The Psychosocial Impact of Sports-Related Concussion in Elite Youth Ice Hockey Players

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

Department of Educational Psychology

University of Alberta

Abstract

Concussion can have adverse long term effects in the cognitive and behavioral development of children and adolescents. Research continues to highlight the fact that children and adolescents are more susceptible to concussion and take longer to recover from this injury. At present, there is a paucity of research evaluating the long-term effects of concussion in children and adolescents. The purpose of this study was to examine the social, emotional, and behavioral functioning of elite youth ice hockey players at baseline and post-concussion. Participants included 76 elite youth ice hockey players between 13-17 years from Calgary and Edmonton, Alberta. Control participants were matched to injured players at the time of injury. Participants completed the Behavior Assessment Scale for Children, Self Report Questionnaire (BASC-2, Adolescent Form) at baseline and 7 days and 3 months post-concussion. The results of the first analysis which examined group changes in psychological functioning using a 2 x 3 (group-by-occasion) fixed effect ANOVA with repeated measures on the second factor showed no significant findings. Athletes in the concussed group were similar to the athletes in the non-injured control group on the 5 composites and 16 subscales of the BASC-2. Results examining change at the individual level using the Reliable Change Index (RCI) showed slightly more concussed athletes (15.8%) with both reliable worsening and clinically meaningful scores on the BASC-2 compared to control participants (10.5%) at 7-10 days post injury. However, at 3 months post injury, there was no difference, as 15.8% of concussed athletes and 15.8% of control participants showed both reliable worsening and clinically meaningful scores on the BASC-2. Although the findings are promising in suggesting a favorable psychological outcome for youth athletes after concussion, it is still important for clinicians to evaluate and monitor psychological

functioning after injury, as some athletes may develop ongoing psychological concerns requiring intervention.

Preface

This thesis is an original work by Andrea Lynn Jubinville. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "The Psychosocial Impact of Sports-Related Concussion in Youth Ice Hockey Players", No. MS4 Pro000024093, August 2011.

Dedication

This dissertation is dedicated to my parents, David and Linda Krol, who have been my pillars of strength through my educational journey. Your unwavering love, support, and encouragement allowed my dream of achieving a PhD come to reality. It was your understanding, patience, and unremitting confidence that provided me with the motivation to persevere right to the end. I also dedicate this dissertation to my husband, Brett Jubinville, who has supported me every step of this journey. Brett, you have taught me to what it takes to be successful- desire, dedication, determination, concentration, and the will to win! Your faith in me is what truly kept my dream alive and for this, I am forever grateful.

Acknowledgements

Foremost, I would like to thank my supervisor, Dr. Martin Mrazik for his unrelenting support, guidance, and encouragement throughout my lengthy academic journey. I will never forget the first conversation Dr. Mrazik and I had when he proposed the idea of completing a doctorate degree under his guidance. His enthusiasm, passion, and faith in me is the reason I am graduating today, with a PhD. With every hurdle encountered along the way, Dr. Mrazik calmly and confidently encouraged me to persevere. His hope and confidence pushed me through the most daunting of times. Thank you, Dr. Mrazik for making my dreams of becoming a doctor possible.

Additionally, I would like to thank my supervisory committee in the department of Educational Psychology including, Dr. George Buck and Dr. Todd Rogers for their academic and professional insight. The time and dedication you devoted to my research is very much appreciated and valued.

Finally, this dissertation would not have been possible without the devoted staff and students at the University of Calgary's Sport Injury Prevention Research Centre. A special thank you to Dr. Carolyn Emery for the time and energy she spent leading and organizing this research project.

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Chapter One: Introduction

Background to the Problem

Over the last two decades, an increase in recreational and sport activity among children and adolescents has been noted across Canada and the United States (Kirkwood et al., 2008; Metzl, 2006). In fact, reports estimate that in the United States alone there are approximately 30 million children and adolescents who are involved in sport and recreation (Metzl, 2006). A proportion of these youth participate in ice hockey. In 2011-2012, Hockey Canada reported over 600,000 registered youth hockey players and the USA Hockey Association reported over 350,000. Because of this widespread participation, ice hockey injuries in youth occur often (Emery et al., 2010; Marchie & Cusimano, 2003). In youth ice hockey, concussion accounts for more than 15% of all injuries and has been found to be the most common specific injury type (Emery & Meeuwisse, 2006; Emery et al., 2010; Emery et al., 2010; K.J. Schneider, Meeuwisse, Kang, G.M. Schneider, & Emery, 2013). By the time adolescent athletes reach high-school, 53% have a positive history of concussive injury (Field, Collins, Lovell, & Maroon, 2003; Lovell & Fazio, 2008). Additionally, by college, 36% of athletes report a history of multiple concussions (Field et al., 2003; Lovell & Fazio, 2008). Children and adolescents are reportedly six times more likely to suffer a concussion during an organized sporting activity compared to a leisure activity (Browne & Lam, 2006). These data highlight the alarming occurrence of sports related concussive injury in children and adolescents. Pediatric concussion remains a significant public health concern and much research is still needed to better recognize, assess and manage these injuries in children and adolescents (Barlow et al., 2010; Callahan, 2010; McKinlay, 2010; Sady et al., 2011).

Sequalae of pediatric concussion. Over the last decade, there has been considerable controversy over whether or not concussion can cause long-term neurobehavioral symptoms in children and adolescents (Halstead et al., 2010; McKinlay, 2010; Overweg-Plandsoen et al., 1999; Yeates, 2010). While it is undeniable that severe head injury in childhood is related to significant disability and mortality, the long term outcomes associated with concussion have been more ambiguous (Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2001). Some researchers argue that children may face significant, on-going problems following concussion which can include cognitive, academic and psychosocial difficulties (McKinlay et al., 2002; Mittenberg, Wittner, & Miller, 1997; Moser, Schatz, & Jordan, 2005; Overweg-Plandsoen et al., 1999; Sady et al., 2011; Yeates, 2010). Conversely, other researchers debate that concussion leaves no residual deficits (Bijur, Haslum, & Golding, 1996; Light et al., 1998; Satz et al., 1997).

Long-term sequelae after concussion in children and adolescents including psychological, education, and health related complaints have been reported (Barlow et al., 2010; Bloom et al., 2001; Broshek & Freeman, 2005; McKinlay et al., 2002; Mittenberg et al., 1997; Overweg-Plandsoen et al., 1999; Segalowitz & Lawson, 1995; Taylor et al., 2010). More specifically, it has been found that children are at significantly increased risk for psychiatric illness (Massagli et al., 2004); including hyperactivity and depression (Bloom et al., 2001; Levin et al., 2007; Massagli et al., 2004; McKinlay et al., 2002; Segalowitz & Lawson, 1995). Other studies have reported learning difficulties, sleep difficulties, speech and language disorders (Anderson et al., 2001), and social dysfunction following concussion (Segalowitz & Lawson, 1995). Concussion can lead to a variety of impairments in children and adolescents (Sady et al., 2011). In some cases, these impairments can persist over time, affecting these children and adolescent's social, emotional and intellectual well-being (Sady et al., 2011).

Concussion, whereby an individual sustains an acute brain injury from mechanical energy to the head, has gained widespread interest in the media and medicine over the last decade (Halstead, Walter, & Council on Sports Medicine and Fitness, 2010; Moser & Schatz, 2012). The Centers for Disease Control and Prevention (CDC) estimates that between 1.4 and 3.8 million sport and recreation related concussions occur each year in children and adults in the United States, with approximately 135,000 presenting to emergency departments (Gioia, Isquith, Schneider, & Vaughan, 2009; Laker, 2011; Langlois, Rutland-Brown, & Wald, 2006). A population based study of sport and recreation related head injuries conducted in one Canadian city (Edmonton, AB) found that in a ten year time period, 63, 219 sport related injuries presented to the Emergency Departments (Harris, Jones, Rowe, & Voaklander, 2012). Of those sport related injuries, 7.8% were sport related head injuries (Harris et al., 2012). Additionally, the rate of sport related head injuries per 100,000 treated in Emergency Departments for individuals between the ages of 10-14 and 15-19 was more than triple the rate for individuals ages 20-24 (Harris et al., 2012). These numbers demonstrate that concussions place significant demands on health care services (Yeates, 2010). Individuals suffering from concussion often spend time in emergency departments. They may then require expensive imaging procedures, the short term use of hospital beds, and in some cases rehabilitative services (Wrightson & Gronwall, 1999).

There has been an abundance of research that has evaluated and assessed those with moderate to severe traumatic brain injury (TBI). In contrast, concussion has historically received much less attention. Moderate to severe TBI causes permanent deficits to a wide range of domains including intellectual functioning, academic achievement, adaptive functioning, and behavioural adjustment (McCrea, 2008; Sady, Vaughan, & Gioia, 2011). However, it is still unclear whether children and adolescents who suffer concussion endure long term deficits as well. The literature on this topic presents controversies and uncertainties (McKinlay, 2010; McKinlay, Grace, Horwood, Fergusson, & MacFarlane, 2009; Yeates & Taylor, 2005). While some have described paediatric concussion as a silent epidemic having long-term cognitive, academic, and psychosocial consequences for children and adolescents (Hartlage, Durant-Wilson, & Patch, 2001; Hessen, Nestvold, & Sundet, 2006; McKinlay, DalrympleAlford, Norwood, & Fergusson, 2002; Sady et al., 2011; Wrightson, McGinn, & Gronwall, 1995), others have described concussion as a benign and inconsequential injury (Light et al., 1998; Satz et al., 1997).

Research Purpose

The purpose of this study was to examine the social, emotional, and behavioral functioning of elite youth ice hockey players ages 13-17 years old at baseline (i.e., prior to injury) and post-concussion (i.e., seven to ten days and three months) using the Behavioral Assessment Scale for Children-Second Edition (BASC-2). First, the composite and scale scores of the BASC-2 were compared across time periods for concussed athletes and healthy controls. Second, individual change on the BASC-2 composite and scales scores were examined using the Reliable Change Index (RCI).

Research Question and Specific Objectives

Research question.

1. At the group level, are there differences between the BASC-2 composite and scale scores for elite youth ice hockey players ages 13- to 17- years who are concussed athletes and the BASC-2 composite and scale scores for elite youth ice hockey

players ages 13- to 17- years who are not concussed at baseline, seven to ten days post injury, and three months post injury?

2. At the individual level, are there differences between the BASC-2 composite and scale scores for elite youth ice hockey players ages 13- to 17- years from baseline to seven to ten days post injury, as well as from baseline to three months post injury?

Objectives.

1. To determine if there are significant changes on the composite and sub-scales of the Self-Report Behavioral Assessment System for Children-2 (BASC-2), from baseline to seven to ten days following concussion in youth ice hockey players compared to healthy controls.

2. To determine if there are significant changes on the composite and sub-scales of the Self-Report Behavioral Assessment System for Children-2 (BASC-2), from baseline to three months following concussion compared to healthy controls.
3. To assess for statistically meaningful change at the individual level across the composite and sub-scales of the BASC-2 from baseline to seven to ten days post injury.
4. To assess for statistically meaningful change at the individual level across the composite and sub-scales of the BASC-2 from baseline to three months post injury.

Background

Operational definitions.

Concussion: The definition of concussion in this study is based on the 2012 International Consensus Statement on Concussion in Sport (McCrory et al., 2013)

> Concussion is a complex pathophsyiological process affecting the brain, induced by biomechanical forces. Several common features that incorporate clinical, pathological, and biomechanical injury constructs that may be utilized in defining the nature of a concussion head injury include:
>
> 1. Concussion may be caused either by a direct blow to the head, face, neck or elsewhere on the body with an "impulsive" force transmitted to the head.
> 2. Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. However, in some cases, symptoms and signs may evolve over a number of minutes to hours.
> 3. Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury, and as such, no abnormality is seen on standard structural neuroimaging studies.
> 4. Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. Resolution of clinical and cognitive symptoms typically follows a sequential course. However, it is important to note that in a small percentage of cases, post-concussive symptoms may be prolonged.

Mild Traumatic Brain Injury (mTBI): The operational definition of mTBI in this study is based on the 2011 World Health Organization Task Force definition which was developed by the Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine (Kristman et al., 2014).

mTBI is an acute brain injury resulting from mechanical energy to the head from external physical forces.

Operational criteria for clinical identification include:

1. One or more of the following: confusion or disorientation, loss of consciousness (LOC) for 30 minutes or less, posttraumatic amnesia for less than 24 hours, and/or other transient neurological abnormalities such as focal signs, seizure and intracranial lesion not requiring surgery;

2. Glasgow Coma Scale of 13-15 after 30 minutes postinjury or later upon presentation for healthcare.

3. These manifestations of mTBI must not be due to drugs, alcohol, medications, caused by other injuries or treatment for other injuries (e.g. systemic injuries, facial injuries or intubation), caused by other problems (e.g. psychological trauma, language barrier or coexisting medical conditions) or caused by craniocerebral injury

Children: The definition of a child that will be used in this study is based on criteria set out by the Canadian Pediatric Society and includes individuals between the ages of 2-12 (Sport readiness in children and youth, 2005).

Adolescent: The definition of an adolescent used in this study is based on criteria set out by the Canadian Pediatric Society and includes individuals between the ages of 13 and 18 (Sport readiness in children and youth, 2005).

Youth: The definition of youth can vary across countries and even between organizations. In Canada, and for purposes of this research study, the term youth will refer to anyone between the ages of 12 and 17 (Alvi, 2012) .

Pediatric: The term pediatric will be used to refer to infants, children and adolescents and will include individuals between the ages of 0-18 (Dobson, Bryce, Glaeser, & Losek, 2007).

Organization of Dissertation

This dissertation contains five chapters, including an introduction, a literature review, methods, results, and discussion. Chapter one, the introduction, included the background, purpose, and questions, and the operational definitions used in the study. Chapter two contains the review of literature on pediatric sports related concussion. An overview of the history of sport concussion, differences across pediatric and adult populations, the assessment and management of this injury, and the effects of multiple concussions and long term outcomes for youth athletes is discussed. Chapter three describes the methods used in this research study. It includes the design, participants, outcome measures, procedure, study objectives, statistical analysis, and ethics. Chapter four reports the results of the study. It includes a description of study participants and the findings from each research objective analysis. Chapter five includes a discussion of the results, limitations and strengths of the study, and future directions for research on this topic.

Chapter Two: Review of Literature

This chapter begins with a historical overview of sports related concussion as well as a review the terminology prevalent in this field of study. Pediatric concussion and, more specifically, pediatric sport related concussion is addressed as well, with attention paid to how this injury differs across children, adolescents, and adults. In addition, the assessment, management, and long term effects of this injury are addressed to provide an understanding of the long ranging implications of concussion in children and youth. This chapter also reviews aspects of the literature pertaining to multiple concussions and cumulative effects. The chapter concludes with the proposed hypotheses for the current study.

Historical Perspectives on Concussion in Sport

The term concussion was coined as an independent medical diagnosis in 900 AD by Arabic physician, Rhazes (Halstead, 2011). It was defined as a transient neurological syndrome that occurred without structural brain injury (Halstead, 2011; Johnston, McCrory, Mohtadi, & Meeuwisse, 2001; McCrory & Berkovic, 2001). This definition was the first to differentiate concussion from other forms of brain injury and was fundamental in building an understanding of this medical condition (McCrory & Berkovic, 2001). From the 10th century AD onward, the clinical features of concussion were observed and studied and compared to other forms of injury such as skull fracture and penetrating brain wounds (McCrory & Berkovic, 2001). In the 16th century, the first theory linking concussive injury to brain movement or shaking was made by Berengario da Carpi (Halstead, 2011). In the clinical cases that were observed, symptoms such as memory impairment, faltering of speech, poor judgement, and difficulty understanding were noted. Da Carpi hypothesized these symptoms to be the consequence of brain movement resulting in brain swelling and hemorrhage (Halstead, 2011). In the 17th century, the development of the microscope allowed physicians and researchers to study the physiological nature of concussive injury, confirming that it was a functional injury rather than a structural injury (Halstead, 2011).

Although concussion has been a distinct clinical entity since 900 AD, the first account of long term sequelae resulting from repetitive concussions was not made until 1928. *Punch drunk* syndrome was the term used to describe the cluster of symptoms seen in some boxers after sustaining multiple head injuries (Halstead, 2011). Shuffling of the feet or difficulty moving were some of the symptoms observed and this condition would force some athletes into early retirement (Halstead, 2011). While our understanding of concussion has evolved considerably since the first description of this disorder in 900 AD, much remains unknown about concussion and permanent pathological change (McCrory & Berkovic, 2001).

Concussion in sport began to receive prominent attention in the early 1900's when President Theodore Roosevelt expressed concern over football injuries that were leading to severe injury and death in athletes (Kelly & Rosenberg, 1997). In response to a plea for safer athletic competition, the National Collegiate Athletic Association (NCAA) was formed (Kelly & Rosenberg, 1997). As a governing body, the NCAA was responsible for implementing rules and regulations to ensure safer participation in sport and more specifically, football (Kelly & Rosenberg, 1997). The establishment of the NCAA began the process of standardization in sport; however, even despite its efforts, the annual incidence of death due to injury in football was high.

It was not until the 1960's that progress was made in successfully reducing the rate of head injury in football (Bailes & Cantu, 2001). The reduction was primarily attributed to changes in helmet design and more stringent rules during game play (Bailes & Cantu, 2001). Since the inquiry of head injuries in football began in 1904, there has been a steady increase in governing bodies and the rules, regulations, helmet standards, and medical care, and coaching techniques have evolved not only in football but also in other contact sports such as rugby, hockey, soccer, and boxing. While our understanding of concussion has drastically changed over the last decade, much effort is still needed to highlight the seriousness of this injury to the public (Guskiewicz et al., 2004). Terms for concussion such as *ding* or *bell ringer* that undermine the importance of this injury should be eradicated so that more athletes, parents, and coaches will treat concussion as a serious medical condition (Guskiewicz et al., 2004).

Concussion and mTBI: Terminological Clarification

It is now widely established that mTBI is a clinical diagnosis that is distinct from moderate and severe brain injury (McCrory et al., 2009). Where moderate and severe TBI are classified according to acute injury characteristics such as unconsciousness and amnesia, scientific literature has shown that these clinical markers have limited utility and sensitivity in the detection of mTBI (McCrea, 2008). Furthermore, although it is well documented that mTBI is characteristically different from moderate and severe TBI, there is ambiguity regarding how mTBI differs from concussion (Gordon, Dooley, Fitzpatrick, Wren, & Wood, 2010; Halstead et al., 2010; Lee, 2007; McKinlay, Bishop, & McLellan, 2011). Throughout the scientific literature the term mTBI is often used synonymously with other classifications such as minor closed head injury (CHI), mild CHI, minor brain injury, mild head injury, minor head injury and concussion

(Anderson, Heitger, & Macleod, 2006; Gordon, 2006; Gordon et al., 2010; Kirkwood, Yeates, & Wilson, 2006; McKinlay et al., 2011; Meehan & Bachur, 2009; Yeates, 2010). Along with the numerous titles for this injury is the existence of several formal definitions which have been proposed over time by a variety of neurosurgeons, neurologists, neuropsychologists, and other multidisciplinary groups (Gioia et al., 2009; Kirkwood et al., 2006) .The varying definitions of this injury emphasize the complexity of mTBI and the conflicting opinions about it (Gioia et al., 2009; Lee, 2007; McKinlay et al., 2011; Meehan & Bachur, 2009; Solomon, Johnston, & Lovell, 2006).

One of the first definitions of concussion was proposed by the Congress of Neurological Surgeons in 1966. They defined concussion as "a clinical syndrome characterized by immediate and transient post-traumatic impairment in neural function, such as alteration of consciousness, disturbance of vision, equilibrium, etc. due to brain stem involvement due to mechanical forces" (as cited in McCrory, 1999, p.136). Since then, numerous other definitions for mTBI and concussion have been created by organizations such as the World Health Organization, the American Academy of Pediatrics, the American Academy of Neurology, the American Congress of Rehabilitation Medicine, and the Concussion in Sport Group. Although there are similarities among these definitions, there is a notable distinction between the most recent definitions of mTBI and concussion (Gordon et al., 2010). Definitions for mTBI delineate the injury as one that may include structural and functional injury, whereas definitions for concussion specify the absence of structural injury (Callahan, 2010; Gordon et al., 2010; McCrory et al., 2009). That is, concussion can be regarded as a subset of mTBI, one that is of lesser severity on the injury classification continuum (Gioia et al., 2009; Gordon et al., 2010; Kirkwood et al., 2006).

Although mTBI and concussion have been used interchangeably throughout the literature and in medical practice, experts from the Concussion in Sport Group collectively agreed in 2009 that since the two terms refer to different injury constructs they should be defined separately and no longer be referred to as congruent diagnoses (Anderson et al., 2006; McCrory et al., 2009). This is due to the fact that the terminology surrounding head injuries is already very confusing (McKinlay et al., 2011). Not only does the term head injury include mTBI and concussion, but also injuries involving the eyes, scalp, teeth, or face (Anderson et al., 2006; Gordon et al., 2010). Furthermore, diagnostic labels are used in medical practice in order to convey a message and facilitate communication (Dematteo et al., 2010). Therefore, terms such as concussion and mTBI should be defined separately and used consistently and accurately in order to ensure mutual understanding among patients, doctors, and lay commentators (Dematteo et al., 2010; McKinlay et al., 2011).

The most current consensus definition for concussion which is separate from mTBI was set out by the Concussion in Sport Group:

> Concussion is a complex pathophsyiological process affecting the brain, induced by biomechanical forces. Several common features that incorporate clinical, pathological, and biomechanical injury constructs that may be utilized in defining the nature of a concussion head injury include: a) concussion may be caused either by a direct blow to the head, face, neck or elsewhere on the body with an "impulsive" force transmitted to the head; b) concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. However, in some cases, symptoms, and signs may evolve over a number of minutes to hours; c) concussion may result in

> neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury, and as such, no abnormality is seen on standard structural neuroimaging studies; d) concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. Resolution of clinical and cognitive symptoms typically follows a sequential course. However, it is important to note that in a small percentage of cases, post-concussive symptoms may be prolonged (McCrory et al., 2013, p. 555).

The most current definition for mTBI, established by the World Health Organization Collaborating Centre Task Force is:

> mTBI is an acute brain injury resulting from mechanical energy to the head from external physical forces. Operational criteria for clinical identification include: a) one or more of the following: confusion or disorientation, loss of consciousness (LOC) for 30 minutes or less, posttraumatic amnesia for less than 24 hours, and/or other transient neurological abnormalities such as focal signs, seizure and intracranial lesion not requiring surgery; b) Glasgow Coma Scale of 13-15 after 30 minutes postinjury or later upon presentation for healthcare; c) these manifestations of mTBI must not be due to drugs, alcohol, medications, caused by other injuries or treatment for other injuries (e.g. systemic injuries, facial injuries or intubation), caused by other problems (e.g. psychological trauma, language barrier or coexisting medical conditions) or caused by craniocerebral injury. (Kristman et al., 2014, p. S266).

The main difference in the abovementioned definitions is that mTBI encompasses patients with Glasgow Coma Scale (GCS) ratings of between 13-15 and patients with focal neurological deficits (Kirkwood et al., 2008; Tator, 2009). Additionally, injuries classified according to the mTBI definition may include cases with intracranial lesions (i.e. structural damage) whereas injuries classified as concussion only encompass cases with functional impairment (Anderson et al., 2006; Tator, 2009). The term concussion is predominantly used in the sports medicine field whereas the term mTBI is more commonly used in other medical specialities (Bodin, Yeates, & Klamar, 2011; Kirkwood et al., 2008).

Despite the recent efforts in separating the clinical diagnoses of concussion and mTBI, there has been some concern that using the term concussion rather than mTBI may undermine the seriousness of the injury (Dematteo et al., 2010). A study conducted by DeMatteo et al. (2010) sought to examine the use of the term concussion in a regional pediatric center. It was found that when children were given a diagnosis of concussion, parents were less likely to consider it a brain injury. This, in turn, had an effect on the management of the child's injury, as children were reported to have an earlier return to school (Dematteo et al., 2010). Results from this study highlight the importance of a diagnostic label when dealing with concussive injuries. As DeMatteo et al. (2010) stated, "if we want to encourage full reporting with subsequent adequate management and convalescence, perhaps we should use the term *mTBI*" (p. 333). Although the authors propose that *mTBI* may be a more suitable term than *concussion,* ultimately, their study highlights the need for more specific descriptors of brain injury, especially in regards to concussion (Dematteo et al., 2010). These descriptors, once established, would allow for consistency among researchers, clinicians and lay people in regards to brain injury terminology and their associated health implications.

The definition of concussion continues to change as well as the assessment and management of this injury in both adult and pediatric populations (Meehan & Bachur, 2009). While some clinicians may choose to follow the definition and guidelines set out by the CISG, others may not. Until unanimous agreement is reached, it is inevitable that clinicians will continue to differ in their use of concussion terminology as well as their approach to the assessment and management of this injury. For purposes of this research project, the definition of concussion established by the CISG will be used. However, due to the fact that concussion was previously regarded as a mild subset of mTBI, and these terms have been used inconsistently and interchangeably, literature examining both mTBI and concussion will be reviewed and discussed. Although the terms mTBI and concussion differ according to new guidelines today, the accepted terminology used at the time of each study will be kept consistent in this review.

Pediatric Concussion

Although experimental research over the last decade has improved our understanding of the pathophysiology of brain injury and what happens to the brain following minor concussive injuries, much of this research has been conducted exclusively with adult populations. Consequently, the current classification schemes and the guidelines for the management of concussion remain specific to adult populations (McCrory et al., 2009). Since pediatric concussion has been regarded as a "serious public health problem" and a "silent epidemic" (Callahan, 2010, p. 873), more research has been devoted to studying this injury in younger populations (Gioia et al., 2009; Lovell & Fazio, 2008; Purcell, 2009). Despite these efforts, additional research is needed in order to understand concussion in children and adolescents. Children and adolescents are developing human beings who are anatomically, physiologically, and behaviourally different from adults (McCrory, Collie, Anderson, & Davis, 2004; McCrory et al., 2009; Purcell, 2009). Thus, children and adolescents with concussion should be evaluated and managed differently (Lovell & Fazio, 2008; McCrory et al., 2004; Purcell, 2009). However, to date, there are no universally accepted guidelines for the diagnosis and management of concussive injury in children and adolescents that are distinct from adults (Grubenhoff, Kirkwood, Gao, Deakyne, & Wathen, 2010; Lovell & Fazio, 2008).

In response to the plea for specific tools and methods to assess concussion in children and adolescents, researchers have begun to establish a broadband approach to the assessment and monitoring of concussion in this population (Gioia et al., 2009) . This approach employs a multi-method, multi-domain, and multi-informant process whereby a child or adolescent's functioning is evaluated through different sources (i.e., parents and teachers) and across many domains (Gioia et al., 2009). This broadband approach focuses on the post-acute stage of recovery (three days to three months following concussion) and although results have been promising thus far (Gioia et al., 2009), there still remains a need for diagnostic tools and assessment approaches for the acute stage of concussive injury in children under the age of ten (Grubenhoff et al., 2010; P. McCrory et al., 2009).

Sport Related Concussion

With a change in the youth sports climate whereby children and adolescents are engaged in highly competitive activities year round, the field of sport medicine has been faced with issues in youth related to anabolic steroid use, stress fractures, over-training, and now concussion (Metzl, 2006). It is well-known that sport related concussions are a common occurrence in the pediatric population (Purcell & Carson, 2008), especially in high contact sports such as football and hockey (Kirkwood et al., 2006). Reports have also indicated that sport related head injuries occur most frequently in athletes that are under the age of 20 (Kelly, 2001; Purcell & Carson, 2008). In fact, in a recent study that was conducted in a Canadian Emergency Department it was found that among a group of 10-14 year olds, 53.4% of the serious head injuries reporting to the ER were sport related and in a group of 15-19 year olds, this percentage was 42.9% (Kelly, Lissel, Rowe, Vincenten, & Voaklander, 2001; Purcell & Carson, 2008). Another study found that sports are the second highest cause of traumatic brain injury in individuals ages 15-24 next to motor vehicles collisions (Gessel, Fields, Collins, Dick, & Comstock, 2007). Over the last two decades, sport concussion in youth has begun to receive more attention in the medical community as scientific evidence continues to highlight the prevalence of this injury and the possible deleterious effects (Broshek & Freeman, 2005; Kirkwood et al., 2006).

Ice hockey. In Canada, over 600,000 male and female athletes participate in ice hockey annually (Hockey canada annual report, 2012). Not only is hockey a popular sport with widespread participation but athletes engaging in this activity move at high rates of speed and frequently make contact with hard surfaces and objects (Goodman, Gaetz, & Meichenbaum, 2001; Honey, 1998; Reed et al., 2010; Smith et al., 2011). It is not surprising, then, that a large proportion of sport related injuries occur during participation in ice hockey (Emery & Meeuwisse, 2006; Emery et al., 2010). Previous reports have suggested that ice hockey is ranked as one of the sports with the greatest proportion of injuries (Emery, Meeuwisse, & McAllister, 2006; Goodman et al., 2001; Tommasone & Valovich McLeod, 2006). In one study, concussion accounted for 15% of all sport related injuries in high school athletes (Meehan, d'Hemecourt, Collins, & Comstock, 2011). In other research, it has been found that 10-12% of hockey players report a concussion every season (Goodman et al., 2001; Halstead et al., 2010; Honey, 1998; Marchie & Cusimano, 2003).

With concussive injuries on the rise, much attention has turned to body checking and subsequent injury rates in youth hockey ("Safety in youth ice hockey: The effects of body checking", 2000; Cusimano et al., 2011; Emery et al., 2010; Marchie & Cusimano, 2003). Research conducted in the 1990's found that body checking is one of the main mechanism for injury in hockey, accounting for 86% of all injuries in youth ages 9-15 years ("Safety in youth ice hockey: The effects of body checking", 2000; Brust, Leonard, Pheley, & Roberts, 1992; Marchie & Cusimano, 2003; Pinto, Kuhn, Greenfield, & Hawkins, 1999). In 2002, Hockey Canada was allowing players as young as nine years old to engage in body checking (Houghton & Emery, 2012; Marchie & Cusimano, 2003). This issue ignited strong debate and controversy throughout the country. Prior to the age of 15, the variation in size (height and weight) between players can be quite substantial ("Safety in youth ice hockey: The effects of body checking", 2000; Brust et al., 1992). In fact, one study found that the size differential can be as high as 53 kg in body weight and 55 cm in height in a group of players 14-15 years old ("Safety in youth ice hockey: The effects of body checking", 2000; Brust et al., 1992). In this age group, with some players twice as strong and twice as heavy as the others, injury is inevitable.

