Mental Health Outcomes of Elite Athletes Following Sport-Related Concussion

by

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A thesis submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

School and Clinical Child Psychology

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Abstract

The purpose of this research was to elucidate the short and long-term mental health outcomes following sport-related concussion (SRC) in a population of elite athletes. Specifically, symptoms consistent with anxiety, depression, and psychological distress were investigated in a population of 196 male professional and collegiate football players ages 18 to 34 years old. All athletes completed self-report measures (PHQ-9, GAD-7, and BSI-18) at baseline. Athletes who sustained a SRC (n = 16) in season as well as musculoskeletal (MSK) (n = 13) and healthy control (n = 21) athletes completed the PHQ-9 and GAD-7 at three time points. Results from the study indicated that athletes with a history of one or more SRCs reported greater symptoms of depression ($F(2, 193) = 10.88$, $p < .001$, partial $\eta^2 = .10$), anxiety ($F(2, 193) = 13.67$, $p < .001$, partial $\eta^2 = .12$), and psychological distress ($F(2, 193) = 18.01$, $p < .001$, partial $\eta^2 = .16$) at baseline in comparison to athletes with no history of SRC. Additionally, athletes who sustained a SRC reported greater levels of depression and anxiety at 24-48 hours post injury in comparison to the MSK and healthy control groups. No differences between groups were detected at later time points suggesting that this increase in depression and anxiety symptoms was short term. Finally, analysis at the individual level showed that 50% of SRC athletes demonstrated a reliable change from baseline to 24-48 hours post injury on the depression and/or anxiety self-report in comparison to 33% of MSK injured athletes and 17% of healthy controls. In addition, 58% of athletes who sustained a SRC reported a reliable decrease in depression and/or anxiety symptoms at one month return to play, suggesting that they were experiencing fewer anxiety and depression symptoms in comparison to baseline. Taken together, this research suggests that a history of SRC impacts baseline self-report of depression, anxiety, and psychological distress. Furthermore, athletes who sustain a SRC experience subtle increases in depression and anxiety symptoms in

the short term that appear to be unique to concussion. However, the athletes' self-reported depression and anxiety symptoms did not reach clinical levels and were short lived.

Preface

This thesis is original work by Carley Hoyle. However, some of the research conducted for this thesis forms part of an international research collaboration, led by Professor John Register-Mihalik, University of North Carolina, with Professor Martin Mrazik being the lead collaborator at the University of Alberta. Specifically, The demographic information and BSI-18 data were collected as part of the larger study. However, the PHQ-9 and GAD-7 data collection along with MSK and healthy control groups were distinct to this thesis research. The research project, of which this thesis is a part, received ethics approval from the University of Alberta Ethics Board, Project Name “Role of Rehabilitation in Concussion Management: A Randomized, Controlled Trial”, No. RES0036946, November 9, 2017.

Dedications

This dissertation and all the years of work that have been devoted to this research is first dedicated to my family. To my parents, for modeling tireless work ethic and providing unconditional support and encouragement every step of the way. To my husband for his patience and support. To my dearest friends, who are have continued to show me unwavering kindness, compassion, and encouragement. This work would not have been possible without my incredible team of family and friends.

Finally, this research is dedicated to those who have been concussed or injured during sport or other circumstances. My professional goals involve continuing to contribute to this field of research in order provide evidence based treatment to individuals who are struggling with concussion and other injuries.

Acknowledgements

Firstly, I would like to express my sincere gratitude to my supervisor Dr. Martin Mrazik for his continuous guidance, wisdom, and encouragement throughout graduate school. I am incredibly grateful for the opportunities and experiences Dr. Mrazik has provided over the past seven years. I attribute many of my successes and professional qualities to the superior guidance of Dr. Mrazik.

I would also like to thank my supervisory committee members Dr. Cormier and Dr. Leighton for their time, effort, and guidance throughout the candidacy and dissertation process. I truly appreciate their unique perspectives, feedback, and contributions to this research. Thank you to Dr. Whelton for his time and sharing of his specialized knowledge in clinical psychology. Additionally, I would like to extend thanks to Dr. Ritchie, my external committee member. I greatly appreciate her time and expertise within the field of sport-related concussion.

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Chapter One: Introduction

The Problem

For athletes participating in high impact sports, such as football, injury is inevitable. The Canadian government recognizes sport-related concussion (SRC) as a public health concern due to the high prevalence rates (Government of Canada, 2018a). According to the Canadian Institute for Health Information, there were 2,407 individuals, ages 18 to 34 years, seen in the emergency department for a sport-related brain injury in Ontario and Alberta during 2016-2017 (CIHC, 2018). Within this sample, head injuries sustained in football yielded the greatest number of emergency department visits in comparison to all other organized sports (CIHC, 2018). In a recent systematic review, researchers found that American style football players sustain a SRC in games approximately three and a half times per every 1000 hours of game activity (Prien, Grafe, Rössler, Junge & Verhagen, 2018). Due to the high incidence and prevalence rates, SRC has received significant media attention and has become a well-known public health concern.

A substantial amount of media coverage involves mental health functioning following SRC in elite athletes. For example, headlines such as "Concussions linked to increased risk of suicide, study shows" (Global News, 2018) and "Concussions, identity crisis and depression in athletes" (Canadian Broadcasting Cooperation News, 2017) are common in today's sport media coverage. Due to the claims made in the media, it is imperative that researchers engage in knowledge translation of current findings to provide the public with a clear, evidence based understanding of mental health outcomes following SRC. Particularly because this information influences the public's perception of SRC, which ultimately influences sport culture. Additionally, an accurate understanding of mental health outcomes following SRC is necessary to inform prevention, assessment, management, and intervention for athletes who sustain SRCs.

Research Purpose

The purpose of this dissertation research was to elucidate the short and long-term mental health outcomes following SRC in a population of elite athletes. Specifically, symptoms consistent with anxiety, depression, and psychological distress were investigated in a population of professional and collegiate football players. Additionally, healthy and musculoskeletal (MSK) comparison groups were included to determine if mental health outcomes are unique to SRC. Overall, this study aimed to contribute to the broader SRC literature by investigating a phenomenon that is not yet well understood.

Research Questions and Objectives

1. Does a history of SRC impact baseline self-report of symptoms of depression, anxiety, and/or psychological distress?

   Objective: To determine if the number of previously sustained SRCs impacts athlete self-report of depression, anxiety, and psychological distress at baseline.

2. At the group level, does sustaining a SRC influence an athlete's self-reported symptoms on measures of depression and anxiety in the short and/or long term?

   Objective: To determine if there are statistically significant changes at the group level on self-reported depression and anxiety symptoms post SRC in the short term (24-48 hours) and/or long term (when an athlete is asymptomatic and at one month post return to play) in comparison to healthy and MSK injured athletes.

3. At the individual level, does sustaining a SRC influence an athlete's self-reported symptoms on measures of depression and anxiety in the short and/or long term?

Objective: To determine if there are clinically meaningful changes in an individual's self-report of depression and anxiety symptoms post SRC in the short term and/or long term.

Organization of Dissertation

This dissertation includes five chapters, comprising an introduction, literature review, methods, results, and discussion. Chapter one, the introduction, includes the research problem, purpose, questions, and objectives. Chapter two includes a literature review on topics of mental health, SRC, biopsychosocial theory related to SRC, as well as mental health outcomes following SRC in elite athletes. Chapter three outlines the methods used in this research study. Specifically, this chapter describes the design employed, selected outcome measures, data collection process, participants included, data analysis procedures, and attainment of ethical approval. Chapter four reports the results of the study including a description of study participants and the findings from each of the three research objectives. Finally, chapter five includes a discussion of the results, strengths and limitations of the study, clinical implications of the findings, as well as future directions for research.

Chapter Two: Literature Review

Mental Health

The Mental Health Commission of Canada recognizes "mental health" as a significant contributor to the overall wellbeing among Canadians (Government of Canada, 2018b). In 2014, the World Health Organization (WHO) defined mental health as, "a state of well-being in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community" (WHO, 2014, p. 1). Mental health is important for many factors including resiliency, physical

health, and overall life satisfaction. Furthermore, it is protective against developing mental illness (Canadian Mental Health Association, 2018).

Mental illness is defined as, “the reduced ability for a person to function effectively over a prolonged period of time because of: significant levels of distress; changes in thinking, mood or behavior; feelings of isolation, loneliness and sadness; the feeling of being disconnected from people and activities” (Government of Canada, 2018b, p.1). According to the Canadian Mental Health Association (2018), mental illness is the result of a complex interplay of genetic, biological, personality, and environmental factors. Mental illness affects individuals of all ages, education levels, socioeconomic statuses, and cultures. Mental illness takes many forms including but not limited to mood disorders, anxiety disorders, personality disorders, and eating disorders. In 2015, Walker, McGee, and Druss published a systematic review and meta-analysis investigating global mortality rates resulting from mental health disorders. Results from the study indicated that individuals with mental health disorders have a reduced lifespan by approximately 10 years. Furthermore, researchers estimated that 14.4% of deaths, which is approximately eight million deaths a year, are attributable to mental illness worldwide. The researchers concluded that mental illness ranks among one of the most substantial causes of death worldwide and more efforts are needed to prevent and treat mental illness (Walker et al., 2015).

The Canadian Mental Health Association (2018) reported that one in five Canadians will personally experience a mental health problem or illness in their lifetime. The most recent Statistics Canada data (2013) indicated that approximately 3 million Canadians (11.6%) aged 18 years or older reported being diagnosed with a mood or anxiety disorder, making these the most common mental illnesses in Canada. Approximately 27% of these individuals reported that their

mental health challenges affected their life “quite a bit” or “extremely” (Statistics Canada, 2013). Researchers have demonstrated that accessing mental health treatments such as cognitive behavioural therapy can increase positive outcomes for individuals with mental health challenges or illnesses. However, according to a review of the literature, stigma towards mental illness has a small to moderate negative effect on accessing treatment (Clement et al., 2015). In Canada, widespread awareness initiatives regarding mental illness have been implemented across the nation in hopes of reducing stigma and increasing available supports (Canadian Mental Health Association, 2018).

Athletes. Athletes are a population which may be especially vulnerable to poor mental health functioning given their unique social role (Rice et al., 2016). Although exercise and fitness support mental health functioning, elite athletes are at a heightened risk of mental health concerns due to the intense mental and physical demands regularly placed upon them (Hughes & Leavey, 2012). In particular, researchers demonstrated that these demands may increase their susceptibility to certain mental health problems such as depression or risk-taking behaviors (Hughes & Leavey, 2012). Furthermore, researchers have shown that peak competitive years for adult elite athletes overlaps with developmental timeframes for the onset of many mental health disorders (Gulliver et al., 2012). For example, two of the most commonly diagnosed mental health disorders in North America, major depressive disorder and generalized anxiety disorder, have a peak onset age of 20 and 30 years, respectively (American Psychiatric Association, 2013). Competing adult elite athletes typically range from 18 to 40 years old depending upon the sport (Hughes & Leavey, 2012). This suggests that collegiate and professional athletes may be at particular risk for poor mental health. Rice and colleagues (2016) published a review investigating mental health of elite athletes and concluded that elite athletes may be at greatest

risk of developing poor mental health if they are injured, approaching/in retirement, or experiencing performance difficulties. Additionally, the authors noted that there are a limited number of methodologically rigorous studies investigating mental health in this population (Rice et al., 2016).

Mental Health Outcomes of Sport-related Injury

Researchers have been investigating mental health following athletic injuries for decades (Bloom, Horton, McCrory & Johnston, 2004). Injury is a major stressor for athletes and can pose significant challenges that affect many aspects of life including school, work, participation in sport, and relationships (Putukian, 2016). In some cases, the athlete's psychological response to injury has been shown to trigger and/or unmask mental health issues such as depression, anxiety, drug use, and other problematic behaviors. Injuries have also been associated with cognitive and emotional reactions (e.g., sadness, anger, grief), which may influence the athlete's overall mental health (Ivarsson et al., 2017). Research on mental health outcomes following injury in collegiate and professional athletes has evolved throughout the years and has been instrumental in developing effective psychological prevention, intervention, and clinical management paradigms for athletes (Ivarsson et al., 2017; Putukian, 2016).

Mental health and SRC. Researchers have acknowledged that SRC, a common injury in many sports, can result in poor short and long-term mental health outcomes (Covassin, Elbin, Beidler, LaFevor & Kontos, 2017; Manley et al., 2017; McCrory et al., 2017; Rice et al., 2018). The phenomena of disrupted psychological functioning post SRC was first investigated by Barth and colleagues in 1989 in a sample of collegiate athletes. Since this ground-breaking research, there has been a significant increase of SRC research funding, media coverage, and increased public awareness (Guay et al., 2016).

In the most recent consensus statement on concussion in sport, investigators agreed that there is a growing body of literature highlighting the importance of considering mental health factors when investigating and clinically managing SRC (McCrory et al., 2017). For example, a concussed athlete may be prone to experience isolation, pain, anxiety, depression, distress, and disruption of daily life (Bloom et al., 2004; Covassin et al., 2017; Manley et al., 2017; Rice et al., 2018). Additionally, researchers have found that athletes' mental health status plays a role in risk and recovery from SRC (McCrory et al., 2017).

Ivarsson and colleagues (2017) and Putukian (2016) reported that athletes report similar mental health outcomes following muscular skeletal injuries (MSK). However, SRC injuries are unique for a variety of reasons. Specifically, SRC is an invisible injury that requires no stitches, casts, tensor bandages, or crutches (Bloom et al., 2004). Additionally, a SRC is a brain injury with no definite recovery time and is sensationalized by the media (Guay et al., 2016).

Elite athletes. In comparison to other young adult athletes, elite athletes represent a unique subset of the sport population as they face unique psychological pressures (Brosheck et al., 2015). Although evidence suggests that participation in organized sport can lead to positive mental health outcomes such as increased mood, decreased emotional distress, and improved self-efficacy, this may not always be true for all elite athletes (Hughes & Leavey, 2012). As mentioned earlier, some elite athletes may be particularly vulnerable to the adverse effects of SRC due to the intense mental and physical demands placed upon them (Guay et al., 2016; Hughes & Leavey, 2012). Professional sport is a multibillion dollar business in which an athlete's performance directly impacts their level of play and contracted salary (Moser, 2007). In collegiate sport, athletes are often provided economic incentives such as scholarships that are

also dependent on performance. In both populations, these elite athletes have exceptional demands to perform, produce, and play.

Due to their social role, elite athletes face many unique social challenges post SRC including media commentary and pressure from fans and/or teammates to return to play quickly (Moser, 2007). The culture of elite sport may also promote the notion that an athlete's ability to tolerate pain and injury is a sign of strength, whereas taking more time to heal can be associated with weakness (Guay et al., 2016). In fact, researchers have shown that elite athletes are often willing to minimize the short and long-term consequences of SRC in the pursuit of their athletic goals (Brosheck et al., 2015). Taken together, it is clear that elite athletes represent a specialized population in which to study the mental health outcomes of SRC.

History of Concussion

A Persian Physicist, Rhazes, first coined the term "concussion" in the 10th century (McCory & Brekovic, 2001). Rhazes was the first to distinguish the difference between a concussion and a more severe brain injury. Specifically, he defined concussion as a transient neurological syndrome resulting from a hit to the head (Halstead, 2011; McCrory & Brekovic, 2001). From the 10th century onward, the clinical features of concussion were observed and compared to other forms of head injuries including skull fracture and penetrating head wounds (McCrory & Brekovic, 2001). In the 16th century, Berengario da Carpi developed the first theory linking concussion to the brain shifting within the skull (Halstead, 2011). Da Carpi hypothesized the observed symptoms (e.g., memory dysfunction, speech impairment, poor judgement, and receptive language challenges) were directly related to the brain shifting within the skull causing swelling and hemorrhage. In the 17th century, microscope technology allowed physicians and

researchers to study the physiology of concussion and confirmed that the injury created functional disturbances rather than structural changes to the brain (Halstead, 2011).

