Concussions in Competitive Artistic Swimming: Investigating Incidence and Injury Context through a Community-Based Approach

by

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A thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy
Graduate Department of Exercise Science
University of Toronto

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2019

Abstract

Artistic (synchronized) swimming is a fast-paced, predominantly female aesthetic sport on which there has been very little research. Despite origins in theatrical performance, the physical demands of artistic swimming have evolved significantly, subsequently increasing the potential for traumatic injury, including concussion. Sport-related concussion is a traumatic brain injury that can result in behavioural complaints, cognitive impairments, mood disturbance, and altered sleep. Despite findings that female athletes may experience a greater rate of concussion, more symptoms, and longer recovery than male athletes, females remain under-represented in sport concussion research. Sport-related concussion in artistic swimming has not yet been examined.

The purpose of this research was to explore the incidence and injury context of sport-related concussion in youth artistic swimmers in Ontario within a community-based research setting. First, a retrospective study examined the injury context factors surrounding concussions sustained during artistic swimming. Second, a prospective study measured the incidence of concussion in this population over one season, and further explored the injury context of concussion. The incidence risk of concussion was 1.91%, and the clinical incidence was 1.91 per 100 athletes. The most frequent mechanism of injury was contact with another athlete, most commonly during pattern transitions and highlights. Concussions occurred most frequently in in-pool training between November and March, and in the deep-end of the pool.

Valuable sport-specific concussion resources for the artistic swimming community were developed through collaboration with Ontario Artistic Swimming. One of these resources was
an injury tracking program. A qualitative study examining coaches’ perceptions of the injury tracker provided valuable feedback for improvements. The important lessons learned from this partnership include the identification of contact between athletes in artistic swimming, findings of concussion incidence comparable to other girls’ sports, and description of the injury contexts associated with concussion in artistic swimming. Exploration of concussion in artistic swimming is warranted to protect the health and safety of these athletes, to expand the research on sport concussion in girls and women, and assist coaches and officials in understanding the nature of concussions in artistic swimming.
Acknowledgments

I am honoured to thank the many people that made this research possible.

First, I would like to thank my supervisor, Dr. Lynda Mainwaring, for your incredible support on the long road of developing and executing this project, and writing this thesis. In addition, I would like to acknowledge and thank my committee members, Dr. Michael Hutchison and Dr. Catherine Sabiston, for your input and assistance in bringing this research from an idea into reality. Thank you to my lab mates for being there to listen, bounce ideas off of, and especially to laugh with.

I would also like to thank the members of Ontario Artistic Swimming for your enthusiasm and dedication to this project. It was a pleasure to work alongside you to improve the safety of the sport that we love. Thank you to all the athletes and coaches who participated, your contribution is incredibly valued.

Last but not least, I would like to thank my family for their amazing support and understanding on this journey. To my incredible husband Glen, I love you and appreciate you more than you know. Thank you to my parents, Sharon and Greg McClemont, for all of your help and motivation. I could not have done this without you. Finally, to my son Liam, your arrival was the biggest motivation of all. I love you Monkey.
# Table of Contents

Acknowledgments.......................................................................................................................... iv  
Table of Contents............................................................................................................................. v  
List of Tables ................................................................................................................................... x  
List of Figures ................................................................................................................................ xi  
List of Appendices ........................................................................................................................ xii  
Chapter 1 Introduction ..................................................................................................................... 1  
1 Introduction................................................................................................................................. 1  
  1.1 Background.......................................................................................................................... 1  
  1.2 Purpose................................................................................................................................. 3  
  1.3 Research Question and Objectives....................................................................................... 4  
  1.4 Rationale.............................................................................................................................. 4  
  1.5 Outline................................................................................................................................ 5  
Chapter 2 Review of Literature........................................................................................................ 6  
2 Review of Literature ................................................................................................................... 6  
  2.1 History of Artistic (Synchronized) Swimming................................................................. 6  
  2.2 Physiology of Artistic (Synchronized) Swimmers .............................................................. 7  
  2.3 Injuries in Artistic (Synchronized) Swimming................................................................. 8  
  2.4 Definition of Sport-Related Concussion........................................................................... 10  
  2.5 Mechanism of Concussion Injury...................................................................................... 10  
  2.6 Pathophysiology of Concussion........................................................................................ 13  
  2.7 Concussion Assessment and Management......................................................................... 17  
  2.8 Sex- and Age-Related Differences in Concussion........................................................... 26  
  2.9 Injury Surveillance Programs .............................................................................................. 30  
  2.10 Concussion Policy, Resources and Education............................................................... 33  
  2.11 Review of Literature Summary......................................................................................... 39
Chapter 3 Research Overview .......................................................................................................40

3 Overview of Research Program ................................................................................................40

3.1 Purpose, Objectives and Hypotheses .................................................................................40

3.2 Definition of Sport-Specific Terms ...................................................................................42

Chapter 4 Study One ......................................................................................................................44

4 Concussions in Youth Artistic Swimmers: A Retrospective Descriptive Study .................44

4.1 Abstract ..............................................................................................................................44

4.2 Introduction ........................................................................................................................45

4.3 Method ...............................................................................................................................47

4.3.1 Participants .............................................................................................................47

4.3.2 Materials ................................................................................................................48

4.3.3 Measures ................................................................................................................48

4.3.4 Procedure ...............................................................................................................48

4.3.5 Analysis ..................................................................................................................49

4.4 Results ................................................................................................................................49

4.4.1 Descriptive Statistics ..............................................................................................49

4.4.2 Chi-Square Analysis ..............................................................................................52

4.5 Discussion ..........................................................................................................................53

4.5.1 Injury Factors .........................................................................................................53

4.5.2 Limitations .............................................................................................................54

4.6 Conclusion and Clinical Implications ................................................................................55

Chapter 5 Study Two .....................................................................................................................56

5 Incidence of Concussion in Youth Artistic Swimmers in Ontario: A Prospective Study ....56

5.1 Abstract ..............................................................................................................................56

5.2 Introduction ........................................................................................................................57

5.3 Method ...............................................................................................................................58
Chapter 5 Study Two .....................................................................................................................58

5.3 Study Design and Participants ..............................................................................................58

5.3.1 Study Design and Participants ..........................................................................................58

5.3.2 Materials and Procedure ....................................................................................................59

5.3.3 Study Variables and Definitions .........................................................................................60

5.3.4 Analysis ................................................................................................................................60

5.4 Results .....................................................................................................................................61

5.4.1 Descriptive Statistics ............................................................................................................61

5.4.2 Incidence ...............................................................................................................................61

5.5 Discussion ...............................................................................................................................62

5.5.1 Incidence and Situational Factors ......................................................................................62

5.5.2 Limitations ............................................................................................................................63

5.6 Conclusion ...............................................................................................................................63

Chapter 6 Study Three ...................................................................................................................65

6 Building a Concussion Safety Program with a Provincial Sport Organization: A
Community-Based Participatory Research Approach ................................................................65

6.1 Abstract ....................................................................................................................................65

6.2 Introduction ...............................................................................................................................65

6.3 Program Design .......................................................................................................................67

6.3.1 The Parties ...........................................................................................................................67

6.3.2 Definition of Roles and Scope .........................................................................................68

6.3.3 Identifying Goals ................................................................................................................69

6.4 Program Implementation .........................................................................................................70

6.4.1 Document Development ....................................................................................................70

6.4.2 Education Initiatives ..........................................................................................................71

6.4.3 Injury Tracking ....................................................................................................................72

6.5 Program Evaluation ................................................................................................................73

6.5.1 Evaluation Methods and Defining Success ......................................................................73
6.5.2 Challenges ..............................................................................................................75
6.6 Discussion ..................................................................................................................76
6.7 Lessons Learned .........................................................................................................79
6.8 Conclusion ..................................................................................................................82

Chapter 7 Study Four .............................................................................................................83
7 Coach Perceptions of Concussion Resources ......................................................................83
  7.1 Abstract ....................................................................................................................83
  7.2 Introduction ...............................................................................................................83
  7.3 Method ......................................................................................................................85
    7.3.1 Paradigmatic Position and Researcher Perspective .............................................85
    7.3.2 Participants .........................................................................................................86
    7.3.3 Interviews ..........................................................................................................87
    7.3.4 Analysis ..............................................................................................................87
  7.4 Results .......................................................................................................................88
    7.4.1 Injury Reporting .................................................................................................89
    7.4.2 Importance of Injury Tracking ..........................................................................90
    7.4.3 Facilitators to User Friendly Tracking .................................................................91
    7.4.4 Barriers to Injury Tracker Use ..........................................................................92
  7.5 Discussion ..................................................................................................................93
  7.6 Conclusion and Implications ......................................................................................95

Chapter 8 General Discussion ........................................................................................................97
8 Discussion .........................................................................................................................97
  8.1 Chapter Summaries ...................................................................................................97
    8.1.1 Chapter 4: Concussions in Youth Artistic Swimmers: A Retrospective
      Descriptive Study .....................................................................................................97
    8.1.2 Chapter 5: Incidence of Concussion in Youth Artistic Swimmers in Ontario .....98
8.1.3 Chapter 6: Building a Concussion Safety Program with a Provincial Sport Organization: A Case of Community-Based Participatory Research ..................100

8.1.4 Chapter 7: Coach Perceptions .................................................................100

8.2 Context .............................................................................................................101

8.2.1 Concussion Incidence .............................................................................101

8.2.2 Concussion Injury Contexts .................................................................103

8.2.3 Community Engaged Research ............................................................104

8.3 Limitations .....................................................................................................108

Chapter 9 Conclusion ................................................................................................109

9 Conclusion .........................................................................................................109

9.1 Results Summary ............................................................................................110

9.2 Clinical Implications and Future Directions .............................................112

References ...........................................................................................................114

Appendices .............................................................................................................152
List of Tables

Chapter 4

Table 1: Categorical variable frequency tables 51
Table 2: Chi-square goodness-of-fit statistics 52

Chapter 5

Table 3: Demographics of concussed athletes 61
List of Figures

Chapter 4

Figure 1: Participant flowchart (retrospective study). 50

Chapter 5

Figure 2: Participant flowchart (prospective study). 59

Chapter 6

Figure 3: Ontario Artistic Swimming concussion safety program components. 67

Figure 4: Map of OAS-researcher partnership on to the Revised CBPR Conceptual Model. 79
List of Appendices

Appendix A: Consent Form (Retrospective Study)

Appendix B: Online Survey Questions (Retrospective Study)

Appendix C: SSO Online Injury Tracker Form 2017-2018 Version

Appendix D: Ontario Artistic Swimming Concussion Policy

Appendix E: SSO Concussion Management Guidelines and Return to Sport Protocol

Appendix F: SSO Return to Sport Progress Tracking Tool

Appendix G: Concussion Information for Athletes and Parents

Appendix H: Interview Guide (Coach Feedback)

Appendix I: Consent Form (Coach Feedback)
Introduction

1.1 Background

Sport-related concussion (SRC) has emerged as a significant issue in the field of sports medicine. Some estimates suggest there are 1.6-3.8 million SRCs in the United States per year (Langlois, Rutland-Brown & Wald, 2006); however, many agree that this range is underestimated because of under-reporting and measurement challenges (Noble & Hesdorffer, 2013). In Ontario, pediatric visits to physician offices and emergency departments because of concussion increased 4.4 times per 100 000 children between 2003 and 2013 (Zemek et al., 2017). Despite the limited epidemiological data available, it appears that SRC is pervasive at all levels of sport participation, from recreational to professional.

According to the Concussion in Sport Group, a concussion is a type of mild traumatic brain injury (mTBI) caused by direct or indirect forces to the head, face, neck or body (McCrory et al., 2017). The result is a complex pathophysiological cascade that manifests as a disruption of regular neurological processes. Concussion is defined as a functional rather than a structural injury, so-called due to the observed disruption in brain function without any accompanying gross structural abnormalities on traditional radiographical images (DiFiori & Giza, 2010). Currently, concussion is diagnosed based solely on signs and symptoms, which are organized into six categories: (1) symptoms, which can be further broken down into somatic, cognitive, and emotional sub-categories, (2) physical signs such as amnesia or loss of consciousness, (3) balance disturbances, (4) behavioural changes, (5) cognitive impairments such as slowed reaction times, and (6) sleep disturbances, such as sleeping more or less than usual (McCrory et al., 2017).