Since body checking is known to be the predominant mechanism of injury in youth hockey, Emery et al. (2010) sought to investigate how the risk of injury and concussion would differ among hockey players in a Canadian pee wee league that permitted body checking compared to one that did not. In total there were 74 pee wee teams that allowed body checking (from Alberta) and 76 teams that did not allow body checking (from Quebec). Teams were followed over the course of one season using a validated injury surveillance system (Emery et al., 2010). Overall, a threefold increased risk of concussion, injury, severe concussion and severe injury was found among pee wee hockey players who belonged to a league that permitted body checking compared to one that did not (Emery et al., 2010). More specifically, in Alberta there were 241 injuries noted with 78 of those injuries being concussion over 85 077 player exposure hours. Conversely, there were 91 injuries in Quebec with 23 of those injuries being concussion in 82 099 player exposure hours (Emery et al., 2010). In sum, body checking in hockey leads to an increase in the incidence of injury and specifically, concussion.

With the potential serious health implications of concussion, limiting body checking and other high-impact collisions in young athletes (< 15 years of age) to reduce the overall incidence of injury was strongly urged by both the American Academy of Pediatrics and the Canadian Paediatric Society ("Safety in youth ice hockey: The effects of body checking", 2000; Houghton & Emery, 2012; Marchie & Cusimano, 2003; Purcell, 2014). In 2011, USA Hockey initiated a policy change removing body checking from youth ice hockey in all Peewee divisions of play (Anton, n.d.). Specifically, athletes under the age of 14 were legally prohibited from engaging in body checking during games across the United States (Anton, n.d.). A similar movement was later initiated in Canada in 2013, whereby body checking was banned from youth ice hockey players in all Peewee (11-12 year olds) levels of play (Hockey Canada, n.d.). The movement to eliminate body checking in Peewee levels of competitive ice hockey did not come without significant controversy and debate. However, with this change, the risk of injury and concussion in youth athletes is expected to decrease substantially (Houghton & Emery, 2012).

How Does Concussion Differ in a Pediatric Population from an Adult Population?

Generally speaking, in a pediatric population, children and adolescents will present with acute signs and symptoms after concussion that are consistent with adults. Like adults, children and adolescents who have experienced concussion often show signs of acute neurobehavioral problems. These problems are diverse and can include somatic complaints (i.e., headaches, fatigue, low energy, sleep disturbance, nausea, vision changes, dizziness), emotional/behavioral complaints (i.e., lowered frustration tolerance, irritability, increased emotionality, depression, anxiety), or cognitive complaints (i.e., reduced speed of information processing, poor attention, poor concentration, trouble with learning and memory) (Anderson et al., 2001; Broshek & Freeman, 2005; Daneshvar et al., 2011; Kirkwood et al., 2006; McCrory et al., 2004). However, while children and adolescents may initially present similarly after concussion to that of adults, it is imperative to recognize that they are actively developing young human beings that have unique needs and different expectations after injury (Kirkwood et al., 2006; Lovell & Fazio, 2008; McCrory et al., 2004). Key differences between children/adolescents and adults in regards to the biomechanics of concussion, the neuroanatomy of the brain, the pathophysiological responses after injury and the long term neurobehavioral outcomes will be discussed in the following sections.

Biomechanical properties and anatomical differences. Researchers studying the biomechanics of concussion have determined that injury results as a consequence of rotational acceleration and/or deceleration forces that stress or strain brain tissue, vasculature, and other neural elements (Bauer & Fritz, 2004; Kirkwood et al., 2006; Meehan, Taylor, & Proctor, 2011). Although the biomechanics of concussion are still being investigated using increasingly sophisticated data from real time accelerometers, video analysis, and dummy reconstruction models, researchers are still unsure whether there is a minimal biomechanical threshold for concussion (Kirkwood et al., 2006; McCrea, 2008). While it is undeniable that significant progress has been made in understanding the biomechanical properties of concussion over the last 40 years, much more investigation is required in order to understand how these forces differentially impact adults and children/adolescents. To date, it is known that the composition and mechanical properties of a child's head differs significantly from that of an adult (Bauer & Fritz, 2004; Halstead et al., 2010; Kirkwood et al., 2006; Meehan, d'Hemecourt, & Comstock, 2010; Meehan et al., 2011). More specifically, brain water content, cerebral blood volume, level of myelination, skull geometry and structure elasticity are known to affect the biomechanics of concussive injury, however, the exact reasons how are undetermined at this point (Daneshvar et al., 2011; Kirkwood et al., 2006; Meehan et al., 2011). A force applied to an adult head will result in different effects compared to that of a child or adolescent (Halstead et al., 2010). That is, the cerebral effects of forces will be stage-dependent, at least up until an individual matures into adulthood (Kirkwood et al., 2006).

In a series of studies using adult anaesthetized Rhesus monkeys, Ommaya, Goldsmith, and Thibault (2002) sought to explore injury thresholds for brains of different masses. The researchers predicted that smaller brains would require more force than larger brains to cause brain injury (Ommaya et al., 2002). Results of three different experiments confirmed their hypothesis that larger brains are more vulnerable at lower levels of angular velocity and acceleration than smaller brains. Stated differently, it was found that higher levels of angular acceleration were required to produce a similar injury in smaller brains (Ommaya et al., 2002). These results may translate to brain injuries seen in adults versus children. That is, since a child has a smaller brain, a greater force and higher levels of angular velocity are required to produce a cerebral injury comparable to that of an adult (Ommaya et al., 2002). It is important to note that although a greater force is needed for an injury to occur in a pediatric brain, the overall response to this injury is less favorable in a developing brain (Kirkwood et al., 2006). The difference in outcome across pediatric and adult concussion will be highlighted in following sections.

In another study conducted by Munoz-Sanchez et al. (2005), the risk of intracranial injury after skull fracture was examined across patients of different age groups. Although the percentages of skull fractures in the adult and pediatric populations were similar, the relative risk of intracranial injury associated with skull fracture was significantly higher in adults (Munoz-Sanchez et al., 2005). That is, adults having experienced a skull fracture were at higher risk of intracranial injury than children with a skull fracture (Munoz-Sanchez et al., 2005). These findings suggest that it takes a greater force to produce clinical symptoms of concussion in children compared to adults (Halstead et al., 2010; Kirkwood et al., 2006; McCrory et al., 2004; Meehan et al., 2011). The exact reason for this difference is unknown, however, researchers speculate that the child's developing brain and skull are significant factors (Halstead et al., 2010).

Another factor hypothesized to influence head injury dynamics is an individual's musculoskeletal system (Kirkwood et al., 2006; Meehan et al., 2011). In general, children have musculoskeletal systems (i.e., neck and shoulder muscles) that are less developed than that of adults (Meehan et al., 2011). Due to the fact that less energy is able to be transferred from the head to the rest of the body after impact, in some instances children are at an increased risk for concussive injury (Kirkwood et al., 2006).

These findings emphasize the importance of accurately recognizing the signs and symptoms of a concussion in a pediatric population. If a child or adolescent presents with postconcussion symptoms after sustaining an impact to the head, it is probable that this force was substantial.

Pathophysiological response. Over the last decade, researchers have investigated the physiological changes following concussion (McCrea, 2008; McCrory et al., 2009; McCrory, Johnston, Mohtadi, & Meeuwisse, 2001). There have been various documented physiological changes in the brain following head injury. Some of these changes include diffuse injury to axons, neuronal cell loss, alterations in cerebral blood flow, and neurochemical, ionic, and metabolic changes (McCrory et al., 2001; Meehan et al., 2011). Findings from research on more severe brain injuries have suggested that the physiological response varies according to the age and development of the brain (Kirkwood et al., 2006). More specifically, in a prospective study examining diffuse brain swelling across adult and children patients, it was found that diffuse brain swelling occurred roughly twice as often in children than in adults (Aldrich et al., 1992). Although this study concerned more severe brain injury, there have been documented cases of diffuse cerebral swelling following concussive injury in children and adolescents which have resulted in increased intracranial pressure, brain herniation, and ultimately coma and death (McCrory et al., 2004; McCrory & Berkovic, 1998). Cerebral swelling following concussion has often been referred to as second impact syndrome (SIS). SIS is thought to occur when an individual who has sustained an initial head injury sustains a second head injury before symptoms associated with the first have fully cleared (McCrory & Berkovic, 1998). In SIS, it is postulated that a second impact causes cerebral vascular congestion resulting in increased intracranial pressure (McCrory & Berkovic, 1998). Although second impact syndrome is rare, the cases that have occurred have been predominantly in children and adolescents (Adler, 2011; McCrory et al., 2004; Meehan et al., 2011). These results suggest that the immaturity of the brain may be an apparent risk factor in developing second impact syndrome (Kirkwood et al., 2006; McCrory & Berkovic, 1998). Although it remains unknown what causes SIS to occur, the catastrophic outcomes of this injury demand rigorous management strategies for concussion, especially for children and adolescents (Adler, 2011).

Neurocognitive outcomes. A common misconception regarding recovery after brain insult is that a younger, more immature brain will be less susceptible to the effects of an injury (Kirkwood et al., 2006). It is often thought that since a young brain is more plastic, it can recover from the effects of a brain injury more quickly and with relative ease (Kirkwood et al., 2006). Unfortunately, research has not supported these commonly held beliefs. In fact, rigorous scientific studies looking at TBI in children have shown that the pediatric brain is arguably more susceptible to diffuse injury (Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2000; Schatz & Moser, 2011). More specifically, it has been found that the younger the child is at the time of injury, the poorer the functional outcome (Anderson et al., 2000). Some explanations put forth to explain these findings are: a) the child's neuronal networks are undergoing rapid growth and thus their brains are more susceptible to the effects of cerebral damage, b) the child has less well-developed skills and knowledge and thus the future acquisition of these abilities may be restricted, and c) an injury to a child's immature brain could interfere with its normal development, especially in regards to the neurobiological and neuroanatomical event sequences (Anderson et al., 2000; Kirkwood et al., 2006). Not only have these findings been discovered in children with moderate and severe TBI, but current research has suggested this may be true in cases of concussion as well (Field et al., 2003; Lovell & Fazio, 2008). A study conducted by

Field, Collins, Lovell, and Maroon (2003) evaluated the symptoms and neurocognitive recovery patterns for both college and high-school level athletes after concussive injury. Overall, it was found that the high-school athletes had slower acute recovery in comparison to the college athletes (Field et al., 2003). Furthermore, the high-school athletes showed memory impairments for up to seven days post injury whereas the college athlete's impairment resolved within 24 hours (Field et al., 2003). High-school athletes may experience a more prolonged recovery from concussion than college athletes (Field et al., 2003). While further research is still needed in this domain, these findings point to the fact that even with concussion, an immature brain may be more vulnerable to the effects of an injury.

Variables Related to Outcomes in Pediatric mTBI and Concussion

The research in this section reviews variables related to outcome after pediatric mTBI and concussion. Outcome research specifically related to pediatric concussion is lacking, therefore findings from pediatric mTBI literature are also reviewed because of the implications it has for sport concussion.

Pre-morbid considerations. It is widely documented that outcomes after mTBI and concussion can vary dramatically across children and adolescents (Stavinoha, Butcher, & Spurgin, 2011). While it is difficult to pinpoint the precise reasons for the variability in outcome after mild head injury, researchers suspect it has to do with a combination of injury characteristics and pre-injury factors (Satz, 2001; Stavinoha et al., 2011). Pre-injury factors include age, sex, cognitive and adaptive functioning, psychiatric functioning, and genetic make-up. Other pre-injury characteristics hypothesized to influence outcome include family environment and socioeconomic status (SES) (Stavinoha et al., 2011). At present, the majority of the research that has been conducted on pre-injury factors and outcomes pertains to populations with moderate and severe brain injury. There is a dearth of research that has specifically examined these factors in relation to outcome in pediatric mTBI and concussion populations. Recognizing how these factors can complicate or improve recovery would improve clinical care and help clinicians achieve the best possible outcomes after concussion (Stavinoha et al., 2011). The following section will address what is currently known about premorbid factors and outcome after mTBI and concussion in a pediatric population.

Age. Contrary to popular belief, the immature brain has been found to be more susceptible to traumatic injury, not more plastic (Ewing-Cobbs, Barnes, & Fletcher, 2003; Kirkwood et al., 2006; Stavinoha et al., 2011; Taylor & Alden, 1997). Different hypotheses to explain the increased vulnerability in children and adolescents have been proposed but research specifically looking at pediatric concussion is still in its infancy and many more studies are required to validate these assertions. One such hypothesis suggests that skills that are underdeveloped at the time of injury may be more vulnerable to disruption than those skills which have been mastered (Anderson et al., 2001; Kirkwood et al., 2006; Wrightson et al., 1995). For example, deficits in the development of language based skills (Anderson et al., 2001) and visual perception abilities (Wrightson et al., 1995) have been reported in preschool children who suffered a mild head injury. These findings suggest that if a mild brain injury occurs at a time when a particular skill is being developed, it may lead to a persisting deficit (Anderson et al., 2001; Ewing-Cobbs et al., 2003; Wrightson et al., 1995). Other hypotheses propose that a) mild head injury may interfere with neurobiological event sequences that are required for normal development in a developing brain; b) the brain structures responsible for skill acquisition may be directly affected by the injury; and c) recovery may be hindered due to the fact that a developing child has a smaller repertoire of skills to work from (Kirkwood et al., 2006; H. S. Levin, 2003). Whatever the reason, it is well-established that the developing brain is more susceptible to insult which can result in a protracted recovery after injury (Field et al., 2003; Kirkwood et al., 2006; Taylor & Alden, 1997).

Sex. At the present time, little is known about sex differences and outcome after concussion in a pediatric population. Most of the research that has been conducted on this topic has been done with adult populations in relation to moderate and severe TBI, not with mild TBI and concussion (Stavinoha et al., 2011). The research that has been done with moderate and severe injuries shows that there are significant differences between the sexes and across different domains (Stavinoha et al., 2011). While males have twice the risk of sustaining a traumatic brain injury than females, females have a mortality rate that is 1.28 times higher than males (Broshek et al., 2005; McKeever & Schatz, 2003). While females have been reported to be at greater risk for brain swelling, males show more serious and rapid neurodegeneration after traumatic brain injury (Balestreri, Steiner, & Czosnyka, 2003 ; Kupina, Detloff, Bobrowski, Snyder, & Hall, 2003; Stavinoha et al., 2011).

Studies on neurocognitive outcomes after moderate to severe traumatic brain injury also highlight differences across sex (Stavinoha et al., 2011). Reports have found males to have significantly impaired memory and processing speed in comparison to age-matched females (Donders & Hoffman, 2002; Donders & Nesbit-Greene, 2004). Differences in executive functioning have also been reported with females retaining better function after injury than males (Niemeier, Marwitz, Lesher, Walker, & Bushnik, 2007).

Although there is scant research examining differences in pediatric concussion outcomes between males and females, the research that has been conducted has reported significant findings. One study evaluating the influence of sex on neurocognitive performance and symptoms following sports related concussion in high school and collegiate athletes found that female athletes had a greater decline on measures of reaction time and they reported more post-concussion symptoms than males (Broshek et al., 2005). Additionally, females were found to be cognitively impaired approximately 1.7 times more frequently following concussion (i.e., 2-4 days following injury) than males (Broshek et al., 2005). Other research that has reported sex differences after concussion have found that females have a higher likelihood of post-concussion syndrome at one month (Bazarian et al., 1999), they have a greater incidence of depression (Fenton, McClelland, Montgomery, MacFlynn, & Rutherford, 1993) and overall more persisting symptoms one year post injury than males (Rutherford, Merrett, & McDonald, 1979). Although sex differences have been reported in mild, moderate, and severe traumatic brain injury, the findings are mixed. More research is needed to clarify how sex may impact outcome after mild brain injury and concussion (McCrory et al., 2009).

Cognitive and adaptive functioning. Recent attention has turned to premorbid cognitive factors when studying outcome and prognosis after concussion. In a large study that examined cognitive ability and the occurrence of post-concussive symptoms at three different time periods post injury, it was found that children with higher cognitive capacity showed less vulnerability to the effects of concussion (Fay et al., 2010). More specifically, children with higher cognitive ability reported significantly less post-concussive symptoms at one, three, and 12 months compared to children with comparable injuries but lower cognitive capacity (Fay et al., 2010). In another similar study, (Ponsford et al. (1999) found that 17% of the children enrolled in the study had parents/caregivers who continued to endorse a high level of symptoms and behavioral problems following concussion. Children with persisting problems were found to be more likely to have a history of previous head injury, learning challenges, premorbid stressors causing behavioral or emotional problems, and neurological or psychiatric problems (Ponsford et al., 1999). Finally, in a study looking at the relationship between concussion and neuropsychological performance in college football players, Collins et al., (1999) found that those athletes with a history of concussion and/or learning disability showed poorer performance on neuropsychological tests measuring executive functioning, speed of processing, memory and self-report of symptoms. The research findings highlighted above provide evidence that pre-existing cognitive or psychosocial difficulties can have significant effects on recovery and outcome after concussion. More emphasis should now focus on prevention and intervention for those children who have risk factors that can exacerbate deficits after concussion (Kirkwood et al., 2008).

Psychiatric functioning. The presence of psychiatric illness prior to mTBI may increase the likelihood of additional problems after injury (Massagli et al., 2004; Stavinoha et al., 2011). Research with adult populations has consistently demonstrated that pre-existing psychiatric illness affects neurocognitive outcomes on measures of intellectual functioning, verbal learning, verbal memory, processing speed, and executive function after mTBI (Mooney & Speed, 2001; Preece & Geffen, 2007; Stavinoha et al., 2011). In a pediatric population, researchers have found that both children with and without prior histories of psychiatric illness are at increased risk of developing psychiatric problems after mTBI, particularly hyperactivity (Massagli et al., 2004). More noteworthy is that prior history of psychiatric illness was found to be a significant independent risk factor for subsequent psychiatric illness after mTBI (Massagli et al., 2004).

While there are likely to be many different determinants of psychiatric problems after mTBI, more research is needed to elucidate the relationships among different factors (Massagli et al., 2004). In any case, it is important for clinicians to inquire about premorbid psychiatric illness when assessing, diagnosing, and managing children and adolescents with mTBI to ensure an effective treatment and intervention plan is employed (Massagli et al., 2004).

Genetics. An allele of the apolipoprotein (APOE) gene has been found to be linked to poorer outcomes following mild to severe brain injuries in adult populations (Moran et al., 2009; Zhou et al., 2008). This same gene has also been linked to negative outcomes after neurological insult such as stroke and cardiopulmonary arrest (Eichner et al., 2002) and an earlier onset of Alzheimer's disease (Kim, Basak, & Holtzman, 2009; Liberman, Stewart, Wesnes, & Troncoso, 2002; Stavinoha et al., 2011). To date, there has only been one study that has examined the role of the APOE gene in relation to outcomes after pediatric mild traumatic brain injury (Moran et al., 2009). Results of this study showed that those individuals with the APOE allele had a more severe early response to injury (Moran et al., 2009). However, contrary to prediction, an association between presence of the APOE allele and long term effects was not found (Moran et al., 2009). That is, children did not report more post-concussive symptoms or perform more poorly on neurocognitive testing than those children without the APOE allele (Moran et al., 2009). More research is needed to elucidate how the APOE allele and other genes are related to recovery and outcome after concussion in children and adolescents.

Environmental factors. Environmental factors that have been implicated in predicting outcome after traumatic brain injury include socioeconomic status (SES), home environment, and family stress (Stavinoha et al., 2011; Yeates et al., 1997). Demographic variables including ethnicity and SES have been found to account for a significant portion of the variability in cognitive performance on tests such as the Wechsler Intelligence Scale for Children (WISC) and the Children's Category Test following moderate and severe TBI (Donders & Nesbit-Greene, 2004). Other research looking at behavior and achievement outcomes in children after moderate and severe TBI have found that parental marital status and family environment are associated with recovery outcomes (Hawley, 2004; Taylor et al., 2002). Following TBI, children who come from high stress environments and who are socially disadvantaged demonstrate more behavioral issues and poorer academic performance compared to those that come from higher functioning families (Taylor et al., 2002). While the family environment is known to impact both cognitive and behavioral outcomes after TBI, Yeates et al. (1997) found the family environment to be more closely linked to behavioral outcomes than to cognitive outcomes. That is, whereas the family environment was found to account for 25% of the variance in behavioral outcome measures, it only accounted for 10% in cognitive outcome measures (Yeates et al., 1997).

While researchers hypothesized that similar findings would emerge in a mTBI population, results contrary to this have been found. In a study conducted by Yeates et al. (2012), the presence of post-concussive symptoms were found to be significantly greater in families with higher SES than in families with lower SES. Yeates et al. (2012) noted that these differences could be because families of higher SES may be more attentive to changes in their children's well-being, or that those families who face adversity may be less inclined to perceive symptoms after injury. To date there is no research examining cognitive and behavioral outcomes after pediatric concussion in relation to environmental factors. A clearer understanding of how the family and broader social environment impacts recovery and outcome after pediatric concussion warrants further study in this domain.

Acute Assessment of Concussion

Providing the best clinical care following pediatric concussion begins with the accurate assessment and diagnosis of this injury (Gioia et al., 2009). Over the last decade there has been an abundance of evaluation methods, assessment tools, and return-to-play guidelines to assist in assessing, diagnosing and managing concussion (Gioia et al., 2009; Piland, Motl, Ferrara, & Peterson, 2003). However, to date, few of these concussion evaluation methods and diagnostic tools have been empirically validated and, thus, may not be appropriate for use with pediatric populations (Gioia et al., 2009; Piland et al., 2003). Current standard of practice guidelines for the assessment and diagnosis of pediatric concussion have been outlined by the Concussion in Sport Group (CISG) and include: a) the evaluation of symptoms, b) neuroimaging, c) objective balance assessment and d) neuropsychological assessment (McCrory et al., 2009; McCrory et al., 2013). For children under the age of ten, different evaluation tools may be required however, for the purposes of this study, only those assessment methods listed above will be discussed.

Symptoms. Following a concussion, a youth athlete is likely to exhibit acute symptoms which may be somatic (e.g., headache), cognitive (e.g., inattention, forgetfulness, slowed processing, feeling “like in a fog”), and/or emotional (lability). They may also present with signs of concussion which may be physical (e.g., loss of consciousness, amnesia), behavioral changes (e.g., irritability, disinhibition), cognitive impairment (e.g., slowed reaction times), and sleep disturbance (e.g., drowsiness) (McCrory et al., 2009; Purcell & Carson, 2008; Yeates, 2010). The most common symptoms include headache and dizziness, with 86% of athletes describing post concussive headache after injury (Collins et al., 2003; Gioia et al., 2009; Hall, Hall, & Chapman, 2005; Meehan & Bachur, 2009). Although these symptoms are not specific to concussion, they have been reported to be more common and severe in children with injuries that involve the head (Barlow et al., 2010; Taylor et al., 2010; Yeates, 2010). The symptoms that manifest after concussion can be important indicators for determining injury severity and predicting recovery and outcome (Collins et al., 2003; Halstead et al., 2010; Lovell & Fazio, 2008). As a result, clinicians routinely use an athlete's report of symptoms to guide decision making in a medical setting. For example, symptoms such as prolonged loss of consciousness (LOC), seizure, neck pain, and amnesia can signal that more in depth medical attention and intervention (e.g., neuroimaging to rule out more serious intracranial injury) may be required (Collins et al., 2003; Guskiewicz, Weaver, Padua, & Garrett, 2000; Kelly, 2001; Thomas, 2011).

Research examining post-concussive symptoms over the last decade has sought to find a marker of injury severity to aid in the clinical assessment, diagnosis, and management of concussion (Collins et al., 2003; Collins et al., 2003). Collins et al. (2003), found that high-school and college athletes with retrograde amnesia had poorer clinical outcomes in relation to athletes with concussion that did not experience retrograde amnesia. More specifically, athletes showed higher symptom scores and more neurocognitive deficits two days post injury in comparison to athletes who sustained concussion but did not have retrograde amnesia. While amnesia was found to be a predictor of poor outcome in this particular study, LOC was not. In another study examining symptoms of concussion in high-school athletes, it was found that those who reported fogginess one week post injury experienced more concussion symptoms than those athletes who did not report fogginess (Iverson, Gaetz, Lovell, & Collins, 2004b). Furthermore, athletes with fogginess also showed poorer performance on measures testing memory functioning, processing speed, and reaction times (Iverson et al., 2004b). Overall, these research findings suggest that athletes who report fogginess after concussion may be more prone to have adverse effects and a slower recovery post injury (Halstead et al., 2010; Iverson et al., 2004b). However, even despite these findings, there isn't enough evidence at the moment to suggest that one symptom is better at predicting injury severity and outcome over another (McCrory et al., 2009; McCrory et al., 2013). The most recent consensus statement for concussion management in sport suggests that the nature, burden, and duration of post-concussive symptoms seem to be more indicative of injury severity than the presence of one particular symptom alone (McCrory et al., 2009; McCrory et al., 2013).

The majority of sport related concussions result in subtle symptoms which can make the assessment and diagnosis of this injury very difficult. One of the complexities in diagnosing a concussion is that similar symptoms can also arise from dehydration, over-training, lack of sleep, and/or illnesses such as anorexia nervosa, anemia, learning disabilities, and depression (Iverson, Brooks, Collins, & Lovell, 2006; Meehan & Bachur, 2009). As a result, not all athletes experiencing concussion symptoms have necessarily suffered this type of injury (Meehan & Bachur, 2009). Although there are inherent challenges in diagnosing concussion, it is especially important in a pediatric population to manage any suspected head injury conservatively (McCrory et al., 2009). That is, if one or more signs or symptoms are present, the athlete should be removed from their sport and the appropriate management strategies employed (McCrory et al., 2009).

Neuropsychological testing. Neuropsychological testing which evaluates memory recall, attention and concentration, inhibition, planning, visual tracking, reaction time, and speed of processing has proved to be a beneficial tool in the evaluation of pediatric concussion (Collie, Darby, & Maruff, 2001; Collins et al., 2003; Echemendia, Putukian, Mackin, Julian, & Shoss, 2001; McCrory et al., 2009). One of the primary benefits of neuropsychological testing is that it allows a clinician to evaluate objectively an individuals' cognitive function after injury (Echemendia et al., 2001). Athletes and, in particular, pediatric athletes have been known to underreport symptoms after sustaining concussion for fear of judgement and/or fear of removal from game play (Delaney, Lacroix, Leclerc, & Johnston, 2000; Lovell & Collins, 1998; Lovell et al., 2002; Van Kampen, Lovell, Pardini, Collins, & Fu, 2006). The underreporting of symptoms by young athletes could lead to a misdiagnosis or an early return to sport putting them at risk for further injury and deleterious consequences (Van Kampen et al., 2006).

There is an added value of neurocognitive testing measures for diagnosis and management of sports related concussion. In one study, high-school and college athletes were evaluated two days post-concussion with a symptom scale and a computerized neuropsychological test (Van Kampen et al., 2006). Results were compared to baseline scores. Overall, 64% of athletes were classified as *abnormal* using self-report of symptoms on a checklist. This figure increased to 83% when athletes were evaluated with the concussion symptom rating scale and a neurocognitive test (Van Kampen et al., 2006). These findings highlight the need for evaluation that goes beyond the self-report of symptoms. Athletes who are symptom free after concussion may still exhibit neurocognitive deficits, suggesting an incomplete recovery. It is not always possible for athletes to complete neurocognitive testing after concussion, therefore physicians and other medical personnel have been advised to be more cautious when returning a player back to sport based solely on the self-report of symptoms (Van Kampen et al., 2006).

Balance testing. Motor function abnormalities are commonly observed after concussion (Cavanaugh, Guskiewicz, & Stergiou, 2005; Guskiewicz, 2001; Mrazik et al., 2000). The assessment of postural stability has become another way for clinicians to objectively evaluate deficits after injury. Although postural instability is not always observed after concussion, in cases where it is, objective clinical tests such as the Balance Error Scoring System (BESS) have provided useful in determining readiness to return to play (Cavanaugh et al., 2005; McCrory et al., 2009). Postural stability deficits following concussion have been found to return to baseline values at approximately three to five days (McCrea et al., 2003; Riemann & Guskiewicz, 2000). The Concussion in Sport Group and the National Collegiate Athletic Association recommend using balance assessment measures routinely in the acute evaluation of concussion. These measures provide valuable information regarding the motor domain of neurological functioning and can aid clinicians in making diagnostic and management decisions (Cavanaugh et al., 2006).

Neuroimaging. The use of computed tomography (CT) and magnetic resonance imaging (MRI) in the assessment of concussion are generally restricted to specific cases where intracerebral structural lesions are suspected (McCrory et al., 2009). This is due to the fact that concussion is a functional injury rather than a structural injury and in most cases, imaging results are normal (Chen et al., 2004; Chen, Johnston, Collie, McCrory, & Ptito, 2007). Other imaging modalities such as functional MRI (fMRI) have been used in concussion research. Functional MRI is an imaging modality that has the capacity to examine the cellular activity within the brain and measure metabolic changes (Dahab & Bernhardt, 2011). Studies have found underlying changes in brain physiology that correlate to symptom severity and recovery after concussion (Chen et al., 2004; Chen et al., 2007; Chen, Kareken, Fastenau, Trexler, & Hutchins, 2003). In one study, it was found that the higher concussion symptom score after injury, the less brain activity in the prefrontal regions of the brain as seen on fMRI (Chen et al., 2007). This reduced brain activation seen on fMRI was found to resolve in conjunction with both post concussive symptoms and cognitive dysfunction (Chen et al., 2007). Another study found that concussed athletes with abnormal activation patterns seen on fMRI following injury took significantly longer to recover than those who did not have fMRI abnormalities after injury (Lovell et al., 2007). Imaging techniques such as fMRI have afforded clinicians and researchers a better understanding of the neuopathological changes following concussion and insight into how imaging can guide return to play decision making (Dahab & Bernhardt, 2011). However, much more research and investigation is needed to understand these changes in a pediatric population. Furthermore, until fMRI becomes more readily available and cost effective, this modality cannot be implemented as a standard assessment tool.

Management of Pediatric Concussion in Sport

The most current management guidelines used for concussion in sport were derived in 2012 by the CISG at the third international symposium. While panel members agreed that majority of concussions (80-90%) will resolve without complication within a seven to ten day time period, it was also recognized that in some cases, certain factors (i.e., age, history of previous concussion) may preclude a short recovery and demand more rigorous management strategies. However, for the majority of concussive injuries, management consists of complete physical and cognitive rest until concussion symptoms abate and then a graduated return-to-play protocol. This step-wise protocol consists of different exertional exercises in the following order:

a) no activity, complete rest,

b) light aerobic exercise such as walking or stationary cycling, no resistance training,

c) sport specific exercise- for example skating in hockey, running in soccer; progressive addition of resistance training at steps three or four,

d) non-contact training skills,

e) full contact training drills, and

f) game play (McCrory et al., 2009, p.437)

This step-wise protocol demands that an athlete must be asymptomatic before progressing to the next level. If post-concussion symptoms appear at any point during this process, the injured athlete must drop back to the previous asymptomatic level and rest for 24 hours before trying again (McCrory et al., 2013). After the step-wise process, medical clearance is required before an athlete is able to return back to play.

