risk factors. Studies indicate that concussion risks are significantly

higher in contact sports such as football, rugby, and hockey compared to non-contact sports. The frequent collisions and physical interactions inherent in these sports contribute to this increased risk. Furthermore, concussions are more likely to occur during actual matches than during practice sessions due to the heightened intensity and competitive nature of games, which can lead to more aggressive play and higher injury risks (Patel & Ahmed, 2020).

Contact Sports

American Football is a contact sport and has one of the highest injury rates of all sports, particularly at the collegiate and professional levels (Prieto-González et al., 2021). According to a report by the National Football League (2020), the overall injury rate during the 2019 season was 4.9 injuries per 1,000 player hours, which was a slight decrease from the previous year. The most common injuries in the NFL are concussions, followed by knee and ankle injuries. The NFL has implemented various measures to reduce the risk of injuries, such as rule changes to limit dangerous hits and the implementation of a concussion protocol. Similarly, a study by the CFL Players' Association, (2020) found that the CFL had an injury rate of 31.6 injuries per 1,000 player-hours during the 2019 season, which is higher than the NFL's injury rate. However, this difference is likely because the CFL has a larger field and requires players to be in motion before the snap, which could increase the risk of injury. Nonetheless, the CFL has also implemented measures to reduce the risk of injuries and improve player safety. While there are some differences in the injury rates between the NFL and CFL, both leagues have taken measures to reduce the risk of injuries and improve player safety.

Increased medical oversight is provided to collision sports including North American football. Currently, the highest rates of SRCs are observed in rugby, hockey, and American football (Pfister et al., 2016). Variations in incidence rates are noted among sports, but American

football is acknowledged for having the most extensive body of literature supporting elevated prevalence rates for SRCs (Webbe, 2011).

Biological Sex

Biological sex is a significant factor in concussion risk. Research indicates that female high school and college athletes are 1.5 to 2.1 times more likely to experience concussions compared to their male counterparts (Lincoln et al., 2011; Covassin et al., 2003). This increased risk among females could be associated with higher anxiety, stress, and depressive symptoms in girls, but is likely due to a combination of physical, psychological, and physiological differences (Doucet et al., 2023; Dick, 2009). Younger athletes, in particular, may experience longer recovery periods, with about half of high school athletes needing more than 14 days to recover (Lau et al., 2009; Lau et al., 2012). These findings, however, lack controls and may have high false positive rates due to recovery criteria issues. Unlike sport-related concussions, there is limited knowledge about the factors influencing concussion risk among females in the military. Given the evolving roles of women in combat, further research is necessary to understand female concussion risks among service members. It is hypothesized that female cadets have a higher sport-related concussion risk than male cadets (Lincoln et al., 2011; Covassin et al., 2003). Conversely, males are at a higher risk for military-related concussions (Hoge et al., 2008). Therefore, it is anticipated that males will have greater risks and rates of training-related and free time-related concussions.

Additionally, a history of concussions and higher baseline psychological symptoms are expected to increase concussion risk. Research has found that females have a higher overall risk of concussions, including sport-related, academy training-related, and free time-related concussions, consistent with findings in high school and collegiate athletes (Lincoln et al., 2011;

Covassin et al., 2003; Abrahams et al., 2014). Outside of athletic contexts, males have a higher risk of military-related concussions and traumatic brain injuries (Bazarian et al., 2005; Cassidy et al., 2004; Hoge et al., 2008). However, studies on concussion incidence among service members have often focused on active-duty personnel and included few females (Wilk et al., 2010; Hoge et al., 2008).

Medical Comorbidities (migraine headaches, learning disorders, previous/multiple concussions)

In addition to biological sex, medical comorbidities such as migraine headaches, learning disorders, and previous concussions significantly influence the risk of subsequent concussions (Kutcher & Eckner, 2010). Abrahams et al. (2014) identified that a history of one or more concussions is one of the strongest predictors of future concussions in athletes, putting them at a higher risk due to increased vulnerability and reduced recovery time between injuries. This association was observed across various sports, although most studies primarily involved male participants. Schneider et al. (2013) also noted that pre-morbid symptoms play a role in concussion risk.

Mental health issues such as anxiety and depression often co-occur, complicating diagnosis and treatment. Pearson et al. (2013) reported that approximately 54% of individuals with generalized anxiety disorder also meet the criteria for depression. This high rate of comorbidity highlights the need for integrated treatment approaches that address multiple aspects of mental health simultaneously. The co-occurrence of these conditions can exacerbate symptoms, delay recovery, and increase the risk of further injuries, creating a cycle that can be difficult to break (Belzer & Schneier, 2004; Nguyen et al., 2005).

Additionally, Guskiewicz et al. (2003) showed that athletes with a history of multiple concussions experience more severe and prolonged symptoms with each new concussion, underscoring the cumulative effect of repeated head injuries. Specifically, a history of two or more concussions is associated with a higher number and severity of symptoms and slower recovery times compared to those with no or only one concussion (Chen et al., 2019; Register-Mihalik et al., 2009; Schatz et al., 2011; Wasserman et al., 2016; Cookinham & Swank, 2020). Recent studies support the cumulative effects of repeated concussions in athletes, emphasizing the need for comprehensive management strategies. For instance, a study by Roby et al. (2023) found that college athletes with a history of multiple concussions experience more severe and prolonged post-injury symptoms, particularly if the injuries occurred outside of sports contexts. This research highlights the importance of considering both sports-related and non-sports-related concussions in developing treatment protocols (Children's Hospital of Philadelphia, 2023). Similarly, Churchill et al. (2021) reported that young athletes with multiple concussions exhibit significant changes in brain structures, suggesting lasting impacts that require ongoing medical attention. These findings underscore the need for further investigation into how repeated head injuries affect athletes over time and across different demographics.

A history of concussion is significantly linked to an increased risk of depression, with the risk varying based on age and the number of concussions sustained. Adolescents with a history of concussion have a 3.3-fold higher risk of being diagnosed with depression (Chrisman & Richardson, 2014), while the risk for the elderly is doubled (Albrecht et al., 2015). The likelihood of developing depression increases markedly with the number of concussions; individuals with three or more concussions have a relative risk of developing depression that

rises from 1.5 to 3 compared to those with fewer than three concussions (Guskiewicz et al., 2007).

Factors such as injury severity, the number of injuries, and age at the time of injury influence the likelihood of post-traumatic brain injury (TBI) depression, indicating that TBI significantly contributes to depression risk across different demographics. A nationwide longitudinal study using large-scale national health insurance data in South Korea confirmed that TBI is significantly associated with an increased risk of depression in the general population (Choi et al., 2022). Athletes with a history of two or more concussions exhibit a higher number and severity of symptoms, and slower recovery compared to those with no or one concussion (Chen et al., 2019; Register-Mihalik et al., 2009; Schatz et al., 2011; Wasserman et al., 2016; Cookinham & Swank, 2020).