Concussion in sport did not become a significant concern until the early 1900s when the term *punch drunk* was coined to describe the cluster of symptoms observed in boxers after sustaining multiple head injuries (Halstead, 2011). Concussion in sport began to receive increasing attention when President Theodore Roosevelt expressed concern regarding the 21 documented American football related deaths due to intracerebral hemorrhage, spinal cord injury, internal bleeding, and cardiac arrest. Consequently, in 1910, the National Collegiate Athletic Association (NCAA) formed in hopes of limiting the number and severity of injuries by rule implementation (Williams & Danan, 2016). However, there was not a decrease in injuries, including SRC, until the late 1960s. The decrease in serious injuries, including SRC, was primarily attributed to changes in helmet design and more stringent rules during game play (Bailes & Cantu, 2001). In 2001, the Concussion in Sport Group published the first consensus statement outlining the most up to date research and best practices when managing SRCs (Aubry et al., 2002). Since then, four more consensus statements have been published, with the most recent being in 2017 (McCory et al., 2017). Within the past 10 years, SRC awareness and research has increased drastically. This period of time is often described as the *perfect storm* of interest, funding, technology, and knowledge translation (McCory et al., 2017). Despite the awareness of SRC for over a century, investigation into the mental health outcomes following SRC has just begun. This area of the field remains largely in its infancy due to the complexity of outcomes related to SRCs (Williams & Danan, 2016).

Current Landscape of SRC

Definition. The vast increase in concussion research has brought substantive changes to the understanding of what a concussion is. As a result, there have been changes to the definition and key terms used to describe a concussion (McCrory et al., 2017). The most current definition of SRC was created by the Concussion in Sport Group at the consensus meeting in 2016 and is as follows:

> Sport-related concussion is a traumatic brain injury induced by biomechanical forces. Several common features that may be utilized in clinically defining the nature of a concussive head injury include:
>
> - SRC may be caused either by a direct blow to the head, face, neck or elsewhere on the body within an impulsive force transmitted to the head.
> - SRC typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. However, in some cases, signs and symptoms evolve over a number of minutes to hours.
> - SRC may result in neuropathological changes, but the acute clinical signs and symptoms largely reflect a functional disturbance rather than a structural injury and, as such, no abnormality is seen on standard structural neuroimaging studies.
> - SRC results in a range of clinical signs and symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive features typically follows a sequential course. However, in some cases symptoms may be prolonged.
> - The clinical signs and symptoms cannot be explained by drug, alcohol, or medication use, other injuries (such as cervical injured, peripheral vestibular dysfunction, etc.) or other

> comorbidities (e.g., psychological factors or coexisting medical conditions) (McCrory et al., 2017, p. 2).

Symptoms. SRCs are difficult to manage clinically and systematically investigate as no two are identical (McCrory et al., 2017). SRCs produce varying severity and duration of symptoms including somatic (e.g., headache), cognitive (e.g., feeling like in a fog), and/or emotional symptoms (e.g., lability). The suspected diagnosis of a SRC may also manifest in one or more of the following clinical domains: (a) physical signs (loss of consciousness), balance impairment (e.g., gait unsteadiness), behavioral changes (e.g., irritability), cognitive impairment (e.g., slowed reaction times), and/or sleep wake disturbance (e.g., drowsiness). If any of these signs are present, a SRC should be suspected and the appropriate management strategy should be initiated (McCrory et al., 2017). The most common reported symptoms following SRC are headache, sleep disturbance, dizziness, feeling in a fog, and issues with balance (McCrory et al., 2017). Mental health concerns such as depression and anxiety are not noted as one of the most common symptoms following SRC. However, poor mental health functioning following SRC can create challenges with regards to recovery and therefore, is now considered in clinical management strategies (Sandel et al., 2017).

Diagnosis and management. SRC is considered to be among the most complex and challenging injuries in sport to diagnose, assess, and manage (McCrory et al., 2017). Currently, there is no perfect diagnostic tool that clearly identifies whether an individual has a SRC. Therefore, the diagnosis often involves many steps and clinical judgement. Typically, the first step involves pulling the athlete out of play/practice to perform a sideline evaluation that consists of a brief screen of the clinical domains mentioned above. The Sport Concussion Assessment Tool (SCAT-5) is currently the gold standard in assessing clinical presentations consistent with

SRC (Echemendia et al., 2017). The SCAT-5 incorporates symptoms consistent with mental health challenges including “more emotional, irritability, sadness, nervous or anxious” symptoms. This allows for a basic screening of mental health symptoms at the time of injury. Based upon the information gathered during the side line assessment the athlete is either allowed to return to play or is removed from play for further diagnostic evaluation. Typically, a locker room evaluation is completed by a physician or athletic therapist and involves a physical exam, further neuropsychological testing, and a conversation with the athlete regarding their status. Based upon this evaluation the player is cleared to play, diagnosed with a concussion, or sent to the hospital to rule our more serious head trauma (McCrory et al., 2017).

In terms of management, researchers suggest that after 24-48 hours of rest the player can gradually become more active as long as physical or cognitive activity does not exacerbate symptoms (Gupta & Sebastianelli, 2019; McCrory et al., 2017). In fact, the old management protocols suggesting to stay in a dark room for longer periods of time increased symptoms consistent with poor mental health functioning such as anxiety and depression (Rice et al., 2016). Most adult athletes recover within ten to fourteen days following a SRC. However, approximately 10 to 20% of athletes experience persistent symptoms and have a more complicated recovery. The strongest and most consistent predictor of slower recovery from SRC is the severity of the athlete’s initial symptoms (McCrory et al., 2017). McCrory and colleagues (2017) developed clinical guidelines for rehabilitation following SRC whereby they recommend a personalized approach based upon the athlete’s presentation. For example, rehabilitation may include psychological intervention, cervical rehabilitation, vestibular rehabilitation, pharmacological treatment, school/work accommodations, and/or a graded exercise program

(McCrory et al., 2017). Professional and collegiate sport organizations have developed return to play protocols that are strictly adhered to in order to ensure player safety (Moser, 2007).

Application of Biopsychosocial Theory to Mental Health Outcomes of SRC

Based upon the array of symptomatology, SRCs are often viewed as having biological, psychological, and social components (McCrory et al., 2017). Therefore, this injury is best understood via the biopsychosocial systems model as described by Engel in 1977. This model was developed as a holistic alternative to the predominant biomedical model. Engel used the biopsychosocial model to demonstrate how illness develops through the complex interaction of biological (e.g. genetics), psychological (e.g. coping), and social factors (e.g. culture). Throughout the years this model has been applied to various illnesses and injuries and has been particularly useful in helping to elucidate the complexity of SRC. In what follows, a discussion is presented of pre-morbid and post-morbid biological, psychological, and social factors that can contribute to mental health outcomes following SRC.

SRC and premorbid biological factors. Biological age is a factor to consider when investigating mental health outcomes following SRC. Specifically, the brains of children and adolescents are particularly susceptible to the effects of SRC due to the brain's developmental stage, particularly the immaturity of the frontal lobe (Mrazik & Sattler, 2014). Following an insult to the developing frontal lobe a variety of symptoms may appear including social deficits, emotional regulation issues, and executive dysfunction (Giza & Hovda, 2014). In young adulthood, the frontal lobes are further developed and have a greater number of neural connections; therefore, the outcomes of SRC are clearer and less severe in the long term in comparison to child and adolescent populations (McCory et al., 2017).

Biological sex has also been shown to be a risk factor influencing the experience of emotional changes, including mental health functioning following SRC (Sandel et al., 2017). Although some researchers have found that females report a greater number of emotional symptoms before and after SRC these findings are not consistent (Bauman et al., 2017; Brown et al., 2015). Researchers hypothesize this inconsistency may be due to hormonal changes related to the female menstrual cycle (Moser, Olek, & Schatz, 2018). Additionally, there are cultural phenomenon such as females being more open about their emotions and being more concerned with future health, which could lead to this increase in reporting (Sandel et al., 2017). Other meta-analysis suggest that female athletes take longer to recover from SRC in comparison to male athletes (Beauman et al., 2017; Brown et al., 2015). Currently, there is not a clear consensus explanation for sex differences in symptom report and mental health outcomes following SRC (Sandel et al., 2017).

Recently, there has been an interest in the role of genetics in predicting risk of SRC, recovery time, mental health, and long-term neurological health following SRC (McCrea et al., 2017). In terms of mental health functioning, genetics may influence pre-injury traits such as resilience and cognitive reserve. Researchers also point to genetic vulnerabilities such as neurobehavioral disorders (e.g. ADHD) and neurotrauma, highlighting the role of comorbidities in SRC occurrence and recovery. The APOEe4 allele is the most researched in SRC literature (McCrea et al., 2017). Recently, in a cohort of concussed collegiate athletes, researchers discovered an association between the APOEe4 allele and total symptom score, cognitive symptoms, physical symptoms, and the presence and severity of headache at 10 days post SRC (Merritt & Arnett, 2016; Merritt, Ukueberuwa & Arnett, 2016). Although researchers have not investigated APOEe4's potential role in mental health outcomes following SRC; researchers

have documented that APOe4 impacts neuropsychological, behavioural, and social functioning (Tangwonchai et al., 2018). Specifically, researchers are beginning to investigate APOe4 associated with depression in adults. Therefore, it is possible that the presence of this allele may be a risk factor for poor mental health functioning following SRC. Although the research in this field has expanded substantially over the past 15 years, results must continue to be interpreted with caution due to the small number of studies, homogeneous populations, small sample sizes, variability in study design, and differences in post injury data collection time points (McCrea et al., 2017).

SRC and postmorbid biological factors. The acceleration and deceleration forces of a concussive impact shift the brain inside the skull, setting off a complex neurometabolic cascade (Giza & Hovda, 2001; Giza & Hovda, 2014). This cascade involves the release of excitatory amino acids, altered brain glucose metabolism, lactate accumulation, reduced cerebral blood flow, and temporary disruptions in neural membranes that impairs connectivity. This results in hypermetabolism or an *energy crisis* which lasts for one or more days. This period is followed by hypometabolism or a *resting depression* lasting five to ten days (Giza & Hovda, 2014). During this period, any additional physical or cognitive activity places additional neurometabolic demands on the fragile recovering brain. If the demands become excessive, metabolism and energy continue to decrease, causing symptoms to worsen. Many of the direct signs and symptoms of SRC are thought to be a result of this cascade. For example, the sudden ionic influx may result in headache. Furthermore, axonal injury/impaired neurotransmission can result in impaired cognition, slowed processing, and slower reaction times (Giza & Hoodva, 2014). Additionally**,** the neurometabolic cascade also affects the physiology in the emotional centers of the brain (McCuddy et al., 2018). Advanced neuroimaging studies have shown that the

neurochemical disturbance after SRC exhibits a similar pattern of brain alterations as individuals diagnosed with clinical depression (Chen, Johnson, Petrides & Pitito, 2008; McCuddy et al., 2018).

SRC and premorbid psychological factors. One of the most robust predictors of poor mental health functioning and prolonged recovery following SRC is a history of mental health challenges prior to injury (McCrory et al., 2017; Sandel et al., 2017). Several studies have found that a history of mental health treatment or diagnoses (e.g., anxiety or depression) resulted in greater endorsement of overall symptoms (Blasundaram, Athens, Scheiders, McCrory & Sullivan, 2016; Iverson et al., 2015) and protracted recovery following SRC (Morgan et al., 2015; Silverberg, Gardner, Brubacher, Paneka, Iverson, 2015; Wojcik, 2014). Researchers have also identified that athletes who endorse more mental health related symptoms at baseline are at a greater risk of experiencing depression and anxiety symptoms post SRC (Yang et al., 2015). Furthermore, researchers suggest that at three months post injury, a history of psychiatric conditions are more predictive of ongoing impairment than the SRC itself (Ponsford et al., 2012). Athletes with no history of mental health disorders, but a family history of mental health disorders are predisposed to developing a mental health disorder. Therefore, clinical interviews are important to obtain an understanding of family history of mental health, particularly for young adult athletes who are at the age of onset for some mental illnesses such as anxiety and depression (American Psychiatric Association, 2013; Sandel et al., 2017).

SRC and postmorbid psychological factors. Psychological functioning can refer to a wide variety of constructs including cognitive, emotional, intellectual, personality, and mental well-being (Kokko, 2018). Although psychological functioning is a broad construct with many

components, this section will focus on the psychological outcomes most implicated post SRC including cognition, coping/temperament, and emotional regulation (Mrazik & Sattler, 2014).

Cognitive disturbances are often an outcome following SRC. For example, well-documented evidence suggests that cognitive dysfunction typically resolves when symptoms resolve (7-10 days) following a SRC (McCrory et al., 2017; Hume et al., 2017). Athletes typically experience cognitive disturbance as symptoms such as feeling in a fog, slower processing speed, issues with sustained attention, and memory difficulties (McCrory et al., 2017). Alsalaheen and colleagues (2017) published a meta-analysis indicating that concussed young adult athletes experienced deficits in memory, attention, and processing speed in comparison to baseline assessments (hedges g = -.43 to -.67). These cognitive deficits correlated with a symptom report one week post SRC. Two weeks following the SRC, these effects diminished (Alsalaheen et al., 2017). A systematic review comprising 11 meta-analyses indicated significant deficits (d = .40 to .80) in cognitive functioning up to one week post SRC in a population of late adolescent and young adult athletes (Karr, Areshenkoff & Garcia-Barrera, 2014). Additionally, researchers have theorized that the decrease in cognitive function following SRC can lead to symptoms of anxiety and depression due to an altered ability to perform tasks in comparison to before the SRC (Arnett, Guty & Bradson, 2019; Kay Newman, Cavallo, Ezrachi & Resnick, 1992).

The association between temperament and coping style may be useful psychological factors to consider when elucidating mental health outcomes following SRC (Blecharz & Siekanska, 2007). An athlete's temperament is manifested in social behaviors such as pain reaction and coping with injury. Specifically, researchers suggest that individuals with a more introverted temperament engage in more avoidant coping strategies following orthopedic

injuries. Kontos and colleagues (2013) discovered that the use of maladaptive coping strategies post SRC can result in prolonged post-concussive symptoms and mental health sequelae in high school and college athletes. Additionally, researchers have shown that collegiate athletes who utilize passive coping strategies report elevated levels of depression, anxiety, lower quality of life, cognitive problems, and physical symptoms post SRC (Maetas et al., 2014). Woodrome and colleagues (2011) suggest that engaging in an active problem-focused coping style is beneficial for reducing prolonged symptoms and mental health outcomes. Therefore, factors such as temperament, which influences an individual's coping style, may affect mental health outcomes following SRC (Kontos et al., 2013; Maetas et al., 2014; Woodrome et al., 2011).

The capacity to regulate emotions also appears to influence the expression and development of mental health challenges post SRC (Sandel et al., 2017). For example, individuals with higher levels of resiliency demonstrate less depression, anxiety, and psychological distress after sustaining a SRC (Losio et al., 2015; Merritt, Lange & French, 2015). Athletes with a history of poor coping and an inability to effectively manage their emotions in the presence of negative life events may be at an increased risk for poor mental health outcomes following SRC (Giza & Hoodva, 2014; Sandel et al., 2017).

SRC and Premorbid social factors. Researchers suggest that a host of unrelated social factors (e.g., financial strain, interpersonal issues, and disrupted familial communication patterns) can increase stress that exists pre SRC which can later contribute to poor mental health functioning post SRC (Sandel et al., 2017). For example, researchers showed that perceived stress due to unrelated social factors following a SRC was positively associated with symptoms consistent with anxiety and depression (Hou et al., 2012). These findings can be understood via the stress diathesis model which would suggest that poor mental health outcomes post SRC may

develop from a biological vulnerability combined with stressful conditions prior to the SRC (Belsky & Pluess, 2009; Monroe & Simons, 1991).

SRC and postmorbid social factors. As social relationships outside the family system are a significant contributor to social development during adolescence and young adulthood it is not surprising that social support influences outcomes post SRC (Covassin et al., 2014). Specifically, Covassin and colleagues (2014) found that concussed collegiate athletes who received high levels of social support reported low levels of post injury anxiety. Although researchers have reported that social stress may be informative in predicting outcomes following SRC, the full impact of stress on one's social relationships is often overlooked and requires scientific and clinical consideration (Sandel et al., 2017).

Finally, the way in which a SRC is medically managed can create secondary problems that produce emotional distress and prolonged symptomatology (Sandel et al., 2017). For instance, inappropriate intervention or prescription of too much rest (e.g., missed school and limitations on social activities) may lead individuals to develop emotional disturbances in response to these unhelpful limitations (Schneider et al., 2013). Taken together, there is a variety of social factors that require consideration when assessing an athlete's mental health functioning post SRC (Sandel et al., 2017; Schneider et al., 2013).