The majority (80-90%) of concussed athletes will fully recover from their injury in 7-10 days (McCrory et al., 2005). However, some athletes experience persistent symptoms that can last for several weeks, months or—in rare cases—years after the injury (Ryan & Warden, 2003). The Berlin consensus defines persistent symptoms as those lasting beyond 10-14 days in adults and longer than four weeks in children (McCrory et al., 2017).
Even for those athletes that do recover within 10 days, the experience of sustaining and recovering from a concussion can be very stressful. Many athletes find it difficult to cope with the rehabilitation process (Bloom, Horton, McCrory & Johnston, 2004). For years, the best practice for concussion management was complete physical and cognitive rest until asymptomatic, followed by a graded return to activity progression (McCrory et al., 2017). However, results of systematic reviews indicate that there is limited support for any treatment of concussion, including these graduated activity protocols (Schneider et al., 2013). It is now believed that complete rest during the acute period (24-48 hours) post-injury, followed by a gradual and progressive return to activity at sub-symptom threshold levels, should be encouraged (McCrory et al., 2017). Due to the nebulous nature of the symptoms, the “invisibility” of the injury, and the restrictive recovery process associated with concussion, the injury experience for athletes is very different from that of musculoskeletal injuries. Athletes report feeling isolated and frustrated during the concussion recovery process (Bloom et al., 2004). There is evidence indicating that concussed athletes are exhibiting a stress response through disruption of the autonomic nervous system (Senthinathan, 2013). This autonomic dysfunction may be exacerbated by the stressful nature of the concussion recovery protocol. This indicates that SRC is unique from other types of athletic injuries, and scientific investigation specific to concussion injury is needed as findings from other injury studies may not be applicable to concussion.

Sport-specific concussion studies have been conducted in some sports, such as football (e.g. Guskiewicz, Weaver, Padua & Garrett, 2000), ice hockey (e.g. Agel, Dompier, Dick & Marshall, 2007), rugby (e.g. Hinton-Bayre, Geffen & Friis, 2004), and soccer (e.g. Dick, Putukian, Agel, Evans & Marshall, 2007); and have generally found higher rates of concussion in competition, and in collision sports (Zuckerman et al., 2015). However, to date there are no concussion studies specific to synchronized swimming.

Artistic (synchronized) swimming is a female-dominated aesthetic sport in which athletes compete against one another with routines set to music. Judges score routines for technical execution, artistic impression, and difficulty. Athletes compete in solo (one athlete), duet (two athletes), team (8 athletes) and combo (10 athletes) categories. The sport, originally called “ornamental swimming or “scientific swimming” was developed from theatrical water ballet performances to include elements from lifesaving techniques and swimming, evolving into a very physically demanding full-contact sport (Federation Internationale de Natation, 2015).
Since the Olympic debut of synchronized swimming in 1984 in which the three countries of Canada, United States of America and Japan participated (FINA, 2015), the sport has grown to be practiced by many countries on all 6 continents.

In the last 20 years artistic swimming has evolved dramatically. Routine choreography has become faster, the athletes must swim much closer to one another, and the aerial acrobatic moves are much higher and more powerful. In addition, as training techniques have evolved athletes have become stronger and more powerful. Due to these developments the chance of contact between the athletes has increased, and with it, the risk of injury. Anecdotally, many participants (athletes, coaches and officials) believe that the evolution of artistic swimming has increased the risk of sustaining a concussion, and that concussions have become an issue in the sport. In recent years there has been a push in Canada to develop and introduce management guidelines and protocols in an attempt to increase safety. However, there is no sport-specific scientific evidence to inform the content of these policies. Furthermore, the greatest increase in pediatric concussion-related doctor’s office and emergency department visits in Ontario between 2003 and 2013 was among females (Zemek, 2017). As a female-dominated sport, artistic swimming provides an opportunity to explore concussions in an under-studied population (McKeever & Schatz, 2003). Together, the aforementioned highlights the importance of research in this area.

1.2 Purpose

The purpose of this program of research is two-fold. First, to investigate the incidence and context of sport-related concussions sustained by amateur club-level artistic swimmers in Ontario. Second, to conduct this investigation within the community in a collaborative partnership with community representatives and develop sport-specific concussion resources as partners. The outcomes of the research will provide a vital starting point in terms of what the risk factors for sustaining a concussion in artistic swimming are, as well as assist in the development and evaluation of resources to promote the health and safety of artistic swimmers in Ontario.
1.3 Research Question and Objectives

The central research question of the research program is as follows: What is the frequency and context of concussions among youth female synchronized swimmers in Ontario? There are five associated research objectives: (a) to determine the incidence of concussion injuries in this population in a single season, (b) to determine the seasonal training phase in which concussions are more frequent, (c) to determine if concussions are more common in any of the competitive age groups, (d) to describe which injury context factors are more frequently present in a concussion sustained during artistic swimming participation, and (e) to develop sport-specific concussion resources for the Ontario artistic swimming community through collaboration with the provincial sport organization.

1.4 Rationale

Answering this research question and addressing the associated research objectives will provide important information for artistic swimming officials in Ontario as the sport governing body develops and implements concussion safety guidelines. In addition, it will add to the understanding of what training contexts are more likely to lead to a concussion and provide a base for the development of sport-specific concussion prevention strategies. Furthermore, it will provide important sport-specific concussion resources for artistic swimming coaches, officials, athletes, and their parents. As artistic swimming continues to grow and advance, and the skills become faster, more powerful and more risky, this type of research and the resulting findings will become more and more important to protect the health and safety of the athletes.

Despite the growth and evolution of the sport, artistic swimming is still widely considered a “fringe” sport by many (Battaglia, 2016). Very little empirical research has been conducted on any aspect of the sport, let alone injuries in these athletes. To date, no studies specifically examining concussion injuries in artistic/synchronized swimming have been published. At this time, the extent of the issue of concussions in artistic swimming is unknown, and investigation into the scope and nature of concussions in this sport will be very important going forward. It is vital to have empirical epidemiological data so that numbers of concussions can be tracked and the effect of any policies introduced by governing bodies can be measured. Furthermore, it is
imperative to understand the contexts surrounding concussions in artistic swimming in order to
determine how best to manage these injuries in these athletes as well as how to prevent and
minimize the risk of sustaining a concussion while participating in the sport. Understanding
which age group concussions are most frequent in, the time of year that athletes are most at risk
for concussions, and what activities are most likely to lead to a concussion, will provide coaches
with valuable information that can assist them in keeping their athletes safe.

1.5 Outline

This thesis is presented as a comprehensive document that can be read as a whole. Alternatively,
Chapters 4, 5, 6 and 7 are also able to be read as independent documents. The thesis is
comprised of nine chapters. Following general introduction (Chapter 1), review of literature
(Chapter 2), and research overview (Chapter 3) sections, there are four chapters presenting four
separate research studies (Chapters 4-7). This is summarized by general discussion (Chapter 8)
and conclusion (Chapter 9) sections.
Chapter 2
Review of Literature

The following section will review the existing literature on aspects of sport related concussion and the physiological characteristics of, and injuries in, artistic swimmers. The mechanisms of concussive brain injury, the pathophysiological changes associated with mTBI and its clinical presentation, and the assessment and management of sports concussion will be discussed. Sex and age differences in concussions will be described. In addition, injury surveillance and concussion policy and education will be reviewed.

2 Review of Literature

2.1 History of Artistic (Synchronized) Swimming

The concept of synchronized swimming (aquatic performance set to music) has been in existence for over a century. In Victorian England, ornamental swimming demonstrations featured men and women performing stunts and parlor tricks in large glass tanks (Valosik, 2016); however, it was quickly decided that women were better suited for the performances (FINA, 2015). Australian Annette Kellerman, the “mother of synchronized swimming”, brought aquatic performances to the United States in the early 1900s which featured combinations of swimming, dancing, acrobatics, and singing and were considered very avant-garde (Woollacott, 2011). As these water pageants grew in popularity, the Red Cross began to use them as a way to increase interest in swimming and decrease the number of drowning deaths in the country (Valosik, 2016). The term ‘synchronized swimming’ was coined when an announcer introduced a water ballet performance at the 1934 World Fair in Chicago using that description (FINA, 2015). Water ballet continued to rise in popularity, culminating with Esther Williams, an American film star who performed in aquatic shows both live and on screen (Valosik, 2016).

Meanwhile, the first competition of ‘scientific swimming’ (figures and strokes from the Royal Life Saving Society’s handbook) was held in Montreal, Canada in 1924 (FINA, 2015). The progression of synchronized swimming from water pageantry to competitive sport continued in the mid-20th century, primarily in North America, and the sport was officially added to the FINA program in 1952 (FINA, 2015). Following a long period of participating in the Olympics as a demonstration sport from 1952 to 1968, synchronized swimming was inducted into the Olympics
in 1984 (FINA, 2015) and has since evolved far from its water ballet origins into a grueling athletic event (Valosik, 2016). In 2018, FINA changed the name of the sport to artistic swimming.

2.2 Physiology of Artistic (Synchronized) Swimmers

To date, the existing literature on the physiological characteristics of synchronized swimmers is sparse and limited. Some research investigated physiological factors related to synchro performance ability. The earliest study that could be retrieved described the body composition of synchro athletes, in which the body fat and lean body weight of 15 synchronized swimmers were compared to 15 female non-athletes (Moffat, Katch, Freedson & Lindeman, 1980). No statistically significant differences were found between the groups. This study also compared ranked ability with body composition scores. No relationship between ability and body fat or lean body weight was found. A second study sought to determine which physiological characteristics of synchro athletes were related to their performance (Yamamura et al., 1999). Like the previous study, anthropometric variables were found to have no relation to synchronized swimming performance. This could be because the inherent drive for sameness in the sport reduces the variation in physique of synchro athletes. Yamamura and colleagues (1999) did find positive correlations between synchro performance and isokinetic muscle strength of the elbow in flexion and extension, isokinetic muscle strength of the knee in extension, abdominal muscle endurance, leg extension power, aerobic power, velocity at onset of blood lactate accumulation, and flexibility as measured by the distance between the open legs. Another study investigated factors of rate of perceived exertion (RPE) in synchro competition performances and found that RPE was at least partially explained by the number of immersions in the routine, heart rate during recovery, minimum heart rate, and peak blood lactate levels (Rodriguez-Zamora et al., 2014).

Other researchers have looked at bone physiology in synchronized swimmers. Liang, Arnaud, Steele, Hatch and Moreno (2005) compared bone strength between synchro athletes and gymnasts, in order to compare the bending stiffness of bone in world-class athletes with different histories of loading due to varying demands of different sports. Synchronized swimmers and gymnasts were found to have similar levels of bone bending stiffness, and both groups had
higher levels of this measure than untrained female controls. A separate study found no
difference in bone speed of sound or bone turnover between adolescent synchronized swimmers
and age- and maturity-matched non-athlete controls (Ludwa, Falk, Yao, Corbett & Klentrou,
2010). This indicates that synchro training may increase bone stiffness without increasing bone
density, which may have some implications for injury studies in synchronized swimming.

A study comparing the effectiveness of post-exercise recovery methods on vagal reactivation in
elite synchronized swimmers found that the performance of a routine significantly lowered
parasympathetic tone and increased sympathetic activity, as indicated by changes in HRV
measures (Schaal et al., 2013). While limited by a small sample size, these findings show the
high physical intensity experienced by synchronized swimmers during the practice of their sport,
and suggest that the disruption of ANS function by concussion (e.g. Gall, Parkhouse &
Goodman, 2004) could significantly hamper a synchronized swimmer’s ability to train and
compete.

2.3 Injuries in Artistic (Synchronized) Swimming

Some studies that have examined injuries in athletes across multiple sports included synchro
athletes (Andrade et al., 2010; Junge et al., 2009; Mountjoy et al., 2010; Mutoh, Takamoto &
Miyashita, 1988). One study describing the incidence of chronic injuries in all the aquatic sports
(swimming, diving, water polo and synchronized swimming) found that 79% of the 24
synchronized swimmers in the study had experienced at least one chronic injury (Mutoh et al.,
1988). Of the reported injuries experienced by these synchro athletes, 45.2% were to the low
back, 25.8% to the wrist, 12.9% to the knee, and 6.5% to the neck. The athletes were not asked
about concussion injuries in that study. A second study examining frequency and type of injury
in aquatic sports at the 2009 FINA World Championships found synchronized swimming had an
injury rate of 28 injuries in 990 athlete exposures (Mountjoy et al., 2010). This rate was in the
middle of the pack as compared to the other aquatic sports.

A study reporting the frequency and causes of athletic injuries among participants in the 2008
Summer Olympic Games found that synchronized swimming was among the sports with the
lowest number of reported injuries per participating athlete (Junge et al., 2009). That being said,
this study required team physicians to report injuries from their teams to the investigators. It is possible that the team physicians for synchro did not pass on the injury information, or even that the athletes themselves did not report their injuries to team doctors for fear of being taken out of the Olympic competition. McCrea et al. (2004) found that athletes may conceal injuries in order to stay in training and competition. A study specifically examining dental trauma injuries in Pan-American Games athletes included 3 synchronized swimmers in the sample, and found that 2 of these athletes had suffered dental trauma (Andrade et al., 2010). This indicates that there is contact being made to the head and face during synchronized swimming, of an intensity sufficient to injure the teeth. It is possible that this amount of force is enough to potentially cause a concussion injury. Taken together, the findings of these various multi-sport studies indicate that synchronized swimmers do sustain injuries during training and competition for their sport.