These findings emphasize the cumulative impact of repeated head injuries, which not only increase the risk of depression but also compound the severity of symptoms (Roby et al., 2023). As Churchill et al. (2021) noted, athletes with multiple concussions display structural brain changes, underscoring the long-term mental health effects of concussion histories. Such findings indicate a need for further research into how cumulative head injuries affect mental health outcomes, including depression, across different age groups and demographics.

Pre-Existing Concussion Symptoms

Baseline or pre-concussion symptoms, such as headache, have been associated with increased concussion risk in youth ice hockey players (Schneider et al., 2013). Baseline symptoms also influence post-concussion symptoms, whereby higher baseline somatization symptoms increase concussion-related symptom burden or reporting (Nelson et al., 2016). Approximately 85% of clinicians use a concussion symptom checklist to diagnose a concussion,

more than any other concussion evaluation tool (Baugh et al., 2016). Given the clinician's reliance on concussion symptoms for diagnosis, increased symptom burden or reporting due to greater baseline symptoms may increase concussion diagnosis likelihood. Thus, increased pre-concussion somatization or concussion symptoms may be associated with increased concussion risk due to physiological mechanisms or increased diagnosis. Individuals with a personal or family history of migraines are more likely to experience severe and prolonged post-concussion symptoms . This connection is thought to be due to the overlap in the pathophysiology of migraines and concussion symptoms. Headaches and fatigue are notably more severe in individuals with multiple concussions (Chen et al., 2019; Cookinham & Swank, 2020; Hänni et al., 2020; Covassin et al., 2013). Both single and multiple concussions increase the likelihood of lower extremity injuries in NFL players and collegiate athletes, suggesting that TBIs may heighten vulnerability to subsequent injuries (McCann et al., 2022; Baker et al., 2022).

Pre-Existing Mental Health Challenges (Anxiety, Depression and ADHD)

The link between concussions and mental health issues such as depression, anxiety and more recently ADHD is well-documented (Kutcher & Eckner, 2010). The disruption of the autonomic nervous system can exacerbate these conditions through several mechanisms: Neuroinflammation: Concussions can trigger neuroinflammation, affecting brain regions involved in mood regulation, such as the prefrontal cortex and amygdala. This can contribute to symptoms of depression and anxiety (Fann et al., 2004). Hypothalamic-Pituitary-Adrenal (HPA) Axis Dysfunction: The HPA axis, which controls stress responses, can be dysregulated following a concussion. This dysregulation can lead to altered cortisol levels and contribute to anxiety and depressive symptoms (Tanriverdi et al., 2010). Concussions can impact and alter neurotransmitter systems, particularly serotonin and dopamine, which play crucial roles in mood

regulation. Disruptions in these systems can lead to depressive and anxious states (Chen et al., 2008). Autonomic Dysfunction or dysregulation can result in physical symptoms such as palpitations, sweating, and gastrointestinal issues, which can exacerbate feelings of anxiety and contribute to a vicious cycle of worsening mental health (Sánchez-Manso, Gujarathi, & Varacallo, 2023). Understanding the role of ANS dysfunction in post-concussion depression and anxiety is crucial for developing effective treatment strategies. Interventions that target ANS balance, such as biofeedback, heart rate variability training, and mindfulness-based stress reduction, have shown promise in alleviating symptoms (Lee, Kim, & Wachholtz, 2015). Pharmacological treatments that address neuroinflammation and neurotransmitter imbalances may also be beneficial. For instance, selective serotonin reuptake inhibitors (SSRIs) are commonly used to treat post-concussion depression (Yue et al. 2017).

Research indicates that ADHD may increase the risk of multiple concussions in males and exacerbate cognitive deficits (Gunn et al., 2022; Nowak et al., 2022). Additionally, anxiety and depression following one or more concussions can worsen the severity of post-concussive symptoms, further complicating recovery (Kutcher & Eckner, 2010; Abrahams et al., 2014). A systematic review by Iverson et al. (2020) revealed that athletes with these pre-existing conditions often experience prolonged recovery times and more severe post-concussion symptoms compared to those without such issues. The review underscores the importance of considering an individual's mental health history in managing and treating sport-related concussions (Iverson et al., 2020).

A recent study of collegiate athletes found that increased baseline anxiety symptoms increased the likelihood of any injury in the following athletic season for both sexes. However, elevated depressive symptoms only increased subsequent injury risk for males (Li et al., 2017).

Since the recent study did not distinguish between concussive and non-concussive injuries (e.g. ankle sprain), it is unclear whether increased psychological symptoms have a specific influence on concussion likelihood. Consequently, the current study sought to determine the role of psychological symptoms on subsequent concussion risk. Research on the cumulative effects of multiple concussions has revealed that military personnel with a history of multiple concussions often experience severe post-concussive symptoms such as sleep disturbances, headaches, depression, PTSD, and anxiety (Bryan, 2013; Wilk et al., 2012; Bryan & Clemans, 2013; Vanderploeg et al., 2012). One study demonstrated that 21.7% of deployed service members with multiple concussions reported experiencing suicidal thoughts or behaviours compared to 6.9% of those with a single concussion and 0% of those with no history of concussion (Bryan & Clemans, 2013). However, the group without a history of concussion was considerably smaller than those with one or multiple concussions, potentially underestimating suicidal ideation in the no-concussion group. Recent research corroborates these findings. For example, veterans with a history of multiple concussions showed greater impairment in memory and higher severity of PTSD symptoms compared to those with a single concussion (Sorg et al., 2021).

Based on the previous literature, we hypothesize that increased pre-existing or pre-injury concussion, somatization, anxiety, and depression symptoms would increase the risk of concussion symptom severity and therefore also the likelihood of a subsequent concussion. The interplay between mental health and concussion recovery is complex, with stress and emotional disturbances potentially prolonging symptom duration (Iverson et al., 2020). The diagnoses of ADD/ADHD have similarly not been assessed for incident concussion risk among service members or cadets. These diagnoses have primarily been an outcome measure after TBI (Miller et al., 2015; Wells, 2010). The difficulty in establishing a comprehensive TBI history, coupled

with the lack of studies examining the relationship between previous medical history and incident concussion among service members, highlights a gap in the current research.

In contrast to the study by Li et al. (2017), the present analysis included somatization symptom scores. Somatization symptoms were significant predictors of any concussion, sport-related concussion, and varsity sport-related concussion. Higher somatization symptoms indicate a greater tendency to express psychosocial or emotional problems as physical ailments (American Psychiatric Association, 2013). Increased pre-concussion somatization symptom scores have been associated with longer recovery times post-concussion (Nelson et al., 2016). Specifically, pre-injury somatization was linked to more acute post-concussion symptoms, thereby extending recovery duration (Nelson et al., 2016). Thus, higher baseline somatization symptoms may influence concussion risk by exacerbating symptoms and facilitating diagnosis. However, it remains unclear whether increasing somatization directly heightens concussion risk or merely aids in diagnosis through heightened symptom experience or reporting. Given the generally healthy cadet population, even small increases in psychological symptoms, particularly somatization, can elevate concussion risk. Although results should be interpreted cautiously due to their small effect size, the significant impact of anxiety and somatization symptoms was maintained in multivariate models.

