Recovery from Concussion in a Cohort of Male High School Students

by

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for the degree of Master of Science

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Abstract

Historically, concussion research has focused on adult populations, but research on high school students is lacking. A retrospective and prospective longitudinal cohort design was used to describe recovery time from concussion and the contribution of history of learning difficulty, history of concussion and school grade of student on recovery patterns in a cohort of 116 male high school students. Significant differences were identified in recovery patterns for youth in this sample expressed as median days to medical clearance 31.5 (range= 5 - 271), as compared to the 7-10 day recovery for adults that has been previously reported in the literature. A history of learning difficulty and history of concussion were significantly associated with increased length of days to medical clearance in the study cohort. Understanding differences in recovery patterns as well as risk factors for prolonged recovery can contribute to more realistic management expectations for high school students.

Keywords

Concussion, mild traumatic brain injury, adolescent, student, management, school, sport, recovery
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# Table of Contents

Acknowledgements ........................................................................................................ iii

Table of Contents ........................................................................................................ iv

List of Tables ............................................................................................................... vii

List of Figures ............................................................................................................. viii

List of Appendices ...................................................................................................... ix

List of abbreviations, symbols, and nomenclature ...................................................... x

Chapter 1 Introduction ................................................................................................. 1

Chapter 2 Literature Review ....................................................................................... 7
  Definition of Concussion ........................................................................................... 9
  Epidemiology .......................................................................................................... 10
  Mechanism of Injury ............................................................................................... 11
  Recognition and Reporting .................................................................................. 12
  Concussion Symptoms ......................................................................................... 14
  Current Principles of Concussion Management ................................................ 16
  Role of Neuropsychological Testing ................................................................ 18
  Concussion in Adolescents ................................................................................. 20
  Prolonged Recovery from Concussion .............................................................. 21
  Contribution of Pre-existing Conditions ........................................................... 22
  Return to Play ........................................................................................................ 23
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Discussion</td>
<td>60</td>
</tr>
<tr>
<td>Main Findings</td>
<td>60</td>
</tr>
<tr>
<td>Pre-Existing Conditions and Student Characteristics</td>
<td>62</td>
</tr>
<tr>
<td>History of Learning Difficulty (Presence of IEP)</td>
<td>62</td>
</tr>
<tr>
<td>History of Concussion</td>
<td>65</td>
</tr>
<tr>
<td>High School Grade at Concussion</td>
<td>66</td>
</tr>
<tr>
<td>Data Management</td>
<td>67</td>
</tr>
<tr>
<td>Interprofessional Management</td>
<td>69</td>
</tr>
<tr>
<td>Limitations of this Study</td>
<td>70</td>
</tr>
<tr>
<td>6 Conclusion</td>
<td>72</td>
</tr>
<tr>
<td>7 Future Directions</td>
<td>73</td>
</tr>
<tr>
<td>8 References</td>
<td>75</td>
</tr>
<tr>
<td>9 Appendices</td>
<td>88</td>
</tr>
</tbody>
</table>
List of Tables

Table 1. Participant Demographics
Table 2. Average Number of Days to Medical Clearance
Table 3. Difference in Recovery Time Between Adults and Youth Sample (n=116)
Table 4. Recovery Patterns for Participants with History of Learning Difficulty (Across Binary Recovery Points)
Table 5. Linear and Logistic Regression Results
List of Figures

Figure 1. Exclusion Criteria
Figure 2. Procedural Flowchart
Figure 3. Distribution of Days to Clearance
Figure 4. Graphs of Median Days to Medical Clearance
List of Appendices

Appendix 1. Six Stage Activity Domains and Corresponding School Accommodations

Appendix 2. Student Concussion Record

Appendix 3. Individual Re-Integration Plan

Appendix 4. Residual Plots

Appendix 5. Binary Recovery Periods and IEP for Learning Difficulty

Appendix 6. Analysis with Inclusion of Students with Two Concussion Records (n=20)
### List of abbreviations, symbols, and nomenclature

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADHD</td>
<td>Attention Deficit Hyperactivity Disorder</td>
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<tr>
<td>Clinic</td>
<td>David L. MacIntosh Sport Medicine Clinic</td>
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<tr>
<td>IEP</td>
<td>Individual Education Plan</td>
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<tr>
<td>IRP</td>
<td>Individual Reintegration Plan</td>
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<td>LD</td>
<td>Learning Disability</td>
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<td>LEC</td>
<td>Learning Enrichment Centre</td>
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<td>PEC</td>
<td>Pre-existing Conditions</td>
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<tr>
<td>SMCS</td>
<td>St. Michael's College School</td>
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</tbody>
</table>
Chapter 1 Introduction

Concussion – considered a type of mild traumatic brain injury (mTBI) – has raised alarm as a significant public health concern and escalated scientific interest in an area that had once concentrated almost exclusively on moderate and severe traumatic brain injuries (Wiebe, Comstock, & Nance, 2011). Evidence linking long-term physical, cognitive and emotional consequences of concussion has provoked more serious consideration of the injury, since mTBIs are estimated to account for 85% of all traumatic brain injuries in the United States (Bazarian et al., 2005). Although media attention tends to spotlight concussions that occur as a result of sports, in fact, concussions more frequently occur as a result of everyday events such as falls and motor vehicle accidents (Centers for Disease Control and Prevention, 2015). Estimates of traumatic brain injuries from recreation and sport-related activity in the United States vary, but the most commonly cited source suggests 1.6 to 3.8 million sports related traumatic brain injuries occur annually (Langlois, Rutland-Brown, & Wald, 2006).

Concussion research to date – which has mainly focused on studies of adults and elite athletes - has improved our understanding of this injury in several key areas. Now accepted by the medical community as a type of traumatic brain injury, there is an agreed upon definition, albeit determined via consensus. This underscores the significance of injuries that had been frequently trivialized or dismissed simply as ‘dings’ and ‘bell-ringers’ (McCrory et al., 2013). Concussion has been poorly understood in the past because it was not consistently defined and therefore the variables related to injury and
recovery were not consistently identified or collected. In 2012, the Concussion in Sport Group defined concussion as: *a complex pathophysiological process affecting the brain, induced by biomechanical forces that result in the rapid onset of short-lived impairment of neurological function that resolves spontaneously* (McCrory et al., 2013). This broadly accepted definition, determined through international consensus, has improved opportunities to understand concussion by establishing common terminology and data elements for scientific investigation (Aubry et al., 2002; McCrory et al., 2005; 2013; 2009). For example, in the summary and agreement statement of the first International Conference on Concussion in Sport in Vienna (2001), Aubry et al (2002) identified professional and amateur sport databases as *valuable resources* for understanding concussion. While recognizing the challenges of confidentiality, privacy and data ownership, this summary and agreement statement argued that a greater loss to public health would be suffered without access to data for scientific research (Aubry et al., 2002). The impact of concussion on public health has encouraged scientific cooperation to strategically collect data to address research priorities focusing on adolescent students with concussion.

Concussion is characterized by functional disturbance since the level of structural disturbance (occurring at the level of molecules and organelles) is not observable following mechanical injury (Giza & Hovda, 2001). Either through direct or indirect force, head acceleration and deceleration is thought to produce diffuse injury via a ‘neurometabolic cascade’ that results in temporary (and occasionally, long-term) dysfunction (Giza & Hovda, 2001). However, a challenge with management of concussion is that suspected lesions resulting from mechanical injury can not be
diagnosed and therefore neuronal and physiologic impairment are inferred based on a person’s subjective symptoms. While current technology is limited in its utility for detecting potential anatomic lesions associated with concussion, continuing research in this area holds promise for providing evidence of subtle abnormalities and future management strategies (Bazarian, Zhu, Blyth, Borrino, & Zhong, 2012; Comper, Bisschop, Carnide, & Tricco, 2005; Echemendia et al., 2013; Hutchison, Schweizer, Tam, Graham, & Comper, 2014; Toledo et al., 2012).

Concussion is not a uniform disorder, affecting individuals differently and often the same person having two concussions differently as well; and because it can create significant functional issues for the patient (e.g., photophobia, nausea, headache, cognitive confusion) during the acute and sub-acute phases, in the absence of biomarkers or imaging findings, careful clinical evaluation is currently the gold standard for establishing an appropriate differential diagnosis. Concussion signs and symptoms may be different for each person, range in severity and may also have delayed onset (Carroll et al., 2004; McCrea et al., 2013). The Centers for Disease Control and Prevention describes symptom presentation in four general categories; physical, thinking/remembeiing, emotional/mood and sleep disturbance (Centers for Disease Control and Prevention, 2015). More specifically, common symptoms may include headache, nausea, vomiting, balance problems, dizziness, light or noise sensitivity, concentration or memory problems, confusion, fatigue, feeling more emotional, anxious or simply “not right” (Centers for Disease Control and Prevention, 2015).

It has been posited that the vast majority of adults who experience symptoms following concussion spontaneously and fully recover within 7-10 days although more
recent studies have challenged this view of recovery (Guskiewicz, McCrea, & Marshall, 2003; Makdissi et al., 2010; McCrea et al., 2003; McCrory et al., 2013). For those who do not recover as quickly, pre-existing factors are thought to play a role in symptom maintenance and recovery duration (McCauley, Boake, Levin, Contant, & Song, 2001; McCrea et al., 2013; Ponsford et al., 2012; Zemek, Farion, Sampson, & McGahern, 2013). For example, a history of concussion may present risks for re-injury and prolonged recovery; and repetitive head trauma, even at the sub-concussion level, has raised concern and intensified scientific investigation linking these injuries to long-term cognitive impairment, neurodegenerative diseases and a condition referred to as chronic traumatic encephalopathy (CTE) (J. Hart et al., 2013; McKee et al., 2009; 2013). Additional research to better understand the relationship between CTE and concussion is required (Tartaglia et al., 2014). Although there is ongoing discussion about any chronic disease process associated with concussion, the literature does, however, provide evidence that impairment from multiple concussions occurs over time and impacts quality of life (Gioia & Isquith, 2004; Iverson, Echemendia, LaMarre, Brooks, & Gaetz, 2012; Stamm et al., 2015).

Past research has focused on concussion risks, recovery patterns and management with populations of adult and elite athletes and led to improved understanding that athletes who do not identify symptoms or who try to play through symptoms take longer to recover and that cognitive disturbance, headache and dizziness are also associated with longer recovery (Makdissi et al., 2010; Solomon & Haase, 2008). Considering that youth represent the largest group participating in recreational and athletic activities, the focus on adults and elite level sport is narrow and insufficient. Younger athletes are also
students and therefore further study is required to understand patterns of recovery from concussion within the school environment as stressors associated with the cognitive process of learning may introduce unique factors that have not been considered in prior studies of adults. Additionally, the study of adult populations has not considered the physical, cognitive and emotional development processes within youth and how these trajectories may influence recovery. Short-term disability and long-term consequences of repetitive concussion suggest young students face added risks and burden with injury (Allensworth, 2014; J. Hart et al., 2013; Janssen & Leblanc, 2010; Lewis, Huebner, Malone, & Valois, 2011). While there has been increasing research examining the sequelae of concussion, the prevalence, severity and nature of long term impairment following concussion and the relationship with populations based on age requires continued investigation (Chen, Johnston, Petrides, & Ptito, 2008; Eisenberg, Meehan, & Mannix, 2014; J. Hart et al., 2013; Jorge & Robinson, 2002; Kontos, Covassin, Elbin, & Parker, 2012). Studies have examined depression in ageing National Football League athletes exposed to repetitive head trauma over time, in addition to symptoms of depression immediately following injury (J. Hart et al., 2013; Jorge & Robinson, 2002). In addition to concerning long-term consequences, younger athletes face immediate consequences from the sequelae of concussion through interruption to their athletic, social and academic participation in school. Allensworth (2014) points to literature examining the vulnerability of youth who fail to realize their potential in the educational system (Allensworth, 2014). Other studies examining youth and school participation have identified the bidirectional relationship of student cognitive engagement and life satisfaction and evidence supporting the benefits of student athletic and physical
participation has established widespread compulsory school activity guidelines (Janssen & Leblanc, 2010; Lewis et al., 2011). These studies suggest that youth may be especially at risk by the emotional sequelae of concussion because it can interfere with immediate school success in addition to potentially leading to impairment later in life. Younger students experience many benefits from participating in academic and physical school activities but concussion jeopardizes this participation. While studies of concussion in adult populations have been generalized to younger populations, past research examining youth with concussion has been limited by methodological weaknesses, including lack of prospective studies, absence of control groups and homogenous subject populations.

The present thesis examines recovery patterns and risk factors associated with recovery from concussion in male high school students reintegrating to comprehensive school activities (academic, athletic and social). This is accomplished by quantifying days to recovery following concussion and also examining the contribution of pre-existing conditions and student characteristics (such as learning difficulty, history of concussion and high school grade-at-injury) following concussion. A principle aim of this thesis is to add to the empirical knowledge base about concussions in high school students and to provide considerations for concussion management and return to the school environment.
Chapter 2 Literature Review

Within the past two decades our understanding of concussion has improved considerably but has also revealed areas for further investigation. A foremost priority is to address concussion in younger populations in order to understand the interaction of mTBI and developmental stages leading to adulthood. An estimated 30 to 45 million youth participate in non-scholastic sport programs in the United States, but this high level of participation in recreational and athletic activity among youth raises concerns regarding the incidence of concussion in this population (Gioia, Schneider, Vaughan, & Isquith, 2009). The Centers for Disease Control and Prevention estimates that 1.6 to 3.8 million traumatic brain injuries occur annually in the United States but the frequency of concussion in youth and cohorts based on age, sex, sport type and level of competition is insufficiently understood due to the paucity of existing studies (Halstead, Walter, Council on Sports Medicine and Fitness, 2010; Koh, Cassidy, & Watkinson, 2003; Kontos et al., 2013). Identifying rates of injury and risk factors can improve management and prevention of concussion in young, school aged populations and address a significant public health issue.