Mental Health Outcomes Post SRC in Elite Athletes

There is no clear consensus on the exact factors contributing to poor mental health functioning post SRC; rather, the literature points to a complex interaction of a variety of factors that exist and contribute to the overall presentation of an athlete post SRC. In what follows is a discussion of mental health outcomes following SRC in populations of elite collegiate athletes. Researchers have begun to show a link between SRC and poor short and long-term mental health

functioning in samples of collegiate and professional athletes (Covassin et al., 2017; Kerr et al., 2012; Kerr et al., 2014; Manley et al., 2017; McCrory et al., 2017; Pryor et al., 2016; Rice et al, 2018). The majority of these adverse outcomes appear in the acute phase and resolve by one month following a SRC (McCrory et al., 2017; Rice et al., 2018). The most widely studied mental health outcome is depression followed by anxiety, general mood disturbance, cognitive function, quality of life, psychological distress, attention deficit hyperactivity disorder symptoms, apathy, suicide, and aggression (Covassin et al., 2017; Manley et al., 2017; Rice et al., 2018). Findings from systematic reviews suggest that mental health outcomes post SRC are likely subtle and are more common in athletes who have sustained multiple concussions, have a history of mental health difficulties, or are retired (Manley et al., 2017; Rice et al., 2018). Authors of the systematic reviews agree that that there is a paucity of well-designed, representative, prospective studies including baseline assessment and multiple time measurements post-SRC (Covassin et al., 2017; Manley et al., 2017; McCrory et al., 2017; Rice et al., 2018).

Depression. According to the American Psychological Association (2020), depression is presence of intense sadness, emptiness, or irritable mood, accompanied by somatic and cognitive symptoms. It is estimated that approximately 12-44% of individuals who sustain a mild Traumatic Brain Injury (mTBI; including concussion) experience some degree of depression within the first three months of injury (Iverson & Lange, 2011). The literature on depression in relation to SRC is mixed due to methodological differences in population selection (e.g., retired athletes versus currently competing athletes), study design (retrospective versus prospective), and controls (healthy and/or injured) (Rice et al., 2018).

When investigating this phenomena in retired athletes, the literature points to a dose response relationship in which depression symptom severity increases with the number of previous concussions (Didbehbani et al., 2013; Guskiewicz et al., 2007, Kerr et al., 2012, Montenigro et al., 2017). For example, Didbehbani and colleagues (2013) reported a moderate but significant correlation (r = .43) between the number of concussions and self-reported depression in a sample of 59 retired National Football League players. Studies involving retired athletes have some methodological challenges including the athlete's retrospective recall of concussion history. Additionally, retired athletes' report of depression symptoms is mediated by other factors such as adverse life events, substance use, and level of social support (Rice et al., 2018). However, a similar dose response relationship was found in a sample of currently playing professional and semi-professional football players (Pryor et al., 2016). Specifically, players with a history of three or more SRCs reported significantly more depression symptoms than players with a history of two or fewer SRCs (Pryor et al., 2016). Taken together, the available literature supports a dose-response relationship between history of SRCs and self-report of depressive symptoms (Didbehbani et al., 2013; Guskiewicz et al., 2007, Kerr et al., 2012, Montenigro et al., 2017; Pryor et al., 2016).

To evaluate the subtle outcomes of SRC, researchers often include a baseline measure to allow for the analysis of individual change. For example, Vargas, Rabinowitz, Meyer, and Arnett (2015) used a reliable change methodology and discovered that concussed athletes (n = 84) reported greater depression symptoms post SRC in comparison to their baseline ratings. Furthermore, the researchers found no differences from baseline to follow-up in a control group comprising healthy, recreationally active, age matched controls. Yang and colleagues (2015) investigated individual change post SRC in a sample of collegiate athletes from a variety of

sports ($N = 67$). The researchers found that concussed athletes who reported symptoms consistent with depression at baseline were four and a half times more likely to experience post-concussion depression symptoms in comparison to concussed athletes who did not report depression symptoms at baseline (Yang et al., 2015).

To better understand the unique outcomes of SRC, Rogier and colleagues (2015) included a muscular skeletal (MSK) injury control group as well as baseline measures to allow for group and individual comparisons. Findings suggested that collegiate athletes from mixed sports reported higher depression symptoms one week post SRC and one week post MSK injury in comparison to their respective baseline scores. However, there were no differences in self-reported depression symptoms between the concussed group and the MSK injury control group at any time point (Rogier et al., 2015). This study highlights the importance of analyzing both individual and group data as well as inclusion of an injured control group to better capture the scope of outcomes associated with SRC.

Authors from the most recent systematic reviews available conclude that relative to healthy controls, there is some evidence for elevated symptoms of depression post-SRC, although this may be confined to the short-medium term only and may be influenced by pre-morbid depression (Covassin et al., 2017; Manley et al., 2017; Rice, 2018). Furthermore, Rice and colleagues (2018) found that six out of the eight controlled studies suggested that athletes reported elevated symptoms of depression up to four weeks post SRC in comparison to healthy non-injured controls. Taken together, it appears that when concussed athletes are compared to their baseline ratings (individual differences) and when compared to healthy non-injured controls (group differences) there is an increase in reported depressive symptoms post SRC (Covassin et al., 2017; Manley et al., 2017; Rice, 2018). However, the effect is less clear when concussed

athletes are compared to MSK controls due to the limited number of high-quality studies available (Covassin et al., 2017; Manley et al., 2017; Rice, 2018).

Anxiety. According to the American Psychological Association (2020), anxiety is an emotion characterized by tension, worry, and physiological changes (e.g., increased heart rate). Compared to studies on depression, there have been fewer investigations of anxiety outcomes in SRC populations (Covassin et al., 2017; Manley et al., 2017; Rice, 2018). Similar to the depression literature there are variable outcomes, largely due to methodological differences. It is estimated that over one third of concussed collegiate athletes experience state anxiety following a SRC (Yang et al., 2015). Furthermore, Yang and colleagues (2015) indicated that collegiate athletes from mixed sports ($N = 67$) who endorsed depression symptoms at baseline were about three and a half times more likely to experience anxiety symptoms post-concussion compared to athletes without depression symptoms at baseline. All studies reporting anxiety outcomes were conducted in populations of competing athletes and varied in terms of inclusion of baseline measures and control groups.

Three studies included healthy controls but no baseline measure of anxiety. The first study indicated that relative to healthy controls, concussed college football players ($n = 36$) reported significantly higher anxiety symptoms at three days and at one week post SRC but not at one month (Singh et al., 2016). The second study revealed that collegiate athletes from mixed sports ($N = 94$) reported higher anxiety scores at one day, one week, and one month post SRC in comparison to healthy controls (Meier, Bellgowan, Mayer et al., 2017). Finally, in a sample of college football players, anxiety symptoms were found to be significantly higher at 13 days post SRC in comparison to a healthy control group; however, there were no differences between the groups at 44 days post SRC (Meier, Bellgowan, Singh, Kuplicki, Polanski, & Mayer, 2015).

Two studies incorporated MSK injury controls into their study design. The first study, Covassin and colleagues (2014) found that concussed mixed sport athletes reported no differences in self-reported anxiety symptoms in comparison to MSK controls ($N = 126$). Similarly, Turner and colleagues (2017) found no differences between a sample of 15 concussed collegiate athletes and 15 MSK injured collegiate athletes on a measure of anxiety at multiple time points after injury. Taken together, these studies suggest that anxiety symptomatology may not be a unique outcome of SRC (Covassin et al., 2014; Meier et al., 2015).

Relative to depression symptoms, studies investigating anxiety symptoms are less consistent (Rice et al., 2018). There is limited research available with the inclusion of both baseline measures and MSK injury controls. Furthermore, none of the current studies investigate individual change in anxiety symptoms at baseline and post SRC, which is imperative as the effects are likely subtle and may not be identifiable by group analyses. With relatively few studies, conclusions related to the link between concussion exposure and anxiety symptoms are premature (Rice et al., 2018).

Psychological distress. Psychological distress is a relatively new research domain within SRC. According to Derogatis (2017), psychological distress refers to a constellation of symptoms consistent with depression, anxiety, and somatization and is often measured using the Brief Symptom Inventory (BSI-18). The BSI-18 is unique as it measures symptoms that are consistent with anxiety, depression, and somatization; but due to its limited discriminant validity, is not diagnostic for these disorders (Lancaster, McCrea & Nelson, 2016). Therefore, its primary purpose is to screen individuals for symptoms consistent with the development of a mental health disorder. More recently this measure has shown clinical utility when screening for mental health functioning in samples of collegiate athletes (Lancaster et al., 2016). For example, a large-scale

study (N = 2,031) investigated high school and collegiate athletes' baseline psychological distress in comparison to general students and found that athletes experience less psychological distress than the general student population (Lancaster et al., 2016). Katz and colleagues (2018) investigated psychological distress at baseline in a sample of 15,681 collegiate athletes. Results gleaned from the BSI-18 indicated no significant differences between athletes who participate in contact sport versus athletes who participate in non-contact sports (Katz et al., 2018). However, there is a paucity of research investigating psychological distress in the acute phase post SRC.

Recently researchers discovered a relationship between the number of previous SRC (four or greater) and poorer self-reported psychological distress in a large sample (N = 8,562) of collegiate athletes (Weber et al., 2018). Although this study included a large sample size, the data were retrospective and the design lacked injury control groups. Additionally, Combs, Wasserman, Rodigo, Guskiewicz, and Mihalik (2017) indicated that there were no significant differences between collegiate athletes with a history of one or more concussions (n = 128) versus a history of no concussions (n = 286). Taken together, it appears that psychological distress may be an outcome associated with multiple SRCs in the collegiate athlete population. However, the number of studies investigating this phenomenon is limited and more investigation at the group and individual level is required before conclusions can be determined.

Summary

Overall, SRC is a complex injury given the many individual developmental, biological, psychological, and social factors that influence outcomes (McCrory et al., 2017). Figure 1.0 is a visual depiction of the complexity of mental health outcomes following SRC. Although systematic reviews suggest a link between SRC and poor mental health, causation cannot be determined due to the lack of well designed, longitudinal, prospective studies that include control

groups (Covassin et al., 2017; Manley et al., 2017; McCrory et al., 2017; Rice et al., 2018). Elite athletes appear to be a particularly vulnerable population to adverse mental health outcomes following SRC due to the immense social pressures placed upon them, the alignment of developmental stage with the onset of mental health disorders, and sport culture (Brosheck et al., 2015; Guay et al., 2016; Hughes & Leavey, 2012). Furthermore, the elite athlete population is often the center of sport media attention and misinformation regarding outcomes following SRC can lead to false and potentially harmful public perceptions of SRC. Therefore, it is imperative that sound research with clear knowledge translation be conducted in populations of elite athletes. Research in this area can inform prevention, assessment, and treatment for athletes who sustain SRC.

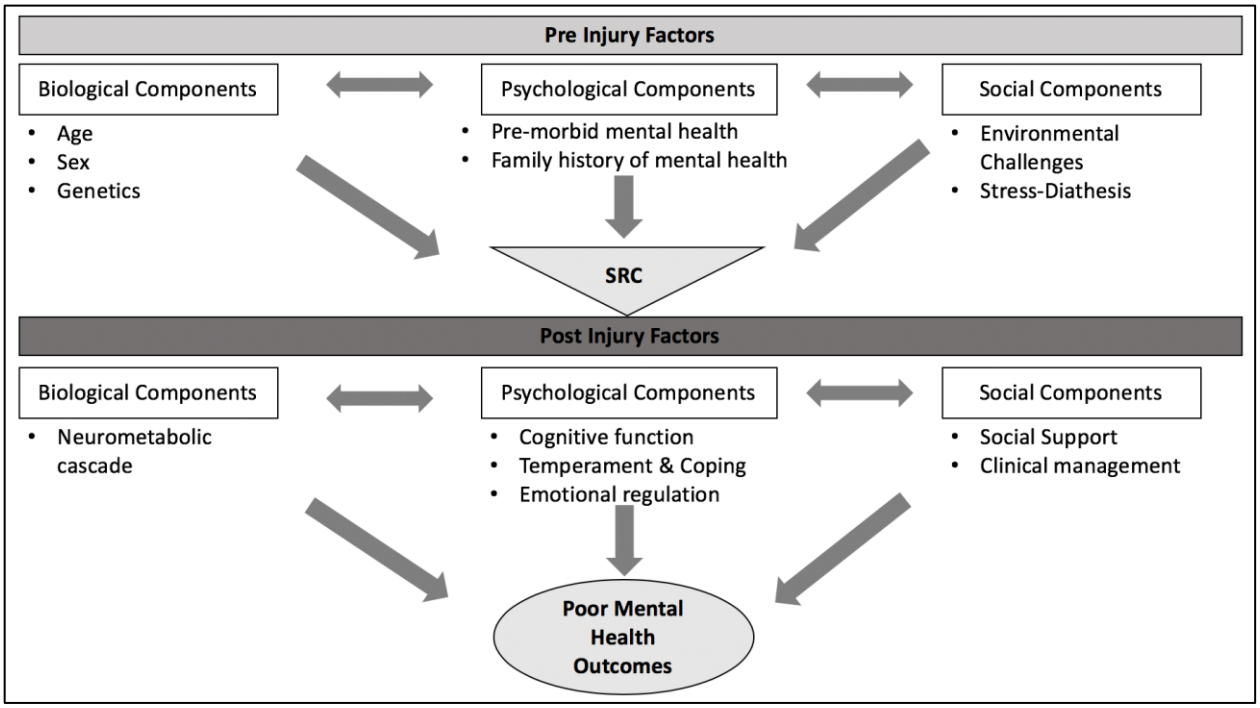

Figure 1.0. Biopsychosocial factors contributing to mental health outcomes post SRC.

Study Hypotheses

After reviewing the available literature on SRC, the following hypotheses are postulated for each research question:

1. Does a history of SRC impact baseline self-report of symptoms of depression, anxiety, and/or psychological distress?

Hypothesis: Based upon players' retrospective report of concussion history, players with a history of multiple (two or greater) SRCs will report significantly poorer mental health across all components including anxiety, depression, and psychological distress in comparison to athletes with a history of no SRC.

2. At the group level, does sustaining a SRC influence an athlete's self-reported symptoms on measures of depression and anxiety in the short and/or long term?

Hypothesis: At the group level, athletes who sustain a SRC will report more depression and anxiety symptoms in the short-term but not in the long-term in comparison to both MSK and healthy control groups. Short-term symptoms are defined as 24 to 48 hours post SRC. Long-term symptoms are defined the asymptomatic and one month RTP time points.

3. At the individual level, does sustaining a SRC influence an athlete's self-reported symptoms on measures of depression and anxiety in the short and/or long term?

Hypothesis: At the individual level, concussed players will exhibit a clinically meaningful increase (significant reliable change) in depression and anxiety symptoms in comparison to their baseline self-report in the short-term but not in the long-term. This clinically meaningful increase is not expected to be present in the MSK and healthy control groups.

Chapter Three: Methods

The purpose of this chapter is to review the methods employed in the study. This chapter is organized into six sections. Specifically, this chapter includes a description of the study design

and the measures selected. Next is an overview of the data collection, quality control, and sampling procedures. Finally, the statistical analysis employed and the attainment of ethics are outlined.

This research was a component of a larger prospective multi-center cohort study "Role of Rehabilitation in Concussion Management: A Randomized, Controlled Trial" at the University of North Carolina, Chapel Hill. This study investigated the effects of a multidimensional rehabilitation protocol versus an enhanced graded exertion on clinical recovery and patient outcomes post SRC. Dr. Mrazik was the primary investigator for the arm of the study involving the University of Alberta and Canadian Football League athletes. Within the broad objective to better understand participant outcomes after SRC, measures were incorporated to assess depression, anxiety, and psychological distress.

Study Design

A prospective cohort study design was used. This study was unable to make use of a true experimental design due to the inability to randomly assign athletes to groups; therefore, a quasi-experimental design was employed. At baseline, all participating athletes were included. During the football season three groups were formed based on inclusion criteria. Specifically, athletes who sustained a SRC formed the SRC group and athletes who sustained a comparable MSK injury formed the MSK control group. Finally, healthy control participants were randomly selected and placed in a third group.

Inclusion criteria for the SRC group was as follows:

a) The player was diagnosed by the team physician with a concussion during practice or play;
b) and had not sustained a concussion within the past three months.

Inclusion criteria for the MSK control group was as follows:

a) The MSK injury resulted in being pulled off the field and not returning to the game or practice;
b) occurred in the same type of play as the concussed athlete;
c) matched the position of the concussed athlete;
d) did not involve the head or neck;
e) was not season ending;
f) and the player had not sustained a concussion within the past three months.

