Investigating Symptoms of Concussion and Depression in Adolescent Athletes Devoid of a Recent Concussion Injury.

by

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A thesis submitted in conformity with the requirements for the degree of Master of Science in Rehabilitation Science

The Rehabilitation Sciences Institute
The University of Toronto

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Abstract

Sport-related concussion is a concern for all athletes involved in sport and recreational activity. At this time, few investigations have sought to examine the relationship between concussion-like and depressive symptoms in an adolescent athlete population prior to the occurrence of a concussion; examining these two symptom categories among a group of healthy individuals is necessary to understand the relationship that exists between concussion and depressive symptoms. This study aimed to investigate the prevalence and relationship between concussion and depressive symptoms, and various demographic and medical history variables. Healthy uninjured adolescent athletes (aged 13 to 18 years old) completed validated symptom scales assessing perceived current concussion-like and depressive symptoms. Findings indicate that many athletes experience concussion-like and depressive symptoms in the absence of a recent injury. Therefore it may be unrealistic for an adolescent athlete to reach asymptomatic status prior to their return-to-play following an actual concussion. Results highlight large differences in the reporting of both concussion-like and depressive symptoms between males and females. Implications for practice and future research are discussed.
Dedication

I would like to dedicate this work to individuals whose lives have been affected by traumatic brain injury. Let this help you find the courage to carry on during your dark times.
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Acronym List

APA – American Psychological Association
BC-PSI-Sf - British Columbia Postconcussion Symptom Inventory–Short Form
BDI - II – Beck Depression Inventory (Version 2)
CCC – Canadian Concussion Collaborative
CCM – Complete Concussion Management Inc.
DSM-IV- Diagnostic and Statistical Manual – 5th Edition
PCS – Post Concussion Scale
MFQ – Mood and Feelings Questionnaire
SMFQ – Short Mood and Feelings Questionnaire
REB – Research Ethics Board
RTP – return-to-play
Chapter 1

Introduction

Over the last 10 to 15 years’ interest in concussive injury in sport has grown dramatically. In turn the public’s knowledge and education about this important issue has increased exponentially. This surge in attention can partly be attributed to both the media as well as the major class action lawsuits that have been filed against national sport organizations like the National Football League (NFL) and National Hockey League (NHL) as a result of concussion-related issues in their former players. Demanding answers, the sports world has turned to research and scientists for their help.

Shortly before this “media frenzy” began, the body of knowledge and evidence surrounding sport-related concussion had been growing steadily. The majority of the concussion literature published to date has focused primarily on injury incidence (i.e. by age, sport and gender), injury symptoms, and factors modifying injury risk and recovery; factors include things like an individual’s sex, age, history of concussion and additional medical history information (i.e. such as a diagnoses of a learning disability or mental health illness). Less research has focused on examining factors that are associated with concussion-like symptoms reported in the absence of a recent injury. Here “recent injury” is operationally defined as a concussion injury in the previous month (i.e. 4 weeks).

More importantly, of the research that has been conducted on sport-related concussion and symptomatology in the absence of injury, the majority of investigations have focused primarily on adults and college-aged athletes. Findings from these investigations have indicated that some factors (i.e. age, sex, history of concussion and medical history) play a role in concussion-like symptom reporting in the absence of injury. At this time, few investigations have focused on the exploration of concussion-like symptomatology specifically in child and adolescent athlete populations in the absence of injury. Furthermore, a limited focus has been placed on identifying symptomatology differences between sex groups.
Preliminary sport-related concussion incidence-focused investigations suggest approximately 300,000 sport-related concussions occur each year, contributing to 8.9% of all sport-related injuries among high school athletes in the United States (1, 2). Although symptoms typically resolve within 7-10 days for most adults, longer recovery times have been observed in child and adolescent populations (3); a recent study published in 2016 by Zemek and colleagues indicated almost 30% of the adolescents who participated in their investigation (n=510) met the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10) criteria for Postconcussion Syndrome diagnoses (i.e. presence of 3 or more symptoms persisting for more than 4 weeks following a suspected concussion injury)(4). Some literature suggests symptom resolution is further complicated by a pre- or co-morbid mood disorder diagnosis like depression, however most of these findings have been observed in adult samples (5-9). Few investigations have examined the impact of a mood disorder like depression prior to or simultaneous to a concussive injury in adolescent athletes (10, 11). Of the investigations that did, findings revealed that individuals endorsing pre-injury depression demonstrated longer recovery times, required lengthy school accommodations and demonstrated greater declines in school performance (10).

If clinicians are to better understand predictors of persistent post-concussion symptoms, investigations should aim to understand the adolescent athlete from a biopsychosocial perspective: “an integration of biological, social, cognitive, affective and behavioural factors emphasizing the complex multifactorial nature of a condition” (12). Preliminary investigations must first focus on generating a clear understanding of pre-existing depression and concussion-like symptoms in absence of a recent concussive injury (i.e. no concussion injury in the previous month) in an adolescent athlete population.

The purpose of this study was to establish normative concussion-like and depressive symptom profiles among a group of uninjured adolescent athletes using two validated symptom measures: The Post-Concussion Scale (PCS) (13) and the Mood and Feelings Questionnaire (MFQ) (14). Demographic and medical history information were also collected and modelled to participant outcome scores. Sex-based analyses in particular were conducted. Correlation was also measured between PCS and MFQ scores.
The thesis contained herein is written according to the traditional format (i.e. using Chapters) stipulated by the University of Toronto, School of Graduate Studies. Chapter 2 provides a broad scoping literature review of the population and the body of knowledge related to sport-related concussion. Chapter 3 defines the research questions, objectives and methods used to answer these queries. Chapter 4 summarizes the investigation results. Chapter 5 discusses the findings, how they compare to previous literature and the implications this investigation has for the clinical concussion management of adolescent athletes. Finally, conclusions and future directions are discussed in Chapter 6.
2.1 Organized Physical Activity in Canada

Sports and recreational activities be it team or individual, are a common past-time among Canadian youth. Over the last three decades youth participation in organized sports has continued to increase (15, 16). A large scale study conducted by the Canadian Fitness and Lifestyle Research Institute (2010 Physical Activity Monitor Survey) indicated approximately 75% of Canadian youth between the ages of 5 and 17 were involved in some sort of organized sport activity (17). Findings indicated participation varied by age and generally decreased as age increased. For example, 83% of 5 to 10 year olds vs. 61% of 15 to 19 year olds were enrolled in an organized sport program in 2011 and 2012 (17). They also identified discrepancies in sport participation among the genders; approximately 91% of boys (5 to 10 year olds) compared to 88% of girls of the same age were involved in organized sport. Similar findings were also seen in older boys (48% engagement in 15 to 19 year olds) as compared to girls (30% engagement) with both of the older age groups reflecting a decrease in overall physical activity as compared to their younger peers (18).

Discrepancies in type of sport engagement have also been identified between the sexes. The CIBC KidSport Report (2014) provided a breakdown of sport involvement by sex (Table 2-1)(19). Results were based on surveys completed by n=733 parents with at least one child participating in sport between the ages of 3 and 17 years old.
Table 2-1. Sport participation stratified by sex (team sports only)

<table>
<thead>
<tr>
<th>Sport</th>
<th>Total</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soccer</td>
<td>38%</td>
<td>43%</td>
<td>31%</td>
</tr>
<tr>
<td>Basketball</td>
<td>18%</td>
<td>22%</td>
<td>13%</td>
</tr>
<tr>
<td>Hockey</td>
<td>17%</td>
<td>25%</td>
<td>7%</td>
</tr>
<tr>
<td>Baseball/Softball/T-ball</td>
<td>16%</td>
<td>19%</td>
<td>13%</td>
</tr>
<tr>
<td>Volleyball</td>
<td>7%</td>
<td>5%</td>
<td>9%</td>
</tr>
<tr>
<td>Football</td>
<td>5%</td>
<td>8%</td>
<td>1%</td>
</tr>
</tbody>
</table>

Table reproduced from the CIBC KidSport Report (2014) (19)

With the exception of volleyball, there was greater male participation than female within each sport.

### 2.2 Benefits to Sport Participation

Organized children’s sport activities first appeared in the 1950’s (i.e little league baseball and minor league hockey) (20-23). Since then, a child’s participation in team sports has been linked to a number of positive benefits including promoting a child’s growth, providing them with a sense of achievement as well as fostering the growth of teamwork, leadership and problem-solving skills (24). It has also been suggested that youth engagement in recreational activities may reduce future health-care costs, contribute to life long physical activity engagement habits and act to offset the risk of childhood obesity (25-27). Both light-intensity as well as moderate to vigorous physical activity have been linked to decreases in risk for cardiovascular disease, and increases in positive health outcomes in youth (28, 29).

Additional cognitive functioning and mental health benefits have also been linked to physical activity (30-32). Among adolescents, individuals involved in organized sports were less likely to engage in negative health behaviours (i.e. smoking and substance use), but they were more likely to consume alcohol (33, 34). Overall sport activity helps to create a diversion from negative youth behaviour (35), and reduces both boredom and the amount of time youth spend in unsupervised activities (36, 37). Sports also offers an avenue to release aggression and can also provide excitement and gratification for the individual (38). Additional benefits include the promotion of positive emotions (39),
provision of a sense of community (40), increases in academic achievement (41), as well as decreases in depression and suicidal ideation (42, 43). Early participation in athletic activities is also reported to help the individual maintain a healthy lifestyle. Establishing physical activity habits early in life reportedly sets the trend for lifelong physical activity engagement, health and nutrition (44). While the primary focus of this thesis highlights the potential negative outcomes of youth-sport, the positive benefits vastly outweigh the risks. Thus physical activity amongst youth should be supported and encouraged.

2.3 Physical Activity as a Protective Factor Against Depression

It is well established in the literature that exercise promotes positive mood and affective states in individuals who engage in physical activity (45, 46). Understanding the relationship and to what extent physical activity moderates mood has not been thoroughly explored (i.e. recreational and leisure sports vs. all-star competitive vs. elite and national competition). The mechanism of action behind physical activity and elevated mood may be attributed to the increase in social opportunities and social support offered through sport (47). Exercise can also provide a distraction from external stressors (48) and can provide a sense of accomplishment while promoting a healthy attitude or perspective about life stressors (49). Physiologically, benefits may be a result of known increases in the synthesis and metabolism of monoamines such as dopamine, serotonin and norepinephrine within the brain during bouts of exercise (50). Despite indications of positive outcome, some inconsistencies have been identified in the literature.

In a recent study (n=2951, mean age = 14) investigators sought to examine the role that physical activity had on depressive symptoms using the Mood and Feelings Questionnaire (Short Version)(51). They found that adolescents who reported spending more time performing physical activity had a lower risk for depression as compared to their peers who exercised less. However they found that exercise intensity (i.e. time spent performing moderate to vigorous physical exertion) had no effect on reducing depressive symptoms. Investigators concluded that amount of physical activity was more important than intensity in terms of eliciting this protective effect (51). Conversely, in a 3-year follow-up study of a large group of adolescents (n=736, mean age = 14.5 years),
investigators sought to objectively evaluate the effect that physical activity had on depressive symptoms. Findings failed to show any association or protective effect between physical activity and depressive symptoms at the 3-year follow-up point (52). Furthermore, findings from a recent systematic review hinted that a strong inverse relationship exists between the two behaviours, but that a causal relationship has not yet been identified (53).

2.4 Negative Outcomes of Sport Participation

Participation in sport has also been associated with a number of negative outcomes including injury (54), team bullying or hazing (55), violence (55), self-esteem and body image issues (56-58) as well as peer pressure to use performance enhancement drugs such as anabolic steroids (59-61). Not necessarily seen at the house league level, but participation in national or elite leagues can be very time consuming and may deter a young athlete from their academic or familial responsibilities. Unrealistic performance expectations from both parents and coaches can also negatively impact a child. Intense and repeated training sessions at more elite levels of competition have been associated with overtraining syndrome – a condition associated with a myriad of other negative effects on the body (62). Negative affect or depression has also been identified as a negative outcome of sport performance (63). Aside from these outcomes, physical injury is also of great concern.

Sports injuries exist on a spectrum from mild (e.g. cuts and bruises) to more severe (e.g. broken bones or dislocations) which require serious medical attention. According to the Public Health Agency of Canada, in 2011 sport and physical activity accounted for 30% of hospitalizations in children aged 5 to 9 years old and 68% of hospitalizations for children aged 10 to 14 years old (64). Sex is also thought to play a role in sport injuries however findings have been inconsistent (65). Some evidence has indicated that although injury rates are higher in males, females sustain more severe injuries (66-68).

Sport-related injuries are an important consideration when choosing to participate in sport, as some sports have a greater inherent risk for injury than others. According to the 2014 Canadian Youth Sports Report, approximately 20% of youths had experienced some sort of sport-related injury in the previous year (69). In males, the majority of sports
injuries were sustained in soccer, hockey or football. Soccer, gymnastics and dance were among the top-injury causing sports for girls. Overall the majority of sport-related injuries in sport are physical in nature (i.e. musculoskeletal), and easy for the athlete, family and coach to understand. With proper care and rehabilitation, the athlete can heal in a timely manner. Being that musculoskeletal sport-related injuries are visible and easily identifiable, practitioners can provide a relatively reliable prognosis and expected healing time to the athlete. However when we shift our focus to concussion injuries, prognosis and outcomes are not as clear.

2.5 Concussions Defined

Unfortunately a universal definition for concussion has yet to be adopted by practitioners, clinicians, researchers and experts working in the field. For the purpose of this thesis, concussion will be operationally defined based on a widely accepted definition provided in the Consensus Statement on Concussion in Sport: “concussion is a complex pathophysiological process affecting the brain, induced by biomechanical forces… resulting in the rapid onset of short-lived impairment of neurological function that resolves spontaneously” (9). Concussion is sometimes referred to as mild traumatic brain injury and vice versa. Both the Centers for Disease Control and the World Health Organization advocate for replacing the term concussion with the term mild traumatic brain injury (70). Alternatively, Seymour (2013) offers some additional explanation as to the use of variable definitions and terminology within concussion/mild traumatic brain injury research. In her article she further explores how the terms are used synonymously, however they may not share the same definition (71). This further adds to the confusion about the injury among health care professionals and patients alike.

2.6 Concussion Pathophysiology

Concussion is highly individualized, meaning no two individuals are affected by the injury in the same way (72). Symptoms are thought to result from acceleration, deceleration or rotational forces causing a stretching, sheering and destruction of the neurons within the brain (73). A subsequent study has revealed that neurons are rendered dysfunctional, not destroyed (74). It is estimated that the minimal threshold of linear gravitational acceleration thought to cause concussion range from 80 to 100 g-forces
(73). To put this into context, this would be approximately 20 times that of the g-force experienced when riding a roller coaster (75). In brain injury, cell death (necrosis) is possible however in the context of mild traumatic brain injury, cell death resulting in permanent neuronal damage is very rare (76, 77).

Also known as the “neurometabolic cascade”, experts believe this is the mechanism of action at the root of concussion symptomatology (73). In brief, application of a sufficient biomechanical force to the head or elsewhere on the body causes a rapid and non-specific depolarization of neurons in the brain. Random release of various excitatory neurotransmitters causes further cell depolarizations and an efflux of potassium ions out of the cell. This up-regulates and places a high demand on potassium pumps to restore homeostasis within the affected neurons. Pumps are overloaded with work and require a large amount of the body’s useable energy form, ATP (adenosine tri-phosphate), to restore homeostasis. Massive ATP requirements in the brain place the brain and the rest of the body in energy starvation mode. Coupled with decreases in cerebral blood flow, the brain is subjected to further energy starvation (78). It is thought that this process results in many of the common symptoms (i.e. cognitive, physical, emotional and sleep-related symptoms) that are identified following brain injury.

2.7 Incidence of Concussion in Canada

Incidence of concussion by age has been well explored in both American and Canadian settings. Findings indicate adolescents between the ages of 15 and 19 years old to be at greatest risk for concussion (79). A recently published Canadian study used medical records from five Edmonton area hospital emergency departments to determine incidence of concussion in adolescents. Investigators reviewed the number of head injuries as compared to all other injuries presenting for medical attention over the course of the 10-year study (1997 to 2008) (80). Records indicated that sport-related concussions accounted for 7.8% of emergency department visits (80). They found that individuals aged 10-14 years had 207.9 sport-related head injuries per 100 000 injuries treated in the emergency department as compared to 203.8 injuries in adolescents aged 15 to 19 years. Overall 70% of sport-related head injury cases that presented to the emergency department were identified in individuals 18 years of age and under (80). Categorized by
sport (per 100 000 injuries): hockey (19.3), cycling (11.0), skiing/snowboarding/sledding (10.0), soccer (8.2) and football (6.0) were among the top-ranking sports that presented to emergency rooms for medical attention (80). In 2014, Macpherson and colleagues published a study that also sought to describe the source of concussion injuries among a paediatric age group (defined as 3 to 18 years old in this study). They also noted the high number of injuries resulting from sport-related causes, however these were second to concussions caused by falls in this age group (81).

Unfortunately injury rates indicated by emergency department visits may provide a gross underestimate of the actual incidence of injury, as many individuals do not present to a hospital for diagnoses or follow-up treatment (82). Among adolescent athletes, head injuries go unrecognized and underreported by athletes (83-87); estimates suggest that approximately half of all suspected injuries go unreported (88).

2.8 Concussion Injury Awareness

Concussion in youth sports is a growing concern for all stakeholders, but primarily for the athletes and their families. Recent media attention on both the National Football League (NFL) and National Hockey League (NHL), as well as the creation of new policies and legislation have helped to raise awareness about risk for concussion in sport. However the media has also perpetuated many negative implications associated with concussion. This leaves the onus on the sporting bodies to establish a fine balance between communicating concussion awareness and inherent risk for injury with the many positive benefits associated with sport participation. Although preliminary concussion awareness efforts are starting to make their way into many amateur sporting associations, there is room for improvement. For example, assessing the need for a customized clinical management approach based on age and sex of the athlete. As such, a number of studies have been conducted to better understand knowledge about concussion at an amateur sport level.

Literature indicates that exposure to and knowledge about concussions varies by age of both the athlete and parent. Approximately 80% of respondents (n=252 youth; n=300 parents of youth participating in sport) surveyed by Bloodgood et al. (2013) had heard of or knew what a concussion was (89). Parents with children between ages of 10 to 13
years old, and individuals using the internet on a daily basis, had a significantly higher knowledge about concussion as compared to other groups (89). Mothers compared to fathers were significantly more likely to view concussions as a “critical issue”. Parental age and ethnicity also had a significant impact on concussion knowledge (89). Looking at youth respondents, younger individuals (13 to 15 year olds) were significantly more likely to agree that “concussions are a critical issue” as compared to the responses of their older peers (16 to 18 year olds) (89). Optimistically, 50% of youth respondents “strongly disagreed” that their friends would think they were dumb for caring about concussions, with girls significantly more likely to strongly disagree than boys (89).

A recent study by Hunt et al. (2015) exploring concussion awareness among a group of American youth football players (8 to 14 years old) generated findings that call for concern (90). One important finding indicated that the majority of the athletes (62.5%) polled did not disagree completely with the following statement, “If I am hit in the head and have a headache, it is okay to continue to play, as long as I didn’t lose consciousness”. However many of the athletes were able to correctly identify a number of common concussion symptoms. This discrepancy illustrates that young athletes have a problem applying symptom knowledge to the consequences of concussions and their own behaviours. This should not come as a surprise because adolescents generally lack the insight and foresight that would be required to make these connections. Poor judgement is thought to be due to the protracted maturation of the prefrontal cortex, the part of the brain that is responsible for executive function (i.e. planning and goal-directed behaviour), that is ongoing during and throughout adolescence (91). Without a fully developed prefrontal cortex, adolescents lack the ability to make mature decisions, especially in risky contexts (i.e. continuing to play football despite a suspected concussion) (92).

However, does more knowledge about concussion symptoms and injury identification make a difference? Yes, evidence indicates that increases in knowledge at an athlete level have been found to positively influence the reporting of concussions to both coaches and parents (93). Use of concussion education training videos have also been shown to be useful, with significant increases seen in knowledge pre- to post education session (94). By enhancing an athlete’s knowledge and promoting early recognition of the injury, the
player is better able to self-identify a suspected injury, and subsequently begin the recovery process earlier (90). Prompt and early detection can also prevent further complications or protracted recovery (90). Awareness and education among athletes, coaches and parents is one of many approaches that can be used to mitigate the negative consequences of concussion in sport.

2.9 Concussion Education and Safety Initiatives

In recent years, education and awareness initiatives surrounding concussion have surged within youth sporting communities. A few of the initiatives that are currently available for the lay public’s use include: Making Head Way - a concussion e-learning series by the Coaching Association of Canada (95); ThinkFirst - an online and school-based concussion education program by Parachute (96); and Heads Up - a multi-audience educational tool created by the Center for Disease Control and Prevention (97).

Although sporting organizations may turn to educational tools like those mentioned above, there is limited evidence available to support the efficacy of these types of programs in enhancing concussion knowledge. So far, efficacy has only been established for one of these programs (Head’s Up). In a study pertaining to Head’s Up published by Covassin et al. (2012), researchers found that up to 77% of coaches were better able to identify a suspected concussion following the program’s use (98). Half (50%) of participants reported they had learned something from the program, and approximately 72% of individuals reported they were educating others about the materials that they had learned (98).

Other organizations like Play Safe (99), The Tom Pashby Sport Fund (100) and the Canadian Concussion Collaborative (Canadian Academy of Sport Exercise Medicine - CCC) (101) provide policy establishment, guidance and support to sport organizations. These bodies are focused on helping organizations review and establish their own individual concussion policies (i.e. return-to-play process, removal from play rules, etc.). Policies and procedures for dealing with concussed athletes are crucial for the safety of all athletes. For example in 2014, the CCC released the following guidelines for sport-organizations (this included school and non-school based organizations), amateur and professional sports. Below were some of the items that the CCC encouraged
organizations to consider and fulfill when establishing their respective concussion policies (102):

i) “an environment that will minimise the incidence of concussion injury (i.e. age limitations for contact sport, safe rules of play, fair and respectful codes of conduct, etc.)”

ii) “an environment that facilitates the early identification of suspected injury by everyone involved (i.e. athletes, coaches, teachers, etc.)”

iii) “a well-rounded approach to the management of the concussed athletes (i.e. provisions and accommodations for sport, academic, family and work life, etc.)”

iv) “access to the appropriate and dedicated care”

v) “a protocol amendment strategy / communication and education strategy”

Additional helpful resources in regards to educational or policy making guidelines can be found on the CCC homepage (101).

2.10 Concussion Policy & Technology Developments

In Canada there is no federal legislation in place at this time that governs or mandates concussion policy for schools or sporting organizations. At the provincial level however, PPM 158 stipulates each school board within the province of Ontario is required to develop and maintain a policy on concussion (103). There is no mandate for sport organizations, and each independent sporting body is free to set their own guidelines. Therefore each organization takes a unique approach to the concussion issue, with a myriad of different policies in place within each one. The rationale for these types of policies is that they facilitate early injury identification while helping to guide injury management, thus aiding to prevent further injury to a given athlete (104). At a national level, Hockey Canada, Snowboard Canada, Curling Canada, Rugby Canada, Ringette Canada and The Canadian Lacrosse Association have all acknowledged that they have a concussion policy in place (105).
Taking a proactive approach to concussion and injury prevention can take many forms and cannot be resolved based on use and implementation of policy alone. Some organizations have opted for game rule changes in hopes of increasing athlete safety. For example, in 2002 the Canadian Hockey Association introduced the *No Head Check Rule* and *Head Checking Penalty* in 2000 (106). Since that time, other sport associations have also begun to follow suit. In 2014, a class-action lawsuit that was filed against both U.S Soccer and FIFA demanded a change in policy regarding rules around heading the ball for children (107). A decision was made in November 2015, with U.S. Soccer and its associated parties agreeing to a number of conditions including (108):

i) “improving concussion awareness and education among all involved parties”

ii) “implementing a uniform concussion management and return-to-play protocol”

iii) “modified substitution rules to allow immediate assessment of suspected injury, without penalty to the team”

iv) “children 10 years and under will be prohibited heading the ball, and limit ball heading activities to practices only for individuals aged 11 to 13 years”

Various other prevention initiatives have also started to appear at the player level such as the “See it, Protect It” sticker (109), “Shockbox” (110) and “ShieldXTechnology” (111). Despite proactive efforts like concussion policy implementation, rule changes and technological advancements, concussion injuries can and will continue to occur in sport.

### 2.11 Return-to-Play Legislation and Concussion-Related Litigation

Although concussion is a serious brain injury, the majority of adolescents recover in a timely manner when their injury is appropriately recognized and managed by a trained professional. However in a distinct group of adolescents, concussions have proven to be fatal. Known as Second Impact Syndrome, some adolescents who sustain repeated concussions within short time span may experience brain swelling or permanent brain damage (112, 113). Unfortunately the untimely deaths of young people due to Second
Impact Syndrome have been the driving force behind the majority of government legislation that now exist.

In United States, the first law – The Zackery Lystedt Law - was passed in Washington state in 2009 (114). One month later Max’s Law was passed in the state of Oregon (115). Now every state in the United States has passed some form of Return-to-Play Law, which applies to all youth involved in sport at a recreational or high school level (116). Each state’s specific legislation can be viewed via: 

For the most part, the majority of laws in place share three main objectives (117):

i) training and education on recognition of injury
ii) removing the athlete suspected of injury from play
iii) returning the athlete to play only after they have been assessed and cleared by a medical practitioner

Some states have even gone so far as to make concussion training mandatory for coaches (117). Other states like Massachusetts are taking further precaution by enacting legislation that requires coaches and trainers to aid in the prevention of “any unreasonably dangerous athletic technique that unnecessarily endangers the health of a student” (i.e. deterring the use of sports equipment as weapons, horse play, etc.) (117).

