

Long-Term Psychological Symptoms after Concussion in Adolescent Ice Hockey Players

by

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Abstract

Individuals who have sustained a sports-related concussion can experience psychological and emotional distress that impacts their quality of life. Although concussion symptoms typically resolve within 30 days from injury, some individuals experience persisting symptoms that continue for months, or even years, after returning to normal activities. Published research indicates that the severity, presentation, and duration of long-term psychological difficulties remain variable, particularly within the pediatric population. This study primarily aimed to assess long-term psychological and emotional symptoms in adolescent ice hockey players after they have sustained a concussion and have been cleared to play and return to normal activities. A secondary objective was to assess differences in psychological and emotional symptoms across injury types. This study used data that was originally collected prospectively as part of a larger cohort longitudinal study on injury surveillance in young hockey players, that ran for a total of five seasons from 2013 through 2018. Baseline testing measures of psychological and emotional functioning including the Strengths and Difficulties Questionnaire (SDQ), Behaviour Assessment System for Children, Second Edition (BASC-2), and the Sport Concussion Assessment Tool – Third Edition (SCAT-3) symptom checklist were compared across two consecutive time points. Random intercept models with players nested by team and individuals, captured the effects of players contributing to the analysis multiple times. Covariates of age, sex and body checking policy were included. Results were analyzed across injury types; concussion, musculoskeletal injury, both a concussion and a musculoskeletal injury and compared to individuals with no injury. Adolescent ice hockey players who sustained a concussion were found to have no evidence of worsening self-reported psychological and emotional symptoms after their injury, compared to their functioning pre-injury. Compared to athletes with no injury,

athletes who sustained a concussion and athletes who sustained a musculoskeletal injury showed no worsening symptoms at a secondary baseline among parent ratings as well. The present study found limited evidence of long-term psychological and emotional symptoms among adolescent ice hockey players up to one-year post-injury after a concussion. However, psychological symptoms were more prevalent in older adolescents, and female players were more likely to endorse emotional symptoms. Players who sustained a concussion showed no negative psychological differences compared to those with a musculoskeletal injury, and those with no injury.

Preface

This thesis is original work by Claire Vasantha David. The current study used data that was collected as a part of a larger study, the Safe to Play (Emery et al., 2013-2018) project conducted by the principal investigator, Dr. Carolyn Emery, and co-principal investigators Dr. Brent Hagel and Dr. Kathryn Schneider. The project was approved by the University of Alberta Research Ethics Board (Pro00133958). Research activities for this thesis were supervised by Dr. Martin Mrazik at the University of Alberta.

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Chapter One: Introduction

Concussion Context

Concussion is a form of mild traumatic brain injury (mTBI) that is common among youth engaged in sports. In Canada, there are an estimated 200,000 pediatric concussions occurring every year, and youth between the ages of 12 – 19 are 5.2 times more likely to report a concussion compared to adults (Champagne et al., 2023). The history of research around concussion symptoms and treatment has slowly evolved since the 1970s with increasing acknowledgment of the injury, subsequent symptoms, and rationale for treatment. In recent years, there has been increased awareness of concussion injuries in the fields of sports medicine and psychology, due to the increasing prevalence of SRC in youth and the evidence of symptomatology following the injury. A recent meta-analysis investigating symptom duration after an SRC found the mean of 14.0 days for individuals to be symptom-free, and the mean of 19.8 days to return to sport (Putukian et al., 2023). Thus, a majority of individuals who suffer concussion return to normal functioning. Yet there is also evidence that some populations experience persisting concussive symptoms (PCS) which refers to symptoms persisting past 30 days post injury (Patricios et al., 2023). This group of individuals who experience persisting symptoms are of particular interest to researchers and clinicians.

Across the literature, there is no definitive answer as to why one individual will develop persisting symptoms and another with a comparable injury will not. Within the pediatric population, there is evidence for various risk factors and predictors of PCS including previous injury history (Miller et al., 2016), sub-acute problems (Iverson et al., 2017), gender and age differences (Ledoux et al., 2019), and psychosocial factors (Zemek et al., 2013), including

internalizing behaviours such as anxiety and depression. Predicting the duration of symptoms for a particular individual after a concussion is further complicated by the absence of biological diagnostic indicators. In a study examining the usage of magnetic resonance imaging (MRI) in identifying PCS at the neuroanatomical level, 85% of the cases were unremarkable and the remaining findings were likely attributed to other factors (Bonow et al., 2017), which largely contributes to the difficulty in determining symptom duration as there are no physical brain abnormalities.

Psychological and Emotional Symptoms of Concussion

Symptoms after a concussion are heterogeneous, spanning across physical, cognitive, behavioural, and emotional domains (Parachute, 2017). Individuals may experience physical and cognitive difficulties such as trouble focusing, challenges with sleep, headaches, dizziness, brain fog, balance, and vision issues (Permenter et al., 2018). Considering the psychological aspect of concussive symptoms, individuals can experience a wide array of emotional and overall mood challenges. After sustaining a concussion, individuals often experience symptoms of anxiety, depression, and health-related concerns, also referred to as somatization (Martin et al., 2020; Mrazik et al., 2016; Sandel et al., 2017). Children and adolescents experiencing persisting symptoms of emotional difficulties after concussion can experience poorer functional outcomes at school and socially (Rose et al., 2016). Given the sensitive neurodevelopmental period of childhood and adolescence, there is a concern for the impact of long-term psychological symptoms after concussion.

Current Study

Long-term outcomes of concussion, particularly psychological and emotional outcomes, are of concern due to the variance of symptoms across individuals who sustain a concussion, and

no identifiable test to determine recovery length. At present there remains questions in the scientific literature regarding which population variables may be at greatest risk for PCS. The purpose of the present study was to investigate the long-term psychological symptoms after concussion in adolescent ice hockey players. The secondary objective of the study was to compare psychological functioning of adolescents who have sustained a concussion to other injury types. The Behaviour Assessment System for Children, Second Edition (BASC-2), Strengths and Difficulties Questionnaire (SDQ) and Sport Concussion Assessment Tool – Third Edition (SCAT-3) were administered to subjects each year to determine baseline functioning and inform the long-term psychological functioning for individuals that sustained an injury (concussion, or musculoskeletal). The present study investigated the long-term emotional and psychological functioning in young athletes who’ve been cleared to return to play after sustaining a concussion and assessed psychological and emotional functioning in athletes across various injury types.

Chapter Two: Literature Review

Sports-Related Concussion Background

For athletes engaged in contact sports, such as ice hockey, there is a known risk of sustaining an injury, and sports-related concussions (SRC) are of high concern. Sports-related brain injuries in adolescents account for 80% of all head injuries in hospital emergency departments (Canada, 2020). Concussions belong to the category of mild traumatic brain injury (mTBI), although the exact definition of concussion has varied considerably over the years. The most recent consensus statement released in 2023 by the “International Consensus Conference on Concussion in Sport,” (Patricios et al., 2023) has provided the following definition:

Sport-related concussion is a traumatic brain injury caused by a direct blow to the head, neck or body resulting in an impulsive force being transmitted to the brain that occurs in sports and exercise-related activities. This initiates a neurotransmitter and metabolic cascade, with possible axonal injury, blood flow change and inflammation affecting the brain. Symptoms and signs may present immediately, or evolve over minutes or hours, and commonly resolve within days, but may be prolonged. No abnormality is seen on standard structural neuroimaging studies (computed tomography or magnetic resonance imaging T1- and T2-weighted images), but in the research setting, abnormalities may be present on functional, blood flow or metabolic imaging studies. Sport-related concussion results in a range of clinical symptoms and signs that may or may not involve loss of consciousness. The clinical symptoms and signs of concussion cannot be explained solely by (but may occur concomitantly with) drug, alcohol, or medication use, other injuries (such as cervical injuries, peripheral vestibular dysfunction) or other comorbidities (such as psychological factors or coexisting medical conditions). (Patricios et al., 2023, p. 697)

The presentation of symptoms varies across individuals, however, symptoms generally fall into four categories: physical (dizziness, headache, stomach sickness, head pressure, difficulty with balance, noise/light sensitivity, blurred vision); cognitive (confusion, sleepiness, difficulty thinking, trouble with memory, low energy); emotional (irritability, nervousness, anxiety, increased emotionality, foggiess, sadness); and sleep (difficulty with sleeping, either too much or too little) (Canada, 2020).