In certain circumstances additional management strategies may be required for concussive injury. The factors to consider when contemplating additional strategies include but are not restricted to a) the presence of specific symptoms (i.e., loss of consciousness > 1 minute), b) history of repeated concussions occurring with less impact force, c) age (i.e., child or adolescent), d) premorbidities (i.e., migraine, depression, learning disabilities, attention deficit hyperactivity disorder (ADHD), and e) participation in high risk sporting activities (McCrory et al., 2013). When these factors are present, a multidisciplinary team of professionals is recommended to guide management and investigations using neuropsychological testing, balance assessment, and neuroimaging. With the management of pediatric concussion, clinicians are advised to take a more conservative approach. Children and adolescents should never return to play on the same day as their injury and the stepwise return to play protocol may be drawn out to allow for more recovery time. For children under the age of ten, clinicians should use age appropriate symptom checklists and parents and teachers should be involved in the assessment and management process (Gioia, Schneider, Vaughan, & Isquith, 2009; Gioia et al., 2009; McCrory et al., 2009; McCrory et al., 2013).

Multiple concussions and cumulative effects. A large proportion of the research on concussion has investigated the immediate and short term outcomes of single concussions, however, it is well documented that many athletes sustain multiple concussions (Belanger, Spiegel, & Vanderploeg, 2010; Field et al., 2003; Iverson, Brooks, Lovell, & Collins, 2006; Lovell & Fazio, 2008; Wall et al., 2006). This is especially true for athletes that participate in high contact sports such as football, hockey, boxing, and soccer (Field et al., 2003; Lovell & Fazio, 2008). The possibility of long term effects after multiple concussions is a concern within the medical communities at large and has ignited a flurry of research (Wall et al., 2006). However, to date, findings are inconsistent in regards to the adverse long-term effects of two or more concussions (Belanger et al., 2010).

Cognitive outcomes after multiple concussions in high school athletes have reported cumulative effects (Guskiewicz et al., 2003; Iverson, Gaetz, Lovell, & Collins, 2004a; Moser & Schatz, 2002; Moser et al., 2005; Wall et al., 2006). One of these studies, conducted by Iverson, Gaetz, Lovell and Collins (2004a) examined the cumulative effects in a group of amateur athletes with a history of multiple concussions. Athletes with a history of three or more concussions were matched to athletes with no previous concussions and administered a computerized neuropsychological test battery (ImPACT) (Iverson et al., 2004a). The athletes completed ImPACT prior to the start of their competitive seasons and again at five days post injury (Iverson et al., 2004a). Results showed that athletes with a history of multiple concussions reported more symptoms overall at baseline than their non-concussed peers (Iverson et al., 2004a). Furthermore, at post-injury athletes with a history of multiple concussions were 7.7 times more probable to drop in memory performance than athletes with no history of concussion (Iverson et al., 2004a).

In another study evaluating high school students with a history of multiple concussions, prolonged neuropsychological effects were also found (Moser et al., 2005). Athletes suffering from recent concussions showed impaired performance on tests of attention, concentration, processing speed and mental flexibility. However, the most notable finding was that athletes with a history of two or more concussions who were symptom free at the time of the testing performed at the same level as those athletes who were recently concussed. These results highlight the fact that components of an individual’s cognition (sustained attention and cognitive flexibility) may be affected by a mild head injury long after the initial insult (Moser et al., 2005).

The research looking at cumulative effects in concussion has produced mixed results over the last decade. While some research has demonstrated cumulative effects related to cognitive functioning in youth athletes with a history of multiple concussion (Iverson et al., 2004a; Moser & Schatz, 2002; Moser et al., 2005; Wall et al., 2006), other research has not (Belanger et al., 2010; Iverson, Brooks, Lovell et al., 2006; Macciocchi, Barth, Littlefield, & Cantu, 2001). However, it should be noted that most of the research looking at cumulative effects of concussion has focused on cognitive functioning. To date, there is scant research looking at the cumulative effects of multiple concussions in regards to emotional and behavioral functioning of youth athletes (Schatz, Moser, Covassin, & Karpf, 2011). It is well documented that some athletes experience significant emotional and behavioral effects following concussion (Bloom et al., 2001; Massagli et al., 2004; McKinlay et al., 2002; McKinlay et al., 2009; Segalowitz & Lawson, 1995). However, it is not known whether there is a cumulative effect of emotional and behavioral symptomatology in youth athletes. Until the research is able to elucidate the long-term cumulative effects of multiple concussions in youth athletes, these injuries should be taken seriously and treated with utmost care and concern.

The Long-Term Impact of mTBI and Concussion

Long-term effects including psychological, education, and health related complaints have been reported following mTBI in children and adolescents (Barlow et al., 2010; McKinlay et al., 2009; Overweg-Plandsoen et al., 1999; Segalowitz & Lawson, 1995; Taylor et al., 2010). Some researchers have examined psychological functioning across several different domains (Anderson et al., 2001; Andrews, Rose, & Johnson, 1998; Bloom et al., 2001; Casey, Ludwig, & McCormick, 1986; Colantonio, Dawson, & McLellan, 1998; Greenspan & MacKenzie, 1994; Max, Lindgren, Knutson et al., 1997; McKinlay et al., 2002; McKinlay et al., 2009; Segalowitz & Lawson, 1995)), whereas other researchers have focused their efforts specifically in one or two areas (e.g., hyperactivity, anxiety, depression) (Levin et al., 2007; Massagli et al., 2004)). Research that has found psychological problems after mTBI and concussion have reported increased behavioral difficulties (Andrews et al., 1998; Casey et al., 1986; Greenspan & MacKenzie, 1994), such as hyperactivity (Bloom et al., 2001; Greenspan & MacKenzie, 1994; Levin et al., 2007; Massagli et al., 2004; McKinlay et al., 2002; Segalowitz & Lawson, 1995), aggressive and antisocial behaviors (Andrews et al., 1998; Max, Lindgren, Knutson et al., 1997; McKinlay et al., 2002; McKinlay et al., 2002), discipline problems (Casey et al., 1986;

McKinlay et al., 2002; McKinlay et al., 2009), and sleep disturbances (Casey et al., 1986; Segalowitz & Lawson, 1995) . Mental health has also been reported as an area of concern, with mild head injury patients reporting overall lower self-esteem and adaptive functioning, (Andrews et al., 1998; Colantonio et al., 1998), and higher levels of loneliness (Andrews et al., 1998), anxiety (Mittenberg et al., 1997), and depression (Bloom et al., 2001; Massagli et al., 2004; Segalowitz & Lawson, 1995). However, in the extant literature, there are also studies that suggest children recover after mTBI with no long term effects on cognitive functioning (Bijur et al., 1996; Ponsford et al., 1999), school performance (Light et al., 1998), and behavioral development (Barker-Collo, 2007; Carroll, Cassidy, Peloso et al., 2004; Fletcher, Ewing-Cobbs, Miner, Levin, & Eisenberg, 1990; Fletcher et al., 1996; Kinsella, Ong, Murtagh, Prior, & Sawyer, 1999; Knights et al., 1991; Light et al., 1998). Overall, the research in this domain has produced mixed findings. There continues to be uncertainty about the long term effects of pediatric mTBI and what factors contribute to adverse outcomes.

Literature examining on-going effects after mTBI and concussion is controversial. Although previous research has attempted to quantify social, emotional, and behavioral outcomes after mTBI and concussion in childhood and adolescence, the methodological rigor of these studies varies dramatically. Injury definitions, inclusion of control groups, longitudinal follow-up, sample sizes, standardized tests, and pre-injury risk factors are important considerations when evaluating studies on this topic. Many of the studies examining long term outcomes after mTBI have concentrated their efforts on aspects of cognition (e.g., attention, memory, and executive function). Those studies that have investigated longer term psychosocial outcomes show substantial variability in their quality. As a result, there is significant discrepancy across studies, making it difficult to draw firm conclusions about long term deficits of mTBI and concussion. Due to the fact that there is no research that has examined the long-term psychosocial impact of sports related concussion using the diagnostic criteria set out by the CISG, literature examining outcomes associated with mTBI will be reviewed below. Although more research is needed to explore psychosocial outcomes after sport concussion explicitly, the mTBI research has applicability since concussion was previously considered to be a subset of mTBI.

Adverse Psychosocial Outcomes

Psychiatric. Hyperactivity and conduct disordered behavior was found to be an adverse psychosocial outcome in a study conducted by McKinlay et al. (2002) in which they examined mild head injury in children under the age of ten. This prospective, longitudinal study followed a birth cohort of children and tracked cases of mild head injury. Groups were separated according to medical attention (i.e., outpatient medical attention or inpatient observation) required by each child. Injured children were compared to non-injured children of the birth cohort on measures of psychosocial, academic, and cognitive functioning. Overall, results from this study showed that children who had a mild head injury requiring temporary hospitalization between the ages of zero and ten years old had increased hyperactivity/inattention and conduct disordered behavior at 10-13 years of age, as rated by mothers and teachers.

In another effort to further understand the long term psychosocial outcomes following childhood MTBI, McKinlay et al. (2009) followed another birth cohort of children who received a MTBI prior to the age of five. The children were evaluated at yearly intervals for 16 years (McKinlay et al., 2009). Information was collected on the children's pre-morbid and post-injury functioning with the use of self-report measures, parental interviews, teacher reports, standardized testing as well as from medical records (McKinlay et al., 2009). The children were evaluated for psychiatric symptoms relating to attention deficit/hyperactivity disorder, conduct disorder, anxiety disorder, mood disorder, as well as alcohol or illicit substance abuse/dependence. Overall, it was found that the more severe cases of MTBI occurring during preschool were associated with an increased prevalence of psychiatric symptoms in adolescence. The psychiatric symptoms were congruent with diagnoses of ADHD, CD/ODD, substance abuse, and mood disorder.

Levin et al. (2007) examined symptoms of inattention and hyperactivity over two years in children five to fifteen who sustained a mild-severe TBI. Psychiatric symptoms were evaluated using the Schedule for Affective Disorders and Schizophrenia for School-Age Children, Present and Lifetime Version. Data collection occurred immediately following the injury as well as at six months, and one and two years post injury. Results showed that 23% of study participants met diagnostic criteria for pre-injury Attention Deficit/Hyperactivity Disorder (ADHD). Additionally, 19.2% met diagnostic criteria for ADHD within two years of their injury.

Lifetime and/or novel psychiatric disorders were assessed by Bloom et al. (Bloom et al., 2001) in a group of 46 children and adolescents one year after TBI. Information was gathered through the use of semi-structured interviews and standardized questionnaires. Results showed that 60% of the sample developed one or more novel psychiatric disorders following TBI. Of the novel psychiatric disorders, ADHD and depression were the most common. In participants with diagnosed ADHD, symptoms were persistent after TBI. Conversely, in those with major depressive disorder, depressive disorder NOS, and dysthymia following TBI, 60% of cases resolved prior to the study diagnostic interview at one year post injury. Results also showed that children with mTBI did not differ from those with moderate and severe TBI. Bloom et al. (2001) stressed the importance of timely identification, monitoring, and treatment for children and adolescents after TBI as persistent and temporary psychiatric effects can occur and negatively impact day to day functioning.

Massagli et al. (2004) sought to examine the incidence of psychiatric illness in children and youth in each of the first three years following injury. They used computerized records of patients that included data on all inpatient and outpatient visits, diagnoses, prescriptions, and demographic information. Participants were 15 years old or under who attained a diagnosis of mTBI defined according to the International Classification of Diseases in an emergency department, hospital or outpatient clinic. Control participants (without mTBI) were selected at random from the computerized records and matched on sex, age, and enrollment date. These records were then reviewed to determine any psychiatric diagnoses over six month intervals in the year prior to the incident as well as the following three years. Psychiatric illness was defined if the patient fulfilled any one criterion; a) had a psychiatric diagnosis; b) prescription for a psychiatric medication or; c) used psychiatric services. Overall, it was found that 26% of mTBI patients (with no prior history of psychiatric illness) showed evidence of a psychiatric illness in comparison to 16% of healthy controls in the first three years after mTBI (Massagli et al., 2004). In addition, the incidence was found to be the highest at one year post injury. It was also determined that the incidence of hyperactivity was 3% in those with no prior psychiatric history following injury in the first year (Massagli et al., 2004).

Other outcome studies have reported novel psychiatric disorders following TBI (Max, Lindgren, Knutson et al., 1997; Max, Lindgren, Robin et al., 1997; Max, Robin et al., 1997; Max et al., 1998). However, a significant correlation between family psychiatric history and family function and the development of a psychiatric disorder after TBI has also been reported (Max, Lindgren, Knutson et al., 1997). While the authors conclude that psychiatric attention is needed following pediatric TBI, there is uncertainty about whether the psychopathology stems directly from the brain trauma itself (Max, Lindgren, Knutson et al., 1997).

Behavior and functional outcomes. In addition to psychiatric outcomes following pediatric mTBI, functional and behavioral outcomes have also been evaluated (Anderson, Morse, Catroppa, Haritou, & Rosenfeld, 2004; Andrews et al., 1998; Andrews et al., 1998; Casey et al., 1986; Colantonio et al., 1998; Greenspan & MacKenzie, 1994).

In 1986, Casey, Ludwig, and McCormick assessed the physical and functional morbidity following acute minor head trauma in 204 children. Participants were children six months to 14 years of age who presented to the emergency department following minor head trauma. In this study, head trauma was defined as minor if there were no signs and symptoms of concussion (i.e., altered state of consciousness, memory loss, or neurological impairment). Children with skull fracture, loss of consciousness, suspected child abuse, or hospital admission were excluded. Information was collected at the time of hospital presentation including details of the injury and socio-demographic information (e.g., parental age and education). One month following the injury, parents were interviewed using questionnaires to assess for the child's physical health status, social or functional limitations, and behavioral problems. Results of the measures were compared to a group of healthy children. The mean age of participants in this study was 4.4 years. Results showed that physical symptoms related to head trauma were rare and overall physical health was comparable between head trauma patients and healthy children. However, even though physical morbidity in children with head trauma was minimal, parents reported substantial functional morbidity (i.e., limitations in play and other daily activities). Specifically, school absenteeism rates were high at 29% and 40% in pre-schoolers and children five to 14 year olds, respectively. In a healthy population, absenteeism rates range from 10% to 19% for grade schools and middle schools, respectively. Furthermore, head trauma participants showed significantly more behavior problems (e.g., sleep disturbances, moodiness, and discipline problems, specific fears) one month following injury than a group of normal, healthy children. Casey, et al. (1986) concluded that regardless of causality, children with minor head trauma are at risk for functional morbidity after injury.

Greenspan and MacKenzie (1994) also examined functional outcome after pediatric head injury. They conducted one year follow-up evaluations on 95 children after being hospitalized for head injury. Information was collected in regards to children's pre-injury and current health status, as well as the family's economic and social resources for the year following the TBI. Health status was determined according to signs and symptoms, physical health, behavior, and enrollment in a special education program. The findings of the study showed that study participants, regardless of head injury severity (i.e., mild-severe), were more likely than children from the general population to have limitations in physical health, behavioral problems, and to be enrolled in special education classes. However, when the authors examined outcome data after controlling for head injury severity, it was found that worse outcomes were associated with poverty, preinjury chronic health problems, and lower extremity injuries. This research echoes the need for appropriate assessment and intervention following TBI. However, Greenspan & MacKenzie (1994) highlight the fact that head trauma itself may not fully account for functional impairment following injury.

Pediatric mental health and psychosocial adjustment after TBI has also been explored (Andrews et al., 1998; Colantonio et al., 1998). A study by Andrews, Rose, and Johnson (1998), examined the social and behavioral effects of TBI using measures to explore self-esteem, loneliness, as well as, adaptive, maladaptive, and aggressive/antisocial behaviors. Participants were 54 children ages six to 17 years who received a primary diagnosis of TBI and were admitted to the department of neurosurgery. Participants were classified according to the severity of their injury. They were interviewed and asked to complete standardized behavior questionnaires. Results of the TBI group were compared to a group of 27 healthy controls recruited from local schools. Overall, it was found that children with TBI had significantly higher levels of loneliness, maladaptive behavior, and lower levels of self-esteem and adaptive behavior compared to healthy controls. No differences were found across the three TBI severity groups (i.e., mild, moderate, and severe).

In a similar study, Colantonio, Dawson, and McLellan (1998) examined quality of life, impairment, disability, and handicap after head injury in a group of adolescents and young adults (i.e., 15-19 years old) five years after sustaining a head injury. Five dimensions of quality of life were evaluated including, physical health, mental health, everyday functioning in social and in role activities, and general perception of well-being. Participants with TBI scored significantly lower than healthy controls on all dimensions of quality of life with the exception of pain for which there were no significant differences between mild, moderate, and severe TBI groups. Colantonio, Dawson, and McLellan (1998) concluded that young adults can have disabling symptoms many years after head injury, even if the injury is considered mild.

Limitations of psychosocial outcome research. Although research has explored the long-term psychosocial impact of mTBI and concussion, the methodological quality of these studies varies (Carroll, Cassidy, Peloso et al., 2004; A. McKinlay, 2010; P. Satz et al., 1997). The inconsistent injury definitions, inclusion of control groups, longitudinal follow-up times, sample sizes, age ranges, outcome measures, and pre-morbid functioning all contribute to conflicting results (Carroll, Cassidy, Peloso et al., 2004; McKinlay, 2010; Satz et al., 1997).

Many of the studies examining psychosocial outcome of mild head injury employ different injury classification systems. That is, the definition and criteria for mTBI varies. For example, under the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM), mTBI includes: fracture of the vault or base of the skull, multiple fractures of the skull, and intracranial injury, including concussion, contusion, lacerations, and hemorrhage. However, mTBI by the World Health Organization (WHO) includes: a) confusion or disorientation, loss of consciousness (LOC) for 30 minutes or less, posttraumatic amnesia for less than 24 hours, and/or other transient neurological abnormalities such as focal signs, seizure and intracranial lesion not requiring surgery; and b) Glasgow Coma Scale of 13-15 after 30 minutes post-injury or later upon presentation for healthcare. In some research, inclusion criteria required altered consciousness (e.g., drowsiness, disorientation). In other research, criteria for mTBI included children with skull fracture. In others, diagnostic criteria were not clearly specified (Bloom et al., 2001; Casey et al., 1986; Greenspan & MacKenzie, 1994; Segalowitz & Lawson, 1995). Without consistent diagnostic criteria, the range of injury severity across studies could be significant. It is likely that some children in these research studies sustained injuries on the more severe end of the mild spectrum, making it difficult to compare findings across studies.

There is no research that has examined the long-term psychosocial impact of sports related concussion strictly using the diagnostic criteria set out by the CISG.

Sample size, age range, and longitudinal follow up time also varied dramatically in the studies reviewed. There were a considerable number of studies with a small sample size (i.e., less than 20 participants) (Andrews et al., 1998; Bloom et al., 2001; Colantonio et al., 1998; Max, Lindgren, Knutson et al., 1997). In research with sample sizes under 20, the statistical power is questionable. Although some studies had larger overall sample sizes, they became less robust when participants were separated into groups according to injury severity (i.e., mild, moderate, and severe) (Bloom et al., 2001; Colantonio et al., 1998; Max, Lindgren, Knutson et al., 1997). Longitudinal follow up time varied across studies, with few reporting more than a 24 month period (Andrews et al., 1998; Bloom et al., 2001; Casey et al., 1986; Greenspan & MacKenzie, 1994; Levin et al., 2007; McKinlay et al., 2002). Finally, subject ages within studies were widespread, often including children and adolescents zero to 15 years of age (Andrews et al., 1998; Bloom et al., 2001; Casey et al., 1986; Casey et al., 1986; Greenspan & MacKenzie, 1994; Levin et al., 2007; Massagli et al., 2004; Max, Lindgren, Knutson et al., 1997; McKinlay et al., 2002; Segalowitz & Lawson, 1995). Age is an important factor to account for as skills are acquired at different periods of development. The long term effects of mTBI and concussion on a developing brain are known to differ according to the developmental stage of a child (Anderson et al., 2000; Kirkwood et al., 2006). Few studies have looked at long term outcomes of mTBI and concussion across specific developmental periods.

Many of the studies in this domain lack appropriate control groups (Bloom et al., 2001; Casey et al., 1986; Colantonio et al., 1998; Greenspan & MacKenzie, 1994; Max, Lindgren, Knutson et al., 1997). Satz (1997) emphasized the need for research in this area to employ two separate control groups. The first control group is a non-injury (i.e., healthy) control group and the second control groups is an other-injury (e.g., orthopedic injury) control group (Satz et al., 1997). It has been suggested that children exposed to injury may be different from healthy controls (Satz et al., 1997) . Therefore, in order to determine the effects of pediatric mTBI on a child's functioning, the use of two separate controls groups is paramount (Satz et al., 1997). There are few studies to date that have followed these guidelines. As a result, it is difficult to draw conclusions and compare findings across studies. In the studies that have utilized two separate control groups, there is controversy over who should be considered a suitable control (McKinlay, 2010). For example, it has been argued that children with burns, lacerations, and fractures experience significantly more trauma and pain than children with mTBI and are not fit to be used as controls (McKinlay, 2010). There is considerable variability across studies in both the inclusion of controls groups and the type of control groups employed.

Few studies have evaluated the relation between pre-injury levels of functioning and outcome after mTBI (Andrews et al., 1998; Bloom et al., 2001; Casey et al., 1986). This is partly due to the fact that many of the studies are retrospective, making the information difficult or impossible to collect. The studies that report pre-injury data often have parents fill out questionnaires that retrospectively rate their child's behavior and level of functioning prior to injury (Colantonio et al., 1998; Greenspan & MacKenzie, 1994; Levin et al., 2007; Massagli et al., 2004; Max, Lindgren, Knutson et al., 1997; McKinlay et al., 2002; McKinlay et al., 2009). However, it is likely that this information is biased by the child's post-injury behavior (McKinlay, 2010). It is also difficult to determine the accuracy of the information when parents are completing questionnaires following a stressful event (McKinlay, 2010). To date, there are no studies that have prospectively collected pre-injury information looking at the social, emotional, and behavioral functioning of children and adolescents.

Finally, many of the studies looking at the social, emotional, and behavioral functioning of children and adolescents after mTBI use different outcome measures (McKinlay, 2010). This makes it difficult to compare findings across studies. Some studies use standardized rating scales and questionnaires, however, many do not. Even those that do employ standardized measures, their sensitivity and specificity to detect subtle changes after mTBI and concussion is unknown (Fletcher et al., 1996). There has been no research to determine which measures are the most appropriate to examine the social, emotional, and behavioral functioning after mTBI and concussion in children and adolescents.

Summary

Today, more than ever, children and adolescents are taking part in recreational and competitive sports leading to an increase in the prevalence of pediatric concussion (Kirkwood et al., 2006; Metzl, 2006). In Canada, a large percentage of young athletes are involved in ice hockey where high speeds, bodily contact, and frequent collisions inevitably lead to a significant proportion of injuries, including concussion (Emery & Meeuwisse, 2006; Emery et al., 2010). Although concussion in sport has received increased awareness over the last decade as research continues to draw attention to the major health implications and the long ranging effects of this injury in professional athletes, there is a paucity of research looking at this issue in youth (Solomon et al., 2006; Stern et al., 2011).

Research has revealed that the pediatric brain is more susceptible to the effects of concussion, responds differently to injury and takes longer to recover in comparison to an adult brain (Field et al., 2003; Gordon, 2006; Purcell, 2009). Research has also alluded to the fact that concussion can have adverse long term consequences, affecting a child or adolescent's cognitive, social and emotional development (McKinlay et al., 2002; McKinlay et al., 2009; Yeates, 2010). These long term effects can have the potential to significantly impact an individual's functioning at home, in the classroom, and in a social setting (McKinlay et al., 2002; Yeates, 2010). Furthermore, with such a high occurrence of concussion, even if a small proportion of children and adolescents face on-going negative outcomes after injury, this represents a significant public health concern (McKinlay et al., 2002; McKinlay, 2010; Yeates, 2010). More research is clearly warranted in order to clarify the psychosocial outcomes of sport related concussion in an adolescent population (Taylor et al., 2010).

Study Hypotheses

Research examining adverse outcomes after mTBI in children and adolescents has produced mixed results (Lee, 2007). While some studies have noted significant changes in emotional, behavioral and cognitive functioning of children and adolescents following concussion, others have not. The controversy regarding academic, behavioral and emotional sequelae of this injury in youth, reinforce the need for more research to be conducted. Based on the current review of the literature, it is hypothesized that there will be changes on the scales of the Behavior Assessment System for Children – Second Edition (BASC-2) (Reynolds & Kamphaus, 2004): that measure anxiety, attention, depression, and difficulties in school. These changes are predicted to be both a) significantly different from baseline scores at seven to ten days and three months post-injury and b) significantly different from the changes seen in a group of healthy controls. The changes are predicted to occur in the following composites and their subsequent scales of the self-report BASC-2 (Reynolds & Kamphaus, 2004): School Problems (attitude to school and attitude to teachers), Internalizing Problems (social stress, anxiety, depression, sense of inadequacy, somatization), Inattention/Hyperactivity (attention problems and hyperactivity), and Personal Adjustment (self-esteem).

Chapter 3: Methods

This chapter is organized into nine sections. First, the specific study objectives are outlined, followed by the study design, and a description of the participants. The instruments used in this research project are then reviewed as well as the process undertaken for injury assessment. The Behavioral Assessment Scale for Children- Second Edition (BASC-2) is described including a description of the scales, length of administration, validity scales, as well as information regarding the tool's reliability and validity. The chapter also reviews the process of data collection and the statistical analyses employed. The chapter concludes with a description of the study ethics obtained.

The current study is one component of a larger prospective multi-center cohort study of concussion in youth hockey players. The study was conducted in both Calgary and Edmonton, Alberta with 44 hockey teams enrolled. All players from each team were evaluated using a pre-season questionnaire and the BASC-2 prior to the start of their competitive seasons. Players were re-administered the BASC-2 following injury at seven to ten days post injury as well at three months post injury. An injury assessment was also completed by the hockey team trainer at the time of injury. In total, injured players and their matched controls were assessed at three different time periods (baseline, seven to ten days post injury, and three months post injury).

As stated in Chapter One, the specific objectives for the current study are:

Specific Objectives

1. To assess the differences in the changes on all the composite scores of the self-report version of the BASC-2, from baseline to seven to ten days and three months between

the group of ice hockey players who were concussed and a group of matched non-concussed controls.

2. To assess the differences in the changes on all the sub-scale scores of the self-report version of the BASC-2, from baseline to seven to ten days and three months following concussion between the ice hockey players who were concussed and the group of healthy controls.

3. To assess for statistically meaningful change at the individual level across the composite and sub-scales of the BASC-2 from baseline to seven to ten days post injury for the group of concussed and non-concussed athletes.

4. To assess for statistically meaningful change at the individual level across the composite and sub-scales of the BASC-2 from baseline to three months post injury for the group of concussed and non-concussed athletes

Study Design and Participants

A prospective cohort study design was used. The participants included male athletes from AA and AAA Bantam, Minor Midget, and Midget hockey leagues in Calgary and Edmonton, Alberta. Bantam players were 13 or 14 years old, Minor Midget players were 15 years old, and Midget players were 16 or-17 years old. Criteria for study inclusion included:

a) participation in the 2011-2012 hockey season,

b) agreement by individual player and a parent/guardian to informed consent,

c) agreement of the team coach to participate in the study, and

d) agreement by the team therapist to collect information about individual player participation and injury throughout the season

Exclusion criteria included:

a) developmental delay,

b) unable to participate at the beginning of the season

c) cognitive impairment (mild to moderate mental retardation),

d) any diagnosed medical condition, and

e) diagnosed concussion 30 days prior to the study start date

The control participants were randomly selected from the group of athletes who completed baseline testing but who did not sustain any injuries to the head. Control participants were matched to injured players based on team enrollment. Therefore, the matching variable included team, level of participation, and age. These matching variables were chosen so that the common characteristics found in athletes such as competitiveness and desire to play, which could influence a participants' approach to completing medical questionnaires, were controlled for. One control was matched to each concussed participant for a total of 110 male controls. The abovementioned study exclusion criteria were also in effect for all control participants. The control participants completed the baseline and follow-up testing in the same manner and at the same time intervals as the concussed participants.

Instruments

Three instruments were administered in this study. These included the Preseason Questionnaire, Injury Assessment, and the BASC-2.

Preseason Questionnaire

A preseason medical questionnaire (PQ) was used to obtain information about each player on each team (see Appendix D). Demographic information collected included age, birthdate, sex, address, telephone number, and city of residence. Information collected related to playing hockey included weight, height, dominant hand, division of hockey, years of hockey played, position played, safety equipment worn, and previous injuries and medical history. Additionally, information regarding previous psychological diagnoses was collected including a) mental retardation, b) learning disorder, c) communication disorder, d) pervasive developmental disorder, e) attention-deficit/hyperactivity disorder, f) disruptive behaviour disorders, g) mood disorders (e.g., depression & bi-polar disorder) and, h) anxiety disorders.

Injury Assessment

Information regarding injuries sustained during play (e.g., games or practices) was documented by the team therapist. Team therapists were in charge of identifying players with suspected concussion and removing them from play. Players with suspected concussion were referred to a sports medicine physician and seen within one week of the injury. Players injured in Calgary were referred to the University of Calgary Sport Medicine Centre and assessed by either: Dr. Brian Benson, Dr. Willem Meeuwisse, or Dr. Kelly Brett. Players injured in Edmonton were referred to the University of Alberta Glen Sather Sport Medicine Clinic and assessed by Dr. Connie Lebrun. Each physician completed a diagnosis and treatment plan form including the expected duration of treatment and whether or not the player was given clearance to return to sport. Additionally, team therapists completed an injury report form (IRF) following an injury to specify further details. This information included injury status (e.g., new or recurrence), how the injury occurred (e.g., sudden onset with contact, sudden onset with no contact, gradual onset, overuse, or unknown), when the injury occurred (e.g., game, practice, other team conditioning), position played at the time of injury (e.g., forward center, forward wing, defense, goalie), whether the player returned to the same game or practice, the events surrounding the injury, the cause of the injury (e.g., body check, other intentional contact, contact with the environment), protective gear worn at the time of the injury (e.g., mouth guard, helmet, brace, tape), injury location, and injury type (e.g., bruise, burn, cut). Following the complete resolution of the injury, the team therapist also indicated: the total number of days the player was unable to participate in daily activities, hockey, and other sports; the contact the player had with health care professionals (e.g., physician, physiotherapist, massage therapist, dentist); treatment received (e.g., x-rays, first aid, MRI/CT, cast, brace etc.); and information regarding return to play.