A handful of sport-specific injury studies have been published. A very early descriptive study found that synchronized swimming had low risk of acute injuries, and a growing risk of over-use injuries (Weinberg, 1986). However, this study was performed before synchro evolved to include more speed, power and riskier highlight manoeuvres. Chu (1999) described the susceptibility of synchronized swimmers to lower back injury, shoulder injury, and medial stress injury in the knee due to synchro’s high strength, speed and flexibility demands. Mountjoy (1999, 2009) has described the pattern of injuries associated with synchronized swimming in some detail. She notes that the three most common musculoskeletal injuries in synchronized swimmers are: shoulder instability, lumbar strain, and patellofemoral syndrome (Mountjoy, 1999). Mountjoy (1999, 2009) is the first to describe the potential for acute traumatic injuries due to contact between synchronized swimmers, noting that the possibility for synchronized swimmers to sustain hematomas, contusions, fractures, disc herniations, and concussions is on the rise. Furthermore, she suggests that due to the heavy training requirements and rigourous work ethic of elite synchronized swimmers, compliance with concussion management guidelines can be very challenging and this population should be identified as in need of education and close follow-up (Mountjoy, 2009). While chronic overuse injuries are more common in synchronized swimming due to the high volume of repetitions needed to achieve perfect synchronization, there is a real risk of traumatic injuries due to collisions with teammates. More rigourous empirical studies by injury type that look specifically at synchronized swimmers are
needed to understand the extent of injuries in the sport. No studies examining concussion injuries directly in synchronized swimming have been published to date. This program of research has begun to close this gap in the literature. Concussion is a potentially serious injury and proper tracking and management is important. The nature of concussive brain injuries and the significance of concussion surveillance systems and concussion policies will be discussed in the following sections.

2.4 Definition of Sport-Related Concussion

Sport-related concussion (SRC) is a complex, heterogeneous injury. It is the result of pathological metabolic changes in the brain, induced by biomechanical forces attendant to a direct or indirect blow to the head (McCrory et al., 2017). Each concussion is unique, as the exact force, timing, and location of the impact will be different, as will each individual’s physiology, genetics, and history (Meaney & Smith, 2011). Historically, loss of consciousness was regarded as a primary indicator of concussion injury, however modern definitions do not include loss of consciousness as a criterion for a concussion (McCrory et al., 2017). While concussion injury has the potential to effect neuropathological changes, it is still considered to be chiefly a functional (vs. structural) injury (McCrory et al., 2017). The diagnosis of concussion is made almost entirely on the clinical observation of signs and symptoms, and there is no established objective test to detect concussion. Therefore, clinicians must rely on their own knowledge, understanding and experience to determine the presence of a concussion, and diagnosis may not be clear (Kutcher & Giza, 2014).

2.5 Mechanism of Concussion Injury

The kinematic parameters of the brain likely play a role in determining the likelihood of an injury, as they may help to predict the brain’s inertia (Duma & Rowson, 2014). The two main categories of forces that cause TBI are contact and inertial (Meaney & Smith, 2011). When the head makes direct contact with another surface, both contact and inertial forces are exerted on the brain, while head motions without direct contact result in inertial forces only (Meaney & Smith, 2011). Inertial forces appear to be the principal cause of concussion injuries. The
component of the acceleration exerted on the brain with this inertial force can also play a role in brain injury. When there is an impact to the head, the brain is acted on by both linear and rotational forces. Research indicates that each of these forces seems to have a different and distinct effect on the brain, both of which contribute to the development of an injury. The linear forces to the head induce a brief intracranial pressure gradient, whereas the rotational forces generate neural tissue strain in the brain (Duma & Rowson, 2014). A cohort study of male high school and collegiate football players found that players who were subsequently diagnosed with a concussion following an impact experienced average peak linear acceleration of 112.1±35.4g and average peak rotational acceleration of 4253±2287rad/sec² (Beckwith et al., 2013). However, a similar study of female collegiate ice hockey players found impacts associated with concussions had an average linear acceleration of only 43.0±11.5g and average rotational acceleration of 4030±1435rad/sec² (Wilcox et al., 2015). This suggests that the forces required to produce a concussion may be sex-specific, and furthermore that less linear acceleration of the head is needed to cause a concussion in females. As synchronized swimming is an all-female sport, it is important that concussions be investigated in these athletes, as they may be more at risk for concussion simply because of their sex.

Synchronized swimmers have the potential to experience both contact and inertial forces to the head, as they could directly strike their head against another surface/object/person, or experience indirect forces through impact to the body. Direct contact could be experienced with their teammates during failed highlight maneuvers, pattern changes (rearranging of the athletes into different formations) and the execution of choreography while on the wrong count or in the wrong place in the pattern. Direct contact with a surface or object could also be experienced through collision with the wall or bottom of the pool, or during dryland training. Indirect forces would likely be less commonly experienced, however could be possible in some scenarios. Given all of these opportunities for contact, and that it appears that the amount of force needed to cause a concussion in females appears to be less than that needed in males, it is definitely possible that synchronized swimmers could be concussed during the practice of their sport.

Numerous studies have examined mechanism of injury of concussion in collision and contact sports. Descriptive epidemiological studies of concussion in multiple sports have identified contact with another athlete as the most common mechanism of injury at both the high school (Marar, McIlvain, Fields & Comstock, 2012; Meehan, d’Hemecourt, Collins & Comstock, 2011)
and collegiate level (Zuckerman et al., 2015). These studies were conducted in the United States and used data collected through national online injury surveillance systems. Contact with another player was also identified as the most frequent mechanism of injury in a Canadian collegiate population, in a study that used interviews and viewing of game film to collect injury data (Delaney, Puni & Rouah, 2006). A study of concussions in youth hockey comparing teams from Alberta and Quebec found player contact to be the mechanism of injury in the majority of concussions (Emery et al., 2010). This comparison study also collected data from an online injury reporting system, to which each team’s athletic therapist reported concussions sustained by players on their team. At a professional level, video analysis has been used to investigate the mechanism of injury in concussions in football (soccer) (Andersen, Arnason, Engebretsen & Bahr, 2004) and ice hockey (Hutchison, Comper, Meeuwisse & Echemendia, 2015). Consistent with the findings from collegiate and youth athletes, Hutchison and colleagues (2015) found contact with another player to be the most common mechanism of injury.

A concussion is primarily a functional injury. Diagnostic imaging tests that use conventional technologies are negative the majority of the time (Bigler & Maxwell, 2012), meaning that there is no significant detectable structural damage to the brain. In fact, any physical damage concomitant to mTBI occurs at the cellular level, on the scale of microns and nanometers (Bigler, 2014), too small to be detectable with computerized tomography (CT) scans or magnetic resonance imaging (MRI). New and emerging imaging technology is now able to capture this minute structural damage. Diffusion tensor imaging (DTI) is a form of MRI with a high enough resolution to image microstructural components of the brain. DTI uses the differential diffusion of water molecules across different tissue types to produce an image (Basser & Jones, 2002). The principal use of DTI is for research purposes; however, the technique is potentially valuable as both a diagnostic and prognostic clinical tool (Gardner et al., 2012).

The primary structural damage in mTBI appears to be in the white matter, with projecting axons being especially vulnerable to tensile strain from an impact (Bigler, 2014) due to their lattice-like morphology. Effects from mild neuronal damage are temporary; as the severity of the structural damage to the neurons increases, so does the likelihood that there will be permanent deleterious effects (Bigler, 2014). It is possible that myelination may confer a degree of protection to axons, as there is evidence that unmyelinated fibres may be more vulnerable to, and experience greater impairment from, fluid percussion injury (Reeves, Phillips & Povlishock, 2005).
2.6 Pathophysiology of Concussion

The microscopic injuries to the tissue induce a sequence of pathophysiological events in the neurons, which has been characterized as a neurometabolic cascade. This cascade has been well described by Giza and Hovda (2001; 2014). It was first defined in animal models, with parts now being substantiated in human studies (Giza & Hovda, 2014). The biomechanical insult to the neurons initially produces an abnormal ion flux over the cell membrane coupled with uncontrolled excitatory neurotransmitter release (Giza & Hovda, 2014). Disruption of the permeability of the neuronal cell membrane causes an influx of sodium and calcium ions with an efflux of potassium ions (Giza & Hovda, 2001). This disturbs the ion gradient across the cell membrane. Normally, the healthy neuron maintains the membrane ion gradient with the ATP-dependent sodium-potassium pump. This gradient is essential for proper neuron function, as the movement of ions across the membrane produces the depolarization and repolarization necessary to create action potentials. The sudden and abnormal ion flux following a concussive blow induces depolarization of the cell membrane, which initiates the wholesale release of excitatory neurotransmitters, especially glutamate (Signoretti, Lazzarino, Tavazzi & Vagnozzi, 2011).

In order to counteract the diffuse depolarization, the neurons attempt to restore the membrane gradient using the sodium-potassium pump, requiring large amounts of energy in the form of ATP. This process is referred to as a period of hypermetabolism and results in hyperglycolysis and a depletion of cellular energy stores (Giza & Hovda, 2014). Following the rapid and widespread depolarization, the brain undergoes the phenomenon of ‘spreading depression’, or inactivity (Hovda, Giza, Bergsneider & Vespa, 2014). Concurrent with the increase in cellular energy demands, cerebral blood flow (which supplies oxygen and glucose) is often reduced due to the concussive blow, and an energy ‘mismatch’ ensues (Giza & Hovda, 2001). This energy mismatch is compounded by the influx of calcium ions hampering the mitochondria’s ability to perform the redox reactions needed to produce ATP (Signoretti, Lazzarino, Tavazzi & Vagnozzi, 2011). The calcium ion flux can also activate cell death pathways and interfere with neural connectivity via disruption of neurofilaments and microtubules (Giza & Hovda, 2001).

The hypermetabolism phase is followed by a hypometabolism phase caused by the energy mismatch, during which cells must use anaerobic respiration to produce energy as aerobic pathways are unavailable (Hovda, Giza, Bergsneider & Vespa, 2014). This hypometabolism can
last for as long as 28 days post-injury (Bergsneider et al., 2000), and causes a spike in cellular lactate and lactic acid, which in turn leads to acidosis and additional membrane breakdown, thus perpetuating the energy crises further (Hovda, Giza, Bergsneider & Vespa, 2014). The metabolic deficit and depressed activity of the brain is believed to be the source of concussion-associated impairments (Giza & Hovda, 2014).

In addition to the metabolic mismatch and energy crises, other pathological processes occur in the neurons following a concussive impact. Abnormally low cellular levels of magnesium have been observed, which can contribute to impaired ATP production as well as hamper protein synthesis and alter membrane receptors to promote further calcium influx (Giza & Hovda, 2001). Concussion alters both excitatory and inhibitory neurotransmission, particularly through modification of N-methyl-D-aspartate (NMDA) receptors and γ-aminobutyric acid (GABA) neurons and receptors (Giza & Hovda, 2014). Studies suggest a significant change in blood levels of brain injury biomarkers following a sport-related concussion (Bouvier et al., 2017; Di Battista et al., 2018; Shahim et al., 2014), however there is not enough evidence to date to support the use of biomarkers as a clinical assessment tool (McCrea et al., 2017). Neuroinflammation, as evidenced by higher than normal levels of cytokines, upregulated inflammatory genes, and activation of microglia, also appears to be present following concussive injury (Di Battista, Churchill, Rhind, Richards & Hutchison, 2019; Giza & Hovda, 2014).

These disruptions all act to produce the constellation of signs and symptoms of concussion, and its observed effects. Evidence indicates that cognition can be disrupted following a concussion. Acute cognitive impairment in terms of comparison to pre-injury neuropsychological scores has been found for at least two days following a concussive injury (Bleiberg et al., 2004). A study of cognition in concussed symptomatic Australian Rules football players found dysfunction of motor systems and attention, but not of learning and memory (Collie, Makdissi, Maruff, Bennell & McCrory, 2006). Guskiewicz, Ross and Marshall (2001) found concussed athletes had significantly lower scores on tests of postural stability and on certain cognitive tests than healthy controls one day after injury. A meta-analysis of the neuro-cognitive impact of concussion found strong acute effects on the domains of delayed memory, memory acquisition, and global cognitive functioning (Belanger & Vanderploeg, 2005). These effects had dissipated by seven days post-injury. A case-control series study of cognitive performance of injured varsity athletes found that concussed athletes performed significantly worse than uninjured athletes on the Code
Substitution Learning, Match to Sample, and Simple Reaction Time subtests of the Automated Neuropsychological Assessment Metrics (ANAM) (Hutchison, Comper, Mainwaring & Richards, 2011). However, there was no significant difference in performance of the concussed athletes from that of athletes with musculoskeletal injuries on any of the ANAM subtests, indicating that it may be the state of being injured that disrupts cognitive function rather than a concussion specifically. Teasing apart the effects of sport injury in general from the unique effects of a concussion injury remains one of the necessary focuses for future concussion research.

Another hallmark of concussion pathophysiology is the disruption and dysfunction of the autonomic nervous system (ANS). The ANS consists of two branches: the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). These branches have generally opposite functions and effects on the other body systems, and work together in concert to allow the body to react to the environment and to maintain homeostasis. Control of the ANS is involuntary and input is from the central nervous system and feedback loops from other body systems. The SNS, often considered the “fight or flight” system, has the general effect of mobilizing the body for action; for example heart rate, perspiration, and blood pressure increase, blood supply is increased to skeletal muscles and decreased to internal organs, and pupils and bronchioles are dilated. The PNS, described as the “rest and digest” system, has roughly the opposite effects: heart rate decreases, blood flow increases to the intestinal tract and decreases to the periphery.