MSK injuries such as an ankle or wrist sprain were appropriate for inclusion as an MSK control. Inclusion criteria for the healthy control group was as follows:

a) The player was currently fully participating in games and practices;
b) did not have a current injury or concussion;
c) had not sustained a concussion within the past three months;
d) and matched the position of the concussed and MSK injured athletes.

Measures

Self-report measures are the most popular approach to measuring mental health outcomes within the SRC population (Covassin et al., 2017; Manley et al., 2017; Rice et al., 2018). Self-reports that yield quantitative data were chosen as the aim of the study was to quantify the athlete's perspective on personal and sensitive topics. Furthermore, this type of data allowed a standardized data collection approach, was cost effective, and easily analyzed at the group and individual level. To assess mental health outcomes in this sample, three measures were selected, the Patient Health Questionnaire (PHQ-9) (Spitzer, Williams & Kroenke, 1999), the Generalized

Anxiety Disorder scale (GAD-7) (Spitzer et al., 1999), and the Brief Symptom Inventory-18 (BSI-18) (Derogatis, 1993).

PHQ-9. The PHQ-9 is a brief, cost free, self-report instrument (see Appendix A) for screening, diagnosing, monitoring, and measuring the severity of depression (Kroenke, Spritzer & Williams, 2001). The PHQ-9 incorporates DSM-IV depression diagnostic criteria, which are placed on a Likert response scale. The participants simply rate the frequency of their symptoms, which factor into the scoring severity index.

A systematic review of the psychometric properties of the PHQ-9 in adult primary care settings revealed that the probability of detecting depression (sensitivity) was between 77% to 88% and the probability of correctly identifying the absence of a depressive disorder (specificity) was between 88% to 94% (Kroenke, Spritzer, Williams & Lowe, 2010). Furthermore, internal consistency (coefficient alpha) was reported between .86 and .89 and the test-retest reliability was found to be .84. In addition, in a sample of 6,000 adults, construct validity was assessed via a 20-item general health survey measuring functionality, self-reported sick days, and clinic visits (Kroenke et al., 2001). Results indicated that as the total score on the PHQ-9 increased there was a substantial decrease in functional status and an increase in sick days and utilization of health care. Taken together, previous research suggests that the PHQ-9 is an effective, psychometrically sound tool for assessing depressive symptoms in the general population (Kroenke et al., 2001; Kroenke et al., 2010).

The PHQ-9 has also shown utility in brain injury populations. Specifically, Fann and colleagues (2005) indicated the PHQ-9 demonstrated high sensitivity (93%) and specificity (89%) when diagnosing major depressive disorder in a population of adults within one year of sustaining a complicated mild, moderate, or severe Traumatic Brain Injury (TBI). In addition, the

researchers reported strong positive correlations between the PHQ-9 and other depression measures such as the Hopkins Symptom Checklist depression subscale (r = .90) and the Hamilton rating scale for depression (r = .78). The PHQ-9 also demonstrated strong test re-test reliability (.76) for patients who sustained a brain injury. Taken together, this suggests that the PHQ-9 is a sufficiently valid and reliable screening tool for detecting major depressive disorder in persons with TBI (Fann et al., 2005).

The PHQ-9 has also been suggested as screening tool for symptoms consistent with depression in competitive sport populations as it has shown a greater sensitivity (95%) and specificity (88%) in athlete populations in comparison to the Beck Depression Inventory and the Depression screener from the Center of Epidemiologic Studies Depression Scale (Smarr & Keefer, 2011; Trojian, 2016). Furthermore, Trojian (2016) suggests that depression screening is useful for multiple reasons including assisting in SRC care, evaluating an athlete's coping abilities post injury, and maximizing athletic performance.

GAD-7. The GAD-7 is a brief, cost free, self-report instrument (see Appendix A) for screening, diagnosing, monitoring, and measuring the severity of anxiety (Kroenke, Spritzer & Williams, 2001). The GAD-7 incorporates DSM-IV anxiety diagnostic criteria, which are placed on a Likert response scale. The participants simply rate the frequency of their symptoms, which factor into the scoring severity index.

In terms of psychometric properties, researchers demonstrated criterion and construct validity of the GAD-7 by comparing independent Generalized Anxiety Disorder (GAD) diagnoses made by mental health professionals, functional status measures, disability days, and health care use in a sample of 2,740 adults from 15 different primary care settings (Spritzer, Kroenke, Williams & Lowe, 2006). Specifically, the GAD-7 showed an 89% probability of

correctly identifying GAD (specificity) and 82% probability of detecting the absence of GAD (sensitivity) (Spritzer et al., 2006). Additionally, the GAD-7 has been used in studies investigating brain injury and concussion and has shown to be a useful and effective tool (Gulliver et al., 2015; Putukian et al., 2015).

BSI-18. The Brief Symptom Inventory (BSI-18) is an efficient measure of general psychological distress in three areas; anxiety, depression, and somatization (see Appendix A). It has been recommended by the Neurological Disorders and Stroke as Common Data Elements for assessment of psychological status in adults with concussion (Lancaster et al., 2016). It is comprised of 18 items on a 5-point Likert response scale, which sum together to create the Global Severity Index (GSI). The BSI-18 has been considered a psychometrically sound tool for use in brain injury populations (Meachen, Hanks, Millis & Rapport, 2008). Specifically, in a sample of 257 patients who sustained a TBI the BSI-18 showed high internal consistency (α = .91), moderate test-retest reliability (.66), and strong construct validity as it correlated with multiple measures of psychosocial adjustment, for example, the Disability Rating Scale (r = .78).

The psychometric properties of the BSI-18 were more recently evaluated in a sample of 2,031 high school and college athletes (Lancaster et al., 2016). The researchers found that the GSI demonstrated greater internal consistency (.83) in comparisons to the three subscales (.66 to .76). This suggests that the GSI is the most reliable marker of psychological distress in the high school and collegiate athlete population. Additionally, the test re-test reliability was found to be moderate over seven days (.56 to .70) and low (.28 to .55) over 165 days. Criterion validity was shown to be strong (.74 to .81). The overall score demonstrated a strong correlation with the symptoms on the Sport Concussion Assessment Tool (SCAT-3) (r = .58) and the multidimensional Personality Questionnaire Negative Emotionality (r = .43). Overall, the BSI-18

has evidence for high internal consistency, moderate test-retest reliability, and strong convergent validity with other measures of emotional functioning in a population of high school and collegiate athletes (Lancaster et al., 2016). This measure has also been used to investigate psychological distress in SRC population (Combs et al., 2017; Weber et al., 2018).

Data Collection and Quality Control

The first portion of data collection occurred at baseline testing, prior to the start of the 2018 football season. At baseline, athletes were informed of the current study and walked through a consent form. Each athlete then had the opportunity to read through the consent form, ask questions, and choose whether to participate in the study. The consent form used for the study can be found in Appendix B. If the athlete consented, they were asked to complete a demographics questionnaire to gather information regarding their age, biological sex, history of concussion, and history of mental health disorders. They also completed the three selected self-report questionnaires to investigate components of mental health (PHQ-9, GAD-7, BSI-18). During the season, if an athlete sustained a concussion, MSK injury, or was randomly selected as a healthy control they were asked to fill out the PHQ-9 and GAD-7 at specified timepoints (see Tables 1.0, 1.1, 1.2, 1.3). The athletic trainers administered the questionnaires and filed the data in a locked secure location for pick up. However, if the athletic trainers were unable or unwilling to collect the data and/or the athlete preferred online reporting a secure online procedure was employed. Specifically, the athletic trainers simply alerted the research coordinator of a concussion or MSK injury and the research coordinator emailed the athlete a password protected version of the questionnaire. It is important to allow flexibility into data collection procedures to ensure the maintenance of collaborative research relationships and safeguard against participant burden.

Table 1.0

Data Collection at Baseline

Questionnaire	Time			
	Baseline			
	Demographics Form	PHQ-9	GAD-7	BSI-18

Table 1.1

Data Collection for Concussed Athletes

	Time		
	24-48 Hours	Asymptomatic	1 Month Post RTP
Questionnaire	GAD-7	GAD-7	GAD-7
	PHQ-9	PHQ-9	PHQ-9

Note. Return to Play = RTP

Table 1.2

Data Collection for MSK Injured Athletes

	Time		
	24-48 Hours	RTP	1 Month Post RTP
Questionnaire	GAD-7	GAD-7	GAD-7
	PHQ-9	PHQ-9	PHQ-9

Note. Return to Play = RTP

Table 1.3

Data Collection for Healthy Controls

	Time		
	Time 1	Time 2	Time 3
Questionnaire	GAD-7	GAD-7	GAD-7
	PHQ-9	PHQ-9	PHQ-9

Note. Times 1, 2, and 3 were be separated by two weeks as that is the approximate amount of time thought to be reflected by the SRC athlete questionnaires (24-48 hours to 1 month RTP).

Sampling and Participants

The population of interest included elite football players. Due to issues with feasibility, purposive sampling was employed to obtain the maximum number of athletes possible. The sample included male elite athletes from the University of Alberta's football team as well as CFL

players from the Edmonton Eskimos, Calgary Stampeders, and Saskatchewan Roughriders. All information was collected at the start of and during the 2018 football season.

Data Analysis

All statistical analyses were carried out using IMB SPSS Statistics for Mac, Version 19.0. Descriptive statistics were calculated to describe the characteristics of the participants. Furthermore, independent samples t-tests and chi-square tests were calculated to compare demographic variables and test outcomes of individuals who were included and excluded from the analysis to determine if the two groups different on key demographic variables such as history of concussion and mental health. However, the sample is one of convenience and because no random assignment was possible in this study the overall generalizability of the results is limited.

Question One. The analysis addressing question one examined the degree to which history of concussion had an effect on mental health (depression, anxiety, and psychological distress) at baseline. This analysis involved grouping players with no history of concussion, history of one concussion, and a history of two or more concussions. Next, a correlation analysis was completed to determine the relationship among the three dependent variables. Multivariate Analysis of Variance (MANOVA) was chosen as the statistical analysis technique as there were multiple dependent variables that were correlated. Furthermore, MANOVA was able to be employed because the sample size in each cell exceeded the number of dependent variables (three) and the dependent variables were moderately correlated ($r = .37$ to $.56$, $p < .001$). In addition, partial eta squared was computed for enhanced interpretation of results.

Question Two. The analysis addressing question two examined differences between the SRC, MSK, and healthy control groups on self-reported depression and anxiety symptoms across

three time points. Two 2-way mixed repeated measures ANOVAs were used as there was a mixture of between-group (injury type) and within-group (time) independent variables. Significance for analyses was set at constraint alpha level ($\alpha = .025$) to avoid increasing the possibility of a type one error. In addition, partial eta squared was computed for enhanced interpretation of results.

Objective Three. The Reliable Change Index (RCI) analysis was used to elucidate individual change from pre- to post injury. The RCI is a standardized difference score which establishes whether an individual's change in scores are meaningful or due to random error (Jacobson & Truax, 1991). To determine the RCI, the post injury scores on the PHQ-9 and GAD-7 were subtracted from the baseline PHQ-9 and GAD-7 scores. The result was then divided by the standard error of the differences. The standard error of the differences was calculated using the formulas shown in Table 2.0. The SD used in the formula for SEM_1 is the standard deviation at baseline and the SD used in the formula for SEM_2 is the standard deviation post-injury (i.e. 24-28 hours, asymptomatic, and 1 month RTP). Correlations between each time point on the PHQ-9 and GAD-7 in the healthy control group were determined (i.e., Pearson product-moment correlation, *r*) to provide the index of test re-test reliability. Reliable change estimates were computed using the sample of 21 healthy control participants who completed the PHQ-9 and GAD-7 questionnaire at three time points after baseline. The reliable change estimates were calculated using a modification of the Jacobson and Truax (1991) formula, which estimates the measurement error with test-retest difference scores. The formula modification involved calculating the S_{diff} using the SEM for baseline and re-test (Iverson, Lovell, & Collins, 2003). The estimated S_{diff} is appropriate to use when re-test data are not available (Iverson et al., 2003).

The cut-off score used to detect reliable change on the PHQ-9 and GAD-7 was set at a value of ±1.65, representing an alpha of $p < .05$, which aligns with previous SRC research (Cantu, 1998; Iverson et al., 2003; Iverson, Brooks, Collins, & Lovell, 2006). For the measures selected, a positive change (greater than 1.65) is indicative of greater mental health challenges (i.e. an increase in depression and/or anxiety symptoms).

Table 2.0

Reliable Change Index Equations

Variable measured	Equation
Reliable Change Index	$RCI = X_2\text{-}X_1/S_{diff}$
Standard error of the difference	$S_{diff} = \sqrt{SEM_1^2 + SEM_2^2}$
Standard error of measurement at time 1	$SEM_1 = SD\sqrt{1\text{-}r_{12}}$
Standard error of measurement at time 2	$SEM_2 = SD\sqrt{1\text{-}r_{12}}$

Note. SD is the standard deviation and r_{12} is the test re-test reliability coefficient.

Ethics and Data Storage

Data collection was approved by the Research Ethics Board at the University of North Carolina and the University of Alberta (Study ID MS2_Pro00073481). The University of Alberta's ethics board viewed this study as low risk for the participants. Risk factors identified included potential fatigue after completing the questionnaires and identification of mental health challenges that they were previously unaware of prior to completion of the questionnaires. As a safeguard to these risks, care was taken to ensure no duplicate information was being asked and when possible shortened versions of questionnaires were selected. Additionally, all questionnaires were reviewed for abnormally high ratings that would require further psychological intervention. However, intervention was not required as there were no high ratings indicative of clinical pathology. Overall, the ethics board viewed the benefits of the study

outweighed the potential risks. The benefits of the study include a greater understanding of athlete mental health at baseline and understanding how injury and SRC differentially impact athletes' mental health.

All data were electronically stored online through the Carolina Data Acquisition and Reporting Tool (CDART). This data management tool is an interactive web-based data system used for large scale data collection. Each participant had the option of completing questionnaires online by creating a log in and password for access to the CDART system or completing paper questionnaires. If players chose to fill out paper copies of the questionnaires a team of research assistants entered the data into the CDART system. This tool is encrypted and only Dr. Mrazik and the principal investigators at the University of North Carolina at Chapel Hill had administrative access to the data.

Chapter Four: Results

The purpose of this study was to investigate the potential mental health outcomes following SRC in a sample of young elite adult athletes. More specifically, this study examined the potential impact that a history of SRC may have on mental health ratings of depression, anxiety, and psychological distress. Finally, this study aimed to better understand the unique mental health outcomes following SRC in the short and long-term in comparison to MSK and healthy controls. This chapter provides a summary of the results.

Participant Characteristics

A total of 230 participants enrolled in the overall study at baseline. Due to incomplete data, 26 participants were immediately excluded from the study sample. Additionally, eight players were removed due to sustaining a concussion within the past three months. Therefore, 196 athletes' baseline data could be used for analysis. The participants' ages ranged from 18 to

34 years, with a mean of 23.70 years (*SD* = 3.35) and a median of 24.00 years. All participants reported to be biologically male and currently identified with the male gender. Additional demographic variables to describe the sample of 196 athletes at baseline are depicted in Tables 3.0, 3.1, and 3.2. Throughout the 2018 season, three groups were formed (SRC, MSK, and Healthy controls) based upon in season injuries. Data were collected on 16 concussions, 11 MSK controls, and 21 healthy controls.

Independent sample t-tests were conducted to identify differences between athletes included (*n* = 196) and excluded (*n* = 34) from the sample. Results indicated no significant differences between athlete self-report of depression (M = .87, SD = .10, *p* = .513), anxiety (M = .64, SD = .09, *p* = .633), or psychological distress (M = .07, SD = .04, *p* = .712). Chi square tests were used to determine if there were any differences between athletes who were included versus excluded on dimensions of concussion history and mental health history. Mental health history was determined based upon athlete's subjective report of a previous diagnosis of a psychiatric disorder, learning disorder (LD), attention deficit-hyperactivity disorder (ADHD), autism spectrum disorder, depression and/or bipolar. Results indicated that there were no differences between participants who were excluded versus those that were included on the variables of history of concussion (*p* = .435) or mental health history (*p* = .603). Finally, although the collegiate athletes were younger (mean age = 20.60) than the professional (CFL) athletes (mean age = 26.00), there were no significant differences between self-report of mental health at baseline (*p* = .834). Although there were no differences between athletes included versus excluded from the analysis the sample is one of convenience and therefore the generalizability of the results remains limited.