School participation is compulsory; therefore a thorough understanding of the academic, physical and social activities and demands in this environment must be integrated with our understanding of concussion. School success is defined by performance in many activity domains; achieving high grades, playing sports and by engaging in and developing peer relationships. The cognitive, physical and emotional impairments associated with concussion challenge participation in these school activities. Although recovery from concussion in adult populations has been comprehensively
examined, there is limited evidence to define typical recovery patterns and the contribution of pre-existing conditions in high school students with concussion, despite strong evidence that an interruption in school participation due to illness can have profound consequences (Lewis et al., 2011; Master, Gioia, Leddy, & Grady, 2012; McGrath, 2010). Additionally, the long-term consequences of repetitive concussions suggests that management and injury prevention for young students – including withdrawal from high risk sports as a preventative initiative - is a priority (Gravel et al., 2013).

More recently, schools are providing support for students with concussion. Concussion education and management is being increasingly addressed through standardized protocols, introduction of rules and legislation for safety in sport and school team management of student reintegration (Gibson, Herring, Kutcher, & Broglio, 2015; Gioia, 2012; Lewington, 2014; Ontario Ministry of Education, 2014). In 2009, the state of Washington enacted legislation outlining the medical care for youth with concussion and by January 2014 similar legislation was in place in all states in the U.S. (Gibson et al., 2015). The historical school focus on athlete safety and return to play policy is expanding to include all aspects of the student’s environment. This includes management of return to comprehensive school activities, with prioritization of student challenges in the learning environment, targeted education for diverse school stakeholders and delineated responsibilities for the student support team. Interdisciplinary and interprofessional partnerships are highlighted in these initiatives. This recognizes the practical role of communication between medical and school professionals to support documentation of medical direction and identification of corresponding school
accommodations in physical, cognitive and sensory activity domains. Emerging policies have also promoted knowledge translation strategies to unite schools, clinicians and researchers in the complex task of addressing the currently limited literature and evidence-based practice for adolescent students with concussion.

**Definition of Concussion**

A commonly referenced definition of concussion is that it is ‘*a complex pathophysiological process affecting the brain, induced by biomechanical forces*’ (McCrory et al., 2009). This definition includes the following parameters, namely, that concussion:

1. May be caused either by direct or indirect force that is transmitted to the head,
2. Typically results in the rapid onset of short-lived impairment of neurologic function that resolves spontaneously,
3. May result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury,
4. Results in a range of symptom severity that may or may not involve a loss of consciousness. There is a typical, sequential course of resolution of these symptoms but in a small percentage of cases, post-concussion symptoms may be prolonged,
5. Is not visible using current neuroimaging technology.

As previously indicated, more recent efforts to define concussion and establish a common understanding has created better opportunities for ongoing knowledge by enhancing data collection and access for well designed research (Hicks et al., 2013). Having said that,
ongoing debate and ever increasing evidence continues to challenge consensus and co-
ordination in this rapidly evolving research area.

**Epidemiology**

Within the United States an estimated 300,000 sports-related concussions are
sustained annually in the 15-24 year old age group and concussions caused by sports are
second only to those caused by motor vehicle accidents (Marar, McIlvain, Fields, &
Comstock, 2012). Data accessed from two national injury surveillance systems indicate
concussion represents the greatest proportion of all injuries for high school athletes
(8.9%) compared with their college counterparts (5.8%) although college athletes had
higher concussion rates across all sports (Gessel, Fields, Collins, Dick, & Comstock,
2007). Among U.S. high school athletic participants, a greater number of head impacts
occur in American football compared with other sports in which head impact is common
(Broglio et al., 2011). Additional evidence also points to football as having the highest
concussion rates, followed by boys’ hockey and then lacrosse (Marar et al., 2012). The
rate of concussion has also been examined for practice versus game participation (Gessel
et al., 2007). Studies to date, examining injury and concussion in student populations,
have raised important issues regarding player conditioning, training, equipment quality,
rules and style of play and biomechanical differences based on player sex and age (Echlin
et al., 2010; Gessel et al., 2007; Harmon et al., 2013; Kontos et al., 2013; Maher,
Hutchison, Cusimano, Comper, & Schweizer, 2014). The High School Reporting
Information Database indicates that among high school athletes, football players have the
highest likelihood of sustaining a concussion (0.47 per 1000 athletic exposures) (Gessel
et al., 2007; Kontos et al., 2013). In sports played by both sexes, girls sustained a higher
rate of concussion compared to boys and concussion comprised a greater proportion of total injuries for girls (Gessel et al., 2007). Several studies have indicated that within the adolescent population, many concussions go unreported and despite recent improvements, data has been historically marred by inconsistent data elements and collection techniques (Daneshvar, Nowinski, & McKee, 2011; Hicks et al., 2013). The best use and design of data elements for a large and complex area such as traumatic brain injury requires ongoing modification and collaboration. These efforts to bring standardization are underway and suggest improved opportunities for future research (Hicks et al., 2013). Education about the nature and consequences of concussion has dramatically improved identification, awareness of risk and reporting behaviour in the past ten years and emerging protocols and legislation have also contributed to this trend (Hootman, Dick, & Agel, 2007). Past research has been limited by several factors including recognition of injury, reporting practice and data collection but the public health impact of concussion given the high level of sport participation and frequency of injury in youth populations has challenged these gaps and prioritized research of youth and concussion.

**Mechanism of Injury**

Compared to adults, studies have suggested that younger athletes face additional risk of injury because of physical, cognitive and emotional immaturity. Reduced neck stability, co-ordination and undeveloped executive functioning in younger individuals may increase susceptibility to injury (Barnes et al., 1998; Kirkwood, Yeates, & Wilson, 2006; Mansell et al., 2010). Developmental differences in youth that are thought to
affect risk of injury include; brain water content, cerebral blood flow, level of myelination and skull geometry (Kirkwood et al., 2006; Prins & Hovda, 2003). A young athlete may reach stages of physical, cognitive or emotional development at different times and maturity levels may influence sports participation, playing style and risk for concussion. While age may determine eligibility for team play or individual participation in sports, it may not account for differences in physical development or cognitive or emotional functioning. Younger athletes, may have more difficulty compared to their adult counterparts attributing symptoms to an event that happened hours or days earlier, especially in the absence of a memorable collision or impact (McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004; Register-Mihalik et al., 2013; Romer, 2010). A rise in sensation seeking newly emerges in adolescence thereby placing them further at risk for concussion through aggressive style of play (Romer, 2010). High school athletes participate in many of the same athletic activities as adults and often with the same rules and expectations for competitive style of play. Younger athletes however, may face additional risks related to their physical, cognitive or emotional maturity and further study is required to understand the interaction of developmental trajectories, sports participation and concussion risks.

**Recognition and Reporting**

It can be challenging to recognize that a concussion has occurred because many of its signs and symptoms can be misattributed to other morbidities (Gioia, 2012; McCrea et al., 2003). Adolescents in particular may lack insight or self-awareness to evaluate associated changes and symptoms of concussion. Parents play an important role
supporting children with concussion by monitoring symptoms and physical and cognitive activity (Gioia, 2012). Teachers, coaches and athletic trainers can also play an important role in recognition and reporting (Broglio et al., 2014; Heyer, Weber, Rose, Perkins, & Schmittauer, 2015; Register-Mihalik et al., 2013).

While detecting and reporting injury benefits from a team approach and careful observation for athletes of all ages, self-report by athletes is nevertheless an important contribution. There may be added vulnerability for younger athletes in terms of self-report because they lack maturity to distinguish symptoms of concussion or evaluate the risks of not reporting (McCrea et al., 2009; Register-Mihalik et al., 2013). In terms of reporting, teenagers may be even more disadvantaged by a unique period of development. They no longer have the mitigating scrutiny and support of parents and other adults because they look physically mature but they may still lack maturity to assume full responsibilities and act independently. The paradox of appearing like an adult but not necessarily acting like an adult is underscored on the playing field where adolescents are more likely than younger athletes to seek adult levels of competition and aggression (Karlin, 2011). Within this paradigm adolescents may be physically more susceptible to injury through more aggressive play but behaviorally they may also be more susceptible to under reporting injury because they may lack corresponding maturity to evaluate risk (Kroshus, Baugh, Daneshvar, & Viswanath, 2014; McCrea et al., 2009; Register-Mihalik et al., 2013). One study of 167 high school athletes indicated that of recalled concussions, 40% were not reported. Participants cited reasons for underreporting as they did not want to be removed from play or they did not think that the injury was serious (Register-Mihalik et al., 2013).
There is limited and sometimes contradictory evidence to understand sex differences in symptoms and reporting of symptoms (Agel & Harvey, 2010; Brooks et al., 2014; Frommer et al., 2011). Behaviour patterns for reporting symptoms that have been addressed in the literature, suggest that females report more symptoms than their male counterparts and that females reported more neurobehavioral and somatic symptoms after concussion compared with their male counterparts who reported more cognitive symptoms (Brooks et al., 2014; Frommer et al., 2011). Additional research is required to understand underlying physical and behavioural sex differences in recognition and reporting but studies have been lacking due to the inconsistent availability of data in adolescent populations.

Recognition and reporting of concussion is a fundamental step for acquiring data, advancing research and improving knowledge. In younger populations recognition and reporting is complex due to differences in adult support roles, athlete awareness and developmental maturity. These factors have impaired our ability to study this population but also underscore the importance of doing so.

Concussion Symptoms

Current understanding of the course of symptom recovery has been derived from available data and study of adult athletes (McCrory et al., 2013). Subjective symptoms most frequently reported include headache, dizziness, fatigue, nausea, sleep disturbance and cognitive problems (Eisenberg et al., 2014; Mansell et al., 2010). However, symptoms are unique to each individual and each injury (Aubry et al., 2002). It is has been reported that symptoms typically resolve in 7-10 days for adults (McCrory, Collie,
Anderson, & Davis, 2004). In younger populations, it is assumed that symptoms generally run their course in the same time frame, but data are lacking. Moreover, in a study examining a clinic sample of elementary, middle and high school students (n=216), those returning to the school environment reported new-onset of problems with paying attention (58%), understanding new material (44%), slowed performance completing homework (49%), headaches interfering with learning (66%) and fatigue in class (54%) (Gioia, 2014). These school challenges in core areas measuring academic competency underscore the importance of continued research focusing on student populations. Returning to school introduces stressors that can exacerbate recovery so relying on studies of adults is inadequate considering the unique learning environment influencing recovery in young populations.

In another study, examining 349 students 5 to 18 years of age, actively symptomatic students reported significantly higher levels of concern for the impact of concussion on school performance than did their non-symptomatic peers. Furthermore, this study found that a greater severity of post-concussion symptoms was associated with poorer school performance and that high school students reported more difficulty than their younger counterparts (Ransom, Vaughan, Pratson, Sady, McGill, & Gioia, 2015). Considering that overexertion can exacerbate symptoms and delay recovery, a better understanding of the course of symptoms for students as well as differences within student populations returning to the compulsory school environment is required (Giza & Hovda, 2001).
Current Principles of Concussion Management

Acute management of concussion has historically included two important principles, rest and graduated return to activity. Physical and cognitive rest following concussion is universally recommended although the recommended duration of rest requires an individualized evaluation, which may vary depending on medical practitioner (Alla, Sullivan, McCrory, Schneiders, & Handcock, 2010; Grady, Master, & Gioia, 2012; McLeod & Gioia, 2010). The literature has increasingly challenged the established paradigm of prolonged rest following concussion, recognizing that too much rest or isolation can have negative consequences (Grady et al., 2012; McLeod & Gioia, 2010; Schneider et al., 2013; Thomas, Apps, Hoffmann, McCrea, & Hammeke, 2015).

Additionally, active rehabilitation and medically directed aerobic exercise has shown promise to safely and more rapidly return individuals to full activity (Leddy & Willer, 2013; Leddy, Sandhu, Sodhi, Baker, & Willer, 2012). A graduated reintegration to activity following a sub symptom progression is typically recommended but there is wide variation in the schedule for medical reassessment during recovery, the level of detailed instruction at each stage and strategies for patient education.