When functioning normally, the SNS is fast-acting and reactive to environmental conditions while the PNS is slow-acting with a dampening effect on the SNS. However, under conditions of chronic stress the function of the ANS is disrupted. This is observed through elevated sympathetic tone, raised cortisol levels, and dampening of the baroreflex (Lucini, Di Fede, Parati & Pagani, 2005). One objective marker used to measure ANS function is heart rate variability (HRV). HRV is a measure of the variance in the interval between heart beats (Berntson et al., 1997). HRV measurement can be broken down into different frequency components. The high frequency component is characterized as a measure of parasympathetic tone, the low frequency component as a measure of sympathetic tone or ANS balance, and the ratio between the two as an index of the interaction between the SNS and PNS (Xhyheri, Manfrini, Mazzolini, Pizzi & Bugiardini, 2012).
An injury such as a concussion can be a very stressful experience for an athlete, and as such one would expect to observe autonomic dysfunction in concussed athletes. Indeed, several studies of ANS activity in individuals with head injury have found a significant effect on HRV. A study of HRV in patients with severe TBI found that those with decreased HRV and parasympathetic tone during the awakening period (period after removal of sedation) had worse neurological outcomes as compared to those with higher HRV and better parasympathetic tone (Rapenne et al., 2001). A comparison study of 14 concussed athletes and 14 matched controls found a difference in HRV during exercise, with the concussed group demonstrating lower levels of HRV compared to their matched controls, even when the concussed group’s symptoms had abated (Gall et al., 2004). A study of stress measures in concussed athletes from time of injury to post return-to-play found significantly decreased HRV high frequency norm (a rough measure of parasympathetic activity) and significantly increased low frequency norm (rough measure of sympathetic activity) in the concussed group immediately (2-7 days) after injury, as compared to their matched controls (Senthinathan, 2013). Interestingly, these disruptions in HRV resolved back to normal levels by the time the athletes returned to play. These results indicate that there is some effect of concussion on autonomic function, particularly in the days following the injury, and that this dysfunction can be detected through HRV measurements. Furthermore, the disruptions to HRV induced by concussion appear to be greater in female athletes, indicating that females may be more susceptible to parasympathetic dysfunction after a concussion (Hutchison et al., 2016). This finding has particular significance for synchronized swimmers given Schaal et al.’s (2013) findings that synchronized swimming significantly decreases parasympathetic activity and increase sympathetic activity.

In addition to findings of physiological markers of stress in concussed athletes, research has shown that concussed athletes exhibit elevated levels of psychological stress. An athletic injury of any type can be very stressful for an athlete. Injured collegiate athletes have higher levels of anxiety and depression and lower self-esteem than uninjured controls immediately following an injury and at a two-week follow-up (Leddy, Lambert & Ogles, 1994). However, there do appear to be differences in the way athletes react to a concussion injury compared to an orthopaedic injury. Mainwaring, Hutchison, Bisschop, Comper and Richards (2010) found different patterns of emotional disturbance post-injury between concussed and ACL-injured athletes. This may be due to the unique physiological effects of a concussion on the brain, and/or may be from the
differences in the post-injury experience. Part of these differences is the current treatment practice of complete rest following a concussion. One week post-injury, concussed athletes reported significantly lower levels of active, planning, acceptance, religion, self-distraction, venting, and self-blame coping strategies than athletes who had suffered an orthopaedic injury (Kontos, Elbin, Newcomer Appaneal, Covassin & Collins, 2013). It is possible that the complete rest is preventing athletes from utilizing many of the coping strategies at their disposal and in turn causing higher levels of stress. It is clear from these findings that concussed athletes are experiencing elevated levels of both physical and psychological stress following injury, and there is a need for more effective stress management strategies during the post-injury period.

2.7 Concussion Assessment and Management

While the search for a reliable biomarker of concussion continues, several objective methods of concussion assessment have been developed to assist clinicians in the evaluation and management of concussed athletes. These approaches include neuropsychological tests, balance tests, and vestibulo-ocular assessments.

The deleterious effect of concussion on balance has been consistently demonstrated. Guskiewicz, Perrin and Gansneder (1996) evaluated the effects of mild head injury on postural sway in high school and collegiate athletes using a computerized posturography system. The mostly male injured participants showed significantly greater postural sway as compared to matched controls up to three days after sustaining a mild head injury. Furthermore, a portion of the injured participants who performed pre-season screening showed a significant increase in postural sway on day one following injury compared to their pre-season scores, which resolved to baseline by day three to five post-injury. Guskiewicz, Ross and Marshall (2001) reported changes in postural stability in concussed collegiate athletes using two different methods, a sensory organization test (SOT) performed on a computerized forceplate and the Balance Error Scoring System (BESS). Concussed athletes were found to have significantly worse SOT scores on day one post-concussion as compared to their baseline scores, and significantly worse scores as compared to controls at one, three and five days post-concussion. A similar pattern of results was observed on the BESS, with significantly worse scores compared to baseline on day one
post-concussion, and significantly worse scores compared to controls at one, three and five days following concussion.

There is some evidence to indicate that balance deficits associated with concussion may be related to symptoms. A study of balance in concussed collegiate athletes grouped by their report of headache (PTH) following concussion found that the presence of PTH had a significant effect on postural sway (Register-Mihalik, Mihalik & Guskiewicz, 2008). Similarly, correlation between self-reported ‘dizziness’ and SOT scores in concussed collegiate athletes has also been reported (Broglio, Sosnoff & Ferrara, 2008). Balance changes following concussion may also be modulated by age and sex. In a study of concussed high school and collegiate athletes, high school males scored slightly worse on the BESS than high school females, and collegiate females scored significantly worse than collegiate males (Covassin, Elbin, Harris, Parker & Kontos, 2012). In addition, high school males scored significantly worse on the BESS than collegiate males, while high school females scored significantly better than collegiate females. Howell, Osternig and Chou (2015) compared dual-task gait balance control performance following concussion in adolescents and young adults. At 72 hours post-concussion there was a significant difference in gait balance control between concussed versus healthy adolescents, however no significant difference was observed between the concussed and healthy young adults. Furthermore, the difference in performance between the concussed and healthy adolescents persisted for the entire two month testing period. Benedict and colleagues (2015) found older age to be associated with worse scores on the BESS following concussion, but no significant relationship between gender and BESS scores in concussed patients at a multidisciplinary concussion center. No significant sex differences in BESS scores were reported in a younger (mean age around 14 years) sample of concussion patients (Sufrinko et al., 2017), suggesting that the effects of sex on balance post-concussion may not emerge until after adolescence.

The inconsistency of the findings relating to the influence of age and sex on balance following concussion may be related to the variety of methods through which it is assessed. In a systematic review of the validity and reliability of balance tests in concussed athletes that included literature on the BESS, SOT, Clinical Test of Sensory Organization and Balance (CTSIB), the Romberg test and the Wii Fit, the BESS was the only test that had reliability and validity evidence for use in the target population of concussed athletes (Murray, Salvatore, Powell & Reed-Jones, 2014). Furman and colleagues (2013) compared the BESS with the National Institute of Health’s
Balance Accelerometer Measure (BAM) in the ability to distinguish acutely concussed, non-acutely concussed, and healthy controls in a sample of adolescent athletes. They reported the BAM could only weakly differentiate non-acutely concussed patients from controls, and could not distinguish between acutely concussed patients and controls. Conversely, the BESS identified both acutely and non-acutely concussed patients from controls. While these findings seem to indicate the BESS is the best test to use in concussion assessment in athletes, some reports call that into question. Practice effects have been reported in both high school and collegiate athletes with repeated administration of the BESS (Mulligan, Boland & McIlhenny, 2013; Valovich, Perrin & Gansneder, 2003), as would be the case in an athlete population that undergoes seasonal baseline testing. In order to increase the sensitivity of the BESS to detect subtle balance changes post-concussion, King and colleagues (2014) suggested introducing an inertial sensor worn on the lumbar spine while performing the test. This ‘instrumented BESS’ has been found to have superior diagnostic ability compared to the clinical BESS score in both chronic (King et al., 2014) and acutely concussed patients (King et al., 2017).

It is consistently demonstrated in the literature that concussion has an effect on objective measures of balance and postural stability. Balance tests, especially the BESS, are an important part of comprehensive concussion management and can assist clinicians in monitoring an athlete’s recovery following concussion.

Deficits in vestibular and ocular functioning following concussion have also been consistently demonstrated. A retrospective review of pediatric patients with acute sport-related concussion or post-concussion syndrome (PCS) found that 29% of acutely concussed patients and 63% of PCS patients met study criteria for vestibule-ocular dysfunction, defined as the presence of at least one subjective complaint and one abnormal result on vestibular/ocular assessment (Ellis et al., 2015). Furthermore, the same study found that a concussed athlete’s odds of developing PCS increased with the diagnosis of vestibule-ocular function (Ellis et al., 2015). Other retrospective reviews of youth sport-related concussion patients have reported that those with abnormal vestibulo-ocular signs at the time of initial evaluation after the concussion take longer to recover than those without (Anzalone et al., 2017; Corwin et al., 2015). Patients with a history of three or more previous concussions had a higher prevalence of vestibular dysfunction, and took longer for those signs to resolve, than patients with a history of two or fewer concussions (Corwin et al., 2015). The test commonly used in these studies is the Vestibular/Ocular Motor Screening
Assessment (VOMS), which consists of assessments of five domains: smooth pursuits, horizontal and vertical saccades, convergence, horizontal vestibular ocular reflex and visual motion sensitivity (Mucha et al., 2014). Studies of the VOMS have reported high internal consistency and a false positive rate of 2-11% (Kontos, Sufrinko, Elbin, Puskar & Collins, 2016; Worts, Schatz & Burkhart, 2018), as well as an ability to identify concussion in adolescent athletes (Mucha et al., 2014).

Another vision test widely studied in sport-concussion research is the King-Devick test (K-D). The K-D was originally developed to assess reading abilities through the detection of changes in saccadic rhythm (Lieberman, Cohen & Rubin, 1983). It involves rapid naming of strings of numbers in horizontal rows; response times and number of errors are counted (Kulp & Schmidt, 1997). Worsened K-D scores following concussion have been reported in numerous sports and in youth, collegiate and adult athletes, including adult boxers and mixed martial arts fighters (Galetta et al., 2011a), adult and junior club-level rugby athletes (King, Brughelli, Hume & Gissane, 2013; King, Hume, Gissane & Clark, 2015), collegiate football athletes (Galetta et al., 2011b; Leong et al., 2015), collegiate soccer and basketball athletes (Galetta et al., 2011b), and adolescent football athletes (Seidman et al., 2015). A meta-analysis of the K-D test in sports concussion reported weighted estimates of a 4.8 second increase (worsening) in K-D scores following concussion and a 1.9 second improvement in K-D scores in control athletes at re-test (Galetta et al., 2016). The meta-analysis also reported a pooled sensitivity of 86% and 90% pooled specificity (Galetta et al., 2016). These findings seem to indicate that the K-D test is an effective sideline test for detecting concussion. However, in a comparison of K-D scores between mTBI patients to non-head injured patients presenting to an emergency department, there was no significant differences between K-D scores of each group and regression analysis indicated that K-D scores did not contribute over any other measure for predicting the presence of mTBI (Silverberg, Luoto, Öhman & Iverson, 2014). Furthermore, Worts et al. (2018) reported a false positive rate for the K-D test of 36% in a sample of healthy high-school athletes. Despite this, the literature to date appears to support the use of test such as the VOMS and K-D to assist in the detection of ocular/vestibular dysfunction associated with sport-related concussion.

Perhaps the most widely used objective assessment in concussion are neuropsychological (NP) tests. These batteries typically consist of several tests of different components of
neuropsychological functioning and can be computerized or paper and pencil. Commonly used NP tests include the Immediate Post-Concussion Assessment for Cognitive Testing (ImPACT), the Sport Concussion Assessment Tool- 5th Edition (SCAT5 and Child SCAT5), the Automated Neuropsychological Assessment Metrics (ANAM) and CogSport/CogState. A survey of schools participating in the High School Reporting Information Online (HS RIO) injury surveillance system found 39.9% of participating schools reported using computerized NP testing in concussion management (Meehan III, d’Hemecourt, Collins, Taylor & Comstock, 2012). Another survey of high school and collegiate athletic trainers reported that 94.7% of respondents administered baseline NP tests to athletes, while 87.5% of respondents used NP testing to assess concussions (Covassin, Elbin, Stiller-Ostrowski & Kontos, 2009).

Baseline NP testing refers to the practice of administering cognitive tests to athletes before a season begins to establish a pre-concussion ‘baseline’ score. The rationale for this approach is that the test can be re-administered if an athlete sustains a concussion during the season and the scores compared to their individual baseline scores as a marker of cognitive recovery. This approach has been criticized for not modifying concussion risk, being cost prohibitive in terms of time and money, being vulnerable to numerous sources of random error and potentially creating a false sense of confidence in clinicians using these tests to determine when an athlete is ready to return to play (Resch, McCrea & Cullum, 2013). Nevertheless, baseline testing is a prevalent practice at many different levels of sport participation and is used as part of the procedure in many research studies.