As previously mentioned, Canada has yet to enact any federal legislation, but as of recent some movement has begun at the provincial level. In June 2016, the Rowan’s Law Advisory Committee Act (Bill 149) was passed in Ontario. The act has yet to mandate any specific action in regards to concussion prevention or recognition strategies. It only stipulates that a committee must convene to discuss the concerns around the cause of Rowan Stringer’s death, a 17-year-old rugby player from Oshawa, Ontario. They will then advise and oversee the implementation of concussion specific laws in Ontario (118). Again, Rowan’s death was attributed to Second Impact Syndrome after she sustained three suspected concussions within a short period of time (119). By establishing laws and legislation, policy makers hope to reduce the number of deaths and permanent disability associated with head injuries in recreational sport.
At a professional level, sport organizations like the National Collegiate Athletic Association (NCAA), National Hockey League (NHL) and National Football League (NFL) have been forced to deal with their athlete’s injuries in a different way (i.e. via lawsuits). In an effort to help remedy the damages, these organizations have opted to contribute large financial compensation to both fund player rehabilitation, formulate injury management strategies and help fund research towards a better understanding of the long term effects associated with repetitive concussive injury. In the NFL, litigation is slowly coming to a close with the association facing up to $1 billion dollars in damages owed to over 20,000 retirees over the next 65 years (120). Litigation against the NHL was ongoing at the time that this thesis was written (121). In amateur sports, the NCAA in partnership with the U.S. Department of Defence appointed $30 million in 2014 to this cause (122). They also pledged to contribute some of their resources to conducting research; over the next three years the NCAA will track and gather over 37,000 athlete baseline assessments and repeat assessment data from injured athletes (122). Not only do baseline assessments provide valuable data for research purposes, but are the most widely accepted clinical management tool that is available for use at this time.

### 2.12 Baseline Concussion Assessments

At this time there is no objective gold standard test to diagnose a suspected concussion. Although imaging like magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI) or computed tomography (CT) scans can be ordered to rule out a suspected brain bleed or more severe lesion, imaging is not routinely used to diagnose concussion (73). Instead a baseline assessment is typically administered prior to an athlete’s competitive season, in other words, when the athlete is free of injury. Although there is some variability in terms of what baseline assessment protocols may include from one organization or business to another, protocols commonly seek to assess the presence of any current concussion-like symptoms (i.e. fatigue, nausea, dizziness, trouble concentrating, etc.), collect a medical history and dossier of prior concussions, hand-grip strength, reaction time, delayed memory recall, verbal memory recall and balance (123). Baseline assessments also typically include a neurocognitive test to assess an individual’s level of cognitive functioning (i.e. ImPACT – Immediate Post-Concussion Assessment and Cognitive Testing) (123). If the athlete sustains a concussion
during the following competitive season, the managing clinical practitioner compares the individual’s baseline assessment (i.e. when the athlete was injury-free), consisting of symptom reports and cognitive abilities, to the their performance on the same measures following injury. Discrepancies between pre- and post-injury time points can then be clearly identified. Significant discrepancies can then be used to estimate injury severity, problematic areas requiring focused concussion management treatment or rehabilitation strategies.

Baseline assessments are also used to monitor and track symptom resolution in injured athletes; baseline results help to provide an objective marker of preparedness for medical clearance or return-to-play (RTP). Baseline assessments also help to raise awareness about concussive injury to coaches, parents and the athletes themselves (124).

For more information, The Centre for Disease Control and Prevention has put together a Baseline Testing FAQ page that can be found here: http://www.cdc.gov/headsup/basics/baseline_testing.html.

2.13 Symptom Reporting in the Absence of Injury (At Baseline)

Baseline symptom scales are modeled around four primary concussion symptom categories: i) emotional and behavioural, ii) physical, iii) cognitive and iv) sleep-related symptoms. Validated symptom checklists for use in adolescents and children include: the Graded Symptom Checklist/Scale (125), Concussion Symptom Inventory (126), The Rivermead Post-Concussion Symptoms Questionnaire (127), Acute Concussion Evaluation (128), Health and Behaviour Inventory (129), Post-Concussion Symptom Inventory (130) and the Post-Concussion Scale (13). Prior literature has indicated that post-concussion symptoms have been reported in healthy adolescent athletes even in the absence of concussion (79, 82). This is mostly due to the fact that concussion symptoms are not exclusive to concussion injury alone (73). Concussion symptoms are non-specific. However a certain level of variability exists among investigations that have examined baseline symptom self-reports in high-school and collegiate aged athletes (131,132).
Investigators have identified a number of personal factors that influence post-concussion symptom self-reports in the absence of injury, some of which can be modified and others that are inherent and unchangeable. In regards to sex, literature suggests females tend to report a greater number of mild symptoms as compared to males (133, 134). The role of a female’s menstrual cycle on baseline post-concussion symptom self-reports and neurocognitive performance deficits has also been explored, however findings were varied (135). In terms of age, similar patterns of symptom reporting have been identified between high school and collegiate level athletes (134). However a systematic review published by Williams et al. in 2015 confirmed that high school aged athletes experience longer recovery times than do college aged athletes (136).

Medical background is also thought to influence symptom self-reports. Investigations of individuals who reported a prior concussion were found to self-report more symptoms compared to individuals without a history of concussion (134). Number of prior concussive injuries also appears to have an affect on athlete preseason symptom reports at both the collegiate and high school level (i.e. a greater number of prior concussions contributes to elevated symptoms at baseline) (134, 137-140). Furthermore a history of psychiatric illness also appeared to elevate symptom scores (141). Similar findings were also identified among adolescents with a diagnosed learning disability (142).

Modifiable factors like stress (143, 144), sleep (145) and personal fitness levels (146) have also been associated with concussion-like symptoms. After controlling for the frequency of stressful events, impact of daily stressors as well as perceived stress (within the last month) contributed to a greater number and severity of self-reported symptoms (144). In regards to sleep, individuals reporting reduced sleep the night prior to baseline testing, reported a greater number of symptoms and higher total symptom severity score as compared to their well-rested peers (145). The effect of sleep quality on symptom presentation was not thoroughly assessed.

As for fitness levels, research conducted in college students indicated “fitter” individuals self-reported fewer symptoms than their less-fit peers (146). Fitness was based on an individuals VO$_{2max}$ score. Conversely in the short-term, exercise appears to induce symptom reporting in individuals who completed symptom reports shortly after
completing a bout of exercise (146). Exercise intensity was also shown to have an effect, with symptoms increasing significantly above baseline with intense exertion as compared to moderate exertion (135). Because physical exertion is known to exacerbate symptom reports, baselines must be completed at rest and at least 10 minutes after cessation of exercise in order to mitigate any effect of fatigue on symptom reports (9).

Setting or environment of baseline test administration has also been examined. Although some evidence suggests that neurocognitive test performance may be negatively effected when completed in a school-based or peer-present setting (as compared to being completed in a private or individual clinic setting), there is no evidence available at this time to suggest that setting has any effect on symptom reports alone (147).

2.14 Depression in Adolescents

Depression is a common mood disorder that affects Canadians of all ages. Statistics suggest that rates of depression are highest among individuals aged 15-24 years old, with 9.0% of females and 5.3% of males meeting the Diagnostic and Statistical Manual of Mental Disorders-Fifth Edition (DSM-V) diagnostic criteria for a major mood disorder (148). A number of negative outcomes have been associated with depression in adolescents including: interpersonal relationship problems, declines in school performance as well as developmental delays across social, emotional and cognitive domains (149-153). Depression in adolescents has also been reported to increase days missed from school, contribute to declines in school performance, increase risk for substance, alcohol and nicotine use, increase risk for binge eating behaviours and increase risk for suicidal ideation (154).

Typical onset for mood disorders like depression is thought to begin during adolescence or earlier (155-160). Although depression has roots in adolescence, research findings demonstrate there is a dramatic increase in rates of depression from adolescence into early adulthood (i.e. from puberty onward) (161). Some literature also indicates there is a negative continuity in mental health (161). Meaning individuals who suffer from depression in their teenage years face a greater risk for recurrent depressive episodes into and throughout adulthood. Once an individual has experienced one episode, they face a
50% increase in risk of experiencing a subsequent episode (162). As will be discussed further below, some evidence suggests that recurrence and risk for a novel depression diagnosis increases following a concussion injury (6-8, 163).

2.15 Depression in Adolescent Athletes

In athletes, depression may present as irritability, poor performance (in either practice or competitive situations), anhedonia (lack of enjoyment of an activity that was once pleasurable), overtraining or drug and alcohol abuse (164). Among athletes, mental health issues may go un-noticed due to stigma or inherent focus that physical injuries receive and their more obvious impact on sport performance (164). Although many of the triggers for depression can be the same within athlete and non-athlete populations, there are a few triggers that are unique to athletes such as injury, pain, competitive fatigue, aging and retirement from sport (165).

Overtraining is also a key concern for athletes, especially for those athletes who compete at an elite level. Moreover, overtraining is of increasing concern because of the dramatic symptom overlap that exists between overtraining and depression (i.e. fatigue, insomnia, appetite changes, weight loss, motivation and diminished concentration) (164). Barriers to depression treatment that are specific to this population include: i) the social stigma associated with a diagnosis, ii) not wanting to appear weak in the eyes of teammates or coaches or iii) having to use anti-depressant medications that may hinder their competitive performance (164, 166, 167).

Following a sport-related injury it is expected that an individual may experience emotional symptoms to some extent. Depressive symptoms may be attributed to pain associated with the injury, or in a competitive athlete’s case, a loss of identity in the sense that the individual is unable to participate in their sport activity for the time being. The emotional consequences of concussion have also been compared to musculoskeletal injuries (i.e. ACL) (168, 169). Findings from a study using a group of collegiate student-athletes (n=16 concussed, n=7 ACL-injured and n=28 control subjects) indicated that individuals with an ACL-injury demonstrated more severe depressive symptoms for a longer period of time following their injury as compared to concussed individuals (169). Findings support the notion that a different mechanism of action may be responsible for
depressive symptoms in the concussed athletes as compared to athletes with a musculoskeletal injury (169).

2.16 The Relationship Between Depressive and Concussion Symptoms

At this time very few studies have reported on the relationship between mental health status (i.e. presence of depressive symptoms) and concussion-like symptoms in the absence of injury. Of the investigations that have been conducted, very few have examined this relationship among an adolescent athlete population. One related study conducted by Covassin et al. (2012) sought to explore the affect of depressive symptoms on neurocognitive test performance in college (n= 837) and high school (n=779) athletes at baseline (170). Investigators then stratified individuals into one of four groups based on their Beck Depression Inventory-Version 2 (BDI-II) score (i.e. minimal depression [0-13 points], mild [14-19 points], moderate [20-28 points] or severe depression [28-63 points]). Irrespective of age and sex, athletes with severe depression reported greater total concussion-like symptoms as compared to athletes in either the minimal or mild depressive groups. Differences were observed between depressive groups in all categories of concussive symptoms (i.e. cognitive, somatic, emotional and sleep-related symptoms). Other differences were observed between sex and age groups, but were not as robust.

In another study (n=104, 44.1% participants were between 15-19 years old) investigators administered the British Columbia Postconcussion Symptom Inventory–Short Form (BC-PSI-Sf; 16-item scale used to assess presence and severity of post-concussive symptoms) and BDI-II (171). Investigators identified significantly high correlations between the two measures (ranging from r=0.73 to 0.76) (171). In this same study, a cut-off score of 14 or greater on the BDI-II was applied to a subsample of participants (n=24). The most commonly reported symptoms in this group on the BC-PSI-Sf were: fatigue (95.8%), irritability (91.7%), sadness (91.7%), nervousness or tension (91.7%), poor concentration (91.7%), memory problems (83.3%) and poor sleeping habits (83.3%).

Another study utilizing the BDI-II and BC-PSI revealed similar findings among a group of community (n=47) and university student participants (n=49) (172). Using a cut-off
score of 14, depressed participants (n=24) had significantly higher scores on the BC-PSI as compared to non-depressed participants (mean=20.00 ± 8.61 vs. mean=6.99 ± 5.75 respectively; p=0.001). The most commonly reported symptoms in the depressed group were: headaches (95.8%), dizziness (75.0%), nausea (62.5%), fatigue (83.3%) and sensitivity to noise (50.0%), slightly different than the items endorsed in the previous study (172).

Using a different concussion symptom scale, the Post-Concussion Syndrome Checklist (PCSC; (143)), Sawchyn et al. (2000) investigated the relationship between the BDI and the PCSC in a group of n=326 undergraduate students. Although less robust than previous findings, investigators found a significantly modest correlation between the two measures (r=0.55). By item, correlations ranged from 0.16 to 0.45 with concentration, fatigue and irritability being most highly correlated with the BDI (173).

2.17 Sex and Gender Considerations in Research

In the context of health related research, a vast body of literature supports the notion that sex and gender should be considered as separate entities. Gender refers to “the array of socially constructed roles and relationships, personality traits, attitudes, behaviours, values, relative power and influence that society ascribes to the two sexes on a differential basis … gender roles and characteristics do not exist in isolation, but are defined in relation to one another and through the relationships between women and men, girls and boys.” (174). Sex refers to biological differences, whereas gender refers to social differences (175).

Since the increase in female participation in sports in the late 1980’s and 90’s, there has been a flux in awareness around the gender differences that exist in the epidemiology of sports injuries (176-178). For example, females face an increased risk for severe knee ligament injury in competitive sports like basketball, soccer and handball (179). In a study conducted by Stevenson et al. (1995), investigators found that female competitive ski racers were up to 3.1 times more likely to have sustained an ACL injury as compared to males competing in the same sport (p<0.001)(179). In an orthopaedic investigation conducted by Ponzer et al. (2001) women were found to report more somatic and psychological symptoms than males in the first few days following their injury (180).
Even after accounting for age, injury severity, education and alcohol dependence, women had double the risk of suffering from major somatic or psychological symptoms in the first few days following injury (180).

When faced with an injury, social norms dependent on our gender impact the way that we act and seek attention from others. For example, men view pain as a weakness therefore they are less likely to report or express it emotionally (181). However women, are nurtured to be more sensitive and fragile, thereby making them more likely to be emotionally expressive when in pain or when seeking care (181). It is well documented in the literature that gender has an impact on the way that men and women seek help for their health concerns (182-187). Reasons for this behaviour have been attributed to the self-categorization theory (188). The theory suggests that when we classify ourselves as a member of a social group, the view we have of oneself shifts from the personal identity to a social identity, thus leading an individual to think, feel and behave according to the norms of the group (188). For example, in an investigation conducted by Pool et al. (2007) a group (n=77) of both male and female undergraduate students reported that men should be able to tolerate more pain. Findings also indicated that identification with one’s gender group moderated the extent of self-reported pain and behaviour that corresponded to the gender norm for pain tolerance (181). In population-based studies, females have been consistently found to experience more severe acute and chronic pain across a range of medical conditions (189-191). In laboratory-based investigations, women have been found to exhibit greater pain sensitivity, enhanced pain facilitation and reduced pain inhibition as compared to men (192).

Researchers further postulate that many of the differences between women’s and men’s health cannot be attributed to biological differences alone (193). An imbalance in social roles and structure “further places men and women in an unequal position for access and control of both physical and non-physical resources related to wellbeing and quality of life markers” (194). In a qualitative study conducted by del Mar Garcia-Calvente et al. (2012), investigators found that women tended to express a worse perception of their health, and also emphasized their exhaustion (194). However men in their investigation tended to overrate their health status (194).
Within traumatic brain injury research literature, investigations have noted significant
gender differences in depression levels, post-concussion symptoms as well as
discrepancies on visual memory tasks following a mild or moderate TBI or sport-related
concussion (195, 196). Women have also been found to have higher rates of
Postconcussion Syndrome as compared to men (197-200). Work by Colantonio et al.
(2010) further emphasize the need to consider sex and gender differences following
traumatic brain injury (201). Investigators suggest that an “examination of health
outcomes based on gender may reflect important differences following a traumatic brain
injury and can help inform health service decision-makers” (201).

2.18 Rationale

Although not commonly discussed in everyday conversation, depression affects the lives
of many Canadian adolescents. Negative outcomes associated with depression in this
population greatly impact quality of life and wellbeing. Conversely, sport and exercise
are thought to provide a protective effect on mood and mental health status, along with a
number of other health benefits (24-32, 35, 39-44). However participation in sport comes
with an increase in risk for injury, including sport-related concussion.

Communicating accurate statistics in regards to the percentage of adolescent athletes who
reach full recovery following a concussion is a challenging task, as definitions of
“prolonged” or “persistent” concussion symptoms often vary drastically from one
investigation to the next (i.e. more than 7 days (202), more than 10 days (203), more than
2 weeks (204), more than 21 days (205), more than 28 days (4)). There is also
considerable variability in how “recovery” is defined within each respective
investigation. For example, recovery may be defined as full-medical clearance or return-
to-play, return to full-time school, or when the individual is no longer reporting any
symptoms (i.e. when they are asymptomatic). Therefore comparing “recovery” across
studies to provide an objective statistic on what a typical recovery trajectory is for this
population is not easily done. Factors such as prior history of concussion, presence of a
learning disability (i.e. ADD/ADHD), diagnoses of a mood disorder, history of migraine,
younger age, and the female sex have also been associated with prolonged recovery
(206). A recent study published by Zemek and colleagues found 39.9% of concussed
adolescent athletes (n=262) met criteria for persistent post-concussive symptoms at 28 days following their injury (4). Although a number of factors have been attributed to prolonged symptom resolution, preliminary evidence indicates that depression and poor mental health status are key factors in prolonged recovery (4, 10, 206).

Very few studies have reported on the relationship between depressive and concussion symptoms in an adolescent population. This may be because the population is hard to access or that adolescents may be hesitant to discuss these types of symptoms (especially athletes). Investigation is required to better understand how depressive and concussion symptoms interact within adolescent athletes. Before we can understand how depression affects recovery from concussion, we must first understand the interaction between these two symptom factors in the absence of recent injury. Understanding symptom overlap between the two categories will better help clinicians to separate or disentangle concussion symptoms from depressive ones, and how depressive symptoms can negatively impact concussion-like symptom reporting.

Creating normative concussion-like and depressive symptom profiles in healthy adolescent athletes will help clinicians to understand what the “injury-free” symptom profile looks like. This will allow clinicians to take a more informed approach to symptom management should an athlete sustain a concussion. Using these benchmarks, clinicians can better gauge when the athlete is ready to be medically cleared and returned-to-play. Examining the athlete as a whole (i.e. physical, mental and emotional wellbeing) may enable practitioners to take a more holistic approach to managing an injured adolescent athlete.

2.1.9 Objectives

Using a sex-based approach, the proposed study aims to establish a foundation for future sport-related concussion research by:

1. Investigating the distribution of the frequency and severity of concussion-like symptoms reported by adolescent athletes (aged 13 to 18 years old) using the Post-Concussion Scale (PCS) (13), in the absence of a recent concussion (i.e no diagnosed concussion in the previous month).
2. Investigating the distribution and severity of depressive symptoms reported by adolescent athletes using the Mood and Feelings Questionnaire (MFQ) (14), in the absence of a recent concussion.

3. Examining the correlation between PCS (13) symptom frequency and symptom severity score and depressive symptom score on the MFQ (14).

4. Conducting sex-based analyses to investigate the effect that sex has on concussion-like and depression symptoms identified in the absence of a recent concussion.

2.20 Research Questions

1. Among adolescent athletes, what type, frequency and severity of concussion-like symptoms can be identified using the PCS, in the absence of a recent concussion?

2. Among adolescent athletes, which depressive symptoms and of what severity can be identified using the MFQ, in the absence of a recent concussion?

3. What differences can be identified by sex in regard to i) PCS and MFQ outcome measure scores and ii) calculated correlational values?

4. How do PCS symptoms and severities self-reported by adolescent athletes assessed at the injury-free time point correlate to symptoms and severities identified on the MFQ at the same time point?

5. Among adolescent athletes, what is the combined effect of the following factors: age, sex, prior depressive episode, history of concussion, and prior medical diagnoses (i.e. depression, anxiety or a learning disability diagnoses) on both PCS and MFQ outcome measure scores, in the absence of concussion?

2.21 Hypotheses

1. Athletes will report a various number and severity of concussion-like symptoms along a normative continuum, however female athletes will report more symptoms of a greater severity relative to males.
2. Depressive symptoms will be normatively distributed within this sample however female athletes will present with a higher MFQ score relative to males.

3. A moderate correlation (0.3 – 0.5) will be identified between PCS and MFQ measure scores.

4. Female athletes will report a greater number and greater symptom severity on both concussion and depressive symptom scales as compared to male athletes.

5. i) Age will contribute significantly to symptom scores, with older participants (both male and female) endorsing more concussion-like and depressive symptoms of greater severity than younger athletes; ii) females will report more symptoms of greater severity on both outcome measures relative to their male peers, iii) participants self-reporting a prior depressive episode will report more symptoms of greater severity on both measures as compared to participants who have not experienced a prior depressive episode; iv) participants with a history of concussion will report more symptoms of greater severity on both measures as compared to participants who do not self-report a history of concussion; v) participants self-reporting a formal diagnosis of depression, anxiety or learning disability will report more symptoms of greater severity on both outcome measures relative to participants who do not have a diagnosis.
Chapter 3

Methods

3.1 Research Ethics Considerations

3.1.1 Ethics Approval

Ethics approval was granted by The University of Toronto Research Ethics Board (REB) on March 13th, 2015. The initial protocol proposed to collect data from athletes who were participating in baseline data collection sessions completed at Complete Concussion Management Clinics Inc. (CCM) in the Greater Toronto Area (GTA). Subsequent protocol amendments were submitted and approved by the U of T REB in June 2015 and October 2015; these amendments aimed to expand the recruitment sites to include community level sport organizations located within the GTA (detailed below).

3.1.2 Amendment 1

Following initial unsuccessful attempts to recruit participants solely from CCM clinics, a protocol amendment was submitted to the REB on June 11th, 2015. CCM clinics were still included in the amended protocol. Approval was granted by the REB within two weeks (June 29th, 2015). Amendments aimed to expand the participant recruitment strategy to include community level sport organizations and two high schools (only one school was contacted and declined to participate). Five soccer, seven lacrosse, five football, nine rugby and ten hockey associations were added to the protocol (total of 36 organizations). Sport organizations included on the amendment were identified using a Google search that was conducted prior to the amendment submission. Search terms included a combination of the following words: “youth”, one of the following: “football, lacrosse, hockey, soccer, rugby”, “associations”, “Greater Toronto Area”, “GTA” or “Toronto”. Separate searches were conducted for each of the targeted sports. The top search results, if they were a sport organization in the GTA, were included in the amendment.
A select number of the sport organizations that were identified by the Google Search were contacted by email in early Summer 2015 (5 football, 8 rugby, 4 lacrosse and 5 soccer). Hockey organizations were not contacted because the hockey season was not ongoing at the time. Email addresses were gathered by navigating the respective sport organization websites; email addresses were typically found using the “Contact Us” link or “Executive Board” link. Emails were directed to the President and Vice Presidents of the Executive Boards identified on each organization’s website. A Risk Management Executive was also included if possible. In some cases emails were sent directly to the sport organization through their website (embedded mailing program). The majority of emails were sent from the student investigator’s (TR) University of Toronto email account.

A limited number of sport organizations responded to the initial email invitations. At least two emails were sent, one as an initial introduction and another ~ 1 to 2 weeks later if the sport organization did not respond to the initial request. In some cases, the student investigator made a follow-up phone call if a central registration/administration number was provided. Five of the 22 (18.2%) organizations replied with immediate interest. Despite repeated attempts to schedule data collection sessions, four of these organizations did not follow through with their participation. Two additional organizations agreed to participate after having had a parent (mutual friend to the investigator) or investigator approach a family member who sat on the organization’s Executive Board. A total of three sport organizations were recruited between early and late summer of 2015. The number of data collection sessions varied for each participating organization and ranged from one to a maximum of four sessions per organization.

### 3.1.3 Amendment 2

A second amendment was submitted on September 30th, 2015 and was approved by the REB on October 21st, 2015. This amendment included the addition of six hockey, three lacrosse, eleven skiing/snowboard clubs, one football scouting organization and 14 cheerleading organizations. Organizations were identified using a similar Google search as used previously. One of the hockey organizations included in the protocol was added after a trainer for the team indicated interest in the project. An introduction was initially
provided by a mutual friend. The owner of the scouting organization was also introduced
to the student investigator by a mutual friend. Invitations were sent to a select number of
the new organizations and all of the hockey organizations (including the hockey
organizations on the previous amendment); in total, emails were sent to 15 hockey
associations, one scouting organization and three cheerleading organizations.

Eight organizations responded immediately to the initial email invitation. Three of these
organizations followed through with their interest, four did not continue with the
initiative and one indicated interest after the study was closed to recruitment. None of the
ski or snowboard clubs were contacted because data collection goals were achieved
before the ski/snowboard season began. The student investigator collected data between
one and two sessions for each participating organization.

Overall, including the study amendments, approximately 14 CCM clinics in the GTA, 72
community sport organizations and two schools were included in the recruitment plan. Of
those, 14 CCM clinics, 42 community sport organizations (5 football, 8 rugby, 4 lacrosse,
5 soccer, 16 hockey, 3 cheerleading clubs and one scouting agency) and one school were
contacted. See appendix 1 for a flow diagram detailing the recruitment process for each
recruitment source (i.e. clinic, sport organization or school).

3.1.4 Informed Consent

Written informed consent was obtained from each participant prior to completing his or
her questionnaires. Guidance and instruction on how to obtain informed consent was
obtained through the REB prior to protocol approval. Special consideration was
implemented because some participants would have been as young as 13 years old.

Parental consent and participant assent were not deemed to be necessary by either study
investigators or REB reviewers. This was based on the rationale that some athletes may
not have parents present to provide their consent and would therefore be ineligible to
participate in the investigation. Alternatively, if parental consent was required and
drafted, the adolescent would be prevented from participating in the investigation
despite their own wishes.
To ensure adolescents were capable of providing consent on their own behalf, the student investigator asked a series of probing questions (see appendix 2). If the participant could answer all the questions satisfactorily, they were deemed to have the capacity to consent. There were no instances that an interested participant was deemed not to have capacity to consent. However should this have occurred, informed consent would have defaulted to parental consent and participant (adolescent) assent.

As data collection took place at various locations outside of the student investigator’s affiliate research hospital (i.e. CCM clinics and at community sport organization practice locations – field side, rink side, etc.) a copy of the signed informed consent document (appendix 3) was not provided to participants (due to lack of available photocopier). Instead each participant was provided with a copy of the REB approved Letter of Information (appendix 4: Version 1 – CCM Participants or Version 2 – Sport Organization Participants). The student investigator’s contact information was highlighted on the Letter of Information, and participants and their parents were encouraged to reach out to study staff should they have any questions or concerns about their participation in the study.