SRC Concussion in Ice Hockey

Ice hockey is a fast-paced, contact sport where players often endure various injuries. The sport has developed over the years to adapt safety policies and has implemented precautions such

as face shields, protective padding, and mouth guards; however, injuries are still a major risk of play (Emery et al., 2017; Kolstad et al., 2023). An examination of injuries in male junior hockey players from 2006 to 2015 found that head and face injuries were the most frequent, accounting for 39% of all game-related injuries, 10% of all game-related injuries were diagnosed as concussions (Tuominen et al., 2017), consistent with rates of concussion found in other studies (Kontos et al., 2016).

A key component of ice hockey at the professional level is contact between players, including body checking. Body checking is a sport-specific skill that must be developed through practice because of the risk to both the initiator of the contact and the player who receives the contact. Proper technique is necessary to be effective in stopping or altering the course of a player with the least amount of injury as is the goal in the professional leagues. The age at which body checking is introduced varies globally and by league. In most parts of Canada, body checking is allowed at the U13 level, previously known as Pee Wee (*Hockey Canada Play Rules*, 2022) which includes children ages 11 – 13 years, at the discretion of the league. Emery et al. (2010) investigated body checking in relation to frequency of injury at the U15 level (previously Bantam) and found there was a 33% decrease in risk of injury among players with at least two years of experience using body checking during play. These results suggest that when body checking is first introduced, the players may sustain more injuries as they have not mastered the skill to effectively body check. One of the main concerns with body checking is the likelihood to sustain a concussion. In a sample of world junior hockey players, concussions were found to be most commonly caused by body checking with contact to the body or head, with 63% of all reported concussions caused by an illegal hit (Tuominen et al., 2017). Therefore, in young teams where body checking is allowed, there is a substantial risk for both musculoskeletal injuries and

concussion, although players with more practice may decrease their injury risk after several years of play.

Long-Term Outcomes from Concussion

The typical progression of SRC recovery begins with individuals experiencing a higher intensity or severity of symptoms closer to the time they sustained their injury, with symptoms lessening and resolving within 30 days, allowing the individual to report to typical activities (Putukian et al., 2023). However, individuals can experience symptoms persisting for several months referred to as “post-concussive symptoms” (Taylor et al., 2010). Current literature of children and adolescents has found symptoms persisting at three months (Anzalone et al., 2022; Barlow et al., 2010; Ponsford et al., 2001), and some studies have noted symptoms persisting years after the injury (Choudhury et al., 2020; Iadevaia et al., 2015; Putukian et al., 2023). Persisting concussion symptoms in athletes of all ages primarily include psychological and cognitive symptoms (Anzalone et al., 2022; Broshek et al., 2022). Despite the presence of lingering psychological symptoms, individuals are often cleared to return to sports or school. The functional outcomes of adolescents experiencing long-term symptoms are of concern. Adolescents with concussions can have difficulties with school and learning following injury, requiring support from both educational and medical teams to reintegrate back into classroom learning (Grady & Master, 2017). Many children and adolescents with PCS do not receive the accommodations necessary and are likely to have increased school absences (Grubenhoff et al., 2015). Overall, adolescents with PCS can experience negatively outcomes that affect quality of life post-concussion (Novak et al., 2016) suggesting this population is at higher risk for a variety of concerns and require support in many aspects of daily functioning.

Psychological Symptoms

There is growing public health concern for the long-term psychological effects after sustaining concussions as media and certain studies have identified a causal relationship between multiple concussions and mental health challenges presenting later in life. A systematic review of the long-term effects of SRC's (Manley et al., 2017) found multiple studies (Didehbani et al., 2013; Guskiewicz et al., 2007; Kerr et al., 2014; Kerr et al., 2012; Montenegro et al., 2017) identifying a dose-response relationship between the number of concussions and depressive symptoms experienced later in life. These studies were primarily focused on retired adult American football players. Given the length of time between the last concussion and time of study there may have been other confounding factors that could contribute to the depressive symptoms, and therefore a causal relationship cannot be confirmed. Subsequently, the most recent consensus statement on concussion in sports (Patricios et al., 2023) states that former athletes, including American football players and soccer players, are not at an increased risk to develop severe mental health outcomes, such as depression, psychiatric conditions, and suicidality due to multiple concussions earlier in life. As well, recent literature has suggested a change in terminology to “persisting symptoms after concussion” (Broshek et al., 2022) as this title conveys the impermanency of the symptoms, supported by the literature (Patricios et al., 2023). As such, the longevity of concussive symptoms, particularly psychological symptoms, remains unclear.

Similarly, there is a concern for persisting concussive symptoms in younger populations, that last beyond the typical recovery period of 30 days (Patricios et al., 2023), when the athlete has been cleared to return to school and sport. A recent meta-analysis identified the association of depression, anxiety, and post-traumatic stress in youth after sustaining a concussion (Emery et

al., 2016). Given the sensitive neurodevelopmental period of adolescence, there is concern for mental and physical implications after a neurological injury. Further, there is evidence that children and adolescents who sustain a concussion are at a much greater risk for developing mental health challenges compared youth with an orthopedic injury (Ledoux et al., 2022), and this population presents with more overall mental health difficulties compared to healthy controls (Gornall et al., 2021). A qualitative study investigating adolescents' experience after sustaining a concussion highlighted the discrepancy between being medically cleared to return to play by professionals and the patient's own interpretation of their recovery (Choudhury et al., 2020). In this study, adolescents expressed significant cognitive, emotional, and social challenges long after they have received treatment for their concussion and have been returned to their typical daily activities highlighting how the psychological impact of a concussion can persist beyond medical and physical symptoms (Choudhury et al., 2020). A meta-analysis of over 3600 studies also found that medical factors overshadowed psychological readiness to return to sport and identified a theme of emotional factors to be associated with returning to sport including anxiety, depression, and mental health concerns (van Ierssel et al., 2022).

Somatic symptoms, characterized by physical symptoms causing emotional distress, are frequently noted as a post-concussive symptom for individuals experiencing longer recovery (Choudhury et al., 2020; Duffield et al., 2021; Mrazik et al., 2016; Teh et al., 2020; Woodrome et al., 2011). Adolescent ice hockey players reported somatic complaints including bodily symptoms (Mrazik et al., 2016), and varsity athletes have reported somatic complaints with the addition of depressive symptoms experienced after returning to the sport (Duffield et al., 2021). Somatic and depressive symptoms are especially concerning given their distressing nature and ability to impact daily functioning (Cerutti et al., 2017).

Although cognitive symptoms are a core feature in the acute concussive period, evidence suggests that there are no long-standing cognitive implications after concussion (Babikian et al., 2011; Ware et al., 2023). However, presence of cognitive symptoms in the acute period could predict longer recovery with post-concussive symptoms, as identified in a study of young children aged 5 -12 (Teh et al., 2020).

There is limited evidence for the long term mental health and psychological implications after concussion for adolescents and children (Ledoux et al., 2022). Given the short developmental period when children are playing contact sports with a risk of concussion, there is limited research on long-term effects for the pediatric population highlighting the novelty of the current study.