Concussion Mental Health Outcome Variables

There is a growing body of evidence indicating that concussions may be associated with an increased risk of depression and anxiety, especially in cases where the injury is severe or results in long-term symptoms. Hoge et al. (2008) conducted a study on U.S. soldiers with mild traumatic brain injuries and found that they were at greater risk of depression and anxiety compared to soldiers without such injuries. Similarly, Hou et al. (2012) identified psychological

factors such as depression and anxiety as risk factors for post-concussion syndrome after mild traumatic brain injury. McInnes et al. (2017) conducted a scoping review and found that anxiety and depression were commonly reported symptoms following mild traumatic brain injury. Finally, Taylor and Nippard (2015) studied the impact of psychological factors on recovery from concussion in athletes and found that higher levels of anxiety and depression were associated with prolonged recovery periods. These studies highlight the need for increased awareness of the potential psychological consequences of concussions and the importance of addressing them in the management and treatment of the injury.

Wagner (2020) evaluated the relationship between subjective mood symptoms on the SCAT3 and comprehensive mental health screening measures during baseline testing in CFL athletes. The study found that certain SCAT3 mood symptoms, such as "sadness," "irritability," "more emotional," and "nervousness," were significant predictors of broader measures (index scores of the BSI-18 and PROMIS 29) of depression and anxiety, suggesting their utility in identifying mental health issues when more comprehensive assessments are unavailable. This information can help clinicians identify athletes dealing with mental health issues when more comprehensive questionnaires are not available.

Theories of Health Recovery

Injuries including concussions are a common occurrence in athletes, and the recovery process can be influenced by a variety of factors, including mental health. Several theories and models propose that individuals with poor mental health may experience slower injury recovery, which can create a negative feedback loop that exacerbates both mental health and physical functioning. The biopsychosocial model (BPS) (Engel, 1977) suggests that health and illness are

shaped by the interplay of biological, psychological, and social factors. While this model encapsulates various theories, a deeper exploration is required to understand these interactions:

Cognitive appraisal theory (Lazarus, 1991), a psychological component of the BPS, examines how individuals interpret and evaluate stressful situations. This theory posits that psychological factors such as stress, anxiety, depression, and negative emotions can influence the body's immune and neuroendocrine systems, thereby affecting injury healing and recovery (Johnson et al., 2015). According to Taylor and Lentz (2017), stressful situations, like an injury, can impact both emotional and physical responses. Individuals with poor mental health, such as high levels of anxiety or depression, may have more negative appraisals of their injury and experience more negative emotions, potentially leading to more severe symptoms and a slower recovery.

Stanford psychologist Alia Crum (2023) was among the first to demonstrate the detrimental effects of a negative stress mindset. She discovered that individuals who perceived stress as debilitating experienced higher levels of anxiety and reported lower happiness compared to those who viewed stress as enhancing. Conversely, those who believed stress had positive effects exhibited greater optimism, improved work performance, and better physical health and immune responses. Crum's research indicates that it is not the stress itself but rather our perceptions and appraisals of it that impact our well-being.

From a social perspective, Cohen and Wills' (1985) Social Support Theory suggests that strong social support plays a crucial role in helping individuals cope with stressful situations, such as injury, and promotes positive health outcomes. Luttrell et al. (2016) suggest that individuals with poor mental health may experience reduced levels of social support, which can adversely affect their recovery from injury and exacerbate symptom presentation.

The health belief model (Rosenstock, 1974) suggests that an individual's beliefs and attitudes about their health and illness can influence their behaviours and health outcomes. Individuals with poor mental health may have negative beliefs and attitudes about their ability to recover from injury, which can impact their adherence to treatment and ultimately their recovery (Goddard et al., 2020). Luszawski et al. (2024) revealed how increased peer-related problems and heightened distress about concussion outcome variables, as reported by both participants and parents, were associated with prolonged recovery periods. Specifically, concerns regarding the effects of the concussion and the child's well-being at the time of injury significantly predicted longer recovery times. Psychological variables are among the strongest risk factors for persistent symptoms and disability after a mild traumatic brain injury (mTBI) more so than objective indicators of injury severity (e.g., loss of consciousness at impact) or structural brain damage (e.g., on diffusion tensor imaging) (Iverson et al., 2017; Lange et al., 2012; Silverberg et al., 2015; van der Naalt et al., 2017). Fear-avoidance behaviour, a coping style in which people avoid or escape from activities and situations that they expect will exacerbate their symptoms, may be an especially important and modifiable risk factor for chronic disability (Cassetta et al., 2021; Silverberg et al., 2018).

In summary, these theories collectively underscore the applicability of the Biopsychosocial Model (BPM) in understanding the relationship between injuries and mental health. They indicate that poor mental health can influence injury symptom severity, recovery, and overall health through various complex pathways and psychological factors. Addressing and treating mental health issues proactively before an injury can improve outcome variables, potentially reducing both injury occurrence and symptom severity. Incorporating mental health care for athletes before injury, during rehabilitation, and after recovery can also promote optimal

performance and well-being. The relationship between mental health and physical health is complex and bidirectional, meaning each can influence the other. Several mechanisms demonstrate how mental health can affect physical health and vice versa, emphasizing the need for a holistic approach to treatment.

Overview and Structure of the Active Rehab Study (ARS)

The Active Rehab Study Consortium, initiated in 2014, emerged from an international meeting involving scientific and sports organizations. Led by The University of North Carolina at Chapel Hill and the Medical College of Wisconsin, the consortium developed a formal protocol titled "Role of Active Rehabilitation in Concussion Management: A Randomized Controlled Trial" (The Active Rehab Study). The study involves collaboration with and recruitment from the CFL, New Zealand Super Rugby, North American Colleges/Universities, and Wisconsin and North Carolina High Schools, representing various sports and age groups. The research complies with US and international guidelines, with approval from The University of North Carolina at Chapel Hill Institutional Review Board. Participants, spanning multiple sports and demographics, provide written and informed consent in adherence to ethical standards. Consent documentation is meticulously tracked throughout the study.

The Active Rehab Study Consortium conducted a randomized controlled trial, enrolling participants based on specific eligibility criteria. Inclusion criteria encompassed ages 12-30, recent concussion with medical evaluation, proficiency in English or French, and ability to provide informed consent. Exclusion criteria involved pre-injury neurological, cognitive, or psychiatric disorders, history of moderate or severe traumatic brain injury, prior participation in active rehabilitation for concussion, uncontrolled seizures, recent head injury causing loss of

consciousness, contraindications to moderate-intensity exercise, cardiovascular complications, and pregnancy. CFL-specific data was utilized in the current study.