There is consistent evidence in the literature that suffering a concussion has an effect on athletes’ NP test scores. A study of 64 high school athletes found significantly worsened ImPACT memory scores at 36 hours and days 4 and 7 following concussion as compared to their baseline scores (Lovell et al., 2003). Similar findings were reported in a larger sample comprised of 104 concussed high school and collegiate athletes that compared ImPACT scores at day 2, 7 and 14 post-concussion to baseline values (McClincy, Lovell, Pardini, Collins & Spore, 2006). These athletes had significantly worse verbal memory, visual memory, processing speed and reaction time scores at day 2 post-concussion, with the significant decreases in visual memory and reaction time scores persisting at day 7 and verbal memory scores at day 14 post-injury (McClincy et al., 2006). Freshman boxers who sustained a concussion during the academic year demonstrated impaired performance on the ANAM on the day of injury and on days 1 to 2 post-
concussion (Bleiberg et al., 2004). A prospective study of concussion recovery in male high school and collegiate athletes reported significant differences from baseline scores on components of the SAC, ANAM, and ImPACT at 24 hours post-concussion (Wang et al., 2016). Adolescent lacrosse and soccer players demonstrated a significant decrease in all ImPACT composite scores within three days of concussion as compared to their baseline scores (Sandel, Schatz, Goldberg & Lazar, 2017). The apparent robust effect of concussion on neuropsychological functioning suggests that NP testing is a viable assessment strategy in concussion management, and could assist in helping athletes return to play safely. Meehan, d’Hemecourt and Comstock (2010) reported that athletes whose concussions were reported to HS-RIO and had NP testing were less likely to return to play on the same day or in less than one week than athletes that did not receive it.

Research also suggests correlations between NP functioning and other markers used in concussion assessment. Benedict et al. (2015) found higher symptom severity scores were associated with lower SAC scores and higher K-D scores were associated with worse SAC immediate memory scores in concussion center patients. In a retrospective cohort study of pediatric concussion patients, those with abnormal gaze stability or tandem gait scores on intake also scored lower on the neurocognitive aspects of ImPACT, and took longer for their scores to resolve to baseline (Corwin et al., 2015). Pearce and colleagues (2015) found convergence insufficiency was associated with lower scores on the verbal memory, visual motor speed and reaction time components of the ImPACT in concussed youth athletes. Overall, evidence suggests that NP testing can enhance the safe management of sport concussion, but should not be used in isolation as the sole determinant of concussion status or recovery (Resch, McCrea & Cullum, 2013).

Current opinion is that the most effective concussion assessment protocols would include multiple modes of assessment. A comprehensive concussion management plan includes clinical sign and symptom evaluations, NP testing, balance assessment and/or vestibulo-ocular tests. This multi-modal approach has been recommended by multiple governing associations and expert panels (Broglio et al., 2014; Giza et al., 2013; Harmon et al., 2019; McCrory et al., 2017). However, it should be noted that many athletes, especially those participating in sport at a grassroots or community level, may not have access to the resources required to receive that standard of care.
Until recently, clinical practice guidelines emphasized physical and cognitive rest following a concussion. The return to activity guidelines authored by the Concussion in Sport group (McCrory et al., 2013) emphasized rest as the ‘cornerstone’ of concussion management and indicate that complete rest should continue until an athlete is asymptomatic. According to these guidelines, once an athlete is asymptomatic at rest they may begin a graded exercise progression to return to play that involves a gradual increase in intensity and duration of activity, only progressing to the next stage if they are able to complete the current stage symptom-free (McCrory et al., 2013). Other current sport concussion treatment guidelines from the American Academy of Neurology (Giza et al., 2013), the American Medical Society (Harmon et al., 2013), and the National Athletic Trainers Association (Broglio et al., 2014) also emphasized rest until symptoms have eased and a gradual progression towards full activity. The most recent consensus statement from the CiSG indicates that complete rest beyond the initial 24-48 hours following a sport concussion is not supported by empirical evidence, and that gradually resuming activity at a level that does not induce symptoms may be more beneficial (McCrory et al., 2017).

The pathophysiological mechanisms underlying concussion provide part of the rationale behind the treatment practice of prescribed rest. Research indicates that the majority of axonal damage and cellular disruption that occurs with a concussion can be resolved with a full return to function, given sufficient time (Grady, Master & Gioia, 2012). Thus a large part of the rationale for rest is that in order to promote full structural and functional recovery during a post-injury period characterized as a metabolic mismatch, one must avoid putting further metabolic demands on the brain (Silverberg & Iverson, 2013). Exercise and activity appears to exacerbate symptoms, especially shortly after the injury, which has been taken as evidence to support rest (Silverberg & Iverson, 2013). Furthermore, past research has suggested the brain may be more vulnerable to further injury during this period, and as such activities that may confer risk of a second impact should be avoided (Wells, Goodkin & Griesbach, 2015). However, evidence for this is equivocal, with other research finding that the second impact phenomenon may not exist (Hebert et al., 2016).

Results from animal studies appear to support an initial rest period. Forced activity during the first seven days following brain lesion in rats resulted in worsening of the neuronal injury and
impaired return of function, while the same activity implemented after seven days only affected functioning (Humm, Kozlowski, James, Gotts & Schallert, 1998). A study using a fluid percussion injury (FPI) rat model found lower levels of exercise-dependent neuroplastic factors and higher levels of cognitive impairment in rats that were exercised immediately after injury, as compared to sham (uninjured) rats, sedentary injured rats and injured rats that were exercised after a 14 day delay (Griesbach, Hovda, Molteni, Wu & Gomez-Pinilla, 2004).

In contrast, there is a lack of evidence in humans to support a period of rest following a concussion. One retrospective study assigned concussed high school and collegiate athletes who had been prescribed a week of cognitive and physical rest into one of three groups based on timing of rest prescription after the injury. Results found that both symptom scores and Immediate Post-Concussion Assessment & Cognitive Testing (ImPACT) measures significantly improved following a prescribed rest period, regardless of how long after the injury the rest was prescribed (Moser, Glatts & Schatz, 2012). However, with no comparison group, it cannot be concluded for certain that rest in and of itself produced the improvements, which may have simply been due to the passage of time. Furthermore, a subset of concussed athletes who were prescribed additional rest beyond the one week showed no difference in symptom scores after the extra rest compared to the group who only performed the initial rest. Another retrospective study with student-athletes used self-report and found that athletes who engaged in a moderate level of activity after a concussion had better neurocognitive outcomes than athletes who engaged in either no or high levels of activity (Majerske et al., 2008). Furthermore, a randomized control trial of emergency room mTBI patients found no significant differences between patients who underwent full bed rest for six days and patients who had no bed rest in post-traumatic complaints at two weeks, three months, or six months (de Kruijk, Leffers, Meerhoff, Rutten & Twijnstra, 2002). Results from these studies indicate at best a very weak effect of rest, and taken together fail to reliably demonstrate that rest is of significant benefit after a concussion.

There are several outstanding issues with the designation of complete rest as a gold-standard for concussion management. Overall, there is a lack of high-quality evidence for the utility of rest after a concussion. A systematic review of the effect of rest and treatment in sport concussion management found that while an initial rest period is potentially favourable, overall evidence for rest following a concussion is scant (Schneider et al., 2013). A later review of clinical trials also highlighted the lack of methodologically rigourous studies directly examining principles of
return to activity (RTA), including rest (Burke, Fralick, Nejatbakhsh, Tartaglia & Tator, 2015). Furthermore, there is a lack of any clear standardized definitions of what ‘complete rest’ entails. In order for the field to progress to more evidence-based management strategies there must be a consensus on the definition of rest. Finally, there is some controversy over the reliance on symptoms to guide recovery decisions. Some research appears to indicate that the presence or absence of symptoms is not an accurate indication of the underlying physiological state. There are low levels of symptoms typically associated with post-concussion (e.g. dizziness, headache, etc.) present in other injured and medical populations, in the general population when exercising, and even in the general population at rest (Alla, Sullivan & McCrory, 2012). Various neurophysiological measures have been found to remain abnormal beyond the “recovery” of clinical signs and symptoms. Electroencephalogram (EEG) measures of brain activity in concussed athletes remained significantly different from uninjured controls eight days after injury, even though symptom scores were no longer different from those of controls (Barr, Prichep, Chabot, Powell & McCrea, 2012). Slobounov et al. (2011) found dysfunction of hemispheric connectivity in concussed athletes who were asymptomatic on both clinical evaluations and neuropsychological tests. A study monitoring concussions in a collegiate football team found a subset of athletes who did not display any outward signs of a concussion and as such were never diagnosed with or treated for one, who had significantly reduced scores on neurocognitive domains of the ImPACT assessment and significantly decreased brain activation during an fMRI cognitive task (Talavage et al., 2014). Taken together, these findings indicate that symptoms may be a poor indicator of underlying neurophysiological and functional status.

More recently, opinion has shifted to consider that complete rest may actually have detrimental effects. A 2015 review identified the following potentially harmful effects of protracted rest following a concussion: anxiety, depression, the “nocebo” effect (development of illness due to expectations of illness), physical deconditioning and exercise tolerance, and negative impact on psychological well-being (DiFazio, Silverberg, Kirkwood, Bernier & Iverson, 2015).

Due to these realizations, some researchers have been investigating the potential role for exercise in concussion recovery. Exercise has been introduced as a therapy in many conditions that the previous standard of practice has been to prescribe rest. Favourable effects of exercise have been found in low back pain (Deyo, Diehl & Rosenthal, 1986), neuropathic pain (Dobson, McMillan
& Li, 2014), whiplash (Schnabel, Ferrari, Vassiliou & Kaluza, 2004), and stroke (Billinger et al., 2014), as well as in several neurodegenerative disease contexts such as Parkinson’s disease (Ebersbach, 2015), multiple sclerosis (Motl & Sandroff, 2015), and Alzheimer’s disease (Frederikson, Sobol, Beyer, Hasselbach & Waldemar, 2014). In addition, there is already some evidence to support the use of exercise in a concussion context. Leddy and colleagues (2010) conducted a pilot study examining the effects of a sub-symptom threshold treadmill exercise program in six athletes and six non-athletes with refractory post-concussion syndrome (PCS), and found a significant reduction in symptom score after the treatment period. Another study with slow to recover concussed adolescents found that concussion symptoms and mood improved and fatigue was decreased following an active intervention using light aerobic exercise, co-ordination exercises, mental imagery and stress reduction (Gagnon, Grilli, Friedman & Iverson, 2015). A review of the literature on the use of the Buffalo Concussion Treadmill Test and the Buffalo Concussion Bike Test found that identifying an individualized ‘dose’ of sub-symptom threshold exercise can speed recovery in post-concussion syndrome, and potentially in acute concussion as well (Leddy, Haider, Ellis & Willer, 2018). These results indicate the potential for exercise to be used during the post-concussion rehabilitation period. However, despite some indications that rest may not be the best management strategy, to date the evidence is not yet robust enough to replace the existing standards.

This literature is significant given that governing bodies in synchronized swimming are beginning to develop synchro-specific ‘return to pool’ guidelines for concussion management. It is important for the health and safety of the athletes that these guidelines are based on the most up-to-date knowledge and understanding of the most effective concussion management strategies.

### 2.8 Sex- and Age-Related Differences in Concussion

Sex differences have been consistently observed in the sport concussion literature in terms of occurrence, symptoms, performance on assessments, and course of recovery. It is often reported that the rate of concussion is higher in females than males in comparable sports, however other findings contradict that assertion. In a review of concussion sex differences in adults, Merritt, Padgett and Jak (2019) found that within studies of soccer, basketball and baseball/softball the
overall finding is that female concussion rates are higher. However, findings from ice hockey and lacrosse are equivocal, with some studies finding no significant differences, some reporting higher rates in males and some higher rates in females (Merritt et al., 2019).

There appears to be a robust effect of sex on concussion symptom profiles. Covassin et al. (2006) found that females were significantly more likely than males to endorse 14 of the concussion symptoms on the ImPACT at baseline amongst 1209 American collegiate athletes. A similar pattern of results were reported in a sample of 260 Canadian collegiate athletes, in which women had a higher mean Post-Concussion Symptom Score (PCSS) than men and lower number of total ‘0’s (Shehata et al., 2009). The same trend has been reported in athletes post-concussion. A prospective cohort study of high school and collegiate athletes reported more symptoms in females than males following concussion (Covassin, Elbin, Harris, Parker & Kontos, 2012). An exploratory factor analysis of the PCSS at baseline and post-concussion for samples of high school and collegiate athletes found that females reported higher levels of cognitive-sensory, sleep-arousal, vestibular-headache and affective symptom factors than males (Kontos et al., 2012). In a retrospective review of 37 concussed youth athletes, Berz and colleagues (2013) reported males had a lower initial symptom score than females, however no significant sex differences were found on any individual symptom scores or in recovery rate. A meta-analysis of 21 cohort studies determined that females were 43% more likely than males to report any symptom at baseline, and had higher odds of reporting difficulty concentrating, problems with hearing/vision, headache/migraine, emotional disturbance and sleep/energy disturbances (Brown, Elsass, Miller, Reed & Reneker, 2015). However, no significant sex differences in symptom reporting were detected following concussion (Brown et al., 2015). Baker et al. (2015) reported that female high school athletes took significantly longer to become asymptomatic following a concussion than male high school athletes. A prospective study examining sex differences in the ImPACT pre- and post-concussion in a pediatric population reported an opposite pattern (Tanveer, Zecavati, Delasobera & Oyegbile, 2017). Males were more likely post-concussion to experience loss of consciousness, confusion and amnesia of before and after event, while females had a higher total symptom score; however, there were no significant sex differences found at baseline (Tanveer et al., 2017).