Follow-up evaluations with the sport medicine physicians were also scheduled at approximately seven days and three months from the initial evaluation. Players completed the paper-and-pencil version of the BASC-2 at these times. Additional follow-up with the sport medicine physician was scheduled when it was considered necessary. At the time of the initial evaluation, a non-concussed teammate of the injured player was randomly selected to act as a control. A teammate was selected as a control so that the variables of age, sex, and exposure were closely matched. The non-concussed control completed the same test procedures as their concussed counterpart.

BASC-2

The Behavior Assessment System for Children – Second Edition (BASC-2) was administered to assess the levels of depression, anxiety, hyperactivity, learning problems, and attention problems of the players at baseline as well as concussed players and their matched control at seven to ten days following concussion and three months following concussion. The BASC-2 is a norm-referenced diagnostic tool designed to assess the behavior and self-perceptions of children and young adults ages 2 to 25 years (Reynolds & Kamphaus, 2004). It is one of the most widely used behaviour rating scales for children and youth. The BASC-2 Self-Report of Personality (SRP) for ages 12 – 21 has 174 items some of which are rated with a "yes" or "no" response and some of which are rated on a scale from "Never" to "Almost Always". The BASC-2 self-report form for adolescents has 5 composite index scores (school problems, internalizing problems, inattention/hyperactivity, emotional symptoms index, personal adjustment) and 14 primary scale scores. There are three report forms including a self-rating scale, a parent rating scale, and a teacher rating scale. The BASC-2 also includes three validity scales that are sensitive to positive or negative response sets by raters (Gladman & Lancaster, 2003; Reynolds & Kamphaus, 2004). There is an F or "fake bad" index which is contained within the SRP (Gladman & Lancaster, 2003; Reynolds & Kamphaus, 2004). This scale assesses for excessively negative responses (Gladman & Lancaster, 2003; Reynolds & Kamphaus, 2004). In cases where this scale is high, either the child under evaluation has very maladaptive behavior or the child was rated more negatively than they should have been (Gladman & Lancaster, 2003; Reynolds & Kamphaus, 2004). Another validity scale specific to the SRP is the L or the "fake good" index (Gladman & Lancaster, 2003; Reynolds & Kamphaus, 2004). This scale measures extremely positive response sets and may reflect a lack of insight, naivete or lack of comprehension of the question (Gladman & Lancaster, 2003; Reynolds & Kamphaus, 2004). The third and final validity scale is the V index which is a general validity check for carelessness, lack of comprehension, or compliance. The validity scales of the BASC-2 are particularly important to ensure that the child being assessed and their caregiver have responded to the questions appropriately. The validity scales allow for a clinician to interpret results with confidence.

The BASC-2 questionnaire takes from 10 to 15 minutes to complete (Reynolds & Kamphaus, 2004). The norms for the BASC-2 were developed from a normative sample of approximately 4, 800 participants. Normative information is available for gender, age, and grade.

The BASC-2 SRP shows internal consistency reliabilities using general norm groups in the middle 0.90s for the Internalizing Problems composite and the Emotional Symptoms Index and in the middle to upper 0.80s for the School Problems, Inattention/Hyperactivity, and Personal Adjustment composites. Reliabilities of the subscales of the BASC-2 are in the middle to upper 0.80s for Attitude to School, Atypicality, Social Stress, Anxiety, and Depression. The remaining subscales have reliabilities in the middle 0.70s to lower 0.80s. Test-retest reliability for the BASC-2 SRP are in the upper 0.70s to low 0.80s for the composite scales. For the subscales, test-retest reliabilities coefficients range from 0.61-0.84. Attitude to School, Depression, and Attention Problems showing the highest test re-test reliability for the adolescent SRP. The BASC-2 also has strong construct, convergent, and discriminative validity with other behavioural rating scales (Achenback System of Empirically Based Assessment Caregiver Report forms (ASEBA).

As indicated at beginning of the discussion of the BASC-2, of particular interest in this study was depression, anxiety, hyperactivity, learning problems, and attention problems. Therefore, the scores for five composite and their16 sub-scales were used. For purposes of this study, only data from the self-rating scale completed was used.

Data Collection

It was necessary to assess each player on each team to obtain baseline data so that baseline data would be available for the players who were later concussed and their matched control at the beginning of the hockey season. Study information packages including a description of the study as well as consent forms were sent home with each player of a participating team. Signed parental consent and assent forms were required to participate in the study. Consent forms can be found in Appendix B and C. The preseason questionnaire and the paper-and-pencil version of the BASC-2 (SRP) were administered at this time for all players for whom parental consent was received. Groups of players were tested at the same time under the supervision of a research assistant.

The concussed hockey players and their control completed the BASC-2 when the concussed player visited their physician seven to 10 days after the date of the concussion and three months after the date of the concussion. The researcher individually administered the BASC-2 on these two occasions to the concussed player and their control.

Statistical Analysis

Study Trax was used for all data entry and storage. All statistical analyses were carried out using SPSS 21.0. Descriptive statistics were used to describe the characteristics of the group of concussed players and the group of controls

Independent samples t-tests were performed on the baseline scores of the BASC-2 of the two groups (concussed athletes and their matched controls) on the 21 composites and subscales of the BASC-2 questionnaire to determine whether these groups were different prior to injury. A Bonferroni adjusted alpha level of 0.01 was used.

The first analysis examined the changes of raw scores on the five composite and 16 sub-scales of the self-report BASC-2 questionnaire from baseline, seven to ten days post injury, and three months post injury. A staged analysis using 2 x 3 (group-by-occasion) fully crossed, fixed effect ANOVA with repeated measures on the second factor was conducted for each composite variable and variable measured by each sub-scale. An alpha level of 0.01 was used to control for type one error rate. Mauchly's test of sphericity was performed to determine whether the assumption of sphericity was violated. When Mauchly's test of sphericity was violated ($p < 0.05$), the Huynh-Feldt correction was used to adjust for the violation.

The second data analysis was used to look for statistically meaningful change in BASC-2 composite and sub-scale scores at the individual level for the concussed players and the matched control players using the Reliable Change Index (RCI) (Jacobson & Truax, 1991). The RCI is a standardized difference score which determines whether individual change on a measure is statistically significant based on the error variance of the test (Jacobson & Truax, 1991). Specifically, the RCI answers the question about whether changes in scores are meaningful or whether changes are due to random error. To determine the RCI, the post injury observed BASC-2 score was subtracted from the baseline observed BASC-2 score. This result was then divided by the standard error of the differences. The standard error of the differences was calculated using the formulas in Table 1. 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., seven to ten days or three months). Correlations between BASC-2 results at the different time points 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 19 uninjured control participants who completed the BASC-2 questionnaire on three occasions. These were calculated using a modification of the Jacobson and Truax (Jacobson & Truax, 1991) formula, which estimates the measurement error with test re-test difference scores. The formula modification involved calculating the S_{diff} using the SEM for baseline and re-test rather than using an estimated S_{diff} (Iverson, Lovell, & Collins, 2003) . The estimated S_{diff} is appropriate to use when re-test data are not available (Iverson et al., 2003).

Table 1.

$RCI = X_2 - X_1 / S_{diff}$

$S_{diff} = \sqrt{SEM_1^2 + SEM_2^2}$

$SEM_1 = SD\sqrt{1 - r_{12}}$

$SEM_2 = SD\sqrt{1 - r_{12}}$

Note:- S_{diff} is the standard error of the difference, SEM is the standard error of measurement, SD is the standard deviation, and r_{12} is the test re-test reliability coefficient.

The cut-off score used to detect reliable change on each subscale and composite of the BASC-2 was set at a value of ±1.65, representing an alpha of $p < 0.10$, two tailed. The 10% level of significance was adopted in order to follow with research in this area (Cantu, 1998; Hinton-Bayre, Geffen, Geffen, McFarland, & Friis, 1999; Iverson et al., 2003; Iverson, Brooks, Collins et al., 2006; Lovell & Collins, 1998).

For the clinical scales on the BASC-2, a positive change signifies a decline in functioning as high scores equate with greater psychological distress. However, for the adaptive scales on the BASC-2, a negative change signifies a decline in functioning as lower scores equate with psychological distress. Athletes were classified into three groups: those who demonstrated statistically significant improvement in psychological functioning, those who demonstrated statistically significant worsening of psychological functioning, and those who did not demonstrate significant change.

Ethics

Ethics approval for this study was granted by the Conjoint Health Research Ethics Board (Faculty of Medicine, University of Calgary) and the Health Research Ethics Board - Health Panel (University of Alberta). The only anticipated discomfort was mild fatigue after having to complete the BASC-2 questionnaires. A potential long term risk of this study is that the BASC – 2 could possibly identify behavioral or emotional difficulties. However, the benefits of this study outweigh the harm. The possible benefits of this study included: a) understanding the behavioral and emotional symptoms typically experienced by athletes with concussion and b) understanding the impact concussion may have on the day-to-day activities of a youth athlete. This information can be used to inform medical practitioners, parents, and athletes about the natural course of concussions and to identify potential social, behavioral, and/or emotional difficulties that may arise as a result of a concussion. This information can then be used to inform practice and treatment for these symptoms. The other benefit of this study was the medical monitoring of players with concussion by specialists. Players were given close medical supervision and only released back to play after receiving clearance from their physician.

All data are securely stored in an office at the University of Calgary, Sports Injury Prevention Centre or in an office at the University of Alberta, Glen Sather Sports Clinic. Participants are identified by a unique study identification number, thereby respecting the confidentiality of the personal information and findings obtained in the study.

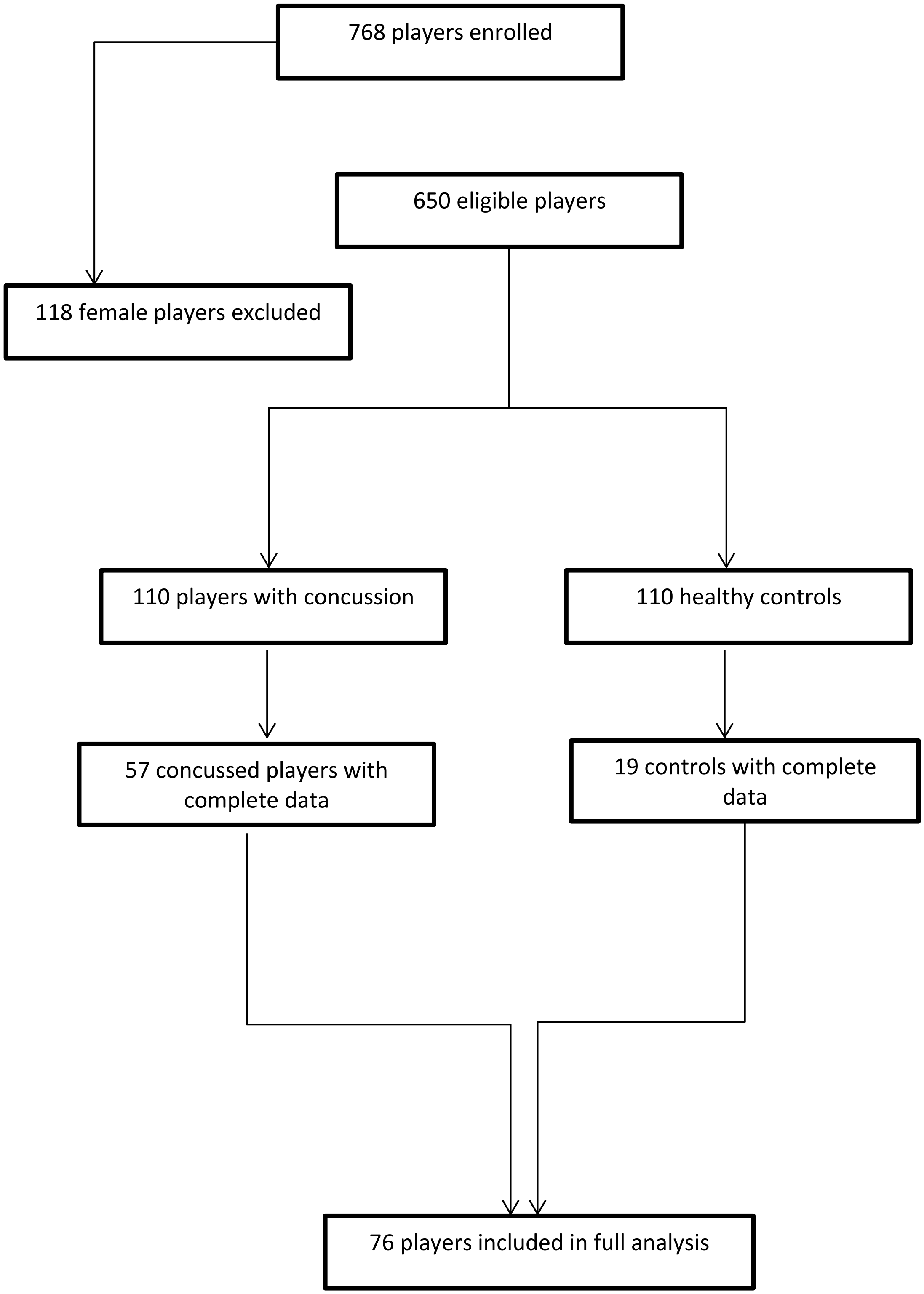
Chapter Four: Results

The purpose of this study was to examine psychosocial outcomes following concussion in elite youth ice hockey players. This chapter provides an overview of results in which outcomes on a self-report psychological scale (BASC-2) were compared across three time periods (baseline, seven to ten days post-injury, and three months post-injury) for a sample of injured and control participants.

Study Participants

A total of 768 elite youth ice hockey players were recruited from 44 teams in Calgary and Edmonton and enrolled in this study at large (see Figure 1). Of these, 118 players (15.0%) were female and were excluded from data analysis due to incomplete data. From September 2011 to April 2012, a total of 110 concussions were reported for the 650 male elite hockey players. Control participants were matched to injured players based on team enrollment. Of the 110 concussed players and 110 matched controls, 144 players were excluded for incomplete data at one or more time periods. . A total of 99 concussed players and 99 matched controls were included in the initial analysis examining baseline BASC-2 data. There were 57 concussed players and 19 matched controls for the remaining follow up analyses. Table 3 shows the characteristics of the cohort by participant status.

Figure 1 Study Recruitment



Comparison of BASC-2 Composite and Sub-scale Scores at Baseline between the Group of Hockey Players who were Concussed and the Group of Hockey Players who were not Concussed

Table 2 depicts the means for each subscale and composite score on the BASC-2 at baseline assessment across the two groups. Independent samples t-tests of the two groups showed no significant difference on the subscales at baseline: Attitude to School $t(196) = 2.44$, $p = 0.02$, Attitude to Teachers $t(196) = 2.11$, $p = 0.04$, Sensation Seeking $t(196) = 1.62$, $p = 0.11$, Atypicality $t(196) = 1.41$, $p = 0.16$, Locus of Control $t(196) = 2.19$, $p = 0.03$, Social Stress $t(196) = 1.93$, $p = 0.06$, Anxiety $t(196) = 0.09$, $p = 0.93$, Depression $t(196) = 0.20$, $p = 0.84$, Sense of Inadequacy $t(196) = 1.26$, $p = 0.21$, Somatization $t(196) = 1.66$, $p = 0.10$, Attention Problems $t(196) = 1.34$, $p = 0.18$, Hyperactivity $t(196) = 0.71$, $p = 0.48$, Relations with Parents $t(196) = -1.05$, $p = 0.30$, Interpersonal Relations $t(196) = -0.13$, $p = 0.90$, Self Esteem $t(196) = 0.27$, $p = 0.79$, and Self Reliance $t(196) = -0.70$, $p = 0.49$. There were also no significant difference on the composite scales: Internalizing Problems $t(196) = 1.51$, $p = 0.13$, Inattention/Hyperactivity $t(196) = 1.37$, $p = 0.17$, Emotional Symptoms $t(196) = 0.61$, $p = 0.54$, and Personal Adjustment $t(196) = -0.69$, $p = 0.49$. However, there was a statistically significant different between the concussed group of athletes and the control group on the composite scale of School Problems. Concussed athletes had higher scores in this domain ($M = 154.28$; $SD = 19.21$) than control athletes ($M = 144.95$; $SD = 18.52$), $t(196) = 3.48$, $p = 0.00$ at baseline.

Table 2

Baseline Raw BASC-2 Scores by Group

Subscale/Composite	Baseline; mean (SD)
School Problems	
Attitude to School	
Injured (n = 99)	7.12 (3.99)
Control (n = 99)	5.83 (3.46)
Attitude to Teachers	
Injured (n = 99)	7.35 (4.17)
Control (n = 99)	6.15 (3.83)
Sensation Seeking	
Injured (n = 99)	13.93 (3.28)
Control (n = 99)	13.11 (3.81)
Composite	
Injured (n = 99)	154.28 (19.21)
Control (n = 99)	144.95 (18.52)
Internalizing Problems	
Atypicality	
Injured (n = 99)	1.91 (2.18)
Control (n = 99)	1.47 (2.17)
Locus of Control	
Injured (n = 99)	4.96 (3.45)
Control (n = 99)	3.90 (3.36)
Social Stress	
Injured (n = 99)	4.29 (2.93)
Control (n = 99)	3.52 (2.75)
Anxiety	
Injured (n = 99)	8.33 (4.53)
Control (n = 99)	8.27 (5.05)
Depression	
Injured (n = 99)	1.59 (1.95)
Control (n = 99)	1.53 (2.27)
Sense of Inadequacy	
Injured (n = 99)	4.82 (3.15)
Control (n = 99)	4.26 (3.03)
Somatization	
Injured (n = 99)	1.65 (1.96)
Control (n = 99)	1.22 (1.63)
Composite	
Injured (n = 99)	318.79 (31.54)
Control (n = 99)	311.97 (32.07)

Table 2 (cont)

Subscale/Composite	Baseline; mean (SD)
Inattention/Hyperactivity	
Attention Problems	
Injured (n = 99)	6.27 (3.64)
Control (n = 99)	5.59 (3.60)
Hyperactivity	
Injured (n = 99)	6.41 (3.23)
Control (n = 99)	6.10 (2.96)
Composite	
Injured (n = 99)	99.14 (15.37)
Control (n = 99)	96.12 (14.94)
Emotional Symptoms Index	
Injured (n = 99)	270.78 (25.05)
Control (n = 99)	268.48 (27.53)
Personal Adjustment	
Relations with Parents	
Injured (n = 99)	21.16 (5.26)
Control (n = 99)	21.90 (4.65)
Interpersonal Relations	
Injured (n = 99)	16.73 (1.77)
Control (n = 99)	16.76 (1.57)
Self-Esteem	
Injured (n = 99)	17.77 (1.78)
Control (n = 99)	17.70 (1.88)
Self-Reliance	
Injured (n = 99)	15.44 (2.72)
Control (n = 99)	15.73 (3.00)
Composite	
Injured (n = 99)	216.04 (19.21)
Control (n = 99)	217.87 (18.05)

Table 3

Participant Characteristics

	Injured (n = 57); mean and (standard deviation)	Control (n = 19); mean and standard deviation
Age	15.05 (1.09)	14.89 (0.94)
	Injured (n = 57); frequency (%) or median (range)	Control (n = 19); frequency (%) or median (range)
Competitive level		
AAA	28 (49.1)	15 (78.9)
AA	29 (50.9)	4 (21.2)
Position		
Forward	39 (68.4)	10 (52.6)
Defense	14 (24.6)	7 (36.8)
Goalie	4 (7.0)	2 (10.5)
Total Concussions		
1	54 (94.7)	0 (0)
2	3 (5.3)	0 (0)
Diagnosed ADHD	1 (1.8)	1 (5.3)
Diagnosed Learning Disability	3 (5.3)	0 (0)
Diagnosed Cognitive Disability	0 (0)	0 (0)
Diagnosed Mood Disorder	0 (0)	0 (0)
Diagnosed Behavior Disorder	0 (0)	0 (0)

As shown in Table 3, participant ages ranged from 13 to 17 years, with a mean age of 15.01 and a standard deviation of 1.09. There were 43 athletes playing at the AAA level and 33 athletes playing at the AA level. Player positions include: 49 forwards, 21 defense, and 6 goalies. Of the 57 injured players, 54 sustained 1 concussion and 3 sustained 2 concussions. Players were screened for pre-existing psychological problems. There were 2 players reported to have a diagnosis of ADHD and 3 players with a diagnosis of a learning disability. No other social, emotional, or behavioral concerns were reported in the sample.

Comparison of Change in BASC-2 Composite and Sub-scale Scores across Time between the Group of Hockey Players who were Concussed and the Group of Hockey Players who were not Concussed

The first objective of this study was to evaluate whether there were significant changes on the five composite and the 16 sub-scales of the self-report BASC-2 questionnaire from baseline, seven to ten days and three months post injury in youth ice hockey players with concussion and healthy matched controls. The mean and standard deviation are reported in Table 4. As shown, the results are organized in terms of the five parts of the BASC-2. Within each part, the results of the subscales are presented first followed with the results of the composite.

School problems. The school problems composite of the BASC-2 is comprised of three sub-scales: attitude to school, attitude to teachers, and sensation seeking. Mauchly's test of sphericity revealed that the assumption of sphericity was met for the Sensation Seeking Subscale, but not for the Attitude toward School subscale, Attitude toward Teachers subscale, or the Composite Scale. Therefore, the F-test statistic was used for the Sensation Seeking subscale and the F-statistic modified by the Huynh and Feldt

Table 4

Baseline, 7-10 day, and Three Month Raw BASC-2 Scores by Group

Subscale/Composite	Baseline; mean (SD)	7-10 Day; mean (SD)	3 Month; mean (SD)
School Problems			
Attitude to School			
Injured (n = 57)	6.75 (3.61)	6.53 (3.45)	6.42 (3.43)
Control (n = 19)	5.95 (3.64)	6.00 (2.91)	5.37 (2.69)
Attitude to Teachers			
Injured (n = 56)	7.23 (4.12)	7.00 (3.93)	6.46 (4.06)
Control (n = 18)	6.67 (4.74)	5.83 (4.02)	6.56 (5.48)
Sensation Seeking			
Injured (n = 57)	13.86 (2.84)	13.33 (2.94)	13.81 (3.65)
Control (n = 19)	13.95 (4.25)	14.00 (2.49)	13.58 (3.49)
Composite			
Injured (n = 56)	153.46 (17.82)	151.05 (17.85)	151.12 (19.54)
Control (n = 18)	152.11 (21.82)	150.28 (15.86)	150.33 (19.21)
Internalizing Problems			
Atypicality			
Injured (n = 56)	1.79 (2.10)	1.27 (1.52)	1.23 (2.05)
Control (n = 18)	1.22 (1.83)	1.61 (1.98)	1.28 (1.53)
Locus of Control			
Injured (n = 57)	4.84 (3.52)	4.40 (3.55)	4.37 (3.30)
Control (n = 19)	4.74 (2.90)	4.68 (2.77)	3.95 (2.74)
Social Stress			
Injured (n = 56)	4.04 (2.70)	4.04 (2.50)	3.75 (3.19)
Control (n = 18)	4.78 (3.32)	3.83 (3.40)	5.11 (4.03)
Anxiety			
Injured (n = 57)	7.79 (4.20)	7.79 (3.75)	7.26 (3.75)
Control (n = 18)	9.39 (6.00)	8.61 (6.03)	9.11 (6.31)
Depression			
Injured (n = 57)	1.58 (1.99)	1.67 (1.99)	1.60 (2.71)
Control (n = 19)	1.63 (1.89)	1.79 (2.59)	1.89 (3.30)
Sense of Inadequacy			
Injured (n = 57)	4.88 (3.22)	4.60 (3.22)	4.54 (3.27)
Control (n = 19)	3.95 (2.44)	4.58 (3.02)	4.42 (3.04)
Somatization			
Injured (n = 57)	1.40 (1.74)	1.96 (2.47)	0.93 (1.40)
Control (n = 19)	1.16 (1.34)	1.63 (2.17)	1.63 (1.61)
Composite			
Injured (n = 56)	315.84 (29.22)	315.02 (31.00)	309.54 (33.57)
Control (n = 18)	313.00 (29.06)	313.61 (35.21)	315.94 (39.63)

Table 4 (cont)

Subscale/Composite	Baseline; mean (SD)	7-10 Day; mean (SD)	3 Month; mean (SD)
Inattention/Hyperactivity			
Attention Problems			
Injured (n = 57)	6.12 (3.29)	6.60 (3.53)	5.88 (3.63)
Control (n = 19)	6.68 (3.65)	6.26 (3.33)	7.47 (3.86)
Hyperactivity			
Injured (n = 56)	5.91 (2.90)	5.34 (2.77)	5.18 (3.57)
Control (n = 18)	7.06 (3.15)	6.39 (2.75)	6.28 (3.20)
Composite			
Injured (n = 56)	97.20 (13.35)	96.68 (14.01)	94.88 (16.52)
Control (n = 18)	102.06 (16.33)	99.39 (14.65)	102.17 (16.98)
Emotional Symptoms Index			
Injured (n = 56)	269.32 (23.42)	271.16 (23.31)	266.04 (27.61)
Control (n = 18)	266.17 (24.03)	265.89 (29.59)	269.61 (35.74)
Personal Adjustment			
Relations with Parents			
Injured (n = 56)	21.23 (4.78)	21.14 (4.48)	21.46 (5.17)
Control (n = 18)	20.83 (4.40)	21.00 (4.04)	21.33 (4.62)
Interpersonal Relations			
Injured (n = 57)	16.84 (1.75)	16.61 (1.62)	16.46 (1.82)
Control (n = 19)	16.21 (2.02)	16.74 (1.52)	16.05 (2.72)
Self-Esteem			
Injured (n = 57)	17.98 (1.56)	17.44 (1.72)	17.67 (2.06)
Control (n = 19)	17.89 (2.21)	17.47 (1.68)	17.32 (2.87)
Self-Reliance			
Injured (n = 56)	15.19 (2.59)	14.91 (2.09)	15.68 (2.58)
Control (n = 18)	16.21 (2.76)	16.37 (2.03)	16.58 (2.34)
Composite			
Injured (n = 56)	216.30 (18.49)	213.46 (14.85)	215.93 (19.41)
Control (n = 18)	217.83 (16.14)	218.56 (14.96)	216.22 (23.32)

SD = standard deviation

procedure was used for the Attitude to School subscale, the Attitude to Teachers subscale, and the composite scale. As shown in Table 5, there was no significant effect of group (injured vs control) or time (baseline, seven to ten days, and three months post injury) and no statistically significant interaction between group and time for three subscales and the composite scale.

Given the absence of an interaction between group and time, hockey players with concussion did not report more school problems compared to hockey players who were not concussed and the school problems 7 to 10 days after concussion did not change across time (Figure 2).

Table 5

Summary ANOVA: Repeated Measures

Injured vs. Controls School Problems

Source	*df*	*MS*	*F*
Attitude to School			
Between Subjects			
Group	1	27.04	0.99
Error	74	27.25	-
Within Subjects			
Occasion	1.79	3.73	0.88
Occasion x Group	1.79	1.11	0.26
Error	132.41	4.24	-
Attitude to Teachers			
Between Subjects			
Group	1	12.23	0.28
Error	72	44.89	-
Within Subjects			
Occasion	1.87	4.72	1.02
Occasion x Group	1.87	5.77	1.25
Error	134.52	4.63	-
Sensation Seeking			
Between Subjects			
Group	1	1.32	0.05
Error	74	24.41	-
Within Subjects			
Occasion	2	0.96	0.27
Occasion x Group	2	2.93	0.82
Error	148	3.59	-
Composite			
Between Subjects			
Group	1	38.73	0.04
Error	72	912.16	-
Within Subjects			
Occasion	1.82	87.37	1.28
Occasion x Group	1.82	1.62	0.02
Error	130.88	68.51	-

*$p < 0.01$

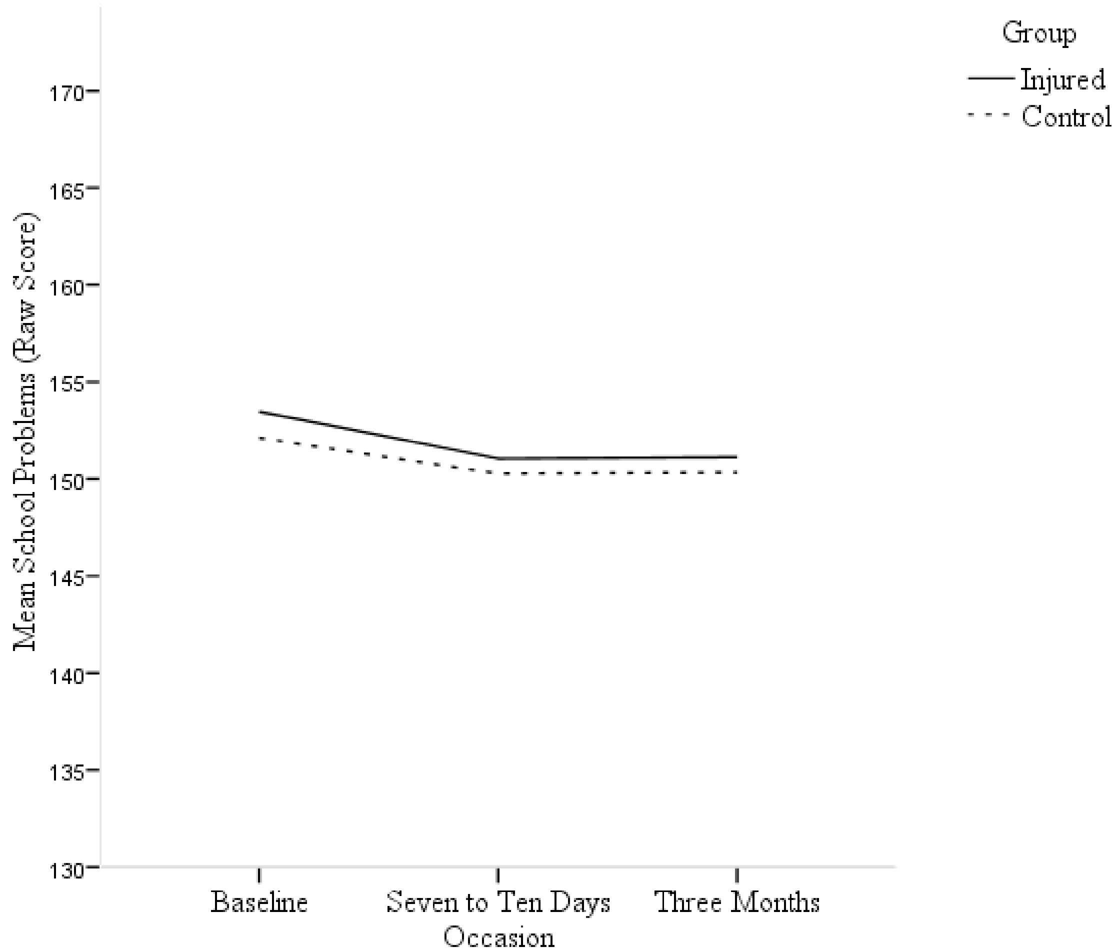


Figure 2. Mean raw scores for school problems at baseline, seven to ten days, and three months across groups.