Musculoskeletal Injuries and Concussion

Sustaining an injury, concussion or otherwise, is a known risk of playing sports. Current literature identifies how specific symptoms may be associated with injury types. Musculoskeletal injuries are considered any orthopaedic injury and trauma to the body that does not involve the head and brain. A current concept review for medical implications of ice hockey injuries found that head and face injuries had the highest injury rate with 15.3 injuries per 1000 player game hours, and upper body injuries occurred at a rate of 11.4 injuries per 1000 player game hours (Mosenthal et al., 2017). The frequent rate of injuries validates the necessity to further understand the nuances of symptoms that are related to specific injuries compared to treating an injury in general.

As previously mentioned, somatic symptoms are significant after concussion (Choudhury et al., 2020; Duffield et al., 2021; Mrazik et al., 2016; Teh et al., 2020; Woodrome et al., 2011). Additionally, somatic symptoms are more frequently supported in the literature in those who've

suffered a concussion compared to individuals who've suffered a musculoskeletal injury (Taylor et al., 2010). This frequency of reported somatic symptoms among adolescents who've sustained a concussion could speak to the neurological association of these symptoms, rather than a symptom of any type of bodily injury. Varsity athletes who've sustained an SRC are also more likely to experience total mood disturbance, and overall emotional dysregulation compared to athletes with a musculoskeletal injury (Hutchison et al., 2009). In consideration of the psychological symptoms associated with brain trauma specifically, including somatic and mood symptoms, these findings align with the need to further evaluate the impact of concussion on adolescent and youth athletes in comparison to other injury types.

Athletes with musculoskeletal injuries may be at risk for difficulties with mood management (anger) compared to those with an SRC in the acute post-injury phase (Hutchison et al., 2009), and throughout recovery (Brewer & Petrie, 1995; McDonald & Hardy, 1990). Feelings of anger/discord that affect an athlete's well-being after injury could be attributed to the athlete's loss of function, removal from play and length of recovery time (Hutchison et al., 2009). Although, losing the ability to play and fully participate in sport due to an injury is a major concern for all athletes (Cross et al., 2016; Hallén & Ekstrand, 2014).

Lastly, there is evidence to suggest that injuries in general are psychologically distressing, and the type of injury itself may hold less significance. Athletes who suffer an SRC or a musculoskeletal injury were found to experience greater overall mood disturbance immediately following the injury which progressively improves throughout the recovery period (Turner et al., 2017).

To summarise, current literature identifies the general emotional disturbance that is connected with any form of injury. Current literature also demonstrates the variation of specific

symptoms as individuals with concussions are more likely to experience somatic and mood symptoms, whereas athletes with musculoskeletal injuries may experience more anger.

Current Study

The current study aimed to assess the long-term psychological and emotional symptoms of adolescent ice hockey players who have experienced a concussion and have been cleared to return to play. Adolescent ice hockey players and their parents were recruited to be a part of a larger cohort study and completed forms collecting demographic and injury data, as well as standardized psychological and emotional functioning measures at annual baseline testing time points over a five-year period. The use of comparison groups for different injury classifications helped to differentiate between symptoms that persisted following an injury in general, in comparison to symptoms associated specifically with a concussion.

The present study contributes to the current literature by providing evidence for the long-term effects of concussion in a pediatric population, which is yet to be defined. The results from the present study will help to inform healthcare professionals, athletic professionals, young athletes, and their parents of the long-term risks that sport-related concussions can have on the mental well-being of the adolescent athlete.

Objective 1

This study primarily aims to assess long-term psychological and emotional symptoms in adolescent hockey players after they have sustained a concussion and have been cleared to play and return to normal activities. The psychological symptoms outcome was obtained from the BASC-2 Behavioural Symptoms Index and the SDQ Total Difficulties score for parent and player forms. The emotional symptoms outcome was obtained from the SCAT-3 completed by

players. Comparisons were made to assess change in outcome scores for individuals who experienced a concussion intervening between two consecutive baseline testing time points.

Alternative Hypothesis

Within the group of athletes who sustained a concussion between two consecutive baseline assessments, there is a statistically significant increase of scores for the psychological symptoms' outcome (BASC-2 & SDQ) on player and parent forms, and the emotional symptoms outcome (SCAT-3) for players. The increase of score will signify a decreased in emotional functioning post-injury.

Null Hypothesis

There is no statistically significant amount of change between pre-injury and post-injury baseline testing scores for the psychological symptoms' outcome (BASC-2 & SDQ) on parent and player forms, and the emotional symptoms outcome (SCAT-3) for players who had an intervening concussion. Alternatively, there will be a statistically significant decrease in scores on the psychological symptoms' outcome (BASC-2 & SDQ) on parent and player forms, and the emotional symptoms outcome (SCAT-3) for players who had an intervening concussion, signifying an improvement in emotional functioning post-injury.

Objective 2

The secondary objective was to assess differences in psychological and emotional symptoms across injury types. Consecutive baseline scores for the psychological symptoms' outcome (SDQ and BASC-2 parent and player forms) and the emotional symptoms outcome (SCAT-3 emotional symptoms cluster) were organized by injury events that occurred between two consecutive baseline assessments to compare the change for individuals who experienced

different types of injuries (concussion, musculoskeletal injury, both a concussion and a musculoskeletal injury, no injury).

Alternative Hypothesis

Players who've had an intervening concussion will produce a statistically significant increase in baseline scores compared to the baseline scores of players who've experienced only a musculoskeletal injury or no injury between consecutive baseline testing timepoints. The increase in baseline scores for players with an intervening concussion would signify more adverse outcomes for players with a concussion.

Null Hypothesis

Compared to the other injury types, players who've had an intervening concussion will not produce the worst outcomes at their secondary baseline.

Chapter Three: Methods

Study Design

The data used for the current study was accessed from a larger cohort study, Safe to Play, (Emery et al., 2013-2018) which was a longitudinal injury surveillance, prospective cohort study for adolescent hockey players. The Safe to Play study (Emery et al., 2013-2018) recruited young ice hockey players, aged 11 to 17 years, from several hockey teams in Alberta, Canada. The study ran for a total of five seasons from 2013 - 2018. Players and their parents completed a thorough baseline assessment each year of the study including demographic (age, sex, height, weight), pre-injury baseline questionnaire (concussions, musculoskeletal), athlete information (level of play, position, body checking policy), psycho-social and behavioural questionnaires (BASC-2, SDQ among others), and concussion testing measures (SCAT-3 used in years 1-4, and SCAT5 in year 5). Teams participating in the study were assigned a team designate to collect

weekly exposure information and to provide injury surveillance. Players who sustained an injury (concussion, or musculoskeletal) were followed up with by sports medicine physicians for evaluations. Study physicians referenced the most current international consensus statement in sports to define a concussion (listed under *Key Terms*), and standardized assessment procedures at initial injury and follow-up assessments. The return to sport protocol followed the standardized RTP protocol (year 1-4) or return to sport strategy (year 5). Data was stored in a secure, electronic database, Research Electronic Data Capture (REDCap).

Baseline assessments consisted of collecting information of psychological and emotional symptoms that were compared across two sequential baseline testing time-points. The independent variable examined in the study was the occurrence of an injury (concussion, musculoskeletal, both, and no injury) between two baseline testing timepoints. The dependent variables were the scores of emotional and psychological symptoms obtained by the measures administered to players and their parents at each baseline. Age, sex, and body checking policy were included as covariates in the analysis.

Participant Eligibility

Participants were originally recruited for the longitudinal study, Safe to Play, (Emery et al., 2013-2018), which involved injury surveillance for adolescent ice hockey players. Data from the Safe to Play, (Emery et al., 2013-2018) study was accessed for the use of the present study.