Table 3.0

Participant Characteristics: Race

Race	Frequency (%) Players Included (n = 196)	Frequency (%) Players Excluded (n = 34)
American Indian/Alaskan Native	1.25	1.14
Asian	2.50	2.24
Native Hawaiian/Pacific Islander	1.25	0.00
African American/Black	32.80	33.02
White	55.70	61.07
Other	5.00	2.53
Unknown	1.50	0.00

Table 3.1

Participant Characteristics: Previous Diagnoses

Previous Diagnosis	Number of Players Included (n = 196)	Number of Players Excluded (n = 34)
ADHD	24	1
Learning Disability	7	0
Depression	2	0
Anxiety	3	1
Migraine	10	2
No Diagnoses Reported	150	30

Table 3.2

Participant Characteristics: Year of most recent Concussion

Year	Number of Players Included (n = 86)	Number of Players Excluded (n = 10)
2004	1	0
2005	0	0
2006	1	0
2007	1	1
2008	3	0
2009	2	0
2010	4	0
2011	1	0
2012	8	0
2013	12	0
2014	11	0
2015	13	0
2016	22	0
2017	7	1
2018	0	8

Question One

A one-way MANOVA was used to determine the effect of concussion history on baseline mental health functioning. Three measures of mental health functioning were included in the analysis: depression (PHQ-9), anxiety (GAD-7), and psychological distress (BSI-18). The assumptions of MANOVA were evaluated. For all general linear models, the dependent variables were continuous and the independent variables consisted of three categorical, independent groups. Further, the study design ensured adequate sample size and independence of observations (i.e. each participant counted as only one observation). The sample size of 196 included 38 or greater cases for each cell of the design. Therefore, this sample had greater than 20 degrees of freedom of error, which is suggested to ensure multivariate normality with unequal sample sizes (Tabachnick & Fidell, 2014). Additionally, one-way MANOVA is robust to deviations from normality. Results of linearity were satisfactory as assessed by scatterplots.

There were no univariate outliers in the data, as assessed via the inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the box. In addition, there were no multivariate outliers in the data, as assessed by Mahalanobis distance ($p > .001$). There was no multicollinearity, as assessed by Pearson correlations (see Table 4.0). Box's test of equality of covariance matrices was used to test the homogeneity of variance-covariance matrices. Results of this test were significant ($p < .001$) for all general linear models indicating a violation of MANOVA. As a result, the more stringent Pillai's criterion was used to evaluate multivariate significance (Tabachnick & Fidell, 2014). Finally, there was homogeneity of variances, as assessed by Levene's Test of Homogeneity of Variance ($p > .050$). Based on the above findings, the results can be interpreted with confidence.

Table 4.0

Pearson Correlations between Mental Health Measures

Measure	PHQ-9	GAD-7	BSI-18
PHQ-9	1	.56	.42
GAD-7	-	1	.37
BSI-18	-	-	1

Note: N = 196

Results from the one-way MANOVA were statistically significant such that there was a statistically significant difference between the groups (history of no concussion, one concussion, two or more concussions) on the combined dependent variables, $F(6, 384) = 8.06$, $p < .001$; Pillai's Trace = .22; partial $\eta^2 = .11$. Due to this significant effect, follow-up univariate ANOVAs (using a Bonferroni adjusted α level of .016) were conducted. Univariate results showed a statistically significant difference in self-reports of depression ($F(2, 193) = 10.88$, $p < .001$, partial $\eta^2 = .10$), anxiety ($F(2, 193) = 13.67$, $p < .001$, partial $\eta^2 = .12$), and psychological

distress ($F(2, 193) = 18.01$, $p < .001$, partial $\eta^2 = .16$) at baseline between the history of concussion groups.

Tukey post-hoc tests showed that players with a history of one concussion ($p < .001$) and players with a history of two or more concussions ($p = .005$) reported greater symptoms of depression at baseline in comparison to players with a history of no concussion. However, there was no statistically significant difference between players with a history of one concussion and players with a history of two or more concussions ($p = .834$). Similar results were found on the measure of anxiety such that players with a history of one concussion ($p < .001$) and players with a history of two or more concussions ($p = .002$) reported greater symptoms of anxiety at baseline in comparison to players with a history of no concussion. However, there was no statistically significant difference between players with a history of one concussion and players with a history of two or more concussions ($p = .771$). Finally, players with a history of one concussion ($p < .001$) and players with a history of two or more concussions ($p = .001$) reported greater symptoms of psychological distress at baseline in comparison to players with a history of no concussion. However, there was no statistically significant difference between players with a history of one concussion and players with a history of two or more concussions ($p = 1.00$). Table 5.0 depicts the means and standard deviations for each mental health measure by each concussion history group. Figure 2.0 displays these results graphically.

Table 5.0

Mean Scores by Concussion History

Measure [mean (SD)]	Concussion History		
	Zero (n = 108)	One (n = 50)	Two or more (n = 38)
Depression	.93 (.14)	1.95 (.32)	2.16 (.23)
Anxiety	.73 (.11)	1.83 (.33)	2.10 (.30)
Psychological Distress	.11 (.04)	1.18 (.22)	1.18 (.33)

Note. Zero = no history of concussion; One = history of one concussion; Two or more = history of two or more concussions.

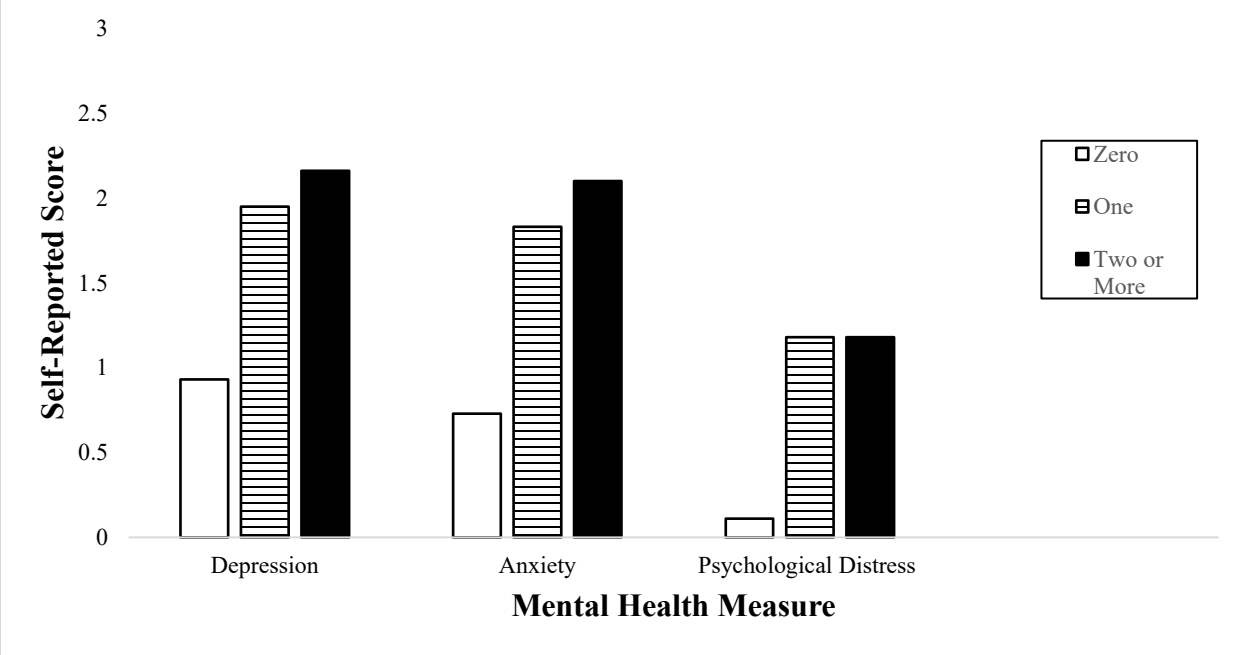

Figure 2.0. Results of one-way MANOVA, mean mental health scores by history of concussion groupings.

Question Two

Two 2-way mixed ANOVAs were used to determine if there were significant differences in self-report of depression and anxiety over time between the injury groups. Two measures of mental health functioning were included: depression (PHQ-9) and anxiety (GAD-7). Over the 2018 season, data was collected on 16 SRCs, 11 MSK injuries, and 21 healthy controls. However, due to missing data, three of the athletes in the SRC group were removed from this

analysis leaving 13 athletes in the SRC group. Of the athletes in the SRC group the average RTP time was 22 days with a median of 17 days and a range of 13 to 61 days. The athlete that took 61 days to recover had a history of one previous SRC and reported mild symptoms consistent with depression and anxiety at baseline (scores of 5 or greater on the PHQ-9 and GAD-7).

Depression. The assumptions of a 2-way mixed ANOVA were evaluated. The design included a continuous dependent variable, a categorical between-subjects factor with three levels (SRC, MSK, Healthy), and a categorical within-subjects factor with four levels (time). There were no outliers as assessed by boxplots. The data are approximately normally distributed, as assessed by Shapiro-Wilk's test of normality ($p = .071$). There was homogeneity of variances as assessed by Levene's test of homogeneity ($p < .043$). Box's test of equality of covariance matrices was used to test the homogeneity of variance-covariance matrices. Results of this test were significant ($p < .001$) indicating a violation. As a result, the more stringent Pillai's criterion was used to evaluate multivariate significance (Tabachnick & Fidell, 2014). Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(5) = .50$, $p < .001$. Due to the bias created by the sphericity violation, the less biased epsilon Greenhouse-Geisser was used to interpret the results.

There was a statistically significant interaction between group (SRC, MSK, Healthy) and time on self-reported depression, $F(5, 96) = 10.72$, $p < .001$, partial $\eta^2 = .34$. Due to this significant effect, follow-up univariate analysis at each time point were conducted to examine the simple main effects for injury groups. Results indicated no differences between groups at baseline ($F(2, 44) = 2.08$, $p = .137$, partial $\eta^2 = .09$). However, there was a statistically significant difference between groups at time one which was 24-28 hours post-injury (SRC and MSK) and time point number one collected for the healthy controls ($F(2, 47) = 11.47$, $p < .001$,

partial $\eta^2 = .33$). Specifically, there was a statistically significant difference between athletes who sustained a SRC and athletes who sustained a MSK injury at the 24-48 hour time point (MD = 2.41, SE = .74, $p = .006$). There was also a statistically significant difference between athletes who sustained a SRC and healthy control players (MD = 3.09, SE = .66, $p < .001$). Finally, there was not a significant difference between MSK injured players and healthy players at time one (MD = .67, SE - .703, $p = .606$). There were no statistically significant differences between groups at the second time point which was when athletes were asymptomatic in the SRC group, returned to play in the MSK group, and the second data collection point for healthy controls ($F(2, 47) = 1.02$, $p = .362$, partial $\eta^2 = .04$). Finally, there were no statistically significant differences between groups at the third time point which was denoted by one month after returning to play for SRC and MSK groups and the third data collection point for the healthy controls ($F(2, 45) = 2.10$, $p = .134$, partial $\eta^2 = .09$).

Next an examination of simple main effects of time by group were carried out by three within-subjects ANOVAs. For athletes who sustained a SRC, there was a statistically significant effect of time on self-reported symptoms of depression ($F(3, 36) = 19.95$, $p < .001$, partial $\eta^2 = .62$). Specifically, for the players who sustained a SRC, there was a statistically significant difference in their self-report of depression symptoms between: baseline and 24-28 hours post-SRC (MD = -2.39, SE = .47, $p = .002$); 24-48 hours post-SRC and asymptomatic (MD = 2.08, SE = .60, $p = .002$); and 24-28 hours and one month post RTP (MD = 4.01, SE = .72, $p = .001$). There were no statistically significant differences between any other pairwise comparison. Finally, were was no statistically significant effects of time on self-reported symptoms of depression for MSK injured athletes ($F(3, 30) = 2.35$, $p = .148$, partial $\eta^2 = .47$) or healthy control athletes ($F(3, 60) = .68$, $p = .565$, partial $\eta^2 = .033$). Results are depicted in Figure 3.0.

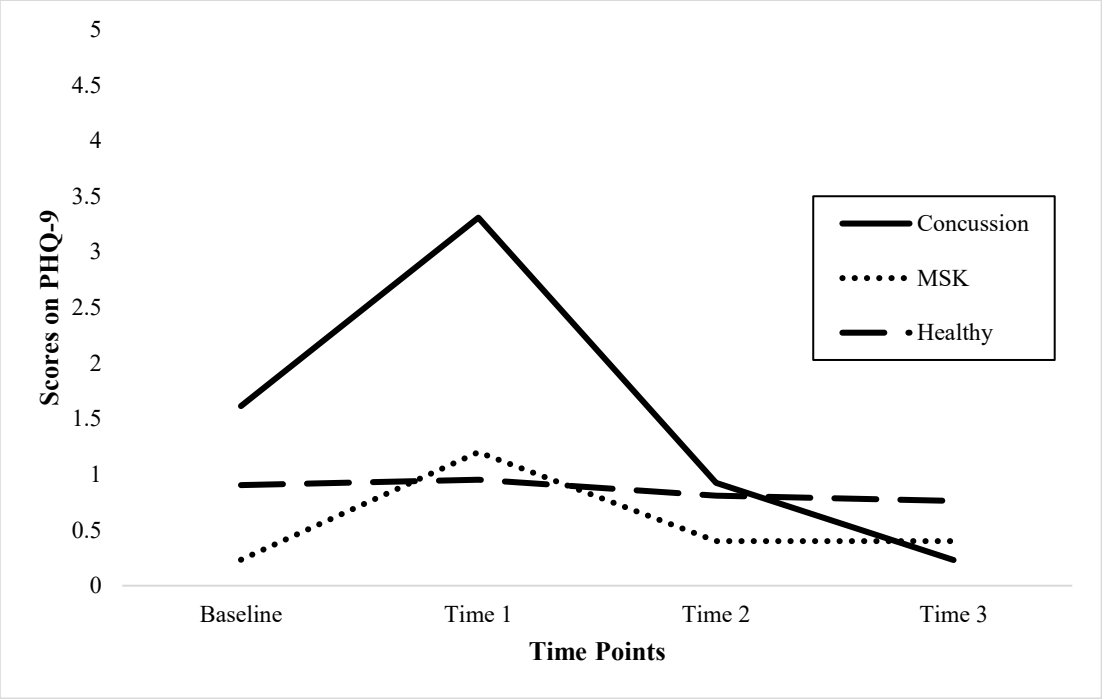

Figure 3.0. Results of the two-way mixed ANOVA, depression scores by time and injury group.

Anxiety. The assumptions of a two-way mixed ANOVA were evaluated. The design assumptions were met, as discussed above. There were no outliers as assessed by boxplots. The data are approximately normally distributed, as assessed by Shapiro-Wilk's test of normality (p = .080). There was homogeneity of variances as assessed by Levene's test of homogeneity (p < .049). Box's test of equality of covariance matrices was used to test the homogeneity of variance-covariance matrices. Results of this test were significant (p < .001) indicating a violation. As a result, the more stringent Pillai's criterion was used to evaluate multivariate significance (Tabachnick & Fidell, 2014). Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, χ^2 (5) = .62, p = .001. Due to the bias created by the sphericity violation, the less biased epsilon Greenhouse-Geisser was used to interpret the results.

There was a statistically significant interaction between the injury group and time on self-reported anxiety, $F(5, 102) = 7.16$, $p < .001$, partial $\eta^2 = .60$. Due to this significant effect, follow-up univariate analysis at each time point were conducted to examine the simple main effects for injury groups. Results indicated no differences between groups at baseline ($F(2, 44) = 2.47$, $p = .097$, partial $\eta^2 = .101$). However, there was a statistically significant difference between groups at time one which was 24-28 hours post-injury (SRC and MSK) and the first data collection point for the healthy controls ($F(2, 47) = 9.57$, $p < .001$, partial $\eta^2 = .29$). Specifically, there was a statistically significant difference between athletes who sustained a SRC and athletes who sustained a MSK injury at the 24-48 hour time point (MD = 2.50, SE = .71, $p = .003$). There was also a statistically significant difference between athletes who sustained a SRC and healthy control players (MD = 2.55, SE = .63, $p = .001$). Finally, there was not a significant difference between MSK injured athletes and healthy athletes at time one (MD = .05, SE = .67, $p = 1.00$). There were no statistically significant differences between groups at the second time point which was when athletes were asymptomatic in the SRC group, returned to play in the MSK group, and the second data collection point for healthy controls ($F(2, 47) = 1.11$, $p = .582$, partial $\eta^2 = .02$). Finally, there was no statistically significant differences between groups at the third time point which was denoted by one month after RTP for SRC and MSK athletes and the third time point for the healthy controls ($F(2, 45) = 1.46$, $p = .243$, partial $\eta^2 = .06$).