The 2012 consensus statement on concussion in sport proposed that a clinical evaluation should encompass:

A. Medical assessment, comprehensive history and neurological evaluation;

B. Determination of clinical status and whether there has been improvement of deterioration since the time of injury;

C. Determination of the need for emergent neuroimaging in order to exclude a more severe brain injury (McCrory et al., 2013).
Management including reassurance, education, reassessment and monitoring are underscored for younger students following a concussion – especially considering the complex reintegration to the school environment. Gaining a comprehensive history may vary depending on whether a young student with suspected concussion reports to a family doctor, sport medicine specialist or emergency department. The emergency department may prioritize the exclusion of more severe brain injury over the less urgent need to address a comprehensive history, concussion education and discussion of a concussion management plan (including school reintegration). Several studies have examined young athletes reporting to emergency departments where education and follow up assessment may not be provided (Bakhos, Lockhart, Myers, & Linakis, 2010; Gilchrist, Thomas, Xu, & McGuire, 2011; Kinnaman, Mannix, Comstock, & Meehan, 2014; Meehan, Taylor, & Proctor, 2011). Therefore, while parents of students may appropriately prioritize an initial emergency department visit, the ongoing management of concussion and follow-up care may be insufficient in terms of follow evaluation (Grubenhoff, Kirkwood, Gao, Deakyne, & Wathen, 2010).

Although universally recommended, there is a lack of follow up care for young students with concussion, with one study reporting that 83% of study participants age 3 to 18 years failed to seek medical follow up after diagnosis (Macpherson, Fridman, Scolnik, Corallo, & Guttmann, 2014). Without follow-up care and medical reassessment to direct activity progression, young students are susceptible to over exertion and prolonged recovery. Medical reassessment provides important education as well as documentation of student recovery and directions for activity progression, which can be shared with a school team (Gioia, 2012; 2014). Medical management of pediatric and adolescent
concussion offers an important intervention for improving outcomes and reducing complications, but ongoing barriers and inconsistency in patient access, education, clinical expertise and school support exist.

**Role of Neuropsychological Testing**

Neuropsychological assessment can be valuable in clinical decision-making following concussion by contributing to a multidimensional perspective of injury. Individual differences with concussion indicate that evaluation of multiple domains should include assessment of symptoms, balance, concussion history, co-morbidities and cognition (Echemendia et al., 2013; 2012). Assessment using symptom scales, balance testing and clinical interview address three of these domains and a neuropsychologist is uniquely qualified to assess and interpret cognitive and psychological factors.

The value of neurocognitive baseline assessment has attracted public, media and scientific attention. The utility of this measure versus the use of well-developed normative data requires further investigation and there is currently insufficient evidence to recommend widespread baseline assessment as an essential component in concussion management strategies (Echemendia et al., 2013). Further study is also required to examine if the use of baseline assessment or normative data is more important or appropriate for individuals with Learning Disabilities (LD) and Attention Deficit Hyperactivity Disorder (ADHD) than for other individuals without these conditions. Neurocognitive assessment of pre-adolescent children is challenged by the limited availability of age appropriate tests and developmental factors that confound interpretation of change in cognitive functioning for younger children (Echemendia et al.,
2013; McCrory et al., 2004). Further study is also required to assess the utility of neurocognitive testing for the management of children with sport related concussion (Echemendia et al., 2013). Traditional, computerized and hybrid models of neuropsychological assessment have been used in professional sport, college, and high school environments however the strength and limitations of each of these models also requires further study (Echemendia et al., 2013).

Traditional tests are time consuming but they allow for individualized or tailored assessment of specific cognitive domains and provide access to large normative databases. Computerized testing models, for example the Automated Neuropsychological Assessment Metric (ANAM) and the Immediate Postconcussion Assessment and Cognitive Testing (ImPACT), are more efficient and portable than traditional NP testing (Echemendia et al., 2013). Studies of computerized NP tests have both affirmed and raised questions about reliability, validity and equivalence of alternative forms of these tests (Broglio, Ferrara, Macciocchi, Baumgartner, & Elliott, 2007; Mayers & Redick, 2012; Resch, Macciocchi, & Ferrara, 2013). Computerized formats are also limited to a sample of cognitive functioning and are typically administered within group versus individual settings. Skilled administration of testing and interpretation of results by a neuropsychologist is recommended however the simplified format can mislead clinicians with less expertise, to overlook underlying complexities. A third model for NP assessment is a hybrid strategy that includes computerized baseline data, followed by a post-concussion assessment combining computerized and traditional testing (Echemendia et al., 2013; Iverson & Schatz, 2015).
The hybrid model seeks the advantages of traditional and computerized models but requires further study to examine its clinical utility.

Neuropsychological testing is an important contribution to a multidimensional assessment of concussion but NP testing is not intended as a stand-alone assessment for concussion management or to determine return to play. NP baseline assessment and the best use of normative data require further study but baseline assessment may have utility for individuals with LD and ADHD (Echemendia, Herring, & Bailes, 2009). Computerized NP tests provide efficient administration but baseline data is complex and best interpreted by a skilled neuropsychologist and considered as a component of a multidimensional assessment approach (Echemendia et al., 2013).

**Concussion in Adolescents**

Concussion in pediatric and adolescent populations has become an area of increasing consideration but because current evidence is focused on concussion in adult populations a lack of understanding of this injury in adolescents persists (Bauer & Fritz, 2004). The maturation process of younger athletes may confound our understanding of concussion in children and adolescents and diagnosis and management requires evaluation through multiple lenses: the developmental trajectory and the natural recovery process and the dynamic evolution of mild traumatic brain injury (McCrory et al., 2009; Purcell, Canadian Paediatric Society, Healthy Active Living and Sports Medicine Committee, 2014; Toledo et al., 2012). Understanding neurocognitive changes following concussion in adults is challenging but becomes more difficult with consideration of the continuing brain development in maturing pediatric and adolescent populations (Giza &
Hovda, 2001; Toledo et al., 2012). Additional research is required to examine concussion and adolescent populations and this research must also consider developmental differences within this group.

**Prolonged Recovery from Concussion**

Prolonged recovery from an injury typically considered as benign and transient raises important questions about proper management and whether certain individuals are pre-disposed for longer than expected return to normal functioning. Additional research is required to understand the contribution of injury related and pre-injury factors and the additional risks for young athletes (Yeates et al., 2009). A sub-symptom threshold progression is typical for reintegration to activity, but rest and isolation for adolescents with concussion must be carefully evaluated against the benefits of modest activity within the school setting (Grady et al., 2012). Sleep disruption, a common symptom following concussion, can become increasingly disordered and prolong recovery (Eisenberg et al., 2014; Mihalik et al., 2013; Schatz, Moser, Covassin, & Karpf, 2011). Sleep management is more challenging with adolescents as ‘normal’ sleep patterns may be difficult to define in younger populations, and some patterns of sleep can interfere with daytime school performance creating attention, cognitive and emotional consequences (O'Brien, 2009). A study examining emotional sequelaes of concussion in undergraduate university student athletes, reported elevated levels of depression, confusion and total mood disturbance for three weeks post injury (Mainwaring et al., 2004). Initial rest, graduated reintegration, sleep hygiene and mood disturbance are important areas for further research in adolescent student populations to improve our understanding of factors that contribute to prolonged recovery.
recoveries, and to identify the most effective strategies for management. Prolonged recovery places an additional burden on school-age children because even short-term disability within the school environment can negatively impact academic achievement and long-term opportunities (Allensworth, 2014; J. Hart et al., 2013).

**Contribution of Pre-existing Conditions**

In adults, it is well recognized that pre-morbid conditions such as depression might be associated with prolonged outcome (McCauley et al., 2001; McCrea, Broshek, & Barth, 2015; Ponsford et al., 2012). Prior studies on children have found that it can be challenging to understand pre-existing conditions since changes in neurocognitive processes that can be affected by concussion, such as speed, memory and verbal fluency, can be difficult to ascertain within the context of developmental growth (Bauer & Fritz, 2004; Gorman, Barnes, Swank, Prasad, & Ewing-Cobbs, 2012). Additionally, pre-morbid conditions such as LD and ADHD also confound the ability to understand impairments as a function of concussion (McCrory et al., 2005; Toledo et al., 2012). Some conditions may only become apparent with additional demands following concussion.

Prolonged patterns of recovery have been identified in young athletes who report delayed onset of symptoms and this raises questions about individual factors that may influence awareness or reporting of concussion symptoms (Morgan et al., 2015). Delayed onset of symptoms, delayed recognition and delayed reporting each merit separate investigation to distinguish underlying factors. Considering the risks of remaining in play and exposure to repeated injury, additional research is required to
better understand behavioural factors and pre-existing conditions that may influence the presentation of signs and symptoms, recognition and reporting in younger student populations.

Studies examining parent child agreement in report of symptoms, suggest that there are differences in the type of symptoms reported by parent and child and that pre-concussion factors (age, learning difficulties, sex) may contribute to patterns of prolonged symptoms (Ayr, Yeates, Taylor, & Browne, 2009; Hajek et al., 2011).

The emotional variability of adolescence and unique characteristics of pre-existing conditions such as anxiety, depression, LD and ADHD are complex considerations for concussion management in younger populations (Giedd & Rapoport, 2010; Gioia, Collins, & Isquith, 2008; Kontos et al., 2012; Ponsford et al., 2012). While there is increasing evidence that pre-existing conditions should be taken into consideration, there is an inconsistent awareness, identification and ability to share information about these pre-existing conditions to design research and improve our knowledge of potential interactions with concussion.

**Return to Play**

Since they are designed for stimulation, school environments can overwhelm and intimidate students returning from concussion (Grady, 2010; Halstead et al., 2010; Master et al., 2012). As in the larger social context, including professional sport, concussions have also been historically dismissed in the school setting (Heyer et al., 2015; Meehan, d'Hemecourt, Collins, & Comstock, 2011; Register-Mihalik et al., 2013; Sady, Vaughan, & Gioia, 2011). Due to high profile examples of catastrophic injuries following concussion, school policies for concussion management have changed for the better

23
(Broglio et al., 2014; Chrisman, Schiff, Chung, Herring, & Rivara, 2014; Dettmer, Ettel, Glang, & McAvoy, 2014; Lewington, 2014). However, it would appear that the focus of concussion management policies remains primarily on returning student athletes to play and addressing the more obvious risks of physical activity. Reducing risk for reintegration to sport has been facilitated by return-to-play guidelines that articulate a step-wise progression for returning to sport and these guidelines have been widely adopted (Guskiewicz & Valovich McLeod, 2011; McCrory et al., 2009; Purcell, 2009).

**Return to Learning**

While the return to play focus addresses concerning risks associated with returning to physical activity, other risks associated with comprehensive school activities have been inadequately considered. Young athletes are primarily students. In addition to returning to play they must also return to the physical, cognitive and social demands within school learning environments. A student recovering from a concussion may experience one or more symptoms that can be made worse with physical stress, as well as cognitive, sensory, and social stressors in the academic classroom. While athletic activity has been a more obvious source of stress following recovery from concussion, there is improving recognition of cognitive, emotional and physical stressors within school academic activity and the need for accommodations. Cognitive, emotional and physical post-concussion effects that impact learning include; attention/concentration, memory consolidation/retrieval, processing speed, cognitive fatigue, anxiety, depression/withdrawal and irritability, headaches, light/noise sensitivity dizziness/balance problems and sleep disturbance (Gioia, 2014). Emerging guidelines to accommodate students returning to these stressors typically identify: reduced, alternative or deferred
assignments, partial school day or class periods, monitoring, rest breaks and team communication.

Principles for returning children and adolescents to learning activities have emerged as an important facet in medical management in recognition of challenges student athletes face in the classroom environment (Master et al., 2012; McAvoy et al., 2013; McGrath, 2010; Sady et al., 2011). Recent recognition has improved school support for students with concussion but management remains inconsistent and additional research and evaluation of management principles is required.

**Comprehensive Team Management**

The challenge for clinicians, parents and school personnel is to appropriately and safely re-integrate students to the school classroom setting and social environment, as well as the playing field, following concussion. Recent legislative efforts in the United States and Canada have challenged school jurisdictions to develop concussion policies with a more comprehensive view of student management (Chrisman et al., 2014; Ontario Ministry of Education, 2014). Team management of comprehensive student activities has also been identified as a research priority (Halstead et al., 2010; Heyer et al., 2015; Master et al., 2012; McGrath, 2010; Sady et al., 2011). Multidisciplinary guidelines with a comprehensive view are emerging. The REAP Concussion Management Program at Rocky Mountain Hospital outlines four general principles for team support of students reintegrating to school following concussion; (R)- remove/reduce physical, cognitive or emotional demands, (E)- educate the support team and student, (A)- accommodate the athlete academically and (P)- pace reintegration (McAvoy & McKercher, 2012). The
Progressive Activities of Controlled Exertion (PACE) model also proposes a practical symptom management approach for the emerging field focusing on young students reintegrating to school activity (Gioia, 2014). The PACE model identifies 10 treatment components based on therapeutic principles in pediatric psychology and other medical disorders and these 10 elements are organized into 4 conceptual stages: (1) setting a positive foundation for recovery, (2) defining the parameters of activity exertion, (3) teaching activity-exertion monitoring skills and (4) reinforcing positive progress (Gioia, 2014).

The literature supports that specific instructions in the form of a prescription for cognitive and physical rest followed by a gradual return-to-learn plan are essential to help student athlete recovery from concussion and make steady progress toward full re-entry into school (return-to-play and other activities) (Master et al., 2012). In the past however, management has been relatively arbitrary and extremely variable, in large part due to limited communication that fails to provide a comprehensive view of the patient and injury.

School teams are increasingly involved in supporting student reintegration following concussion and interprofessional relationships between clinics, schools and researchers have been identified as systemic changes required to improve scientific access for future epidemiological studies in young student populations (Hicks et al., 2013; Provvidenza et al., 2013; Tator, 2012).