The inclusion criteria for the present study were as follows:

- a) Players consented to the Safe to Play, (Emery et al., 2013-2018) study and completed necessary requirements for original inclusion: between the age of 11 and 17 years, players were registered in Hockey Calgary or Edmonton teams, agreement of a head coach and team designate to collect player participation and injury data

- b) Players and/or their parents completed two consecutive baseline testing administrations. Baseline testing took place annually and consecutive baseline testing administrations could have been completed in any of the following years, 2013 – 2014, 2014-2015, 2015-2016, 2016-2017, 2017-2018.
- c) Players had any of the following injury events between two consecutive baseline testing timepoints: a concussion, a musculoskeletal injury, both a concussion and a musculoskeletal injury during the same event, no injury.
- d) Players and parents completed the SDQ and/or BASC-2, and the SCAT-3

The exclusionary criteria were as follows:

- a) Players did not complete at least two baseline testing administrations that were consecutive at any point for the duration of the study.

Injury Classification

To compare changes in psychological functioning across individuals who endured various injuries, intervening injury events that occurred between two consecutive baselines determined injury classification. As baseline testing occurred annually, injuries could occur at any point during the 52-weeks between consecutive baseline testing time points. Incidents of injury were divided into four classification types:

Incident type one: Ice hockey players with no injury between two consecutive timepoints.

Incident type two: Ice hockey players with a concussion injury between two consecutive baseline testing timepoints.

Incident type three: Ice hockey players with a musculoskeletal injury between two consecutive baseline testing timepoints.

Incident type four: Ice hockey players who sustained both a concussion and a musculoskeletal injury during one event between two consecutive baseline testing timepoints.

As the players could sustain multiple injuries between any given two baseline testing time points, the player would be accounted for in multiple injury classifications throughout the study. One participant could be entered into the study multiple times if they sustained different types of intervening injuries between baseline time points. For example, if a player sustained a concussion during one event, then later that year sustained a musculoskeletal injury, the analysis would account for two contributions of datum to each injury classification. Therefore, demographic data reported in Table 1 references datum incidents, not by participant.

Key Terms

- a) Concussion, or a Sport-Related Concussion (SRC) is defined by the fifth international consensus statement (McCrory et al., 2017), which was the most recent statement available at the time of data collection, defined as “a traumatic brain injury induced by biomechanical forces.”
- b) Musculoskeletal injury, defined as: an injury that either required medical attention, the player was unable to finish the practice session or game, or the player was unable to participate in subsequent sports activities due to the injury.
- c) Psychological symptoms outcome, referring to the harmonized data of the SDQ Total Difficulties score and BASC-2 Behavioural Symptoms index on respective parent and adolescent forms. Includes symptoms of behavioural, emotional, conduct, and social problems.

- d) Emotional symptoms outcome, referring to the cluster of emotional/mood questions on the symptom evaluation checklist of the SCAT-3. Includes symptoms of irritability, sadness, nervousness, emotional

Outcome Measures

BASC-2

Players and parents completed the BASC-2 (Reynolds, 2004). The BASC-2 is a standardized, multi-dimensional, individually administered questionnaire, used to assess child and parent perceptions of the child's behavioural and emotional functioning. The BASC-2 provides age-based evaluations; therefore, the corresponding form was administered depending on the age of the player at time of the survey completion. The parents in the present study either completed the BASC-2 Parent Rating Scales: Adolescent (12-21 years old) or the BASC-2 Parent Rating Scales: Child (8-11 years old). The players completed the BASC-2 Self-Report of Personality: Adolescent (12-21 years old), or the BASC-2 Self-Report of Personality: Child (8-11 years old). The BASC-2 has robust evidence of validity for use in evaluating children and adolescents emotional and behavioural disturbance (Reynolds, 2004). There are five composite indexes composed of 16 clinical scales. For the purpose of the present study, only the Behavioural Symptoms Index from both the parent and child forms was utilized, which provides an overall measure of psychological adjustment.

SDQ

Players and parents completed the SDQ (Goodman, 1997) at each baseline timepoint. The SDQ is a screening questionnaire designed to evaluate behavioural difficulties for children between 2 – 17 years old. The SDQ has strong reliability and validity, making it an effective

measure of psychopathology and adjustment in children and adolescents (Goodman, 2001). For the present study, only the Total Difficulties Score was analyzed.

When the Safe to Play study (Emery et al., 2013-2018) was first initiated in 2013, emotional symptom monitoring was collected through the BASC-2 parent and youth forms. However, two years into the study, the principal investigators decided to switch to the SDQ as it was shorter and easier to complete. There is evidence of a significant correlation between these two summary indices, SDQ Total Difficulties and BASC-2 Behavioural Symptoms Index (Van Slyke, 2007). Therefore, the current study utilized the combined results from the SDQ Total Difficulties score and the BASC-2 Behavioural Symptoms Index for both parent and youth forms to create the first outcome of psychological symptoms. Both the SDQ and the BASC-2 collect information across the following domains: emotional symptoms, conduct problems, attention (hyperactivity/inattention), and relationships (Goodman, 1997; Reynolds, 2004). Data harmonization of the SDQ Total Difficulties score and the BASC-2 Behavioural Symptoms Index to create the psychological symptoms outcome score, is described below.

SCAT-3 Emotional Symptoms Cluster

The SCAT is the most commonly used screening tool used to assess sports related concussions as it is a standardized measure that can be used at baseline, during injuries at sideline by any trained professional, and post-injury to monitor recovery. At the time of the data collection for the present study, the SCAT-3 was the most current version available, originally released in 2017 by the International Concussion Group, and was used in the study. The SCAT-3 includes a symptom checklist to be completed by the player to rate the severity of symptoms they are experiencing from zero (none) to six (severe) at time of administration. The symptom checklist is comprised of 22 symptoms across cognitive, physical, and emotional domains. For

the purpose of the current study, only the questions that addressed emotional symptoms were considered, referred to as the emotional symptoms outcome. The emotional symptoms outcome included questions that addressed the following: more emotional, irritability, sadness, and nervous/anxious. Players completed the symptom evaluation checklist assessing their current functioning at the time of administration.

Covariates

Age group (U13, U15, U18), sex (male, female), and body checking policy (allowed, disallowed) were used as covariates due to recent literature identifying the significance of their impact on concussion outcomes.

Statistical Analysis

All analyses were completed using Stata 18, with alpha α set to 5% with 95% confidence intervals (StataCorp, 2023). Assumptions for all analyses were assessed prior to the analysis.

Psychological Symptoms Outcome (BASC-2 & SDQ) for Players (Model 1) and Parents (Model 2)

To obtain the psychological symptoms outcome, the SDQ Total Difficulties score for both the player and parent forms were converted from raw scores to Z scores using combined sex norms (Mellor, 2005) and then transformed into T-scores. Once the parent and player SDQ Total Difficulties scores were in T-score format, they were combined with the BASC-2 Behavioural Symptoms Index T-scores to produce the independent variable of psychological symptoms for parent and player forms.

To assess change from an initial baseline testing timepoint to the subsequent baseline testing for the psychological symptom outcome, the study used random intercept models nested by team (Rabe-Heskth & Skrondal, 2022). As the present study is longitudinal, the model

considered cross-specified random effects for players as well. Player and team clustering provides unbiased estimates for the random effects within the model, to reduce sources of error and bias. Team clustering accounted for players changing their team throughout the study, given that the coding for each team is unique to the season of play. The random intercept models were fit with forced covariates of age group (U13, U15, U18), sex (male, female), and body checking policy (allowed, disallowed). Lastly, each incident classification was assessed for regression to the mean for their pre-injury and post-injury scores for the psychological symptoms' outcome scores to assess the amount of change, as the model included repeated data that may include natural variation (Barnett et al., 2004).