3.1.5 Harm Protocol

As part of this investigation, one questionnaire (the Mood and Feelings Questionnaire) sought to evaluate symptoms of depression endorsed by study participants. In light of the sensitive and serious nature of some of the items on the questionnaire, a harm protocol was developed to ensure participant safety. Appendix 5 outlines the criteria for implementing the harm protocol. To ensure the harm protocol could be implemented for all participants, the completed questionnaires were to be reviewed immediately following the participant’s completion of the survey (at the recruitment location). If a participant’s questionnaire met any of the four criteria indicated in the harm protocol, they would be asked to speak privately with the student investigator. During the private interview the student investigator disclosed the reason for concern and briefly discussed help options with the participant. A list of distress resources (appendix 6) was also provided. At the conclusion of the brief interview, participants were asked if they could provide contact information (either email or phone number) for follow-up purposes. All participants were
contacted by the student investigator approximately one week later to check-in with how they were doing.

3.1.6 Contacting Parents – Harm Protocol

When the harm protocol for the study was initially developed and approved by the REB, the research team had not explicitly outlined how parents would be contacted (i.e. in the case that a participant had indicated intention for self-harm). Study investigators did not anticipate that a participant’s parents would need to be contacted when the study protocol was originally submitted for REB approval. In the rare circumstance that a parent would need to be contacted, a parent’s contact information would be obtained from the athlete’s coach/sporting organization, and thus this information was not collected *a priori*. After consulting with a psychiatrist at St. Michael’s Hospital in regards to legal obligations and the duty to report, the student investigator was advised that participants under the age of 16 years old were required to have their parents notified of their significant symptoms of depression as well as their suicidal thoughts and feelings. Parental contact information (phone number and name) was obtained directly from the relevant contact person at the sport organization (e.g. athlete’s coach). Parents of the relevant participants were then contacted. When communicating with parents, the student investigator explained the nature of the phone call and her relationship to the participant. The student investigator communicated concerns specifically about the participant meeting the harm protocol. In all cases, this related to suicidal ideation. Some parents requested to have the distress resource sheet and their child’s MFQ score forwarded to them, which the student investigator then provided. After initial contact with parents, no further follow-up was conducted. Coaches were notified of all communication with their athlete’s parents.

3.2 Recruitment Settings and Procedures

Participants were recruited from two sources: i) Complete Concussion Management Inc. clinics and ii) various community sport organizations in the GTA.

3.2.1 Recruitment
There was a three-step communication process that took place prior to working face-to-face with athletes within CCM clinics or sport organizations in the community.

Primary contact was made with the Clinic Director (CCM) or President/Vice-President of the sport organizations. Following primary study approval within the sport organization or clinic, secondary contact was made with CCM practitioners or coaches to organize a time for data collection. Tertiary contact was made face-to-face with the athletes in their respective settings. In both settings, initial introductions and purpose of student investigator presence was provided to the athletes by the hosting clinician or coach. A total of 3 of 14 (21.4%) CCM clinics and 6 of 42 (14.3%) sport organizations (one rugby, one lacrosse, one soccer, two hockey and one cheerleading club) participated in data collection. A total of 17 data collection sessions were conducted across both settings: 12 sessions with independent sport organizations [(12/17 (70.6%); n=133 participants recruited (80.6%)] and 5 sessions with CCM clinics [(5/17 (29.4%); n=32 participants recruited (19.4%)]. See appendix 7 for clinic and sport organization collection dates, and number of participants approached/refused.

3.2.2 Complete Concussion Management Inc. (CCM) Clinics

Prior to beginning this investigation, a connection had been established by the student investigator with the CEO and President of CCM, Dr. Cameron Marshall (Doctor of Chiropractic). CCM specializes in concussion management of amateur athletes. The business’ primary function was to conduct baseline concussion assessments. Dr. Marshall was keen to incorporate research into his business model and agreed to collaborate with the study investigators. Using existing methods of communication, Dr. Marshall shared CCM’s involvement in the study with his satellite clinics throughout the GTA. Initial communication by Dr. Marshall was made by email (April 27th, 2015), and introduced both the study and the student investigator. Follow-up communication was then completed for each clinic approximately one week later, via email. Inquiries were made as to any prospective baseline assessments that were booked within the satellite clinics in the upcoming weeks and months. Initial attempts to connect with CCM clinics, and to align with baseline testing procedures in Spring 2015 were unsuccessful. Despite initial REB approval in early March 2015, only n=3 participants had been recruited from CCM.
by May 2015. At the time, due to the novel nature of baseline assessments, high cost, time required to complete assessments and lack of perceived benefit, many clinics in the GTA did not have any planned baseline assessments (for season-appropriate sports such as soccer, rugby, football, lacrosse). Furthermore, as the investigation was to be conducted at the time of the athlete’s baseline assessment, data collection would then revolve around competitive season start dates (e.g. early-spring for summer sports and early-fall for winter sports). Therefore there was a limited window of opportunity to engage with clinics that were conducting baseline assessments. Following unsuccessful attempts to recruit participants using this strategy, the student investigator’s Program Advisory Committee (PAC) suggested that recruitment be expanded to sport organizations within the GTA (discussed further below).

CCM clinics were contacted again in late Summer 2015; inquiries were made as to projected baseline assessments that would be ongoing in Fall 2015 (i.e. hockey). Although a number of clinics were responsive in email communications, not all clinics had planned or had ongoing baseline assessments at the time of contact. Inquiries and participant recruitment was more successful at the second time point.

In total, between both Spring 2015 and Summer/Fall 2015, fourteen CCM affiliated clinics were contacted and invited to participate in the study. Three clinics (21.4%) of the fourteen clinics participated in data collection. The number of data collection sessions varied by clinic: one session for one clinic, and two sessions for two clinics, for a total of five data collection sessions (5 /17 = 29.4%) completed with CCM affiliated clinics.

3.2.3 CCM Clinic Procedures

The student investigator approached athletes before or after they had completed their baseline assessment. In most cases the study was introduced to one or two athletes at a time, as athletes typically had set, staggered appointment times at the clinic to complete their assessment. Introductions took place in the waiting room area of the respective clinics. The majority of athletes had their parents present when initial introductions were made. The student investigator first introduced herself and her role as a student researcher at the University of Toronto within the Rehabilitation Sciences Institute, and indicated that the study was part of her thesis project. The contents of the Letter of Information
were then verbally reviewed with the athletes. T.R then outlined the purpose of the investigation, the measures that would be administered, time necessary for completion, privacy and security of information and the rights of research participants. This introduction took ~ 7-10 minutes to complete. After initial introductions, individuals were then invited to take part in the investigation. Informed consent was obtained prior to an individual’s participation in the study (as detailed above in section, 3.1.4 Informed Consent).

3.2.4 Community Sport Organizations

Following Program Advisory Committee (PAC) suggestions to expand participant recruitment to sport organizations in the GTA, the student investigator conducted a brief Google search to identify targeted sports organizations (as described in section 3.1.2 Amendment 1, above). One sport organization was added that was not identified in the Google searches. This organization was previously known to one of the primary investigators.

Following REB approval of the amendment submissions, the student investigator attempted to contact each of the identified sport organizations. Communication was conducted by email and telephone. In some cases, a brief a PowerPoint presentation was made by the student investigator to the Executive Board members of the organization. In-person presentations highlighted the objectives of the study and the involvement of the organization and their athletes. Presentations were provided to two organizations, however only one of these organizations ended up partaking in the study.

Following initial email, telephone and on-site presentations, final approval from the sport organization (i.e. President, Vice President, Executive Board Committee) was granted. Administrative staff then filtered eligible teams by age. Each of the team’s respective coaches were then contacted via email by the organization’s administrative staff. Following initial communication with coaches, the student investigator followed-up with each of the identified team coaches to organize a data collection session. Data collection sessions were either planned to occur before or after the team’s practice session.
3.2.5 Community Sport Organization Procedures

Coaches provided athletes with an introduction as to the presence and purpose of the investigator at their practice. Similar to the process taken while working with athletes at CCM clinics, the student investigator introduced herself as a Master’s student at the University of Toronto. The same introductory presentation was provided to these athletes as was provided to athletes recruited from CCM clinics. Interested individuals were then invited to participate in the investigation. Capacity to consent was gauged and informed consent was gathered from all interested individuals prior to completion of their questionnaires. The athlete recruitment process, either at CCM clinics or with sport organization, was identical. The only difference being that when working with athletes at the sport organization level, the student investigator would address the entire team at one point in time. Parents were also not typically present at these sessions, as many parents dropped their child off to practice.

3.3 Participant Eligibility

Eligibility requirements stipulated that participants must have been: i) present at a given recruitment location at the time that the study was being carried out (i.e. a) CCM clinic or b) were registered with the participating community sport organization), ii) were between the ages of 13 and 18 years old at time of survey completion, iii) were able to read, write and speak English and iv) were deemed to have the capacity to provide consent to participate in the research. As this investigation sought to identify concussion-like and depressive symptoms in the absence of a recent concussion, “recent” for the purposes of this investigation is operationally defined as < 1 month (i.e. 30 or 31 days). Therefore individuals who self-reported a concussion injury within the 4 week time window prior to their participation in this investigation were excluded from data analysis.

3.4 Data Collection

Data collection settings varied according to the recruitment approach.

At both settings a small collapsing table was set up with an REB-approved study banner. Clipboards were also available for athletes to use, as table and writing space was typically absent at all venues. Only one investigator from the research team (the student
investigator, T.R.) was present at the data collection sessions. The student investigator approached all potential participants with information regarding the respective study, collected informed consent and administered the relevant questionnaires.

### 3.4.1 Setting & Recruitment Timeline

Five CCM clinic data collection sessions were held between May 9th, 2015 to October 10th, 2015. A total of 42 athletes were approached, 10 individuals refused (23.8%) and 32 individuals consented and completed surveys (76.2%). See appendix 7 for participant approached/refused/consented tracking log.

Six community sport organizations (one organization each from lacrosse, soccer, rugby and cheerleading and two from hockey) agreed to participate in the study. Twelve data collection sessions were held from July 15th, 2015 to November 28th, 2015. A total of 167 athletes were approached, 34 individuals refused (20.4%), 133 consented and completed the surveys (79.6%).

Between both recruitment settings, 17 data collection sessions were completed: 209 athletes were approached, 44 refused (21.1%) and 165 completed surveys (78.9%).

A total of 155 individuals were included in the study (93.9% of all consented participants) (see section 3.7.2 for exclusion rationale). See appendix 7 for breakdown of athletes approached, refused and completed for each data collection session.

### 3.4.2 Outcome Measures

This study was conducted using an observational, cross-sectional design. All measures were provided to each participant in a pre-organized questionnaire package after they provided informed consent. Measures were completed sequentially and were only completed once by each participant at one time point (i.e. no follow-up period). Data forms were de-identified using a coded ID number system. The same number code matched with the participant’s consent form. Participant name did not appear anywhere on the surveys. Surveys took approximately 10-20 minutes (including time for informed consent) to be completed. See appendix 8 for the questionnaire package that was provided to participants.
Prior to completing their questionnaires, participants were given the following instructions: i) “complete the surveys as best you can”, ii) “if you don’t feel comfortable answering any of the questions, you do not have to do so”, iii) “when you get to the 4th page (PCS survey), even though you don’t have current concussion, you may still be experiencing some of the symptoms. Please circle the appropriate symptom and severity if it applies to you”, iv) “let me know if you have any questions or if you are unsure of any questions, at any point”.

3.4.3 Survey I: Demographics and Medical History

A 16-item survey developed for this study inquired about participant sex, age and current sport or the sport that the baseline assessment was being completed for. Position and level of competition were also collected. The medical history component assessed for a history of concussion, number of prior concussions, date of last concussion and duration of symptoms (if relevant). The survey also inquired as to the presence of a learning disability diagnoses, history of anxiety (diagnoses and presence of anxiety symptoms in the previous 2 weeks) and history of depression (diagnoses and number of previous episodes). Most items had a Guttmann scale response however some questions allowed for an open-ended response. According to Microsoft Word, the document was rated as having a score of 6.6 on the Flesch-Kincaid Grade Level reading scale (207). See appendix 8 for a copy of the survey. The primary objective of this survey was to contextualize and gain further insight as to the modifying and personal factors that existed among the community-based convenience sample that was captured.

3.4.4 Survey II: The Post-Concussion Scale (PCS)

The PCS (13) is a 22-item self-report symptom severity scale with a 7-point Guttmann scale response, validated for use in 11-18 year olds. Symptoms in the tool were generated based on the author’s experience, and commonly identified symptoms while working with professional and amateur athletes. Symptoms can be categorized into four overarching symptom factors: emotional and behavioral, physical, mental and sleep-related symptoms (208, 209). Scoring for this measure was as follows: “0” no symptom, “1 or 2” mild symptom, “3 or 4” moderate symptom, and “5 or 6” severe symptom. The PCS can be summated in two ways: 1) by symptom frequency (out of 22), and 2) by total
symptom severity (out of 132). The symptom frequency score is calculated by adding up the number of reported symptoms, with a maximum score of 22; a higher score indicating more symptoms. This score is referred to as PCS 22 in this thesis. To calculate symptom severity, the severity number (i.e. score of 0 to 6) indicated for each of the 22-items is summed. This score is referred to as PCS 132 in this thesis. See appendix 8 for a copy of the survey. Normative trends in reported symptoms and severity were calculated for the entire sample and by sex group as described in section 3.7 Data Management & Analyses (see below).

3.4.5 Survey III: The Mood and Feelings Questionnaire (MFQ)

The MFQ (14) is a 33-item depression symptom survey with a 3-point Guttmann response scale. Three response options are available for the participant: “not true”, “sometimes” and “true”. A numerical score is awarded (0, 1 or 2) for the respective options. This scale inquires about depressive symptoms in the past two weeks, and is intended to identify a major depressive disorder (MDD) in children and adolescents. Supporting literature for the MFQ (child version) indicates a cut-off score of 27 or higher indicates a MDD (210). Authors of the measure indicated that this cut-off point should be interpreted with caution as their study utilized a population with a high proportion of individuals with depression. Authors of the MFQ insist that no distinct cut-off point exists, and cut-off should be relative to the population in which the measure is being utilized.

In an investigation (n=104 adolescents between the ages of 10 and 19 years old) conducted by Wood et al., a mean score of 20.5 ± 13.2 was identified in non-depressed patients vs. a mean score of 36.9 ± 12.4 in individuals with major depression (210); based on the most optimal intersection point of specificity (0.78) and sensitivity (0.78) a score of ≥ 27 was selected. See appendix 8 for a copy of the MFQ. Normative trends in reported symptoms were calculated for the entire sample and by sex group as described in section 3.7 Data Management & Analyses (see below).
3.5 Participant Safety

Although not necessary for a depression diagnoses, suicidal ideation (i.e. suicidal intent or thoughts) is one of the most profound symptoms that an individual can experience when diagnosed with a major mood disorder like depression. Within the MFQ, there were a number of questions that fall under the guise of suicidal ideation (items # 16-19). These included: i) “I thought that life wasn’t worth living”, ii) “I thought about death or dying”, iii) “I thought my family would be better off without me”, and iv) “I thought about killing myself”. Within the context of this investigation, reporting any one of these symptoms indicated that the participant could be an immediate risk to themselves or others. A harm reduction approach was taken to ensure participant safety within this investigation. The procedure for caring out the harm protocol is as described above (see appendix 5, and sections 3.1.5 and 3.1.6)

3.6 Validity & Reliability of Outcome Measures

3.6.1 PCS

The Post-Concussion Scale is one of 20 symptom scales commonly used to evaluate sport-related concussion symptoms (211). It is a theoretically derived scale (212). Created by Lovell & Collins (1998), this scale was developed based on the author’s former experiences working with amateur and professional level athletes. Items in the scale were designed to reflect that of the symptoms reported by athletes and not that of the equivalent medical terminology, further contributing to its strength as a self-report measure (13).

According to the guidelines published by the American Academy of Neurology, of the available evidence, symptom scales and checklists can accurately identify concussion in athletes suspected to have been injured (213). Guidelines indicated that tools had a sensitivity ranging from 64 to 89 percent and specificity ranging from 91 to 100 percent (213).

A systematic review conducted by Gioia and colleagues (2009) identified the PCS as one of five concussion symptoms scales readily validated for use in paediatric and adolescent population (ages 5-22) (214). Overall they concluded that psychometric evidence for the
identified scales is stronger for adolescent aged individuals than younger children (214). In total Gioia et al. (2009) identified 10 studies that provided psychometrics for the Post-Concussion Scale (214). The PCS was also one of three (of the five) scales evaluated that provided reliability data, and one of two (of the five) that had a reported a reliable change index. All five scales evaluated provided validity data of some kind, however the PCS had the greatest number of validity studies conducted out of all the identified scales. Validity findings indicated differences among injured vs. non-injured groups. Internal consistency fell within the high range (Cronbach’s $\alpha = 0.87 – 0.94$) and test-retest in the moderate range ($r = 0.55-0.65$). Sample sizes of the respective studies utilizing the PCS ranged from $n=56$ to $n=1746$ athletes, and typically included high school and college aged individuals. Appropriately, the PCS has been used extensively in a number of paediatric investigations (204, 215-220).

A study conducted by Lovell and colleagues in 2006 indicated similar findings; high internal consistency was seen in both a normal un-injured sample (Cronbach’s $\alpha = 0.89-0.94$) and concussed sample ($\alpha = 0.92-0.93$) (217). Test-retest reliability was not as strong ($r = .65$) (221). Construct validity has also been explored; a four-factor structure has been identified within the PCS: Somatic, Cognitive, Emotional and Sleep symptoms. (222). A revised factor structure has since been proposed by Kontos and colleagues in 2012: Vestibular-Somatic, Affective, Sleep-Arousal and Cognitive-Sensory symptoms (208).

### 3.6.2 MFQ

The MFQ is available in both a short (11-items) and long form (33-items), however only the long form offers a parallel version for both the child and parent. Authors have deemed the MFQ to be appropriate for use in individuals aged 8 to 18. The MFQ was established based upon The Diagnostic and Statistical Manual of Mental Disorders – 3rd Edition (DSM-III) diagnostic criteria for a major depressive disorder (MDD). MDD symptoms are covered within the measure except DSM-III inquiries regarding suicide attempts (223).

Authors of the MFQ note that cut-off scores are highly dependent on the population in which the measure is being used (i.e. community sample vs. psychiatric inpatients, etc.). Some variability in cut-off scores is discriminated by age; one investigation had set child
cut-off scores to ≥ 9 and adolescent to ≥ 12 (223). Other investigators have stratified groups into low (< 20), medium (20-34) and high scores (> 34) (224). As mentioned above, a cut-off of ≥ 27 has also been suggested as yielding optimal sensitivity (0.78) and specificity (0.78) and misclassification a rate of (0.22) for the measure (225). However authors who proposed this cut-off score (i.e. ≥ 27) noted their sample contained a high proportion of depressed individuals. Therefore this point may not be generalizable to samples where MDD is lower (i.e. within a community sample) (225). Other authors had identified ≥ 29 as an optimal cut-point (sensitivity 68%, specificity 88%, and positive screen rate 21%) (226). Authors caution that the most mathematical optimal cut-point may not always be the best from a clinical or research standpoint (226). Using the same cut-point of ≥ 29, other investigators noted a sensitivity of 59.2%, specificity of 89.7%, positive predictive value of 85%, and negative predictive value of 69% (227). Other investigations have utilized ≥ 17 as cut-score (228, 229).

There is limited psychometric data available for the MFQ. However available data suggests the measure is both valid and reliable; a Cronbach’s alpha of both 0.94 (225) and 0.95 (226) had previously been identified for the MFQ. The MFQ has also demonstrated high convergent validity with the Beck Depression Inventory (r=0.91, p<0.01) (230)

3.7 Data Management & Analysis

Following the completion of each data collection session, the student investigator transported completed surveys and participant informed consent documents to the designated storage location. Participant questionnaires were separated from consent forms and stored in a locked cabinet. Informed consent documents containing participant name, signature and ID coding number, were stored in a separate locked cabinet.

3.7.1 Data Entry

All participant data were entered into SPSS software (Version 22) by the student investigator (231). 30% of the data set (i.e. n=47 participant questionnaire packages) were dual-entered by a second student to assess for data entry reliability. Each data point in the two data sets were cross-checked. There was 98.5% agreement between the two
data sets. Participant surveys were consulted when discrepancies were identified, and corrections were made when appropriate.

3.7.2 Exclusions

Prior to beginning formal data analyses, data were reviewed for potential exclusions. The data from two study participants (n=2) were removed from the data set as their age was below the inclusion criterion of ≥ 13 years old. Although age limitations were discussed with athletes prior to their participation, perhaps the athletes had not noted this exclusion criteria. Six participants (n=6) failed to complete a full page of either the PCS or MFQ surveys, thus all of their data were removed from the data set. This decision was made after consulting with a Biostatistician for guidance.

As an aim of the study was to establish baseline or normative values amongst uninjured youth athletes, two participants who reported having sustained a recent concussion were excluded from the data set. One participant (n=1) noted they had sustained a concussion within 1-2 weeks prior to participation in the study and the other within 3-4 weeks (n=1). These athletes were excluded as they had a “recent” concussion (i.e. within 4 weeks of their participation in this investigation) as defined previously.

In total, 10 participants (6.1% of those that had consented) were excluded from the data set resulting in a final sample of n=155 participants for data analyses.

3.7.3 Missing Data

Among the n=155 cases included in the study, some data points were missing from the completed surveys. Ten participants (n=10) had missing data on the PCS (ranging from one to five items) and three participants had one missing data point on the MFQ. Median imputation (each individual’s median score for the respective measure) were input for missing items on both PCS and MFQ questionnaires.

Three participants (female: n= 2; male: n=1) did not indicate their age on their demographics survey. The calculated median age of their respective sex group was used for these individuals (e.g. female: 15 years old; male: 14 years old). Missing points (n=1
case) on the medical history portion of the demographics questionnaire were left blank and coded as missing.

### 3.7.4 Data Analyses

Basic descriptive and frequency statistics were calculated for collected participant demographic variables (i.e. age, sport played, history of concussion, history of depression etc.). As a major focus of this investigation sought to delineate differences between males and females, preliminary analyses focused on identifying discrepancies between sex groups. Pearson’s Chi square tests were run to identify any significant differences of age, sport played, history of concussion and medical history background among male and female groups. Chi square tests were not performed for sex and number of prior concussions, and sex and number of prior depressive episodes as there were too many cells with low frequency counts to run this analysis.

After completing basic descriptive and frequency analyses to describe the sample that was captured, analytic tests were selected to answer research questions #1 (Among adolescent athletes, what type, frequency and severity of concussion-like symptoms can be identified using the PCS, in the absence of a recent concussion?) and #2 (Among adolescent athletes, which depressive symptoms and of what severity can be identified using the MFQ, in the absence of recent concussion?). First, histograms depicting the distribution of PCS 22, PCS 132 and MFQ scores were created and visually inspected for purposes of directing further statistical tests (i.e. parametric for normally distributed data vs. non-parametric tests for non-normally distributed data). Histograms were created for each outcome measure for the entire sample (see appendix 9: Figures 1,2,3) and then for each sex group (see appendix 9: females – Figures 4,6,8; males – Figures 5,7,9).

Visual inspection of each measure’s respective histogram depicted that outcome scores (PCS 22, Figure 1; PCS 132, Figure 2; MFQ, Figure 3) were non-normally distributed. Visual inspection of each sex-specific histogram pertaining to each outcome measure revealed a similar non-normal distribution. Outcome scores from each measure were positively skewed with a long right-handed tail. This reflected the fact that many participants had reported that they were not currently experiencing concussion-like or depressive symptoms at time of survey completion (i.e. they had a score of 0), with a
decreasing number of individuals reporting more severe symptoms on both the PCS and MFQ scales. Having identified a non-normal distribution for both PCS and MFQ scores, subsequent analyses utilized non-parametric tests. To answer research question # 3(i) (What differences can be identified by sex in regard to PCS and MFQ outcome score?), complete measure scores were examined for the entire sample, then comparisons were made between sex groups. Mann Whitney U tests were run using median outcome measure scores to determine if there were significant differences between sex groups for each measure.

An itemized analysis was also performed for both outcome measures, to identify any discrepancies between sex groups in terms of both symptom severity and frequency of symptoms reported. For symptom severity analyses, mean score per item was calculated, ranked (i.e. most severe symptoms reported and least severe symptoms reported) and compared between the sex groups. Median scores were not used here as most items had a median score of “0”. Mann Whitney U tests were used to identify significant differences in mean item score between groups. For symptom frequency analyses, percentages of individuals reporting a symptom (regardless of severity) were calculated and ranked (i.e. most common reported symptoms and least common reported symptoms) and compared between sex groups.

To answer research questions # 3 (ii) (What differences can be identified by sex in regard to calculated correlational values?) and #4 (How do PCS symptoms and severities self-reported by adolescent athletes assessed at the injury-free time point correlate to symptoms and severities identified on the MFQ at the same time point?), the association between outcome measure scores was examined. Correlational analyses were generated to examine the relationship between depressive symptoms (MFQ score) and concussion-like symptom frequency (PCS score out of 22) and severity (PCS score out of 132). The non-parametric equivalent of the Pearson’s r test was used, the Spearman’s Rho correlation coefficient calculation. First, correlational tests were run on the entire sample and then for each sex group.

To answer research question # 5 (Among adolescent athletes, what is the combined effect of the following factors: age, sex, prior depressive episode, history of concussion, and
prior medical diagnoses [i.e. depression, anxiety, or a learning disability diagnoses] on both PCS and MFQ outcome measure scores, in the absence of a recent concussion?), analyses sought to investigate the role that sex, age and medical history had on concussion-like and depressive symptoms (i.e. outcome measure scores). Demographic variables (i.e. predictor variables) were regressed to outcome measure scores using generalized linear models (negative binomial regression with log link) and logistic regressions. Linear regression models were not utilized because a linear relationship was not identified between predictor variables and outcome scores. A log-10 transformation was applied to outcome measure data in an attempt to “normalize” the data. No significant improvement was identified. Upon further consultation with a Biostatistician, it was noted that no transformation would be helpful in normalizing the data. Therefore data was kept and analyzed from raw form.