A multi state Summit on Childhood Brain Injury in 2011, identified five essential components for supporting students with mTBI: (1) screening, identification and assessment (2) medical to school transition (3) tracking of child’s progress over time, (4)
professional development for school personnel; and (5) data collection (Dettmer et al., 2014). Each of these components requires a comprehensive view of injury and team infrastructure.

Collective, multidisciplinary research initiatives are required to advance the understanding of injury assessment, diagnosis, management and prevention (McCrea et al., 2015). Interdisciplinary coordination has been identified as better than the sum of its parts in regard to rehabilitation and management of individuals with TBI (Seeley, Pickard, Allanson, & Hutchinson, 2014). The public health impact of concussion has led to a social and scientific reconsideration of narrow sport and physical activity based paradigms that have been insufficient. An important shift towards broader and global understanding of concussion factors has led to a prioritization of vulnerable populations. Coordinated interprofessional partnerships can improve concussion management for adolescent students returning to the school environment and this study provides an example how such partnerships can also provide a framework for research. This investigation can contribute to improved management for students returning to school with concussion by describing average days to recovery for a male adolescent cohort, differences in recovery patterns for high school students and adults and the contribution of pre-existing factors such as learning difficulty and history of concussion and school grade at concussion.
Chapter 3 Methods

Objectives

The primary objective of the present study was to describe the recovery pattern for adolescent students following concussion. A secondary objective was to explore pre-existing factors that may contribute to longer recovery times.

Examining the first objective required:

1. Quantification of recovery defined as days to medical clearance following a diagnosed concussion.

The secondary objective explored:

2. Describing the influence of pre-existing conditions on student recovery from concussion, specifically: learning difficulty, history of concussion and school grade of student at time of concussion.

Hypotheses

H1. The average time to recovery (measured in days to medical clearance following date of injury) for the study population of adolescent male students will exceed the typical recovery for adults of 7-10 days that has been reported in the literature (McCrary et al., 2004).

H2a. Students with pre-existing learning difficulty (operationally defined as those having an Individual Education Plan (IEP) for school accommodation and
support) will take longer to recover from concussion than students without pre-existing learning difficulty.

H2b. Students with a history of concussion (documented as number of previous self-reported concussions in clinic medical records) will take longer to recover than students without a history of concussion and that each additional concussion will further prolong recovery.

H2c. The school grade of the student at the time of their concussion will contribute to recovery duration, whereby days to recovery will increase with the school grade of the student.

**Design**

This study used a retrospective and prospective longitudinal cohort design. Retrospective data was available from July 1, 2011 to August 31, 2013 and the prospective data was collected from September 1, 2013 to April 30, 2015. The clinical group of interest was high school students at St. Michael’s College School with concussion. Data were collected by (1) David L MacIntosh Sport Medicine Clinic personnel and (2) St. Michael's College School (SMCS) Learning Enrichment Centre (LEC) personnel.

**Study setting**

A single academic institution, St. Michael's College School (SMCS), that includes all male students from Grades 9 to 12, provided the setting for this research. In
September 2007, St. Michael's College School (SMCS) implemented a formal program to provide school team support for students identified as having learning difficulties. The school established a Learning Enrichment Centre (LEC) that provides a resource environment for students, coordination of school team support and administrative activities including documentation within a student support database. The LEC has responsibility for development of an individual educational plan (IEP) for each student identified with a learning difficulty or need for school support. Learning difficulties include, Learning Disabilities (LD), Attention Deficit Hyperactivity Disorder (ADHD), depression, anxiety, and migraine headaches. An IEP is also developed for students without diagnosis but who benefit from school support and accommodation.

In response to a growing awareness that students who suffer concussions may also present with cognitive impairment (an acquired form of LD) and an understanding of the rigorous academic and athletic demands within the private school setting, St. Michael's College School implemented a formal concussion management strategy in 2011 with oversight by the Learning Enrichment Centre.

The David L. MacIntosh Sport Medicine Clinic (the Clinic) provided the medical management of participants in this study. This medical facility at the University of Toronto is responsible for clinical care and management of university athletes who suffer sports related injuries, including concussion (Comper, Hutchison, Richards, & Mainwaring, 2012). The Clinic introduced return-to-activity (RTA) guidelines in 2011 that include prescriptive clinical information for returning concussed students to activities in four domains of life including sport/physical activity, school, work and social life. These guidelines were developed through clinical expertise, experience, and
research efforts over the past 15 years (Comper et al., 2005; 2012; Hutchison, Comper, Mainwaring, & Richards, 2011; Hutchison, Mainwaring, Comper, Richards, & Bisschop, 2009; Richards, Hutchison, Ekhtiari, & Comper, 2013). The guidelines recognize that within each of the principal domains there exist physical, cognitive, and sensory stressors. For each type of stressor, there is a six-stage progression: from rest to return to premorbid activity. These guidelines have been used to support the university student population and more recently (since 2011) to manage the younger student population at St. Michael's College School. Despite no universally accepted guidelines for students returning to school following concussion, St. Michael's College School adopted the Clinic medical guidelines that are depicted in Appendix 1. Therefore, all students were required to obtain medical clearance from a clinic physician prior to returning to full cognitive and physical activity.

Subjects

Recruitment

Study participants were SMCS students with a medical diagnosis of concussion and having obtained medical clearance between July 1, 2011 to April 30, 2015. Any student who experienced a concussion during the school year was managed through the school’s concussion management program. All students under 16 years of age provided written assent to permit de-identified data from this program to be used for this research. Written consent was also obtained from a parent of students under 16 years of age. Students 16 years of age and older provided written consent for their de-identified data to be used for the present research. All students with concussion were managed through the
SMCS concussion management program but consent/assent for participation in the study was optional for parents and students.

**Inclusion criteria**

Study participants included all students who were enrolled in the high school grades of SMCS during the time of their concussion. Participants were admitted to the school concussion management program after the time of their concussion. Sport or physical activity related concussions occurred either at the school or in the community. A medical doctor at the Clinic established the diagnosis of concussion and determined clearance to return to full activity. Diagnosis of concussion at the clinic required 1) identification of a mechanism of injury and 2) a minimum of one symptom score greater than zero. Participants were male students between the ages of 13 years to 18 years and all participants were English speaking.

**Exclusion Criteria**

Examining total records (n=208), students who declined consent (n=6) or who could not be contacted for consent (n=46) were excluded. Records of twenty students with more than one concussion sustained within this longitudinal study were also excluded. These participants were excluded, as including two concussion records from the same participant would have violated the independence of points for the analysis. Separate linear mixed model analyses which included these 20 participants indicated a change in inference of results and thus 40 records were removed from the analyses in this study. The observation that 20 participants sustained more than 1 concussion is outside
the current scope of this study as findings from previous studies suggests that repeat injuries sustained within shorter periods of time may lead to protracted recovery (Eisenberg, Andrea, Meehan, & Mannix, 2013; Giza, 2001). Further, these students may have had a unique profile, which increased their vulnerability to repeat injury (Eisenberg, Andrea, Meehan, & Mannix, 2013; McCrea et al., 2003; Prins, Alexander, Giza, & Hovda, 2013; E. B. Wasserman, Abar, Shah, Wasserman, & Bazarian, 2015). As depicted in Figure 1, a sample of 116 students with 1 concussion sustained during the study dates July 1, 2011 to April 30, 2015 and complete concussion records for the period July 1, 2011 to April 30, 2015 were examined.

Figure 1. Exclusions
Procedures

Ethics Approval from the University of Toronto Office for Research Ethics Review Board PROTOCOL REFERENCE # 30640 was obtained October 17, 2014.

Clinic physicians provided clinical management and prescriptive advice for all students with concussion from St. Michael’s College School. If a SMCS student was suspected to have sustained a concussion, they were referred by the Learning Enrichment Centre personnel to the Clinic for evaluation by one of the sport medicine physicians. Once the diagnosis of concussion was confirmed, the physician provided the patient and parent with a medical note that documented the initial management and follow-up process according to stages and domains of activity that are illustrated in Appendix 1. Since recovery from concussion duration can be highly variable in any population, regular weekly evaluation appointments with a physician were scheduled until the patient was medically cleared to resume full school participation in academic and physical activity. Follow-up physician evaluations were determined in six stages of recovery in physical, sensory and cognitive categories of stressor. Existing return to play protocols have articulated six stages for physical recovery and the clinic expanded these six stages to include six stages for cognitive and sensory recovery as well. Depending on the severity/complexity of concussion and corresponding recovery, patients may have been referred to the Clinic’s neuropsychologist for consultation. Please refer to the Procedural Flowchart in Figure 2.
Data Collection and Data Entry

As part of the concussion management protocol between the Clinic and SMCS, the medical note provided to patient and/or parent/guardian, was also provided to the Learning Enrichment Centre personnel at SMCS. All information was captured electronically and resided in an LEC database, which was used and updated by LEC personnel. Please see Appendix 2 for a sample student record. Based on the medical direction by the physician at the Clinic LEC teachers created an Individualized Reintegration Plan (IRP) that is illustrated in Appendix 3. The IRP documented medical direction and corresponding school accommodations throughout each stage of the recovery process. Since January 1, 2012 student recovery was separately documented in
three domains: Physical, Cognitive and Sensory. Recovery in the Physical domain (stage 6 with no activity restrictions) was used as the outcome for medical days to clearance in this analysis. The LEC teachers coordinated the student support team with ongoing communication with parents, students and teaching faculty and updated the Individual Reintegration Plan with new medical direction and school based accommodations to reflect the student’s activity progression and current status.

**Participant Characteristics**

As Figure 1 indicates, 116 records were included in the analysis. The average age of high school students in the sample was 15.13 years of age (SD = 1.19, range =13-18 years of age). Of these participants, the high school grade of student at the time of their concussion was as follows: Grade 9, 40.5% (n=47), Grade 10, 26.7% (n= 31), Grade 11, 18.1% (n= 21) and Grade 12, 14.7% (n=17). Within this sample (n=116), 44 students (37.9%) had pre-existing learning difficulties (defined as the presence of IEP). Of these, 6.8 % (n=17) were grade 9 records, 7.7% (n=15) were grade 10 records, 12.9% (n=9) were grade 11 records and 3% (n=3) were records of students in grade 12. IEP records were evaluated as a dichotomous variable but the following medical and/or psychological diagnosis was also documented; Attention Deficit Hyperactivity Disorder; 9.5% (n=11), Learning Disability 9.5% (n=11), 8.6 % anxiety (n=10), depression 2.7% (n=3), migraine headache 4.3% (n=5); and 10.3% (n=12) of students had no diagnosis but were undergoing assessment and receiving school accommodations and support. IEPs documenting co-morbid diagnosis accounted for 6.9% (n=8) records. Within the total sample of 116 participants, 46.6 % (n=54) participants had a history of concussion.
Based on medical record, participants with a history of 1 concussion was 33.6% (n=39), participants with a history of 2 concussions 9.7% (n=12) and 2.6% (n=3) of participants had a history of 3 concussions. Origin of injury for over 50% of participants was from hockey, football and rugby. Specifically hockey accounted for 41.4% (n=48) of injuries, football 12.1% (n=14), and rugby 6% (n=7). Concussion reported from in school athletic activity accounted for 46.6% (n=54) of injuries and concussion in community sports activity accounted for 49.1% (n=57) of injuries. Place of injury data was not available for 4.3% (n=5) of participants. Participant demographics are provided in Table 1.
Table 1. Participant Demographics (n=116)

<table>
<thead>
<tr>
<th>Participant Demographics and Characteristics (n=116)</th>
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<tbody>
<tr>
<td>Pre existing condition: School grade</td>
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<tr>
<td>Grade 9 40.5% (n=47)</td>
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<td>Grade 10 26.7% (n=31)</td>
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<td>Grade 11 18.1% (n=21)</td>
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<td>Grade 12 14.7% (n=17)</td>
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<tr>
<td>Pre existing condition: IEP for learning difficulty</td>
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<tr>
<td>IEP (yes) 37.9% (n=44)</td>
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<td>IEP (no) 62.1% (n=72)</td>
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<td>IEP ADHD 9.5% (n=11)</td>
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<td>IEP LD 9.5% (n=11)</td>
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<td>IEP Anxiety 8.6% (n=10)</td>
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<td>IEP Depression 2.7% (n=3)</td>
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<td>IEP Migraine Headache 4.3% (n=5)</td>
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<tr>
<td>IEP Not specified (Undergoing assessment) 10.3% (n=12)</td>
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<tr>
<td>IEP (comorbidities) 6.9% (n=8)</td>
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<tr>
<td>Pre existing condition: History of concussion</td>
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<tr>
<td>History of concussion (no) 53.4% (n=62)</td>
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<tr>
<td>History of concussion (yes) 46.6% (n=54)</td>
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<td>History of concussion (1) 33.6% (n=39)</td>
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<td>History of concussion (2) 10.3% (n=12)</td>
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<td>History of concussion (3) 2.7% (n=3)</td>
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<tr>
<td>Place of injury</td>
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<tr>
<td>School (yes) 46.6% (n=54)</td>
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<tr>
<td>Community and reported to school (yes) 49.1% (n=57)</td>
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<tr>
<td>Origin of Injury</td>
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<tr>
<td>Football 12.1% (n=14)</td>
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<tr>
<td>Hockey 41.4% (n=48)</td>
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<tr>
<td>Rugby 6% (n=7)</td>
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<tr>
<td>Other 40.5% (n=47)</td>
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</table>

Statistical Analysis

Data analysis included the calculation of descriptive and inferential statistics. Descriptive analysis was performed to describe central tendency (mean, median and mode), dispersion, skewness and kurtosis for recovery measured in days to clearance. Frequencies were generated for participant demographics as illustrated in Table 1.
A one-sample Kolmogorov-Smirnov test was conducted to examine the difference in recovery time between youth in this sample and recovery for adults reported in the literature. Values of comparison were taken by consensus literature (McCrory et al., 2005) in adults indicating that typical recovery time is between 7-10 days following concussion. The value of 10 days was used as a comparison mean, with a standard deviation of 3 days.