Current Study:

Current research suggests that athletes with increased levels of anxiety, depression, somatization, previous concussion history, learning disorders, ADHD, SCAT symptom severity scores, and BSI scores are at an increased risk for more severe symptoms or outcome variables following a sport-related concussion (SRC). This study seeks to fill a gap in the literature by examining the relationship between pre-concussion demographic factors and BSI outcome variable scores with the severity of post-concussion mental health symptoms (outcome variables) in professional football players (CFL) immediately after a concussion. Our goal was to determine the key predictors or vulnerability factors for high-symptom responders, thereby enhancing the understanding of concussion outcome variables and informing targeted intervention strategies. Given that these concussion risk factors may contribute to more severe symptoms and prolonged recovery times, understanding concussion outcome variables could aid in forecasting the duration of recovery. Additionally, this knowledge could help identify situations where proactive treatment should be prioritized, thereby improving the management and outcome variables of concussions in athletes.

The present study adds to the existing body of literature by delving deeper into the application of contemporary neuropsychological tests for SRC in both screening and managing the mental health of athletes. Using data collected from The ARS Study by Gauthier et al.

(2019), we analyzed the relationship between pre-concussion BSI variables (anxiety, depression, somatization, and total BSI scores) and their post-concussion levels in CFL players. The study aims to investigate the following hypotheses:

Objective:

The objective of this study is to examine the relationship between baseline or pre-concussion variables—including anxiety, depression, somatization, previous concussions, learning disorders, ADHD, total SCAT symptom severity scores, and BSI total scores—and mental health outcome variables following a concussion.

1) ***Alternate Hypothesis:*** There is a statistically significant positive correlation between demographic variables and Brief Symptom Inventory (BSI) mental health outcome variables—specifically anxiety, depression, somatization, and total BSI scores—at baseline.

2) ***Alternative hypothesis:*** Pre-concussion BSI and SCAT total symptom scores will show a significant increase post-injury, as indicated by t-test analyses.

3) ***Alternative hypothesis:*** Pre-concussion BSI variables, along with demographic factors, will predict higher levels of depression and anxiety in BSI outcome measures post-concussion, as determined by correlation and regression analyses.

Chapter Three: Method

This chapter outlines the research methods employed in this study, providing a comprehensive overview of the research design, key terms, participants, measures, data collection procedures, ethical considerations, and statistical analyses.

Participants

The data utilized in the present study were sourced from participants enlisted during pre-season medical evaluations held at nine distinct team locations within their respective cities at the onset of both the 2017 and 2018 seasons. A total of 809 participants were approached to participate in the study. Sixteen participants did not complete portions of the SCAT3 and BSI-18 and were removed from the study. Overall, the final sample size (N) was 793 CFL adult players (18 years and older). The conclusive constituted approximately 90% of the CFL population indicating a good representation. The athletes were all male and ranged from 21 to 37 years old (M= 25.35, SD = 2.79).

Inclusion Criteria

a) consent/agreement of CFL to participate in the study, b) completion of SCAT3 at BSI-18 at the start of the 2017 – 2019 season and c) cleared by medical personnel prior to participating in baseline testing.

Exclusion Criteria

a) another injury besides a concussion, b) non - proficient English language speaker and c) not medically cleared from previous concussion diagnosis.

Key Terms:

a) **Concussion (Sport-Related Concussion, SRC):** According to the fifth International Consensus Statement (McCrory et al., 2017), which was the most current at the time of data collection, a concussion or SRC is defined as "a traumatic brain injury induced by biomechanical forces." This definition underscores the physical nature of the injury and its connection to biomechanical impacts, commonly occurring in sports contexts. It should be noted this definition was chosen given that the study took place prior to the more recent (6^{th}) International Consensus Statement.

b) **Mental Health:** The World Health Organization (WHO, 2014) defines mental health as a state of well-being where individuals recognize their potential, manage the normal stresses of life, work productively, and contribute to their community. This definition highlights the holistic nature of mental health, encompassing emotional, psychological, and social well-being.

c) **Outcome Variables:** In this study, outcome variables refer to the specific symptoms measured, providing quantifiable data to assess the effects of concussion on mental health.

d) **Anxiety:** Anxiety is characterized by a state of worry, uneasiness, apprehension, or fear about future uncertainties, often accompanied by physiological responses such as muscle tension and elevated blood pressure (American Psychological Association, 2013). This definition captures both the emotional and physical aspects of anxiety, making it a key focus in understanding post-concussion mental health outcomes.

e) **Depression:** Depression is defined as a persistent state of sadness, hopelessness, and a loss of interest in activities that were once enjoyable. It may also manifest in physical symptoms such as chronic pain or digestive issues, highlighting the complex interplay between mental and physical health (American Psychological Association, 2013).

f) **Somatisation**: Somatisation is generally defined as the tendency to experience psychological distress in the form of somatic symptoms and to seek medical help for these symptoms, which may be initiated and/or perpetuated by emotional responses such as anxiety and depression (Al Busaidi, 2010).

f) **Demographic Variables:** refer to the presence of ADHD, learning disabilities, and a history of mental health conditions.

g) **Mental Health Variables:** consist of the BSI outcome measures, including scores for anxiety, depression, and somatization.

h) **Athlete:** In this study, the term "athlete" specifically refers to individuals within the sample who are active competitors in the Canadian Football League (CFL), aged 21 to 37 years. This demographic focus allows for targeted analysis relevant to this unique population.

Research Design and Data Collection

Data collection was securely conducted by team medical personnel using both paper-and-pencil and electronic methods. This process included baseline mental health assessments at the start of the season and injury diagnoses by qualified team physicians. Participants provided demographic information, completed medication and medical history questionnaires, and filled out Standardized Concussion Assessment Tool (SCAT) symptom assessments. The study employs a longitudinal repeated measures design, combined with survey methods, which allows for a high level of control over variables while examining significant relationships without unnecessary complexity (Muijs, 2011). The study leverages data from the "Methodology and Implementation of a Randomized Controlled Trial for Early Post-concussion Rehabilitation: The ARS," conducted by Register-Mihalik et al. (2019). Specifically, baseline reports of concussion and mental health symptoms were gathered from the SCAT and the BSI-18. The demographic variables included a prior history of concussion, pre-morbid mental health diagnosis history, prior history of learning disorders, and prior history of ADHD. Participants were assessed at 2 time points, baseline (pre-season) and within 48 hours of being diagnosed with concussion.

Outcome Measures (Mental Health Variables)

BSI-18 Depression

Clinical research in mental health has historically grappled with the challenge of patient-reported outcome variables lacking rigorous methodology, often assessing broad symptoms like fatigue and depression, resulting in incomparable data (Gershon et al., 2010). Recognizing the need for standardized symptom measurement, quantitative self-report measures have emerged as the gold standard for evaluating mental health outcome variables following SRCs (Rice et al., 2018). The BSI-18, a widely applied self-report questionnaire, has become a cornerstone in assessing psychological distress and psychopathology symptoms in this context.

Derived from the original BSI, the BSI-18 comprises 18 items measuring three crucial dimensions: somatization, depression, and anxiety. Respondents employ a 5-point Likert scale to rate the severity of symptoms over the past week. Individual dimension scores are calculated by summing relevant items, and an overall assessment is provided through the Global Severity Index (GSI). Specifically designed for individuals aged 18 and older, the BSI-18 serves as a versatile tool for screening psychological symptoms and monitoring changes in symptomatology over time. Additionally, it provides norms for various populations, enabling comparisons within specific groups or against the general population.