Emotional Symptoms Outcome (SCAT-3) Completed by Players (Model 3)

Frequency distributions of emotional symptom scores on the SCAT-3 revealed a preponderance of zero values (85%). Therefore, the emotional symptoms cluster score on the SCAT-3 was made binary for scores of zero compared to scores of one or more. A random intercept logistic regression analysis with one random intercept around the participant was completed to estimate odds ratios (ORs; with 95% CI) for the relation of higher symptom scores after an injury based on symptom reporting pre-injury, and for age, sex, and body checking policy. ORs provide the relative odds of higher symptom reporting in each injury group relative to the non-injured group.

Ethics

This study was a part of a larger cohort, longitudinal study on injury surveillance in adolescent ice hockey players, Safe to Play (Emery et al., 2013-2018). The present study used the data collected in the original study. Ethics was approved prior to the beginning of the present study by the Research Ethics Board at the University of Alberta (Pro00133958).

Chapter Four: Results

Demographic data for each analysis model after inclusion/exclusion criteria were applied is displayed in Table 1, including body checking policy, age, sex, and injury related data. Models of psychological symptoms, based on adolescent self-report on the SDQ and BASC-2 (Model 1), included 562 participants with a total of 857 baseline pairs available for analysis. Models of psychological symptoms, based on the parent ratings on the SDQ and BASC-2, included 512 participants with a total of 758 baseline pairs available for analysis (Model 2). Lastly, emotional symptoms as assessed by the SCAT-3 symptom checklist completed by players, were available for 848 participants, with a total of 1308 baseline pairs (Model 3). Distribution of data within each of the models is displayed in Table 2. All models included age, sex and body checking policy as covariates in the analysis. Model assumptions were tested prior to the analysis, and homoskedasticity of residuals and normality of residuals were assessed and found to be acceptable and unrelated to variables in the model.

Model 1

Model 1 (Table 4) involved a random intercept model of adolescent harmonized scores on the SDQ Total Difficulties and the BASC-2 Behavioural Symptoms Index score. Relative to un-injured players, there was statistically significant evidence that players who sustained a concussion, and players who experienced a musculoskeletal injury, between two consecutive baseline assessments reported slightly less symptoms than those who sustained no injury at the secondary baseline (Table 4). There was a difference in multivariate results and bivariate results for individuals who sustained a concussion and individuals who sustained a musculoskeletal injury. Bivariate associations (Table 7) were nonsignificant, and multivariate results were significant suggesting a covariate variable was confounded with injury type and thereby

accounting for the change in significance. As age for players in the U15 and U18 group was significant in the bivariate (Table 7) and full model (Table 4), it is likely that injury type was conflated with age, and therefore the covariate variable of age was responsible for the effect change in for players with concussions and those with a musculoskeletal injury. Considering the age group covariate, players in the U15 group and players in the U18 group revealed higher scores on the psychological symptoms outcome (SDQ/BASC-2 combined), which indicates more psychological symptoms, compared to individuals in the U13 groups. Sex and body checking policy showed no significant effect. Adjacent comparison of injury types revealed no significant overall effect of injury type. Previous baseline symptoms rated by players were a strong predictor of psychological symptoms at the secondary baseline (Table 4).

Model 2

Model 2 (Table 5) involved a random intercept model of parent-rated psychological symptoms outcomes using the harmonized SDQ Total Difficulties score and the BASC-2 Behavioural Symptoms Index. There were no significant differences among all injury types found in the full model or between adjacent comparisons. Sex and body checking policy had no effect on outcomes. There was a significant effect for the U15 age group, indicating parents of players between the ages of 13-15 reported higher symptoms at a secondary baseline assessment compared to players below 13 years old, similar to the findings in Model 1. As well, previous baseline symptoms rated by parents were a strong predictor of psychological symptoms at the secondary baseline (Table 4).

Model 3

Model 3 (Table 6) involved a logistic model of player-rated SCAT-3 emotional symptoms scores from the initial baseline administration to secondary consecutive baseline

administration. The model revealed no significant effect for individuals who sustained a concussion or injury of any type. Emotional scores at the previous baseline that were greater than one was found to be significant as the largest predictor of elevated emotional scores at a second baseline with an odds ratio of 4.8 (Table 6), suggesting that players with pre-existing emotional symptoms are most likely to continue to report persisting symptoms at a second baseline. Sex was significant, revealing males reported half as many emotional symptoms on the SCAT-3 compared to females (Table 6). Body checking policy and age group were not significant predictors of emotional outcomes between baseline comparisons.

Group Means

Group means for each injury type were compared from the previous baseline measure to secondary baseline measures on the SDQ Total Difficulties score and the BASC-2 Behavioural Symptoms Index Scores for both parent and adolescent forms (Table 6). The group means across all models and forms (player and parent, pre and post baselines) were in the typical range and remained relatively stable with little to no change at the second baseline. There was no evidence of regression to the mean across all injury types. Group means for adolescents are displayed in Figure 2, and group means for parents are displayed in Figure 3.

Objective 1: Psychological and Emotional Outcomes in Concussed Athletes

The primary objective of the study was to assess the long-term psychological functioning of adolescent hockey players who have sustained a concussion. To test this objective, athletes who sustained an intervening concussion between two baseline assessments were included in the analysis and compared to athletes with intervening musculoskeletal injuries or no injuries. Baseline assessments included the administration of psychological measures (SDQ, BASC-2, SCAT-3) that took place approximately 52 weeks apart. Random intercept models assessed

harmonized T scores based on the SDQ Total Difficulties score and BASC-2 Behavioural Symptoms index from parent and player ratings. Ratings by players who sustained a concussion revealed lower symptom scores at the second baseline, indicating no evidence of worse psychological functioning post-concussion. However, in comparing different age groups, players in the U15 and U18 age groups were found to have a significant increase in scores indicating poorer psychological functioning at a second baseline compared to the players in the U13 group. There was no significant effect among players who sustained a concussion for parent scores. Similar to the adolescent scores, parents of players in the U15 group had significantly higher scores compared to the U13 reference group at a secondary baseline. The logistic regression model using the SCAT-3 emotional systems cluster revealed no significant effect for players who sustained a concussion. However, the analysis revealed endorsement of emotional symptoms at a previous baseline was predictive of elevated emotional symptoms at a second baseline regardless of injury, suggesting that players with pre-existing emotional symptoms are likely to continue reporting emotional symptoms. As well, females reported twice as many emotional symptoms compared to males.

The results of the study confirmed the null hypothesis, suggesting no significant long-term psychological symptoms in adolescent ice hockey players who have sustained a concussion, although players in the older age groups, females, and those with pre-existing mental health symptoms may be at a greater risk for increased mental health symptoms.

Objective 2: Comparison of Psychological and Emotional Functioning Across Injury Types

The second objective of the current study was to assess changes in long-term psychological functioning across injury subtypes. Random intercept models for player and parent harmonized scores based on the SDQ Total Difficulties and the BASC-2 Behavioural Symptoms

index compared across two consecutive baseline assessments were used to assess this objective. Results from were compared across injury classifications of concussions, musculoskeletal injuries, combined a concussion and a musculoskeletal injury, and no injury. Individuals who sustained an intervening concussion and those who sustained a musculoskeletal injury were found to have a minimal change in psychological functioning at a secondary baseline compared to those with no injury on adolescent harmonized T scores (Table 3). Results from the random-intercept model revealed individuals who sustained both a concussion and a musculoskeletal injury at the same time showed no significant change between consecutive baseline assessments. Age was found to be a significant covariate. The logistic regression model based on SCAT-3 symptoms revealed o males were less likely to endorse emotional symptoms compared to females. The results confirm the null hypothesis of the second objective, in that individuals with a concussion do not experience worsening psychological functioning compared to those with a musculoskeletal injury and or those without an injury.