Preliminary non-parametric statistics were generated to explore the individual influence of presence of IEP, grade at concussion and previous number of concussions on days to medical clearance. Based on the non-normal distribution of days to clearance (i.e. positively skewed), a Mann Whitney U-test was suitable to investigate if differences existed between the groups who did and did not have an IEP on days to medical clearance. Spearman’s rho correlation examined the association between grade at concussion and previous number of concussions on medical days to clearance.

Considering the non-normal distribution (positively skewed data), a log of days to clearance was computed and assumptions of linear regression (i.e. normal distribution, homoscedasticity, independence of points) were assessed and met. Please refer to Appendix 4. A linear regression analysis examined the dependent variable of log of days to clearance and the contribution of each of the following independent variables: pre-existing conditions (history of learning difficulty (dichotomous), history of concussion (continuous) and grade of student (continuous).

To quantify recovery time points and to explore the individual influence of IEP, school grade and previous number of concussions on days to medical clearance before
and after 4, 6 and 8-week cut-off points in recovery patterns, preliminary statistics were generated.

A Chi-square analysis examined if group differences existed in the number of individuals who cleared before and after 4, 6 and 8-week cut-offs, based on the presence of an IEP. Spearman rho correlations examined both grade at concussion and concussion history in their association with the number of individuals who cleared before and after the binary 4, 6 and 8-week cut-offs.

To further examine the contributions of pre-existing conditions and student characteristics (history of learning difficulties, history of concussion and grade of student), a logistic regression analysis was used. The logistic regression examined the three binary recovery periods (cut points at 4 weeks, 6 weeks and 8 weeks) as dependent variables and the contribution of pre-existing conditions history of learning difficulty, history of concussion and grade of student as independent variables. The binary recovery periods were chosen to expand on whether the variables of interest had differential contributions along different points in the recovery trajectory. The binary recovery period cut points were determined based on the literature that has examined prolonged recovery or post concussive syndrome at 4 weeks, 8 weeks and beyond; however prior studies also discuss the limited available evidence to conceptualize ‘normal’ or prolonged recovery periods for pediatric and adolescent populations (Barlow et al., 2010; Cantu, Guskiewicz, & Register-Mihalik, 2010; McCrea et al., 2013; Zemek et al., 2013). This study’s primary hypothesis was that younger populations would have longer recovery than the typical recovery of 7-10 days that has been identified in adult populations. However, since the literature examining recovery patterns in adolescent populations is limited, this
study’s cut periods were used to further describe recovery patterns in this unique population.

The regression models provided an explanatory model to examine the unique inferences of the variables of interest. A linear regression enabled the exploration of continuous data, which enhances the sensitivity of the analysis to predict the influence of independent variables. Logistic regressions were additionally conducted to further describe patterns that may exist along the recovery trajectory. IMB SPSS Version 23 was used to conduct all statistical analyses with the threshold for statistical significance set to $p \leq 0.05$.

**Variables Collected**

Individualized learning needs and accommodations for students with pre-existing learning difficulties were documented in an Individual Education Plan (IEP) and if a student sustained an injury, concussion management and accommodations were documented in an Individual Reintegration Plan, (IRP). Individualized Education Plans had been developed for educational programming for students with a medical or psychological diagnosis for learning disabilities (LD), attention deficit hyperactivity disorder (ADHD), anxiety, depression and migraine headaches as well as for students who were receiving educational program support for learning difficulties and undergoing a medical or psychological assessment. A student support database was developed to store comprehensive student information for school team communication, support and research. A record of each concussion and concussion history was also stored within the database and an Individual Reintegration Plan was developed for educational program
support once a student was medically diagnosed with a concussion and until medical clearance and return to full school activity without accommodations or support. Once a student had been medically cleared, the IRP was no longer active but the record was retained.

In summary, the school database provided a comprehensive view of the student population through the documentation of typical demographic variables for all students in the school (age, grade, teachers, courses) and chronic and acute learning support accommodations for students with learning difficulty and concussion through the IEP and IRP.

**Independent Variables**

**Pre-existing Conditions and Student Characteristics**

Students with a history of learning difficulty (IEP), history of concussion and high school grade of student at time of concussion were evaluated for their contribution to recovery patterns.

**History of Learning Difficulties**

Records were assigned to morbidity or a no-morbidity group based on whether a student had an IEP for learning support. IEP development was based on medical or psychological report with a diagnosis of ADHD, LD, depression, anxiety, and migraine headache and also for students with a history of learning difficulty in school, receiving school accommodations and no diagnosis but who were undergoing medical or psychological assessment for learning difficulty. This strategy of documenting support
for learning accommodations complied with the Ontario Ministry of Education policy (Education, 2013). Students with an IEP were considered as a dichotomous variable because the presence of an IEP in a school setting reflected the impact of learning difficulty in the school environment. The Ministry of Education in Ontario advises that the determining factor for the development of an Individual Education Plan for school support should be the demonstrated learning difficulty and likelihood of the student to benefit from support rather than any specific medically diagnosed or undiagnosed condition. For this reason participants with any comorbid diagnosis were not factored as a continuous variable because the salient issue in the ecological school environment is the need for and benefit from school support as defined by an IEP. A further rationale for the IEP as a dichotomous variable is that students, families and schools may have relied upon an initial or primary diagnosis for designing school support and the development of an IEP. Investigation of comorbidities was inconsistent and associated stigmas with some conditions may have been a disincentive for additional diagnosis when individualized support was already in place. Students with an IEP but without a formal medical or psychological assessment or diagnosis were included in the analysis because their experience with learning difficulty and support is more consistent with students who have a diagnosis and IEP.

**History of Concussion**

A continuous variable for number of concussions was based on the student’s medical record (patient self report during clinical assessment).
Grade of Student

A continuous variable for school grade (9-12) of each student at time of concussion injury was based on the student’s school record.

Dependent Variables

Days to Recovery

A logarithm of days to recovery was calculated to transform the non-normal distribution in raw data reported as medical days to clearance. This transformation enabled the use of parametric regression models to address this study’s objectives.

Binary Recovery Periods

The recovery timelines of participants (reported in days) was dichotomized at 4 weeks, 6 weeks and 8 weeks, to evaluate patterns and the contribution of independent variables. A regression analysis was used to determine the unique contribution of pre-existing conditions and student characteristics, school support for learning difficulty (IEP), history of concussion and school grade of student at the point of concussion and the influence of these independent variables at various points in the recovery trajectory.
Chapter 4 Results

Recovery Time (Hypothesis 1)

Measures of central tendency were calculated for days to medical clearance. The mean number of days to medical recovery was 43.17, SD 36.70; the mode was 29 days and the median number of days to recovery for the full sample (n=116) was 31.5 (range=5 - 271). The value of skewness was 2.88 indicating that the data for clearance was positively skewed. The kurtosis value was 12.72, indicating a sharp/leptokurtic distribution. Please refer to Figure 3 Distribution Graph of Days to Clearance.

Figure 3. Distribution of Days to Clearance

Measurement using the median value of days to recovery provides an understanding of the skewed distribution of days to recovery. The median days to medical clearance for students with no history of concussion was 31 days (range= 5 - 271): Students with a history of 1 concussion, 31 days (range= 9 -136), students with a history of 2 concussions, 47.5 days (range= 8 - 142) and students with a history of 3 concussions, 72 days (range= 25 - 89). The median days to recovery for students with a
history of learning difficulty (defined by having an IEP) were 41.5 (range= 8 - 271).

Examining the median days to medical clearance by students’ school grade yielded the following: Students in Grade 9 were cleared in 30.0 (range= 8 - 136), Grade 10, 30.0 (range= 5 - 142), Grade 11, 31 (range= 18 - 271) and Grade 12, 38 (range= 6 - 118).

Measurements of Mean Days to Medical Clearance are provided in Table 2 and graphs of Median days to Medical Clearance are provided in Figure 4.

**Table 2. Mean Days to Clearance**

<table>
<thead>
<tr>
<th>Days to Medical Clearance</th>
<th>Participants</th>
<th>Overall Mean</th>
<th>Grade 9 N=47</th>
<th>Grade 10 N=31</th>
<th>Grade 11 N=21</th>
<th>Grade 12 N=17</th>
</tr>
</thead>
<tbody>
<tr>
<td>(N=116)</td>
<td>43.17 (36.70)</td>
<td>39.43 (29.75)</td>
<td>38.39 (27.49)</td>
<td>50.29 (56.19)</td>
<td>53.47 (38.82)</td>
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</tr>
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</table>

**History of Learning Difficulty**

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=44</td>
<td>N=72</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>53.89 (46.77)</td>
<td>36.63 (27.24)</td>
</tr>
<tr>
<td></td>
<td>N=17</td>
<td>N=30</td>
</tr>
<tr>
<td></td>
<td>41.53 (30.21)</td>
<td>38.23 (29.94)</td>
</tr>
<tr>
<td></td>
<td>N=15</td>
<td>N=16</td>
</tr>
<tr>
<td></td>
<td>44.53 (32.29)</td>
<td>32.63 (21.57)</td>
</tr>
<tr>
<td></td>
<td>N=9</td>
<td>N=12</td>
</tr>
<tr>
<td></td>
<td>79.33 (78.57)</td>
<td>28.50 (6.53)</td>
</tr>
<tr>
<td></td>
<td>N=3</td>
<td>N=14</td>
</tr>
<tr>
<td></td>
<td>94.33 (20.50)</td>
<td>44.71 (36.63)</td>
</tr>
</tbody>
</table>

**History of Concussion**

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=62</td>
<td>N=54</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>39.05 (38.75)</td>
<td>47.91 (37.93)</td>
</tr>
<tr>
<td></td>
<td>N=25</td>
<td>N=22</td>
</tr>
<tr>
<td></td>
<td>33.60 (19.79)</td>
<td>46.05 (37.48)</td>
</tr>
<tr>
<td></td>
<td>N=20</td>
<td>N=11</td>
</tr>
<tr>
<td></td>
<td>31.90 (15.55)</td>
<td>50.18 (39.63)</td>
</tr>
<tr>
<td></td>
<td>N=8</td>
<td>N=13</td>
</tr>
<tr>
<td></td>
<td>42.46 (28.83)</td>
<td>63.00 (85.42)</td>
</tr>
<tr>
<td></td>
<td>N=9</td>
<td>N=8</td>
</tr>
<tr>
<td></td>
<td>48.78 (49.11)</td>
<td>58.75 (25.04)</td>
</tr>
</tbody>
</table>

**History of Concussion (Hx C) and History of Learning Difficulty (Hx LD)**

<table>
<thead>
<tr>
<th></th>
<th>Hx C (No) and Hx LD (No)</th>
<th>Hx C (Yes) and Hx LD (Yes)</th>
<th>Hx C (Yes) and Hx LD (No)</th>
<th>Hx C (No) and Hx LD (Yes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=40</td>
<td>N=22</td>
<td>N=32</td>
<td>N=22</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>30.55 (22.93)</td>
<td>53.27 (38.49)</td>
<td>44.23 (30.50)</td>
<td>54.5 (54.74)</td>
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<td></td>
<td>N=16</td>
<td>N=8</td>
<td>N=14</td>
<td>N=9</td>
</tr>
<tr>
<td></td>
<td>28.38 (13.13)</td>
<td>40.00 (35.78)</td>
<td>49.50 (39.30)</td>
<td>42.89 (26.46)</td>
</tr>
<tr>
<td></td>
<td>N=11</td>
<td>N=6</td>
<td>N=5</td>
<td>N=9</td>
</tr>
<tr>
<td></td>
<td>27.09 (15.50)</td>
<td>54.67 (48.87)</td>
<td>44.8 (29.55)</td>
<td>37.78 (14.25)</td>
</tr>
<tr>
<td></td>
<td>N=5</td>
<td>N=6</td>
<td>N=7</td>
<td>N=3</td>
</tr>
<tr>
<td></td>
<td>29.20 (5.93)</td>
<td>59.33 (35.99)</td>
<td>28.00 (7.35)</td>
<td>119.33(133.61)</td>
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<td></td>
<td>N=8</td>
<td>N=2</td>
<td>N=6</td>
<td>N=1</td>
</tr>
<tr>
<td></td>
<td>40.50 (45.30)</td>
<td>84.00 (13.14)</td>
<td>50.33 (22.31)</td>
<td>115.00 (NA)</td>
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</table>
Figure 4.a  Median days to medical clearance stratified by school grade of student at concussion (n=116)

Figure 4.b  Median days to medical clearance for participants with a history of concussion and stratified by school grade at concussion (n=54)
Figure 4.c  Median days to medical clearance for participants with a history of concussion (Yes/No)

Figure 4.d  Median days to medical clearance for participants with history of concussion (number of previous concussions) (n=54)
Figure 4.e  Median days to medical clearance for participants with a history of Learning Difficulty (IEP) stratified by school grade (n=44)

Figure 4.f  Median days to medical clearance for participants with no history of Concussion and no history of Learning Difficulty stratified by school grade (n=40)
Figure 4.g  Median days to medical clearance for participants with a history of Concussion and history of Learning Difficulty and stratified by school grade (n=22)

Figure 4.h  Median days to medical clearance for participants by place of injury (n=116)
Differences in recovery patterns for adults and youth

The average time to recovery (measured in median days to medical clearance following diagnosis of concussion) was 31.5, (range= 5-271) for the study population of male high school students. A one-sample Kolmogorov-Smirnov nonparametric test was conducted to examine the difference in recovery patterns between adults and youth in this sample. Values of comparison were taken by consensus literature indicating that typical recovery time for adults is between 7-10 days following concussion (McCrory et al., 2005). The value of 10 days was used as a comparison mean, with a standard deviation of 3 days. As illustrated in Table 3 below, results indicated a significant difference in recovery patterns for youth in this sample compared to the normally distributed recovery pattern in adults ($D= 9.923, p= .0001$). These differences were significant in
comparisons of the recovery for youth in this sample at each high school grade level and the recovery that has been reported for adults; 9 ($D=5.507, p<0.0001, M=39.423, SD=29.752$), 10 ($D=5.021, p<0.0001, M=38.387, SD=27.487$), 11 ($D=4.656, p<0.0001, M=50.286, SD=56.197$) and 12 ($D=3.544, p<0.0001, M=53.471$). 38.820).