The focus on the BSI-18 depression subscale in the study aimed to assess the frequency of the depressive symptom outcome variable in CFL athletes with a history of concussions. This depression subscale is a quantitative self-report measure widely used by physicians and athletic trainers to evaluate depressive mental health outcomes post-SRC (Rice et al., 2018). Notably, it was chosen for its good internal consistency, as demonstrated by Meachen and colleagues (2008), who found moderate to strong internal consistency for the depression index in individuals with traumatic brain injuries.

The selection of the BSI-18 depression subscale is underscored by its relevance to athletes with a history of concussion, as evidenced by Weber and colleagues' (2018) study comparing baseline scores of athletes with and without concussion history. Athletes with a history of concussions showed higher BSI-18 depression subscale scores, emphasizing its accuracy in measuring psychological distress in this specific population. In summary, the BSI-18, with a focus on the depression subscale, addresses the methodological limitations of traditional mental health patient-reported outcome variables, offering a standardized and validated approach for assessing and monitoring psychological symptoms post-SRC (Rice et al., 2018; Meachen et al., 2008; Weber et al., 2018).

BSI-18 Anxiety

The aim of utilizing the BSI-18 anxiety subscale was to evaluate the prevalence of anxiety symptoms among CFL pre concussion. As mentioned earlier, the BSI-18 anxiety subscale is one of the three subscales integrated into the broader BSI-18 framework, encompassing somatization, depression, and anxiety dimensions (Franke et al., 2017). Comprising six items rated on a five-point Likert Scale (ranging from 0 for "not at all" to 4 for "extremely"), the anxiety subscale yields an overall score within the range of 0 to 24 (Combs et al., 2017; Weber et al., 2018). Elevated scores on this subscale signify heightened levels of distress (Lancaster et al., 2016).

According to Meachen and colleagues (2008), the selection of the BSI-18 anxiety subscale was grounded in its widespread use and robust internal consistency, as evidenced by a Cronbach's α range of .74 to .83 (Dancey & Reidy, 2007). Accounting for demographic factors, this subscale demonstrates incremental validity in predicting a patient's psychosocial, psychological, and functional status (Meachen et al., 2008). Moreover, it has been instrumental

in exploring the psychometric properties of individuals with traumatic brain injuries (TBI) and assessing the emotional well-being of athlete's post-SRCs (Meachen et al., 2008; Lancaster et al., 2016).

In the study by Lancaster et al. (2016), a comprehensive analysis, including test-retest reliability, internal consistency reliability, and concurrent validity, was conducted on athletes' BSI-18 scores. The findings indicated commendable internal consistency, fair to poor test-retest reliability, and substantial convergent validity concerning other measures of emotional functioning. The selection of this index is particularly apt as it specifically addresses anxiety-related mental health symptoms in athletes with a history of concussions, aligning with the focus population in this investigation.

Statistical Analysis

Several analyses were conducted to examine the relationship between baseline mental health factors and post-concussion outcome variables. First, the assumptions required for Pearson correlation and stepwise regression analyses were evaluated, and outliers were managed using casewise diagnostics. The analysis began with an assessment of baseline frequencies to determine the prevalence of pre-existing conditions among participants. Descriptive statistics were then calculated for psychological measures (BSI) to understand their distribution and variability. Next, we explored correlations among the demographic variables (history of concussion, history of LD, history of ADHD, history of mental health diagnoses) with the Total Symptom score from the SCAT and mental health symptoms (BSI total score, BSI- somatization, BSI – depression, BSI – anxiety) at baseline. The BSI scores were categorized into 5 groups (average, minimal, mild, moderate, and severe) using normative data from McCrea et al. (2016). Next, we undertook a t-test to evaluate group-level differences of Total Symptom score from the

SCAT and BSI outcome variables. among the 39 participants who were diagnosed with concussions, comparing baseline and post-injury data. Then, regression analysis was employed to predict the relationship between the baseline demographic variables, baseline Total SCAT symptom Score, and BSI outcome variable scores with post-injury BSI Depression and BSI Anxiety Scores. This approach allowed us to explore the relationships between key variables—previous concussions, BSI anxiety, and BSI depression—and the dependent variable, symptom scores. Stepwise regression was employed to pinpoint significant predictors of these post-injury outcome variables.

The statistical analyses were conducted using IBM SPSS Statistics for Macintosh, Version 28 statistical software, with significance levels set at $p < 0.05$. This approach aligns with the study's objectives, which include examining correlations between predictor variables and outcome variables prior to concussion (Objective 1), conducting t-tests to identify significant the relationship in BSI and SCAT scores at baseline or pre-concussion (Objective 2), and using regression analysis to predict post-concussion BSI anxiety and depression based on baseline factors (Objective 3).

Ethics

This study, sourced data from the ARS overseen by Dr. Mrazik and Dr. Naidu. Ethics approval (Pro00073481) for this project was secured from the University of Alberta's Research Ethics Board. Participants underwent an informed consent process, detailing the study's purpose, requirements, and risks/benefits. As per CFL regulations, athletes underwent baseline testing, including SCAT3 and neuropsychological tests, before participating. The study adhered to international research standards, gained approval from relevant ethics boards, and followed clinical trial registration standards (NCT02988596).

Chapter 4: Results

The purpose of this study was to further understand the relationship between baseline or pre-concussion demographic and mental health factors—including anxiety, depression, somatization, previous concussion history, learning disorders, ADHD, SCAT symptom severity scores, BSI scores—and mental health outcome variables following a concussion.

Baseline Frequencies

Table 1 shows the baseline frequency of specific conditions among participants. A history of concussion was reported by 358 individuals, representing 45.1% of the sample. Mental health diagnoses were less common, reported by 8 participants (1.0%). ADHD was more prevalent, with 79 participants (10.0%) reporting the condition, aligning with other literature noting the relatively high frequency of ADHD in football. Lastly, 33 participants (4.2%) reported having a learning disorder. These frequencies emphasize the prevalence of concussion history and ADHD in the sample, while mental health diagnoses and learning disorders are less common.

Descriptive Statistics

Table 2 presents the descriptive statistics for the study's psychological measures. SCAT Symptom Severity scores ranged from 0.00 to 70.00, with a mean of 1.75 and a standard deviation of 4.73, indicating low average symptom scores but considerable variability among participants. Somatization scores from the BSI were generally low, with a mean of 0.21 and a standard deviation of 0.78. Depression scores showed similarly low variability, with a mean of

0.26 and a standard deviation of 0.93. Anxiety scores were slightly higher, with a mean of 0.40 and a standard deviation of 1.13, reflecting moderate concern among participants. The BSI, with a mean of 0.88 and a standard deviation of 2.41, exhibited the greatest variability and highest symptom scores among the psychological measures. Overall, these statistics suggest that while the sample reports low average levels of psychological symptoms—expected among healthy professional football players—there was significant variability, particularly in symptom scores as measured by the SCAT and the BSI.