Next, an examination of simple main effects for time by group were carried out by three within-subjects ANOVAs. For athletes who sustained a SRC, there was a statistically significant effect of time on self-reported symptoms of anxiety ($F(3, 25) = 33.10$, $p < .001$, partial $\eta^2 = .50$). Specifically, for the athletes who sustained a SRC, there was a statistically significant difference

in their self-report of anxiety symptoms between: baseline and 24-28 hours post-SRC (MD = -1.69, SE = .50, p = .032); 24-48 hours post-SRC and asymptomatic (MD = 2.39, SE = .67, p = .023); and 24-28 hours and one month post RTP (MD = 3.08, SE = .60, p = .002). There were no statistically significant differences between any other pairwise comparison. For athletes who sustained a MSK injury, there was no statistically significant effect of time on self-reported anxiety ($F(2, 14) = 4.01$, p = .101, partial η^2 = .31). Finally, for athletes in the healthy control group, there was no statistically significant effect of time on self-reported depression ($F(3,60)$ = .30, p = .757, partial η^2 = .02). Results are depicted below in Figure 4.0

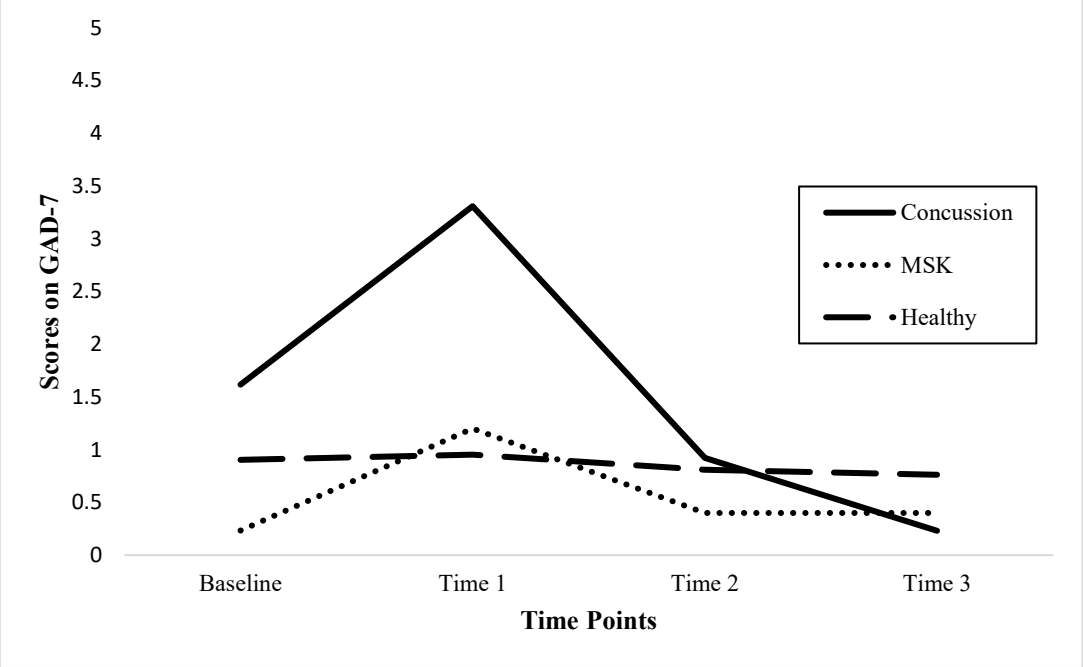

Figure 4.0. Results of the two-way mixed ANOVA, anxiety scores by time and injury group.

Question Three

The RCI was used to assess clinically meaningful change in mental health functioning (anxiety and depression) at the individual level across time. The statistical parameters used to calculate the RCI for the PHQ-9 and GAD-7 across the three time points are listed below in Table 6.0, 6.1, and 6.2. The formulas used to calculate the RCI can be found in Chapter 3 in

Table 2.0. For each athlete who sustained a SRC scores from 24-48 hours, asymptomatic, and one-month post RTP were compared to their baseline scores. This procedure was implemented for the MSK and healthy athletes as well. The athletes included in this analysis are identical to those included in question two.

Table 6.0

Descriptive Statistics, SEMs, S_{diffs}, for Healthy Controls at Time 1

Measure	M (SD) (N = 21)		r_{01}	SEM_1	SEM_2	S_{diff}
	Baseline	Time 1				
Depression (PHQ-9)	.86 (1.59)	1.10 (1.92)	0.73	.83	1.01	1.31
Anxiety (GAD-7)	.90 (1.70)	.95 (1.86)	0.76	.83	.91	1.24

Table 6.1

Descriptive Statistics, SEMs, S_{diffs}, for Healthy Controls at Time 2

Measure	M (SD) (N = 21)		r_{02}	SEM_1	SEM_2	S_{diff}
	Baseline	Time 2				
Depression (PHQ-9)	.86 (1.59)	1.10 (2.00)	0.68	.90	1.12	1.44
Anxiety (GAD-7)	.90 (1.70)	.81 (1.81)	0.74	.86	.92	1.26

Table 6.2

Descriptive Statistics, SEMs, S_{diffs}, for Healthy Controls at Time 3

Measure	M (SD) (N = 21)		r_{03}	SEM_1	SEM_2	S_{diff}
	Baseline	Time 3				
Depression (PHQ-9)	.86 (1.59)	.86 (1.56)	0.74	.81	.80	1.14
Anxiety (GAD-7)	.90 (1.70)	.76 (1.34)	0.76	.83	.66	1.06

SRC Athletes. This analysis was conducted on 12 athletes who sustained a SRC and completed the self-report forms at all four data collection points. Examination of the RCI showed that five of 12 athletes (42%) and two of 12 athletes (17%) who sustained a SRC reported a statistically significant increase in depression and anxiety symptoms respectively from baseline to 24-28 hours post-SRC. Additionally, four of 12 athletes (33%) and five of 12 athletes (42%) who sustained a SRC demonstrated a statistically significant decrease in depression and anxiety symptoms respectively from baseline to the asymptomatic time point. Finally seven of 12 athletes (58%) and four of 12 athletes (33%) and who sustained a SRC showed a statistically significant decrease in depression and anxiety symptoms respectively from baseline to one month post RTP. Table 7.0 and 7.1 depicts these results for athletes who sustained a SRC as well as outlines concussion modifiers the athlete endorsed at baseline.

Table 7.0

Results from the RCI: SRC Athletes

	24-28 Hours		Asymptomatic		1 Month RTP		SRC Modifiers	
Participant	Depression	Anxiety	Depression	Anxiety	Depression	Anxiety	# of Previous SRC	Previous Diagnoses
1	↑			↑			3	
2							1	
3	↑				↓	↓	1	LD
4							1	
5	↑	↑		↓	↓	↓	3	
6			↓	↓	↓	↓	3	
7	↑						0	
8							3	ADHD
9			↓		↓	↓	3	
10	↑			↓	↓		1	
11		↑	↓	↓	↓		1	
12			↓		↓		2	

Note. Up arrows signify a significant increase (RCI > 1.65), meaning the player endorsed more symptoms in comparison to baseline report. Down arrows signify a significant decrease (RCI > -1.65), meaning the player endorsed less symptoms in comparison to baseline report.

Table 7.1

Results from the RCI: SRC Athletes

	Depression RCI			Anxiety RCI			SRC Modifiers	
Participant	24-48 hours	Asymptomatic	1 Month Post RTP	24-48 hours	Asymptomatic	1 Month Post RTP	# of Previous SRC	Previous Diagnoses
1	**2.29**	1.39	0.88	0.00	**2.39**	0.00	3	
2	1.53	0.69	0.88	1.62	0.00	0.00	1	
3	**2.29**	-0.69	**-2.63**	1.62	-1.59	**-1.88**	1	LD
4	0.00	0.69	-0.88	0.00	-0.80	-0.94	1	
5	**5.35**	0.69	**-1.75**	**4.85**	**2.39**	**-2.82**	3	
6	1.53	**-2.08**	**-2.63**	0.00	**-2.39**	**-3.77**	3	
7	**2.29**	0.00	0.00	0.00	0.00	0.00	0	
8	1.53	0.00	0.00	1.62	0.00	0.00	3	ADHD
9	0.00	**-2.08**	**-2.63**	1.62	0.00	**-1.88**	3	
10	**2.29**	-0.69	**-3.51**	0.00	**-3.98**	-0.71	1	
11	1.53	**-2.08**	**-2.63**	**3.24**	**-2.39**	0.00	1	
12	1.53	**-2.77**	**-4.39**	1.62	-0.80	-0.94	2	

Note. Significant RCI values > 1.65 are in bold face.

MSK Athletes. This analysis was conducted on 11 athletes who sustained an MSK injury and completed the self-report forms at all four data time points. Examination of the RCI results showed that two of the 11 athletes (18%) and three of the 11 athletes (27%) who sustained a MSK injury reported a statistically significant increase in depression and anxiety symptoms respectively from baseline to 24-28 hours post-injury. Additionally, one of 11 athletes (9%) and zero of 12 athletes who were injured demonstrated a statistically significant decrease in depression and anxiety symptoms respectively from baseline to the RTP. Finally two of 12 athletes (18%) and four of 12 athletes (33%) and who were injured showed a statistically significant decrease in depression and anxiety symptoms respectively from baseline to one

month post RTP. Table 8.0 and 8.1 depicts these results for players who sustained MSK injury as well as outlines any concussion modifiers the athlete endorsed at baseline.

Table 8.0

Results from the RCI: MSK Athletes

	24-28 Hours		RTP		1 Month RTP		Concussion Modifiers	
Participant	Depression	Anxiety	Depression	Anxiety	Depression	Anxiety	# of Previous SRC	Previous Diagnoses
13		↑	↓		↓		0	
14							0	
15							4	
16							0	
17							0	
18		↑					0	
19	↑					↓	0	
20						↓	1	Migraine
21	↑	↑			↓	↓	2	
22						↓	0	
23					↓		0	

Note. Up arrows signify a significant increase (RCI > 1.65), meaning the player endorsed more symptoms in comparison to baseline report. Down arrows signify a significant decrease (RCI > -1.65), meaning the player endorsed less symptoms in comparison to baseline report.

Table 8.1

Results from the RCI: MSK Athletes

	Depression RCI			Anxiety RCI			SRC Modifiers	
Participant	24-48 Hours	RTP	1 Month Post RTP	24-48 Hours	RTP	1 Month Post RTP	# of Previous SRC	Previous Diagnoses
13	0.76	**-2.08**	**-2.63**	**2.43**	0.00	0.00	0	
14	0.00	0.00	0.00	0.00	0.00	0.00	0	
15	0.00	0.00	0.00	0.00	0.00	0.00	4	
16	0.00	0.00	0.00	0.00	0.00	0.00	0	
17	0.76	-0.69	-0.88	0.00	0.00	0.00	0	
18	1.53	0.00	0.00	**2.43**	0.00	0.00	0	
19	**3.06**	0.00	0.00	1.62	1.59	**1.88**	0	
20	0.00	0.00	0.00	0.00	0.00	**-1.88**	1	Migraine
21	**2.29**	-0.69	**-1.75**	**3.24**	1.59	**1.88**	2	
22	0.76	0.00	0.00	0.00	0.00	**1.88**	0	
23	0.00	0.00	0.00	0.00	0.00	0.00	0	

Note. Significant RCI values > 1.65 are in bold face.

Healthy Athletes. This analysis was conducted on 21 healthy athletes who completed the self-report forms at all four data time points. Examination of the RCI results showed that one of the 21 healthy athletes (5%) and two of the 21 healthy athletes (10%) reported a statistically significant increase in depression and anxiety symptoms respectively from baseline to their first self-report in season. Additionally, one of 21 healthy athletes (5%) and two of 21 (10%) healthy athletes reported a statistically significant increase in depression and anxiety symptoms respectively from baseline to the second time point, two weeks after the first report. Finally, one of the 21 healthy athletes (5%) reported a significant increase in depression symptoms, while another healthy athlete (5%) reported a significant decrease in depression symptoms at the third time point, two weeks after the second report. Finally, four of 12 healthy athletes (19%) reported a statistically significant decrease in anxiety symptoms at the third and final time point. Table 9.0

and 9.1 depicts these results for healthy athletes as well as outlines any concussion modifiers the athlete endorsed at baseline.

Table 9.0

Results from the RCI: Healthy Athletes

	Time 1		Time 2		Time 3		Concussion Modifiers	
Participant	Depression	Anxiety	Depression	Anxiety	Depression	Anxiety	# of Previous SRC	Previous Diagnoses
24							1	
25					↓		1	
26							0	Migraine
27							0	
28	↑	↑	↑	↑	↑	↑	0	
29		↑		↑		↑	0	
30							1	
31							1	
32							2	
33							0	
35							0	
35							1	
36							0	
37							0	
38							0	
39							0	
40							0	ADHD
41							0	
42						↑	1	
43						↑	0	
44							0	

Note. Up arrows signify a significant increase (RCI > 1.65), meaning the player endorsed more symptoms in comparison to baseline report. Down arrows signify a significant decrease (RCI > -1.65), meaning the player endorsed less symptoms in comparison to baseline report.

Table 9.1

Results from the RCI: Healthy Athletes

	Depression RCI			Anxiety RCI			SRC Modifiers	
Participant	Time 1	Time 2	Time 3	Time 1	Time 2	Time 3	# of Previous SRC	Previous Diagnoses
24	-1.53	-0.69	-0.88	-0.81	-1.59	-0.94	1	
25	-0.76	-1.39	**-1.75**	-0.81	-1.59	-0.94	1	
26	-0.76	-0.69	-0.88	0.00	0.00	0.00	0	Migraine
27	0.00	0.00	0.00	0.00	0.00	0.00	0	
28	**3.82**	**3.47**	**3.51**	**3.24**	**2.39**	**1.88**	0	
29	0.00	0.00	0.00	**3.24**	**2.39**	**1.88**	0	
30	0.00	-0.69	-0.88	0.00	-0.80	0.00	1	
31	0.00	0.00	0.00	0.00	-0.80	0.00	1	
32	0.00	-0.69	0.88	0.00	-0.80	-0.94	2	
33	0.00	0.00	0.00	0.00	-0.80	-0.94	0	
35	0.00	0.00	0.00	0.00	0.00	0.00	0	
35	0.00	0.00	0.00	0.00	0.00	0.00	1	
36	0.00	0.00	0.00	0.00	0.00	0.00	0	
37	0.00	0.00	0.00	0.00	0.00	0.00	0	
38	0.00	0.00	0.00	0.00	0.00	0.00	0	
39	0.00	0.00	0.00	0.00	0.00	0.00	0	
40	0.76	1.39	0.00	1.62	1.59	0.00	0	ADHD
41	0.00	0.00	0.00	1.62	1.59	0.00	0	
42	0.76	1.39	-0.88	0.00	0.00	**1.88**	1	
43	0.00	0.00	0.00	0.00	0.00	**1.88**	0	
44	1.53	1.39	0.88	0.00	1.59	0.00	0	

Note. Significant RCI values > 1.65 are in bold face.

Chapter Five: Discussion

For athletes participating in high impact sports, injury is inevitable. SRC remains a public health concern among Canadian athletes (Government of Canada, 2018a). Researchers suggest that athletes can display a wide range of physical, cognitive, and emotional symptoms following a SRC (Iverson et al., 2017; McCory et al., 2017). Due to the complexity of this injury involving biological, psychological, and social features it can be best understood by Engel's (1977)

biopsychosocial model. Given that a large portion of the brain is used for social interaction, emotional regulation, and decision making it is not surprising that an insult to the brain may cause disruptions in mental health functioning (Iverson et al., 2017). In particular, researchers are beginning to identify a link between SRC and problematic mental health outcomes in the elite athlete population (Covassin et al., 2017; Kerr et al., 2014; Manley et al., 2017; McCrory et al., 2017; Rice et al., 2018). Elite athletes represent a unique subset of the sport population as they face unique psychological pressures including intense mental and physical demands. Therefore, elite athletes may be particularly vulnerable mental health outcomes of SRC (Brosheck et al., 2015).