A generalized linear model (negative binomial regression with log link) was used to regress predictor variables to PCS 22 score (dependent variable). In this model PCS 22 outcome score was treated as a count. This statistical test tolerated the over dispersed number of zeros (due to a large number of participants who did not self-report any current concussion-like or depressive symptoms at time of survey completion). Sex, age, number of prior depressive episodes, number of previous concussions, combined medial history (aggregate defined below) were entered as factors, and MFQ score as a covariate in the model. The same model was used within each sex specific group to examine the effect this had on the model. Comparisons between the total sample, males and females for the same model are provided.

Due to the large number of participants with an outcome score of “0” on the PCS and MFQ (i.e. participants who reported they were not experiencing any depressive (n=35, 22.6%) or concussion-like symptoms (n=43, 27.7%) at the time of questionnaire completion), this posed a challenge to the types of regressions that could be run with the data. A generalized linear model, such as a gamma with log link was explored for use with PCS 132 and MFQ continuous outcome scores. However this test excluded cases with a “0” response, therefore this test was not appropriate. A mixed-model may have been useful to analyze this distribution of data however these types of models typically involve an advanced statistical interpretation, which is beyond the scope of this thesis.
Alternatively, converting continuous outcome scores to categorical/ordinal outcome scores would allow for various logistic regressions to be run. PCS cut-off scores were objectively defined with reference to prior work of Lovell et al. (2006)(217). Lovell and colleagues derived a 5-category ranking scale based on participant PCS severity score (out of 132). Classification was based on an investigation that utilized n= 707 high school students and n=1039 college students. Categories were originally determined based on percentile (i.e. individuals scoring in the “extremely high” category had a continuous score falling within the 98th percentile). Identified cut-off scores were directly applied to the current data set. It is important to note that two separate scales were derived, one for males (based on n=1391 healthy controls) and one for females (based on n=355 healthy controls). These scales were applied to the data that was captured in this investigation; frequencies were calculated for male and female groups, stratified based on their scoring category. Table 3-1 shows the breakdown of females for each scoring category. Figure 3-10 provides a visual interpretation of the percentage of females in each group. Table 3-2 provides a breakdown of males for each scoring category. Figure 3-11 provides the visual interpretation of the percentage of males in each group.

Table 3-1. Female PCS Cut-Off Points

<table>
<thead>
<tr>
<th>PCS Category (Score Range)</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Normal (score 0)</td>
<td>13 (16.5)</td>
</tr>
<tr>
<td>Broadly Normal (1-9)</td>
<td>32 (40.5)</td>
</tr>
<tr>
<td>Borderline (10-20)</td>
<td>17 (21.5)</td>
</tr>
<tr>
<td>Very High (21-43)</td>
<td>9 (11.4)</td>
</tr>
<tr>
<td>Extremely High (44+)</td>
<td>8 (10.1)</td>
</tr>
</tbody>
</table>
Figure 3-10. Percentage of Females Within Each PCS Scoring Category

Table 3-2. Male PCS Cut-Off Points

<table>
<thead>
<tr>
<th>PCS Category</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low – Normal (score 0)</td>
<td>30 (39.5)</td>
</tr>
<tr>
<td>Broadly Normal (1-5)</td>
<td>27 (35.5)</td>
</tr>
<tr>
<td>Borderline (6-12)</td>
<td>12 (15.8)</td>
</tr>
<tr>
<td>Very High (13-26)</td>
<td>4 (5.3)</td>
</tr>
<tr>
<td>Extremely High (27+)</td>
<td>3 (3.9)</td>
</tr>
</tbody>
</table>
Lastly, a cut-off score of “normalcy” was objectively defined using these categories. Low PCS scorers fell within the lower three categories (i.e. low-normal, broadly-normal and borderline). High PCS scorers fell in the upper two categories (very high and extremely high). Using this cut-off point, Chi square analyses were run to determine if there was an association between sex and high PCS score.

MFQ continuous outcome scores were also converted to an ordinal outcome. Wood et al. suggested a cut-off score of ≥ 27 on the MFQ, as this point yielded optimum sensitivity (0.78) and specificity (0.78) and misclassification rate of (0.22) (210) for a depressive diagnoses. Rates were derived from an investigation of n=104 adolescents (aged 10-19) who had been referred to a psychiatric outpatient facility (210).

Table 3-3. MFQ Cut-off Score

<table>
<thead>
<tr>
<th>Score on MFQ</th>
<th>Total (n=155) (%)</th>
<th>Female (n=79) (%)</th>
<th>Male (n=76) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High MFQ score ≥ 27</td>
<td>13 (8.4%)</td>
<td>11 (13.9%)</td>
<td>2 (2.6%)</td>
</tr>
</tbody>
</table>

As previously mentioned, the significant number of participants self-reporting a score of zero on the PCS and MFQ posed some challenges when trying to establish a predictive model. The best way to perform a regression with this data was to stratify and recode
For PCS 132 a cumulative odds ordinal logistic regression with proportional odds was run using the following predictors in the model: age, prior depressive episode, history of concussion, combined medial history (diagnoses of either a learning disability, anxiety or depressive disorder) as factors, and MFQ score as a covariate. Separate models were run for sex groups because PCS scoring categories varied slightly for males and females. The female model was run first (n=79). The following assumptions were met:

I) The assumption of non-multicollinearity was met according to tolerance and VIF (variance inflation factors) values.

II) The assumption of proportional odds was also met, as assessed by a full likelihood ratio test comparing the fit of the proportional odds model to a model with varying location parameters, \[ \chi^2(15) = 19.945, p=0.174 \], where an insignificant result is desirable.

The male model was run second (n=75). The following assumptions were met:

I) The assumption of non-multicollinearity was met according to tolerance and VIF (variance inflation factors) values.

II) The assumption of proportional odds was met, as assessed by the full likelihood ratio test comparing the fit of the proportional odds model to a model with varying location parameters, \[ \chi^2(15) = 2.963, p=1.000 \].

A similar model using a slightly different regression technique, binomial logistic regression, was used to regress predictor variables to the MFQ dichotomized outcome scores (i.e. < 27 and ≥ 27) (n=154). Model predictor variables included: age, prior depressive episode, history of concussion and combined medical history aggregate as factors in the model. PCS 132 could not be included in the model because including “0” scoring cases in the test of linearity, caused 43 cases to be excluded.
Next, outliers needed to be considered. When the data points are suspected of being legitimate, some authors argue that data are more likely to be representative of the population as a whole if outliers are not removed (i.e. it represents natural variations in the data) (232). On the contrary, reasons to remove outliers include: i) data was measured incorrectly, ii) data was recorded wrong or iii) conditions for the experiment may have been inappropriate. Therefore this model was run twice, once including outliers and again with outliers removed. The first model presented included outliers (largest SD = 5.409).

The following assumptions were tested and met for the model:

I) Linearity of the continuous variables with respect to the logit of the dependent variable was assessed via the Box-Tidwell (1962) procedure. A Bonferroni correction was applied using all nine terms in the model results in a statistical significance being accepted when p<0.00556 (233). Based on this assessment, all continuous independent variables were found to be linearly related to the logit of the dependent variable.

II) According to the omnibus statistic table ($\chi^2 (5) = 29.673$, p<0.000) and the Hosmer and Lemeshow test (p=0.827), where an insignificant p-value indicates the model was not of poor fit), the model was found to be of good fit. Explained variation in the dependent variable based on the model was approximately 39.9% (according to the Nagelkerke R Square) with a sensitivity of 15.4% and specificity of 97.9%.

The same model was then run once again, but with outliers removed above or below 2 standard deviations. A total of 4 individual data sets (n=4 participants) were removed, n=150 participants were included in the subsequent model. The following assumptions were tested and met for the second model:

I) Linearity assumption was the same as reported above.

II) According to the omnibus statistic table ($\chi^2 (5) = 38.506$, p<0.000) and the Hosmer and Lemeshow test (p=1.000, where an insignificant p value indicates the model was not a poor fit), the model was found to be of good fit. Explained variance in the dependent variable based on the model was approximately 62%, with a sensitivity of 66.7% and specificity of 97.6%. 

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All statistical analysis techniques were discussed with experienced biostatisticians at The Faculty of Medicine at the University of Toronto and St. Michael’s Hospital. Laerd Statistics, an online SPSS user guide was also consulted to facilitate appropriate statistical test selection and interpretation of SPSS outputs (234).

3.8 Sample Size Calculations

Sample size calculations for participant recruitment were based on more stringent analytical tests that were planned for the data (i.e. regression models). Sample size calculations for logistic regression models were based on the work of Peduzzi et al. (1996) (235). Their work used the following formula:

\[ N = \frac{10k}{p} \]

Where “p” is the smallest proportion of negative or positive cases in the population and “k” is the number of covariates (i.e. independent variables). The model with the smallest proportion of negative or positive cases would be the MFQ regression model (described further below). In this model, a continuous MFQ score was dichotomized in one of two scoring categories (i.e. a high or low MFQ score). Groups were based on a cut-off score of ≥ 27 as indicated by the literature (210). This value was shown to have a high rate of sensitivity and specificity of correctly identifying individuals who had a depression diagnosis vs. individuals who did not. If we look at the incidence rate of depression in Canadian youth (aged 12-19 years), we can see that it falls between 5% for males and 12% females (236). Taking a more conservative estimate, we would assume that ~10% of our sample may have a significant depressive score, falling within the high MFQ group (i.e. ≥ 27). This would be the smallest proportion of individuals that we would have in a given group for our regression models.

Using the regression model defined in the above section:

\[ N = \frac{10 \times 5}{0.10} = 500 \]
Additional literature indicates that as a general rule of thumb, factor analysis require a sample size of ~300 individuals, and ~50 for relationship and test of associations (i.e. correlations) (237). Due to the scale and time restrictions imposed on this project, obtaining a sample size of 500 individuals was not realistic. Alternatively, calculations and models will be utilized as described. Authors note that caution should be used when interpreting findings due to the limitations imposed based on sample size.
Chapter 4

Results

4.1 Study Sample Characteristics

A total of n=79 females and n=76 males (total sample n=155) were included in the data analyses. Females ranged in age from 13 to 17 years old and males from 13 to 18 years old (Table 4-1; Figure 4-1). The median age for the entire sample was 15. By sex group, the median age for females was 15 and 14 for males. Chi square analyses revealed there was no significant interaction between age and sex \( \chi^2(5)= 7.59, p=0.180 \) (asymp.sig 2-sided). Two cells had an expected count of less than 5 (16.7%).

Table 4-1. Age Frequencies by Total Sample and by Sex.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Total Number (%)</th>
<th>Number of Females (%)</th>
<th>Number of Males (%)</th>
<th>Pearson’s Chi square</th>
<th>Asymp. Sig (2-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>41 (26.5)</td>
<td>21 (26.6)</td>
<td>20 (26.3)</td>
<td>7.59</td>
<td>0.180</td>
</tr>
<tr>
<td>14</td>
<td>36 (23.2)</td>
<td>15 (19.0)</td>
<td>21 (27.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>34 (21.9)</td>
<td>23 (29.1)</td>
<td>11 (14.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>29 (18.7)</td>
<td>13 (16.5)</td>
<td>16 (21.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>13 (8.4)</td>
<td>7 (8.9)</td>
<td>6 (7.9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>2 (1.3)</td>
<td>0</td>
<td>2 (2.6)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Participants self-reported the sport that they were presently participating in at the time of survey completion (Table 4-2). Sports included soccer, ice hockey, rugby, lacrosse and cheerleading. Individuals of both sexes were recruited from each sport with the exception of cheerleading (females only) and lacrosse (males only).

Table 4-2. Participant Sport of Origin.

<table>
<thead>
<tr>
<th>Sport</th>
<th>Total Number (%)</th>
<th>Number of Females (%)</th>
<th>Number of Males (%)</th>
<th>Pearson’s Chi square</th>
<th>Asymp. Sig (2-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soccer</td>
<td>25 (16.1%)</td>
<td>13 (16.5%)</td>
<td>12 (15.8%)</td>
<td>53.81</td>
<td>0.000</td>
</tr>
<tr>
<td>Ice Hockey</td>
<td>70 (45.2%)</td>
<td>31 (39.2%)</td>
<td>39 (51.8%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rugby</td>
<td>18 (11.6%)</td>
<td>16 (20.3%)</td>
<td>2 (2.6%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lacrosse</td>
<td>23 (14.8%)</td>
<td>0</td>
<td>23 (30.3%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheerleading</td>
<td>19 (12.3%)</td>
<td>19 (24.1%)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Competitive League **</td>
<td>132 (85.2)</td>
<td>62 (78.5)</td>
<td>70 (97.4)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** n=2 missing
The majority of athletes, both males (n=39, 51.8%) and females (n=31, 39.2%) were recruited during their participation in ice hockey (n= 70, 45.2% of the total sample) (Figure 4-2). Rugby players made up the smallest proportion of the study sample (11.6% of the total sample). Chi square analyses revealed a significant association between sport and sex [$\chi^2(4)= 53.81, p<0.000$ (asymp. sig. 2-sided)]. The majority of athletes were competing in their sport at a competitive rep level or higher (n=132, 85.2%) at time of survey completion.

4.2 Self-Reported History of Concussion

Almost one-third (31.6%, n=49) of study participants self-reported a history of concussion (Table 4-3). Chi square analyses indicated there was no statistically significant association between sex and prior history of concussion [$\chi^2(1)=0.47, p=0.495$ (asymp. sig. 2 sided)]. However more males than females self-reported a previous concussion (34.2% vs. 29.1% respectively). The majority of individuals that had reported a history of concussion, had only sustained one prior injury (females n=18, 78.3%; males n=18, 69.2%). A smaller proportion of participants had sustained multiple injuries (2 concussions: females n=4, 17.4%; males n= 5, 19.2%, 3 concussions or more: females
A Chi square analysis was not performed to determine statistical differences between sex and prior number of concussions because 4 cells (50%) had an expected count of less than 5.

Table 4-3. Concussion History and Number of Prior Injuries

<table>
<thead>
<tr>
<th>Self-Reported History of Concussion</th>
<th>Total n=155 (%)</th>
<th>Female n=79 (%)</th>
<th>Male n=76 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No - History of Concussion</td>
<td>106 (68.4)</td>
<td>56 (70.9)</td>
<td>50 (65.8)</td>
</tr>
<tr>
<td>Yes - History of Concussion</td>
<td>49 (31.6)</td>
<td>23 (29.1)</td>
<td>26 (34.2)</td>
</tr>
<tr>
<td>Prior concussions = 1</td>
<td>36 (73.5)</td>
<td>18 (78.3)</td>
<td>18 (69.2)</td>
</tr>
<tr>
<td>Prior concussions = 2</td>
<td>9 (18.4)</td>
<td>4 (17.4)</td>
<td>5 (19.2)</td>
</tr>
<tr>
<td>Prior concussions = 3 or more</td>
<td>4 (8.2)</td>
<td>1 (4.3)</td>
<td>3 (11.5)</td>
</tr>
</tbody>
</table>

Of the participants that self-reported a history of concussion, the majority of them sustained their injury more than a year prior to their participation in this study (71.4%) (Table 4-4). Approximately 22.5% (n=11) of participants had sustained a concussion one month to one year prior to participating in the study.

Table 4-4. Time Since Last Concussion Injury

<table>
<thead>
<tr>
<th>Time Since Injury</th>
<th>Total (n=49) (%)</th>
<th>Female (n=23) (%)</th>
<th>Male (n=26) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 year +</td>
<td>35 (71.4)</td>
<td>15 (65.2)</td>
<td>20 (76.9)</td>
</tr>
<tr>
<td>&gt; 6 months but &lt; 1 year</td>
<td>5 (10.2)</td>
<td>2 (8.7)</td>
<td>3 (11.5)</td>
</tr>
<tr>
<td>&gt; 3 months but &lt; 6</td>
<td>4 (8.2)</td>
<td>4 (17.4)</td>
<td>0</td>
</tr>
<tr>
<td>&gt; 1 month but &lt; 3</td>
<td>2 (4.1)</td>
<td>2 (8.7)</td>
<td>0</td>
</tr>
<tr>
<td>Missing/Unknown</td>
<td>3 (6.2)</td>
<td>0</td>
<td>3 (11.5)</td>
</tr>
</tbody>
</table>
4.3 Self-Reported Medical History

Amongst the total study sample, some participants endorsed a history of learning disability (9%) or other mental health concern (anxiety diagnosis 10.3%; depression diagnosis 6.5%). Presence of anxiety symptoms in the past two weeks was the most commonly reported medical concern (20%) (Table 4-5). Proportions for medical history variables were comparable between males and females with the exception that a higher proportion of females indicating they had experienced a prior depressive episode (n=19, 24.1%) relative to males (n=8, 11.2%) (Figure 4-3); this was statistically significant [$\chi^2 (1) = 4.77$, $p=0.029$ (asymp.sig. 2-sided)].

*Table 4-5. Medical Diagnosis and Symptom Presence*

<table>
<thead>
<tr>
<th>Diagnosis or Symptom</th>
<th>Total Number (%)(n=155)</th>
<th>Number of Female (%)(n=79)</th>
<th>Number of Male (%)(n=76)</th>
<th>Pearson’s Chi square</th>
<th>P-Value (asymp. sig. 2 sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Prior Learning Disability Diagnosis</td>
<td>14 (9.0)</td>
<td>8 (10.1)</td>
<td>6 (7.9)</td>
<td>0.21</td>
<td>0.646</td>
</tr>
<tr>
<td>*Prior Anxiety Diagnosis</td>
<td>16 (10.3)</td>
<td>10 (12.7)</td>
<td>6 (7.9)</td>
<td>0.90</td>
<td>0.344</td>
</tr>
<tr>
<td>**Anxiety Symptoms in Prior 2 weeks</td>
<td>31 (20.0)</td>
<td>20 (25.3)</td>
<td>11 (14.5)</td>
<td>2.45</td>
<td>0.117</td>
</tr>
<tr>
<td>*Prior Depression Diagnosis</td>
<td>10 (6.5)</td>
<td>6 (7.6)</td>
<td>4 (5.3)</td>
<td>-</td>
<td>0.746</td>
</tr>
<tr>
<td>*Prior Depressive Episodes</td>
<td>27 (18.1)</td>
<td>19 (24.1)</td>
<td>8 (11.2)</td>
<td>4.77</td>
<td>0.029</td>
</tr>
<tr>
<td>Number of Depressive Episodes - One</td>
<td>7 (25.9)</td>
<td>4 (21.1)</td>
<td>3 (37.5)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Number of Depressive Episodes - Two</td>
<td>5 (18.5)</td>
<td>3 (15.8)</td>
<td>2 (25.0)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Number of Depressive Episodes - Three</td>
<td>3 (11.1)</td>
<td>3 (15.8)</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>*Number of Depressive</td>
<td>12 (44.4)</td>
<td>9 (47.4)</td>
<td>3 (37.5)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
The last row of Table 4-5 presents an aggregate variable that was synthesized based on a learning, anxiety or depression diagnoses. A participant was categorized into this aggregate if they had any one or more of these diagnoses. Note that this did not account for individuals endorsing anxiety symptoms in the prior two weeks or individuals reporting one or more depressive episodes. Twenty-six participants were found to have at least one diagnosis, with a slightly greater proportion of females compared to male participants (n=14 vs. n=12 respectively). This difference was not statistically significant \( \chi^2 (1)=0.08, p=0.776 \) (asymp. sig. 2-sided).

Figure 4-3. Percent of Individuals Self-Reporting a Medical History (By Sex)
4.4 PCS and MFQ Scores

Three main outcome scores that were used within the remainder of the analyses are presented here: i) PCS frequency score (out of 22), ii) PCS symptom intensity (severity) score (out of 132) and iii) MFQ total score (out of 66). Table 4-6 presents mean and median outcome scores by measure for the entire sample. Findings illustrated that the majority of study participants reported minimal symptoms of minimal severity on both concussion and depressive measures, in the absence of a recent injury.

Table 4-6. Participant Measure Scores – Total Sample

<table>
<thead>
<tr>
<th></th>
<th>Total (Mean/SD)</th>
<th>Total Median/ IQR</th>
<th>Total Skewness/ Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCS – Frequency (22)</td>
<td>4.22 (5.10)</td>
<td>2 (6)</td>
<td>1.57/2.06</td>
</tr>
<tr>
<td>PCS - Severity (132)</td>
<td>10.14 (17.76)</td>
<td>3 (11)</td>
<td>3.04/10.42</td>
</tr>
<tr>
<td>MFQ</td>
<td>7.79 (11.38)</td>
<td>3 (8)</td>
<td>2.30/5.05</td>
</tr>
</tbody>
</table>

Outcome measure scores were then compared across sex groups (Table 4-7, see appendix 10). Median scores for both the PCS and MFQ revealed clear discrepancies between male and female groups. Females had a greater median score on all outcomes measures as compared to males, in the absence of a recent injury. Subsequent Mann-Whitney U tests were run to determine if these were statistically significant differences. Note that distributions of the outcome scores for males and females were similar, as assessed by inspection of pyramidal histogram. Median PCS frequency score (PCS 22) was significantly higher for females (4.00) than males (1.00), $U=1775, z=-4.45, p<0.000$; median PCS severity score (PCS 132) was significantly higher for females (7.00) than males (1.00) $U=1795, z=-4.37, p<0.000$; median MFQ score was significantly higher for females (7.00) than males (1.00) $U=1502, z=-5.41, p<0.000$.

4.5 Comparing Concussion-Like and Depressive Symptoms Between Sex Groups

Reported concussion-like symptoms were also compared across sex groups.
Figure 4-4 shows the mean score for each symptom on the PCS in ascending order, from least severe symptoms to most for females. Mean symptom scores ranged from $0.16 \pm 0.78$ (vomiting) to $1.41 \pm 1.74$ (fatigue) for females. The data for males is included for reference.

Figure 4-4. Itemized PCS Score - Descending Order (Females)

* - asterisks indicate a non-significant difference (i.e. $p>0.05$) for respective symptom between sex groups

Figure 4-5 shows the PCS symptom breakdown in ascending order for males, from least severe reported symptom to most. Mean PCS scores ranged from $0 \pm 0.00$ (vomiting) to $0.59 \pm 1.235$ (trouble falling asleep) for males. Data for females is included for reference.
Figure 4-5. Itemized PCS Score – Descending Order (Males)

* - asterisks indicate a non-significant difference (i.e. p>0.05) for respective symptom between sex groups

Table 4-8 provides a summary of the top five most severe and least severe PCS symptoms for each sex group. Three of the top-five most severe and three of the top-five least severe concussion-like symptoms were shared between the sexes (common symptoms are shown in bold). The most severe shared symptoms between sex groups included fatigue (females: mean=1.41 ± 1.74 vs. males: mean= 0.54 ± 1.00), nervousness (females: mean=1.14 ± 1.42 vs. males: mean=0.33 ± 0.77) and trouble falling sleep (females: mean =1.00 ± 1.59 vs. males: mean = 0.59 ± 1.24). The least severe shared symptoms between sex groups included: sensitivity to noise (females: mean = 0.35 ± 1.05 vs. males: mean= 0.09 ± 0.437), nausea (females: mean= 0.30 ± 0.97 vs. males: mean= 0.08 ± 0.39) and vomiting (females: mean = 0.16 ± 0.78 vs. males: mean = 0.00 ± 0.00). For the majority of symptoms on the PCS (n=17, 77.3%), Mann Whitney U tests indicated there were significant differences between symptom mean scores by sex group. Tests indicated that females experienced significantly more severe concussion-like
symptoms as compared to males (p<0.05). Five of the 22 PCS symptoms (nausea, drowsiness, visual problems, sleeping more and trouble falling asleep) did not have significantly different mean scores between sex groups (denoted by asterisks * in Figures 4-4, 4-5 and Table 4-8).

Table 4-8. Top Five Most Severe to Least Severe PCS Symptoms (By Sex)

<table>
<thead>
<tr>
<th>Most Severe Reported Symptoms</th>
<th>Females (mean score/SD)</th>
<th>Males (mean score/SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue (1.41 ± 1.74)</td>
<td></td>
<td>Trouble Falling Asleep** (0.59 ± 1.23)</td>
</tr>
<tr>
<td>Nervousness (1.14 ± 1.42)</td>
<td></td>
<td>Fatigue (0.54 ± 1.00)</td>
</tr>
<tr>
<td>Difficulty Concentrating</td>
<td>(1.06 ± 1.64)</td>
<td>Sleeping More** (0.36 ± 1.00)</td>
</tr>
<tr>
<td>Trouble Falling Asleep**</td>
<td>(1.0 ± 1.59)</td>
<td>Nervousness (0.33 ± 0.77)</td>
</tr>
<tr>
<td>Headache (0.94 ± 1.44)</td>
<td></td>
<td>Difficulty Remembering (0.32 ± 0.88)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Least Severe Reported Symptoms</th>
<th>Females (mean score/SD)</th>
<th>Males (mean score/SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity –Light (0.38 ±1.12)</td>
<td></td>
<td>Sensitivity – Noise (0.09 ± 0.44)</td>
</tr>
<tr>
<td>Sensitivity –Noise (0.35 ± 1.05)</td>
<td></td>
<td>Nausea (0.08 ± 0.39)**</td>
</tr>
<tr>
<td>Visual Problems (0.33 ± 0.93) **</td>
<td></td>
<td>Feeling Slowed Down (0.08 ± 0.48)</td>
</tr>
<tr>
<td>Nausea (0.30 ± 0.97)**</td>
<td></td>
<td>Balance Problems (0.05 ± 0.28)</td>
</tr>
<tr>
<td>Vomiting (0.16 ± 0.78)</td>
<td></td>
<td>Vomiting (0.00 ± 0.00)</td>
</tr>
</tbody>
</table>

Each cell in descending order, ** non-significant difference between sexes for specified item.