Sex differences have been reported in other post-concussion outcomes as well. Broshek et al. (2005) reported that along with a greater number of symptoms, females also demonstrate greater
cognitive impairment following concussion than males. Female athletes were found to have higher horizontal scores on the vestibular ocular reflex component of the Vestibular/Ocular Motor Screening tool than male athletes post-concussion, indicative of greater vestibulo-ocular dysfunction (Sufrinko et al., 2017). Sex differences in the location of white matter abnormalities have also been reported in mTBI patients (Fakhran, Yaeger, Collins & Alhilali, 2014).

Moving beyond physiological differences, there also appear to be sex differences in concussion knowledge and reporting. A study of concussion knowledge and reporting in high school athletes found sex differences in levels of concussion knowledge, with females demonstrating significantly higher levels than males, as well as sex differences in reasons for not reporting a concussion (Wallace, Covassin & Beidler, 2017). Female athletes have also been reported to have higher reporting intention than male athletes without any difference in the likelihood that they will continue to play with concussion symptoms (Kroshus, Baugh, Stein, Austin & Calzo, 2017).

Research suggests differences between male and female athletes in terms of concussion vulnerability, symptoms, post-concussion cognitive and physiological effect, and concussion knowledge and reporting behaviour. These differences indicate a need to consider athlete sex when conducting concussion research and implementing concussion education and resources.

Age differences have also been consistently reported in the concussion literature. A comparison of concussion recovery in high school and collegiate athletes reported a longer duration of post-concussion cognitive dysfunction in the high school athletes, even though the collegiate athletes’ concussions were deemed to be more severe (Field, Collins, Lovell & Maroon, 2003). Zuckerman et al. (2012) found adolescent athletes took a longer time on average to return to baseline measures of three ImPACT measures and post-concussion symptom scale, as compared to the average recovery time of young adult athletes. A systematic review and meta-analysis of concussion recovery time in high school and collegiate athletes found that high school athletes self-reported symptom recovery at 15 days, while collegiate athletes self-reported symptom recovery at just 6 days post-concussion (Williams, Puetz, Giza & Broglio, 2015). However, when recovery was measured in terms of neuropsychological test results, recovery times were very similar between high school and collegiate athletes (Williams et al., 2015). It is important to note that this review and meta-analysis was only comprised of six studies. A review including
11 studies reported there is evidence that young athletes take longer to recover than their older peers in terms of both neuropsychological test results and symptoms; however, there is not sufficient evidence to indicate that younger age increases the risk of prolonged (> 4 weeks) recovery (Foley, Gregory & Solomon, 2014).

Baillargeon, Lassonde, Leclerc and Ellemberg (2012) reported a greater reduction in P3b amplitude (an event-related potential evoked by an oddball task) in concussed adolescents than concussed children or concussed adolescents. Covassin et al. (2012) found age-related differences in performance on memory tasks and balance tests following concussion. High school athletes scored significantly worse than collegiate athletes on verbal memory at two and seven days post-concussion and visual memory at two days post-concussion (Covassin et al., 2012). A comparison of dual-task gait balance control deficits in adolescents and young adults post-concussion reported that adolescents experienced greater deficits both initially and throughout the two month recovery period as compared to matched controls (Howell, Osternig & Chou, 2014).

However, other studies examining age differences in concussion have not reported significant differences. In a comparison of symptom scores of 13-16 year old and 18-22 year old athletes at baseline and following concussion, no significant differences were found between age groups for presence of symptoms, severity of symptoms, total symptom scores or in the return to baseline scores (Lee, Odom, Zuckerman, Solomon & Sills, 2013). Nelson and colleagues (2016) examined age differences in the acute recovery following concussion in collegiate and high school athletes, and reported no clinically significant age differences in acute recovery course.

Overall, research findings point towards an effect of an athlete’s age on concussion recovery and post-concussion cognition. This suggests age should be taken into consideration in concussion research and clinical practice. Taken together with the findings of the effects of athlete sex in concussion, this points towards targeting concussion resources and interventions to the specific population of interest. In Ontario, artistic swimmers are almost all female and adolescent or younger. Any concussion prevention efforts or resource implementation should be based on findings from young, female athletes. Ideally, this basis would be findings from the Ontario artistic swimmers themselves. This supports the need for sport-specific concussion research in the province.
2.9 Injury Surveillance Programs

In regards to health-related topics, a surveillance system is typically used in public health settings to collect ongoing data, analyze that data, interpret the results and circulate those results (Holder et al., 2001). Injury surveillance programs have several benefits, including the ability to craft and implement interventions and monitor the impact of said interventions, the appropriate allocation of resources, and the ability for different organizations to compare data and assist one another (Holder et al., 2001). Injury surveillance is an important step in a ‘sequence of prevention’ of sport injuries (van Mechelen, 1997). Step one in the sequence is identifying the problem and describing injury incidence and severity, step two is to recognize the mechanisms and factors leading to injury, this is followed by the introduction of preventative measures and the evaluation of those measures (van Mechelen, Hlobil & Kemper, 1987). While a general injury surveillance system can be valuable in evaluating the incidence and severity of a sports injury problem, the diversity of injuries across different sports makes it incredibly difficult to capture all the potential risk factors for all sports in one system, suggesting that sport-specific surveillance is needed for specific research problems (van Mechelen, 1997).

Injury surveillance systems have been implemented by many different sport organizations. Surveillance has been used by the International Rugby Board (IRB), the Federation Internationale de Football Association (FIFA), the International Olympic Committee (IOC), the National Collegiate Athletic Association (NCAA), U Sports (formerly Canadian Interuniversity Sport), and the National Federation of State High School Associations (NFHS). The IRB established a Rugby Injury Consensus Group (RICG), which produced a consensus statement on the definitions and procedures related to the study of injuries in rugby union (Fuller et al., 2007). An injury surveillance system for rugby union was created based on the standardized definitions and methodologies specified by the RICG, and was implemented to record the incidence, mechanisms and factors associated with injuries at the 2007 IRB Rugby World Cup (Fuller, Laborde, Leather & Molloy, 2008). The IRB’s consensus statement was based on a consensus statement on injury definitions and research procedures for football (soccer) (Fuller et al., 2007). Following the First World Congress on Sports Injury Prevention, FIFA put together a working group to establish a consensus statement regarding the associated definitions and identification of
the issues surrounding reporting and data collection in football injuries (Fuller et al., 2006). The Union of European Football Associations (UEFA) also developed the UEFA model for descriptive injury epidemiology studies in professional football for use in football-specific injury surveillance (Hägglund, Waldén, Bahr & Ekstrand (2005). The UEFA football safety research project was comprised of three stages: consensus discussions within the UEFA Medical Committee, two pilot studies and approval of the design and forms by team doctors (Hägglund et al., 2005). Whereas the systems for football and rugby were developed to be specific to those sports, the IOC needed a surveillance system that could be used across a wide variety of sports (Junge et al., 2008). The IOC adapted a surveillance system used in international football and handball tournaments and piloted its use in team sport events at the 2004 Olympic Games (Junge et al., 2006). This system was modified to also be applicable to individual sports and used for all sports in the 2008 Olympic Games (Junge et al., 2008).

Academic athletic associations have also developed and implemented injury surveillance systems. The governing body of Canadian inter-university sport, now called U Sports, developed and implemented the Canadian Intercollegiate Sport Injury Registry (CISIR) to measure injury rates and athlete risk and serve as an outcome measure for prevention efforts (Meeuwisse & Love, 1998). The system was initially developed to be specific to the sport of football, with the intention of extending it to additional sports (Meeuwisse & Love, 1998). The American counterpart, the NCAA, has developed its own Injury Surveillance System (ISS) which is the largest collegiate sports injury database in the world (Dick, Agel & Marshall, 2007). The ISS uses a representative sample of NCAA institutions to collect injury and exposure data through the athletic trainers at the participating institutions, which is its primary goal (Dick et al., 2007). The secondary goal of the ISS is to provide information to the institutions for risk management decisions (Dick et al., 2007). First developed as a paper-and-pencil system, the ISS was converted to a web-based method and is now on its second iteration of an online platform (Kerr et al., 2014). A strength of the ISS are the data quality control measures incorporated into the system. Data pass through a verification process to flag and correct invalid data before it reaches the database, specifically to assess exposure counts, injury data and time loss (Kerr et al., 2014). As with the CISIR, the NCAA ISS began with football as the sole sport and as of 2005 had expanded to monitor all NCAA championship and emerging sports, as well as 50 club and intramural activities (Dick et al., 2007). At the high school level, the National High School
Sports-Related Injury Surveillance Study uses the High School: Reporting Information Online (HS RIO) tool to measure and describe injuries in high school athletes in the United States. The instruments and methods of the HS RIO are based on those of the NCAA ISS (Kerr, Comstock, Dompier & Marshall, 2018). Injury and exposure data from five boys’ and four girls’ sports are collected through online reports by affiliated athletic trainers (Rechel, Yard & Comstock, 2008). The collection of detailed exposure data allows for the measurement of injury rates in these collegiate and high school populations, a useful measure in epidemiological research.

Data from these various surveillance systems have been reported in the sports injury literature. The IRB reported 83.9 injuries per 1000 player match hours and 3.5 injuries per 1000 player-training hours at the 2007 Rugby World Cup, with lower limb muscle and ligament injuries being the most common (Fuller et al., 2008). At the 2010 Women’s Rugby World Cup, a match injury incidence of 35.5/1000 player hours was reported, with knee ligament injuries reported most frequently (Taylor, Fuller & Molloy, 2011). A match injury incidence of 89.1/1000 player hours and training injury incidence of 2.2/1000 player hours, again with lower limb muscle/tendon/ligament injuries being the most common, was measured at the 2011 IRB Rugby World Cup (Fuller, Sheerin & Targett, 2012). The UEFA football injury study reported an incidence of 8.0/1000 player hours from 2001 to 2008 among players from 23 UEFA teams (Ekstrand, Hägglund & Waldén, 2011). Similar to findings from rugby, incidence was higher in matches than in training, and thigh strain was the most commonly reported injury (Ekstrand et al., 2011). The IOC surveillance system captured a clinical incidence of 111.8 injuries per 1000 athletes and an injury risk of 11% at the 2010 Olympic Winter Games (Engebretsen et al., 2010) and a clinical incidence of 128.8 injuries per 1000 athletes and the same injury risk of 11% at the 2012 Olympic Summer Games (Engebretsen et al., 2013). Data from the NCAA ISS have been reported in a multitude of publications specific to different sports and injury types. The overall injury rate from the 2009-10 through 2013-14 academic years was estimated to be 6.0 per 1000 athlete exposures, with sprains and strains being the most commonly reported injury type (Kerr et al., 2015). Similarly, numerous publications report the descriptive epidemiology of injuries at the high school level for each specific sport using the HS RIO system.

Epidemiological studies specific to concussion have also used data from these surveillance systems. An overall incidence of concussion of 12.5/1000 player match hours was reported at the 2015 Rugby World Cup (Fuller, Fuller, Kemp & Raftery, 2016). The UEFA injury study
measured a concussion incidence of 0.06/1000 player hours amongst 26 teams from the 2001-02 through 2009-10 seasons (Nilsson, Hägglund, Ekstrand & Waldén, 2013). Analysis of 25 sports in the NCAA found an overall incidence rate of 4.47 per 10,000 athlete-exposures, with the highest incidence rates occurring in men’s wrestling, men’s and women’s ice hockey, and football (Zuckerman et al., 2015). A descriptive epidemiology of concussion in 20 sports using data from HS RIO reported an overall concussion incidence of 2.5 per 10,000 athlete exposures in the 2008-10 academic years (Marar, McIlvain, Fields & Comstock, 2012).

None of the aforementioned studies included artistic or synchronized swimming. It has been noted that due to variations in injury trends and issues between different populations, it is necessary to gather data specific to distinct groups in order to properly characterize injuries and implement intervention strategies in those groups (Graitcer, 1987). Van Mechelen (1997) argues that sports injury problems are very sport-specific and many specific etiological factors can be at play simultaneously, which suggests the need for a sport-specific surveillance system over a general one. Therefore, due to the possibility in artistic swimming for contact of the type that could cause a concussion injury, it is important that sport-specific epidemiological studies be conducted.