Internalizing problems. The internalizing problems composite of the BASC-2 is comprised of seven sub-scales: atypicality, locus of control, social stress, anxiety, depression, sense of inadequacy, and somatization. Mauchly's test of sphericity revealed that the assumption of sphericity was met for the Atypicality and Sense of Inadequacy subscales, but not for the Locus of Control, Social Stress, Anxiety, Depression, Somatization or the Composite Scale. Therefore, the F-statistic was used for the Atypicality and Sense of Inadequacy subscales and the F statistic modified by the Huynh Feldt procedure was used for the Locus of Control, Social Stress, Anxiety, Depression, and Somatization subscales, as well as the composite scale. As shown in Table 6, there was no significant effect of group (injured vs control) or time (baseline, seven to ten days, and three months post injury) and no statistically significant interaction between group and time for seven subscales and the composite scale. Given the absence of a significant interaction between group and time, hockey players with concussion did not report more internalizing problems compared to hockey players who were not concussed and the internalizing problems 7 to 10 days after concussion did not change across time (Figure 3).

Table 6

Summary ANOVA: Repeated Measures

Injured vs. Controls Internalizing Problems

Source	*df*	*MS*	*F*
Atypicality			
Between Subjects			
Group	1	0.14	0.02
Error	72	6.66	-
Within Subjects			
Occasion	2	0.91	0.46
Occasion x Group	2	2.91	1.48
Error	144	1.97	-

Table 6 (cont)

Source	*df*	*MS*	*F*
Locus of Control			
Between Subjects			
Group	1	0.29	0.01
Error	74	26.00	-
Within Subjects			
Occasion	1.88	6.15	1.67
Occasion x Group	1.88	1.87	0.51
Error	139.09	3.68	-
Social Stress			
Between Subjects			
Group	1	16.41	0.81
Error	72	20.18	-
Within Subjects			
Occasion	1.75	4.87	1.20
Occasion x Group	1.75	9.65	2.38
Error	126.08	4.05	-
Anxiety			
Between Subjects			
Group	1	83.10	1.59
Error	73	52.39	-
Within Subjects			
Occasion	1.76	3.24	0.45
Occasion x Group	1.76	4.45	0.62
Error	128.57	7.20	-
Depression			
Between Subjects			
Group	1	1.07	0.10
Error	74	10.82	-
Within Subjects			
Occasion	1.74	0.38	0.11
Occasion x Group	1.74	0.26	0.08
Error	128.66	3.40	-
Sense of Inadequacy			
Between Subjects			
Group	1	5.44	0.25
Error	74	21.88	-
Within Subjects			
Occasion	2	0.44	0.11
Occasion x Group	2	3.55	0.91
Error	148	3.91	-

Table 6 (cont)

Source	*df*	*MS*	*F*
Somatization			
Between Subjects			
Group	1	0.07	0.01
Error	74	6.36	-
Within Subjects			
Occasion	1.86	5.48	2.40
Occasion x Group	1.86	5.05	2.21
Error	137.55	2.28	-
Composite			
Between Subjects			
Group	1	21.24	0.01
Error	72	2425.09	-
Within Subjects			
Occasion	1.80	53.52	0.14
Occasion x Group	1.80	374.50	0.99
Error	129.77	380.06	-

*$p < 0.01$

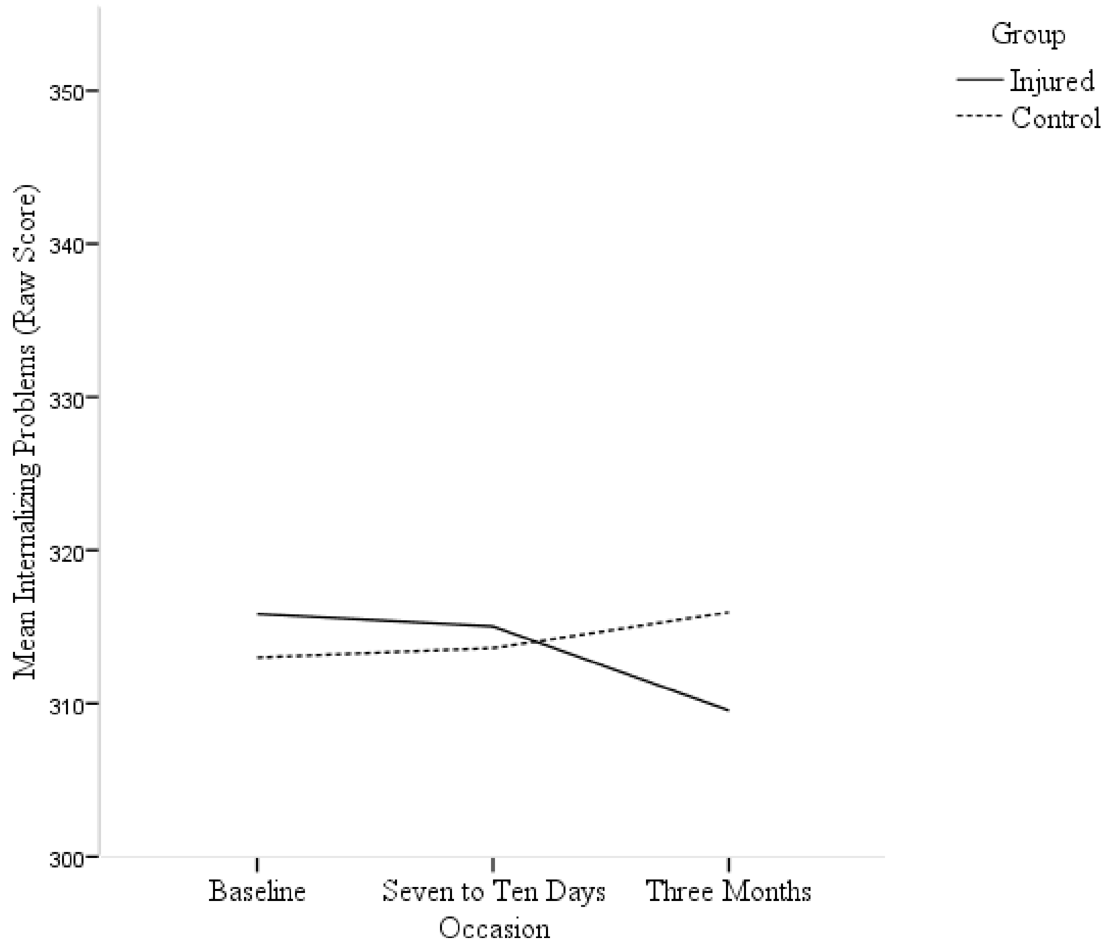


Figure 3. Mean raw scores for internalizing problems at baseline, seven to ten days, and three months across groups.

Inattention/hyperactivity. The inattention/hyperactivity composite of the BASC-2 is comprised of two sub-scales: attention problems and hyperactivity. Mauchly's test of sphericity revealed that the assumption of sphericity was met for the Attention Problems subscale, but not for the Hyperactivity subscale, or the Composite scale. Therefore the F-test statistic was used for the Attention Problems subscale and the F statistic modified by the Huynh Feldt procedure was used for the Hyperactivity subscale and the composite scale. As shown in Table 7, there was no significant effect of group (injured vs control) or time (baseline, seven to ten days, and three months post injury) and no statistically significant interaction between group and time for two subscales and the composite scale. Given the absence of an interaction between group and time, hockey players with concussion did not report more Inattention/Hyperactivity problems compared to hockey players who were not concussed and the Inattention/Hyperactivity 7 to 10 days after concussion did not change across time (Figure 4).

Table 7

Summary ANOVA: Repeated Measures

Injured vs. Controls Inattention/Hyperactivity

Source	*df*	*MS*	*F*
Attention Problems			
Between Subjects			
Group	1	15.81	0.53
Error	74	29.67	-
Within Subjects			
Occasion	2	1.28	0.34
Occasion x Group	2	13.29	3.57
Error	148	3.72	-

Table 7 (cont)

Source	*df*	*MS*	*F*
Hyperactivity			
Between Subjects			
Group	1	49.26	2.13
Error	72	23.18	-
Within Subjects			
Occasion	1.87	9.42	3.27
Occasion x Group	1.87	0.03	0.01
Error	134.86	2.89	-
Composite			
Between Subjects			
Group	1	1002.79	1.78
Error	72	565.04	-
Within Subjects			
Occasion	1.90	38.09	0.65
Occasion x Group	1.90	75.16	1.29
Error	137.11	58.42	-

*$p < 0.01$

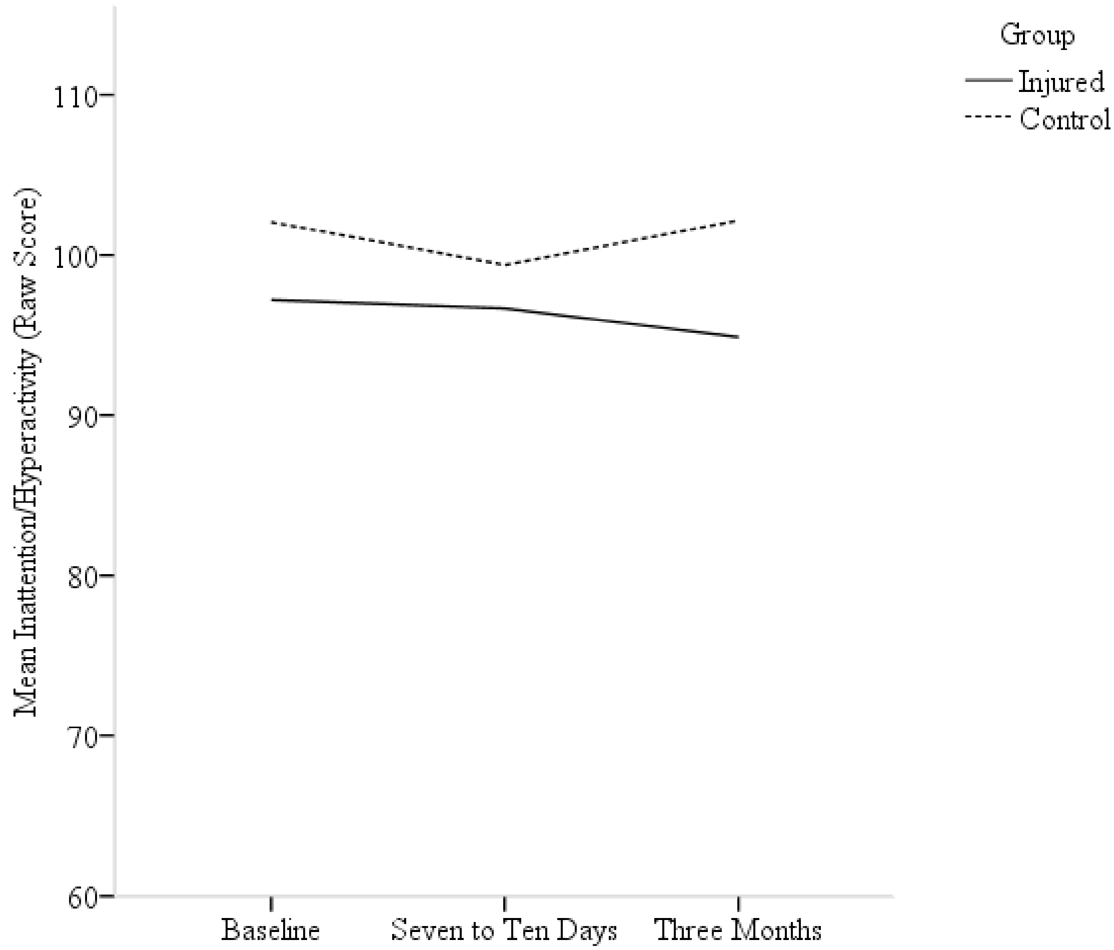


Figure 4. Mean raw scores for inattention/hyperactivity at baseline, seven to ten days, and three months across groups.

Emotional symptoms index. The emotional symptoms index of the BASC-2 is comprised of six sub-scales: social stress, anxiety, depression, sense of inadequacy, self-esteem,and self-reliance. Mauchly's test of sphericity revealed that the assumption of sphericity was met for the Sense of Inadequacy and Self Reliance subscales, but not for the Social Stress, Anxiety, Depression, Self Esteem or the Composite Scale. Therefore, the F-statistic was used for the Sense of Inadequacy and Self Reliance subscales and the F statistic modified by the Huynh Feldt procedure was used for the Social Stress, Anxiety, Depression, and Self Esteem subscales, as well as the composite scale. As shown in Table 8, there was no significant effect of group (injured vs control) or time (baseline, seven to ten days, and three months post injury) and no statistically significant interaction between group and time for six subscales and the composite scale. Given the absence of an interaction between group and time, hockey players with concussion did not report more emotional symptoms compared to hockey players who were not concussed and the emotional symptoms 7 to 10 days after concussion did not change across time (Figure 5).

Table 8

Summary ANOVA: Repeated Measures

Injured vs. Controls Emotional Symptoms Index

Source	*df*	*MS*	*F*
Social Stress			
Between Subjects			
Group	1	16.41	0.81
Error	72	20.18	-
Within Subjects			
Occasion	1.75	4.87	1.20
Occasion x Group	1.75	9.65	2.38
Error	126.08	4.05	-

Table 8 (cont)

Source	*df*	*MS*	*F*
Anxiety			
Between Subjects	1	83.10	1.59
Group	73	52.39	-
Error			
Within Subjects	1.76	3.24	0.45
Occasion	1.76	4.45	0.62
Occasion x Group	128.57	7.20	-
Error	1	83.10	1.59
Depression			
Between Subjects			
Group	1	1.07	0.10
Error	74	10.82	-
Within Subjects			
Occasion	1.74	0.38	0.11
Occasion x Group	1.74	0.26	0.08
Error	128.66	3.40	-
Sense of Inadequacy			
Between Subjects			
Group	1	5.44	0.25
Error	74	21.88	-
Within Subjects			
Occasion	2	0.44	0.11
Occasion x Group	2	3.55	0.91
Error	148	3.91	-
Self Esteem			
Between Subjects			
Group	1	0.77	0.10
Error	74	7.59	-
Within Subjects			
Occasion	1.89	4.36	2.29
Occasion x Group	1.89	0.59	0.31
Error	139.94	1.91	-
Self Reliance			
Between Subjects			
Group	1	53.90	4.30
Error	74	12.54	-
Within Subjects			
Occasion	2	4.08	1.62
Occasion x Group	2	1.24	0.49
Error	148	2.53	-

Table 8 (cont)

Source	*df*	*MS*	*F*
Composite			
Between Subjects			
Group	1	106.86	0.07
Error	72	1607.77	-
Within Subjects			
Occasion	1.74	11.55	0.04
Occasion x Group	1.74	333.74	1.28
Error	125.43	260.10	-

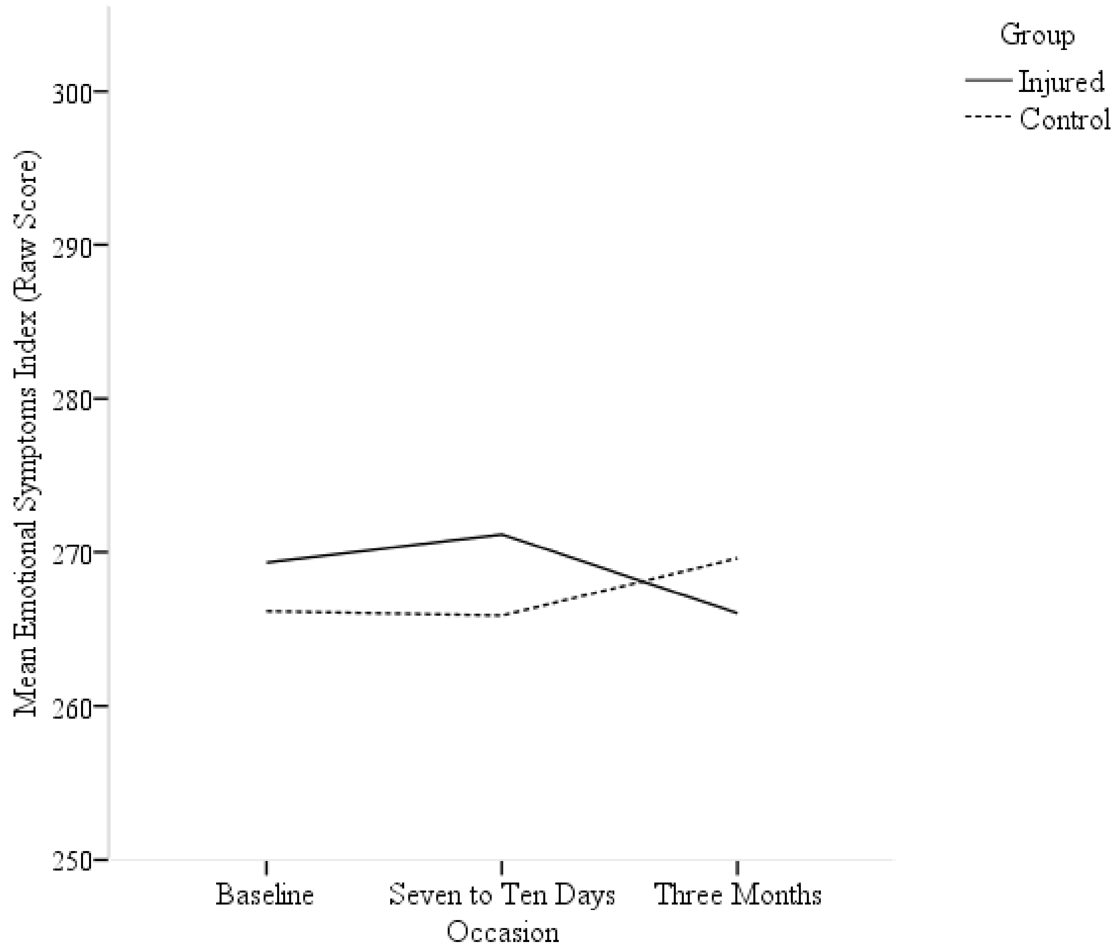


Figure 5. Mean raw scores for emotional symptoms index at baseline, seven to ten days, and three months across groups.

Personal adjustment. The personal adjustment composite of the BASC-2 is comprised of four sub-scales: relations with parents, interpersonal relations, self-esteem, and self-reliance. Mauchly's test of sphericity revealed that the assumption of sphericity was met for the Interpersonal Relations and Self Reliance subscales, but not for the Relations with Parents, Self Esteem, or the Composite scale. Therefore, the F-statistic was used for the Interpersonal Relations and Self Reliance subscales and the F statistic modified by the Huynh Feldt procedure was used for the Relations with Parents and Self Esteem subscales, as well as the composite scale. As shown in Table 9, there was no significant effect of group (injured vs control) or time (baseline, seven to ten days, and three months post injury) and no statistically significant interaction between group and time for four subscales and the composite scale. Given the absence of an interaction between group and time, hockey players with concussion did not report more personal adjustment problems compared to hockey players who were not concussed and the personal adjustment problems 7 to 10 days after concussion did not change across time (Figure 6).

Table 9

Summary ANOVA: Repeated Measures

Injured vs. Controls Personal Adjustment

Source	*df*	*MS*	*F*
Relations with Parents			
Between Subjects			
Group	1	2.05	0.04
Error	72	55.15	-
Within Subjects			
Occasion	1.84	2.40	0.38
Occasion x Group	1.84	0.34	0.05
Error	132.52	6.25	-

Table 9 (cont)

Source	*df*	*MS*	*F*
Interpersonal Relations			
Between Subjects			
Group	1	3.95	0.56
Error	74	7.08	-
Within Subjects			
Occasion	2	2.60	1.68
Occasion x Group	2	2.13	1.38
Error	148	1.55	-
Self Esteem			
Between Subjects			
Group	1	0.77	0.10
Error	74	7.59	-
Within Subjects			
Occasion	1.89	4.36	2.29
Occasion x Group	1.89	0.59	0.31
Error	139.94	1.91	-
Self-Reliance			
Between Subjects	1	53.90	4.30
Group	74	12.54	-
Error			
Within Subjects	2	4.08	1.62
Occasion	2	1.24	0.49
Occasion x Group	148	2.53	-
Error	1	53.90	4.30
Composite			
Between Subjects			
Group	1	217.10	0.29
Error	72	738.33	-
Within Subjects			
Occasion	1.84	20.87	0.17
Occasion x Group	1.84	92.02	0.76
Error	132.27	120.64	-

*p< 0.01

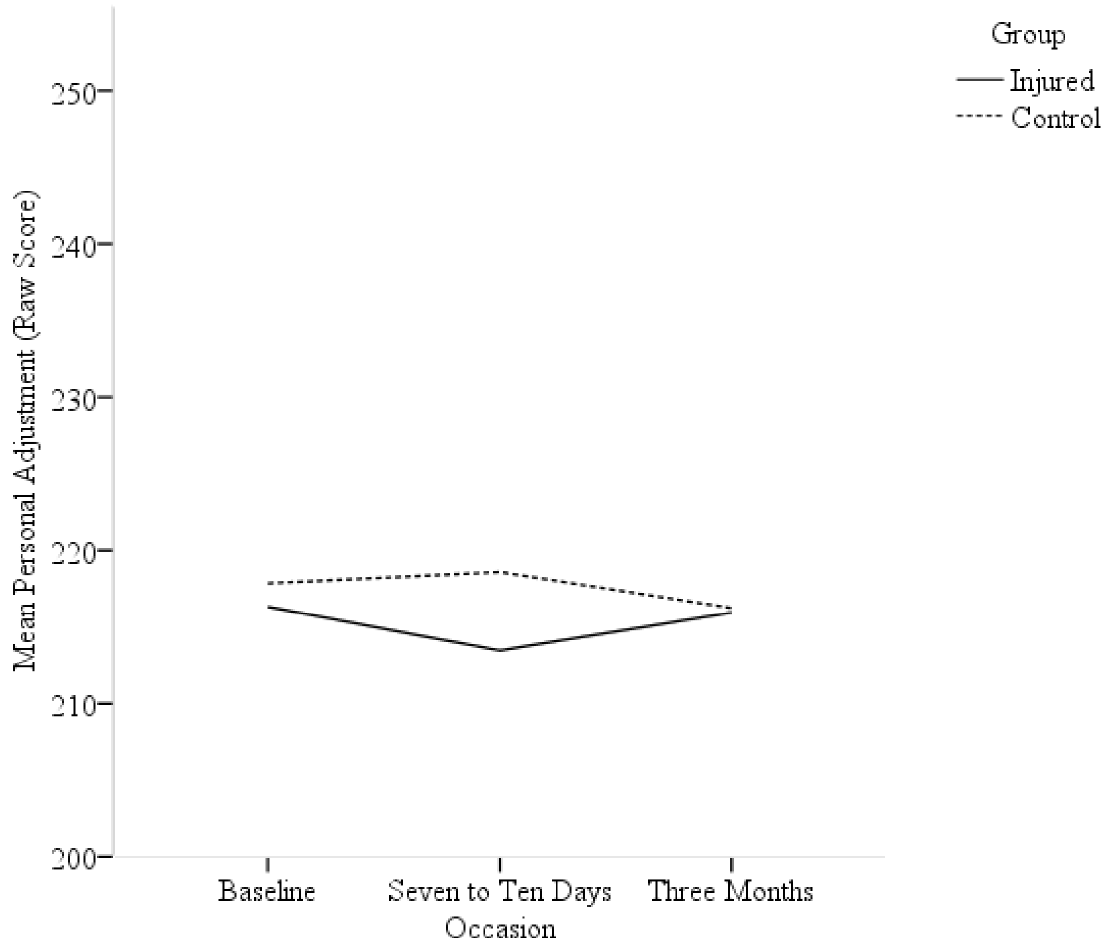


Figure 6. Mean raw scores for personal adjustment at baseline, seven to ten days, and three months across groups.

Analysis of Change across Time at the Individual Level

In order to assess for individual variation and clinically meaningful change across time at the individual level for each sub-scale and composite score of the BASC-2, the Reliable Change Index (RCI) (Hinton-Bayre et al., 1999; Jacobson & Truax, 1991) was used. The composite and sub-scale scores of the BASC-2 were examined for each athlete across the assessment intervals (baseline, seven to ten days, and three months). The statistical parameters used to calculate the RCI for the BASC-2 measure at seven to ten days and three months are listed in Table 10 and Table 11 respectively. The formulas used to calculate the RCI can be found in Chapter 3, Table 1. Scores from seven to ten days post injury were compared to baseline scores (see Table 12, 13, 14). Similarly, scores from three months post injury were compared to baseline scores (see Table 15, 16, 17).

Table 10

Descriptive Statistics, SEMs, S_{diffs}, for Healthy Control Participants at Seven to Ten Days

Subscale/Index	M (SD)		r_{12}	SEM_1	SEM_2	S_{diff}
	Baseline	7-10 Days				
School Problems	151.37 (21.45)	150.28 (15.86)	0.77	10.31	7.62	12.82
Attitude to School	6.75 (3.61)	6.53 (3.45)	0.68	2.03	1.94	2.81
Attitude to Teachers	6.68 (4.61)	5.83 (4.02)	0.78	2.17	1.89	2.88
Sensation Seeking	13.95 (4.25)	14.00 (2.49)	0.74	2.17	1.27	2.52
Internalizing Problems	313.42 (28.30)	313.61 (35.21)	0.74	14.43	17.95	23.03
Atypicality	1.21 (1.78)	1.61 (1.98)	0.50	1.26	1.40	1.89
Locus of Control	4.74 (2.90)	4.68 (2.77)	0.41	2.23	2.13	3.08
Social Stress	4.58 (3.34)	3.83 (3.40)	0.85	1.28	1.31	1.83

Table 10 (cont)

Anxiety	9.84 (6.16)	8.61 (6.03)	0.81	2.71	2.65	3.79
Depression	1.63 (1.89)	1.79 (2.59)	0.31	1.56	2.13	2.64
Sense of Inadequacy	3.95 (2.44)	4.58 (3.02)	0.65	1.45	1.80	2.31
Somatization	1.16 (1.34)	1.63 (2.17)	0.69	0.75	1.21	1.42
Inattention/ Hyperactivity	101.95 (15.88)	99.39 (14.65)	0.76	7.74	7.14	10.54
Attention Problems	6.68 (3.65)	6.26 (3.33)	0.73	1.89	1.72	2.55
Hyperactivity	7.00 (3.07)	6.39 (2.75)	0.70	1.69	1.51	2.27
Emotional Symptoms Index	42.95 (5.24)	42.72 (6.53)	0.78	11.16	13.91	17.83
Personal Adjustment	217.16 (15.96)	218.56 (14.96)	0.80	7.09	6.64	9.71
Relations with Parents	20.89 (4.28)	21.00 (4.04)	0.79	1.97	1.86	2.71
Interpersonal Relations	16.21 (2.02)	16.74 (1.52)	0.53	1.39	1.05	1.74
Self Esteem	17.89 (2.21)	17.47 (1.68)	0.75	1.11	0.84	1.39
Self Reliance	16.21 (2.76)	16.37 (2.03)	0.57	1.81	1.33	2.25

N= 19

Table 11

Descriptive Statistics, SEMs, S_{diffs}, for Healthy Control Participants at Three Months

Subscale/Index	M (SD)		r_{12}	SEM_1	SEM_2	S_{diff}
	Baseline	3 Months				
School Problems	151.37 (21.45)	149.84 (18.79)	0.83	8.90	7.79	11.83
Attitude to School	6.75 (3.61)	6.42 (3.43)	0.51	2.54	2.81	3.50
Attitude to Teachers	6.68 (4.61)	6.58 (5.33)	0.65	2.72	3.15	4.16

Table 11 (cont)

Sensation Seeking	13.95 (4.25)	13.58 (3.49)	0.76	2.06	1.69	2.67
Internalizing Problems	313.42 (28.30)	316.58 (38.62)	0.63	17.26	23.55	29.20
Atypicality	1.21 (1.78)	1.21 (1.51)	0.64	1.07	0.90	1.40
Locus of Control	4.74 (2.90)	3.95 (2.74)	0.29	2.45	2.32	3.37
Social Stress	4.58 (3.34)	4.95 (3.98)	0.71	1.79	2.13	2.78
Anxiety	9.84 (6.16)	9.63 (6.54)	0.73	3.23	3.43	4.71
Depression	1.63 (1.89)	1.89 (3.30)	0.31	1.57	2.73	3.15
Sense of Inadequacy	3.95 (2.44)	4.42 (3.04)	0.73	1.27	1.58	2.03
Somatization	1.16 (1.34)	1.63 (1.61)	0.49	0.96	1.14	1.49
Inattention/Hyperactivity	101.95 (15.88)	103.21 (17.11)	0.70	8.70	9.37	12.79
Attention Problems	6.68 (3.65)	7.47 (3.86)	0.69	2.04	2.16	2.97
Hyperactivity	7.00 (3.07)	6.53 (3.29)	0.65	1.81	1.93	2.65
Emotional Symptoms Index	42.95 (5.24)	43.58 (7.67)	0.64	14.54	21.35	25.84
Personal Adjustment	217.16 (15.96)	215.74 (22.76)	0.61	9.98	14.23	17.38
Relations with Parents	20.89 (4.28)	21.26 (4.50)	0.61	2.67	2.80	3.87
Interpersonal Relations	16.21 (2.02)	16.05 (2.72)	0.45	1.49	2.01	2.50
Self Esteem	17.89 (2.21)	17.32 (2.87)	0.47	1.61	2.09	2.64
Self Reliance	16.21 (2.76)	16.58 (2.34)	0.67	1.59	1.35	2.09

Across the 16 subscales and 5 composite scales of the BASC-2, 22 (36.8%) concussed players and 7 (36.8%) control players showed a reliable worsening of symptoms on one or more subscales and composites from baseline to 7-10 days post-injury (see Tables 12 and 13). Of the 22 concussed players, one had a previous diagnosis of Attention Deficit/Hyperactivity Disorder (ADHD). There were 28 (49.1%) concussed players and 7 (36.8%) control players who showed a reliable improvement of symptoms on one or more subscales and composites at 7-10 days post injury. There was one injured subject at seven to ten days post injury who showed an elevated L index score, suggesting that this subject may have responded to items on the BASC-2 in a socially desirable way. This player showed a reliable improvement on one subscale of the BASC-2, somatization. There was also one control subject who showed an elevated V index, suggesting this subject may have been careless in completing the BASC-2 or uncooperative with the assessment process. This subject did not show a reliable worsening or improvement of symptoms on any composites or subscales of the BASC-2. Table 14 shows the reliable worsening and reliable improvement for each subscale and composite at 7-10 days post-injury.