Sex groups shared similar most and least common symptoms. Importantly, prevalence of each symptom in males was far less than what was reported by females. For example fatigue was the most common symptom in both sex groups, however over half of females (55.7%) as compared to 27.6% of males reported experiencing this symptom. Similar trends were identified for the remaining symptoms (Table 4-9).
Depressive symptoms as self-reported by participants on the MFQ were also compared across the two sex groups (Figures 4-6 to 4-9). Female depressive symptoms from lowest mean score to highest mean score (i.e. from most severe to least severe) are depicted in Figures 4-6 & 4-7. Depressive symptoms ranged from 0.11± 0.42 (talking more slowly) to 0.75 ± 0.81 (feeling tired).
Figure 4-6. MFQ Symptoms from Least Reported to Most – Ascending Order (Females - Part I)

Figure 4-7. MFQ Symptoms from Least Reported to Most - Ascending Order (Females – Part II)
Male depressive symptoms from lowest mean response to highest are depicted in Figures 4-8 & 4-9. Mean depressive symptom scores ranged from 0 (3-way item tie: not feeling loved, feeling my family would be better off without me and thinking about killing oneself) to 0.38 ± 0.59 (feeling tired).

Figure 4-8. MFQ Symptoms From Least Reported To Most – Ascending Order (Males – Part I)

* - asterisks indicate a non-significant difference (i.e. $p>0.05$) for respective symptom between sex groups
Table 4-10 provides a summary of the top five most severe and least severe MFQ symptoms for each sex group. Three of the top-five most severe and three of the top-five least severe depressive symptoms were shared between the sexes (common symptoms shown in bold). Shared most-severe symptoms included: feeling tired (females: mean = 0.75 ± 0.81 vs. males: mean = 0.38 ± 0.59), indecisiveness (females: mean = 0.72 ± 0.73 vs. males: mean = 0.28 ± 0.56) and feeling miserable or unhappy (females: mean = 0.56 ± 0.62 vs. males: mean = 0.25 ± 0.47). Shared least-severe symptoms included feeling my family was better off without me (females: mean = 0.18 ± 0.45 vs. males: mean = 0.00 ± 0.00), feeling that life was not worth living (females: mean = 0.16 ± 0.44 vs. males: mean = 0.01 ± 0.12) and thinking about killing oneself (females: mean = 0.13 ± 0.40 vs. males: mean = 0.00 ± 0.00). For the majority of symptoms on the MFQ (n=27, 81.8%) Mann Whitney U tests indicated there were significant differences between symptom mean scores by sex group; tests indicated that females reported significantly more severe
depression symptoms as compared to males (p<0.05). Six of 33 MFQ symptoms (talking more slowly, thinking about death or dying, moving more slowly, thinking bad things would happen, sleeping more than usual, and eating more than usual) did not have significantly different mean scores between sex groups (denoted by asterisks * in Figures 4-6 to 4-9, Tables 4-8 & 4-9).

Table 4-10. Top Five Most Severe and Least Severe MFQ Symptoms (By Sex)

<table>
<thead>
<tr>
<th>Most Severe Reported Symptoms</th>
<th>Females (mean score/SD)</th>
<th>Males (mean score/SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeling Tired (0.75 ± 0.81)</td>
<td>Feeling Tired (0.38 ± 0.59)</td>
<td></td>
</tr>
<tr>
<td>Indecisiveness (0.72 ± 0.73)</td>
<td>Indecisiveness (0.28 ± 0.56)</td>
<td></td>
</tr>
<tr>
<td>Grumpy With Parents (0.66 ± 0.71)</td>
<td>Feeling Miserable/Unhappy (0.25 ± 0.47)</td>
<td></td>
</tr>
<tr>
<td>Difficulty Concentrating (0.59 ± 0.71)</td>
<td>Eating More (0.24 ± 0.49) **</td>
<td></td>
</tr>
<tr>
<td>Feeling Miserable/Unhappy (0.56 ± 0.62)</td>
<td>Worrying-Aches/Pains (0.22 ± 0.51)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Least Severe Reported Symptoms</th>
<th>Females (mean score/SD)</th>
<th>Males (mean score/SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family Better Off Without Me (0.18 ± 0.45)</td>
<td>Did Everything Wrong (0.01 ± 0.12)</td>
<td></td>
</tr>
<tr>
<td>Life Not Worth Living (0.16 ± 0.44)</td>
<td>Life Not Worth Living (0.01 ± 0.12)</td>
<td></td>
</tr>
<tr>
<td>Thinking About Death/Dying (0.15 ± 0.46) **</td>
<td>Not Feeling Loved (0.0 ± 0.00)</td>
<td></td>
</tr>
<tr>
<td>Thinking About Killing Oneself (0.13 ± 0.40)</td>
<td>Family Better Off Without Me (0.0 ± 0.00)</td>
<td></td>
</tr>
<tr>
<td>Talking More Slowly (0.11 ± 0.42) **</td>
<td>Thinking About Killing Oneself (0.0 ± 0.00)</td>
<td></td>
</tr>
</tbody>
</table>

Each cell in descending order, ** non-significant difference between sexes for specified item

Table 4-11 provides a summary of the most and least commonly reported depressive symptom complaints. Males and females shared a number of the same most (n= 3) and least common symptoms (n=4) (in bold). Importantly, more females than males reported experiencing a shared symptom. For example, 55.7% of females reported “It was hard for me to make up my mind” as compared to 32.9% of males. This trend was the same for all shared symptoms denoted here.
Table 4-11. Most Commonly Reported MFQ Symptoms to Least Commonly Reported MFQ Symptoms

<table>
<thead>
<tr>
<th>Most Commonly Reported Symptom</th>
<th>Females (%)</th>
<th>Males (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>It was hard for me to make up my mind (55.7)</td>
<td>I felt so tired I just sat around and did nothing (32.9)</td>
<td></td>
</tr>
<tr>
<td>I felt grumpy or cross with my parents (51.9)</td>
<td>I felt miserable or unhappy (23.7)</td>
<td></td>
</tr>
<tr>
<td>I felt so tired I just sat around and did nothing (51.9)</td>
<td>It was hard for me to make up my mind (22.4)</td>
<td></td>
</tr>
<tr>
<td>I felt miserable or unhappy (49.4)</td>
<td>I ate more than usual (21.1)</td>
<td></td>
</tr>
<tr>
<td>I found it hard to think properly or concentrate (46.8)</td>
<td>I worried about aches and pain (18.4)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Least Commonly Reported Symptom</th>
<th>Females (%)</th>
<th>Males (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I thought nobody really loved me (15.2)</td>
<td>I thought that life wasn’t worth living (1.3)</td>
<td></td>
</tr>
<tr>
<td>I thought my family would be better off without me (15.2)</td>
<td>I did everything wrong (1.3)</td>
<td></td>
</tr>
<tr>
<td>I thought life wasn’t worth living (13.9)</td>
<td>I thought I could never be as good as other kids (1.3)</td>
<td></td>
</tr>
<tr>
<td>I thought about death or dying (11.4)</td>
<td>I thought nobody really loved me (0)</td>
<td></td>
</tr>
<tr>
<td>I thought about killing myself (10.1)</td>
<td>I thought about killing myself (0)</td>
<td></td>
</tr>
<tr>
<td>I talk more slowly than usual (7.6)</td>
<td>I thought my family would be better off without me (0)</td>
<td></td>
</tr>
</tbody>
</table>

Each cell in descending order. Shared symptoms between males and females are bolded.

4.6 Suicidal Ideation In Females

As suicidal ideation is a key indicator of depression (regardless of age), it is important to note that “thinking about killing oneself, feeling that life was not worth living, and feeling that my family would be better off without me” were some of the least reported symptoms for both males and females. However females reported significantly (p<0.05) more suicidal ideation symptoms than did males.

A total of n=8 participants met harm protocol criteria, all of which were female (n=5 cheerleaders, n=3 rugby players) with a median age of 15 (range of 13 to 16 years old).
Among this group of individuals, n=5 participants met one criterion on the harm protocol, n=2 met two criteria and n=1 met three criteria on the harm protocol. In all cases, individuals fulfilled criteria i-iii on the harm protocol (see appendix 5). None of the participants had verbally indicated to the student investigator that they were at risk to themselves or others (i.e. criteria iv).

4.7 Relationship Between PCS and MFQ Scores

Correlation coefficients were calculated for the two primary outcome measures for the entire sample. Spearman’s Rho $r$-value indicated that MFQ/PCS 22 had a correlation coefficient of $r=0.68$ (p<0.000). MFQ/PCS 132 had a correlation coefficient of $r=0.68$ (p<0.000) (Table 4-12). $r$-values were significant and were considered to be of moderate, borderline strong, correlational strength.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Correlation MFQ &amp; PCS (22) (r)</th>
<th>p-value</th>
<th>Correlation MFQ &amp; PCS (132) (r)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (n=155)</td>
<td>0.68</td>
<td>&lt;0.000</td>
<td>0.68</td>
<td>&lt;0.000</td>
</tr>
<tr>
<td>Female (n=79)</td>
<td>0.68</td>
<td>&lt;0.000</td>
<td>0.69</td>
<td>&lt;0.000</td>
</tr>
<tr>
<td>Male (n=76)</td>
<td>0.57</td>
<td>&lt;0.000</td>
<td>0.55</td>
<td>&lt;0.000</td>
</tr>
</tbody>
</table>

$r$ was also calculated within each sex group. Analyses identified moderate strength correlations between the MFQ/PCS 22 and MFQ/PCS 132 outcome scores for both male and female groups (Table 4-12). All $r$-values were significant within each sex group. However, $r$-values were weaker (by 0.10 or >) within the male group as compared to the $r$-values calculated for the same measures in the female group.

4.8 Stratifying Outcome Scores into Ordinal Groups – PCS

Re-grouping of continuous PCS 132 score into symptom categories (i.e. low-normal, broadly-normal, borderline normal, very high and extremely high) allocated a greater proportion of females to higher symptom categories as compared to males, with the exception of the low-normal category, where more males than females were allocated (39.5% vs. 16.5% respectively) (Table 4-13).
Table 4-13. PCS Continuous Score as Score Categories

<table>
<thead>
<tr>
<th>PCS Category</th>
<th>Females n (%)</th>
<th>Males n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Normal</td>
<td>13 (16.5)</td>
<td>30 (39.5)</td>
</tr>
<tr>
<td>Broadly Normal</td>
<td>32 (40.5)</td>
<td>27 (35.5)</td>
</tr>
<tr>
<td>Borderline</td>
<td>17 (21.5)</td>
<td>12 (15.8)</td>
</tr>
<tr>
<td>Very High</td>
<td>9 (11.4)</td>
<td>4 (5.3)</td>
</tr>
<tr>
<td>Extremely High</td>
<td>8 (10.1)</td>
<td>3 (3.9)</td>
</tr>
</tbody>
</table>

Using the cut-off score of “normalcy” (i.e. low-normal, broadly normal and borderline scores were considered to be a Low PCS Score, very high and extremely high were considered to be a High PCS Score) a Chi square analysis was run to assess association between sex and high PCS score. Findings indicated that there was a statistically significant association between sex and high PCS score $[\chi^2(1) = 4.484, p=0.034$ (asymp.sig 2 sided)] (Table 4-14). Females were significantly more likely (n= 17, 21.5%) to fall in the High PCS group as compared to males (n=7, 9.2%).

Table 4-14. Chi square Between Sex and High PCS Score

<table>
<thead>
<tr>
<th>PCS Category</th>
<th>Total n (%)</th>
<th>Females n (%)</th>
<th>Males n (%)</th>
<th>Pearson’s Chi square</th>
<th>Asymp. Sig. 2 Sided</th>
</tr>
</thead>
<tbody>
<tr>
<td>High PCS Score</td>
<td>24 (15.5)</td>
<td>17 (21.5)</td>
<td>7 (9.2)</td>
<td>4.48</td>
<td>0.03</td>
</tr>
</tbody>
</table>

*all expected cell frequencies greater than five

4.9 Stratifying Outcome Scores into Ordinal Groups – MFQ

More males than females fell within the Low MFQ group (97.4% vs. 86.1%, respectively). A small proportion of respondents (8.4%) fell into the High MFQ category, the majority of which were females (84.6%). Chi square analyses revealed statistically significant association between sex and ranking within the High MFQ group (Fisher’s
Exact Test, exact sig [1-sided] p=0.01); a significantly higher proportion of females (13.9%) had a score ≥ 27 on the MFQ than did males (2.6%) (Table 4-15).

Table 4-15. MFQ Score ≥ 27 Cut-Off Point

<table>
<thead>
<tr>
<th>Score on MFQ</th>
<th>Total n (%)</th>
<th>Female n (%)</th>
<th>Male n (%)</th>
<th>Exact Sig. (1-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High MFQ ≥ 27</td>
<td>13 (8.4%)</td>
<td>11 (13.9%)</td>
<td>2 (2.6%)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

*Fisher’s Exact Test – one cell with an expected frequency less than 5*

4.10 Using Demographic and Medical History Information to Predict Outcome Scores

A generalized linear model (negative binomial distribution) was used to regress demographic predictor variables to PCS 22 count score. Analyses indicated that sex was a statistically significant predictor in the model (table 4-16, see appendix 10); males were found to have a lower log count on the PCS 22 than females. Conversely, females were found to have a PCS 22 score 1.64 times that of males, holding other predictor variables constant. MFQ score was also a statistically significant predictor in the model. Looking at the entire sample (n=154), for every one unit increase on the MFQ there was an increase of 1.06 times the PCS 22 score. In sex-specific models, among females there was an increase of 1.05 and 1.13 increase in males. In the male only model, participants self-reporting 3 or more concussions (n=3) had a PCS 22 score 4.76 times greater than males who did not report a history of concussion; this was statistically significant (p= 0.023). Age, number of prior depressive episodes and combined medical history were not found to be statistically significant predictors in the model, for both total sample and sex-based models.

A cumulative odds ordinal logistic regression with proportional odds was run using PCS 132 ordinal outcome categories. Separate models were run for female and male data as categories were based on slightly different scoring ranges. Table 4-17 presents data for the female group (n=79). The model was found to have significantly predicted the dependent variable over and above the intercept-only model [χ² (5)= 59.53, p<0.000].
Findings indicated that a decrease in age (expressed in years) was associated with an increase in the odds of falling in the low-normal category, with an odds ratio of 1.59 (95% CI, 1.08 to 2.34), Wald $\chi^2 (1)=5.645$, $p=0.018$. A decrease in one unit on the MFQ total score was associated with an increase in the odds of falling in the low-normal category with an odds ratio of 1.15 (95% CI, 1.09 to 1.21), Wald $\chi^2 (1)=26.177$, $p<0.000$. History of prior depressive episode (irrespective of diagnoses) ($p=0.698$), history of concussion ($p=0.458$) and combined medical history ($p=0.203$) were not significant predictors of PCS 132 symptom category for females.

**Table 4-17. Effects of Predictor Variables on PCS 132 Scoring Categories - Females Only**

<table>
<thead>
<tr>
<th>Predictor Variable</th>
<th>B</th>
<th>SE</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Odds Ratio</th>
<th>Lower CI</th>
<th>Upper CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>-.466</td>
<td>.1961</td>
<td>5.645</td>
<td>1</td>
<td>.018</td>
<td>.628</td>
<td>.427</td>
<td>.922</td>
</tr>
<tr>
<td>Prior Depressive Episode</td>
<td>-.254</td>
<td>.6561</td>
<td>.150</td>
<td>1</td>
<td>.698</td>
<td>.776</td>
<td>.214</td>
<td>2.806</td>
</tr>
<tr>
<td>History of Concussion</td>
<td>.387</td>
<td>.5213</td>
<td>.522</td>
<td>1</td>
<td>.458</td>
<td>1.473</td>
<td>.530</td>
<td>4.092</td>
</tr>
<tr>
<td>Combined Medical History</td>
<td>.815</td>
<td>.6410</td>
<td>1.618</td>
<td>1</td>
<td>.203</td>
<td>2.260</td>
<td>.643</td>
<td>7.937</td>
</tr>
<tr>
<td>MFQ Total Score</td>
<td>-.138</td>
<td>.0269</td>
<td>26.177</td>
<td>1</td>
<td>.000</td>
<td>.871</td>
<td>.827</td>
<td>.919</td>
</tr>
</tbody>
</table>

**Note:** prior depressive episode = yes, concussion history = no, combined medical history diagnoses = yes

* reference category – low-normal PCS Symptom Intensity, CI – confidence interval (95%)

The same model was run again with males only (n=75) (Table 4-18). The final model statistically significantly predicted the dependent variable over and above the intercept-only model $\chi^2 (5)=32.671$, $p<0.000$. Analyses indicated that a decrease for every one unit on MFQ total score was associated with an increase in the odds of falling in the low-
normal category, with an odds ratio of 1.32 (95% CI, 1.16 to 1.52), Wald $\chi^2 (1)=16.288$, $p<0.000$. Age ($p=0.638$), history of prior depressive episode (regardless of diagnoses) ($p=0.330$), history of concussion ($p=0.671$), and combined medical history ($p=0.501$) were not significant predictors of PCS 132 scoring category for males.

**Table 4-18. Effects of Predictor Variables on PCS 132 Scoring Categories – Males Only**

<table>
<thead>
<tr>
<th>Predictor Variable</th>
<th>B</th>
<th>SE</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Odds Ratio</th>
<th>Lower CI</th>
<th>Upper CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>-.077</td>
<td>.1634</td>
<td>.221</td>
<td>1</td>
<td>.638</td>
<td>.926</td>
<td>.672</td>
<td>1.276</td>
</tr>
<tr>
<td>Prior Depressive Episode</td>
<td>-1.023</td>
<td>1.0510</td>
<td>.948</td>
<td>1</td>
<td>.330</td>
<td>.359</td>
<td>.046</td>
<td>2.820</td>
</tr>
<tr>
<td>History of Concussion</td>
<td>-.215</td>
<td>.5024</td>
<td>.181</td>
<td>1</td>
<td>.671</td>
<td>.807</td>
<td>.300</td>
<td>2.172</td>
</tr>
<tr>
<td>Combined Medical History</td>
<td>.516</td>
<td>.7662</td>
<td>.453</td>
<td>1</td>
<td>.501</td>
<td>1.675</td>
<td>.373</td>
<td>7.521</td>
</tr>
<tr>
<td>MFQ Total Score</td>
<td>-.282</td>
<td>.0698</td>
<td>16.288</td>
<td>1</td>
<td>.000</td>
<td>.755</td>
<td>.658</td>
<td>.865</td>
</tr>
</tbody>
</table>

**Note: prior depressive episode = yes, concussion history = no, combined medical history diagnoses = yes

*reference category – “low-normal” PCS Symptom Intensity, CI – confidence interval (95%)

The next model utilized a binomial logistic regression model to regress predictor variables to MFQ High and Low categories (Table 4-19). The first model presented included outliers in the analysis (largest SD = 5.409). For individuals with a history of depression (irrespective of a diagnoses) the odds of having a MFQ score ≥ the cut-off increased by a factor of 2.44 ($p<0.000$). Age ($p=0.435$), sex ($p=0.112$), history of concussion ($p=0.401$), combined medical history ($p=0.794$) were not found to be significant predictors of an individual having a MFQ cut off score ≥ 27.
Table 4-19. MFQ Score Dichotomized By Cut-Off Score (≥ 27) - With Outliers

<table>
<thead>
<tr>
<th>Predictor Variable</th>
<th>B</th>
<th>SE</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Odds Ratio</th>
<th>Lower CI</th>
<th>Upper CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1.392</td>
<td>0.876</td>
<td>2.524</td>
<td>1</td>
<td>.112</td>
<td>4.024</td>
<td>.722</td>
<td>22.423</td>
</tr>
<tr>
<td>Age (years)</td>
<td>0.231</td>
<td>0.295</td>
<td>.609</td>
<td>1</td>
<td>.435</td>
<td>1.259</td>
<td>.709</td>
<td>2.247</td>
</tr>
<tr>
<td>Prior Depressive Episode</td>
<td>-3.206</td>
<td>0.835</td>
<td>14.732</td>
<td>1</td>
<td>.000</td>
<td>0.41</td>
<td>.008</td>
<td>.208</td>
</tr>
<tr>
<td>History of Concussion</td>
<td>-.660</td>
<td>0.787</td>
<td>.704</td>
<td>1</td>
<td>.401</td>
<td>.517</td>
<td>.111</td>
<td>2.416</td>
</tr>
<tr>
<td>Combined Medical History</td>
<td>0.213</td>
<td>0.815</td>
<td>.068</td>
<td>1</td>
<td>.794</td>
<td>1.237</td>
<td>.251</td>
<td>6.106</td>
</tr>
</tbody>
</table>

**Note: sex = females, prior depressive episode = no, concussion history = yes, combined medical history diagnoses = no prior diagnosis, CI – confidence interval (95%)**

The second model excluded outliers (±2 SD) (n=150) (Table 4-20). Sex (p=0.337), age (p=0.680), history of depression (p=0.995), history of concussion (p=0.272) and combined medical history (p=0.952) were not significant predictors of an individual having a MFQ score ≥ 27.
### Table 4-20. MFQ Score Dichotomized By Cut-Off Score (≥ 27) - WithOUT Outliers

<table>
<thead>
<tr>
<th>Predictor Variable</th>
<th>B</th>
<th>SE</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Odds Ratio</th>
<th>Lower CI</th>
<th>Upper CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1.222</td>
<td>1.272</td>
<td>.923</td>
<td>1</td>
<td>.337</td>
<td>3.393</td>
<td>.280</td>
<td>41.068</td>
</tr>
<tr>
<td>Age (years)</td>
<td>-.172</td>
<td>.416</td>
<td>.170</td>
<td>1</td>
<td>.680</td>
<td>.842</td>
<td>.372</td>
<td>1.905</td>
</tr>
<tr>
<td>Prior Depressive Episode</td>
<td>-20.613</td>
<td>3488.713</td>
<td>.000</td>
<td>1</td>
<td>.995</td>
<td>.000</td>
<td>.000</td>
<td>-</td>
</tr>
<tr>
<td>History of Concussion</td>
<td>-1.121</td>
<td>1.020</td>
<td>1.207</td>
<td>1</td>
<td>.272</td>
<td>.326</td>
<td>.044</td>
<td>2.408</td>
</tr>
<tr>
<td>Combined Medical History</td>
<td>.058</td>
<td>.972</td>
<td>.004</td>
<td>1</td>
<td>.952</td>
<td>1.060</td>
<td>.158</td>
<td>7.122</td>
</tr>
</tbody>
</table>

**Note:** sex = females, prior depressive episode = no, concussion history = yes, combined medical history diagnoses = no prior diagnosis, CI – confidence interval (95%)
Chapter 5

Discussion

This study aimed to profile normative symptoms of concussion and depression in adolescent athletes, in the absence of a recent concussion. Analyses focused on investigating the type (e.g. emotional, behavioural, physical, and sleep-related), frequency and severity of concussion-like symptoms using the Post-Concussion Scale (PCS). The Mood and Feelings Questionnaire (MFQ) was used to establish the normative profile of depressive symptoms reported in this age group. The associative relationship between the two symptom domains (i.e. concussion-like and depressive symptoms) was also examined. Demographic and medical history variables were assessed for their suitability as predictors for either PCS or MFQ outcome scores. Analyses primarily focused on identifying discrepancies between sex groups.

Adolescent athletes, 13 to 18 years old (median age of 15 years) and involved in various sports, were captured in this study. Individuals had a diverse medical history background with almost 1/3 (n=49) of participants reporting a history of concussion (at least one prior injury). Participants reported various prior learning disabilities, anxiety and depression diagnoses as well as a history of depression and anxiety episodes (regardless of diagnosis). Median outcome measure scores showed a clear discrepancy between sex groups, with females endorsing significantly more concussion-like and depressive symptoms than males. Despite significant symptom severity differences, males and females reported experiencing similar concussion and depressive symptoms. Moreover, significant associations were identified between concussion and depressive symptom measures (i.e. on the PCS and MFQ). However stronger associations between outcome measure scores were identified in females as compared to males. Regression analyses revealed limited demographic and medical history variables were significant predictors of outcomes measure scores. Significance for predictor variables varied within each model.
5.1 Study Sample Characteristics

5.1.1 Age

Although this study sought to capture individuals aged 13 to 18 years, there were proportionately less participants for each year increase in age. Use of convenience sampling contributed to this uneven distribution. To reach recruitment goals, many teams, sport organizations and clinics were contacted. A greater number of teams that included younger athletes responded to investigator inquiries in regards to participating in the study. Older athlete teams were contacted but refused to participate. Teams with younger athletes were more responsive to inquiries and therefore made up the majority of the sample. However it may also have been that there were more teams with younger adolescents (13-15 years old) compared to older adolescents (16-18 years old). This is cohesive with trends that have been identified in physical activity participation amongst youth and adolescents (17).

As youth age, they have more freedom to participate in activities of their choice. In light of this freedom, adolescents may opt to spend their time focusing on interests other than sports as they approach adulthood. It is likely that older adolescents would have other responsibilities, and therefore can no longer focus their time on athletics (i.e. academic and job responsibilities, etc.). These findings are supported by 2010 Physical Activity Monitor conducted by the Canadian Fitness and Lifestyle Research Institute (17). Reports indicated that generally as youth age, participation in leisure sport activities tends to decrease (17). Although trends indicated that more boys than girls were involved in organized sport activities (18, 19), the sampling method utilized in this study does not allow for an accurate assessment of this occurrence.

5.1.2 Sport Participation

As convenience sampling was utilized in this study, conclusions could not be made as to the true rate of participation by sport for each sex. However national surveys of adolescent participation in organized sport indicated that soccer was the most popular team sport followed by basketball, hockey, baseball, volleyball and football (19). This trend did not appear in the data, as hockey (n=70, 45.2%) was the predominant sport that
athletes were participating in at time of survey completion, followed by soccer (n=25, 16.1%). Due to the short time frame for data collection, time of year greatly influenced the types of sports played and thus the type of athletes that were captured in this study.

5.1.3 History of Concussion

Within the sample captured in this study, 31.6% of participants reported a history of concussion. More males (34.2%) than females (29.1%) reported a history of concussion, however this difference was not found to be statistically significant (p=0.495). When looking at the existing literature on this topic, in sex comparable sports, females were found to have a greater concussion incidence rate relative to males (238, 239). However in this study, mechanism of injury was not acquired from participants; although athletes reported their respective sport at time of survey completion, we did not captured how the athlete sustained their concussion while involved in their current sport. Any conclusion regarding incidence of concussion by sex and sport are therefore limited in this context. Differences in incidence by sex have also been reported (240), with more females sustaining concussion injuries as compared to males (2, 215, 241).