There is growing interest in elucidating the mental health outcomes following SRC to inform clinical practices including rehabilitation and return to play process. Although SRC has received increased awareness over the last decade there remains a paucity of methodologically sound research examining mental health outcomes in elite athlete populations (Arnett et al., 2019). The current study examined mental health outcomes of elite young adult athletes in comparison to MSK injured and healthy controls. The intention of this research was to increase knowledge about the unique mental health outcomes of SRC in an elite population in order to facilitate future prevention and intervention strategies that are clinically applicable for these athletes.

Question One

The analysis addressing question one examined the degree to which history of SRC had an effect on mental health functioning (depression, anxiety, and psychological distress) at baseline. It was hypothesized that athletes with a history of two or more SRCs would report higher depression, anxiety, and psychological distress in comparison to athletes with no history

of concussion. Results from the analysis showed that athletes with a history of one SRC and athletes with a history of two or more SRCs reported higher levels of depression, anxiety, and psychological distress at baseline in comparison to athletes with no history of SRC. Although this effect was statistically significant, the results have subtle clinical significance. Specifically, the difference between the groups was approximately one and a half, meaning that the athletes endorsed between one and two more symptoms in comparison to the other groups. Although the results suggest that this effect would not occur due to chance or error alone, it can be concluded that the differences are very subtle.

This finding is supported by previous researchers who have identified that athletes with a history of SRC (typically two or greater) report more symptoms of depression at baseline in comparison to athletes with a history of no SRCs (Covassin et al., 2017; Didehbani et al., 2013; Guskiewicz et al., 2007; Kerr et al., 2012; Manley et al., 2017; Pryor et al., 2016; Rice et al., 2018). The literature available on outcomes of anxiety are mixed with most studies pointing towards a trend or possible link between history of SRC and anxiety symptoms at baseline (Covassin et al., 2016). Finally, psychological distress was a fairly unknown area with only two previous studies investigating these outcomes. Weber and colleagues (2018) found similar results to the current study suggesting a difference between athletes with a history of one or more SRCs versus a history of no concussions. However, Combs and colleagues (2017) found no differences between self-reported psychological distress and SRC history at baseline.

Although for the most part the results of the current study are in line with previous findings in the literature, this study is unique. Specifically, the majority of previous studies did not speak to the clinical implications of their findings, which is important to note when bridging the gap between research and practice. Many of the studies reported “statistically significant

differences" at baseline; however, it is helpful to know the clinical relevance of those differences. For example, in the current study, the differences between groups were very subtle. This research is not suggesting that athletes with a history of SRC have clinical levels of depression and anxiety at baseline. This is an important distinction to make as when the media views research results they may misinterpret statistically significant for clinically significant findings, which may skew the public's perception of mental health outcomes post SRC. Overall, objective one of the current study contributes to the pre-existing premature findings suggesting that a history of SRC has a subtle impact on mental health functioning at baseline. However, further research is needed to continue to elucidate this complex phenomenon.

Question Two

The second analysis investigated the impact of SRC on self-report of depression and anxiety symptoms over time at the group level. It was hypothesized that athletes who sustained a SRC during the season would report more depression and anxiety symptoms (as measured by the PHQ-9 and GAD-7) in the short term (24-48 hours) in comparison to both the MSK and healthy control groups. The hypotheses were accurate as the results indicated an interaction effect between injury groups for both depression and anxiety outcome measures. Further analysis showed no significant differences between groups at baseline. However, players who sustained a SRC reported greater levels of depression and anxiety at 24-48 hours post SRC in comparison to the MSK injury and healthy control groups. Across all three time points there were no differences in self-reported depression and anxiety symptoms between the MSK injured athletes and the healthy control athletes. This suggests that athletes who sustained a SRC were unique in their experience of depression and anxiety symptoms in the short term (24-48 hours post SRC). There were no differences between SRC athletes, MSK injured athletes, and healthy controls at

the asymptomatic/RTP, and one month port RTP time points suggesting that athletes only experienced an increase in depression and anxiety symptoms in the acute phase of the SRC injury.

In addition, the main effect of time was significant for players who sustained a SRC. Specifically, these experienced an increase in depression and anxiety symptoms at 24-48 hours post SRC in comparison to baseline, asymptomatic, and one month post RTP. This effect of time was not found in the MSK or healthy control groups, again suggesting this finding is unique to SRC. However, it may be important to note that no athletes reported a level of depression or anxiety at any time point that would meet the criteria for even mild depression or anxiety (as identified by the PHQ-9 and GAD-7 cut off points). Therefore, the increase in depression and anxiety symptoms at 24-28 hours post SRC was subtle and not indicative of clinical pathology. Taken together, although athletes who sustain a SRC experienced a subtle increase in symptoms of anxiety and depression that appear to be unique, the symptoms were short-lived.

The results from objective two are also consistent with some previous findings in the literature. In particular, Hutchison and colleagues (2009) also found that athletes experienced short-term emotional challenges (i.e. depression, tension, anger, fatigue, and decreased self-esteem) after sustaining a SRC that was different from MSK control athletes, which were defined as a soft tissue injury resulting in removal from play for a minimum of 48 hours and a maximum of a three weeks. However, Manwaring and colleagues (2011) found that both athletes who sustained a SRC and ACL injuries reported similar increases in depression symptoms post-injury in comparison to healthy controls. Additionally, Rogier and colleagues (2015) found that athletes who sustained a SRC and a MSK injury reported higher levels of depression at one week post injury but not at the one month and three month evaluations, also suggesting short-term

challenges. Their criteria for an injured control was quite broad and included any injury as defined by NCAA that resulted in removal from play for one or more days (e.g., ACL tear, ankle sprain, separated shoulder). Taken together, it appears that the nature and severity of the MSK injury control group may explain the discrepancy in findings across the literature. Specifically, ACL injuries are often season ending, require surgical intervention, and typically require a longer rehabilitation times than a SRC. As ACL injuries are less comparable to a SRC in terms of severity and rehabilitation time, the criteria Hutchinson and colleagues (2009) and the current study employed appear to be a closer comparison to a SRC injury. Overall, the current research would suggest that SRC are unique and present different mental health challenges than comparable MSK injuries do.

The current research findings support a hypothesis of a biological mechanism underling the mental health challenges experienced by athletes who sustain SRCs. In particular, Chen and colleagues (2008) used functional magnetic resonance imaging to illustrate that athletes who sustained a SRC had reduced dorsolateral prefrontal cortex activity and increased anterior cingulate and medial orbital frontal region activity, which is comparable to findings in individuals diagnosed with major depression. Additionally, Meier and colleagues (2015) found that concussed athletes' anxiety and depression reports in the acute phase after SRC predicted diminished cerebral blood flow one month later, suggesting another possible biological mechanism underlying the initial disturbance in mental health functioning. Although the underlying cause of these mental health challenges may have biological underpinnings they also are likely involve social and psychological factors as suggested by Engle's biopsychosocial model (1977).

Specifically, Covassin and colleagues (2014) examined social support post SRC and MSK injuries. They found that both groups identified similar sources of social support but that the MSK control players expressed more satisfaction in their social support compared to the SRC group. In addition, the researchers found that satisfaction in social support from family at baseline significantly predicted state anxiety at the time of RTP only in the SRC group. Therefore, SRC athletes with greater satisfaction in family support at baseline were less likely to report state anxiety post-SRC (Covassin et al., 2014). Results from this research provides implications for the importance of prevention. For example, family counseling to enhance strong family social support prior to the start of a season may be a beneficial protective social factor against adverse outcomes following SRC.

Finally, the results of the current study likely have psychological underpinnings. Specifically, Yang and collegues (2015) found that depression at baseline was a risk factor for both self-report of anxiety and depression symptoms post SRC. Vargas and colleagues (2015) also found that the greater baseline depression symptoms were the greater they were post SRC. This research points to the importance of baseline screening and prevention/intervention at the outset of the season to mitigate some of the adverse mental health outcomes that could occur following an injury.

Question Three

Questions one and two investigated changes at the group level, which is the predominate approach in the SRC literature. However, analysis at the group level can obscure individual variability and subtilties that are known to exist following SRC (Echemendia et al., 2001). Analysis at the individual level has also lead to changes in clinical management of SRC. Specifically, previous SRC management guidelines were based on arbitrary exclusion policies

whereby SRC athletes were removed from play for a fixed period of time. However, more recent guidelines utilize an individualized approach to management and RTP procedures (McCory et al., 2017). The RCI is often the statistical approach clinicians use to analyze individual differences over time to aid decision making about RTP processes (Temkin, Heaton, Grant & Dikmen, 1999).

Therefore, the final investigation involved analysis at the individual level to determine the impact of a SRC on an athlete's self-reported depression and anxiety in the short and long-term. It was hypothesized that an athlete who sustained a SRC during the season would demonstrate a reliable change in depression and anxiety symptoms (as measured by the PHQ-9 and GAD-7) from baseline to post SRC in the short term (24-48 hours) but not in the long-term (asymptomatic and one month post RTP). Furthermore, it was hypothesized that the control groups (MSK and healthy athletes) would not exhibit a reliable change in depression and anxiety symptoms in both the short and long-term.

Results showed that more athletes who sustained a SRC (50%) compared to MSK (33%) and healthy controls (17%) displayed a reliable increase in depression and/or anxiety symptoms between baseline and 24-48 hours post SRC. At 24-48 hours post injury a greater number of SRC athletes demonstrated a change in depression (42%) in comparison to anxiety (17%). Whereas MSK injured athletes and healthy controls reported similar changes in anxiety and depression.

It was also evident that athletes who were injured (SRC and MSK) seemed to "get better" as evidenced by a reliable decrease in symptoms of depression and anxiety in comparison to their baseline self-reports. Specifically, SRC athletes reported reliable reduction in depression and/or anxiety symptoms at the asymptomatic time point (50%) and at the one month port RTP time

point (58%) in comparison to their baseline self-reports. Few MSK injured athletes showed improvement at the RTP time point (8%) but many reported an improvement at one month post RTP (42%). Taken together, this suggests that athletes experienced improvements in their mental health functioning after successfully returning to play after a month. Of note, all athletes discussed in question two and three returned to play within a reasonable time frame (Median = 17 days) and therefore these results cannot be generalized to athletes who experience a protracted recovery.

Although the greatest number of athletes demonstrated a reliable change post SRC in comparison to MSK and healthy athletes, it is interesting that the SRC group of athletes also had the greatest number of previous SRCs. A history of previous SRC is typically a risk factor for sustaining another SRC. Additionally, the results from objective one showed that athletes with a history of SRC typically report greater symptoms consistent with depression and anxiety at baseline, which is why analysis at the individual level is imperative. Overall, results from objective three are hopeful as at the individual level 58% of athletes reported less symptoms of depression and anxiety at one month post RTP in comparison to their baseline self-report. This suggests athletes who sustained a SRC did not experience long-term mental health challenges.

The current results are similar to other findings in the literature that implemented a reliable change methodologies. Specifically, Vargas and colleagues (2015) assessed depression at baseline and post SRC in a sample of collegiate athletes. They found that 20% of athletes post SRC reported a reliable change in depression (increased depressive symptoms) in comparison to the healthy control group which only showed a 5% reliable change in depression symptoms. These researchers concluded that the prevalence of depression post SRC is substantially elevated in comparison to baseline. Merier and colleagues (2015) also found that 18% college football

athletes reported moderate clinical depression at 24 hours post SRC. Only 7% of athletes endorsed depression symptoms one week post SRC and no athletes endorsed depression symptoms at one month post SRC. In terms of anxiety, the researchers found that 35% of athletes qualified as anxious at 24 hours post SRC, 7% at one week, and none at one moth post SRC. Finally, Yang and colleagues (2015) found that nearly 20% of athletes who sustained a SRC reported some depression and 33% reported anxiety at one day post SRC. Taken together, it appears there is some consensus between the current study and the available literature in that change at the individual level is most prominent in the acute phase of SRC. However, the current study is unique in that the SRC and MSK injured athletes appeared to get better after returning to play for a month. This potentially could provide some evidence to suggest that athletes may become more resilient after a successful RTP.

Strengths and Limitations

Strengths of the current study include incorporation of control groups with stringent inclusion and exclusion criteria. Specifically, consultation with physicians, athletic trainers, and the previous literature were used to develop the selection criteria for a comparable MSK injury group. In addition, the most current definition for a SRC was used (McCrory et al., 2017) and athletes required a physician diagnosis to qualify for the SRC group. These parameters and control groups made it possible to begin to understand if mental health outcomes are unique to SRC. In addition, quantitative self-report measures with evidence of validity and reliability in the SRC population were used. Furthermore, the PHQ-9 and GAD-7 were carefully chosen as the repeated measures questionnaires because they minimized athlete burden and are cost effective. Quantitative self-reports are the most prominent approach to assessment of mental health outcomes in the literature (Covassin et al, 2017; Rice et al., 2018). Additionally, the current study

investigated changes in depression and anxiety at both the group and individual level, which was a gap in the literature identified by Arnet, Guty, and Bradson (2019).

However, the current study was not without limitations. There are inherent limitations due to the study design and procedures. First, the study design is quasi-experimental which poses a potential threat to the internal validity because groups that form naturally may not have shared equal variability. However, to increase internal validity control groups were included in the design, which is a quality indicator of quasi-experimental research (Gersten, et al., 2005). To further increase internal validity, all athletes from participating teams completed questionnaires at baseline to obtain a measurement of pre-injury functioning. Benefits of quasi-experimental studies include their strong external validity in comparison to a true experiment, feasibility, timeliness, and affordability in comparison to randomized control trials (Maciejewski, Curtis & Dowd, 2013). Second, in terms of data collection procedures, athletes may have completed questionnaires on paper or electronically. This impacted the quality of data and may have some influence on the integrity of results due to the inconsistencies of data collection (Lavarkas, 2008). However, this flexible procedure of data collection was necessary in collect the fullest data possible. Third, the study design required self-reported concussion history. Rice and colleagues (2018) noted that relying on self-reported history may be problematic due to memory bias and the possibility of inaccurate self-diagnosis. Due to ethical and privacy concerns, self-report was the only possible method for obtaining medical history and information. However, one of the greatest challenges faced by researchers collecting data via self-report quantitative measures, which is the predominant methodology in SRC literature, is the issue of accurate self-report. In particular, athletes may be motivated to under-report or over-report symptoms including their experience of mental health.

Under-reporting is a relatively common issue in the athletic population (Arnett et al., 2019; Broshek et al., 2015). Specifically, athletes may have the tendency to under-report symptoms in general, including depression and anxiety, as they are typically keenly aware that reporting symptomology will likely result in them being withheld from RTP (Arnett et al., 2019). For example, in a sample of 75 high school and collegiate athletes, Kontos and colleagues (2012) found that no athletes met criteria for even mild clinical depression at baseline. In the overall sample (N= 196) of the current study, 8% of athletes reported mild depression, 7% of athletes endorsed mild anxiety, and 3% reported mild psychological distress at baseline (as identified by each measures mild cut off score). No athletes at baseline indicated moderate to severe levels of mental health challenges. In the general population, about 11.6% of Canadians aged 18 years and older reported being diagnosed with a mood or anxiety disorder (Statistics Canada, 2013). Although exercise, fitness, and organized sport are favorable for mental health functioning, elite athletes are at a heightened risk of mental health concerns due to the intense mental and physical demands regularly placed upon them (Hughes & Leavey, 2012). Although the current study appears to be more in line with the Canadian averages of depression and anxiety diagnoses, there is still cause for concern. A possible explanation for athletes under-reporting at baseline and post-injury is the social desirability bias, where raters provide desirable answers regardless of accuracy (Duckworth & Yeager, 2015). In order to mitigate this bias, athletes were encouraged to provide honest responses, were informed that responses were confidential, and were able to complete questionnaires privately. However, the issue of under-reporting may also be tied to characteristics of the person who is collecting the data. Specifically, researchers have found that female examiners may elicit more symptoms than a male examiner. Furthermore, male athlete/male examiner dyads tend yield the lowest symptom reports (Frommer et al., 2011).

Specific to the current research, all participants and all athletic trainers collecting data post-injury were male. Therefore, this athlete examiner gender dyad may be a confounding variable to consider when collecting data and a possible reason for potential under-reporting post injury in this study.