Table 12

Injured players with reliable worsening at 7-10 days post injury across the BASC-2 composites

Subject	SCH	INZ	INH	ESI	PER
4					
12					
14					
16					↓
24					
28			↑		
29					
32		↑		↑	↓
33		↑			
34		↑	↑	↑	↓
37					↑
39					↓
43		↓			

Table 12 (cont)

45	↑	↑		↑	↓
54					↓
59					↓
61					
63					
64				↑	
66					
67					
76					

Note: SCH = School Problems, INZ = Internalizing Problems, INH = Inattention/Hyperactivity, ESI = Emotional Symptoms Index, PER = Personal Adjustment. For clinical composites (SCH, INZ, INH, ESI) '↑' = reliable worsening and '↓' = reliable improvement. For adaptive composites (PER), '↑' = reliable improvement and '↓' = reliable worsening. Subject number was randomly assigned to participants.

Table 13

Injured players with reliable worsening at 7-10 days post injury across the BASC-2 subscales

Subject	ATS	ATT	SEN	ATP	LOC	SOC	ANX	DEP	SIN	SOM	ATN	HYP	REL	INT	SEL	SRL
4														↓		
12		↑										↑				
14						↑				↑		↑				
16																
24																↓
28											↑	↑			↓	
29														↓		
32										↑					↓	
33										↑						
34									↑	↑	↑	↑	↓	↓		↓
37									↓	↑	↑					↑
39															↓	
43						↓										↓
45	↑	↑				↑			↑		↑					
54		↑				↑						↑		↓		↓
59			↓							↑	↑					↓
61	↑												↓			
63											↑					
64				↓		↑		↑				↓				
66	↑						↑									
67				↑												
76	↓														↓	

Note: ATS=Attitude to School, ATT= Attitude to Teachers, SEN= Sensation Seeking, ATP= Atypicality, LOC=Locus of Control, SOC= Social Stress, ANX= Anxiety, DEP= Depression, SIN= Sense of Inadequacy, SOM= Somatization, ATN= Attention Problems, HYP= Hyperactivity, REL= Relations with Parents, INT= Interpersonal Relations, SEL= Self Esteem, SRL= Self Reliance. For clinical subtests (ATS, ATT, SEN, ATP, LOC, SOC, ANX, DEP, SIN, SOM, ATN, HYP) '↑' = reliable worsening and '↓' = reliable improvement. For adaptive subtests (REL, INT, SEL, SRL), '↑' = reliable improvement and '↓' = reliable worsening.

Table 14
Reliable worsening and reliable improvement using the RCI from baseline to 7-10 days post-injury separated by group

Clinical Composites/Sub-Scales	Reliable Worsening, n (%)	Reliable improvement, n (%)
School Problems		
Injured (n = 56)	1 (1.8)	1 (1.8)
Control (n = 18)	0 (0.0)	1 (5.6)
Attitude to School		
Injured (n = 57)	3 (5.3)	4 (7.0)
Control (n = 19)	0 (0.0)	1 (5.3)
Attitude to Teacher		
Injured (n = 57)	3 (5.3)	3 (5.3)
Control (n = 19)	0 (0.0)	1 (5.3)
Sensation Seeking		
Injured (n = 57)	0 (0.0)	2 (3.5)
Control (n = 19)	1 (5.3)	1 (5.3)
Internalizing Problems		
Injured (n = 56)	4 (7.1)	2 (3.6)
Control (n = 18)	2 (11.1)	0 (0.0)
Atypicality		
Injured (n = 56)	1 (1.8)	5 (8.9)
Control (n = 18)	1 (5.6)	1 (5.6)
Locus of Control		
Injured (n = 57)	0 (0.0)	0 (0.0)
Control (n = 19)	1 (5.3)	0 (0.0)
Social Stress		
Injured (n = 56)	4 (7.1)	5 (8.9)
Control (n = 18)	0 (0.0)	1 (5.6)
Anxiety		
Injured (n = 57)	1 (1.8)	3 (5.3)
Control (n = 18)	0 (0.0)	1 (5.6)

Table 14 (cont)

Depression		
Injured (n = 57)	1 (1.8)	0 (0.0)
Control (n = 19)	2 (10.5)	1 (5.3)
Sense of Inadequacy		
Injured (n = 57)	2 (3.5)	4 (7.0)
Control (n = 19)	2 (10.5)	1 (5.3)
Somatization		
Injured (n = 57)	6 (10.5)	4 (7.0)
Control (n = 19)	2 (10.5)	0 (0.0)
Inattention/Hyperactivity		
Injured (n = 56)	2 (3.6)	0 (0.0)
Control (n = 18)	1 (5.6)	2 (11.1)
Attention Problems		
Injured (n = 57)	6 (10.5)	0 (0.0)
Control (n = 19)	0 (0.0)	1 (5.3)
Hyperactivity		
Injured (n = 56)	5 (8.9)	5 (8.9)
Control (n = 18)	1 (5.6)	2 (11.1)
Emotional Symptoms Index		
Injured (n = 56)	4 (7.1)	1 (1.8)
Control (n = 18)	1 (5.6)	0 (0.0)
Adaptive Composite/Sub-Scales	Reliable Worsening, n (%)	Reliable improvement, n (%)
Personal Adjustment		
Injured (n = 56)	7 (12.5)	4 (7.1)
Control (n = 18)	1 (5.6)	0 (0.0)
Relations with Parents		
Injured (n = 56)	2 (3.6)	4 (7.1)
Control (n = 18)	0 (0.0)	1 (5.6)
Interpersonal Relations		
Injured (n = 57)	4 (7.0)	2 (3.5)
Control (n = 19)	0 (0.0)	2 (10.5)

Table 14 (cont)

Self Esteem		
Injured (n = 57)	4 (7.0)	1 (1.8)
Control (n = 19)	2 (10.5)	0 (0.0)
Self Reliance		
Injured (n = 57)	5 (8.8)	3 (5.3)
Control (n = 19)	2 (10.5)	0 (0.0)

At the 3-month assessment, 19 (33.3%) concussed players and 8 (42.1%) control players showed a reliable worsening of symptoms on 1 or more of the 16 subscales and 5 composite scales of the BASC-2 measure (see Tables 14 and 15). Of these 19 injured players, 1 had a previous diagnosis of ADHD. There were 35 (61.4%) concussed players and 8 (42.1%) control players who showed a reliable improvement of symptoms on one or more subscales and composites at 3 months post injury. There were three injured participants who showed an elevated L index score, suggesting that these participants may have responded to items on the BASC-2 in a socially desirable way. The first of these players showed a reliable improvement on two subscales (Attention Problems and Self-Reliance) at three months. The second player showed a reliable improvement on two composites (Inattention/Hyperactivity and Personal Adjustment), and three subscales (Attention Problems, Hyperactivity, and Self-Reliance). The third player showed a reliable improvement on one composite (Personal Adjustment) and three subscales (Attitude to School, Relations with Parents, and Self Reliance), as well as a reliable worsening on one subscale (Sensation Seeking). There was one control subject who showed an elevated V index, suggesting this subject may have been careless in completing the BASC-2 or uncooperative with the assessment process. This subject showed a reliable improvement on one composite (School Problems) and four subscales (Attitude to Teachers, Sensation Seeking, Atypicality, and Interpersonal Relations), as well as a reliable worsening on one subscale (Attention Problems). Table 17 shows the reliable worsening and reliable improvement for each subscale and composite at 3 months post-injury.

Table 15

Injured players with reliable worsening at 3 months post injury across the BASC-2 composites

Subject	SCH	INZ	INH	ESI	PER
3					
4					
10					
12					
16		↑			
28		↑	↑	↑	↓
29					
34					↓
38					
40					
45	↑				
54					
55					
59					
61					
64	↓				↓
66					
70					
76					↑

Note: SCH = School Problems, INZ = Internalizing Problems, INH = Inattention/Hyperactivity, ESI = Emotional Symptoms Index, PER = Personal Adjustment. For clinical composites (SCH, INZ, INH, ESI) '↑' = reliable worsening and '↓' = reliable improvement. For adaptive composites (PER), '↑' = reliable improvement and '↓' = reliable worsening. Subject number was randomly assigned to participants.

Table 16

Injured players with reliable worsening at 3 months post injury across the BASC-2 subscales

Subject	ATS	ATT	SEN	ATP	LOC	SOC	ANX	DEP	SIN	SOM	ATN	HYP	REL	INT	SEL	SRL
3	↓		↑	↓												
4	↑			↑		↓									↓	
10																↓
12	↑								↑	↓	↑					
16				↑	↑						↑					
28	↑			↑				↑	↑		↑	↑	↓	↓	↓	
29																↓
34																↓
38							↓				↑					
40	↑									↓						
45	↑					↑			↑		↑		↓			
54	↑		↑			↑						↑	↑			
55			↑	↓						↑						
59																↓
61	↑			↓	↓											
64				↓		↑						↓				
66			↑		↑			↑								↑
70	↑															
76	↓		↑										↑			↑

Note: ATS=Attitude to School, ATT= Attitude to Teachers, SEN= Sensation Seeking, ATP= Atypicality, LOC=Locus of Control, SOC= Social Stress, ANX= Anxiety, DEP= Depression, SIN= Sense of Inadequacy, SOM= Somatization, ATN= Attention Problems, HYP= Hyperactivity, REL= Relations with Parents, INT= Interpersonal Relations, SEL= Self Esteem, SRL= Self Reliance. For clinical subtests (ATS, ATT, SEN, ATP, LOC, SOC, ANX, DEP, SIN, SOM, ATN, HYP) '↑' = reliable worsening and '↓' = reliable improvement. For adaptive subtests (REL, INT, SEL, SRL), '↑' = reliable improvement and '↓' = reliable worsening. Subject number was randomly assigned to participants.

Table 17

Reliable worsening and reliable improvement using the RCI from baseline to 3 months post-injury separated by group.

Clinical Composites/Sub-Scales	Reliable Worsening, n (%)	Reliable improvement, n (%)
School Problems		
Injured (n = 57)	1 (1.8)	6 (10.5)
Control (n = 19)	0 (0.0)	2 (10.5)
Attitude to School		
Injured (n = 57)	8 (14.0)	5 (8.8)
Control (n = 19)	0 (0.0)	1 (5.3)
Attitude to Teacher		
Injured (n = 57)	0 (0.0)	1 (1.8)
Control (n = 19)	1 (5.3)	1 (5.3)
Sensation Seeking		
Injured (n = 57)	5 (8.8)	0 (0.0)
Control (n = 19)	0 (0.0)	2 (10.5)
Internalizing Problems		
Injured (n = 57)	2 (3.5)	1 (1.8)
Control (n = 19)	2 (10.5)	1 (5.3)
Atypicality		
Injured (n = 57)	3 (5.3)	8 (14.0)
Control (n = 19)	2 (10.5)	1 (5.3)
Locus of Control		
Injured (n = 57)	2 (3.5)	2 (3.5)
Control (n = 19)	0 (0.0)	3 (15.8)
Social Stress		
Injured (n = 57)	3 (5.3)	2 (3.5)
Control (n = 19)	1 (5.3)	0 (0.0)
Anxiety		
Injured (n = 57)	0 (0.0)	3 (5.3)
Control (n = 19)	0 (0.0)	2 (10.5)
Depression		
Injured (n = 57)	2 (3.5)	0 (0.0)
Control (n = 19)	2 (10.5)	0 (0.0)
Sense of Inadequacy		
Injured (n = 57)	3 (5.3)	7 (12.3)
Control (n = 19)	1 (5.3)	2 (10.5)
Somatization		
Injured (n = 57)	1 (1.8)	7 (12.3)
Control (n = 19)	1 (5.3)	0 (0.0)
Inattention/Hyperactivity		
Injured (n = 57)	1 (1.8)	3 (5.3)
Control (n = 19)	2 (10.5)	1 (5.3)

Table 17 (cont)

Attention Problems		
Injured (n = 57)	5 (8.8)	3 (5.3)
Control (n = 19)	2 (10.5)	1 (5.3)
Hyperactivity		
Injured (n = 57)	2 (3.5)	3 (5.3)
Control (n = 19)	1 (5.3)	1 (5.3)
Emotional Symptoms Index		
Injured (n = 57)	1 (1.8)	0 (0.0)
Control (n = 19)	1 (5.3)	1 (5.3)
Adaptive Composite/Sub-Scales	Reliable Worsening, n (%)	Reliable improvement, n (%)
Personal Adjustment		
Injured (n = 57)	3 (5.3)	3 (5.3)
Control (n = 19)	1 (5.3)	1 (5.3)
Relations with Parents		
Injured (n = 57)	2 (3.5)	2 (3.5)
Control (n = 19)	0 (0.0)	1 (5.3)
Interpersonal Relations		
Injured (n = 57)	1 (1.8)	0 (0.0)
Control (n = 19)	1 (5.3)	1 (5.3)
Self Esteem		
Injured (n = 57)	2 (3.5)	0 (0.0)
Control (n = 19)	1 (5.3)	0 (0.0)
Self Reliance		
Injured (n = 57)	4 (7.0)	9 (15.8)
Control (n = 19)	1 (5.3)	1 (5.3)

There was one concussed player with a pre-existing diagnosis of ADHD who showed a reliable worsening of symptoms at 7-10 days on three clinical subscales (hyperactivity, social stress, and attitude to teachers), two adaptive subscales (self reliance and interpersonal relations), and one adaptive composite (personal adjustment). This player did not show a reliable improvement at 7-10 days on any subscales or composites. At 3 months post-injury, this player showed a reliable worsening of symptoms on 4 clinical subscales (hyperactivity, social stress, sensation seeking, and attitude to school). This player showed a reliable improvement at 3 months post-injury on 1 adaptive subscale (relations with parents).

There were 3 concussed players with pre-existing diagnoses of LD. Of these, at 7-10 days post injury, 1 player showed no reliable worsening on any subscales or composites. This player showed a reliable improvement on 1 clinical composite (internalizing problems) and 3 clinical subscales (hyperactivity, anxiety, and social stress). At 3 months post injury, this player showed reliable improvement on 1 clinical composite (internalizing problems) and two clinical subscales (anxiety and sense of inadequacy). The second player with a previous diagnosis of LD showed a reliable improvement on 2 clinical subscales (attitude to school and atypicality) at 7-10 days post injury. They also showed a reliable improvement on two clinical subscales (attitude to school and atypicality) and one clinical composite (school problems) at three months post-injury. The third player with LD showed a reliable improvement at 3 months post-injury on 1 clinical subscale (attention problems) and 1 adaptive subscale (self-reliance). Table 18 shows reliable worsening and reliable improvement on the composites of the BASC-2 for each player with a previous diagnosis of ADHD or LD at 7-10 days post injury. Table 19 shows reliable worsening and reliable improvement on the composites of the BASC-2 for each player with a previous diagnosis of ADHD or LD at 3 months post injury.

There were 3 players who had 2 concussions. Of these, 1 player showed a reliable worsening at 3 months post-injury on 1 clinical subscale (sensation seeking). This player also showed a reliable improvement on 2 clinical subscales at 3 months post injury (attitude to school and atypicality). The second player did not show a reliable worsening or a reliable improvement on any subscales or composites at 7-10 days or 3 months post injury. The third player with multiple concussions showed a reliable improvement at 7-10 days in 2 clinical subscales (attitude to school and atypicality) as well as a reliable improvement at 3 months post injury in 2 clinical subscales (attitude to school and atypicality) and 1 clinical composite (school problems).

Table 18
Reliable change comparisons for athletes diagnosed with Attention Deficit/Hyperactivity Disorder (ADHD) or Learning Disability (LD) from baseline to 7-10 days post-injury on five BASC-2 Composites.

Subject	SCH	INZ	INH	ESI	PER
54					↓
1		↓			
18					
65					

Note: SCH = School Problems, INZ = Internalizing Problems, INH = Inattention/Hyperactivity, ESI = Emotional Symptoms Index, PER = Personal Adjustment. For clinical composites (SCH, INZ, INH, ESI) '↑' = reliable worsening and '↓' = reliable improvement. For adaptive composites (PER), '↑' = reliable improvement and '↓' = reliable worsening. Subject number was randomly assigned to participants.

Table 19
Reliable change comparisons for athletes diagnosed with Attention Deficit/Hyperactivity Disorder (ADHD) or Learning Disability (LD) from baseline to 3 months days post-injury on five BASC Composites.

Subject	SCH	INZ	INH	ESI	PER
54					
1		↓			
18	↓				
65					

Note: SCH = School Problems, INZ = Internalizing Problems, INH = Inattention/Hyperactivity, ESI = Emotional Symptoms Index, PER = Personal Adjustment. For clinical composites (SCH, INZ, INH, ESI) '↑' = reliable worsening and '↓' = reliable improvement. For adaptive composites (PER), '↑' = reliable improvement and '↓' = reliable worsening. Subject number was randomly assigned to participants for data analysis.

Of the 22 concussed players who showed a reliable worsening of symptoms across 1 or more BASC-2 subscales and composites from baseline to 7-10 days post injury, 9 (40.9%) did not show a reliable worsening of symptoms across any subscales and composites from baseline to 3 months. Of the 19 concussed players who showed a reliable worsening of symptoms across 1 or more BASC-2 subscales and composites at 3 months post injury, 6 (31.6%) did not show a reliable worsening of symptoms across any subscales and composites at 7-10 days post-injury. There were 13 (22.8%) concussed players who showed a reliable worsening of symptoms across 1 or more subscales or composites of the BASC-2 at both 7-10 days post-injury and 3 months. Table 20 highlights the number of BASC-2 composites and subscales that had reliable worsening at 7-10 days and 3 months post injury.

Table 20

Number of BASC-2 composites and subscales with reliable worsening at 7-10 days post injury and 3 months post injury

Subject	7-10 Days	3 Months
4	1	3
12	2	3
16	1	4
28	4	13
29	1	1
34	11	2
45	9	6
54	6	4
59	4	1
61	2	1
64	3	2
66	2	3
76	1	1

Note: Subject number was randomly assigned to participants.

Discussion

It is known that the pediatric brain is more susceptible to the effects of concussion, responds differently to injury, and takes longer to recover in comparison to an adult brain (Field et al., 2003; Gordon, 2006; Gordon, Dooley, & Wood, 2006; Purcell, 2009). Concussion can lead to adverse long term consequences which may affect a child or adolescents' cognitive, social, and emotional development (McKinlay et al., 2002; McKinlay et al., 2009; Yeates, 2010). These long term effects have the potential to significantly impact an individuals' functioning at home, in the classroom, and in a social setting (McKinlay et al., 2002; Yeates, 2010). Although concussion in sport has received increased awareness over the last decade as research continues to draw attention to the major health implications and the long ranging effects of this injury in professional athletes, there remains a paucity of research examining psychosocial outcomes of concussion in adolescents (Solomon et al., 2006; Stern et al., 2011). The current study examined the social, emotional, and behavioral outcomes of elite youth ice hockey players in a group of concussed players as well as in a group of healthy control participants. The intention of this research was to increase knowledge about psychosocial outcomes of sport related concussion in an adolescent population in order to facilitate future prevention and intervention strategies for youth athletes. This is the first study to examine psychosocial outcomes following concussion in adolescent athletes.

Changes at the Group Level

The results of the first analysis which examined group changes in psychological functioning across three time periods (baseline, seven to ten days post injury, and three months post injury) in a group of youth ice hockey players with concussion and a group of healthy control participants showed no significant findings. That is, athletes in the concussed group were similar to the athletes in the non-injured control group on the five composites (School Problems, Internalizing Problems, Inattention/Hyperactivity, Emotional Symptoms Index, and Personal Adjustment) and 16 subscales (Attitude to School, Attitude to Teachers, Sensation Seeking, Atypicality, Locus of Control, Social Stress, Anxiety, Depression, Sense of Inadequacy, Somatization, Attention Problems, Hyperactivity, Relations with Parents, Interpersonal Relations, Self-Esteem, and Self-Reliance) of the BASC-2 psychological measure. Furthermore, athletes social, emotional, and behavioral functioning was stable over the follow up period, as no significant changes were seen to occur between the time the athletes filled out the BASC-2 questionnaire at baseline (prior to injury) compared to seven to ten days post injury and three months post injury. Additionally, athletes scores on the BASC-2 measure at baseline (prior to the start of their competitive seasons) were not significantly different between the injured group and the control group in all composites and sub-scales with the exception of the School Problems composite. This indicates that athletes' level of psychological functioning was comparable prior to injury. Stated differently, there is no evidence to suggest that the two groups of athletes (injured vs non-injured) were different premorbidly.

There has been no previous research that has explored the psychosocial outcomes of concussion in youth athletes specifically, however, there is previous research examining psychological functioning with children after mTBI. Until recently, concussion was classified under the broader term of mTBI, which encompasses head injury of varying severity. It is difficult to compare previous research findings to the current study, as most research conducted on this topic has used the mTBI injury classification system, which is not specific to sport concussion and likely includes injuries on the more severe end of the mild spectrum. However, in previous research which has examined psychosocial outcomes after mTBI in children, adverse outcomes have been reported (Andrews et al., 1998; Bloom et al., 2001; Casey et al., 1986; Colantonio et al., 1998; Greenspan & MacKenzie, 1994; Levin et al., 2007; Massagli et al., 2004; Max, Lindgren, Knutson et al., 1997; McKinlay et al., 2002; McKinlay et al., 2009; Mittenberg et al., 1997; Segalowitz & Lawson, 1995), however, not by all studies (Barker-Collo, 2007; Bijur et al., 1996; Carroll, Cassidy, Holm, Kraus, Coronado, & WHO Collaborating Centre Task Force on Mild Traumatic Brain,Injury et al., 2004; Carroll, Cassidy, Holm, Kraus, Coronado, & WHO Collaborating Centre Task Force on Mild Traumatic Brain,Injury, 2004; Carroll, Cassidy, Peloso et al., 2004; Fletcher et al., 1990; Fletcher et al., 1996; Kinsella et al., 1999; Light et al., Ponsford et al., 1999). The incongruent findings on the long term effects of mTBI in a pediatric population are likely due to methodological differences and limitations across studies (McKinlay et al., 2002). Satz (1997) conducted a review on research conducted on the psychosocial outcomes after mTBI and reported on the numerous methodological limitations found in this area of research. Specifically, it was noted that many studies conducted on this topic did not include: a) inclusion of control groups, b) use of a longitudinal design with follow-up assessment after the injury, c) clear definition of mild injury d) inclusion of at least 20 children with mild head injury, e) use of standardized tests to measure outcomes and, f) control for pre-injury risk factors (Satz et al., 1997). The present findings should be considered in relation to previous research in this field however, with an understanding of the methodological weaknesses that may be present in earlier studies.

The current study aspired to meet the methodological shortcomings addressed by Satz (1997) in order to provide a more rigorous evaluation of the social, emotional, and behavioral outcomes after concussion as well as to make it generalizable to other youth athlete groups. First, this study employed an appropriate control group that was similar to the injured players with respect to demographic features (e.g., age, sex, educational background, general social background, and competitive level of hockey). Although the control group did not include players with other body injuries, players were screened for pre-injury risk factors and excluded if they reported a recent head injury (within 30 days of the study start date) or any previous medical or psychological conditions. Furthermore, the current study prospectively collected data at baseline (pre-injury) on the social, emotional, and behavioral functioning of athletes, eliminating the possibility of injury related biases. Previous studies have often collected pre-injury behavior information after an injury has occurred. However, it is unlikely that the information collected post-injury has been uninfluenced by the injury itself, at least in some way. Furthermore, it is known that there are inaccuracies in parents' retrospective reports of a child's medical and developmental history (McKinlay, 2010).

Many previous studies have used a broad definition of mTBI resulting in study samples that include more severe injuries (Gronwall, Wrightson, & McGinn, 1997; Satz et al., 1997). The current study used the definition of concussion established by the CISG (McCrory et al., 2013). Each injured player was assessed by a sports medicine specialist to ensure that injuries more severe than concussion were not included in this study. Specifically, those individuals who were admitted to the hospital or demonstrated radiological findings on imaging tests such as CT or MRI were not included. The strict diagnostic criteria of concussion used in this study set it apart from other research, as many previous studies have failed to differentiate different injury types (Yeates & Taylor, 2005).

This study used a widely established, norm-referenced diagnostic tool (BASC-2) to evaluate the psychological functioning of youth athletes. The BASC-2 is a standardized tool which has strong psychometric properties and is widely used by practicing psychologists. It is known to provide an accurate indication of behavioral problems in children as well as for predicting future social, emotional, and behavioral adjustment. Despite using a comprehensive psychological assessment tool such as the BASC-2, there was no change identified across any of the five composites or 16 subscales between groups (concussed vs control) or across time (baseline, seven to ten days, and three months).

Previous research has reported increased behavioral difficulties (Andrews et al., 1998; Casey et al., 1986; Greenspan & MacKenzie, 1994), such as hyperactivity (Bloom et al., 2001; Greenspan & MacKenzie, 1994; Levin et al., 2007; Massagli et al., 2004; McKinlay et al., 2002; Segalowitz & Lawson, 1995), aggressive and antisocial behaviors (Andrews et al., 1998; Max, Lindgren, Knutson et al., 1997; McKinlay et al., 2002; McKinlay et al., 2002), discipline problems (Casey et al., 1986; McKinlay et al., 2002; McKinlay et al., 2009), and sleep disturbances (Casey et al., 1986; Segalowitz & Lawson, 1995). Mental health concerns have also been reported, with mTBI patients reporting overall lower self-esteem and adaptive functioning, (Andrews et al., 1998; Colantonio et al., 1998), and higher levels of loneliness (Andrews et al., 1998), anxiety (Mittenberg et al., 1997), and depression (Bloom et al., 2001; Massagli et al., 2004; Segalowitz & Lawson, 1995). In the current study, the social, emotional, and behavioral functioning of youth athletes remained relatively stable across the duration of the study.

Although the results from this study are in contrast to the findings from abovementioned studies, it is important to recognize that the individuals studied here were a unique subset of the general youth population. This is the first study, to our knowledge, to investigate the psychosocial outcome after concussion in a group of elite youth ice hockey players. Elite youth athletes are generally highly motivated to recover from injury in order to get back into sport (Echemendia et al., 2001). Furthermore, elite youth athletes show overall better physical and mental health compared to youth not involved in sport (Fox, 1999). In fact, research has shown that physical activity and sport participation is associated with improved psychological functioning (Fox, 1999; Stathopoulou, Powers, Berry, Smits, & Otto, May 2006; Warburton, Nicol, & Bredin, 2006). For example, it has been found that youth who participate in regular physical activity have improved mood, self-esteem, and self-efficacy (Fox, 1999; Stathopoulou et al., May 2006; Warburton et al., 2006). Sport participation has also been found to be important in fulfilling basic psychological needs for youth including, competence, autonomy, and relatedness (Deci & Ryan, 2008). It is possible that the results of this study differ from previous research on psychosocial outcomes following mTBI because of the unique characteristics of the elite youth athletes that were studied.

Another possible explanation for these unexpected findings is that many athletes' motivation to continue playing after injury may cause them to minimize areas of difficulty (Bruce & Echemendia, 2004; Covassin, Swanik, & Sachs, 2003; Delaney et al., 2000; Meehan & Bachur, 2009; Purcell & Carson, 2008). Adolescent athletes are greatly influenced by their peers and participating in sport is often an important part of their identity and social acceptance. Therefore, athletes may be reluctant to volunteer information about their social, emotional, and behavioral functioning because they do not want to judged negatively or be perceived as weak by their teammates or coaches (Delaney et al., 2000; Field et al., 2003; Meehan & Bachur, 2009). Previous research has found that athletes, at all levels of competition under-report symptoms of concussion (Delaney et al., 2000; Field et al., 2003; Van Kampen et al., 2006). The BASC-2 is a psychological questionnaire that relied on the subjective reporting of symptoms by the athletes. Athletes completed the BASC-2 questionnaire at baseline in a group setting, which may have increased the desire for athletes to minimize their difficulties in order to provide the most favorable impression to their coaches and peers. The BASC-2 has numerous validity scales that are used to detect those individuals who may respond to items in a way that is either: inconsistent, overly positive, or overly negative. Although the validity scales were used to detect those athletes who may have had a guarded response style, it is still possible that the athletes in this study were able to deny any difficulties in order to appear 'normal'.

Research in this field has also criticized studies that use standardized tools that may not be sensitive enough to detect the subtle deficits present after concussion (McKinlay et al., 2002; McKinlay et al., 2009). This is the first study that has been conducted on psychosocial outcomes after concussion in youth using the BASC-2 measure. Although, there is researching documenting its clinical utility with a general adolescent population, there have not been any studies looking at its utility with injured elite youth athletes specifically. It is possible that the BASC-2 was not able to detect the more subtle deficits that may occur after concussion, as the BASC-2 was not developed specifically for this purpose.

Changes at the Individual Level

The results from the first part of this study were generated from data analyzed at the group level. Although this approach has predominated in the literature, it obscures the significant individual variability that is known to exist among athletes after concussion (Echemendia et al., 2001; G. L. Iverson, Brooks, Collins et al., 2006). Research shows that concussion results in signs and symptoms that are different for each individual. For example, while some may report memory difficulties and problems learning following concussion, others may only have physiological complaints (Echemendia et al., 2001; G. L. Iverson et al., 2003). Additionally, while most athletes recover spontaneously within a few days (Makdissi et al., 2010), others may take substantially longer (Iverson et al., 2003). Former concussion management guidelines used to be based on arbitrary exclusion policies whereby concussed athletes were removed from play for a fixed period of time. Today, concussion management guidelines utilize an individualized approach to assessment, recognizing that recovery trajectories vary from individual to individual (McCrory et al., 2013). Individualized assessment is vital to the management of the pediatric athlete after concussion to ensure that a full recovery has been made before the athlete returns back to sport (Halstead et al., 2010; Purcell, 2009). Individualized assessment typically involves evaluating not only post-concussion symptoms but also cognitive functioning using neuropsychological test batteries(Van Kampen et al., 2006). With an individualized approach to concussion management, data analysis at the group level becomes more trivial. The RCI is a statistical approach which has allowed clinicians to determine both the statistical and clinical significance of individual change overtime (Temkin, Heaton, Grant, & Dikmen, 1999). That is, does a difference in test performance across time signify real change in the individual or just chance variation (Temkin et al., 1999)? The RCI has been used in many types of health research including clinical psychology (Hageman & Arrindell, 1993; N. S. Jacobson, Roberts, Berns, & McGlinchey, Jun 1999; N. S. Jacobson & Revenstorf, 1988; D. C. Speer & Greenbaum, 1995; D. C. Speer, Jun 1992), clinical neuropsychology (Chelune, Naugle, Luders, Sedlak, & Awad, Jan 1993; Heaton et al., 2001; G. L. Iverson, 1998; Temkin et al., 1999), and sports neuropsychology (Barr & McCrea, Sep 2001; Hinton-Bayre et al., 1999). Specifically, in regards to concussion, the RCI is used regularly to assist clinicians in making safe return to play decisions for athletes on an individualized basis.