Brief Symptom Inventory (BSI) Frequencies

Table 3 presents the frequency distribution of participants across different severity categories for the BSI and its subscales: somatization, depression, and anxiety. Most participants fall into the "Average" category for all measures. A smaller percentage are classified as "Minimal": 4.9% for the BSI total score, 8.3% for somatization, 9.5% for depression, and 4.8% for anxiety. Fewer participants fall into the "Mild" category, with 2.1% for the BSI total score, 1.6% for somatization, 2.3% for depression, and 2.5% for anxiety. The "Moderate" and "Severe" categories include only a few participants: 0.3% for the BSI total score, 0.5% for somatization, 0.3% for depression, and 0.6% for anxiety in the "Moderate" category, and 0.3% for both the BSI total and depression, 0.4% for somatization, and 0.9% for anxiety in the "Severe" category.

These distributions indicate that most participants exhibit normal symptom levels, with few reporting severe psychological symptoms, consistent with expectations for a healthy population. The BSI total score and its subscales follow a similar pattern, indicating minimal psychological distress in the majority of participants.

Objective 1:

Correlation Coefficients Pearson Correlation

A Pearson Correlation analysis was conducted to explore the relationships between predictor and outcome variables prior to concussion. Table 4 presents the correlation coefficients between various baseline characteristics, SCAT symptom scores, and psychological measures, including BSI somatization, depression, and anxiety. Correlations between a history of concussion and other variables are generally weak, with the highest being with Depression ($r = 0.078$, $p < .05$), indicating a small but statistically significant association. The correlation between mental health diagnosis and ADHD diagnosis is moderate ($r = 0.092$, $p < .05$), while the correlation between mental health diagnosis and learning disorder diagnosis is slightly stronger ($r = 0.105$, $p < .01$). These findings suggest that individuals with a mental health diagnosis are somewhat more likely to also have ADHD or a learning disorder prior to concussion.

The SCAT Symptom Severity score shows moderate correlations with mental health diagnosis ($r = 0.116$, $p < .01$), ADHD diagnosis ($r = 0.154$, $p < .01$), and the BSI ($r = 0.536$, $p < .01$), indicating that higher symptom scores are linked to greater psychological distress. The BSI shows strong correlations with Somatization ($r = 0.692$, $p < .01$), Depression ($r = 0.701$, $p < .01$), and Anxiety ($r = 0.785$, $p < .01$), indicating that individuals reporting higher levels in one category tend to report higher levels in others as well. Anxiety shows the strongest correlation with the BSI, suggesting it is a major contributor to overall psychological distress in this sample. Overall, these correlations indicate that while some baseline characteristics are weakly associated with psychological symptoms, SCAT Symptom Severity is more strongly linked to overall psychological distress, as measured by the BSI and its subscales. The significant correlations among the BSI subscales suggest that these psychological constructs are closely related in this population.

Objective 2:

T-Test Analysis

T-tests were conducted to compare baseline BSI scores (Somatization, Depression, Anxiety, and Total Score) with post-injury scores. The analysis revealed a significant increase in somatic symptoms after injury, with somatization scores showing a notable difference ($p = .004$ with equal variances assumed, $p = .005$ with unequal variances). Depression scores also worsened significantly post-injury ($p = .007$ with equal variances assumed, $p = .008$ with unequal variances). Additionally, the Total BSI Score indicated a significant rise in overall psychological distress ($p = .009$ for both equal and unequal variances). In contrast, anxiety scores did not show a significant difference between baseline and post-injury levels ($p = .153$), suggesting that anxiety symptoms remained relatively stable following the injury.

The effect size analysis reveals moderate decreases in somatization, depression, and overall psychological distress following injury, as indicated by consistently negative effect sizes across Cohen's d, Hedges' correction, and Glass's delta. Somatization and depression show particularly notable changes. However, the impact on anxiety is less clear, with Cohen's d and Hedges' correction suggesting a small, non-significant decrease, while Glass's delta indicates a moderate reduction. Overall, these findings suggest that traumatic brain injury has a substantial effect on increasing certain psychological symptoms, though the effect on anxiety is less pronounced. For anxiety, the T-test suggests no significant difference, likely due to sample size

or variability, while Glass's delta indicates a moderate effect, emphasizing that there could still be a meaningful but not statistically detectable change.

Objective 3:

Regression Analysis: Predicting Post-Injury Anxiety

Table 5 presents the results of a regression analysis predicting post-concussion anxiety. The dependent variable was post-concussion BSI anxiety from the post-injury assessment, with pre-injury variables—including pre-morbid mental health diagnosis, learning disorder (LD), ADHD, history of concussions, and BSI subscale scores (somatization, depression, and anxiety)—as predictors. The analysis revealed that two predictors significantly contributed to post-injury anxiety levels. First, pre-injury BSI somatization scores showed a significant negative relationship with post-injury anxiety ($\beta = -0.697$, $t = -3.127$, $p = 0.004$), indicating that higher pre-injury somatization was associated with lower post-injury anxiety. Conversely, pre-injury BSI anxiety scores had a significant positive association with post-injury anxiety ($\beta = 0.649$, $t = 2.405$, $p = 0.022$), suggesting that participants with higher pre-injury anxiety experienced greater post-injury anxiety. Total SCAT symptom severity also emerged as a significant predictor of post-injury anxiety ($\beta = 0.627$, $t = 5.553$, $p < 0.001$), indicating that participants with more severe symptoms reported higher levels of anxiety post-injury. Other variables, including pre-injury BSI depression ($\beta = 0.164$, $t = 0.584$, $p = 0.563$), concussion history ($\beta = 0.158$, $t = 1.407$, $p = 0.170$), ADHD diagnosis ($\beta = -0.001$, $t = -0.009$, $p = 0.993$), and learning disorder diagnosis ($\beta = 0.016$, $t = 0.118$, $p = 0.906$), did not significantly predict post-injury anxiety levels.

In summary, the most influential predictors of post-injury anxiety were pre-injury somatization, pre-injury anxiety, and SCAT symptom severity, with the latter accounting for the largest portion of the variance in anxiety levels after the injury. Additionally, none of the participants with a pre-existing mental health diagnosis had been diagnosed with a concussion, indicating that a sample including individuals with pre-injury mental health diagnoses might yield different results.

Regression Analysis: Predicting Post-Injury Depression

Table 6 presents the results of a regression analysis identifying predictors of depression following a concussion. The analysis included pre-injury variables (such as pre-existing mental health diagnoses, learning disorders, ADHD, and concussion history) and baseline BSI subscale scores (somatization, depression, and anxiety). The Total BSI score was excluded due to collinearity with its subscales. The results showed that SCAT Symptom Severity score was the only significant predictor of post-injury depression ($\beta=0.702$ $t=5.091$, $p<0.001$), indicating that higher severity of concussion-related symptoms strongly predicts increased levels of depression. A stepwise regression confirmed that Baseline SCAT Symptom Severity Score was the sole significant factor ($R^2=0.48$, $F(1,37)=33.74$, $p<0.001$).