<table>
<thead>
<tr>
<th>Grade</th>
<th>One-sample Kolmogorov-Smirnov test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>5.507</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>10</td>
<td>5.021</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>11</td>
<td>4.565</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>12</td>
<td>3.544</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Overall sample</td>
<td>9.225</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

Influence of Pre-existing Conditions (Hypothesis 2)

A linear regression analysis explored the unique influence of history of learning difficulties, history of concussion and school grade at concussion on a logarithm of days to medical clearance. This model had significant findings overall, $F(112,3)=4.658, p=.004$, accounting for 8.7% of variability in the population ($R^2_{adj}=0.087$). A main effect of presence of IEP was found ($B=0.321, p=.018, CI[0.056, 0.587]$), whereby those who did have an IEP were associated with a longer number of days to clearance when compared to those who did not have an IEP. This finding had a small effect size, $r=.183$. History of concussion also had a main effect on the log of days to clearance ($B=
0.191, \( p = .025 \), CI[0.024, 0.357]), whereby increasing number of previous concussions was associated with an increased length in days to clearance. That is, participants who reported a higher number of previous concussions took longer to recover/achieve medical clearance than those who reported fewer concussions. This finding had a small effect size, \( r = .151 \). Please refer to Table 5.

Preliminary non-parametric statistics were generated to explore the individual influence of presence of IEP, grade at concussion and previous number of concussions on days to medical clearance. Based on the non-normal distribution of days to clearance (i.e. positively skewed), a Mann Whitney U-test was suitable to investigate if differences existed between the groups who did and did not have an IEP on days to medical clearance. There was a statistically significant difference between IEP groups (\( U = 2001, p = .018 \)), whereby those with an IEP (\( Mdn=41.5 \) days) took longer to achieve medical clearance than those without an IEP (\( Mdn=29.0 \) days). Spearman’s rho correlation examined the association between grade at concussion (\( r_s = .106, p = .256 \)) and previous number of concussions (\( r_s = .204, p = .028 \)) on medical days to clearance. While high school grade of student at concussion was not statistically significant, high school grade continued to be used in the regression models as removing this variable might confound an understanding of the contribution of history of learning difficulty and history of concussion.

Preliminary statistics were generated to explore the individual influence of IEP, grade and previous number of concussions on days to medical clearance before and after the 4-week cut-off. A Chi-square analysis examined if group differences existed in the number of individuals who were medically cleared before and after the 4-week cut-off,
based on the presence of an IEP. IEP was found to be significant on predicting individuals who were medically cleared before and after the 4-week cut-off ($\chi^2 (1) = 4.424, p = 0.035$). Those who did not have an IEP were more likely to receive medical clearance beyond the 4-week mark. Of those participants without an IEP, 54.2% were medically cleared before 4 weeks and 45.8% cleared after 4 weeks. This distribution changes in the group with an IEP in that only 34.1% were medically cleared before 4 weeks, compared to 65.9% who were medically cleared beyond the 4-week cut off. Spearman rho correlations revealed that both grade at concussion ($r_s = .127, p = .175$) and previous number of concussions ($r_s = .064, p = .197$) were not significantly associated with the binary 4-week cut-off.

To explore the individual influence of IEP, grade and previous number of concussions on days to medical clearance before and after the 6-week cut-off, preliminary statistics were generated. A Chi-square analysis examined if group differences existed in the number of individuals who were medically cleared before and after the 6-week cut-off, based on the presence of an IEP. IEP was found to be significant on predicting individuals who were medically cleared before and after the 6-week cut-off ($\chi^2 (1) = 6.662, p = 0.010$). Those who had an IEP were more likely to receive medical clearance beyond the 6-week mark. For participants who did not have an IEP, 73.6% received medical clearance before 6 weeks, compared to a 26.4% minority that received medical clearance after 6 weeks. For participants with an IEP, 50% received medical clearance before 6 weeks and 50% received medical clearance after. These descriptive findings indicate a slower trend in achieving medical clearance for those with an IEP. Spearman rho correlations revealed that grade at concussion ($r_s = -.016, p = .868$) and
previous number of concussions ($r_s = .134, p = .153$) was not significantly associated with the binary 6-week cut-off.

To explore the individual influence of IEP, grade and previous number of concussions on days to medical clearance before and after the 8-week cut-off, preliminary non-parametric statistics were generated. A Chi-square analysis examined if group differences existed in the number of individuals who cleared before and after the 8-week cut-off, based on the presence of an IEP. IEP was found to be significantly predictive of those individuals who cleared before and after the 8-week cut-off ($\chi^2 (1) = 6.412, p = 0.011$). Those who had an IEP were more likely to be medically cleared beyond the 8-week mark. A strong majority of participants (87.5%) without an IEP were medically cleared before 8 weeks, compared to 12.5% who were medically cleared beyond 8 weeks. Conversely, 31.8% of those with an IEP took longer than 8 weeks to achieve medical clearance, compared to 68.2% who achieved medical clearance before 8 weeks. Spearman rho correlations revealed that grade at concussion ($r_s = .143, p = .126$) was not significantly associated with the binary 8-week cut-off of days to clearance. However, number of previous concussions was significant in its association with the 8-week binary cut-off point ($r_s = .255, p = .006$), whereby those who reported more previous concussions were more likely to receive medical clearance after the 8 weeks compared to those who reported fewer concussions.

Taken together, these preliminary findings suggest that presence of an IEP plays a role in conceptualizing recovery patterns following concussion with presence of an IEP playing a larger role as time since concussion increases. These results are presented in Table 4. Even though both grade at concussion and previous number of concussions
were largely not significant in these analyses, they continued to be included in statistical models as these factors may confound the IEP finding in a regression model.

**Table 4. Recovery Patterns for Participants with History of Learning Difficulty (across binary recovery points)**

<table>
<thead>
<tr>
<th></th>
<th>4 weeks</th>
<th>6 weeks</th>
<th>8 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
</tr>
<tr>
<td>Present (IEP)</td>
<td>34.1%</td>
<td>65.9%</td>
<td>50%</td>
</tr>
<tr>
<td>No IEP</td>
<td>54.2%</td>
<td>45.8%</td>
<td>73.6%</td>
</tr>
</tbody>
</table>

**Binary Recovery Periods**

**Binary Recovery – 4-week cut-off**

A binary logistic regression analysis was utilized to predict 4-week clearance outcomes for those with an IEP, while again, accounting for grade at concussion and previous concussion count history. The outcome variable, 4-week clearance was coded as 0= participant cleared before 4-week period and 1= participant cleared beyond the 4-week period. A test of the full model with predictors compared to the null model (no predictors) was not statistically significant, $\chi^2(3)= 7.694, p= .053$. The strength of the association between the aforementioned predictors and the 4-week clearance cut-off was weak, with Cox and Snell’s $R^2= 0.064$ and Nagelkerke’s $R^2= 0.086$. However, there was a significant main effect of IEP, where those who did have an IEP were 2.4 times more likely to achieve clearance beyond the 4-week period ($OR= 2.409, p= .030$, CI[1.086,5.341]). Please refer to Table 5. This finding had a moderate effect size, $d=$
Based on the entire sample (N=116), 53% (N=62) of the participants cleared after 4 weeks. Of those 62 participants who took longer than 4 weeks to achieve clearance, 47% (N=29) had an IEP, compared to 28% (N=15) who had an IEP and achieved clearance before 4 weeks. Please refer to appendix 5. School grade at concussion as well as history of concussion did not have predictive significance in this model.

**Binary Recovery – 6-week cut-off**

A binary logistic regression analysis was performed to predict 6-week clearance outcomes for those with an IEP, accounting for grade at concussion and previous concussion count history. The outcome variable, 6-week clearance was coded as 0= participant cleared before 6-week period and 1= participant cleared beyond the 6-week period. A test of the full model with predictors compared to the null model (no predictors) was statistically significant, $\chi^2(3)= 8.556$, $p = .036$. The strength of the association between the aforementioned predictors and the 6-week clearance cut-off was weak, with Cox and Snell’s $R^2= 0.071$ and Nagelkerke’s $R^2= 0.098$. However, there was a significant main effect of IEP, where those who did have an IEP were 2.68 times more likely to achieve clearance beyond the 6-week period ($OR = 2.68$, $p = .016$, CI[1.202,5.980]). Please refer to table 5. This finding had a moderate effect size, $d = 0.58$. Descriptively, 35% (N=41) of the participants cleared after 6 weeks. Of those 41 participants who took longer than 6 weeks to achieve clearance, 54% (N=22) had an IEP, compared to 29% (N=22) who had an IEP and achieved clearance before 6 weeks. Please refer to appendix 5. Grade at concussion as well as history of concussion were not significant in predicting likelihood of achieving medical clearance beyond 6 weeks.
**Binary Recovery – 8-week cut-off**

A binary logistic regression analysis was utilized to predict 8-week clearance outcomes for those with an IEP, and taking into account grade at concussion and previous concussion count history. The outcome variable, 8-week clearance was coded as 0= participant cleared before 8-week period and 1= participant cleared beyond the 8-week period. A test of the full model with predictors compared to the null model (no predictors) was statistically significant, $x^2(3)=17.979$, $p=.000$. Compared to the above binary models, the strength of the association between the aforementioned predictors and the 8-week clearance cut-off was moderately strong, with Cox and Snell’s $R^2=0.144$ and Nagelkerke’s $R^2=0.228$, thus accounting for a maximum of 23% of the variation in the sample of male youth. Further, there was a significant main effect of IEP, where those who did have an IEP were 3.47 times more likely to achieve clearance beyond the 8-week period ($OR=3.47$, $p=.018$, CI[1.241, 9.711]). Please refer to Table 5. This finding had a strong effect size, $d=0.69$. Descriptively, 20% (N=23) of the participants took longer than 8 weeks to achieve medical clearance. Of those 23 participants who took longer than 8 weeks to achieve clearance, 68% (N=14) had an IEP, compared to 32% (N=30) who had an IEP and achieved clearance before 8 weeks. Please refer to appendix 5. History of concussion was also significant in this model ($OR=2.23$, $p=.010$, CI[1.216, 4.100]), whereby those with a higher previous concussion count were 2.23 times more likely to be cleared beyond the 8-week cut off compared to those who had fewer previous concussions. This finding had a moderate effect size, $d=0.44$. Grade at concussion did not have predictive significance in this model.
Table 5. Linear and Logistic Regression Results (n=116)