Chapter Five: Discussion

Long-term psychological effects after sustaining a concussion are a concern as psychological symptoms vary in duration after an injury across individuals. Typical symptom resolution occurs within 30 days after sustaining a concussion (Patricios et al., 2023), but evidence suggests psychological symptoms can persist for weeks, months and several years after injury, long after individuals have been cleared to return to typical activities (Broshek et al., 2022; Choudhury et al., 2020; Yeates, 2010). The variation of evidence on symptom duration poses the concern of permanent psychological changes after sustaining a concussion and requires further investigation. The present study investigated the long-term psychological effect of concussion in adolescent ice hockey players, and compared across different injury types including musculoskeletal injuries, combined musculoskeletal injury and concussion, and no injury. To do this, adolescent ice hockey players and their parents completed measures of emotional and psychological functioning at annual baseline assessments over five seasons, and injury data was collected throughout the study at the time of injury.

Objective 1

The primary objective of the current study was to assess long-term psychological changes in athletes who have sustained a concussion. The analysis examined the scores from parent and player ratings on the SDQ/BASC-2 and the SCAT-3 compared across two consecutive baseline assessments. It was hypothesized that athletes who sustained a concussion would show worsening psychological functioning at the second baseline that took place up to one-year post-injury. Contrary to the hypothesis, the results from the analysis of the player-reported scores revealed no worsening of psychological functioning at a second baseline among adolescent athletes who sustained a concussion. There was a trend in the data that older age groups (U15

and U18) may be at risk for some psychological adjustment issues as described below. Overall, however, findings are inconsistent with literature identifying the presence of emotional distress more than one-year post-injury (Choudhury et al., 2020; van Ierssel et al., 2022).

As the design of the current study compared baseline assessments one year apart, the concussion injury could have occurred at any time point within the 12 months between baseline testing, with the vast majority of the injuries occurring greater than 180 days prior to the secondary baseline testing, giving the athletes ample recovery time before their re-assessment. As well, all players that were included in the analysis were medically cleared for returning to sport after their concussion at the time of the secondary baseline assessment, therefore, the results do not speak to the severity of symptoms at the time of injury or to symptom severity in players who were not cleared. Similarly, other studies found a significant decrease of somatic symptoms at the 12-month time point post-injury, despite an increase in parent-reported somatic symptoms in the early period at one month (Taylor et al., 2010). Therefore, the results of the current study suggest recovery trends that are consistent with the typical concussion recovery timeline (Patricios et al., 2023; Putukian et al., 2023) with no evidence of long-term psychological sequelae after a concussion.

Another consideration for the positive psychological functioning post-concussion found in the present study is the possibility that athletes were under-reporting their symptoms. There is substantial evidence in the literature that adolescent athletes are likely to under-report psychological symptoms after sustaining a concussion (Davies & Bird, 2015; Ferdinand Pennock et al., 2020; Kroshus et al., 2015). Therefore, the lower reports of symptoms in the present study could be an underestimate of true emotional problems. Given that the present study included adolescent ice hockey players in highly competitive leagues, they are faced with substantial

pressure to perform and may fear the repercussions of reporting symptoms after their injury such as losing their positions or missing valuable game time (Cusimano et al., 2017; Kay et al., 2015). Further, despite increased awareness in the public of concussion symptom severity and the importance of intervention (Hickling et al., 2020), there is evidence young athletes are still being encouraged to play through their injury instead of seeking treatment. Kroshus et al. (2015) found more than a quarter of an adolescent athlete sample have experienced the pressure to continue playing in a game after direct head impact from either teammates, parents, or coaches.

Consistent with recent studies (Bunt et al., 2022), the present study found males were half as likely to report emotional symptoms on the SCAT-3, compared to females, a phenomenon not exclusive to athletes. Moser et al. (2019) identified adolescent females specifically between the ages of 13-17, the same age group as the present study, show greater emotional endorsement. The present study found no significant sex effects identified in the analysis of the harmonized psychological symptoms outcome (SDQ and BASC-2) on either parent or player forms.. Therefore, these findings highlight a discrepancy in symptom reporting across sexes, with males less likely to report emotional symptoms, yet it is unclear how minimized the symptoms were in the male group due to the evidence of under-reporting in the literature.

The present study also found adolescent age groups of U15 (13-14 years), and U18 (15-17 years) reported higher psychological symptom scores at a second baseline than those in the U13 (11-12 years) group, consistent with the literature (Bunt et al., 2022; Moser et al., 2019). Adolescents above the age of 13 were found to have elevated psychological symptoms at a secondary baseline suggesting they are more likely to report symptoms compared to younger adolescents under the age of 13. Given the emotional development and physiological changes that contribute to emotional lability during this period, it is understandable that older adolescents

report more psychological symptoms and highlight the need for monitoring post-concussion as they could be at greater risk for developing persisting symptoms.

Objective 2

The secondary objective was to compare the psychological functioning of athletes who sustained a concussion to other injury types. It was hypothesized that athletes who sustained a concussion would show worse psychological functioning compared to the other injury and non-injury classifications. The results from the current study did not support the hypothesis, as the concussed athletes showed small rates of psychological improvement relative to the athletes without injuries at a secondary baseline. Athletes who sustained a musculoskeletal injury also showed a statistically significant improvement in psychological functioning post-injury, yet a smaller effect than those with a concussion. Athletes who sustained a combined concussion and a musculoskeletal injury during the same event showed no statistically significant change post-injury. The results from the current study are supported by evidence that individuals with concussions show less emotional distress such as anger, compared to individuals with musculoskeletal injuries (Brewer & Petrie, 1995; Hutchison et al., 2009; McDonald & Hardy, 1990). In comparing other injuries to concussions, it is important to assess the severity of the injury in the comparison group, as certain musculoskeletal injuries can be permanent, and thereby more emotionally distressing. For example, athletes who sustained an anterior cruciate ligament (ACL) injury showed worse emotional symptoms such as depression for a longer duration compared to athletes with a concussion and those with no injury at all (Mainwaring et al., 2010). However, an ACL injury is more severe in nature due to the extensive treatment, recovery, and possibility to end a career, compared to the recovery trajectory of a concussion that is severe at the onset but typically results in eventual pre-injury functioning. The findings from

the present study reject the notion that all injuries, regardless of etiology, are associated with long-term psychological distress.

Study Strengths and Limitations

The present study contributes valuable evidence to the current literature on long-term psychological symptoms in adolescent ice hockey players after sustaining a concussion. The results found adolescent athletes who have sustained a concussion do not show worse mental health outcomes up to one-year post-injury. Further, there is no evidence of poorer emotional and psychological functioning in adolescent athletes who have sustained a concussion compared to those with other injury types. The present study contributes novel evidence as there are limited longitudinal studies in the pediatric population, assessing mental health after a concussion (Gornall et al., 2021; Ledoux et al., 2022). The study had a large sample size of over 1060 participants, increasing statistical power and validating the results. Lastly, the outcome measures used in the present study to assess ice hockey players are commonly used within the athlete population contributing to the generalizability of results to other types of athletes.

As with all studies, the present study is not without limitations. A considerable limitation of the present study is the reliance on self-reported measures to assess emotional functioning in adolescent athletes on the SCAT-3. Given the considerable evidence of under-reporting of injury-related symptoms and endorsement of injury in athletes, the results from the present study may be an under-estimate of true emotional functioning. This challenge is consistent across all studies investigating mental health in athletes due to stigma in the sports industry and fear of the repercussions after sustaining an injury. The results from the psychological symptoms outcome, however, are validated by two raters (self-report and parent-reports) which contributes to the confidence of the findings.