Prevalence of concussion varied dramatically in the literature depending on the population that was captured. One study found that by the start of high school, ~53% of student athletes reported a history of concussion (215). Additional studies found an injury rate of 31.8% (242) and 7.7% (215) in high school aged athletes. Investigators warn however that the actual incidence of concussion injury may be much higher than what was reported (240).

It is important to consider the following when interpreting concussion history for this sample. 1) An objective definition was not provided on the survey for athletes to reference when indicating their concussion history response. Although concussions were discussed in the introductory dialogue (i.e. prior to survey completion), individuals may not have been clear on what defines a concussion. II) recall bias may have contributed to the under or over reporting of injuries. Underreporting may have been due to recall issues attributed to a) memory (i.e. simply forgetting about an injury), b) if there was a more severe musculoskeletal injury occurred simultaneously, or c) the event happened so long ago that the individual could not recall or did not attribute that event to a concussion.
Over-reporting may have occurred if an individual had an incorrect perception or catastrophic definition of concussion (i.e. every bump on the head causes a concussion), misclassifying a non-injurious event as an injurious one. Alternatively, individuals may have over-reported because they wished to skew or falsely their data, which may be due to one of many reasons such as social desirability (e.g. showing off to their peers) or attention-seeking behaviour. III) An individual may have failed to report a concussion because they feared potential negative repercussions for their honesty, especially for a recent concussion (i.e. fearing removal from play, fear of having to tell their parents or not having told their parents, etc.). A recent investigation conducted by Register-Mihalik et al. (2013) sought to better understand reasons for concussion underreporting behaviour amongst athletes (93). Suggested reasons included: perceived lack of injury severity, not wanting to be removed from the game, not wanting to let teammates down, not wanting to let coaches down, lack of knowledge about concussive symptoms and not wanting to be removed from practice (93).

Given the high number of participants who reported a history of concussion (31.6%) within this study, there appears to be a need for wide spread dissemination of concussion education to the lay public, especially to adolescent athletes. With such a substantial number of adolescents reporting prior concussions at such an early point in their athletic career, it is important to consider the implications this may have on future cognitive and psychological development, as well as the risk for subsequent repeated injuries. There is some literature that indicates individuals with a history of repeat concussions have a reduced threshold for subsequent injuries (88, 243-246).

5.1.4 Multiple Prior Concussions

Of the individuals that reported a prior history of concussion, a subset of that group reported having sustained multiple prior injuries (2 prior concussion = 18.4% and 3 or more prior concussions = 8.2%). The small sample size precluded the ability to conduct sex-based analyses of repeat concussion incidence. However it is known that athletes who participate in contact/collision sports are at a greater risk for repeat concussions (243, 247-249). In this subset of individuals, longstanding deficits are of great concern. In a multicentre study of n=600 high school athletes, investigators found significantly
higher ratings of cognitive, physical, and sleep-related concussion-like symptoms in athletes with a history of two or more concussions, compared to individuals with one or no prior history of concussion (140). Deficits on neuropsychological and memory-based tests have also been identified among high school and amateur athletes with a history of repeat injury (i.e. 2 or more concussions) as compared to individuals with 1 prior injury (242, 243, 250). Furthermore, repetitive concussions have been implicated as a precursor to post traumatic stress disorder (251), substance abuse (252), anxiety and depressive disorders (251, 253). History of severe and multiple concussions has also been linked with poorer cognitive outcomes, including slower recovery (246), persistent cognitive impairments (254, 255), as well as short and long-term neuropsychiatric issues (246, 254, 255)(i.e. late-life depression (256)).

Alternatively, a prior investigation has found no measurable effect of one or two prior concussions on either neuropsychological test performance or symptom reports (257). Investigators argue if there was an effect, it was too minor to have been detected in their study (257). This may be the case within this current study; group sizes in multiple concussion groups may have been too small to detect a significant affect in outcome measure scores and regression models.

5.1.5 Time Since Injury

Time since injury reported in participant surveys indicated that many athletes who endorsed a history of concussion, were reporting an injury that occurred over a year prior to their participation in this study. More females (34.8%) than males (11.5%) reported a more recent injury (i.e. < 1 year). It is important to note that three males could not recall the time or details of their last injury. This speaks to the fact that self-reported anecdotal evidence may not be the best indicator of an individual’s true concussion history. This also brings into question the accuracy of symptom self-reporting. This is a crucial consideration because at this time there is no other objective way to diagnose a concussion injury other than based on subjective symptom complaints.

5.1.6 Participant Medical History
Medical history within the scope of this study included a prior learning disability, anxiety or depression diagnoses. The demographic survey also inquired whether the participant had experienced any recent anxiety symptoms (i.e. within the two weeks prior to completion of surveys) or any prior depressive episode, regardless of whether they had been diagnosed with either disorder or not. Anxiety was the most common medical diagnosis reported by participants (10.3%), followed by a learning disability (9.0%) or depression diagnosis (6.5%). Comparisons between sex groups indicated that there were no significant differences in the proportion of males to females who self-reported any of these concerns, with the exception of depressive episodes; a significantly greater proportion of females (24.1%) reported having experienced a prior depressive episode as compared to males (11.2%)(p=0.029).

Rates captured in this study were slightly higher than those that had been previously captured by Statistics Canada: 4% of youth (aged 12-19) reported a prior anxiety diagnosis (258), 3.2% of youth (aged 5-14 years) reported a prior learning disability (259), and 2.7% of youth (aged 12-19 years) reported a prior depression diagnosis (258).

One notable finding was that fewer individuals self-reported a depression diagnosis (6.5%) as compared to the number of individuals who reported having experienced a prior depressive episode (18.1%). A similar trend was seen within each sex group (females: diagnoses = 7.6% vs. prior episode = 24.1%; males: diagnoses = 5.3% vs. prior episode = 11.2%); more females reported a depressive episode and formal depression diagnoses than males.

Although not specific to adolescents, individuals often live many years with their mood disorder before they seek help or treatment. Research indicates some people may wait an average of 6 to 8 years from initial onset of a mood disorder before they seek help (260). In this case an individual can still receive treatment without having to seek a formal diagnosis (i.e. peer-to-peer support, school guidance counsellors, online depression programs, talk therapy via a non-medical professional etc.). Part of the stigma associated with mental health illness is associated with the diagnosis itself. Individuals may also be ashamed or afraid of having a diagnosis, fearing that their family may find out (261, 262). This is especially important in the context of an adolescent population.
5.2 Self-Reported Concussion Symptoms

One of the primary objectives of this study was to investigate self-reported concussion-like symptoms among adolescent athletes, in the absence of a recent concussion injury. Looking at the entire sample, participants had a median PCS frequency score (PCS 22) of 2 and a median PCS symptom severity score (PCS 132) of 3 suggesting overall low levels of symptomatology. Scores were non-normally distributed with many participants having a score of zero overall (i.e. no symptoms reported). The number of participants decreased as scores increased in frequency and severity. When stratifying outcome measure scores by sex, females self-reported more symptoms overall (PCS 22 median score of 4) and more severe concussion-like (PCS 132 median score of 7) symptoms as compared to males. Males had a median score of 1 on both measures. Differences between the sexes were significant (p<0.000).

These findings were similar to the findings of Iverson and colleagues; in one of the largest studies done to date, Iverson’s investigation sought to examine baseline concussion symptoms on the PCS using a sample of n=33,732 (n=17,290 males, n=14 668 females) students athletes (13-18 years old) (142). Males had a mean symptom severity score of 4.5 (SD 7.9) and median score of 1. Mean PCS severity score for females was 6.5 (SD 9.9) with a median score of 3. Iverson’s findings appear to be communicating the same result as the present study; females experienced a greater number of concussion-like symptoms and symptoms of greater severity as compared to males.

Within the current study an itemized symptom analyses by sex group was also conducted. Symptoms that were the most severe were often the most common within each sex group, however the order varied slightly between these two rankings (see Tables 4-8 and 4-9). For females, the most severe symptom was fatigue (1.41) and for males, falling asleep (0.59). It was evident that females were reporting more severe symptoms as compared to males, with the mean symptom score for most severe symptom more than double that of most severe symptom among males (i.e. 1.41 vs. 0.59).

Importantly, sex groups reported roughly the same symptoms as their most and least common symptom complaints. Looking at symptom frequency analyses (Table 4-9),
fatigue was the most common symptom among females, with over half (55.7%) of females self-reporting this symptom. Fatigue was also the most common symptom among males, however only 27.6% of males self-reported this symptom. Similar symptoms were shared at the top and bottom end of PCS symptom frequency analyses. Members of each sex group self-reported concussion-like symptoms, but far greater proportion of females had self-reported these symptoms as compared to males.

Iverson and colleagues conducted a similar itemized symptom analyses for each sex group (Table 5-1).

Table 5-1. Most and Least Common Reported Symptoms on The PCS by Sex (Reproduced from Iverson et al. [2015]).

<table>
<thead>
<tr>
<th>Most Common Symptoms</th>
<th>Females (%)</th>
<th>Males (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fatigue (26.8)</strong> *</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleeping less than usual (25.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Trouble falling asleep</strong> (23.0)</td>
<td></td>
<td><strong>Fatigue (20.3)</strong> *</td>
</tr>
<tr>
<td><strong>Headache (24.6)</strong> *</td>
<td></td>
<td><strong>Trouble falling asleep</strong> <em>(18.4)</em></td>
</tr>
<tr>
<td><strong>Sadness (22.6)</strong></td>
<td></td>
<td>Difficulty concentrating (17.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Headache (16.2)</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Sadness (13.4)</strong></td>
</tr>
<tr>
<td>Least Common Symptoms</td>
<td>Sensitivity to noise (6.7) *</td>
<td>Visual problems (5.9)</td>
</tr>
<tr>
<td><strong>Balance problems (6.6)</strong></td>
<td></td>
<td><strong>Balance problems (4.2)</strong></td>
</tr>
<tr>
<td><strong>Vomiting (4.6)</strong> *</td>
<td></td>
<td><strong>Numbness/tingling (3.7)</strong> *</td>
</tr>
<tr>
<td><strong>Numbness/tingling (3.9)</strong></td>
<td></td>
<td><strong>Vomiting (3.3)</strong> *</td>
</tr>
<tr>
<td><strong>Nausea (3.4)</strong> *</td>
<td></td>
<td><strong>Nausea (3.1)</strong></td>
</tr>
</tbody>
</table>

Items in descending order. Bolded items are shared between sex groups. *Asterisks indicate symptom was shared with present study.

Similar to the study conducted here, males and females in Iverson’s investigation reported similar most and least common symptom complaints (bolded). Findings indicated that more females than males were found to have reported a given symptom. For example, fatigue was the most commonly reported symptom overall, with 26.8% females reporting this symptom as compared to 20.3% of males. This trend was the same for the top-five most common and top-five least common symptoms in Iverson’s study.

Similar findings were identified in the current study (i.e. similar most and least common symptom complaints were shared across the sex groups), with a greater number of
females having endorsed shared most common symptoms as compared to males. However more females within the current study appeared to be experiencing symptoms as compared to the females captured in Iverson’s study (i.e. fatigue prevalence of 55.7% vs. 26.8% respectively). This trend can be seen among other symptoms as well. Looking at the male groups between the two studies, scores were comparable with minor variations between symptom frequencies.

Additional literature provides support for these findings. In 2015, a systematic review looking at baseline concussion symptoms among individuals aged 12 to 26 years old confirmed that females were 43% more likely than males to report symptoms associated with concussion in the absence of injury (82). More specifically, females had a higher-odds of reporting headache, difficulty concentrating, vision/hearing problems, emotional symptoms, and energy/sleep disturbances. Findings indicated that at both baseline and post-concussion, females had a significantly higher total symptom score (i.e. symptom severity) on the PCS as compared to males (82). An investigation by Lovell et al. (2006) reported similar results (217). Conversely, some literature has indicated the opposite finding, indicating that self-reported concussion symptoms at baseline are minimally related to sex (131, 134). This does not appear to be the case in this current study.

A number of plausible explanations have been suggested to explain the occurrence of concussion-like symptoms in uninjured, healthy athletes. One investigation attributed elevated symptoms to a lack of sleep; participants self-reporting low sleep quantity the night prior to baseline testing reported greater symptoms as well as a higher total symptom severity score compared to their well rested peers (145). Authors argued the same effect was not seen for sleep quality (145).

The effect of exercise has also been postulated as a cause of concussion-like symptoms in the absence of concussion. Therefore consideration must be given when collecting symptom measures following exercise. Prior evidence suggested that the athlete must be in a completely rested state and at least 10 minutes post-exercise to lessen the influence of fatigue on subsequent symptom reports (9). Unfortunately exercise intensity was not further discussed within this context, nor were repeated bouts of exercise (i.e. multiple days of intense training). Fitness level was also thought to effect symptom reports. An
investigation using collegiate level athletes found that self-reported levels of physical fitness accounted for a significant variance in the PCS symptoms reported at baseline (146).

In the context of this study, these factors (i.e. sleep quantity, prior exercise and fitness level) may have had an affect on the self-reported symptoms captured. It may have been the case that participants were poorly rested at time of survey completion. The majority of participants included in this study were enrolled in sports leagues at the competitive level or higher. Competitive sports demand more time and dedication, often time requiring the athlete to attend practices on multiple occasions within one given week on top of their regularly scheduled games. This takes time away from other commitments like academic and social obligations. With only so many hours in the day, poor time management can contribute to lack of sleep in this population (263). Some participants’ symptoms may have been affected by a recent exercise bout, as a few individuals completed their surveys following their practice. However if the athlete need only be at a resting state for a minimum of 10 minutes then this may not have played a large role in the context of this particular study.

A number of explanations have been provided as to why females report more symptoms of greater severity than males. Some speculate that differences can be attributed to hormones and menses in females (264, 265). Dependent on the phase of cycle a female is in when she completes either her baseline or post-injury assessment, this could affect any number of concussion-like symptoms. Symptoms actively observed on measures like the PCS are similar to the symptoms that are observed in Premenstrual Syndrome (PMS) (264, 265). Shared symptoms include feeling tired, trouble sleeping, upset stomach, headache or backache, trouble concentrating, irritability, mood swings, anxiety and depression (266). However there are some symptoms that are unique to PMS, and thus would not be commonly identified on concussion symptom assessments (i.e. swollen or tender breasts, bloating, constipation, diarrhoea, joint or muscle pain) (266). Conversely, subsequent investigations have found no affect of menstrual cycle on total symptom severity or number of symptoms endorsed by females (135, 267). To aid in disentangling PMS from baseline or post-injury symptom reports, researchers have suggested that females report their average PMS symptoms and severity at time of baseline assessment.
Alternatively concussion symptom baseline assessments could be obtained twice, once in the premenstrual phase and once again during the follicular phase to then rule out affects of hormones on concussion-like symptom reporting (82). These data were not collected in the present study thus the contribution of PMS or hormonal fluctuation upon symptom discrepancies could not be determined.

Additionally, symptom reporting in females could be attributed to the fact that females may be more open to reporting symptoms (268). Or, females may be more attentive to symptoms that require medical attention than males (268). In other words females may be more in tune with their bodies as compared to males. A similar gender-based explanation has to do with the social roles that we fill as women and men. Inherent in our western culture, where much of our concussion literature originates from, is the way that females are raised and taught to behave. Each male and female has a social role to fill, and it is taught from infancy. Women are taught to be delicate, fragile and sensitive (269). Men are taught to be tough, strong and hegemonic (269). These roles carry over to the way that we care for ourselves and the way in which we seek attention from others (262, 270). Furthermore, it is also likely that there is a discrepancy in the way that males and females experience and report concussion-like symptoms. What a female may consider as a moderate or severe symptom, males may perceive as a non-existent or minimal symptom. In other words, pain threshold or tolerance may differ between the sexes thereby resulting in a large discrepancy in symptom frequency and severity reporting.

As discussed in the literature review within this thesis, symptoms of concussion are highly non-specific and can be attributed to a number of other medical, psychological conditions or as a result of regular daily life (73). Some of the most common symptoms (i.e. headache, dizziness, irritability, memory problems, and poor concentration) have been identified in a number of other non-TBI populations including healthy college students (173) , chronic pain suffers (271) , personal injury claimants (272) (free of TBI) and depression sufferers (273). Symptoms are vague and can be related to many other events or stressors in an individual’s life. In athletes, these symptoms could also be attributed to over training (274), fatigue or chronic injury (275, 276).
A number of implications for this finding (i.e. healthy individuals self-reporting concussion-like symptoms) have been previously discussed in the literature. Iverson argues “understanding the normative rate of concussion-like symptoms, sex differences, and their association with pre-existing athlete characteristics and health conditions is essential for guiding medical management after sports-related concussion and for making return-to-play decisions” (142). The idea that post-concussed athletes need to be symptom free (i.e. asymptomatic) prior to RTP is not synonymous with symptom presence in healthy individuals. From time to time, or even on a daily basis, individuals may experience concussion-like symptoms, which could be attributed to any number of reasons, or for no reason whatsoever. In this light, perhaps “normal” in terms of concussion symptom presence, is not merely the absence of symptoms.

By attributing “normal” or even “fully recovered” to being completely asymptomatic, individuals may have an unrealistic expectation that they must reach this state following their injury. This seems highly unlikely given the fact that healthy uninjured individuals have been found to report concussion-like symptoms. This also further complicates the idea of persistent symptoms following concussion injury (i.e. symptoms lasting more than 1 month). Known as the “good-old-days” bias, following injury individuals often believe they were “better off” or in a better health state prior to their injury (277-279). It can be explained like somewhat of a false disposition of an individual’s former selves health status; the individual fails to acknowledge that they weren’t completely symptom free prior to their injury to begin with. In this way, if they perceive their post-injury selves as experiencing persistent post-concussion symptoms, instead of as what was actually “normal”, it may further contribute to their psychological distress and thus further perpetuate symptoms.

Conversely, in the case of adolescent athletes, if they know they must be symptom free in order to RTP, and evidence indicates this is an unrealistic expectation, they are perhaps not telling the truth in order to avoid being kept out of play. Furthermore, if females demonstrate a greater number of symptoms and greater total symptom severity at baseline as compared to males, it would be logical to assume that these particular symptoms would carry over following an injury, and in fact they do. Females have been shown to report more concussion symptoms of greater severity as compared to males following
injury (197, 241, 280-283). If RTP is predicated on asymptomatic status and menses plays a role in symptom presentation, it is unlikely that the female will ever reach an asymptomatic state. Therefore it has been suggested that RTP could be “inappropriately delayed in females” because of this reason (82).

5.3 Depressive Symptoms

The second major objective of this study sought to examine self-reported symptoms of depression among adolescent athletes using the Mood and Feelings Questionnaire. Similar to concussion symptom trends identified in this sample, females reported experiencing more depressive symptoms as compared to males (median score 7 vs. 1 respectively). This discrepancy in symptom score was significantly different between the two sex groups (p<0.000). Looking at score distribution histograms, scores were positively skewed with a long right-handed tail. Many individuals, both males and females, endorsed no depressive symptoms whatsoever, with a decreasing number of individuals self-reporting symptoms of an increasing severity.

Among participants that reported depressive symptoms, males and females shared many of the same most (n=3) and least (n=4) common depressive symptoms, however the proportions between the sexes varied greatly. For example 51.9% of females reported “I felt so tired I just sat around and did nothing” compared to only 32.9% of males. Overall more females reported experiencing a given symptom as compared to males. Similar symptom trends were noted for symptom severity, with females experiencing significantly more severe depressive symptoms than males. Only 6 out of 33 symptoms were not found to be significantly different (i.e. p>0.05) between sex groups: talking more slowly, thinking about death or dying, moving more slowly, thinking bad things would happen, sleeping more than usual and eating more than usual.

In Canada the lifetime prevalence for a major mood disorder (i.e. depression) among adolescents aged 15-19 years old is 7.6% overall and by sex, 4.3% for males and 11.1% for females (284). Being that depression prevalence is almost double in females, it would be expected that females would report more depressive symptoms within the context of this study. Although males do not report depressive symptoms to the same extent that females do doesn’t mean they are not experiencing these symptoms. Perhaps females
were more willing to share their symptoms and experiences with study investigators. This then translates to an increase in depression prevalence as compared to males, but this could be a misleading finding. Males may have chosen not to share their feelings because they feel that it would be a sign of weakness. In the context of this study, data was collected in a group setting. For this reason males may not have wanted to share their feelings while in the company of their peers, or with an unfamiliar person (i.e. the student investigator) with which they had no rapport. As with concussion-like symptoms, it may be that females are more in tune with their bodies and therefore readily notice when things “aren’t right”.

Putting these speculations aside, there may actually be a difference in the prevalence of depression between males and females. Males may have better coping resources or may be better able to tolerate life stressors that contribute to depressive symptoms. Furthermore, males may be better able to compartmentalize troublesome parts of their life, and move forward with other daily life tasks without letting depressive symptoms dominate their thoughts and being. Alternatively, a number of explanations have also been provided to explain why males may choose not to discuss depressive symptoms including: i) emotionality may be seen as feminine and therefore weak, ii) as a man, one is suppose to be able to rise above “pain”, and iii) it is unmanly to discuss emotions (285). Furthermore, males are thought to experience depression differently than women do. They are more likely to feel tired or irritable, or lose interest in their work, family or hobbies (286). They may also display sudden anger, heightened feelings of loss of control, greater risk-taking behaviour or aggression (287). Some have also suggested that typical depression symptoms in males may manifest in a way that is not captured in currently accepted diagnostic criteria (i.e. DSM-IV) (288). In response to this idea, a number of alternative male-focused depression scales have been developed and validated including the Gotland Male Depression Scale (GMDS) (289) as well as the Masculine Depression Scale (MDS)(290). Both the GMDS and MDS have provided empirical evidence supporting men’s alternative expression of depression.

Findings from this current study replicated what had been previously identified in the literature. Using an abbreviated version of the MFQ, the SMFQ (Short-Mood and Feelings Questionnaire), investigators identified the same non-normal distribution in
symptom scores among a group of adolescents (8-17 years old) (227). Similarly, they identified that “0” or “not true” was the most common response on the SMFQ (227). This was the case for males enrolled in this current study, but not for females. Three symptoms: i) “It was hard for me to make up my mind”, ii) “I felt grumpy or cross with my parents” and iii) “I felt so tired I just sat around and did nothing” did not have a median response of “0”. Sund et al. (2001) conducted another investigation with a community sample of n=2465 adolescents (13 & 14 years old)(230). The median score for the entire sample was 8, 6 for males and 10 for females respectively; these scores were slightly higher than what was identified for each group in the current study. This may have been because a community sample was used with Sund’s investigation, whereas an athlete sample was used in the current study.

Within the current study, physical activity may have provided a protective effect against depressive symptoms. Physical activity and sport allows for increased social opportunities and greater social support (47). It can also act as a distraction from life stressors (48), and can provide a sense of accomplishment and improved self-esteem (49). Frequency of vigorous exercise has also been associated with fewer depressive symptoms in young people (p=<0.001) (291). Investigators suggest that exercise can moderate depressive symptoms via biological pathways, as well as via social and psychological factors (291).

In Sund’s first investigation discussed here (2001), investigators provided an itemized breakdown of most and least common symptoms for participants in their study (Table 5-2).

Table 5-2. Most and Least Commonly Reported Depressive Symptoms (Reproduced from Sund et al. [2001]).

<table>
<thead>
<tr>
<th></th>
<th>Female (%)</th>
<th>Male (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most Common Reported</td>
<td>I thought I looked ugly (66.5)</td>
<td>It was hard for me to make up</td>
</tr>
<tr>
<td>Symptoms</td>
<td>It was hard for me to make up</td>
<td>my mind (49.4) **</td>
</tr>
<tr>
<td></td>
<td>my mind (63.6) **</td>
<td>I felt grumpy and cross with</td>
</tr>
<tr>
<td></td>
<td>I felt grumpy and cross with</td>
<td>my parents (48)</td>
</tr>
<tr>
<td></td>
<td>my parents (48)</td>
<td></td>
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</table>
In this investigation (n=2465) three of the top-five most common symptoms (in bold) and four of the least common reported symptoms were shared between the sex groups. This was similar to the study conducted here (i.e. n=3 shared top-five symptoms between sex groups, n=4 shared least common reported symptoms). Similarly, Sund et al. identified 3 of same top-5 five most common symptoms as identified in the current study (indicated with **). However Sund’s study noted a greater prevalence for each symptom. For example, in the present study 55.7% of females reported “It was hard for me to make up my mind”, as compared to 63.6% of females in Sund’s investigation. This was similar for all the top-ranked symptoms between the two investigations. The same pattern was seen for males, with a greater prevalence of males self-reporting a shared symptom in Sund’s investigation than in the current study.

For least commonly reported symptoms, the opposite trend was seen. With a greater number of females self-reporting a symptom in the present study compared to females in Sund’s investigation (i.e. “I thought about killing myself”; 10.1% vs. 7.4% respectively).
This was the same trend for all shared symptoms in females. This was not the case for males. Within the context of this current study there were fewer males reporting shared symptoms. For example in Sund’s study, 4.2% of males endorsed (either a “sometimes true” or “true” response) “I thought about killing myself” vs. 0% in the present study. Overall Sund found that MFQ scores in females were significantly higher than in males (230), which was the same finding for the study presented here.

Aside from the negative outcomes of mood disorders in adolescents, depression is associated with a negative continuity in mental health (161). For example depression during adolescence has been associated with anxiety disorders, substance related disorders, and bipolar disorder (292-294), unemployment (294) and physical health problems into adulthood (295). Depression is also a major risk factor for suicide. In fact, more than 50% of adolescent suicide victims reportedly have a depression diagnoses at time of death (296).

Given the severity of health implications associated with depression in adolescents, routine screening in this population may be an effective preventative measure. Screening can: i) inform changes in clinical practice, ii) provide information to facilitate service development and iii) help establish normative symptom data among adolescents (297). However some research has indicated that children and youth may provide poor self-assessments of their mood state due to reading and language limitations (i.e. when completing self-report questionnaires), and their tendency to report current symptoms rather than their symptoms over a prolonged period of time (298, 299). On the contrary, there is also some evidence that suggests that even children with significant mental health problems are able to provide some insight to their difficulties (300-302).