<table>
<thead>
<tr>
<th>Predictor</th>
<th>B</th>
<th>S.E.</th>
<th>t</th>
<th>p-value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade at Concussion</td>
<td>0.079</td>
<td>0.060</td>
<td>1.320</td>
<td>0.190</td>
<td>1.252, 3.677</td>
</tr>
<tr>
<td>Presence of IEP*</td>
<td>0.321</td>
<td>0.134</td>
<td>2.396</td>
<td>0.018*</td>
<td>0.056, 0.587</td>
</tr>
<tr>
<td>Number of Previous Concussions</td>
<td>0.191</td>
<td>0.084</td>
<td>2.269</td>
<td>0.025*</td>
<td>0.024, 0.357</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Predictor</th>
<th>B</th>
<th>S.E.</th>
<th>Odds Ratio</th>
<th>p-value</th>
<th>95% CI</th>
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</thead>
<tbody>
<tr>
<td>Clearance after 4 weeks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade at Concussion</td>
<td>0.299</td>
<td>0.181</td>
<td>1.348</td>
<td>0.098</td>
<td>0.946, 1.922</td>
</tr>
<tr>
<td>Presence of IEP*</td>
<td>0.879</td>
<td>0.406</td>
<td>2.409</td>
<td>0.030*</td>
<td>1.086, 5.341</td>
</tr>
<tr>
<td>Number of Previous Concussions</td>
<td>0.132</td>
<td>0.256</td>
<td>1.142</td>
<td>0.606</td>
<td>0.691, 1.887</td>
</tr>
<tr>
<td>Clearance after 6 weeks</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade at Concussion</td>
<td>0.024</td>
<td>0.19</td>
<td>1.025</td>
<td>0.897</td>
<td>0.707, 1.486</td>
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<tr>
<td>Presence of IEP*</td>
<td>0.986</td>
<td>0.409</td>
<td>2.681</td>
<td>0.016*</td>
<td>1.202, 5.980</td>
</tr>
<tr>
<td>Number of Previous Concussions</td>
<td>0.353</td>
<td>0.258</td>
<td>1.424</td>
<td>0.171</td>
<td>0.858, 2.362</td>
</tr>
<tr>
<td>Clearance after 8 weeks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade at Concussion</td>
<td>0.439</td>
<td>0.238</td>
<td>1.551</td>
<td>0.065</td>
<td>0.974, 2.472</td>
</tr>
<tr>
<td>Presence of IEP*</td>
<td>1.245</td>
<td>0.525</td>
<td>3.471</td>
<td>0.018*</td>
<td>1.241, 9.711</td>
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<tr>
<td>Number of Previous Concussions*</td>
<td>0.803</td>
<td>0.310</td>
<td>2.233</td>
<td>0.010*</td>
<td>1.216, 4.100</td>
</tr>
</tbody>
</table>

To examine the exclusion of 40 records (20 students with 2 concussion records) please refer to appendix 6 for linear and logistic regression analysis with inclusion of participants with repeat concussions (n=156).
Chapter 5 Discussion

Main Findings

This study was designed to gain a better understanding of recovery patterns for adolescent students with concussion in a high school setting. The primary hypothesis was confirmed in that male high school students returning to the school setting following concussion took longer to recover than the 7-10 day recovery that has been previously identified for adults (McCrory et al., 2005). While the position that adults who experience symptoms following concussion spontaneously and fully recover within 7-10 days has been more recently challenged, the 7-10 day period was used for this analysis because it has been frequently referenced and has contributed and influenced management design and expectations (Guskiewicz, McCrea, & Marshall, 2003; Makdissi et al., 2010; McCrory et al., 2013). This study provides evidence of significant differences in recovery patterns based on the 7-10 recovery for adults and therefore challenges the historical use of this recovery expectation for the management of high school students.

Since the high school cohort in this study received management from the David L. MacIntosh Sport Medicine Clinic it is additionally useful to examine the recovery patterns in this cohort with the recovery patterns for the university student population that also received concussion management from the same clinic. Unpublished data from the David L. MacIntosh Sport Medicine clinic identifies an average of 20 days to medical clearance for the university student population and an average of 45 days to medical clearance for high school students (from various community schools), who were medically managed at the Clinic (Comper, Hutchison and Richards, personal...
communication). This comparison identifies that high school student recovery (45 days to medical clearance) is longer than that of university students but also that average recovery for adult university students (20 days to medical clearance) exceeds the recovery of 7-10 days that has been previously reported in the literature. The 45-day average to medical clearance for all high school students that are medically managed at the Clinic is beyond the average of 31.5 days for participants in this study attending the same high school. Several factors may have contributed to this difference. The Clinic managed a diverse population of high school students including male and female, public and private school students with potential differences in history of concussion, history learning difficulty and school grade distribution. The unique interprofessional relationship between the Clinic and the high school that is the setting of this study may have also contributed to differences in recovery times between high school students in this study (SMCS) and the recovery times reported for all high school students managed at the Clinic. While outside the scope of this study, further investigation is warranted to examine the components of management and interprofessional communication that contribute to recovery patterns.

Addressing the second hypothesis, results of this study found that a history of learning difficulty and history of concussion contributed to longer recovery patterns than the study population average but that school grade of student did not.

These findings address a concerning gap in concussion literature by describing recovery patterns and risk factors for prolonged recovery in a high school student population. The historical assumption that adult patterns of recovery are appropriate to guide the management of adolescent students has created expectations that are incorrect
and impractical. This study found that male high school students face longer recoveries than adults and furthermore, students with a history of learning difficulty and history of concussion are at additional risk for prolonged recovery. This improved evidence and the public health impact of concussion and youth argue for reconsideration of current practice based on entrenched attitudes and behaviours that put youth at risk. Legislation, school protocols and policies for sport participation can reduce risk of concussion in youth and challenge resistance with scientific evidence.

**Pre-Existing Conditions and Student Characteristics**

**History of Learning Difficulty (Presence of IEP)**

This study found that history of learning difficulty (presence of an IEP) contributed to recovery patterns beyond the study population average. Prolonged patterns of recovery for students with pre-existing conditions (anxiety, depression, ADHD, LD and migraine headaches) have been increasingly addressed in the literature (Max et al., 2011; McCauley et al., 2001; McKinlay, Ligtering, & Than, 2014). The identification of pre-morbid conditions in many prior studies has been based on medical or psychological assessment/diagnosis and or self-report of these diagnoses but understanding these factors has been inconsistent. Not all students who experience difficulty with learning, have equal access to formal diagnosis because families and school boards have inconsistent financial resources (Gallagher-Mackay & Kidder, 2014). Additionally, a formal assessment process may be perceived as intimidating and time consuming and the stigma associated with some diagnoses may prevent disclosure of this
information to a school or to new medical professionals at the time of concussion. These factors can confound the ability of researchers to understand pre-existing learning and psychosocial conditions. This study design utilized the variable of students with an Individual Education Plan in an attempt to provide more robust understanding students with a history of learning difficulty who return to the school environment following concussion.

Within this study cohort (n=116), 37.9% (n=44) of students had a pre-existing IEP. Across all public high schools in the province of Ontario, in which this study took place, 22% of students have an IEP and this percentage has been reported to be increasing steadily over the past two decades suggesting an evolving process towards improved identification of students who struggle with learning in the school environment (Gallagher-Mackay & Kidder, 2014). The higher percentage of students with an IEP in this cohort compared to the provincial data may be explained by socio-economic factors. Family income requirements for private high school tuition may have also influenced the ability for families in this study cohort to have previously accessed costly private assessments. For this study’s analysis students with an IEP included students with a prior medical or psychological diagnosis for ADHD, LD, anxiety, depression and migraine headaches. It also includes students who had an IEP but who did not have a medical or psychological diagnosis. Students with an IEP and without an assessment/diagnosis accounted for 10.3% (n=12) of the study population. Across Ontario public schools, 41% of students receive IEP support without a formal assessment or diagnosis and this has been largely attributed to these assessments being financially prohibitive for many students and school boards (Gallagher-Mackay & Kidder, 2014). While differences exist
between this study population and the provincial public school population, in terms of formal and informal assessment procedures leading to the development of an IEP, the use of an IEP is used in both school environments to identify and support students at risk. Provision of an IEP with or without formal assessment can control for socio-economic differences and provide a valuable ecological consideration for management of school reintegration following concussion. Previous studies that rely only on formal diagnosis may be limited in that they do not account for a significant population of students who have pre-existing learning difficulty.

While including school IEP data is an improvement to understanding students with pre-existing learning conditions there are still challenges with defining students with pre-existing learning difficulty. This study accessed medical records and school records to identify students with pre-existing medical or psychological assessment and also included students with an IEP that had not received a formal diagnosis through medical or psychological assessment. This strategy, while attempting to control for barriers to formal assessment may still have been limited by not factoring students who may meet criteria for diagnosis of a pre-existing condition or the provision of an IEP but who were unaware of their needs or chose not to pursue or disclose diagnosis for various reasons or choose not to engage school support through an IEP. Comparing school and medical clinic records, this study found that medical interview of students with concussion revealed pre-existing conditions that were not captured by the school, however in these cases students were already receiving support through an IEP either because they had identified another pre-existing diagnosis or they had been undiagnosed but had demonstrated pre-existing difficulty with learning. Awareness, financial resources,
timely access to services and mental health stigmas have challenged the ability to identify students with learning difficulties and study the influence of pre-existing factors on concussion recovery patterns. The growing evidence that proactive understanding of mental health and learning difficulties can inform management of students following concussion suggests that the systemic school and health system barriers to timely assessment for young students with mental health concerns must be challenged (Schwean & Rodger, 2013). A contextual understanding of student functioning (with or without a formal diagnosis) may contribute to designing strategies for concussion management and reintegration of students to the school environment. The management of traumatic brain injury is strengthened by a multi-level approach that also includes an ecological understanding of student functioning (Gioia & Isquith, 2004).

**History of Concussion**

This study found that a history of concussion contributed to prolonged patterns of recovery. Repetitive injury from concussion has been a leading focus of attention from the public domain through anecdotal media coverage, professional sport litigation and more rigorous investigation in the scientific community. The scientific evidence, relying on studies designed from available data for adult professional athletes points to cumulative damage with repetitive injury. The management of younger populations has been increasingly prioritized but has historically relied on existing evidence from adult studies (McCrory et al., 2005). This study adds to the literature focusing on young students with concussion by describing the contribution of history of concussion to prolonged recovery in this population. This information is useful for medical and school management including student education regarding risk and recovery with concussion.
High School Grade at Concussion

This study examined high school grade of students at concussion to explore activity factors in the school environment that may exacerbate symptoms and prolong recovery. Prior studies have identified that students in increasing high school grade report more symptoms and school difficulties during recovery from concussion but research has also provided evidence that younger students face additional risk for injury and recovery (Ayr et al., 2009; Gioia, 2015; Ransom, Vaughan, Pratson, Sady, McGill, & Gioia, 2015; Shrey, Griesbach, & Giza, 2011). There are typically distinctions in the high school experience of students in grades 9 through 12 with each school grade introducing additional demands and complexity relating to academic skills, self-reliance, peer relationships, self-advocacy and level of athletic competition. This study hypothesized that students in higher grades would have longer recoveries but found that school grade did not have a significant predictive influence on recovery patterns. The ability to understand differences between high school grade of student in this cohort may have been limited by several factors; the uneven distribution of participants across grade levels, the unique school environment that standardized student expectations across all high school grades and the complex interaction of school grade of student and age of student.

All participants in this study attended a private boys’ school with rigorous academic and co-curricular demands at each high school grade level. Students entering this school at the beginning of high school in grade 9 would have already faced increased expectations through a competitive admissions process for school entry. Furthermore, students at every grade, once admitted, were required to meet challenging academic
standards each year to maintain enrollment status for the next grade. Students in all school grades were required to participate in co-curricular activities and meet additional community service requirements. The ability to understand differences across participant school grade in this study design may have been limited by universally higher expectations that were atypically standardized across all high school grades in this study setting. Simply put, in the school environment of this cohort, Grade 9 students faced many of the same rigors of Grade 12 students. Students in grade 9 through grade 12 in this cohort may be less differentiated by school grade in concussion recovery patterns because they are less differentiated before school admission and also in their subsequent school experience.

School grade may have lacked precision to evaluate more specific underlying factors that influence student recovery in the school environment. Further study is required to understand school grade as well as age as predictors of patterns of recovery from concussion. Diversity in school environments and student maturation processes challenge our ability to study the unique contributions as well as the interaction of school expectations (defined as school grade) and student development (defined as age) following concussion.

**Data Management**

Through interprofessional collaboration, a student support database was refined to prospectively identify important data elements for school management and research. While the level of data available for this study is not typically well organized or utilized for concussion management in most schools, this current limitation points to an important priority to support additional research and broader understanding of younger student
populations and concussion. The abundance of data for adults and professional athletes has enabled much of the current concussion literature. Considering the unique factors in the developmental trajectory of students and occupational demands of school, it is insufficient to continue to rely on the study of adults to design management for younger student populations. Our scientific understanding of youth has been limited by the paucity of available data therefore by improving data collection and data availability this study has responded to a core barrier for strategic research and suggests opportunities for further study.

This study examines a cohort of male high school students receiving the same school and medical support and includes comprehensive documentation. Explicit written medical direction following a 6 stage activity progression (cognitive, physical and sensory activity) was provided to students/parents and then shared with the school team who provided corresponding school accommodations for these 6 stages and 3 domains of activity. School documentation of standardized support through an Individualized Reintegration Plan (IRP) included consideration of pre-existing learning difficulties, regular monitoring, education and team communication. While a written plan articulated expectations and responsibilities for the adult support team members it also included appropriate expectations and responsibilities for the student. Transparency and active participation in documenting a plan promoted student engagement in the recovery processes and the rehabilitation literature acknowledges that awareness and engagement of the patient in the treatment plan is a powerful active ingredient (Dijkers, Hart, Tsaousides, Whyte, & Zanca, 2014). A documented plan also served as a reassuring road map towards graduated and progressive recovery and provided regular feedback.
supporting executive functioning deficits resulting from concussion as well as those that may have pre-existed injury.

The comprehensive and standardized documentation for all students with concussion provided robust data to evaluate recovery patterns for this cohort and examine the contribution of pre-existing conditions. This model suggests data elements that can be prioritized for future study and management of younger student populations.