2.10 Concussion Policy, Resources and Education

Increase in the awareness of the risk of sustaining a concussion while participating in sports, coupled with awareness of the potential seriousness of a concussion injury and the need for proper detection and management of concussions, has sparked governments, school boards, and sport organizations to design and implement concussion policies and procedures. While every state in the United States had some form of legislation mandating concussion management guidelines and education programs in place by 2014, Canada had lagged behind (Hachem, Kourits, Mylabathula & Tator, 2016). Following the death of a young athlete due to complications from a sports related concussion injury, the province of Ontario introduced and enacted legislation mandating the establishment of an advisory committee to make recommendations based on the findings of the coroner’s inquest (Bill 149, 2016). While this was related to sport concussion, it did not include any policy or recommendations for concussion prevention or management. In 2014 the Ontario Ministry of Education implemented a program
requiring school boards to introduce concussion management and prevention policies (PPM No. 158); however, this is not formal legislation (Ontario Ministry of Education, 2014). An investigation into the implementation of these policies in one of the school boards found significant gaps in staff training and parent education (Hachem et al., 2016). Subsequently, royal assent was given to Rowan’s Law in 2018. This legislation mandates that all sport organizations and schools in Ontario have concussion protocols and mandatory concussion education for their members.

In 2018 the Canadian Olympic and Paralympic Sport Institute (COPSI) Network released the Sport-Related Concussion Guidelines for Canadian National and National Development High-Performance Athletes (COPSI, 2018). The intention of this document was to guide sport-concussion management for national sport organizations, national team and national development athletes, and provincial sport organizations. According to the Canadian Concussion Collaborative, proper implementation of concussion management and prevention policies necessitates user- and context-specific protocols in any event or activity that carries a risk of concussion (Fremont, Bradley, Tator, Skinner & Fischer, 2015). This reinforces the need for governing bodies in artistic swimming to develop and implement sport-specific concussion safety policies. In order for these policies to be most effective, scientific investigation of concussions in artistic swimming is needed.

Even when legislation mandates the implementation of safety policies, organizations may not always fully comply. A survey of municipal park and recreation departments in the United States found that only one-third were requiring coaches to complete concussion education training (Kim, Spengler & Connaughton, 2016). A survey of NCAA schools revealed that stakeholders in the vast majority of the schools felt that their institution’s concussion plan was going “well” or “very well”, but that gaps still existed in coach education, sports medicine staffing and athlete education (Baugh et al., 2015). Not only are there gaps in organizational compliance and implementation, gaps can also exist in medical professionals’ familiarity with concussion legislation. Carl and Kinsella (2014) surveyed pediatricians and reported strong levels of concussion knowledge but most were not familiar with concussion legislation and did not use concussion guidelines in their practices. These findings indicate that not only is there a need for sport-specific concussion policies, there will also be a need for knowledge translation and implementation plans in order to maximize the effectiveness of safety policies.
Many organizations have developed concussion resources and made them publically available. In the United States, resources are available from the Centers for Disease Control and Prevention (CDC), Concussion Legacy Foundation, American Academy of Neurology, International Concussion Society and the Concussion Alliance, to name a few. Several resources are available in Canada as well. Parachute Canada is a charitable organization dedicated to injury prevention that offers online and downloadable resources and a mobile application. They also offer concussion protocol resources for schools, sport organizations and health care professionals. The Ontario Brain Injury Association (OBIA) has an online page with concussion frequently asked questions and links to additional resources for children, adults and professionals. The OBIA also sponsors a brain injury/concussion helpline, online concussion support group and brain injury peer support group. Concussions Ontario is a portal is led by the Ontario Neurotrauma Foundation, a funding organization for concussion research and improvements to care, that provides concussion information and standards for high quality post-concussion care and services. It offers adult and pediatric concussion guidelines and links to other concussion organization websites. The Toronto Acquired Brain Injury (ABI) Network connects brain-injured patients with hospital and community-based programs, including concussion patients. The Toronto ABI Network links to resources for both professionals and individual patients and their families. The Government of Ontario also provides concussion information and links to resources on the Rowan’s Law page.

The plethora of concussion resources available and policy-mandated concussion education means that athletes and their coaches are exposed to a large amount of concussion information, presumably increasing their knowledge of concussions. Students’ mean scores on a concussion knowledge quiz increased following participation in the Sports Legacy Institute Community Educators (SLICE) concussion education curriculum as compared to scores before participation (Bagley et al., 2012). Female gender and age older than 13 were associated with passing the quiz after the presentation. Coaches who used the CDC Heads Up Concussion in High School Sports educational toolkit self-reported an increase in their concussion knowledge and a change in their attitudes towards concussion to view it as more serious (Sarmiento, Mitchko, Klein & Wong, 2010). A survey of youth sport coaches who used the CDC Heads Up toolkit found 77% of coaches reported being better able to identify potential concussions in athletes and 50% reported that the materials helped them to learn something new (Covassin, Elbin & Sarmiento, 2012). An
evaluation of the effectiveness of the Hockey Concussion Education Project found junior ice hockey players that viewed an educational DVD or participated in an interactive computer module displayed a positive trend in concussion knowledge, while the players that did not participate displayed a negative trend in concussion knowledge (Echlin et al., 2010). The majority of coaches who received two or more modalities of legislated concussion education in Washington State were able to answer concussion knowledge questions correctly (Chrisman, Schiff, Chung, Herring & Rivara, 2014).

Whereas many studies have found concussion education resources can help athletes and coaches increase their knowledge about concussions, other studies do not support that effect. A prospective cohort study of collegiate ice hockey players found no significant improvement in concussion knowledge and only a small decrease in intention to continue playing with a concussion following mandated concussion education (Kroshus, Daneshvar, Baugh, Nowinski & Cantu, 2014). Another prospective cohort study reported concussion knowledge scores improved immediately following an education intervention but effects disappeared by the end of the season (Kurowski, Pomerantz, Schaiper, Ho & Gittelman, 2015). A comparison of the concussion knowledge of collegiate athletes to that of non-athletes showed that despite being exposed to formal concussion education, varsity athletes did not have higher levels of concussion knowledge than the non-athletes (Knollman-Porter, Brown & Flynn, 2018). Thus, the actual effects of education on concussion knowledge are not clear.

Differences in the content and delivery of various concussion education programs could be the reason for conflicting results of the effects of education. Kroshus et al. (2014) found variation in the content and delivery of concussion education to ice hockey players, and reported that receiving concussion information in video form was associated with highest rates of player recall of education material while receiving it by email was associated with the lowest rates of recall. A qualitative literature review of knowledge transfer in concussion education determined that different groups of people participating in concussion education experienced optimal learning under different conditions (Provvidenza & Johnston, 2009). According to that review, physicians learn better through education outreach, interaction and reminder messages; athletic trainers and physiotherapists through problem- and evidence-based practice, socialization and peer-assisted learning; coaches through reflective processes; and athletes through e-learning, video games and peer support (Provvidenza & Johnston, 2009). These findings suggest that
knowledge translation is an important consideration when designing concussion education initiatives, and how education is delivered may need to be tailored to the audience. In some cases, a variety of educational modalities may need to be employed to ensure everyone is reached.

Even if education is successful in increasing athletes’ or coaches’ concussion knowledge, this may not transfer to any changes in attitudes towards concussion or in reporting behaviour. In a retrospective survey, 72% of high school soccer players who received concussion education reported that they would always notify their coach if they had symptoms, compared to only 36% of players who had not received any concussion education (Bramley, Patrick, Lehman & Silvis, 2012). Wallace, Covassin and Beidler (2017) found that female athletes had higher total concussion symptom knowledge than male athletes, and male athletes were more likely than female athletes to not report concussions for eight out of thirteen reasons. However, a prospective cohort study of NCAA male ice hockey players found that preseason concussion knowledge was not associated with in-season reporting behaviour, although intention to report concussion symptoms was significantly related to reporting (Kroshus, Baugh, Daneshvar, Nowinski & Cantu, 2015). Register-Mihalik et al. (2013) found that higher levels of concussion knowledge were associated with increased concussion reporting in practices but not games, and more favourable attitude towards reporting was associated with decreased reports of sport participation while symptomatic in high school athletes. An examination of the effect of coach concussion education on athlete reporting found that most modes of coach education were not associated with increased awareness of their athletes’ concussions, and coaches who used video and quiz education modalities were actually less likely to be aware of their athletes’ concussions (Rivara et al., 2014). The equivocal findings in terms of the connection between concussion knowledge and reporting indicates that knowledge alone is not a sufficient predictor of whether or not an athlete will report a concussion.

If concussion knowledge is not a reliable predictor of reporting, what does predict it? Experiencing a previous concussion does not appear to improve reporting. A cross-sectional survey of high school athletes from multiple sports found a larger number of previous concussions was associated with a worse attitude towards concussion and with negative concussion disclosure behaviour (Register-Mihalik, Valovich McLeod, Linnan, Guskiewicz & Marshall, 2017). Athlete sex appears to be related to concussion disclosure, with higher rates of
concussion reporting described in female athletes than in male athletes (Kerr, Register-Mihalik, Kroshus, Baugh & Marshall, 2016; Wallace et al., 2017). The most common reasons for an athlete not disclosing a concussion reported in the literature include: not wanting to be removed from the game or practice, not wanting to let their coaches or team mates down, and not thinking their concussion was serious (Fraas, Coughlan, Hart & McCarthy, 2014; Kerr et al., 2016; LaRoche, Nelson, Connelly, Walter & McCrea, 2016; McCrea, Hammeke, Olsen, Leo & Guskiewicz, 2004; Register-Mihalik et al., 2013).

Some researchers have attempted to describe or predict concussion reporting using existing psychological theories. Kerr et al. (2014) used the socio-ecological framework (Stokol, 1992) to summarize and organize factors related to disclosure of concussion. According to their categorization, the most commonly reported reasons for not disclosing a concussion in the included studies were factors from the intrapersonal level (Kerr et al., 2014). In an application of the Theory of Planned Behaviour to the prediction of concussion symptom reporting, intention to report symptoms was significantly associated with reporting behaviour, subjective norms and self-efficacy were significantly associated with both intention and behaviour, and attitude about perceived reporting outcomes was significantly associated with intention but not behaviour (Kroshus, Baugh, Daneshvar & Viswanath, 2014). These studies suggest that it may be useful to consider existing theories and models in the explanation of concussion reporting behaviour.

Despite the link between concussion resources, education and reporting remaining unclear, the effects of concussion resources and education appear to be positive. Research suggests sport-specificity and variety in education modalities are important. Findings indicate that concussion resources should be sport-specific to be most effective, which underlines the importance of developing concussion resources specific to artistic swimming. In addition, studies suggest that a variety of education modalities are needed to maximize the effectiveness of concussion education. This indicates that to be of optimal use to the artistic swimming community, multiple resources should be employed.
2.11 Review of Literature Summary

There are relatively few published studies examining artistic/synchronized swimming. Findings indicate that performing a competitive routine places high physical demand on these athletes, and that certain physiological characteristics such as isokinetic strength of certain joints and muscular and aerobic power may be related to performance outcomes. The limited reports of injuries in artistic/synchronized swimming demonstrate a research focus on chronic overuse injuries, with the suggested potential for acute traumatic injuries such as sport-related concussion.

Sport-related concussion is a brain injury which causes disturbances to neurological function and results in a constellation of clinical signs and symptoms in physical, cognitive, somatic, and sleep domains. While concussion is not detectable using traditional imaging technologies, there is a complex neurobiological cascade affecting the brain’s metabolism that appears to underpin the effects of a concussion. Changes to psychological factors like mood and autonomic nervous system disruption have been reported. Lasting neurological or psychological effects are still being characterized, and taken together the current knowledge of concussion indicates that these injuries should be taken seriously and the risk mitigated where possible. An important aspect of sport-related concussion prevention strategies is the monitoring of the number of concussions in the population of interest through injury surveillance. The implementation of organizational and sport-specific concussion policies will also play a role in protecting artistic swimmers from concussion injuries during participation in their sport.
Chapter 3
Research Overview

3 Overview of Research Program

3.1 Purpose, Objectives and Hypotheses

This research had two purposes: (1) to investigate the number and nature of concussions among youth artistic swimmers in Ontario, and (2) to investigate concussion and develop sport-specific concussion resources through collaboration with the community. The research objectives were as follows: (1) to determine the single-season incidence of concussions among youth (less than 18 years of age) Ontario artistic swimmers, (2) to determine the seasonal training phase in which concussions are most frequent, (3) to determine the competitive age group in which concussions are most common, (4) to describe which injury context factors are more frequently present in a concussion sustained during artistic swimming participation, and (5) to develop sport-specific concussion resources for artistic swimming through collaboration with the provincial sport organization.

Three hypotheses were tested: (1) Concussions would be more frequent during the specific preparatory phase of the training season than in the general preparation phase, general competition phase or specific competition phase, (2) Concussions would be more frequent in the 13-15 age group than in the 11-12 age group or the Junior/16-20 age group, and (3) Contact with another athlete during highlights would be the more frequent mechanism of injury than contact with a surface or non-contact trauma during pattern transitions, swimming warm-up, or dryland training. It was hypothesized that concussions would be more frequent in the specific preparation phase because this is a period of intense training before the competitions begin. It was expected that more concussions would occur during training because of the aesthetic nature of the sport. Other aesthetic sports, for example cheerleading, have found higher numbers of concussions in training compared to competition (Marar et al., 2012; Schulz et al., 2004; Shields & Smith, 2009). More concussions were expected in the 13-15 age group as compared to other competitive age groups because the demands in terms of skills and training dramatically increase between the 11-12 age group and the 13-15 age group, which could lead to a “mismatch”
between an athlete’s ability and the training demands. It was suspected that highlights and pattern transitions would be the activities most frequently associated with sustaining a concussion because these are relatively high risk compared to other artistic swimming maneuvers due to the movement of the athletes relative to one another.