Aside from negative quality of life outcomes, some literature has indicated that depressive symptoms are associated with prolonged concussion symptom resolution (i.e. greater time until return to play, symptomatic for more than 4 weeks, etc) (10). If adolescents are experiencing depressive symptoms, with some adolescents experiencing significantly more symptoms than others (i.e. based on cut-off score on the MFQ), proactive depressive treatment prior to a concussive injury may be an effective approach to reducing the risk for a prolonged recovery should an injury occur.
5.4 Suicidal Ideation

Suicide is not a common topic of discussion among young people due to the stigma and many negative connotations associated with mental health illness. Despite suicide being somewhat of a taboo topic, it affects the lives of many young people and their families. According to statistics reproduced by the Centre for Addiction and Mental Health (CAMH), in 2012 suicide accounted for 17% of deaths among youth aged 10 to 14 years old, 28% among youth aged 15 to 19 years old, and 25% among young adults aged 20 to 24 years old (303). This type of death is needless and completely preventable if the right precautions are taken. Prevention in this case starts with promoting mental health wellness from a very young age.

Although a harm protocol was included within the REB protocol for this study, investigators did not foresee it having to be used; individuals captured in this study were not considered to be “high-risk”. Furthermore it was thought that participation in athletics would further preclude this group of adolescents from experiencing depressive symptoms to such an extreme extent (i.e. to the point of suicidal thoughts). It was also thought that participants, even if they felt suicidal, wouldn’t openly express their feelings or intentions to study investigators. Findings in this domain were not as expected; most alarming was the number (n=8) and the young age (median age of 15, range 13-16 years old) of the participants that met harm protocol criteria. Although females were identified from two sporting areas (i.e. rugby and cheerleading), sport will not be discussed any further because no conclusions can be made as to sport and risk of suicidal ideation based on the sampling method that was utilized.

Interestingly no males within this study met harm-protocol criteria. This may have reflected their reluctance to share this personal information with study investigators, or simply that males may not have been experiencing suicidal ideation symptoms to the same extent that females were. The fact that only females self-reported suicidal symptoms was cohesive with the large difference in median MFQ symptom severity score identified between males and females (1 vs. 7, respectively), as well as the number of males compared to females that fell in the high MFQ score group (n= 2 vs. n=11, respectively). Although evidence indicates that more than 75% of suicides involve men,
women attempt suicide 3 to 4 times more often (303, 304); it could be speculated in this case that men don’t share their concerns and thus do not receive help. Therefore they resort to suicide. In the case of females, it could be that they want help, and that they pursue suicidal action (i.e. attempt suicide) or endorse suicidal symptoms in hopes that they can receive some sort of attention or help that they desperately need. In other words, perhaps fewer females intend to complete suicide.

The key message here is that there is reason to be concerned that depression is clinically significant enough in adolescents to contribute to suicidal thoughts and behaviours. What is even more troubling is that this was identified in adolescents as young as 13 years old. Sadly, depression and suicide are not common topics of conversation between youth and their peers, parents or other authority figures (i.e. teachers, guidance counsellors, religious leader, etc.). Findings illustrate the seriousness of the current situation, and that significant preventative action needs to be taken to help protect adolescents. Preventative measures should strive to ensure that thoughts do not develop into actions and behaviours.

Most importantly, when conducting research of a similar nature (i.e. when assessing suicidal ideation in minors) it is imperative that a contingency plan be in place to address and manage situations where suicidal ideation is recognized by a study investigator. Contingency plans may include specialized suicide training, community distress resources, a practitioner whom can provide immediate assessment of the participant in question, parental contact information or a debriefing education session for concerned parties. In light of the extent of the resources that are required to address suicidal behaviours and thoughts in young people, it has been argued that it may be easier to avoid asking about suicidal ideation altogether; this is not a practical solution to tackling this problem. In light of the reality that some adolescents can and will continue to experience depression to such a severe extent that they are contemplating suicide, it is imperative that future investigations develop an appropriate plan and expect to implement their harm protocol.

5.5 Association Between PCS and MFQ Symptoms
The third objective of the study was to identify and examine the correlational relationship between concussion-like symptoms on the PCS, to depressive symptoms identified on the MFQ. In this study, $r$-values were calculated between PCS 22 & MFQ and PCS 132 & MFQ. Significant ($p<0.000$) moderate, borderline strong correlations were identified in the total sample group ($r = 0.68$ and 0.68 respectively) and female group ($r = 0.68$ and 0.69 respectively). Weaker significant correlations were identified in males ($r = 0.57$ and 0.55, respectively). Although a weaker correlation was identified in males, this was not likely to have been a clinically significant difference from females. Overall significant symptom overlap existed between concussion and depressive symptoms within the sample captured here.

Similar trends have been identified in previously conducted investigations. In 2012, Covassn and colleagues sought out to examine sex differences in adolescents (n=779) and college aged athletes (n=837) on baseline concussion symptom reporting in relation to depressive scores using the Beck Depression Inventory (170). Findings indicated elevated levels of depression were significantly associated with self-reported symptoms of concussion. No sex differences on depression or concussion symptom scores were identified. Both age groups (high school vs. college athletes) endorsed the same total number of depression and concussion symptoms. Furthermore, an investigation conducted by Bailey et al. (2010) identified significant correlations (moderate to large effect) between baseline neurocognitive performance and anxiety, depression, substance abuse and suicidal ideation; authors emphasized the need for psychological distress screening as a part of concussion baseline assessment (141).

Although the PCS doesn’t aim to assess depressive symptomatology, it may be picking up on some of the common emotionally rooted symptoms. In both adolescents and adults, depression can manifest in similar physical symptoms (i.e. headaches), cognitive (i.e. difficulty concentrating, difficulty remembering), sleep-related symptoms (i.e. trouble falling asleep), and emotional symptoms (i.e. nervousness, irritability) as does concussion. Although this study cannot make a causal link between concussion and depressive symptoms, there was significant association between the two types of symptoms.
It is likely that symptom manifestation (of both depression and concussion symptoms) in healthy, uninjured individuals can be attributed to multiple factors such as, daily stress, relationship stressors, social conflict, hormonal fluctuations (an especially prominent factor in adolescents going through or on the verge of puberty), as well as familial issues among others. Findings from this study support the notion that concussion symptoms are non-specific, and may be related to depressive symptoms. Given that depressive and concussive symptoms are correlated, it may be possible that concussion-like symptoms would respond to traditional depressive treatments (i.e. psychotherapy, cognitive behaviour therapy, etc.). However this will not be further discussed here.

5.6 Severe Concussion and Depressive Symptoms

Determining a clinically significant severity for both concussion-like and depressive symptoms was estimated by establishing high scoring cut-off points for each outcome measure. For the PCS, a participant was categorized as a high scorer if they had PCS severity score within either the “very high” or “extremely high” scoring range (varied by sex group). For females, “very high” was a score equal to 21 to 43 and “extremely high” was a score equal to 44+. For males, “very high” was a score equal to 13 to 26 and “extremely high” was a score equal to 27+. Not surprisingly, there was a significant association between sex and high PCS score (p=0.034) with females being more likely (21.5%) than males (9.2%) to fall in the high scoring category. MFQ scores were also dichotomized into what was thought to be clinically different groups (i.e. low vs. high scoring groups). Again there was a significant association between sex and scoring group, with females being more likely (13.9%) to fall in the high scoring group as compared to males (2.6%) (p=0.011). Speculated reasoning behind these sex differences are discussed in previous sections.

Overall there were a larger proportion of females at the severe end of the symptom spectrum (for both concussion-like and depressive symptoms) as compared to males. Within the female group, there were proportionately more females experiencing severe concussion symptoms (21.5%) as compared to depressive symptoms (13.9%). A similar trend was seen in males, with a greater proportion of individual’s self-reporting severe concussion symptoms (9.2%) as compared to severe depressive symptoms (2.6%). This
indicates that there was likely something else that was contributing to elevated concussion-like symptoms other than poor mental health status (i.e. depressive symptoms). There is reason for concern here because if these adolescents were experiencing concussion-like symptoms to this extent in the absence of a recent injury, the occurrence of an actual injury would only further exacerbate these symptoms. This could lead to further complications in the recovery period, or to a prolonged recovery period in general.

Further investigation is warranted to help understand why severe symptoms originate in an injury free state. More time and attention should be paid to helping alleviate symptoms in the injury-free state (i.e. at baseline) in order to set the athlete on a better foot should they then sustain a concussion. Regrettably very few investigations have focused on this objective at this time.

5.7 Predicting Outcome Scores

5.7.1 Predicting Concussion Symptom Frequency

The final objective of this study sought to investigate the affect that demographic (i.e. age and sex) and medical history factors (i.e. history of depression, history of concussion, medical diagnoses) had on symptom scale scores (PCS and MFQ) in adolescent athletes. The first regression model looked at PCS 22 as a log count score. Sex was found to be a significant predictor, with females having a PCS 22 score 1.64 times that of the male group (p=0.025). MFQ score was also a significant predictor within the model; the interval rate ratio (IRR) was 1.06. Meaning for every one-unit increase in MFQ, PCS 22 count increased by a factor of 1.06. MFQ score was a significant predictor for PCS symptom frequency in both sex groups (females IRR = 1.05, p=0.001 vs. males IRR = 1.13, p=0.002). Comparing males to females, depressive symptoms appeared to have a greater effect on PCS symptom presentation in the male group; for every one unit increase on the MFQ, female PCS score increased by a factor of 1.05 as compared to males, who’s score increased by a factor of 1.13. This difference in IRR indicates there was a greater crossover effect of depressive symptoms to concussion-like symptoms in males as compared to females. Note there was only a modest difference between sex group IRRs. It is not likely that this was clinically significant. Age, prior number of
depressive episodes and combined medial history (diagnosis only) were not significant predictors of PCS 22 score.

Findings from the male model also indicated that history of concussion was a significant predictor of PCS frequency score (p=0.023). Males with a history of 3 or more concussions had a PCS symptom frequency score 4.76 times that of a male who did not have a history of concussion. This could indicate that prior concussions in males may have a longstanding affect on current symptoms of concussion, even in an injury free state. Notably this finding is based on a very small group of males (n=3) therefore this result should be interpreted with caution. Additionally, a significant effect was not seen in males with fewer prior concussions (i.e. 2 or less). For the total sample and female group, number of prior concussions was not found to be a significant predictor of PCS frequency score. This is different than previous findings.

Prior investigations found that athletes reporting one prior concussion endorsed more concussion-like symptoms during preseason baselines than athletes who did not have a history of concussion (138). A similar finding was identified by Brooks et al. (2014) among a group of n=768 adolescent athletes (305); males and females with a history of concussion reported more baseline symptoms than their same-sex counterparts. Similarly, Register Mihalik found a significant association between a history of concussion and symptom presence at baseline assessment among high school and collegiate aged athletes (p<0.001) (134). Reasons for the null finding in this current study may be attributed to the small group sizes of individuals with a prior history of 2 or more concussions. Prior literature indicates that age did not have a significant impact on concussion-like symptoms reported at baseline (134, 170, 217).

In summary, findings from the first model have some important implications for clinical management of concussion injuries in adolescent athletes. As stated previously, if an individual is experiencing exacerbated symptoms at baseline, it would be logical to assume that a concussion would only further elevate these symptom complaints. The female sex, MFQ score and a history of multiple concussions (males only) were shown to significantly predict PCS 22 score. The significant effect that depressive symptoms have on PCS score should be taken into consideration when conducting baseline symptom
assessments for adolescent athletes, and emphasizes the need to address these symptoms prior to a concussion.

5.7.2 Predicting Concussion Symptom Intensity

A second model, using an ordinal logistic regression equation was run for each sex group. Both male and female models significantly predicted the dependent variable over and above the intercept-only model (p<0.000). MFQ score was a significant predictor of PCS symptom severity (PCS 132) within both sex models (p<0.000), where a lower MFQ score was associated with greater odds (OR = 1.15) of falling in the “low-normal” PCS scoring category. Significance here reflects the level of correlation identified between the two measures. Additionally in females, younger age was associated with a greater odds (OR = 1.59, p=0.018) of falling in the “low-normal” PCS score category, as compared to older participants. The remaining factors: prior depressive episode, history of concussion and medical history were not significant predictors within either sex-based model.

5.7.3 Predicting Depression Symptoms

Two separate binomial regression models were run for the MFQ, one including outliers and one without. In the outliers-included model, number of prior depressive episodes significantly predicted whether or not an individual would fall in the high scoring group (p<0.000); risk increased by a factor of 2.44. This same effect was not identified as a significant predictor in the outlier-excluded model (prior depressive episode, p= 0.995). In this case, outliers had a significant affect on the model that was produced. Including outliers within this model described a different impact of prior depressive episodes on current mood state. Here it is important to note the small group size of the high scoring group (n=13). Therefore this result should be interpreted with caution.

In both models, sex, age, history of concussion and combined medial history were not significant predictors of an individual falling in the high score group (i.e. clinically significant depressive symptoms). The null-effect of sex and age was unexpected, as sex and age have both been found in the literature to be closely linked with depressive symptoms (i.e. older individuals and individuals of the female sex, are more likely to suffer from depression(306-308)). History of concussion and prior medical diagnoses
also did not appear to predict a high MFQ score. Thus indicating that any clinically significant ongoing depressive symptoms were not significantly attributed to a prior concussion or medical diagnoses. In summary, because few (if any) demographic factors were identified as significant predictors of a high MFQ score, this indicates that there must have been other factors contributing to excessive and severe depressive symptoms other than what was measured in this study (i.e. sex, age, history of concussion or a prior medical diagnoses). These factors may have included a familial history of psychiatric disorder (309) or a history of substance abuse (310, 311) for example.

It is also important here to note that small sample size imposes some limitations to how model findings can be interpreted. Sample size calculations for logistic regression models denoted that ~300 to 500 individuals should have been recruited in order to run the analytical tests that were required. However, the sample collected was nearly half the minimum amount of the participants that were required. When working with small prevalence rates (i.e. rate of depression in adolescents ~ 10%), it can be a challenge to recruit enough subjects into an investigation. This is further illustrated by the non-normal distribution of concussion-like and depressive symptoms in this population. Further limitations were also imparted on the types of analytical tests that could be run due to non-linear relationship between variables and over-dispersion of true zero scores. With these limitations in mind, the best analytical methods were chosen but results have an insufficient power within these types of regression models (i.e. ordinal regression and binomial regression models).

5.8 Limitations

In addition to sample size limitations, there are a number of other factors one must consider when interpreting the findings described above. Limitations include sources of sampling and measurement error.

Sampling error in this study may have been due to the convenience sampling method that was utilized for recruitment. Severe depression and concussion-like symptoms can impact many aspects of an individual’s life and wellbeing, and can be incredibly debilitating. Athletes who were severely symptomatic may not have felt well enough to complete surveys, or may not have attended practice or baseline testing when recruitment
took place. Particularly in individuals who suffer from clinical depression, anhedonia could have played a large role in excluding these particular individuals from the study. With anhedonia, the individual is no longer motivated to participate in an activity they once loved (312). In the context of this study, the athlete would have since removed themselves from the team or sport altogether.

Measurement error should also be considered when interpreting findings. Recruitment and the environment in which surveys were completed may have played a large role in the types of responses received. As surveys were completed in a group setting (i.e. surrounded by their teammates, coaches, etc.) individuals may have been afraid to share their personal and emotional feelings with study investigators while in the presence of their peers. Although n=8 participants has endorsed significant suicidal symptoms. Within a group setting, individuals may have been more prone to coordinating their responses (i.e. regression to the mean). Fear of being ostracized by their peers, individuals may have responded in a way they felt was socially acceptable. Furthermore in some cases, parents were present at testing locations. This may have also caused undue pressure upon participants to respond in a particular way.

Timing of survey completion may have also skewed results. As participants were approached and recruited at either a baseline testing assessment appointment (clinic), or before or after their sport practice, their attention may not have been completely focused on the task at hand. They may have felt rushed or inpatient about participating in the study, thus causing them to quickly circle and answer questions without fully understanding what was being asked of them. As discussed above, fatigue (for those participants who just finished a practice prior to completing their surveys), may have also influenced the responses received. Or if the individual had a bad practice (i.e. they weren’t making plays they should have, or their coach was giving them a hard time about their performance), this may have also influenced participant mood and therefore the responses that were provided. Athletes with chronic sports injuries, aggravated by or further injured during practice may have also impacted self-reported symptoms on either measure.
The environment within which participants completed their surveys may have also impacted the responses that were received. Either in the waiting room of a clinic or sideline at a field or ice rink there were a number of distractors present. Noise, poor lighting conditions, uncomfortable seating arrangements may have all played a role in the types of responses that were received.

The affect of testing environment on symptom reports was also examined, as surveys were completed in a group-based setting. Postulated risks to administering tests in a group setting include participants failing to adhere to instructions and participants not being able to ask questions, as well as assumed participant comprehension of the task (313). At the individual level, participants may be more likely to become distracted, less likely to ask questions about things they don’t understand, or more prone to not taking the task seriously (i.e. goofing off with friends). They are also less likely to receive one-on-one feedback, which may contribute to lowering their motivation, or facilitating greater levels of boredom among the group (313). All of these factors may have contributed to over or under-reporting of symptoms within the study.

The survey itself may have influenced the responses provided by participants. Within the demographics portion of the survey, individuals were asked about a history of concussion, but surveys failed to provide an appropriate definition for concussion. Although concussion was discussed with participants prior to them consenting and completing their surveys, knowledge and preconceptions that the athletes may have had about concussion may not have been accurate. It’s reasonable to assume that individuals may hold different definitions or misconceptions about concussion. Therefore it would have been appropriate to have provided an objective, standardized definition on each survey for the participant to reference when self-reporting a history of concussion. The demographic and medical history questionnaire also did not inquire as to if the individual was suffering from a recent musculoskeletal injury or ongoing chronic health condition (i.e. diabetes, severe asthma). These factors may have also played a role in the types or severity of concussion-like and depressive symptoms that were reported.

Reading difficulty of the surveys utilized within this study could have also posed a problem for participants. Although survey-reading level was deemed to have been at a
6.6 Flesch-Kinkaid reading level, this may not have been appropriate for those individuals with a learning disability. Although the PCS and MFQ have been validated in populations younger than age 13, there may be exceptions to age appropriateness. Younger individuals may have had trouble understanding certain items on questionnaires and therefore answered them incorrectly. Furthermore participants may not have followed the appropriate instructions for each survey. For example, the PCS asked about how the participant was feeling in the present day, while the MFQ asked the participant to recall the how they’d been feeling over the past two weeks. Participants may not have kept this in mind when completing each survey. Instead any depressive symptoms that were reported may have been due to an isolated event, not a longstanding mood issue.

Lastly the MFQ cannot be used to diagnose depression therefore any interpretation is limited to depressive symptoms, not depression itself.

Importantly sex was inquired within participant questionnaire packages, not gender. In some ways the lines between gender and sex are blurred. For example, in Western culture, individuals are often raised in a way that reflects their sex. It has become such a norm that men are masculine and females are feminine, that going against this grain is still somewhat of a taboo (i.e. individuals who identify as transgender). Given the population that was investigated here, it is difficult to say whether or not a young person would be able to separate sex from gender. They may think of the two statements as one in the same, when in fact they have very different meanings. Therefore to separate sex and gender in the context of this study is not something that will be attempted. To that extent, we must use caution when interpreting sex-based findings as there is likely a blurring of both biological and socio-cultural factors that contribute to the outcomes that have been identified in the two sex groups.

5.9 Implications for Rehabilitation Science

As rehabilitation scientists, our role is to help an individual fulfill their occupational and functional goals. However often times when rehabilitation science is discussed, it is in the context of injury or illness. This study offers the perspective that rehabilitation science has a place in improving health and wellbeing in the absence of disability or sickness; our practice can take a more proactive and preventative approach as compared to a reactive
one, especially in relation to concussion injury management. Ultimately, a better understanding of an individual and who they are in the absence of injury, allows a better understanding of the individual should they sustain an injury, and who they will be following the injury.

Findings from this study indicated that healthy adolescent athletes experience concussion-like and depressive symptoms in the absence of a recent injury. Importantly, a significant number (n=24) of adolescents captured in this study indicated they were experiencing concussion-like symptoms to a severe extent (i.e. PCS symptom severity score falling in the “very high” and “extremely high” categories). Not only are these symptoms likely to worsen following an injury, but may very well negatively impact adolescent quality of life while in an injury-free state. This has important implications for the clinical management of athletes. Identifying clinically significant concussion-like symptoms at baseline illustrates the need for a proactive approach to addressing problematic symptom areas. Not only can the managing practitioner identify these troublesome areas, but they can encourage treatment or refer the athlete to a specialist to better address symptom concerns.

A number of athletes in this study also reported they were experiencing clinically significant depressive symptoms. Similar to severe concussion-like symptoms, these too can negatively impact quality of life (irrespective of a concussion). In the context of concussion, depressive symptoms have also been shown to negatively impact recovery following a concussion injury in this population (10). Some evidence has also indicated that post-concussion depressive symptoms are associated with an increase in suicide risk, poor functional outcomes, lower cognitive performance and reduced quality of life (253, 314-317). Despite known implications of depressive symptoms on recovery from injury, concussion baseline or post-injury assessments do not typically assess or measure depressive symptoms. Therefore addressing mood concerns prior to injury is of great advantage to the athlete who is at risk for concussion (i.e. individuals involved in high-speed contact and collision sports).

Identifying a potential mood disorder at baseline, prior to injury, allows for a proactive approach to treatment. Irrespective of a concussion injury, screening for depression can
be useful in young people. Moreover, depression is not routinely assessed for in any other aspect of an adolescent’s life (i.e. school, annual physician check-ups).

Due to the stigma that surrounds depression and other mental health disorders, this is not a common topic of conversation for adolescents. Including some sort of depressive assessment in baseline protocols would be multi-beneficial for the health of an adolescent athlete. Openly discussing mood disorders like depression with youth will help to educate them to the warning signs, when they should seek help and also how they can go about seeking help. As with many mental health disorders, starting the conversation is often the most difficult part to overcome.

Lastly, current clinical management practice requires athletes to be completely asymptomatic prior to their RTP following a concussive injury. If athletes are symptomatic at baseline, without a current injury, it seems impractical that they are required to be symptom free in the weeks following a recent concussion. This seems to be particularly important for females. If females are experiencing concussive symptoms to a greater extent in the absence of a recent injury, then it would be a reasonable expectation that these symptoms would be further exacerbated following an injury. In terms of clinical management of females, clinicians may wish to give special attention to the effect that a females menstrual cycle may have on exacerbating concussion-like symptoms in both pre- and post-injury states. This may lead clinical management practitioners and researchers to question the notion that females experience greater concussion-like symptoms following concussion injury as compared to males. Overall findings allude to the fact that perhaps athletes aren’t symptom free at time of RTP. Perhaps they are only indicating a lack of symptoms in order to RTP more quickly. More importantly, keeping athletes out of play or school for too long following a concussive injury has also been found to contribute to both anxiety and depressive symptoms in this population (318-321).
Chapter 6

Conclusion and Future Directions

Despite common clinical guidelines stipulating that athletes are to be asymptomatic prior to RTP (following a concussion injury), many adolescent athletes exhibit concussion-like symptoms in the absence of a recent injury. Reframing the idea that individuals need to be completely symptom-free prior to returning to sporting activities, school or social activities may be doing more harm than good. As seen here, females experience significantly greater concussion-like symptoms at baseline as compared to males. This may play a role in symptom presentation following injury and the time it takes to reach RTP status. For inappropriate reasons athletes may be kept out of sport for too long, perhaps perpetuating negative symptoms, especially depressive ones. Objective tests and tools are needed not only to better diagnose a potential concussion but also to better inform the athlete, as well as a clinician or team coach, when an individual is ready to return-to-play safely (i.e. to identify when they’ve completely healed from their injury). Attention should be paid to further understanding and exploring the non-specificity of concussion-like symptoms.

In many cases, athletics contributes a great sense of self to an individual’s identity. In the event of a concussion, removing an athlete from that part of their life may contribute to the negative cascade of symptoms that follow in the days and weeks post-injury. Within this study, depressive and concussion-like symptoms were seen to be highly associated with one another. This also speaks to the fact that concussion symptoms are non-specific and could be caused by any one ongoing health issue or life stressor. It is important to note that concussion-like symptoms reported in this study could not be solely explained by depressive symptoms alone. Further investigations are required to understand the role of sleep, substance abuse, social relationships and family psychiatric history on adolescent athlete symptom presentation at baseline.

A small subset of participants self-reported concussion-like and depressive symptoms at a clinically significant level, despite the absence of a recent concussion. There are reasons for concern here given the young age of the participants who self-reported these
symptoms. Undoubtedly symptoms of this severity could contribute to lowering the quality of life in a young person. At this crucial stage in development and growth these effects may contribute to longstanding problems both into and throughout adulthood. Screening and identifying problematic concussion-like and depressive symptoms at baseline (within a clinical management environment) may provide an opportunity for treatment that wouldn’t otherwise be provided. Irrespective of an actual injury, athlete wellness could be monitored and targeted for improvement.

Identifying the presence of concussion and depressive symptoms in athletes at baseline indicates that this should be taken into consideration when treating an athlete following injury. However at this time very few investigations have sought to understand how excessive depressive and concussion-like symptoms affect recovery following an actual injury. Prospective longitudinal investigations could track and follow individuals across a prolonged period of time, especially after sustaining a concussion, to identify how excessive symptoms affect recovery. Specifically, how excessive baseline concussion or depressive symptoms impact the recovery trajectory (i.e. number of days until RTP), and the affect they may have on other cognitive and functional domains. Thereafter proactive treatment interventions could be examined for use in the pre-injury phase (i.e. imagery or talk therapy to address troublesome concussion or depressive symptoms).

Most importantly this study illustrates the need to evaluate and prescribe treatment based on the sex of the athlete. If symptoms are significantly different at baseline, this undoubtedly has an impact on how symptoms present themselves following a concussion. Given that mood has been identified as a bigger factor in females, this should be a larger consideration in the clinical management and treatment of females than males.