**Interprofessional Management**

The literature has increasingly drawn attention to the importance of interprofessional management between school and medical professionals (Baker et al., 2014; Heyer et al., 2015; Sady et al., 2011). This study design highlights an interprofessional concussion management model that enabled the collection of data for this analysis. This model also highlights several concussion management principles: communication, written documentation, student support teams, key contact/student recovery coach, defined roles/ responsibilities and educational initiatives. Schools have a strategic opportunity and increasingly, a legal mandate to provide comprehensive concussion management (Chrisman et al., 2014; Ellenbogen, 2014; Gibson et al., 2015; “Policy/Program Memorandum No. 158, School Board Policies on Concussion,” 2014). In a rapidly evolving field, medical and scientific expertise can valuably contribute to management and address research gaps. The seriousness of concussion injury and impact on student health has been insufficiently addressed with siloed response. Responding to knowledge gaps through an iterative process of translating research and responding to clinical needs and questions has been an successful strategy for improving...
many complex areas of health care (Graham et al., 2006). This research advances evidence of recovery patterns and risk factors and also provides a model of interprofessional partnership for concussion management and research.

**Limitations of this Study**

The scientific study of concussion and high school students has been insufficiently addressed and this research provides a needed contribution to advance knowledge within this field. This study is limited to examining patterns of recovery from concussion in a cohort of male high school students in a private school setting but nevertheless suggests opportunities for further research examining additional cohorts, for example younger students, girls and students in diverse school environments.

This study accessed medical and school records to improve consideration of participants with a history of learning difficulty and history of concussion but still may not have included participants who did not identify conditions due to lack of awareness or stigma. This study found that pre-existing learning difficulty and history of concussion contributed to prolonged recovery patterns in this cohort but self awareness and self report of both learning difficulties and history of concussion may have limited this analysis. Examination of learning difficulty based on presence of IEP provided a contextual understanding of students but did not provide a specific understanding of conditions such as Learning Disability, Attention Deficit Disorder, depression and history of migraine headache. Analysis of the school grade of participants in this study may have been limited by the unique characteristics of the school environment (which placed similar demands on participants in all grades) as well as the uneven distribution of
participants across grade levels. Based on findings from previous literature, school grade of student and age of student contribute to risk but further study is required to improve our understanding of their interaction and influence on patterns of recovery.
Chapter 6 Conclusion

Adolescent students require more time to recover from concussion than their adult counterparts. Additionally, a history of learning difficulty and/or a history of concussion contribute to risk for longer recovery.

The unique demands within the school environment, developmental trajectory of adolescents and pre-existing factors (learning difficulty, history of concussion and high school grade of student) are complex but important considerations for the management of students returning to school after concussion. Concussion in high school students is a concerning public health issue, therefore proactive awareness and discussion of risk factors and sport participation is an important preventative component of concussion management.

Responding to this information, current management expectations based on the study of adults should be reconsidered as they may be unrealistic and place additional burden on younger students. Identification, education and cautious management for students at risk for injury and prolonged recovery can be valuable interventions.
Chapter 7 Future Directions

This study examined a cohort of adolescent male high school students reintegrating to school after concussion. This research design featured a concussion management strategy developed between one school and one sport medicine clinic. This relationship articulated the following management principles:

- Interprofessional communication;
- Standardized medical direction and corresponding school accommodations;
- Stepwise progression in comprehensive activity domains;
- Written individualized reintegration plan;
- Student support teams with defined roles and responsibilities;
- Education tailored to various stakeholders.

Further research is needed to evaluate concussion management principles and design locally responsive management strategies tailored to available resources and needs (Master et al., 2012; McAvoy, 2012; McAvoy et al., 2013; Ransom et al., 2015; Sady et al., 2011). This study is limited by an analysis of male adolescent high school students within one academic institution and receiving care from one sport medicine clinic and research institution but nonetheless contributes to future concussion management and research models.

Prior studies of adults have established a valuable framework but additional evidence regarding concussion in younger populations is required (McCrory et al., 2013). Examining additional cohorts, based on age, sex, school, sport type and level can further our understanding of recovery patterns and risk factors for students returning to the school environment.
Education has been identified as ‘mainstay’ of concussion management but further research is required to understand the best design and effectiveness to improve recognition and reporting behaviors that have interfered with our ability to understand the incidence of concussion and design research (McCrory et al., 2005).

Multidisciplinary efforts have been identified as ‘better than the sum of its parts’ and knowledge translation, team management and a comprehensive view of injury in this complex area can promote additional study (Dettmer et al., 2014). Multidisciplinary communication can also improve access to data that has been a historical limitation for the study of younger populations. Addressing this core barrier is a research priority.

Policy and legislation have been historically lacking in youth environments but there have been recent efforts to improve accountability for this concerning public health issue (Chrisman et al., 2014; Gibson et al., 2015). New policy will improve concussion documentation and data but the effectiveness of novel legislation will also require evaluation – and these are both opportunities for future scientific investigation.
Chapter 8 References


Gallagher-Mackay, K., & Kidder, A. (2014). *Special Education.* 1-16.


RECOVERY FROM CONCUSSION IN A COHORT OF MALE HIGH SCHOOL STUDENTS


# Appendix 1. 6 Stage Activity Domains and Corresponding School Accommodations

<table>
<thead>
<tr>
<th>Stage</th>
<th>Physical</th>
<th>Cognitive</th>
<th>Sensory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 - No attendance</strong></td>
<td>No attendance at any school activities.</td>
<td>No attendance at classes, No assignments, studying, tests.</td>
<td>Very little or no screen time.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No group work / meetings.</td>
</tr>
<tr>
<td><strong>2 - Trial attendance</strong></td>
<td>No gym / PA classes. No field trips. No clinics. No labs.</td>
<td>Trial attendance with no note taking and little or no participation expected in discussions, etc. No assignments, studying or tests.</td>
<td>Minimal screen time No group work / meetings. No tech / media / music classes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No tech / media / music classes.</td>
</tr>
<tr>
<td><strong>3 - Partial attendance</strong></td>
<td>Participation in gym / PA classes according to PA (Sport) progression*. No field trips. No labs.</td>
<td>Progression of attendance, participation in class and note-taking (possibly assisted). No assignments, studying, tests.</td>
<td>Minimal screen time Limited group work / meetings. No tech / media / music classes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No tech / media / music classes.</td>
</tr>
<tr>
<td><strong>4 - Increased participation</strong></td>
<td>Participation in gym / PA classes according to PA (Sport) progression*. Limited clinics or labs. No field trips.</td>
<td>Attendance at all academic classes with near normal participation and note-taking. Progress studying / homework. No assignments, tests.</td>
<td>Increased screen time Slightly increased group work. No tech / media / music classes.</td>
</tr>
<tr>
<td><strong>5 - Near normal participation</strong></td>
<td>Participation in gym / PA classes according to PA (Sport) progression*. More clinics, labs, brief field trips.</td>
<td>Full attendance, participation and note taking in classes. Near normal studying. Assignments with accommodation. No tests.</td>
<td>Near normal screen time. Normal group meetings, some work on group assignments.. Limited tech / media / music classes.</td>
</tr>
<tr>
<td><strong>6 - Unrestricted participation</strong></td>
<td>Full participation in gym / PA classes, clinics, labs and field trips.</td>
<td>Full academic activities.</td>
<td>Normal screen time and group work.. Normal tech / media / music classes.</td>
</tr>
</tbody>
</table>
Appendix 2. School Concussion Record

SMCS Student Concussion Record

<table>
<thead>
<tr>
<th>Date of Concussion</th>
<th>Grade at Concussion</th>
<th>Origin</th>
<th>Place</th>
<th>Referral</th>
<th>Student ID</th>
<th>Concussion ID</th>
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<tbody>
<tr>
<td>May 13, 2014</td>
<td>11</td>
<td>Hockey</td>
<td>SMCS</td>
<td>Student</td>
<td>1237890456</td>
<td>3-42</td>
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CURRENT STAGE

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</tr>
<tr>
<td>Cognitive</td>
<td>May 30, 2014</td>
</tr>
<tr>
<td>Sensory</td>
<td>May 30, 2014</td>
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</table>

CLEARANCE

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<th>Days to Medical Clearance</th>
<th>Date of Clearance</th>
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</thead>
<tbody>
<tr>
<td>Not Yet Cleared</td>
<td>Non-Closure Reason</td>
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ASSESSMENTS

<table>
<thead>
<tr>
<th>Date / Location / ID</th>
<th>Physical Advice</th>
<th>Cognitive Advice</th>
<th>Sensory Advice</th>
<th>Next Appointment</th>
</tr>
</thead>
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<tr>
<td>May 30, 2014</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May 15, 2014</td>
<td>Progress 1/3</td>
<td>Progress 1/3</td>
<td>Progress 1/3</td>
<td>May 21, 2014</td>
</tr>
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<td>Dr. X</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 3. Individual Re-Integration Plan

**CONCUSSION MANAGEMENT: Individual Re-Integration Plan**

**Student:** John Smith  
**Homeroom:** 09A  
**Date of Concussion:** Jan 6, 2014  
**Next Appointment:** Jan 13, 2014

**PHYSICAL**  
4  
**Aerobic Exercise**  
Normal  
**Drills**  
Sport-specific movement most relevant to student’s sport or PE unit.  
**Cognitive Tasks**  
Add thinking or decision-making (e.g. ball or puck handling, shooting, passing, positional play,  
**Resistance Training**  
15 minutes per day of body-weight floor exercises (e.g. planks, lunges, squats, pushups, sit-ups,  
**Team Functions**  
Team meetings, practices to perform above exercises. No matches.

**COGNITIVE**  
6  
**Attendance**  
Normal  
**Writing**  
Normal, but may have accommodations / exemptions for missed assignments.  
**Reading**  
Normal, but may have accommodations / exemptions for missed assignments.  
**Participation**  
Normal  
**Assignments / Tests / Homework**  
Normal, but may have accommodations / exemptions for missed assignments.

**SENSORY**  
6  
**Normal screen time and group work.**  
Normal tech/media/music classes.

**ASSESSMENTS**  

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Status</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENG1D1-02</td>
<td>English</td>
<td>exempt</td>
<td>regular</td>
</tr>
<tr>
<td>FRF1D1-05</td>
<td>French (Core)</td>
<td>exempt</td>
<td>regular</td>
</tr>
<tr>
<td>CGC1D1-01</td>
<td>Geography of Canada</td>
<td>exempt</td>
<td>regular</td>
</tr>
<tr>
<td>PPL1O1-08</td>
<td>Healthy Active Living Ed</td>
<td>exempt</td>
<td>regular</td>
</tr>
<tr>
<td>MPM1D1-07</td>
<td>Principles of Mathematics</td>
<td>deferred</td>
<td>TBD</td>
</tr>
<tr>
<td>REL1O1-08</td>
<td>Religious Education</td>
<td>exempt</td>
<td>regular</td>
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<tr>
<td>SNC1D1-07</td>
<td>Science</td>
<td>deferred</td>
<td>TBD</td>
</tr>
<tr>
<td>AVWI1O-02</td>
<td>Visual Arts-Comprehensive</td>
<td>exempt</td>
<td>regular</td>
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Record Last Modified: January 1, 2014  
Modified By: [Teacher name]
Appendix 4. Residual Plots

Considering the non-normal distribution (positively skewed data), a log of days to clearance was computed to proceed with a linear regression analysis. Assumptions of linear regression (i.e. normal distribution, homoscedascity, independence of points) were assessed and met.

Histogram: Normal distribution of residuals
(Note: residuals are indicative of log of days to medical clearance)
Appendix 4. Residual Plots continued

**Normal P-P Plot illustrating linear distribution of residuals**
(Dependent variable: Log of days to medical clearance)

![Normal P-P Plot](image)

**Scatterplot of standardized versus predicted residuals.**
Assumption of homoscedasticity was met as no pattern was found with the residuals.  
(Dependent variable: Log of days to medical clearance)

![Scatterplot](image)
Appendix 5. 4, 6 and 8-week Binary Recovery Periods for Learning Difficulty (IEP)
Appendix 6. Analysis with inclusion of students with two concussion records (n=20)
40 records

Regression Analysis including repeated measures (n=156)

<table>
<thead>
<tr>
<th>Predictor</th>
<th>B</th>
<th>S.E.</th>
<th>t</th>
<th>p-value</th>
<th>95% CI</th>
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<tr>
<td>Grade at Concussion</td>
<td>0.099</td>
<td>0.557</td>
<td>1.805</td>
<td>0.073</td>
<td>-.009, .207</td>
</tr>
<tr>
<td>Presence of IEP*</td>
<td>0.257</td>
<td>0.119</td>
<td>2.306</td>
<td>0.022*</td>
<td>.039, .511</td>
</tr>
<tr>
<td>Number of Previous</td>
<td>0.103</td>
<td>0.07</td>
<td>1.481</td>
<td>0.141</td>
<td>-.034, .242</td>
</tr>
<tr>
<td>Concussions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Predictor</th>
<th>B</th>
<th>S.E.</th>
<th>Odds Ratio</th>
<th>p-value</th>
<th>95% CI</th>
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</thead>
<tbody>
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<td>Clearance after 4 weeks</td>
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<td>1.897</td>
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<td>-.003, .147</td>
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