In contrast, other pre-injury variables—including somatization, depression, anxiety, concussion history, ADHD diagnosis, and learning disorder diagnosis—did not significantly predict post-injury depression, suggesting these factors are not associated with changes in depression levels after an injury in this sample. Notably, none of the participants with a pre-existing mental health diagnosis had a concussion, which could influence these findings. Overall, the analysis suggests that baseline concussion symptom severity score is the key determinant of

post-injury depression, while other pre-injury psychological and diagnostic factors do not have a significant impact.

Chapter 5 – Discussion

Objective 1

The first objective was to assess whether predictor variables such as mental health diagnoses, ADHD, and learning disorders were significantly correlated with outcome variables prior to concussion. The analysis revealed that individuals with pre-existing mental health diagnoses were more likely to also have ADHD or a learning disorder, suggesting a strong relationship between these variables before injury. Furthermore, the SCAT Symptom Severity Score was found to be moderately linked to higher levels of psychological distress, indicating its utility in predicting mental health challenges in at-risk individuals prior to concussion.

These findings support the broader literature, which highlights the moderate to strong correlation between ADHD, learning disorders, and mental health diagnoses and their significant impact on psychological distress, as seen in the SCAT and BSI assessments (Drobnjak, 2013; Franke et al., 2017). The use of such measures helps clinicians to identify mental health issues pre-concussion, allowing for better preventative strategies and support for affected individuals.

Objective 2

The second objective was to determine if there were significant changes in BSI symptoms (outcome variables), including anxiety, depression, and somatization, following a concussion. T-tests revealed a significant increase in somatization ($p = .004$) and depression ($p =$

.007) post-injury, as well as an overall rise in psychological distress (p = .009). However, anxiety scores did not show a significant difference (p = .153) between baseline and post-injury levels. The effect size analysis highlighted moderate increases in somatization, depression, and overall psychological distress following the injury. Despite the lack of significant change in anxiety, the results suggest that concussions substantially impact somatization and depression, while the effect on anxiety is less pronounced. The observed discrepancies between the T-test results and effect size analysis for anxiety may be due to variability or sample size, indicating that while changes in anxiety were not statistically significant, they might still be meaningful.

Research demonstrates that somatization and depressive symptoms significantly increase after a concussion. Lau et al. (2011) and Lambert et al. (2022) found that common symptoms such as headaches and dizziness are frequently reported alongside depressive symptoms, which supports the T-test findings of significant increases in somatization (p = .004) and depression (p = .007). Polinder et al. (2018) also demonstrated an immediate rise in overall psychological distress post-concussion, which aligns with our results (p = .009). Anxiety tends to be more variable in the acute phase of a concussion. Although some studies report non-significant changes in anxiety, this variability, as seen in our study (p = .153), may still indicate meaningful changes, as suggested by effect size analyses (Lariviere et al. (2019). While anxiety might not show a significant statistical increase, its potential impact should not be disregarded.

Additionally, post-concussion symptoms are influenced by a mix of somatic, cognitive, and emotional factors, contributing to the overall psychological distress (Polinder et al., 2018). This further supports our findings of increased distress following the injury. While depression and somatization are consistently impacted, anxiety appears less predictable, potentially explaining the lack of significant findings in your analysis. Regarding anxiety, studies report

variability in outcomes. While some individuals with PPCS experience increased anxiety, the overall effects are less consistent compared to somatization and depression. The observed variability may account for the lack of statistically significant changes in anxiety ($p = .153$), despite effect size analysis indicating potentially meaningful shifts (Polinder et al., 2018; Lambert et al., 2022). This suggests that while statistical tests did not capture significant differences, underlying changes in anxiety levels may still hold clinical relevance, warranting further investigation.

Objective 3

The next objective was to conduct a regression analysis to understand the relationship between baseline (pre-concussion) demographic variables and mental health results and how they predict post-concussion mental health outcome variables, specifically BSI anxiety and depression. The anxiety regression analysis revealed that pre-injury somatization and anxiety, along with the SCAT Symptom Severity Score, were significant predictors of post-injury anxiety. Intriguingly, higher pre-injury somatization was associated with lower post-injury anxiety, while higher pre-injury anxiety and greater SCAT Symptom Score predict increased anxiety after an injury. One explanation for this relationship with pre-injury somatization is that individuals accustomed to persistent physical complaints may develop coping mechanisms, reducing their emotional reactivity to new symptoms like those from an injury. Additionally, these individuals may be less sensitive to symptom changes, perceiving post-injury symptoms as less distressing due to their habitual focus on somatic experiences.

Another possibility is that those with chronic somatic symptoms normalize physical sensations, which could result in less anxiety when new symptoms arise. Somatization might also shift their focus to physical rather than emotional concerns, leading to lower anxiety post-

injury. In some cases, somatization may even serve as a defence mechanism, displacing psychological distress into physical symptoms and shielding individuals from heightened anxiety. This finding highlights the complex interplay between somatization and anxiety, suggesting that pre-existing symptom management strategies may play a protective role in moderating post-injury anxiety. Other factors, such as pre-injury depression, ADHD, learning disorders, and concussion history, were not significant predictors of post-injury anxiety in our population.

In contrast, the depression regression analysis showed that the SCAT Symptom Score was the only significant predictor of post-injury depression, indicating that higher severity of concussion symptoms strongly correlates with increased depression levels after an injury. Thus, predictors of a depressed mood post-injury may be nonspecific and associated with a broad range of symptoms, not just mental health symptoms. Specifically, pre-injury somatization is linked to more acute post-concussion symptoms including depression and anxiety, which can extend recovery duration (Nelson et al., 2016). Therefore, higher baseline somatization symptoms may influence concussion risk by exacerbating symptoms and facilitating diagnosis. These studies support our findings and underscore the importance of recognizing and addressing the psychological consequences of concussions in their management and treatment. This also aligns with Iverson et al.'s (2017) systematic review in which pre-injury mental health factors, such as anxiety and somatization, influence post-injury mental health outcomes. Their review supports the finding that higher symptom severity scores predict worse post-concussion outcomes, including increased anxiety and depression, in line with the SCAT symptom severity predictor in our regression analysis. McCrea et al. (2003) highlight the importance of baseline characteristics, such as pre-injury mental health and post-concussion symptom severity, as key predictors of

recovery and post-injury mental health outcomes. The alignment between these studies and results from the current study indicate the critical role of symptom severity and pre-injury mental health in shaping post-concussion psychological outcomes.

Strengths and Limitations

This study has several notable strengths. One major strength is the large sample size of 793 CFL players, which improves the generalizability of the findings. Additionally, the inclusion of 358 participants with a history of concussion provides robust statistical power. However, the study's cross-sectional and retrospective design limits the ability to draw causal. A limitation is the reliance on self-reported measures like the SCAT3 and BSI-18, which are susceptible to response biases, such as socially desirable answers or underreporting due to stigma and pressure to play (Duckworth & Yeager, 2015; Gulliver et al., 2012; Rice et al., 2018). Poor mental health literacy and personal attitudes may further hinder accurate reporting of symptoms, compromising data reliability (Creswell & Creswell, 2018; Sawyer et al., 2001; Van Raalte et al., 1992).