In summary, normative symptom studies like the one conducted here are needed to better understand a population that are most at-risk for concussion in sport. Findings are crucial to informing an evidence-based approach to the clinical management of concussed athletes. At this time we know very little about how to speed-up or improve the recovery from a concussion. A better understanding of the individual prior to their injury will help us better understand who the individual will be following their injury.
References


Appendices
Appendix 1 – Recruitment Source Flow Diagram

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<th>CCM Clinics</th>
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<th>Schools</th>
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hockey n=0.0 soccer n=5.0 football n=5.0 rugby n=8.0 lacrosse n=4.0
soccer n=3.0 football n=2.0 rugby n=1.0 lacrosse n=1.0
hockey n=2.0 soccer n=1.0 rugby n=1.0 lacrosse n=1.0
n=14
n=3
n=3
n=14
n=3
n=0
n=0
n=2
n=1
n=0
Appendix 2 - Gauging Capacity to Consent

Probing Questions

The following questions will be asked to interested participants after the letter of information is read with them, but before informed consent is obtained (some questions require further elaboration). If a “no” response is reported for any of the questions the individual will be read the specific section of the letter of information again. The relevant questions will be asked once more. If the same “no” response is provided, this individual defaults to not having the capacity to consent. The individual can refer to their letter of information while answering these questions as needed.

1. Do you understand the purpose of the study, can you tell me what you think it is in one sentence?
2. Do you understand that your participation in this investigation is completely voluntary and you can stop / withdraw at any point in time?
3. Do you know how I will protect the information I collect from you? Please describe.
4. Do you understand that if you indicate you are a risk of harming yourself or others, precautions may be taken to ensure your safety? What kinds of precautions can be taken?
5. Do you have any questions or concerns about your role as a participant?
6. Do you believe that you fully understand your role as research participant?
Appendix 3 – Informed Consent

Informed Consent for Participation in a Research Study

Before participating in the proposed research study, *Investigating Depression and Concussion Symptoms in Young Athletes*, I want to make sure you understand your rights as a research participant. I want to emphasize that your participation in this research study will NOT change your status within your sport. I want to emphasize that you can stop your participation at any time.

If you believe I have answered all of your questions and feel comfortable participating in the described study, you can give me permission to collect information about you by providing your consent below.

Participant Study ID Number: ____________

________________________________________
Participant Name (please print)

________________________________________
Participant Signature  Date

________________________________________
Student Investigator

________________________________________
Signature of Investigator  Date

I agree to allow the information collected to be used in a subsequent follow-up investigation pertaining to concussive injury in adolescent athletes

________________________ (Initial)
Appendix 4 – Letters of Information

VERSION 1 - CCM Clinic

Letter of Information To Participate in A Research Study

Investigating Depression and Concussion Symptoms in Young Athletes

Introduction

I am conducting a research study investigating depression and concussion symptoms in adolescent athletes at baseline assessment (prior to participating in your sport this season and prior to sustaining a concussion injury). Using three surveys I will collect information about your mood, concussion symptoms and medical history. Depression is defined as feeling sad, blue, unhappy, miserable, or down in the dumps so much so that it interferes with everyday life for weeks or longer. Your answers will be used to better understand mental health and concussion-like symptoms that exist among adolescent athletes who do not have a concussion. Your responses will also help us understand how gender (male or female) and history of concussion and/or mood disorder affects the way you feel right now even though you do not have a concussion.

Before agreeing to take part in this research study, it is important that you read the information in this letter. It includes details we think you need to know in order to decide if you wish to take part in this study. You may also wish to discuss the study with a Complete Concussion Management clinician, a family member or close friend. Although this research study is partnered with Complete Concussion Management, your participation is voluntary and will NOT affect the care or treatment you receive at CCM. If you are worried about your treatment or care please talk to your Complete Concussion Management doctor or clinic directly. Or you can visit CCM’s website: www.completeconcussions.com for more information.

Investigators

Student Investigator: Tian Renton, MSc. Candidate Rehabilitation Sciences Institute at The University of Toronto Email: tian.renton@mail.utoronto.ca

Main Supervising Investigator: i) Dr. Jane Topolovec Vranic PhD, Clinical Researcher, Trauma and Neurosurgery Program; Associate Scientist, Keenan Research Centre of the Li Ka Shing Knowledge Institute; Associate Professor in the Department of Occupational Science and Occupational Therapy, The University of Toronto

• Mailing Address: St. Michael’s Hospital 30 Bond St, Bond 3-012 Toronto, ON M5B 1W8 Email: topolovec-vranicj@smh.ca

Co-Supervisor

ii) Dr. Angela Colantonio, Professor in the Department of Occupational Science and Occupational Therapy, The University of Toronto; CIHR Chair in Gender, Work and Health; Senior Scientist, Toronto Rehabilitation Institute (UHN).
Your Involvement

Your participation involves filling out 3 questionnaires that will take approximately 10 - 20 minutes to complete. These questionnaires can be completed either before or after the baseline testing you are completing today for your sport. The first questionnaire is a demographic survey asking about basic personal information, sport participation and brief medical history. The medical history portion asks about any depression, anxiety or learning disorder diagnoses you may have. The Post-Concussion Scale (PCS) consists of 22 questions investigating physical, cognitive, emotional and sleep related symptoms that you may be experiencing right now. These symptoms typically follow concussive injury. The Mood and Feelings Questionnaire (MFQ) is a 33-item questionnaire investigating any depressive symptoms you may have experienced in the past two weeks.

Potential Harms

A number of risks have been identified for this research study. You may be at risk for sudden onset of emotional distress when recalling symptoms or sensitive health information when answering survey questions. Some questions may cause some individuals to be uncomfortable, especially if you have not discussed these feelings with a parent or friend before. You may also come to realise you are suffering from symptoms you had not been aware of before now. Although you are encouraged to keep all responses confidential, sharing personal information with your peers may cause additional uncomfortable situations, teasing or taunting.

Potential Benefits

You have the opportunity to contribute to the body of knowledge surrounding adolescent depression, a topic not well explored in young athletes. You have the opportunity to self-reflect on your feelings, behaviours and thoughts, which can be constructive for positive behaviour change. Questionnaires may present you with an opportunity to discuss depression and concussion symptoms, and provide a platform for you to seek help if required or needed.

Harm Protocol

Due to the sensitivity of the health information (i.e. past medical history) collected, some of your symptoms or responses may be shared with your parent or a Complete Concussion Management clinician. This will only happen if you indicate that you are at an immediate risk to hurting yourself or others. By sharing your feelings with a clinician or your parent, we can ensure you receive the help and resources you may need.
Protecting Your Health Information

Your confidentiality and privacy is a key. For this reason your name will not be included on any of the questionnaires. All information collected will be kept in a secure space with access limited to only research investigators directly involved.

Results

Data collected throughout this investigation will be published in a thesis dissertation to be presented to the board of reviewers at The University of Toronto in summer/fall 2016. Dissertations are released to the University and are available for the public to access. When completed the published manuscript can also be found here: http://www.abiresearch.utoronto.ca

Participation and Withdrawal

Participation in any research study is voluntary. Your participation will not change the care you receive from CCM clinicians. If you decide to participate in this study, you are free to change your mind without giving a reason. You can stop participating at any time by talking to me or by emailing any of the other study investigators. You can also request to have your information removed from the data pool. Your information may not be removed from the data pool if you decide to withdraw after formal data analysis has started (set to begin September 2015).

Research Ethics Board Contact

If you have any questions regarding your rights as a research participant, you may contact The Office of Research Ethics at The University of Toronto. Phone: (416) 946-3273 – Monday to Friday 9:00a.m to 5:00p.m

Email: ethics.review@utoronto.ca I thank you for your interest in participating in my research study!
Letter of Information To Participate in A Research Study Investigating Depression and Concussion Symptoms in Young Athletes

Introduction

I am conducting a research study investigating depression and concussion symptoms in adolescent athletes. Using three surveys I will collect information about your mood, concussion symptoms and medical history. Depression is defined as feeling sad, blue, unhappy, miserable, or down in the dumps so much so that it interferes with everyday life for weeks or longer. Your answers will be used to better understand mental health and concussion-like symptoms that exist among adolescent athletes who do not have a concussion. Your responses will also help us understand how sex (male or female) and history of concussion and/or mood disorder affects the way you feel right now, even though you do not have a concussion.

Before agreeing to take part in this research study it is important that you read the information in this letter. It includes details we think you need to know in order to decide if you wish to take part in this study. You may also wish to discuss the study with a parent or close friend. Your participation is voluntary and will NOT affect your status within your sport organization/school.

Investigators

Student Investigator: Tian Renton, MSc. Candidate Rehabilitation Sciences Institute at The University of Toronto Email: tian.renton@mail.utoronto.ca

Supervising Investigator: i) Dr. Jane Topolovec Vranic PhD, Clinical Researcher, Trauma and Neurosurgery Program; Associate Scientist, Keenan Research Centre of the Li Ka Shing Knowledge Institute; Associate Professor in the Department of Occupational Science and Occupational Therapy, The University of Toronto

• Mailing Address: St. Michael’s Hospital, 30 Bond St, Bond 3-012, Toronto, ON M5B 1W8 Email: topolovec-vranicj@smh.ca

Co-Supervisor:

ii) Dr. Angela Colantonio, Professor in the Department of Occupational Science and Occupational Therapy, The University of Toronto; CIHR Chair in Gender, Work and Health; Senior Scientist, Toronto Rehabilitation Institute (UHN).

• Mailing Address: The University of Toronto, Department of Occupational Science & Occupational Therapy 160-500 University Ave., Toronto, ON M5G 1V7 Phone: (416)978-1098 – Monday to Friday 9:00a.m-5:00p.m Email: angela.colantonio@utoronto.ca
**Your Involvement**

Your participation involves filling out 3 questionnaires that will take approximately 10 - 20 minutes to complete. The first questionnaire is a demographic survey asking about basic personal information, sport participation and brief medical history. The medical history portion asks about any depression, anxiety or learning disorder diagnoses you may have. The Post-Concussion Scale (PCS) consists of a 22 questions investigating physical, cognitive, emotional and sleep related symptoms that you may be experiencing right now. These symptoms typically follow concussive injury. The Mood and Feelings Questionnaire (MFQ) is a 33-item questionnaire investigating any depressive symptoms you may have experienced in the past two weeks.

**Potential Harms**

A number of risks have been identified for this research study. You may be at risk for sudden onset of emotional distress when recalling symptoms or sensitive health information when answering survey questions. Some questions may cause some individuals to be uncomfortable, especially if you have not discussed these feelings with a parent or friend before. You may also come to realize you are suffering from symptoms you had not been aware of before now.

Although you are encouraged to keep all responses confidential, sharing personal information with your peers may cause additional uncomfortable situations, teasing or taunting.

**Potential Benefits**

You have the opportunity to contribute to the body of knowledge surrounding adolescent depression, a topic not well explored in young athletes. You have the opportunity to self-reflect on your feelings, behaviours and thoughts, which can be constructive for positive behaviour change. Questionnaires may present you with an opportunity to discuss depression and concussion symptoms, and provide a platform for you to seek help if required or needed.

**Harm Protocol**

Due to the sensitivity of the health information (i.e. past medical history) collected, some of your symptoms or responses may be shared with your parent or coach/teacher. This will only happen if you indicate that you are at an immediate risk to hurting yourself or others. By sharing your feelings with a coach/teacher or parent, we can ensure you receive the help and resources you may need.

**Protecting Your Health Information**

Your confidentiality and privacy is a key concern. For this reason your name will not be included on any of the questionnaires. All information collected will be kept in a secure space with access limited to only the research investigators directly involved.
Results

Data collected throughout this investigation will be both published in a thesis dissertation, and presented to a Review Board at The University of Toronto in Summer/Fall 2016. Dissertations are released by the University and are available for public access. When completed the published manuscript can also be found here: http://www.abiresearch.utoronto.ca

Participation and Withdrawal

Participation in any research study is voluntary. Your participation will not change your status within your sport organization. If you decide to participate in this study you are free to change your mind without giving a reason. You can stop participating at any time by talking to me or by emailing any of the study investigators. You can also request to have your information removed from the data pool. Your information may not be removed from the data pool if you decide to withdraw after formal data analysis has started.

Research Ethics Board Contact

If you have any questions regarding your rights as a research participant you may contact The Office of Research Ethics at The University of Toronto. Quote protocol number #31307. Phone: (416) 946-3273 – Monday to Friday 9:00a.m to 5:00p.m

Email: ethics.review@utoronto.ca Thank you for your interest in participating in my research study!
Appendix 5 – Harm Protocol

Procedure for Addressing Participant Distress

This harm protocol will be followed in the event that the participant has met at least one of the four following criteria:

i) participant answers “true” to question # 16 on the MFQ: “I thought that life wasn’t worth living”.

ii) participant answers “true” to question # 18 on the MFQ: “I thought my family would be better off without me.”

iii) participant answers “sometimes true” or “true” to question # 19 on the MFQ: “I thought about killing myself”.

iv) participant verbally indicates to a researcher or CCM clinic staff that they are at risk of harming themselves or others.

The harm protocol is being followed because a participant has reported one of the above symptoms on the MFQ or they’ve indicated that they may be at risk of hurting themselves or others. The list of distress resources should be provided to the participant, and they will be encouraged to discuss their depression symptoms. If deemed appropriate, a parent(s) may be notified. If an immediate risk is suspected, the participant will be directed to the nearest hospital for urgent attention.
Appendix 6 – Distress Resources

Distress Resources

- **Help Centres**

CAMH – Centre for Addiction and Mental Health
Child, Youth and Family Services

*Website:*
http://www.camh.ca/en/hospital/care_program_and_services/child_youth_and_family_program/Pages/child_youth_and_family_program.aspx

*Out-patient Services:* 416-535-8501, press 2

*In-patient Services:* 416-535-8501, ext 39988

*Family Support Services:*
http://www.camh.ca/en/hospital/care_program_and_services/support_for_families_and_friends/Pages/default.aspx

**Canadian Mental Health Association**

*Website (general):* http://toronto.cmha.ca/mental-health/find-help/

*Family Support Services:*
http://toronto.cmha.ca/mental_health/help-for-caregivers-and-family-members/#.VJl5yKAC0U

*Website (youth specific resources):*
http://toronto.cmha.ca/mental_health/youth-zone/#.VJl6H6AC0U

- **Telephone Hotlines - Youth Resources**

**Kids Help Phone**
24 hour national phone and online counselling services, referral and information for children, youth and adolescents in distress
Phone: 1800-668-6868

**Youth Distress Line, Street Outreach Services**
Phone: 416-926-0744

**Good2Talk Helpline**
Phone: 1866-925-5454

- **Online Chat for Youth**

  i) **Online Support/Chat**
  Youthspace.ca
  support@youthspace.ca

- **Telephone Hotlines – Parental Resources**

<table>
<thead>
<tr>
<th>Service</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toronto Distress Centres of Toronto &amp; GTA Help Line</td>
<td>416-408-HELP (4357)</td>
</tr>
<tr>
<td>Family and Mental Health Services, Depression (Toronto)</td>
<td>416-595-9230</td>
</tr>
<tr>
<td>Child and Adolescent Mental Health Services (Mississauga &amp; Toronto)</td>
<td>905-451-4566</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Service</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crisis Response Services for Children (Peel Region)</td>
<td>416-410-8615</td>
</tr>
<tr>
<td>Integrated Community Mental Health Response Program (North York &amp; Etobicoke)</td>
<td>416-498-0043</td>
</tr>
<tr>
<td>Distress Centres Ontario</td>
<td>416-486-2242</td>
</tr>
<tr>
<td>Mental Health Crisis Line</td>
<td>1888-893-8333</td>
</tr>
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</table>

- **Intervention Teams**

<table>
<thead>
<tr>
<th>Service</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crisis Intervention Team - Toronto</td>
<td>416-289-2434</td>
</tr>
<tr>
<td>Crisis Intervention Team – Mississauga</td>
<td>905-848-7495</td>
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</tbody>
</table>
### Appendix 7 - Approached / Refused Participant Tracking Log

<table>
<thead>
<tr>
<th>CCM Clinic or Sport Organization</th>
<th>Date</th>
<th># Approached</th>
<th># Refused</th>
<th># Included in Investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>May 9, 2015</td>
<td>4</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>S - Lacrosse</td>
<td>July 15, 2015</td>
<td>15</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>S - Lacrosse</td>
<td>July 16, 2015</td>
<td>12</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>S – Soccer</td>
<td>July 27, 2015</td>
<td>12</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>S – Soccer</td>
<td>Aug. 12, 2015</td>
<td>13</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>S – Soccer</td>
<td>Aug. 24th, 2015</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>S – Soccer</td>
<td>Aug. 31st, 2015</td>
<td>12</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>C</td>
<td>Sept. 29, 2015</td>
<td>9</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>S – Rugby</td>
<td>Sept. 30, 2015</td>
<td>19</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>C</td>
<td>Oct. 1, 2015</td>
<td>7</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>S – Rugby</td>
<td>Oct 7, 2015</td>
<td>13</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>Oct 9, 2015</td>
<td>8</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>C</td>
<td>Oct 10, 2015</td>
<td>14</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>S – Cheerleading</td>
<td>Oct 17, 2015</td>
<td>23</td>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td>S – Hockey</td>
<td>Oct 19, 2015</td>
<td>17</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td>S – Hockey</td>
<td>Nov. 18, 2015</td>
<td>12</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>S – Hockey</td>
<td>Nov 26, 2015</td>
<td>14</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>209</td>
<td>44</td>
<td>165</td>
</tr>
</tbody>
</table>

CCM Clinic, S = Sport Organization
Appendix 8 – Participant Questionnaires

Participant Information

Participant Study ID Number: ____________________

Please check the appropriate box or provide a written response where indicated for the questions below. Please remember to write clearly.

Personal & Sport Information

1. What is your sex?
   a) female [ ]
   b) male [ ]
   c) other [ ]

2. What is your birthday (day/month/year)? _______________________

3. What sport are you enrolled in OR completing your baseline concussion assessment for today?
   a. soccer [ ]
   b. hockey [ ]
   c. rugby [ ]
   d. football [ ]
   e. lacrosse [ ]
   f. cheerleading [ ]
   g. other (specify): ______________________

4. What level is the league you play in currently (i.e. house league, Rep, A/AA/AAA), please specify?

5. What position do you play most of the time (specify)?

Medical History Information

CONCUSSION HISTORY
6. Have you ever had a concussion?
   a) Yes [ ]
   b) No [ ]
c) Maybe [ ]

7. How many concussions have you had?
   a) 0 [ ]
   b) 1 [ ]
   c) 2 [ ]
   d) 3 or more [ ]

8. When was your last concussion?
   a) month/year: __________________________
   b) This doesn’t apply to me [ ]

9. How long did the symptoms last after your most recent concussion?
   a) A few hours or days [ ]
   b) A few weeks [ ]
   c) A few months [ ]
   d) More than 6 months [ ]
   e) This doesn’t apply to me [ ]

10. Are you still experiencing symptoms?
    a) Yes [ ]
    b) No [ ]
    c) This doesn’t apply to me [ ]

PAIN

11. On a scale of 1 to 10, 1 being no pain and 10 being the most pain you’ve ever been in, what would you rate your pain today? (please circle the appropriate answer)
    1  2  3  4  5  6  7  8  9  10

LEARNING DISABILITY

12. Do you have a learning disability? If yes, please specify.
    a) Yes [ ]
    b) No [ ]
HISTORY OF ANXIETY

Anxiety can experienced as tension or as worrisome, recurring or intrusive thoughts. Some people may experience physical symptoms including sweating, trembling or rapid heartbeat. – American Psychological Association.

13. Have you ever been diagnosed with anxiety?
   a) Yes [  ]
   b) No [  ]

14. Have you experienced any anxiety symptoms in the past two weeks?
   a) Yes [  ]
   b) No [  ]
   d) This doesn’t apply to me [  ]

HISTORY OF DEPRESSION

Depression is defined as feeling sad, blue, unhappy, miserable, or down in the dumps so much so that it interferes with everyday life for weeks or longer – National Institutes of Health

15. Have you ever been diagnosed with depression?
   a) Yes [  ]
   b) No [  ]

16. How many depressive episodes have you had?
   a) 0 [  ]
   b) 1 [  ]
   c) 2 [  ]
   d) 3 [  ]
   e) 4 or more [  ]
### Post-Concussion Scale (PCS)

Participant Study ID Number: ________________

*Instructions: Please indicate symptom presence and severity by circling the appropriate number. If you are not experiencing a symptom, circle “0”. If you are experiencing the symptom circle the appropriate severity. I.e. “1” or “2” = mild, “3” or “4” = moderate, and “5” or “6” severe.*

<table>
<thead>
<tr>
<th>Symptom</th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Nausea</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Vomiting</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Balance Problems</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Dizziness</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Fatigue</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Trouble falling asleep</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sleeping more than usual</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sleeping less than usual</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Drowsiness</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sensitivity to light</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sensitivity to noise</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Irritability</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sadness</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Nervousness</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Feeling more emotional</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Numbness or tingling</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Feeling slowed down</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Feeling mentally foggy</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Difficulty concentrating</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Difficulty remembering</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Visual problems</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Lovell & Collins (1998)
MOOD AND FEELINGS QUESTIONNAIRE: Long Version

This form is about how you might have been feeling or acting recently.

For each question, please check (✓) how you have been feeling or acting in the past two weeks.

If a sentence was not true about you, check NOT TRUE.
If a sentence was only sometimes true, check SOMETIMES.
If a sentence was true about you most of the time, check TRUE.

Score the MFQ as follows:
NOT TRUE = 0
SOMETIMES = 1
TRUE = 2

<table>
<thead>
<tr>
<th>To code, please use a checkmark (✓) for each statement.</th>
<th>NOT TRUE</th>
<th>SOMETIMES</th>
<th>TRUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I felt miserable or unhappy.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2. I didn’t enjoy anything at all.</td>
<td></td>
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<tr>
<td>3. I was less hungry than usual.</td>
<td></td>
<td></td>
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<tr>
<td>4. I ate more than usual.</td>
<td></td>
<td></td>
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<tr>
<td>5. I felt so tired I just sat around and did nothing.</td>
<td></td>
<td></td>
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<tr>
<td>6. I was moving and walking more slowly than usual.</td>
<td></td>
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<tr>
<td>7. I was very restless.</td>
<td></td>
<td></td>
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<tr>
<td>8. I felt I was no good anymore.</td>
<td></td>
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<tr>
<td>9. I blamed myself for things that weren’t my fault.</td>
<td></td>
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<tr>
<td>10. It was hard for me to make up my mind.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>11. I felt grumpy and cross with my parents.</td>
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<tr>
<td>12. I felt like talking less than usual.</td>
<td></td>
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<tr>
<td>13. I was talking more slowly than usual.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>I thought there was nothing good for me in the future.</td>
<td></td>
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<tr>
<td></td>
<td>I thought that life wasn’t worth living.</td>
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<tr>
<td></td>
<td>I thought about death or dying.</td>
<td></td>
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<tr>
<td></td>
<td>I thought my family would be better off without me.</td>
<td></td>
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<tr>
<td></td>
<td>I thought about killing myself.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I didn’t want to see my friends.</td>
<td></td>
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<tr>
<td></td>
<td>I found it hard to think properly or concentrate.</td>
<td></td>
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<tr>
<td></td>
<td>I thought bad things would happen to me.</td>
<td></td>
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<tr>
<td></td>
<td>I hated myself.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>I felt I was a bad person.</td>
<td></td>
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<tr>
<td></td>
<td>I thought I looked ugly.</td>
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<tr>
<td></td>
<td>I worried about aches and pains.</td>
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<tr>
<td></td>
<td>I felt lonely.</td>
<td></td>
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<tr>
<td></td>
<td>I thought nobody really loved me.</td>
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<tr>
<td></td>
<td>I didn’t have any fun in school.</td>
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<tr>
<td></td>
<td>I thought I could never be as good as other kids.</td>
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<tr>
<td></td>
<td>I did everything wrong.</td>
<td></td>
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<tr>
<td></td>
<td>I didn’t sleep as well as I usually sleep.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I slept a lot more than usual.</td>
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</tr>
</tbody>
</table>

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Appendix 9 – Outcome Measure Score Distribution Histograms

Figure 3-1. Histogram of PCS 22 (Symptom Frequency) – Total Sample

Figure 3-2. Histogram of PCS 132 (Symptom Intensity) – Total Sample
Figure 3-3. Histogram of MFQ – Total Sample

Figure 3-4. Histogram of PCS 22 Score (Symptom Frequency) – Females Only
Figure 3-5. Histogram of PCS 22 Score (Symptom Frequency) – Males Only

Figure 3-6. Histogram of PCS 132 Score (Symptom Intensity) – Females Only
Figure 3-7. Histogram of PCS 132 Score (Symptom Intensity) – Males Only

Figure 3-8. Histogram of MFQ Score – Females Only
Figure 3-9. Histogram of MFQ Score – Males Only
## Appendix 10 - Tables

### Table 4-7. Participant Measure Score – By Sex

<table>
<thead>
<tr>
<th></th>
<th>Females (Mean/ SD)</th>
<th>Female Median (IQR)</th>
<th>Female Skewness /Kurtosis</th>
<th>Males (Mean/ SD)</th>
<th>Male Median (IQR)</th>
<th>Male Skewness/ Kurtosis</th>
<th>Mann-Whitney U</th>
<th>Z Score</th>
<th>Asymp Sig (2-sided test)</th>
</tr>
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<td>PCS – Frequency (22)</td>
<td>5.96 (5.876)</td>
<td>4 (8)</td>
<td>1.111/0.450</td>
<td>2.41 (3.319)</td>
<td>1 (4)</td>
<td>1.884/3.615</td>
<td>1775</td>
<td>-4.450</td>
<td>.000</td>
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<tr>
<td>PCS – Severity (132)</td>
<td>15.35 (22.131)</td>
<td>7 (17)</td>
<td>2.313/5.403</td>
<td>4.72 (8.950)</td>
<td>1 (6)</td>
<td>3.605/15.011</td>
<td>1795</td>
<td>-4.371</td>
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<tr>
<td>MFQ</td>
<td>11.86 (13.733)</td>
<td>7 (13)</td>
<td>1.634/1.794</td>
<td>3.55 (5.825)</td>
<td>1 (5)</td>
<td>3.250/12.843</td>
<td>1502</td>
<td>-5.410</td>
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<td>Males Only n=75</td>
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<td>95% CI</td>
<td>P-Value</td>
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<td>Combined Diagnoses History – Yes</td>
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<td>Yes</td>
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<td>0.78-2.48</td>
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<td>ref</td>
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<td>MFQ Score Total</td>
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<td>1.05</td>
<td>1.02-1.07</td>
<td>0.001</td>
<td>1.13</td>
<td>1.05-1.22</td>
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