Another limitation of the current study was the inconsistent usage of measures throughout the duration of data collection. The study originally collected emotional functioning data using the BASC-2. However, a couple years into the study, emotional functioning measurement was changed to the SDQ to improve response rate and efficiency as the SDQ is shorter in length. Although there is evidence of similarities between the two measures, and these two measures are often used interchangeably in a clinical setting, the inconsistency in measurement could have affected the psychological symptoms outcome.

The complexity of the study design could have influenced the outcomes as well. Given that a player could contribute to the analytic models' multiple times based on the injuries they sustain and the number of observations (pairs of baseline assessments), the models were unable to be divided by player resulting in an overlap of symptom reporting across models. To address this concern, the models were nested by player and team to account for the random effects of repeating players, however it is still worth acknowledging in the interpretation of results.

Conclusions and Future Research

This study contributes valuable evidence to the current literature on the duration of psychological symptoms after sustaining concussion in an adolescent athlete population. The current study found no evidence of long-term psychological distress or emotional dysfunction up to one year post concussion. Further, the study found no evidence of worsening psychological outcomes in adolescents' athletes who sustain a concussion, compared to athletes with other injury types, and those athletes with no injuries at all. As there is concern for the long-term mental health outcomes in athletes, this study supports the consensus statement that most athletes recover well after sustaining a concussion and there are no long-term psychological sequelae to be concerned about. However, given the significant evidence on under reporting among athletes who sustain a concussion, these results should not undermine the value of psychological monitoring and treatment. Further, although there were no significant group differences implying worse psychological outcomes after concussion in the current study, the individual experience of persisting concussive symptoms should not be over-looked.

Future studies should continue to investigate the long-term psychological and emotional implications of sustaining a concussion in different age groups and athletic populations. As the current study assessed adolescent athletes, special attention should be paid to the under 11 age group. As well, the study should be repeated with other sports with high contact (e.g., rugby, soccer, ringette) to translate the results globally across athletes. To further understanding the duration of psychological symptoms after sustaining an injury, future studies should investigate symptoms at varying timepoints post-injury to specify the time point of symptom resolution.

Tables

Table 1 <i>Demographic Data for Total Dataset and Each Model</i>				
	Total Dataset	Model 1: Adolescent Scores (SDQ/BASC- 2)	Model 2: Parent Scores (SDQ/BASC-2)	Model 3: Emotional Symptoms Score (SCAT-3)
Number of Observations (o)	1746	857	758	1308
Sex				
Female	158 (9.0%)	73 (8.5%)	53 (7.0%)	109 (8.3%)
Male	1588 (91.0%)	784 (91.5%)	705 (93%)	1199 (91.7%)
Age Group				
U13	291 (16.7%)	179 (20.9%)	182 (24.0%)	231 (17.7%)
U15	636 (36.4%)	267 (31.2%)	232 (30.6%)	478 (36.5%)
U18	819 (46.9%)	411 (48%)	344 (45.4%)	599 (45.8%)
Body Check Policy				
Body Checking	954 (54.6%)	443 (51.7%)	399 (53.6%)	712 (54.4%)
Non-Body Checking	685 (39.2%)	359 (41.9%)	322 (42.5%)	520 (39.8%)
Missing	107 (6.1%)	55 (6.4%)	37 (4.9%)	76 (5.8%)
Injury type				
No injury	1297 (74.3%)	668 (77.9%)	593 (78.2%)	1020 (78.0%)
Concussion	177 (10.1%)	57 (6.7%)	59 (7.80%)	100 (7.60%)
Musculoskeletal	180 (10.3%)	96 (11.2%)	76 (10.0%)	136 (10.4%)
Both Concussion & Musculoskeletal	92 (5.3%)	36 (4.2%)	30 (4.0%)	52 (4.0%)

o - pairs of consecutive baseline assessments used in analysis

Table 2 <i>Distribution of Data for Each Model</i>			
	Model 1: Adolescent Forms (SDQ/BASC-2)	Model 2: Parent Forms (SDQ/BASC-2)	Model 3: Emotional Symptoms Score in Players (SCAT-3)
Participants	N= 562	N= 512	N=848
Consecutive Baseline Testing Pairs	673 (78.6%) One 122 (14.2%) Two 45 (5.3%) Three 17 (1.98%) Four	363 (47.9%) One 98 (12.9%) Two 35 (4.6%) Three 16 (0.5%) Four	571 (43.7%) One 171 (13.1%) Two 71 (5.4%) Three 35 (2.7%) Four
Injury occurrences (concussion, musculoskeletal and both)	422 (75.1%) - None 104 (18.5%) - One 27 (4.8%) - Two 6 (1.1%) - Three 2 (0.4%) - Four 1 (0.2%) - Five	386 (75.4%) - None 94 (18.4%) - One 27 (5.3%) – Two 4 (0.8%) - Three 0 (0.0%) - Four 1 (0.2%) - Five	629 (74.1%) None 169 (19.9%) One 38 (4.5%) Two 8 (0.9%) Three 1 (0.1%) Four 3 (0.4%) Five
Timeline from injury to second baseline	1 (0.5%) ≤ 30 days 4 (2.1%) 31-90 days 24 (12.7%) 91-180 days 160 (84.7%) >181 days	0 (0.0%) ≤ 30 days 2 (1.2%) 31-90 days 23 (13.9%) 91-180 days 140 (84.8%) >181 days	3 (1.0%) ≤ 30 days 7 (2.4%) 31-90 days 26 (9.0%) 91-180 days 252 (87.5%) >181 days

Table 3 <i>Model 1 Analysis: Adolescent Scores on the SDQ/BASC-2 at second baseline</i>			
Variable	Coefficient	95% CI	
		Lower	Upper
Psychological Symptoms Previous Baseline	*0.439	0.378	0.500
Sex			
Female	reference		
Male	-0.787	-2.933	1.359
Age group			
U13	reference		
U15	*2.566	0.862	4.269
U18	*2.501	0.633	4.369
Body Checking Policy			
Body Checking	reference		
Non-Body Checking	0.847	-0.663	2.357
Missing	-0.824	-2.926	1.278
Injury Type			
No Injury	reference		
Concussion	*-2.275	-4.249	-0.301
Musculoskeletal	*-1.765	-3.391	-0.139
Both Concussion & Musculoskeletal	-1.267	-3.718	1.185
Constant	24.773	20.780	28.767
N _o	857		
N _p	562		

N_o=number of observations (baseline pairs)

N_p=number of participants

†=obtained through Wald test

*Indicates statistical significance based on a 5% significance level

Table 4 <i>Model 2 Analysis: Parent scores on the SDQ/BASC-2</i>			
Variable	Coefficient	95 % CI	
		Lower	Upper
Psychological Symptoms			
Previous Baseline	*0.481	0.414	0.548
Sex			
Female	reference		
Male	0.270	-1.879	2.420
Age group			
U13	reference		
U15	*1.909	0.376	3.443
U18	0.786	-0.910	2.482
Body Checking Policy			
Body Checking	reference		
Non-Body Checking	0.412	-0.999	1.823
Missing	0.111	-2.038	2.259
Injury type			
No injury	reference		
Concussion	0.916	-0.740	2.571
Musculoskeletal	1.376	-0.170	2.921
Both Concussion & Musculoskeletal	-0.616	-2.914	1.681
Constant	22.367	18.200	26.535
N _o	758		
N _p	512		

N_o=number of observations (baseline pairs)