The RCI was used in this study to determine whether there was statistical change at the individual level on the BASC-2 composites and subscales across three different time periods (baseline, seven to ten days, and three months post injury). The RCI was calculated using a modified version of the Jacobson & Truax formula (Jacobson & Truax, 1991). As noted in the previous chapter, at the first post-injury assessment interval, 22 (38.6%) of injured athletes and 7 (36.8%) of control participants showed a reliable worsening of symptoms across one of more of the BASC-2 composites and subscales. However, of the participants who demonstrated a statistically reliable worsening of scores, there were fewer participants whose scores reached levels that would be considered clinically relevant by a psychologist. In order to establish whether a score is clinically relevant, the BASC-2 normative data is used to determine an individuals' psychological functioning relative to a norm reference group. Specifically, a score is classified as 'At-Risk' if it falls between one and two standard deviations from the mean. Composites or subscales that fall within the At-Risk range signify that difficulties are present and careful monitoring is required. A score is classified as 'Clinically Significant' if it is two or more standard deviations from the mean. Clinically significant denotes a high level of maladaptive behavior and/or the absence of adaptive behavior. Clinically significant scores often lead to formal diagnosis and treatment by a psychologist.

In this study, while it is important to take note of which players showed a reliable worsening of scores using the RCI, it is also important to consider how many players' scores were also clinically relevant (i.e., falling into the At-Risk or Clinically Significant range). At the first post-injury assessment interval (7-10 days), there were only nine injured players (15.8%) who showed reliable worsening as well as clinically significant scores. There were two (10.5%) control participants who also showed reliable worsening and clinically relevant scores at the first post-injury assessment interval (7-10 days). More specifically, the BASC-2 composites and subscales that were identified as being areas of difficulty for concussed players included: School Problems, Attitude to School, Attitude to Teacher, Sense of Inadequacy, Somatization, Inattention/Hyperactivity, Hyperactivity, Relations with Parents, Self Esteem, and Self Reliance. Hyperactivity was the subscale that showed the greatest number of concussed players (5.3%) with difficulties in this area. All others composites and subscales showed only one (1.8%) or two (3.5%) players with both statistically and clinically significant findings.

Previous research has shown that some individuals show an increase in hyperactivity following mTBI (Bloom et al., 2001; Greenspan & MacKenzie, 1994; Levin et al., 2007; Massagli et al., 2004; McKinlay et al., 2002; Segalowitz & Lawson, 1995). Our research shows that in elite youth ice hockey players, hyperactivity may be a problematic area for some athletes following concussion. At the first post-injury assessment interval (seven to ten days post injury), 5.4% of our injured sample showed scores in the hyperactivity domain that were both statistically significant as well as clinically relevant. These players' scores fell within the At-Risk classification range and were statistically different from their scores at baseline. Of the three players who showed difficulties in this domain at the first post injury assessment interval, two (3.5%) continued to show statistically and clinically relevant scores at the second post-injury assessment interval (three months post injury). However, it is important to note that one of the players who showed an increase in hyperactivity at both assessment intervals had a previous diagnosis of ADHD. These findings suggest that for a small number of elite youth athletes, hyperactivity may be an area of concern following concussion and youth athletes with a history of ADHD may also be particularly prone to difficulties in this area.

At the second post-injury assessment interval, 19 (33.3%) of injured athletes and 8 (42.1%) of control participants showed a reliable worsening of symptoms across one of more of the BASC-2 composites and subscales. However, there were only nine injured players (15.8%) who showed both reliable worsening as well as clinically relevant scores. There were three (15.8%) control participants who also showed reliable worsening and clinically relevant scores. More specifically, the BASC-2 composites and subscales that were identified as being areas of difficulty for concussed players at the second assessment interval (three months post injury) included: Attitude to School, Sensation Seeking, School Problems, Atypicality, Locus of Control, Social Stress, Depression, Sense of Inadequacy, Internalizing Problems, Attention Problems, Hyperactivity, Inattention/Hyperactivity, Emotional Symptoms Index, Relations with Parents, Self Reliance, and Personal Adjustment. Attitude to School and Sensation Seeking were the two subscales that had the greatest number of concussed players (three (5.3%) and four

(7.0%), respectively) with difficulties in this area. All others composites and subscales had only one (1.8%) or two (3.5%) players with both statistically and clinically significant findings.

It is possible that an increase in the Attitude to School domain was observed merely due to the fact that athletes completed the BASC-2 questionnaire at baseline, prior to, or at the very beginning of their academic year. Athletes were starting back to school fresh after summer break and just beginning with new teachers, new classmates, and new subject material. It is possible the athletes rated these items more favorably at baseline because they were not feeling the pressure of exams and assignments. In contrast, at the second post-injury assessment interval, athletes would have likely been in the middle of their academic year and facing more stresses. As for the Sensation Seeking domain, it is possible that participant's scores fell into the clinically relevant range as elite athletes are likely to be individuals who engage in more risk taking behaviors compared to those in the normative sample. Elite athletes are exposed to risky and novel experiences frequently as a result of being in competitive sports. These experiences may differentiate elite athletes from others not involved in competitive sport in the domain of Sensation Seeking. It is difficult to comment on whether Sensation Seeking behavior is observed to be higher in a group of concussed athletes in relation to an injury, or whether their scores fall within the clinically relevant range because they are a unique subset of the general adolescent population.

Overall, looking at the findings as a whole, there were slightly more concussed athletes (15.8%) with both reliable worsening and clinically meaningful scores on the BASC-2 compared to control participants (10.5%) at the first post-injury assessment interval (seven to ten days). However, at the second post-injury assessment interval (three months), there was no difference, as 15.8% of concussed athletes and 15.8% of control participants showed both reliable worsening and clinically meaningful scores on the BASC-2.

An important consideration when reviewing the results from the RCI analysis in this study is the issue of social desirability. Social desirability is the inclination for an individual to respond to questions in a favorable manner in order to be viewed positively by others (Holtgraves, 2004). As previously mentioned, the participants of this study completed the BASC-2 questionnaire prior to the start of their competitive seasons in a group setting. That is, although they completed the self-report questionnaires independently, they were surrounded by their teammates, coaches, and other study personnel. Additionally, in some cases, at the time of baseline testing, teams were still making decisions about player eligibility. It is possible that the athletes responded to the questions on the BASC-2 in a more favorable way at baseline compared to the first and second assessment intervals when they were not surrounded by their teammates and coaches and they were not feeling pressure about being selected for the team. A closer look at the data shows that at the first post-injury assessment interval, of the 22 injured players who had a reliable worsening of scores, eight (36.4%) athletes had at least one BASC-2 domain that was rated to be in the low range for the clinical scales or in the high range for the adaptive scales at baseline. Scores that fall into these ranges indicate higher levels of functioning compared to the average. There were also four (57.1%) control participants who had at least one BASC-2 domain that was rated to be in the low range for the clinical scales or in the high range for the adaptive scales at baseline. Additionally, at the second post-injury assessment interval, of the 19 injured players who had a reliable worsening of scores, nine (47.4%) athletes had at least one BASC-2 domain that was rated to be in the low range for the clinical scales or in the high range for the adaptive scales at baseline. There were also three (37.5%) control participants who had at least one BASC-2 domain that was rated to be in the low range for the clinical scales or in the high range for the adaptive scales at baseline. These findings suggest that athletes were eager to respond to the BASC-2 questionnaire at baseline in a way that would be viewed favorably by others. Players may have been nervous about appearing weak, especially at the start of their competitive season. It is also possible players responded favorably to items on the BASC-2 while decisions were still being made about team composition and structure. Taking this into account, reliable worsening may actually be attributed to the fact that athletes were more inclined to respond favorably at baseline compared to the other post-injury assessment intervals.

It is difficult to determine precisely those players who may have responded in a socially desirable way at baseline, thus elevating the percentage of players who show a reliable worsening of BASC-2 scores over time. However, previous research has found that there are inherent challenges using clinical information from athletes as they do not always give an accurate report of their difficulties (McCrea, 2001; Van Kampen et al., 2006). Furthermore, the under-reporting of concussion symptoms is a phenomenon that has been documented at all levels of athletic competition (Van Kampen et al., 2006). Thus, it remains an important consideration when reviewing the findings of this study.

There was a subset of participants who showed reliable worsening across one or more BASC-2 composites and subscales at both post-injury assessment intervals. In the concussed group, there were 13 (22.8%) players who showed worsening of symptoms at seven to ten days post injury as well as at three months post injury. In the control group, there were five (26.3%) players who showed worsening of symptoms across one or more subscales and composites of the

BASC-2 at both follow up assessment intervals. Although there were players who showed reliable worsening in BASC-2 domains at both assessment intervals, many of the elevated domains were not considered clinically relevant. That is, although they were statistically different from baseline ratings, they still fell within the average range of functioning compared to the normative sample. Furthermore, many of the domains that showed a statistically significant result using the RCI were observed to have been in the low or high range at baseline, suggesting the possibility of underreporting at baseline.

Clinical Implications

The results of the current study have important clinical implications for professionals who diagnose and treat youth athletes following concussion. First, psychological functioning should be considered as part of the standard evaluation process following head injury in youth athletes. Research shows that in some athletes, mental health issues can be a long term consequence of injury (McCrory et al., 2013). It is also known that early intervention for psychological concerns is vital to avoid longer term problems. Although the results from the group analysis of the current study show no differences in psychological functioning between concussed athletes and healthy controls, data at the individual level show that a small percentage of concussed athletes have statistically and clinically significant changes from baseline to post-injury functioning. These results are of note because they signify that psychological difficulties may be present or they may have the potential of developing into something more significant.

However, there are factors that complicate the interpretation of mental health functioning following concussion that clinicians must keep in mind. First, the issue of underreporting of symptoms in injured athletes is important. In the current study, some athletes rated themselves to be within the low or high range of functioning on clinical and adaptive scales at baseline, which could indicate either underreporting or socially desirable responding. In these athletes, significant change on the BASC-2 could be related to underreporting at baseline rather than change from an injury. Additionally, although there may be statistically significant changes across scores from baseline to post-injury assessment, clinicians must also determine whether the scores are clinically relevant. That is, how do these scores compare to a normative sample and are they high/low enough to signify that clinical intervention is necessary? Second, clinicians should pay attention to those athletes who demonstrate both statistically and clinically significant change across domains at numerous time periods. It is possible that these players have the potential of developing more significant psychological difficulties compared to those athletes who only show transient change.

In the management of an injury that has potential deleterious effects on a youth brain, a conservative approach to concussion assessment should be adopted. This is the first study to examine psychosocial functioning after concussion in sport in a group of elite youth ice hockey players. Although the findings are promising in suggesting a favorable psychological outcome for youth athletes after concussion, it is still important for clinicians to evaluate and monitor psychological functioning after injury, as a small percentage of athletes may develop ongoing psychological concerns requiring intervention.

Limitations and Future Direction

There are a few limitations that should be considered in this study. To begin, it should be noted that the data in this study were collected on male hockey players between the ages 13-17 within Alberta, Canada. The results, therefore, may not be generalizable to other athletes in different sports, different age groups, or different skill levels. Furthermore, it may not be generalizable to other athlete populations outside of Alberta. Future research should consider looking at the psychosocial outcomes of concussion in other youth athlete populations.

The BASC-2 is a psychological assessment tool that has never been used with concussed youth athletes in particular. Therefore, the items on this questionnaire are not specific to concussive injuries. Furthermore, the BASC-2 is a lengthy questionnaire with many of the items specifically designed to capture pathological behaviors and attitudes that may not pertain to an otherwise healthy sample. Normative values for the BASC-2 were taken from the test manual that was standardized on youth from the United States of America. It is possible that Canadian BASC-2 population results could be different. Future research may consider studying the psychosocial outcome of concussion in youth athletes using both a standardized psychological questionnaire in addition to a structured interview. This would allow researchers to obtain more information in regards to areas that appear to be problematic following concussion. It is possible other contributing factors led to an increase in problem behaviors for injured athletes and this information is impossible to obtain strictly from a self-report questionnaire.

Another limitation of this study may be the motivation of the athlete when completing the BASC-2. It has been established in the literature that athletes may purposefully try to lower their test scores at baseline so that they can return to play as soon as possible following concussion (Covassin, Elbin, Stiller-Ostrowski, & Kontos, 2009; Makdissi et al., 2001). Although the BASC-2 has validity scales that are sensitive to positive or negative response sets, the motivation of the athlete to complete the questionnaire as accurately as possible is unknown. Furthermore, athletes completed the baseline BASC-2 in a group environment where they were more likely to be distracted by their peers. It is unknown what effect this testing environment could have on the athlete's responses. Future research should consider collecting parent and teacher reports of social, emotional, and behavioral difficulties in youth following concussion. Since it is well documented that athletes underreport difficulties after concussion, having parent and/or teacher ratings of psychological functioning would provide more objective information on levels of functioning as well as provide insight into areas that may be problematic for the athlete. Furthermore, it is possible that teachers may provide a better indication of youth athlete functioning after injury as the subtle deficits of concussions are likely more noticeable in a structured learning environment. Furthermore, future research may consider collecting baseline data on an individualized basis rather than in a group setting, as it is uncertain the effect this had on the accuracy of athlete responses.

The amount of complete data collected reduced the overall sample size of the study. Therefore the small sample size is a limitation that may have reduced the ability to detect a significant difference between the injured players and matched controls.

Selection bias is also possible as the study sample relied on injured players to attend medical appointments to obtain a concussion diagnosis and complete study questionnaires. It is possible that some players may have been less motivated than others to seek medical attention. This may have led to a study sample based on convenience, as data was only collected on players who showed up for their medical appointments.

Conclusion

Youth athletes are particularly important to study because not only are they are at a unique stage of development, but they are also faced with many academic and social pressures (Colantonio et al., 1998). In comparison to adults, concussed youth often have the added challenges of keeping up to a fast-paced academic curriculum, a busy school environment, and socially with their peers (Colantonio et al., 1998). In some cases, concussed youth may miss school for extended periods of time, putting them behind in their studies and isolating them from their peer group. This has the potential of negatively impacting their self esteem, independence, and overall mental health functioning (Colantonio et al., 1998). This study is the first to examine the psychosocial outcomes of concussion in elite youth athletes.

Overall, the results from this study suggest a favorable psychological outcome after concussion in elite youth ice hockey players. Specifically, at a group level, concussed athletes appear no different than healthy controls in regards to their psychological functioning on the BASC-2 questionnaire. At the individual level, a small percentage (5.3%) of athletes showed an increase in symptoms related to hyperactivity at an initial post-injury assessment interval, and only 3.5% of athletes continued to show these difficulties at three months post-injury. Although a small percentage of elite youth athletes may develop psychological difficulties after concussion, it remains an important component to evaluate as research shows that the best outcome occurs when intervention is applied early. Additional research with a larger sample size, a more diverse athlete group, and data obtained from parents and teachers will provide more insight into the psychosocial outcomes of concussion on adolescents.

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Appendix A: Information Sheet

Letter of Invitation: Elite Youth Ice Hockey Concussion Study

Dear coaches, players and parents,

This is an invitation to participate in an upcoming Ice Hockey Concussion Study that will begin in the fall of 2011 and run throughout the 2011-2012 season. Please find a brief description of the study below.

Background and Purpose:

Concussions are the most common injury type in elite youth ice hockey. Concussions can lead to longer term sequelae including prolonged symptoms (i.e. headache, dizziness, neck pain) and neurocognitive deficits. **The primary purpose of this study is to evaluate two** neurocognitive **tools** (SCAT2 and ImPACT computerized neurocognitive test) in the assessment of neurocognitive function (i.e. reaction time, memory, concentration, attention and processing speed) both **pre-season and following concussion**. The SCAT2 is a standardized evaluation of concussion used on the bench and in clinical return-to-play decisions in elite levels of play (i.e. major junior, NHL). The validity of the SCAT2 and the added value of the ImPACT in return to play decisions in youth elite ice hockey is unknown. This study will evaluate the validity of baseline neurocognitive testing (i.e. SCAT2 and ImPACT) and examine the utility of these tools in medical return to play decisions and in predicting prolonged recovery from concussion.

What is involved?

Baseline Testing:

We will recruit 30 teams from Bantam and Midget AAA and AA Quadrant Hockey and Female AAA Bantam and Midget in Calgary (and 10 teams in Edmonton). Pre-season testing will be completed at the Sport medicine Centre, University of Calgary or at the Glen Sather Clinic, University of Alberta in September 2011. This will provide a baseline to evaluate neurocognitive changes that may occur following a concussion and throughout recovery. This testing is not the current standard of practice in elite youth ice hockey but more typical in elite adult leagues (i.e. major junior, NHL). Baseline testing will take approximately 90 minutes.

Before baseline testing, there will be an information package sent home that includes a consent form, a preseason medical questionnaire and a behavioral questionnaire. On the day of testing, each participant will complete the SCAT2 (which is completed with a research assistant and an iPad) and one ImPACT test on a computer. Each participant will also be wearing a heart rate monitor (to monitor fluctuations in heart rate that occur during the session) and will do tests of neck and balance function. These measures will allow for evaluation of changes that occur following concussion, many of which have not been evaluated in youth ice hockey players previously.

During the season:

During the season, if the team trainers suspects a player has sustained a concussion, they will have the opportunity to follow-up with the study sport medicine physician at the Sport Medicine Centre at the University of Calgary or at the Glen Sather Clinic at the University of Alberta within a week following the injury. At this time, the player will also repeat the baseline tests. Athletes will be assessed weekly until return to play and at three months following concussion. The same measures will be repeated at each visit.

Why do this study?

This research is important when one considers the potential for concussion in elite youth ice hockey and the large numbers of youth participating. The preseason measures will facilitate assessment of changes that may occur following a concussion and allow monitoring of recovery. This will help develop a greater understanding of concussion outcomes in youth ice hockey players and inform the development of standard of care assessment and treatment guidelines.

We hope that you will consider participating in this study and look forward to working with you and your team during the season.

For more information, please contact:

Dr. Carolyn Emery

Sport Injury Prevention Research Centre

University of Calgary

(403) 220.4608

Appendix B: Consent Form

CONSENT FORM

TITLE: Elite Youth Ice Hockey Concussion Study

INVESTIGATORS:

Principal Investigator: Dr. Carolyn Emery, University of Calgary

Co-Investigators (University of Calgary): Dr. Willem Meeuwisse, Dr. Brian Brooks, Dr. Karen Barlow, Kathryn Schneider, Tracy Blake, Kirsten Taylor

Co-Investigators (University of Alberta): Dr. Martin Mrazik, Dr. Connie Lebrun, Andrea Krol

This consent form is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. For further details about this study, or to have your questions addressed please contact us. Please take the time to read this carefully and to understand any accompanying information. If you choose to participate, please keep your copy of this form and return the study copy (signed and witnessed) to your team designate.

<u>BACKGROUND</u>

Concussions are the most common injury type in elite youth ice hockey. Concussions can lead to long-term sequelae including prolonged symptoms (i.e. headache, dizziness, neck pain) and neurocognitive deficits. The SCAT2 is a standardized evaluation of concussion used on the bench and in clinical return-to-play decisions in elite levels of play (i.e. major junior, NHL). The validity of the SCAT2 and the added value of the ImPACT in return to play decisions in youth elite ice hockey is unknown. This study will evaluate the validity of baseline neurocognitive testing (i.e. SCAT2 and ImPACT) and examine the utility of these tools in medical return to play decisions and in predicting prolonged recovery from concussion.

In addition to neurocognitive changes that may occur with concussion, we will also be looking at other changes to functions in the body that may occur with concussion. These include changes in heart rate and heart rate variability, changes in neck function and balance, and behavioural changes.

Measuring Heart Rate (HR) and HR variability (the time between heartbeats) have been shown to be a non-invasive way of measuring the ability of the nervous system to regulate the function of the heart and cardiac system. HR and HRV have been shown to change depending on age and sex, and depending on the training or exercise capacity of the individual. They have also been shown to change after an individual has sustained a concussion. There is very little information looking at HR and HRV in a pediatric population in general, and none examining the changes they undergo after a concussion in athletes under 18 years old.

Balance problems and dizziness are commonly reported following concussions. The inner ear is a primary contributor to balance and is important to enable clear vision when the head is moving quickly (dynamic visual acuity). Little is currently known about changes in dynamic visual acuity (DVA) that may occur following a concussion Baseline values for dynamic visual acuity in youth ice hockey players are not currently known. Headaches and neck pain are also commonly reported following a concussion and may occur secondary to injury to the neck. Alterations in clinical tests for the vestibular system and cervical spine may occur following a concussion. Baseline and follow-up evaluation of commonly used neck and vestibular tests will be included as part of this study.

Behavioral, emotional and social changes have also been shown to occur after concussion in some individuals. We will be using a behavioural questionnaire to assess for any changes before and after concussion. Currently there is little research that has been conducted in this area.

A number of Alberta Bantam, Minor Midget and Midget Hockey Teams have agreed to take part in this research project. We would like to invite your child to participate. Your child's team has been randomly selected to participate in this survey. There are expected to be more than 1000 hockey players in this study.

WHAT IS THE PURPOSE OF THE STUDY?

The primary purpose of this study is to evaluate two neurocognitive tools (SCAT2 and ImPACT computerized neurocognitive test) in the assessment of neurocognitive function (i.e. reaction time, memory, concentration, attention and processing speed) both during the pre-season and following a concussion.

WHAT WOULD MY CHILD HAVE TO DO?

We will be recruiting 30 teams in Calgary (and 12 teams in Edmonton) from Bantam and Midget AAA and AA Quadrant Hockey and Female AAA Bantam and Midget. Pre-season testing will be completed at the Sport medicine Centre, University of Calgary as well as in the Glen Sather Sports Clinic, University of Alberta in September 2011. Testing will occur after team rosters have been finalized but before regular season games begin. This will provide a baseline to evaluate neurocognitive changes that may occur following a concussion and throughout recovery. This testing is not the current standard of practice in elite youth ice hockey but more typical in elite adult leagues (i.e. major junior, NHL). Baseline testing will take approximately 90 minutes.

Before baseline testing, there will be an information package sent home that includes a consent form, a preseason medical questionnaire and a behavioural questionnaire. On the day of testing, each participant will complete the SCAT2 (which is completed with a research assistant on an iPad) and one ImPACT test on a computer. Each participant will also be wearing a heart rate monitor (to monitor fluctuations in heart rate that occur during the session) and will do tests of neck function and balance. These measures will allow researchers to evaluate changes that occur following concussion, many of which have not been evaluated in youth ice hockey players previously.

During the season:

During the season, if a team trainer suspects that a player has sustained a concussion, they will have the opportunity to follow-up with the study sport medicine physician at the Sport Medicine Centre at the University of Calgary or at the Glen Sather Clinic at the University of Alberta within a week following the injury. At this time, the player will also repeat the baseline tests. Athletes will be assessed weekly until return to play and at three months following concussion. The same measures will be repeated at each visit.

ARE THERE ANY BENEFITS FOR MY CHILD?

If you agree to participate in this study there may or may not be a direct medical benefit to your child. His/her injury risk may be decreased during the study but there is no guarantee that this research will help him/her. If your child experiences a sports injury during the study duration, the team therapist (who will be attending every practice and game) will be assessing for injuries and making recommendations for follow-up treatment. The information we get from this study may help us to provide better sport injury prevention in future adolescent sport activities.

DOES MY CHILD HAVE TO PARTICIPATE?

No, your child does not have to participate.

WILL THERE BE FINANCIAL COMPENSATION, OR WILL THERE BE COSTS FOR THE PARTICIPANT?

There will be no financial compensation to the child or costs to the child as a participant in this study.

WILL MY CHILD'S RECORDS BE KEPT PRIVATE?

All of the information collected from the survey will be anonymous and will remain strictly confidential. Only the investigators responsible for this study, the research assistants who will be doing the baseline assessments, the statistician who will analyze the data, the University of Calgary, Conjoint Health Research Ethics Board and the University of Alberta Research Ethics Board will have access to this information. Confidentiality will be protected by using a study identification number in the database. Any results of the study, which are reported, will in no way identify study participants.

IF MY CHILD SUFFERS A RESEARCH RELATED INJURY, WILL WE BE COMPENSATED?

In the event that your child suffers an injury because of participating in this research, the University of Calgary, University of Alberta, the Calgary Health Region or the researchers, will provide no compensation. You still have all your legal rights. Nothing said here will in any way alter your right to seek damages.

SIGNATURES

If you agree to allow your child to participate, we require you to sign and return this form to your designated team study personnel. Two copies of the form are provided. Please keep one for your records. Please have another adult witness your signature on the copy that you return to us.

Your signature on this form indicates that you have understood to your satisfaction, the information regarding participation in this research project and agree to allow your child participate as a subject. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. Your child is free to withdraw from the study at any time without jeopardizing your health care. Continued participation should be as informed as your initial consent, so you should feel free to ask for clarification throughout your child's participation. You will be informed if there is new information available through this study period. If you have further questions concerning matters related to this research, please contact:

Dr. Martin Mrazik (780)-492-8052

The plan for this study has been reviewed for its adherence to ethical guidelines and approved by the Health Research Ethics Board-Health Panel (REB) at the University of Alberta. For questions regarding participant rights and ethical conduct of research, contact the University of Alberta Research Ethics Office at (780) 492-2615.

Please keep this letter for your own information, in case you would like to contact us later.

CONSENT FOR ELITE YOUTH ICE HOCKEY CONCUSSION STUDY

Parent/Guardian's Name (Printed)	Signature and Date
Child's Name (Printed)	Signature and Date
Investigator/Delegate's Name (Printed)	Signature and Date
Witness Name (Printed)	Signature and Date

PLEASE SIGN THIS PAGE AND RETURN THE

FULL DOCUMENT TO YOUR TEAM DESIGNATE.

KEEP THE OTHER COPY FOR YOUR RECORDS

Appendix C: Assent Form

Assent Form for Players (under 18 yrs)

TITLE: Elite Youth Ice Hockey Concussion Study

INVESTIGATORS:
Principal Investigator: Dr. Carolyn Emery
Co-Investigators (University of Calgary): Dr. Willem Meeuwisse, Dr. Brian Brooks, Dr. Karen Barlow, Dr. Tish Doyle-Baker, Dr. Jian Kang, Kathryn Schneider (PhD Candidate), Tracy Blake, Kirsten Taylor
Co-Investigators (University of Alberta): Dr. Martin Mrazik, Dr. Connie Lebrun, Andrea Krol (PhD Student)

This consent form is only one part of agreeing to be in this study. It should give you the basic idea of what the research is about and what being a part of it will mean. Please, take the time to read and understand the information. If you have questions or need more information about this study, please let us know. ***If you choose to participate, please keep a copy of this form and return the other copy (signed and witnessed) to your team designate.***

BACKGROUND

A concussion is a mild brain injury. It is the most common injury in elite youth ice hockey. Concussions can lead long lasting problems like headache, dizziness, and neck pain as well as problems with concentration and memory. The SCAT2 is a standardized test for those who have had concussions. It is used to help doctors to make return-to-play decisions. ImPACT is a test that checks reaction time, how fast your brain makes sense of information, and memory. We do not know how important the SCAT2 and the ImPACT are in return-to-play decisions in youth elite ice hockey. This study will look at the validity of the SCAT2 and ImPACT; how helpful they are in making choices about returning to sport; and predicting who will take longer to get better after a concussion.

Concussions can also change how other parts of your body works, like your heart, your neck, how well you can balance, and how you act, think and feel. Part of this study will look at if your heart works differently after a concussion by measuring your heart rate and the time in between heartbeats. We do not have a good understanding about how these change after a concussion.

Many people have dizziness and problems balancing after a concussion. The inner ear plays a big part in balance and is important in order to have clear vision when the head is moving quickly. We do not have a good understanding about these things change after a concussion.

Headaches and neck pain are also common after a concussion. In this study, we will test balance, how the neck moves and how strong the neck muscles are before and after a concussion and to see if there is a difference.

Concussions can make some people think, feel and act differently. We will ask you to answer some questions that will help us see if any changes happen after a concussion.

Your team has been randomly selected to participate in this study. We would like to invite you to be involved. More than 1000 hockey players are expected to take part in this study.

WHAT IS THE PURPOSE OF THE STUDY?

The purpose of this study is to look at how well the SCAT2 and ImPACT work for testing how hockey players 13-17 years old think, react, remember and focus before and after a concussion.

WHAT WOULD I HAVE TO DO?

We will be asking 30 teams in Calgary (and 12 teams in Edmonton) from Bantam and Midget AAA and AA Quadrant Hockey and Female Bantam and Midget AAA teams to be in the study. Pre-season testing will take place at the Sport Medicine Centre, University of Calgary in September 2011. Testing will be done after team rosters are set but before the regular season starts. This will give us information that we can look back on so we can see any changes that may happen after a concussion. This testing is not currently done in every elite youth hockey league, but is used regularly in major junior hockey and the NHL. Pre-season testing will take about 90 minutes.

Before pre-season testing, there will be an information package sent home that you and your parents will fill out. It includes this consent form, questions about your medical and injury history and questions about how you think, act and feel. These forms must be returned to your team designate BEFORE you are allowed to take part in the study. The name of your team designate will given to you when you receive your package. On pre-season test day, you will do the SCAT2 on the iPad and one ImPACT test on a computer. You will also be wearing a heart rate monitor and will do tests for neck function and balance.

During the season:

During the season, if your team trainer thinks that you have had a concussion, you will be able to see the study sport medicine doctor at the Sport Medicine Centre at the University of Calgary within a week. You will see the doctor every week until you are back to sport as well as three months after your concussion. You will repeat the pre-season tests at each visit.

If one of your teammates has a concussion, you might be asked to act as a healthy control. This will involve coming into the Sport Medicine Centre and repeating the baseline tests at the same time as your teammate.

If you get injured and have to miss more than one week of hockey (practices and/or games), you will have the chance to see the study sport medicine doctor at the Sport Medicine Centre at the University of Calgary.

ARE THERE ANY BENEFITS FOR ME?

If you agree to be in this study there may or may not be a direct medical benefits. You may have less risk of injury during the study but there is no guarantee that this research will help you. If you have a sports injury during the study, your team therapist will assess you and give you advice about any treatment they think would help you.

DO I HAVE TO BE IN THE STUDY?

If you agree to be in the study, we need you to sign and return one copy of this form to your volunteer team designate. Please have another adult witness your signature on the copy that you return to us. Please keep the other copy for your records.