Despite assurances of confidentiality, self-report measures can still lead to inaccurate reporting due to memory bias and pressures to continue playing (Warmath & Winterstein, 2019). While the BSI-18 is recognized for its efficiency and is widely used, it may not fully capture injury recovery time for CFL athletes, with anxiety scales accounting for more variance than depression scales (Lancaster et al., 2016; Dewitt et al., 2018). Future research should explore using SCAT3 and BSI-18 during baseline testing to replicate and expand on these findings.

The study's findings underscore the need for more comprehensive measures tailored to athletes' psychological responses, especially in contexts where shorter questionnaires like the BSI-18 are favoured for practical reasons. Finally, the study's insight into pre-injury mental

health factors, such as anxiety and somatization, highlights their role in post-concussion psychological distress, particularly anxiety and depression (Hoge et al., 2008; McInnes et al., 2017; Fann et al., 2004). These results align with existing research, emphasizing the predictive power of SCAT Symptom Scores in post-concussion mental health outcomes (Giza et al. 2013).

Conclusions and Future Directions

The findings of this study determined that subjective depressive symptoms on the BSI-18 appear to reasonably predict concussion outcome variables, suggesting the BSI-18 might be a useful screener for CFL athletes. This study has the potential to significantly impact a wide range of individuals and groups, including football coaches, sports medicine professionals, sports psychologists, football players, and possibly the general public. By enhancing our understanding of the relationship between mental health and concussion recovery, the research could transform how we perceive, treat, and rehabilitate sports injuries.

Future research should focus on several key areas to build on the findings of this study. First, expanding the sample size and including a more diverse population could enhance the generalizability of the results and provide a more comprehensive understanding of the relationships between baseline characteristics and post-injury outcome variables. Additionally, longitudinal studies tracking individuals over a longer period could offer insights into the long-term effects of concussion on mental health and recovery trajectories. Exploring the role of additional psychological and environmental factors, such as social support and coping strategies, could further illuminate the mechanisms underlying post-concussion mental health changes. Investigating the effects of specific concussion management and intervention strategies on mental health outcome variables could offer valuable insights for developing targeted therapeutic

approaches. Such research would allow mental health professionals to better interpret outcome variables for athletes with these conditions and to customize interventions more effectively. Future studies on mental health and cognitive performance in professional athletes should incorporate additional methods for assessing mental health, such as interviews and third-party questionnaires, as well as comprehensive neurocognitive evaluations and other high-psychometric tests to achieve more accurate results. Furthermore, integrating qualitative research methods could enhance the understanding of individual experiences and subjective perceptions of concussion-related psychological distress, offering a more nuanced perspective on the impact and recovery process.

Overall, there is a significant need for further research into the relationship between pre-concussion and post-concussion mental health among professional athletes. This study lays the groundwork for future investigations aimed at enhancing our understanding of how to better support athletes' mental health and achieve more precise results for each individual. While there have been notable advancements in the diagnosis and management of SRCs due to numerous high-quality, systematic studies, a similar focus is needed for athlete mental health following SRC. Increased attention in this area could drive research to improve intervention strategies, enhance methodological quality, and ensure more accurate diagnoses and management of mental health in athletes. By advancing SRC and mental health research, this study, along with future studies, could raise awareness about the importance of mental health screening in sports and contribute to more effective support for athletes.

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Table 1

Baseline Frequency

	Frequency	Percent
History of Concussion	358	45.10
Mental Health Diagnosis	8	1.00
ADHD Diagnosis	79	10.00
Learning Disorder	33	4.20

Table 2

Descriptive Statistics at Baseline

	N	Minimum	Maximum	Mean	Standard Deviation
SCAT Symptom Severity	780	0.000	70.000	1.751	4.730
BSI - Somatization	793	0.000	7.000	0.214	0.778
BSI - Depression	793	0.000	14.000	0.259	0.932
BSI -Anxiety	792	0.000	11.000	0.399	1.127
BSI - Total	793	0.000	32.000	0.884	2.408

Table 3

BSI Total Category Frequencies

Category	BSI	Somatization	Depression	Anxiety
Average	733(92.4%)	707(89.2%)	696(87.8%)	722(91.0%)
Minimal	39(4.9%)	66(8.3%)	75(9.5%)	38(4.8%)
Mild	17(2.1%)	13(1.6%)	18(2.3%)	20(2.5%)
Moderate	2(0.3%)	4(0.5%)	2(0.3%)	5(0.6%)
Severe	2(0.3%)	3(0.4%)	2(0.3%)	7(0.9%)

Table 4

Correlations at Baseline

	Mental Health Diagnosis	ADHD Diagnosis	Learning Disorder Diagnosis	SCAT Symptom Severity	Brief Symptom Inventory	Somatization	Depression	Anxiety
History of Concussion	0.061	0.028	0.001	0.063	0.057	0.062	0.078*	0.050
Mental Health Diagnosis	----------	0.092*	0.105**	0.116**	0.003	0.016	0.019	-0.027
ADHD Diagnosis		----------	0.373**	0.154**	0.081*	0.049	0.056	0.066
Learning Disorder Diagnosis			----------	0.071	0.020	-0.003	0.036	-0.023
SCAT Symptom Severity				----------	0.536**	0.468**	0.310**	0.504**
Brief Symptom Inventory					----------	0.692**	0.701**	0.785**
Somatization						----------	0.452**	0.560**

Depression							----------	0.450**
Anxiety								----------

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5

Regression Data of Variables: Predicting Anxiety of Variables Post-Injury

Predictor Variable	Beta	t	P
Pre-Brief Symptom Inventory Somatization	-0.697	-3.127	0.004
Pre-Brief Symptom Inventory Depression	0.164	0.584	0.563
Pre-Brief Symptom Inventory Anxiety	0.649	2.405	0.022
Concussion History	0.158	1.407	0.170
ADHD Diagnosis	-0.001	-0.009	0.993
Learning Disorder Diagnosis	0.016	0.118	0.906
SCAT Symptom Severity	0.627	5.553	< 0.001

a. Dependent Variable: Anxiety Post Injury

Note: Nobody from the sample who had a pre-existing mental health diagnosis was diagnosed with a concussion

Table 6

Regression Data of Variables: Predicting Depression of Variables Post-Injury

Predictor Variable	Beta	t	P
Pre-Brief Symptom Inventory Somatization	0.067	0.248	0.806
Pre-Brief Symptom Inventory Depression	0.005	0.015	0.988
Pre-Brief Symptom Inventory Anxiety	0.090	0.275	0.785
Concussion History	0.005	0.035	0.973
ADHD Diagnosis	-0.051	-0.374	0.711
Learning Disorder Diagnosis	0.085	0.506	0.617
SCAT Symptom Severity	0.702	5.091	< 0.001

a. Dependent Variable: Depression Post Injury

Note: Nobody from the sample who had a pre-existing mental health diagnosis was diagnosed with a concussion