N_p=number of participants

†=obtained through Wald test

*Indicates statistical significance based on a 5% significance level

Table 5 <i>Model 3 Analysis: SCAT-3 Emotional Symptom Scores</i>			
Variable	Odds Ratio	95% CI	
		Lower	Upper
Previous Baseline SCAT-3 Emotional Symptoms Score			
0			
≥1	*4.704	3.235	6.838
Sex			
Female			
Male	*0.523	0.281	0.974
Body Checking policy			
Body Checking	Reference		
Non-Body Checking	1.519	0.942	2.451
Missing	0.661	0.265	1.650
Age group			
U13	Reference		
U15	1.588	0.898	2.807
U18	1.283	0.702	2.346
Injury type			
No Injury	Reference		
Concussion	0.776	0.382	1.574
Musculoskeletal	0.935	0.510	1.716
Both Concussions & Musculoskeletal	0.931	0.367	2.359
Constant	0.100	0.036	0.275
N _o	1308		
N _p	848		

N_o=number of observations (baseline pairs)

N_p=number of participants

†=obtained through Wald test

*Indicates statistical significance based on a 5% significance level

Table 6
Comparison of Means Across Injury Types for Psychological Symptoms (T-Scores) on the SDQ/BASC-2

	Adolescent Forms (Model 1)		Parent Forms (Model 2)	
	Initial Baseline	Second Baseline	Initial Baseline	Second Baseline
No Injury	44.62 (8.04)	45.89 (8.47)	46.28 (6.96)	46.13 (7.46)
Concussion	45.93 (9.84)	44.23 (6.76)	46.67 (8.37)	47.23 (7.90)
Musculoskeletal Injury	45.72 (9.09)	44.97 (8.86)	45.29 (7.08)	46.68 (8.30)
Both Concussion and Musculoskeletal Injury	45.09 (7.98)	44.80 (8.98)	46.04 (6.22)	44.16 (5.74)

Figures

Figure 1

Participant Distribution by Model with Inclusion Criteria

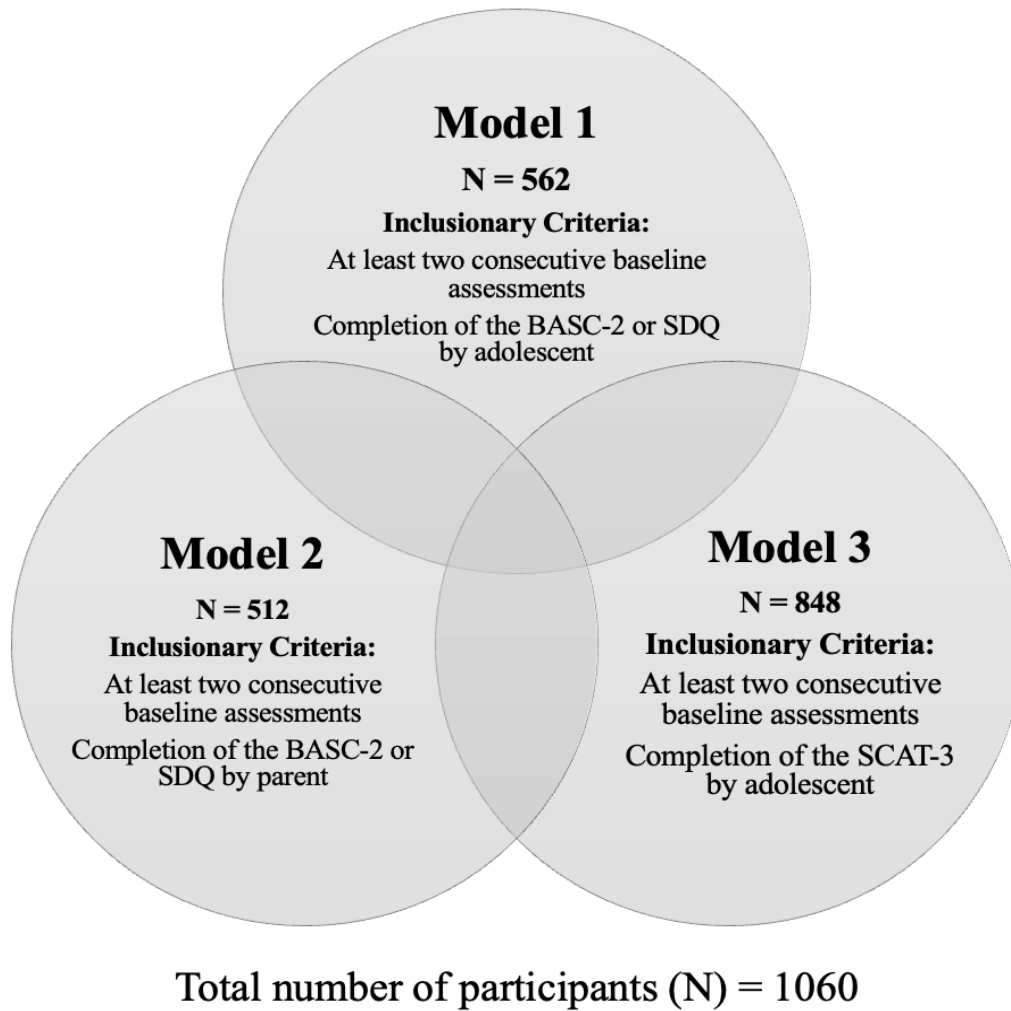


Figure 2

Comparison of Means Across Injury Types at Initial and Second Baselines for the SDQ/BASC-2 T-Scores Adolescent Forms

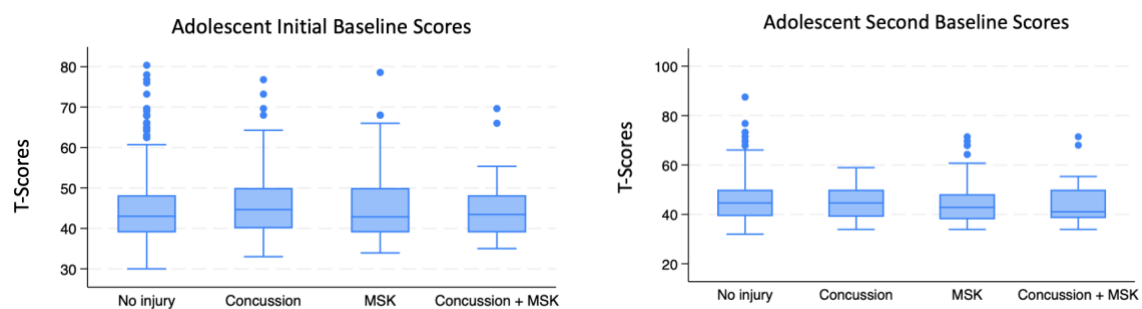
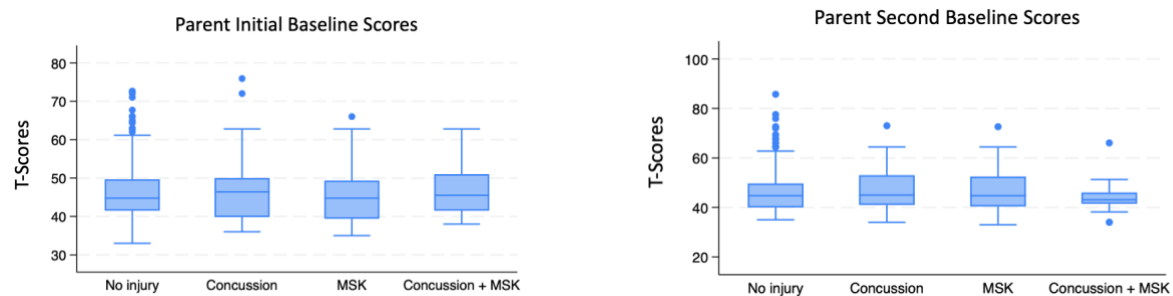


Figure 3

Comparison of Means Across Injury Types at Initial and Second Baselines for the SDQ/BASC-2 T-Scores on Parent Forms



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