Taking part in this study is voluntary. You may leave the study at any time by telling the Research Coordinator, Maria Romiti, by phone (403-220-8949) or by email (maromiti@ucalgary.ca). Your involvement and registration in the club/team will not change if you do not want to be in the study. Your coaching staff will know who is or is not in the study. This knowledge will not have any effect on how your relationship with your coaches or on the coaches' decisions about playing time. Please feel free to ask any questions you have that come up during the study that you think will help your understanding. You will be told of any new information that is available during the study.

WILL I BE PAID FOR BEING IN THE STUDY, OR DO I HAVE TO PAY FOR ANYTHING?

You will not get paid for being a part of this study. You will not have to pay for anything.

WILL MY RECORDS BE KEPT PRIVATE?

All of the information collected throughout the study period will have the names taken off and will remain private. Only the investigators responsible for this study, the research coordinator who will be doing the pre and post season testing, the statistician who will analyze the data and the University of Calgary, and the Conjoint Health Research Ethics Board will have access to this information. Using only a study identification number in the database will protect privacy. The reported results of the study will not identify you in any way.

IF I SUFFER A RESEARCH RELATED INJURY, WILL WE BE COMPENSATED?

If you are injured from participating in this research, the University of Calgary, Alberta Health Services and the researchers will not provide compensation. You still have all your legal rights. Nothing said here will in any way alter your right to seek damages.

SIGNATURES

Your signature on this form means that you have understand the information about taking part in the research project and agree to be a subject. This does not waive your legal rights nor release the investigators, or involved institutions from their legal and professional responsibilities. You are free to leave the study at any time without jeopardizing your health care. If you have more questions related to this research, please contact:

Ms. Maria Romiti (Research Coordinator)	(403) 220-8949
Dr. Carolyn Emery (Principle Investigator)	(403) 220-4608

If you have any questions concerning your rights as a possible participant in this research, please contact The Director, Office of Medical Bioethics, University of Calgary, at 403-220-7990.

Player´s Name (Print) Signature and Date

Contact Information

Address:

Phone:

Witness' Name (Print) Signature and Date

Dr. Carolyn Emery

Investigator/Delegate's Name

The University of Calgary Conjoint Health Research Ethics Board has approved this research study.

PLEASE SIGN THIS PAGE AND KEEP ONE COPY FOR YOUR RECORDS

Appendix D: Preseason Questionnaire

Study Subject ID#

(to be completed by study coordinator):

HOCKEY STUDY 2011-2012

UNIVERSITY OF CALGARY

Sport Injury Prevention Research Centre

Preseason Baseline Questionnaire

Name:

Today's Date: ___ / ___ / ___ (Day, Month, Year)

Gender: ☐ Male ☐ Female

Age: **City:**

Phone #: (   ) -

Height: _______ feet ____ inches **or** _______ cm

Date of Birth: ___ / ___ / ___ (Day, Month, Year)

Weight: (lbs) **or** (kg)

Dominant Hand (for writing): ☐ Right ☐ Left

Age Group: ☐ Bantam ☐ Minor Midget ☐ Midget

Association:

Division: ☐ AAA ☐ AA ☐ A

Position: ☐ Forward ☐ Defense ☐ Goalie

Team Name:

Please check off how many years of organized hockey you have played prior to this season (check only one):

☐ 0 years	☐ 5 years	☐ 10 years
☐ 1 year	☐ 6 years	☐ 11 years
☐ 2 years	☐ 7 years	☐ 12 years
☐ 3 years	☐ 8 years	☐ 13 years
☐ 4 years	☐ 9 years	☐ Other: _________

EQUIPMENT (check all that apply):

a) Mouthguard:

At games: ☐ always ☐ less than 75% ☐ never

At practices: ☐ always ☐ less than 75% ☐ never

Type of mouthguard worn: ☐ Dentist custom-fit ☐ off the shelf

b) Helmet:

Make: ☐ Bauer ☐ CCM ☐ Itech ☐ Jofa ☐ Mission ☐ Nike ☐ RBK ☐ Other: _________

Type: ☐ full clear visor ☐ full wire cage ☐ combination visor/cage

Age: ☐ new this season ☐ new last season ☐ 2-3 years old ☐ >3 years old

INJURY AND MEDICAL HISTORY:

1. Have you ever had a concussion or been "knocked out" or had your "bell rung"?

☐ Yes ☐ No *if **yes**, please list:*

Date:	Activity at the time	Time unconscious		Memory loss (yes or no)	Time loss before FULL return to sport
eg. (DD/MM/YY)	*hockey, skateboarding, etc.*	*0min*	*30sec*	*no*	*1day, 10 days, etc*

If you answered **yes** to Question 1, please indicate whether you have any persistent problems with:

a) memory	☐ Yes	☐ No
b) dizziness	☐ Yes	☐ No
c) headaches	☐ Yes	☐ No

2. In the past **6 weeks,** have you had an injury requiring medical attention AND at least one day of time lost from physical activity?

☐ Yes ☐ No

*If **yes**, please describe this injury or these injuries to the best of your ability:*

Injury Date	Injury Type	Body Part	Sport of Occurrence	Treatment description	Estimated time loss from sport (days/wks)
eg. (DD/MM/YY)	*sprain, bruise, etc.*	*knee, nose, etc.*	*soccer, wakeboarding, etc.*	*first aid, physio, etc.*	*1day, 3 weeks, etc*

3. In addition to any injury described in questions 2, have you had any other injury requiring medical attention AND at least one day of time lost from physical activity in the past **ONE YEAR**?

☐ Yes ☐ No

*If **yes**, please describe this injury or these injuries to the best of your ability:*

Injury Date	Injury Type	Body Part	Sport of Occurrence	Treatment description	Estimated time loss from sport (days/wks)

4a. Do you have any incompletely healed injuries?

☐ Yes ☐ No

*If **yes**, describe this injury to the best of your ability:* ____________

4b. Are you currently receiving treatment for this injury/these injuries?

☐ Yes ☐ No

*If **yes**, describe this injury to the best of your ability:* ____________

5. Are you currently taking any medication **for injuries**? (Please check all the apply)

☐ Advil
☐ Tylenol
☐ Other If Other, please list: ____________

6. Do you take any medications (asthma inhaler, advil, tylenol, etc) on a regular basis ?

☐ Yes ☐ No

*If **yes**, please list:* ____________

7. Are you currently taking any supplements (Vitamins, Minerals, Protein Powder, etc) ?

☐ Yes ☐ No

*If **yes**, please list:* ____________

8. Have you been diagnosed by a physician with a bone fracture, arthritis, or other muscle or bone related condition?

☐ Yes ☐ No Year: ____________

*If **yes**, describe this condition(s) to the best of your ability:* ____________

9. Have you been diagnosed by a physician with a systemic disease (ie. cancer, thyroid disease, heart disease)?

☐ Yes ☐ No Year: ____________

*If **yes**, describe this condition(s) to the best of your ability:* ____________

questionnaire continues →

10. Have you ever been diagnosed by a physician with a circulation or heart-related problem (ie. heart murmur, irregular heart beat, congenital deformity of the heart)?

☐ Yes ☐ No Year: ____________

*If **yes**, describe this condition(s) to the best of your ability:* ____________

11. Have you been diagnosed by a physician with a neurological disorder (ie. Brain injury, cerebral palsy, pinched nerve, "stinger", multiple sclerosis, etc)?

☐ Yes ☐ No Year: ________

*If **yes**, describe this condition(s) to the best of your ability:* ________

12a. Have you ever experienced headaches?

☐ Yes ☐ No

12b. If yes, are they associated with (please check all that apply):

☐ Nausea
☐ Vomiting
☐ Sensitivity to Light
☐ Sensitivity to Noise

12c. Does anyone else in your family experience headaches?

☐ Yes ☐ No

*If **yes**, please list:* ________

13a. Have you ever been concerned that you have an attention or learning issue?

☐ Yes ☐ No

*If **yes**, describe to the best of your ability:* ________

13b. Have you ever been formally diagnosed by a health care professional (physician, psychologist, etc) as having an attention or learning issue?

☐ Yes ☐ No

*If **yes**, describe to the best of your ability:* ________

13c. Have you ever been formally diagnosed by a health care profession (physician, psychologist, etc) with any of the following: (please check all that apply)

☐ Cognitive Delay
☐ Communication Disorder
☐ Pervasive Developmental Disorder
☐ ADHD
☐ Learning Disability
☐ Anxiety Disorder
☐ Other: ________

☐ Disruptive Behaviour Disorder:
  ☐ Oppositional Defiant Disorder
  ☐ Conduct Disorder
☐ Mood Disorder:
  ☐ Depression
  ☐ Bi-Polar

questionnaire continues →

14. Have you had surgery in the past year?

☐ Yes ☐ No Date: ________

*If **yes**, describe this condition(s) to the best of your ability:* ________

15. In the past **6 weeks**, how many weeks and how many hours per week (on average) did you participate in a school PE class?

_________ *number of weeks* _________ *hours per week*

16. Based on the past **6 weeks** of activity, did you participate in any sports on a weekly basis **(NOT including PE class)**?

☐ Yes ☐ No

*If **yes**, please estimate the average number of hours per week you participated in each sport:*

SPORT	hrs/week	SPORT	hrs/week	SPORT	hrs/week
Aerobics		Floor hockey		Skateboarding	
Alpine skiing		Football		Snowboarding	
Badminton		Golf		Soccer	
Baseball		Gymnastics		Squash	
Basketball		Hiking/ Scrambling		Speed skating	
Boxing (incl. kick)		Hockey		Swimming	
Cross-country skiing		Horse riding		Tennis	
Cycling (road or mtn)		Lacrosse		Track and field	
Dance		Martial arts		Volleyball	
Dirt biking		Rock climbing		Waterpolo	
Diving		Rollerblading		Weight training	
Field hockey		Rugby		Wrestling	
Figure skating		Running		*Other:	
				**Please describe:*	

Appendix E: Weekly Exposure Sheet

Canadian **I**ntercollegiate **S**port **I**njury **R**egistry*

UNIVERSITY OF CALGARY

Province: ______________

Age Group: ______________

Weekly Exposure Sheet
HOCKEY STUDY 2011-2012

Division: ______________

Team: ______________

Sport Medicine Centre

Week of:

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Date (Month/Day)	/	/	/	/	/	/	/
Session (Game=G, Practice= P)							
Game Outcome (Win=W, Tie=T, Loss=L)							
Game Penalty Minutes by team (your team / opponent)	/	/	/	/	/	/	/
Duration (0.0 hours)							
Session Description (ie, regular season game, playoff game, tournament game, skill training, conditioning, scrimmage, etc.)							

Athlete	PC	R	IID	PC	R	IID	PC	R	IID	PC	R	IID	PC	R	IID	PC	R	IID	PC	R	IID

PC

Please enter a participation code (**PC**) for each player indicating:

- **F** *Full* (75%)
- **P** *Partial* (<75%)
- **0** *None* (0)

R (Reason)

If athlete is NOT fully participating (i.e. coded "P" or "O") please indicate if they are:

- **I** Injured in hockey (Note MUST complete Injury Report Form)
- **N** Non-hockey related injury (Note do not need to complete Injury Report Form)
- **S** Sick
- **O** Other

IID (Injury ID #) *specifies injury report form ID # to attribute time loss*

Appendix F: Injury Report Form

UNIVERSITY OF CALGARY

Sport Medicine Centre

INJURY REPORT FORM

HOCKEY STUDY 2011-2012

Injury ID #:
Province:
Phone #:

On this form, please report any injury (new or recurrent) occurring during hockey (game, practice or dryland training activity) which requires medical attention and/or results in the inability to complete the session of activity in which the injury occurred and/or requires you to miss at least one day of sporting activity. In completing this form feel free to get the assistance of a parent or coach. Please have any attending medical practitioner (physician, nurse, physiotherapist, athletic therapist) complete the appropriate section on page 5 of this form.

Upon completion*, please return this form to your team designate.

*Please do not submit form until player has fully returned to competitive play and has completed questions 20 through 26.

1. Name:

2. Gender: ☐ Male ☐ Female

3. Study Subject ID #:

4. Team:

5. Age Group: ☐ Bantam ☐ Minor Midget ☐ Midget

6. Division: ☐ AAA ☐ AA

7. Date of Birth: ____ / ____ / ____ (Day / Month / Year)

8. Date of Injury: ____ / ____ / ____ (Day / Month / Year)

9. This injury involved:
- ☐ **Sudden onset & contact with another player or equipment**
- ☐ **Sudden onset & NO contact with another player or equipment**
- ☐ **Gradual onset / overuse**
- ☐ **Unknown**

10. Injury Status:
- ☐ **New Injury**
- ☐ **Recurrence of Injury from this year**
- ☐ **Recurrence of Injury from previous year**

11. Was bracing or taping used on the injured area or limb at the time of injury?
☐ **Yes** ☐ **No** if **yes**, what type?

12. Injury occurred during:
- ☐ **Practice**
- ☐ **Game** (a) ☐ *regular season* ☐ *tournament* ☐ *playoff* ☐ *exhibition* (b) ☐ *warmup* ☐ *1st period* ☐ *2nd period* ☐ *3rd period*
- ☐ **Other Team Conditioning** (specify):

13. Position playing at the time of injury:
☐ **Forward (Centre)** ☐ **Forward (Wing)** ☐ **Defense** ☐ **Goalie** ☐ **n/a**

14. Was the player able to return to the same game or practice in which they were hurt?
☐ **Yes** ☐ **No** ☐ **n/a**

Injury Report Form Continued Page 2

Injury ID #:

15.A) Describe to the best of your ability the events surrounding the injury:

____
____
____
____

15.B) Please check off all that apply to describe the cause of your injury:

☐ **Body Check**
*if **yes**:* ☐ delivered
☐ received

☐ **Other Intentional Player Contact**
please specify: ☐ elbowing ☐ slashing ☐ cross-checking
☐ tripping ☐ roughing

☐ **Incidental Contact with another player or their equipment**

☐ **Contact with the environment, NOT another player**
*if **yes**:* ☐ puck
☐ boards
☐ net

☐ **No contact**

☐ **Unknown**

16. Was there a penalty called directly related to the injury event? ☐ **Yes** ☐ **No**

*16a) If **yes**, what was the penalty?*
☐ Stick related - Describe:________________ ☐ Checking related - Describe:________________ ☐Fighting

*16b) If **yes**, what was the consequence of the penalty?*
☐ 2 minute minor ☐ 5 or 10 minute major ☐ Removal from game ☐ Suspension

*16c) If **yes**, who received the penalty? (check all that apply)*
☐ Injured player ☐ Injured player's teammate ☐ Opposing team player

17. Protective gear worn at the time of injury *(check all that apply):*

☐ **Mouthguard**
*if **yes**, specify:* ☐ Dentist custom-fit ☐ off the shelf

☐ **Brace**
*if **yes**, specify:* ☐ Knee ☐ Ankle ☐ Other*
**please describe:*

☐ **Tape**
*if **yes**, specify:* ☐ Knee ☐ Ankle ☐ Other*
**please describe:*

☐ **Helmet**
make: ☐ Bauer ☐ CCM ☐ Itech ☐ Jofa ☐ Mission ☐ Nike ☐ RBK ☐ Other ________
model (eg. Junior 652C, Jr Ignite 4, etc.): ________________________
type: ☐ full clear visor ☐ full wire cage ☐ combination visor/cage
helmet age: ☐ new this season ☐ new last season ☐ 2-3 years old ☐ >3 years old

☐ **Other Equipment** *(please describe)*:

Injury Report Form Continued Page 3

Injury ID #:

18. Injury Location (*check all that apply, circle affected side where applicable*):

☐ Head	☐ Throat	☐ Hand (L / R)	☐ Pelvis	☐ Ankle (L / R)
☐ Face	☐ Shoulder (L / R)	☐ Finger (L / R)	☐ Hip (L / R)	☐ Foot (L / R)
☐ Ears (L / R)	☐ Collarbone (L / R)	☐ Back	☐ Groin (L / R)	☐ Toes (L / R)
☐ Eye (L / R)	☐ Upper arm (L / R)	☐ Side (L / R)	☐ Genitals	☐ Other*
☐ Nose	☐ Elbow (L / R)	☐ Ribs (L / R)	☐ Upper Leg (L / R)	
☐ Teeth	☐ Forearm (L / R)	☐ Chest	☐ Knee (L / R)	
☐ Neck	☐ Wrist (L / R)	☐ Abdomen	☐ Lower leg (L / R)	

Please describe:

19.Type of Injury (*check all that apply to this injury*):

☐ Bruise	☐ Cut	☐ Dislocation	☐ Knocked out
☐ Burn	☐ Blister	☐ Broken bone	☐ Concussion
☐ Bleeding	☐ Joint swelling	☐ Muscle strain	☐ Other*
☐ Abrasion/Scrape	☐ Joint/ ligament sprain	☐ Tendonitis	

Please describe:

***Please do not complete questions 20 through 26 until the player has returned fully to competitive play and has finished all injury-related care.*

20. Total number of days you were unable to participate in your normal activities of daily living:
(i.e.. work, school, camp, other) ☐

21. Total number of days you were unable to participate in any sport due to this injury: ☐

22. Total number of days you were unable to participate in hockey: ☐

23. Total number of days (or hours) your parent or guardian missed work as a direct result of your injury: ☐ days ☐ hours

24. Did you see any health care professional(s) for assessment or treatment of this injury? ☐ Yes ☐ No

(*if **yes**, please check all that apply once you have completed all care for this injury*)

☐ Physician (Family)	(Total # visits _____)	☐ Massage therapist	(Total # visits _____)
☐ Physician (Specialist)	(Total # visits _____)	☐ Dentist	(Total # visits _____)
specialty: ____________________		☐ Chiropractor	(Total # visits _____)
☐ Physiotherapist	(Total # visits _____)	☐ Other*	(Total # visits _____)
☐ Athletic Therapist	(Total # visits _____)		

Please specify:

25. Did you receive any other treatment for this injury? ☐ Yes ☐ No

(*if **yes**, please check all that apply. Be as specific as possible, including location of service provided*)

☐ First Aid	☐ MRI/CT (#)	☐ Cast (#)	☐ Crutches	☐ Surgery
☐ Xrays (#)	☐ Bone Scan (#)	☐ Brace	☐ Taping	☐ Medications
☐ Other*				

Please describe:

26. Who provided you with clearance to return to activity?

☐ Self ☐ Parent ☐ Coach ☐ Therapist ☐ Physician ☐ Other*

Please describe:

HOCKEY 2011-2012 ASSESSMENT

Athlete's Name: **IID**

Date of Assessment: ____ / ____ / ____
Day Month Year

Patient's specific complaint:

History (including any previous injury to structure(s):

Observation:

Functional Tests:

Special Tests:

Palpation:

Impression/Assessment: ______________________________
Side Region Type of Injury (i.e. Rt AC Joint- 2degree sprain)

SMC Diagnostic Code(s):

1	
2	
3	

Referral:

- ☐ Study Sport Medicine Physician
- ☐ Physician
- ☐ Dentist
- ☐ Hospital
- ☐ Medi-clinic
- ☐ Physiotherapist
- ☐ Chiropractor
- ☐ Massage Therapist
- ☐ Athletic Therapist
- ☐ Other, please describe: ______________________________

Injury Severity Score: **At time of injury** ☐ **At return to play** ☐

____ / ____ / ____
Day Month Year

____ / ____ / ____
Day Month Year

1 = unable to perform any normal daily activities (i.e. walk, go to school)
2 = unable to participate (i.e. practice) in sport
3 = able to practice but unable to compete in sport
4 = able to compete but performance is impaired
5 = fully able to compete as if there was never an injury

Assessor's signature: ______________________________

If you were seen by a physician, physiotherapist, athletic therapist or other medical practitioner for this injury please have them complete one of the following sections:

Upon completion, please return this form to your team designate

HOCKEY STUDY 2011-2012

Athlete's Name: | ***IID***

Date: ____/____/____ (Day / Month / Year) | UCDC

Attending Medical Practitioner's Name:

Occupation (i.e.. Family Physician/Specialist/Therapist/etc):

Diagnosis:

Treatment Plan:

Expected/Recommended duration of treatment:

Is this athlete cleared to resume unrestricted competition? ☐ Yes ☐ No

IF NO:

Expected date of clearance: ______________________

Conditions of clearance: ______________________

Does this athlete require medical follow up prior to clearance? ☐ Yes ☐ No

HOCKEY STUDY 2011-2012

Athlete's Name: | ***IID***

Date: ____/____/____ (Day / Month / Year) | UCDC

Attending Medical Practitioner's Name:

Occupation (i.e.. Family Physician/Specialist/Therapist/etc):

Diagnosis:

Treatment Plan:

Expected/Recommended duration of treatment:

Is this athlete cleared to resume unrestricted competition? ☐ Yes ☐ No

IF NO:

Expected date of clearance: ______________________

Conditions of clearance: ______________________

Does this athlete require medical follow up prior to clearance? ☐ Yes ☐ No

Appendix G: BASC-2 Child

Self-Report–Adolescent
Computer-Entry Form

SRP–A
Ages 12–21

BASC-2

Behavior Assessment System for Children, Second Edition

Cecil R. Reynolds, PhD, and Randy W. Kamphaus, PhD

Your Name ________________ (First / Middle / Last) Date ________ (Month / Day / Year) Birth Date ________ (Month / Day / Year)

School ________________ Grade ______ Sex: ☐ Female ☐ Male

Age ______ Other Data ________________

Directions:

This booklet contains sentences that young people may use to describe how they think or feel or act. Read each sentence carefully. For the first group of sentences, you will have two answer choices: **T** or **F.**

Circle **T** for **True** if you agree with a sentence.

Circle **F** for **False** if you do not agree with a sentence.

Here is an example:

1. I like parties. (T) F

For the second group of sentences, you will have four answer choices: **N, S, O,** and **A.**

Circle **N** if the sentence **never** describes you or how you feel.

Circle **S** if the sentence **sometimes** describes you or how you feel.

Circle **O** if the sentence **often** describes you or how you feel.

Circle **A** if the sentence **almost always** describes you or how you feel.

Here is an example:

2. I enjoy doing homework. N (S) O A

If you wish to change an answer, mark an X through it, and circle your new choice, like this:

2. I enjoy doing homework. N (S̶) (O) A

Give the best response for you for each sentence, even if it is hard to make up your mind. There are no right or wrong answers. Please do your best, tell the truth, and respond to every sentence.

Before starting, please fill in the information in the box above these directions.

PEARSON Assessments

Product Number 30038

Mark: T – True F – False

1. I like who I am. .... T F
2. I hate taking tests. .... T F
3. Nothing goes my way. .... T F
4. My muscles get sore a lot. .... T F
5. People tell me I should pay more attention. .... T F
6. Things go wrong for me, even when I try hard. .... T F
7. I get mad at my parents sometimes. .... T F
8. I used to be happier. .... T F
9. I often have headaches. .... T F
10. I don't care about school. .... T F
11. I can never seem to relax. .... T F
12. I always go to bed on time. .... T F
13. My classmates don't like me. .... T F
14. I worry about tests more than my classmates do. .... T F
15. My parents are always right. .... T F
16. If I have a problem, I can usually work it out. .... T F
17. I never break the rules. .... T F
18. I have not seen a car in at least 6 months. .... T F
19. What I want never seems to matter. .... T F
20. I worry about little things. .... T F
21. Nothing is fun anymore. .... T F
22. I never get into trouble. .... T F
23. I tell the truth every single time. .... T F
24. I never seem to get anything right. .... T F
25. I have never been mean to anyone. .... T F
26. My friends have more fun than I do. .... T F
27. I like loud music. .... T F
28. I always do what my parents tell me. .... T F
29. No matter how much I study for a test, I am afraid I will fail. .... T F
30. I cover up my work when the teacher walks by. .... T F
31. I wish I were different. .... T F
32. I have just returned from a 9-month trip on an ocean liner. .... T F
33. Nobody ever listens to me. .... T F
34. Often I feel sick in my stomach. .... T F
35. I think that I have a short attention span. .... T F
36. My parents have too much control over my life. .... T F
37. My teacher understands me. .... T F
38. I just don't care anymore. .... T F
39. Sometimes my ears hurt for no reason. .... T F
40. I don't like thinking about school. .... T F
41. I worry a lot of the time. .... T F
42. I get along well with my parents. .... T F
43. Other children don't like to be with me. .... T F
44. I wish I were someone else. .... T F
45. I tell my parents everything. .... T F
46. I can handle most things on my own. .... T F
47. I like to take chances. .... T F
48. I am sometimes jealous. .... T F
49. My parents are always telling me what to do. .... T F
50. I often worry about something bad happening to me. .... T F
51. I don't seem to do anything right. .... T F
52. I like everyone I meet. .... T F
53. I have attention problems. .... T F
54. Most things are harder for me than for others. .... T F
55. I have some bad habits. .... T F
56. Other children are happier than I am. .... T F
57. I would rather be a police officer than a teacher. .... T F
58. I always do homework on time. .... T F
59. I take a plane trip from New York to Chicago at least twice a week. .... T F
60. I never quite reach my goal. .... T F
61. I feel good about myself. .... T F
62. Sometimes, when alone, I hear my name. .... T F
63. Nothing ever goes right for me. .... T F
64. I get sick more than others. .... T F
65. I give up easily. .... T F
66. My parents blame too many of their problems on me. .... T F
67. My teacher cares about me. .... T F
68. Nothing about me is right. .... T F
69. My stomach gets upset more than most people's. .... T F

Remember: N – Never S – Sometimes O – Often A – Almost always

70. My school feels good to me. . . . . N S O A
71. I get so nervous I can't breathe. . . . . . . N S O A
72. I am proud of my parents. . . . . N S O A
73. Other kids hate to be with me. . . . . N S O A
74. I like the way I look. . . . . N S O A
75. People say bad things to me. . . . . N S O A
76. I am dependable. . . . . N S O A
77. I like it when my friends dare me to do something. . . . . N S O A
78. When I get angry, I can't think about anything else. . . . . N S O A
79. I get blamed for things I can't help. . . . N S O A
80. I worry when I go to bed at night. . . . . N S O A
81. I feel like my life is getting worse and worse. . . . . N S O A
82. School is boring. . . . . N S O A
83. I forget things. . . . . N S O A
84. Even when I try hard, I fail. . . . . N S O A
85. My teacher trusts me. . . . . N S O A
86. People act as if they don't hear me. . . . N S O A
87. I like to play rough sports. . . . . N S O A
88. I have trouble standing still in lines. . . N S O A
89. I can't seem to turn off my mind. . . . . . N S O A
90. I am disappointed with my grades. . . . N S O A
91. I get upset about my looks. . . . . N S O A
92. I feel like people are out to get me. . . . N S O A
93. I feel depressed. N S O A
94. I sleep with my schoolbooks. . . . . N S O A
95. I listen when people are talking to me. . . . . N S O A
96. I stay awake for 24 hours without getting tired. . . . . N S O A
97. Teachers make me feel stupid. . . . . N S O A
98. No one understands me. . . . . N S O A
99. I feel dizzy. . . . . N S O A
100. Someone wants to hurt me. . . . . N S O A
101. I feel guilty about things. . . . . N S O A
102. I like going places with my parents. . . . N S O A
103. I feel that nobody likes me. . . . . N S O A
104. I am good at things. . . . . N S O A
105. I am lonely. . . . . N S O A
106. I can solve difficult problems by myself. . . . . N S O A
107. I like to experiment with new things. N S O A
108. I get nervous. . . . . N S O A
109. My parents expect too much from me. . . . . N S O A
110. I worry but I don't know why. . . . . N S O A
111. I feel sad. . . . . N S O A
112. I get bored in school. . . . . N S O A
113. I have trouble paying attention to the teacher. . . . . N S O A
114. When I take tests, I can't think. . . . . N S O A
115. Teachers look for the bad things that you do. . . . . N S O A
116. I am left out of things. . . . . N S O A
117. I like to ride in a car that is going fast. . . . . N S O A
118. I talk while other people are talking. . . . . N S O A
119. Even when alone, I feel like someone is watching me. . . . . N S O A
120. I want to do better, but I can't. . . . . . . N S O A
121. My looks bother me. . . . . N S O A
122. I hear voices in my head that no one else can hear. . . . . N S O A
123. I am good at making decisions. . . . . . N S O A
124. I have trouble sitting still. . . . . N S O A
125. I pay attention when someone is telling me how to do something. . . . . N S O A
126. My parents are easy to talk to. . . . . . . N S O A
127. Teachers are unfair. . . . . N S O A
128. I have a hard time slowing down. . . . . N S O A
129. I like going to bed at night. . . . . N S O A
130. I see weird things. . . . . N S O A
131. I get nervous when things do not go the right way for me. . . . . N S O A
132. My mother and father like my friends. . . . . N S O A
133. People think I am fun to be with. . . . . N S O A
134. I feel like I have to get up and move around. . . . . N S O A
135. Other people find things wrong with me. . . . . N S O A
136. I like to make decisions on my own. . . N S O A
137. I like to be the first one to try new things. . . . . N S O A

Remember: N – Never S – Sometimes O – Often A – Almost always

138. Little things bother me. .... N S O A
139. I am blamed for things I don't do. .... N S O A
140. I worry about what is going to happen. .... N S O A
141. My mother and father help me if I ask them to. .... N S O A
142. I feel like I want to quit school. ...... N S O A
143. I have trouble paying attention to what I am doing. .... N S O A
144. I fail at things. .... N S O A
145. My teacher is proud of me. .... N S O A
146. I feel out of place around people. .... N S O A
147. I like to dare others to do things. ..... N S O A
148. I talk without waiting for others to say something. .... N S O A
149. Someone else controls my thoughts. .... N S O A
150. I quit easily. .... N S O A
151. I am slow to make new friends. ...... N S O A
152. I do things over and over and can't stop. .... N S O A
153. My friends come to me for help. ..... N S O A
154. People tell me to be still. .... N S O A
155. My parents listen to what I say. .... N S O A
156. I like to be close to my parents. ...... N S O A
157. My teachers want too much. .... N S O A
158. When I get angry, I want to break something. .... N S O A
159. I get phone calls from popular movie actors. .... N S O A
160. I hear things that others cannot hear. .... N S O A
161. I get mad at others. .... N S O A
162. I have trouble sleeping the night before a big test. .... N S O A
163. I am liked by others. .... N S O A
164. People tell me that I am too noisy. .... N S O A
165. I feel that others do not like the way I do things. .... N S O A
166. I am someone you can rely on. .... N S O A
167. When I get angry, I want to hurt someone. .... N S O A
168. When I start talking, it is hard for me to stop. .... N S O A
169. People get mad at me, even when I don't do anything wrong. .... N S O A
170. I am afraid of a lot of things. .... N S O A
171. My parents trust me. .... N S O A
172. I hate school. .... N S O A
173. My parents are proud of me. .... N S O A
174. Ideas just race through my mind. ..... N S O A
175. My teacher gets mad at me for no good reason. .... N S O A
176. Other people are against me. .... N S O A