However, sometimes athletes over-report symptoms at baseline. Over-reporting or providing sub optimal effort on performance based tasks (e.g., cognitive screen) at baseline is termed “sandbagging”. Athletes who have previously sustained a SRC at the elite level have gone through the RTP process which typically requires the athlete to return to at least baseline levels of function on performance measures and/or self-reported symptoms prior to returning to play (McCrory et al., 2017). Therefore, it is possible that athletes intentionally inflate their symptom reports at baseline in order to expedite the RTP time line should they sustain a SRC. Schatz, Elbin, and Anderson (2017), found that 6% of college athletes reported a history of sandbagging behaviour and a third of athletes reported they did not provide maximal effort on cognitive testing and/or inflated their reported symptoms at baseline. With regards to the behaviours behind “sandbagging,” the researchers identified that if the players perceived very high utility of the baseline assessment they were about five times more likely to provide maximal effort. Therefore, it may be important to educate athletes about the utility of the baseline assessment process. In addition, training examiners to scan for outliers beyond typical baseline performance and self-reported symptoms can help identify athletes who may be sandbagging. This method was employed in the current study as an outlier in the data (e.g., moderate to severe reports of depression or anxiety) could possibly be sandbagging but may also be a true report of an athlete struggling with mental health and requiring supports. Therefore, all examiners were trained to look for such outliers and to contact Dr. Mrazik to provide appropriate support options

to the athlete. Ensuring accuracy of baseline assessment is critical for the management of SRC, as these data are often used to support targeted management strategies and treatments (McCory et al., 2017; Schatz et al., 2017). Due to the problematic nature of over and under-reporting in the athletic population an idea to combat these challenges is explored below in future directions.

Clinical Implications

The results from the current study suggest that prevention, assessment, diagnosis, and intervention should be driven by the biopsychosocial model. SRC is a complex injury that requires a holistic examination of symptoms, signs, and functioning at the biological (e.g., headache), psychological (e.g., depression), and social (e.g., family support) levels. The available literature, including the current study, suggests that adverse mental health outcomes can occur post SRC at the elite level (Arnett et al., 2019). Therefore, clinicians should routinely screen for depression and anxiety post SRC. In addition, there is an extensive literature demonstrating that depression is associated with cognitive impairments. As such, clinicians should be aware that when depression is comorbid with cognitive impairments post SRC, it may mediate some of the cognitive challenges that are reported or observed. Therefore, successful resolution of depression may result in improved cognitive functioning.

From a psychological intervention perspective there are many evidenced based strategies for managing depression and anxiety (Conder, A., Conder, R. & Friesen, 2020). Researchers suggest that psychoeducation is an important first step. Specifically, providing knowledge to players, parents, and coaches gives them the ability to quickly recognize and appropriately manage the injury. Further psychoeducation surrounding the possible outcomes of concussion and average length of recovery may be important for players to understand (Conder et al., 2020). In addition, Cognitive Behavioural Therapy (CBT) is often used as a first line treatment for

anxiety and depression symptoms among athletes who sustain SRC (Hou et al., 2012). Specifically, identifying maladaptive cognitions that are often reinforced by popular media can be helpful. Mindfulness interventions may also be helpful to teach the athlete to observe their symptoms without judgement or reaction and a focus on acceptance rather than trying to actively control difficult experiences such as injury (Conder et al., 2020). Additionally, relaxation and stress management tools with the aim of increasing self-regulation by breathing and imagery can also be useful for athletes (Brown & Grebang, 2009). Finally, some behavioural management strategies such as school and/or work accommodations including dimming the lights, minimizing noise, reducing screen time, extending deadlines, and allowing frequent breaks are helpful in managing the return to school and work processes (Conder et al., 2018; Sady, Vaughn & Gioia, 2011). Taken together, there are many evidenced based strategies from the psychology literature that can be adapted and may be particularly useful in managing mental health challenges that some athletes face post SRC.

Conclusion and Future Directions

In summary, the findings of the current study suggest that a history of SRC impacts baseline self-report of anxiety, depression, and psychological distress. However, the differences are subtle and do not suggest that athletes with a history of concussion have clinical levels of anxiety, depression, and psychological distress. Only mild elevations in self-report were noted. In addition, it appears that the experience of increased anxiety and depression symptoms 24-48 hours post SRC are unique to that group as the MSK and healthy control groups did not experience the same change in symptoms. Although athletes who sustained a SRC reported elevations of depression and anxiety, they returned back to baseline functioning once asymptomatic and in-fact many of them reported less symptoms at one month post RTP in

comparison to their baseline self-report. Overall, these results are hopeful for elite athletes participating in football.

Future researchers should continue to investigate this phenomenon with larger sample sizes, across multiple sports, and include both female and male athletes to elucidate an accurate prevalence of depression and anxiety following SRC. Furthermore, it will be important to adopt standardized criteria for the selection of MSK injured athletes as previous research using varying degrees of MSK injuries arrive at different conclusions (Hutchison et al., 2009, Manwaring et al., 2011, Rogier et al., 2015). Having more stringent, clear, and consistent criteria for MSK control athletes will help to determine if increased depression and anxiety is simply a function of being injured in general or if it is in fact unique to SRC. Additionally, future researchers should consider using common anxiety and depression measures, such as the PHQ-9 and GAD-7, so results across studies can begin to be compared directly. Similarly, researchers should consider using the same post injury data collection time points for direct comparison of results.

As mentioned earlier, one of the greatest challenges faced by researchers collecting data via self-report quantitative measures is the issue of athletes under-reporting or over-reporting symptoms. To circumvent this challenge, Ramanathan and colleagues (2012) incorporated a performance-based measure of affect. Specifically, they examined 256 collegiate athletes at baseline with using the Beck Depression Inventory (BDI-FS) and the Affective Word List (AWL). The AWL involved recalling 16 affectively valanced words, half of which were positive and half of which were negative. Researchers then subtracted negative words from positive words recalled on initial trials and created a “positive affect group” and “negative affect group”. Researchers found that 80% of those in the negative affect group reported some depression, compared with only 20% of the positive affect group, thus providing some validity for the AWL.

Taken together, Ramanathan and colleagues (2012) demonstrated that athletes who show negative cognitive biases at baseline are also likely to report at least mild depression. Therefore, performance-based measures provide an option for identifying athletes who are at risk for depression post-concussion and who may under-report depression symptoms post SRC and require clinical follow-up. Overall, the literature examining mental health outcomes of SRC continues to be in its early stages with many fruitful avenues to continue to explore. The current study was unique and filled in some gaps present; however, more research is required to better understand this complex injury.

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Appendix A: Measures

The Patient Health Questionnaire (PHQ-9)

Patient Name _____ Date of Visit _____

Over the past 2 weeks, how often have you been bothered by any of the following problems?	Not At all	Several Days	More Than Half the Days	Nearly Every Day
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed or hopeless	0	1	2	3
3. Trouble falling asleep, staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself - or that you're a failure or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed. Or, the opposite - being so fidgety or restless that you have been moving around a lot more than usual	0	1	2	3
9. Thoughts that you would be better off dead or of hurting yourself in some way	0	1	2	3
Column Totals	_____	+ _____	+ _____	
Add Totals Together	_____			

10. If you checked off any problems, how difficult have those problems made it for you to Do your work, take care of things at home, or get along with other people?

☐ Not difficult at all ☐ Somewhat difficult ☐ Very difficult ☐ Extremely difficult

Generalized Anxiety Disorder 7-item (GAD-7) scale

Over the last 2 weeks, how often have you been bothered by the following problems?	Not at all sure	Several days	Over half the days	Nearly every day
1. Feeling nervous, anxious, or on edge	0	1	2	3
2. Not being able to stop or control worrying	0	1	2	3
3. Worrying too much about different things	0	1	2	3
4. Trouble relaxing	0	1	2	3
5. Being so restless that it's hard to sit still	0	1	2	3
6. Becoming easily annoyed or irritable	0	1	2	3
7. Feeling afraid as if something awful might happen	0	1	2	3
Add the score for each column	+	+	+	
Total Score *(add your column scores)* =				

If you checked off any problems, how difficult have these made it for you to do your work, take care of things at home, or get along with other people?

Not difficult at all _____
Somewhat difficult _____
Very difficult _____
Extremely difficult _____

Source: Spitzer RL, Kroenke K, Williams JBW, Lowe B. A brief measure for assessing generalized anxiety disorder. *Arch Inern Med.* 2006;166:1092-1097.

ACTIVE REHAB

Brief Symptom Inventory 18 (BSI-18)

0a. Date assessment completed: _____ /_____/_____ Participant ID: _____

0b. Clinician initials: _____

0c. Form completed: ☐ Online (1) ☐ On Paper (2)

If on paper:
0d. Initials of person completing data entry: _____

0e. Data entry date: _____/ _____/ _____

BSI-18

Below is a list of problems people sometimes have. Read each one carefully and mark the number that best describes HOW MUCH THAT PROBLEM HAS DISTRESSED OR BOTHERED YOU DURING THE PAST 7 DAYS INCLUDING TODAY.
Do not skip any items.

How much were you distressed by:	Not at all	A little bit	Moderately	Quite a bit	Extremely
1. Faintness or dizziness	0	1	2	3	4
2. Feeling no interest in things	0	1	2	3	4
3. Nervousness or shakiness inside	0	1	2	3	4
4. Pains in the heart or chest	0	1	2	3	4
5. Feeling lonely	0	1	2	3	4
6. Feeling tense or keyed up	0	1	2	3	4
7. Nausea or upset stomach	0	1	2	3	4
8. Feeling blue	0	1	2	3	4
9. Suddenly scared for no reason	0	1	2	3	4
10. Trouble getting your breath	0	1	2	3	4
11. Feeling of worthlessness	0	1	2	3	4
12. Spells of terror or panic	0	1	2	3	4
13. Numbness or tingling in parts of your body	0	1	2	3	4
14. Feeling hopelessness about the future	0	1	2	3	4
15. Feeling so restless you couldn't sit still	0	1	2	3	4
16. Feeling weak in parts of your body	0	1	2	3	4
17. Thoughts of ending your life	0	1	2	3	4
18. Feeling fearful	0	1	2	3	4

Appendix B: Consent Form

Consent to Participate in a Research Study

Title of Study: Role of Rehabilitation in Concussion Management: A Randomized, Controlled Trial
Principal Investigator: Johna Register-Mihalik, University of North Carolina

Co-Investigators: Kevin Guskiewicz, Mike McCrea, Steve Marshall, Karen McCulloch, Jason Mihalik
Canadian Site-Investigators: Dr. Martin Mrazik, Dr. Dhiren Naidu, University of Alberta
Funding Source and/or Sponsor: National Football League (NFL) Foundation

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What is the purpose of this study?
The potential benefit of introducing a program of active rehabilitation *during* symptom recovery following has been proposed as a new method for injury management, but there have been no studies that help us understand how this might help with recovery and function after concussion. The purpose of this study is to understand what types of activities improve outcomes following a concussion. You are being asked to be in the study because you are currently an active collegiate athlete.

Are there any reasons you should not be in this study? As long as you are an athlete on a team, there is no reason you should not be in the study.

How many people will take part in this study? Approximately 6,600 participants from high schools, colleges/universities, and professional organizations (Canadian Football League) will participate in this study.

How long will your part in this study last? If you only complete the baseline assessment, your time will only last the 1 hour and 30 minutes it takes to complete the baseline assessment. Should you complete the post-injury assessments and either set of study rehabilitation activities (graded exertion only OR multidimensional), your participation would include this baseline assessment and would last until 1-month following the concussion that triggered your entrance into the rehabilitation activities.

What will happen if you take part in the study? This is a randomized control trial and your team may either be randomized to the multidimensional rehabilitation group (MDR) or enhanced graded exertion (EGE) group.

You will complete the following as part of the study:

- Pre-season baseline tests (many that are similar to previous baseline medical evaluations) of your thinking/memory, symptoms, balance, coordination, vision, quality of life, demographics, and medical history.
- If you are concussed and complete the post-injury activities, you would also complete these same measures (except medical history) more detailed demographics and a timed gait/memory task 24-48 hours post-concussion, when you no longer have symptoms, and 1-month after your concussion.
- At the 1-month assessment, you will also complete some questions about your experience in the study and the care you received.
- From 24-48 hours after the injury you *along with your Athletic Therapist,* will also be asked to track your activities (physical and cognitive) and your symptoms each day until 7 days after you have fully returned to participating in your sport. The study team *from the University of Alberta* will also track your care over the period of your concussion recovery.

- Rehab exercises, supervised by a medical provider *(team physicians and Athletic Therapists)* at your site, that work on your thinking, balance, vision, and general well-being four times per week until you have fully returned to play in your sport.
- Once you no longer have symptoms, you will continue to be progressed through the graded exertion protocol (per above), while continuing your rehabilitation (graded exertion or multidimensional) exercises, supervised by *your team physician and Athletic Therapist* at your site, until you fully return to play.

What are the possible benefits from being in this study? Research is designed to benefit society by gaining new knowledge. You may benefit from the exercises during the rehabilitation post-injury paradigm.

What are the possible risks or discomforts involved from being in this study? Your risk of experiencing discomfort or issues as a result of the assessments is minimal. However, when participating in the graded exertion or the multidimensional activities (should you be in this group), you may experience increases in symptoms or other unknown discomforts. You should report these to the researchers and/or medical professionals from *your team*. *Your team physician* will decide if you need to stop exercises or activities during an assessment or exercise session. In addition, should you feel you need to stop, you may do so at any time. The research staff and medical professionals at your school will help you get follow-up care if needed. There may be uncommon or previously unknown risks and you should report any problems to the researcher listed at the back.

If you choose not to be in the study, what other treatment options do you have? You do not have to be in this research study in order to receive treatment. You should reach out to *your team physician and/or team Athletic Therapist* for additional treatment options.

What if we learn about new findings or information during the study? You will be given any new information gained during the course of the study that might affect your willingness to continue your participation.

How will information about you be protected? You will be assessed and if you complete post-injury exercise activities, these will occur in your normal athletic training environment. No study-specific data about you will be shared outside the research team or the data center. Data sent to UNC-Chapel Hill will not have personal information. Every participant is given a research identification number that removes personal information. Only the Canadian site investigators will have a master list. You will not be mentioned individually in publications or presentations and all study data will be stored in a secure location.

Participants will not be identified in any report or publication about this study. Although every effort will be made to keep research records private, there may be times when federal or state law requires the disclosure of such records, including personal information. This is very unlikely, but if disclosure is ever required, UNC-Chapel Hill will take steps allowable by law to protect the privacy of personal information. In some cases, your information in this research study could be reviewed by representatives of the University, research sponsors, or government agencies (for example, the FDA) for purposes such as quality control or safety.

What will happen if you are injured by this research? If you become ill or injured as a result of being in this study, you will receive necessary medical treatment, at no additional cost to you. By signing this consent form you are not releasing the investigator(s), institution(s) and/or sponsor(s) from their legal and professional responsibilities. The University of Alberta will provide you medical care.

What if you want to stop before your part in the study is complete? You can withdraw from this study at any time, without penalty. The investigators have the right to stop your participation at any time because you have had an unexpected reaction, failed to follow instructions, or because the entire study has been stopped.

Will you receive anything for being in this study? No compensation is provided for completing this study.

Will it cost you anything to be in this study? It will not cost you anything to be in this study.

Who is sponsoring this study? This research is funded by the National Football League Foundation. This means that the research team is being paid by the sponsor for doing the study.

What if you have questions about this study? You have the right to ask, and have answered, any questions you may have about this research. If you have questions about the study (including payments), complaints, concerns, or if a research-related injury occurs, you should contact the researchers listed on the first page of this form. A description of this clinical trial will be available on www.clinicaltrials.gov, as required by U.S. Law. This website will not include information that can identify you. At most, the website will include a summary of the results. You can search this website at any time.

What if you have questions about your rights as a research participant? All research on human volunteers is reviewed by a committee that works to protect your rights and welfare. If you have questions or concerns about your rights as a research subject, or if you would like to obtain information or offer input, you may contact the Institutional Review Board at the University of Alberta Research Ethics Office at 780-492-2615 or by email to *the University of Alberta (reo@ualberta.ca)*. The study's principle investigator (Johna Register-Mihalik) can be reached at (919) 962-2702 (johnakay@email.unc.edu) and the Canadian Investigator (Martin Mrazik) 780-492-8052 (mrazik@ualberta.ca)

Participant's Agreement: I have read the information provided above. I have asked all the questions I have at this time. I voluntarily agree to participate in this research study.

_____ _____

Signature of Research Participant Date

_____

Printed Name of Research Participant

_____ _____

Signature of Research Team Member Obtaining Consent Date

_____

Printed Name of Research Team Member Obtaining Consent