The research consisted of three studies. A retrospective cross-sectional survey study (Study One) was the preliminary step to determine whether artistic swimmers had sustained concussions as a direct result of their participation in the sport, and to begin to elucidate the injury contexts surrounding these concussions. Study One addressed research objectives 2, 3 and 4, and their associated hypotheses. Objective 2 was to determine the seasonal training phase in which concussions were more likely to occur, and it was hypothesized that concussions would be more frequent in the specific preparatory phase. Objective 3 was to determine the competitive age group in which concussions were most frequent, and it was hypothesized that concussions would be most common in the 13-15 age group. Objective 4 was to describe which injury context factors are more frequently present in a concussion sustained during artistic swimming participation, and it was hypothesized that highlights and pattern changes would be the artistic swimming activities most frequently leading to a concussion.

Following the retrospective study, a prospective cohort study (Study Two) was conducted to measure the incidence of concussion in Ontario artistic swimmers over a competitive season, and to continue to describe the concussion injury contexts. Study Two addressed research objectives 1 through 4. Objective 1 was to determine the single-season incidence of concussions among youth (less than 18 years of age) Ontario artistic swimmers. There was no hypothesis associated with this objective because to my knowledge concussions have never been measured in artistic swimmers before. Objectives 2-4 and their associated hypotheses are described above.

Concurrent to these studies, a suite of sport-specific concussion resources for artistic swimming were developed in collaboration with the provincial sport organization, Synchro Swim Ontario (SSO). The development of these resources addressed Objective 5. Study Three describes the development of these resources through the collaboration between the academic researcher and community organization. The purpose of Study Three was to describe the collaborative process between the university-based principal investigator and the community-based sport organization, Synchro Swim Ontario, in the development and implementation of the concussion safety
program, and to evaluate said program. This program is a collection of sport-specific concussion resources compiled to assist the athletes, coaches and officials of artistic swimming in Ontario in recognizing and managing concussions sustained during participation in artistic swimming, and addressed the fifth research objective: to develop sport-specific concussion resources for the Ontario artistic swimming community.

It is important to the success of similar programs of research, and resources, to characterize the successful aspects of the collaboration between the two parties, as well as the difficulties experienced in the process. It is equally important to evaluate the content and delivery of the concussion safety program in order to maximize the effectiveness and utility of the program to the members. A summary and analysis of the collaboration can be found in Chapter 6.

An important part of the concussion safety program was the implementation of an injury tracking program, which relied on an online injury tracking tool to collect data on all injuries sustained by Ontario artistic swimmers, including concussions. In order to evaluate the injury tracker and identify ways in which it could be improved, a qualitative study examining coaches’ perceptions of the tracker was performed (Study Four). This study is presented in Chapter 7.

The specific details of the research methods for each of the four studies can be found in the following chapters. Each study is presented in its own chapter encompassing rationale, methods, results and discussion.

### 3.2 Definition of Sport-Specific Terms

**Seasonal Training Phase:** A macrocycle of the Yearly Training Plan (YTP) used by Canadian artistic swimming coaches for periodization of training. The YTP for club-level athletes taught in the Canadian artistic swimming coach education programs consists of four phases: general preparation (September-October), specific preparation (November-December), general competition (January-March) and specific competition (April-June). This YTP is based on the main championship meet of the season occurring in May/June and off-season of July-August.

**Competitive Stream:** The competitive pathway that an athlete is following for the season. In Ontario, there are three streams: Novice, Provincial, and National, or FINA. Novice athletes
compete locally and have the fewest practices and competitions, Provincial level athletes compete within the province and have an intermediate number of practices and competitions, and National stream athletes compete out of the province against other Canadian club teams and have the most practices and competitions.

**Competitive Age Group:** The competitive structure used in Ontario (and Canada) is aligned with that used by FINA in FINA-sanctioned meets. Athletes compete in categories called competitive age groups that are determined by age. These categories are consistent across the competitive streams and are as follows: 10 & Under, 11-12, 13-15, Junior (16-18), and Senior (18+).

**Routine:** Artistic swimmers compete in various routine events. A solo routine is comprised of one athlete, a duet routine of two, a team of four to eight, and a combo of four to ten. Routines have set time limits that vary by age category. In Junior and Senior, athletes compete in Technical and Free events. Technical routines must contain a set of required skill elements that must be performed in a particular order. Athletes in the 13-15 and younger age categories compete in a Figures event in place of a technical routine.

**Choreography:** The sequence of movements that make up a routine.

**Highlight:** A risky maneuver in which one or more athletes is propelled out of the water by their team mates.

**Pattern Transition:** The movement of artistic swimmers from one ‘pattern’ or formation to another. Typically happens quickly and requires a high degree of precision so athletes do not collide.
Chapter 4
Study One

4 Concussions in Youth Artistic Swimmers: A Retrospective Descriptive Study

4.1 Abstract

Objective: To describe and characterize the situational factors of concussions sustained by a sample of female youth competitive artistic swimmers.

Design: Retrospective, cross-sectional study.

Setting: Current and former Ontario club-level artistic swimmers who completed an online survey about the circumstances surrounding their concussions.

Participants: A convenience sample of 230 female artistic swimmers was screened. Fifty swimmers (21.7%) reported sustaining concussions between the ages of 11-18 years.

Independent Variables: Eight variables (age, mechanism of injury, specific activity at time of injury, diagnosing individual, time lost due to injury, location, activity type, and seasonal training phase) were examined.

Outcome Measures: Analyses included descriptive statistics and chi square goodness-of-fit tests.

Results: 69 concussions from 50 artistic swimmers were analyzed. 15 swimmers reported sustaining two concussions, and two swimmers reported sustaining three. The mean age of occurrence was 13.93 (±1.97) years. The most commonly reported mechanism of injury was athlete-athlete contact (81.2%) and performing highlights (37.7%). Family doctors were the medical practitioners most commonly diagnosing concussions (39.1%). The most commonly reported time loss due to injury was more than 4 weeks (34.8%). Concussions occurred most commonly in pool training (94.2%), in the deep-end of the pool (78.3%), and in the specific
preparation and general competition training phases (68.1% combined). Chi square tests were significant for all variables (p<0.05).

**Conclusions:** This study is the first to examine concussions in the under-studied sport of artistic swimming. Concussions occur most frequently from swimmer-to-swimmer contact, and often result in a greater than 4 week time loss from the sport. Further epidemiological research is warranted.

### 4.2 Introduction

Females are underrepresented in sport-related concussion (SRC) research (McKeever & Schatz, 2003; Resch, Rach, Walton & Broshek, 2017) despite findings that indicate the incidence of concussion is higher in female athletes (Dick, 2009). Higher concussion incidence rates have been reported in female compared to male athletes in both collegiate (Kerr et al., 2017) and high school sports (Gessel, Fields, Collins, Dick & Comstock, 2007). In one epidemiological study of concussions in 27 high school sports, there was an overall incidence rate equivalent to 0.26 per 1000 athlete exposures in females (O’Connor et al., 2017). Similarly, incidence rates between 0.17 and 0.73 concussions per 1000 athlete exposures have been reported in female high school soccer, volleyball, basketball and softball players (Rosenthal, Foraker, Collins & Comstock, 2014). Females tend to comprise the majority of the membership in aesthetic sports, in which there is also a paucity of research. To date, there are no concussion studies specific to artistic swimming. It is important to study concussions in this population in order to assist in concussion prevention in these athletes, as well as to increase our knowledge of concussions in female aesthetic sports.

Artistic swimming (AS), formerly called synchronized swimming, is an aesthetic sport in which athletes (mostly females) compete against one another with routines set to music. The sport, originally called ornamental swimming or scientific swimming, was developed from theatrical water ballet performances to include elements from lifesaving techniques and swimming, evolving into a very physically demanding full-contact sport (Federation Internationale de Natation, 2015). Since the Olympic debut of synchronized swimming in 1984 in which only three countries participated (FINA, 2015), the sport has grown to be practiced by many countries
on 6 continents. At the most recent World Aquatic Championships, athletes from over 40 countries competed in AS (FINA, 2017).

In the last 20 years AS has evolved dramatically: faster routine choreography, tighter pattern formations, and higher and more powerful aerial acrobatic moves. Consequently, the chance of incidental contact between the athletes has increased, and likely, the risk of injury. Recently, the province of Ontario has mandated all provincial sport organizations implement concussion policies with the enactment of Rowan’s Law (2018). Despite these initiatives, there is no sport-specific empirical evidence to inform the content of these policies.

One of the few studies examining injuries in AS reported an injury rate of 28 injuries in 990 athlete exposures at the 2009 Federation Internationale de Natation (FINA) World Aquatic Championships (Mountjoy et al., 2010). Dental trauma in artistic swimmers has also been reported, which indicates head and face impacts of sufficient intensity to injure teeth are occurring; therefore, it is possible that this amount of force is enough to cause a SRC (Andrade et al., 2010). The American Academy of Pediatrics (2001) defines contact sports as those in which athletes routinely make contact with one another but with less force than in collision sports. According to this definition, AS could be classified as a contact sport. Mountjoy, the former team physician for Canada Artistic Swimming (formerly Synchro Canada), was the first to describe the potential for acute traumatic injuries due to contact between synchronized (artistic) swimmers (Mountjoy, 1999; Mountjoy, 2009). Furthermore, she has suggested that the heavy training requirements and rigorous work ethic of elite synchronized (artistic) swimmers challenge compliance with concussion management guidelines, indicating a need for education and close follow-up (Mountjoy, 2009).

Given the nature of the sport and this call to action by Mountjoy (2009), investigation into the scope and nature of SRCs in AS is critical going forward. Sport-specific epidemiological data on concussions would inform future concussion guidelines and safety policies. Understanding the contexts surrounding concussions in AS would help to determine how to manage risks associated with concussions in this sport, thereby informing prevention.

Thus, the purpose of this study was to describe and characterize the nature and contexts of SRCs sustained by female youth artistic swimmers in Ontario, Canada. The objectives were: (1) to determine the seasonal training phase in which concussions were more likely to occur, (2) to
determine the competitive age group in which concussions are most common, and (3) describe which injury context factors are more frequently present in a concussion sustained during artistic swimming participation. We hypothesized that concussions would be more frequent in the specific preparation phase than in the general preparation phase, general competition phase or specific competition phase. We hypothesized that concussions would be more frequent in the 13-15 age group than in the 11-12 age group or the Junior/16-20 age group. We hypothesized that contact with another athlete during highlights would be the more frequent mechanism of injury than contact with a surface or non-contact trauma during pattern transitions, swimming warm-up, or dryland training. We believe the results elucidate the contexts leading to SRC in AS and provide a base for future research.

4.3 Method

4.3.1 Participants

This study was approved by the Research Ethics Board at the University of Toronto (Protocol #34507). A link to participate in the study was sent by Synchro Swim Ontario (SSO), the provincial sport governing body in Ontario, to all of the member clubs, with a request that it be forwarded to their memberships. All members were invited to participate. In addition, participation invitations were posted to SSO’s social media (Facebook and Instagram) pages. Inclusion criteria were current or former Ontario artistic swimmers, between the ages of 11 and 18. Athletes needed to be registered in a competitive AS category, and had experienced a SRC between September 2012 and September 2017. The email invitation would have reached approximately 1260 members (the number of registered novice and competitive athletes with SSO in the 2017-2018 competitive season), of which 741 would have been within the age range and competitive level to be included in the study. It is unknown how many respondents were reached through the social media postings; however, SSO had 2912 followers on Facebook and 1688 followers on Instagram at the time the study invitation was posted. Participants gave informed consent prior to participating. A copy of the consent form is included in Appendix A.
4.3.2 Materials

The data collection instrument was developed by the first author, in collaboration with SSO board members and administrators (Appendix B). Wording and order of the questions were based on that of the PlaySafe Injury Tracker (Sunnybrook Office for Injury Prevention, 2017), developed as an accessible online tool for Canadian sport organizations to track injuries in their membership. The content of the injury tracker is based on the injury surveillance form used by the International Olympic Committee (IOC) (Junge et al., 2008). The IOC surveillance form was piloted at the 2004 Athens games and fully adopted for the 2008 Beijing games, and was itself based on questions used in soccer (Junge et al., 2008). The PlaySafe tracker used the questions from the IOC form and adapted them to be more applicable in a community setting, guided by the principles of the Translating Research into Injury Prevention Practice (TRIPP) framework (Finch, 2006). The PlaySafe tracker is customizable and was tailored to be specific to Ontario artistic swimming by the principal investigator and members of SSO. The survey was reviewed for face and content validity during the customization process.

The data were collected and managed using digital tools from REDCap (Research Electronic Data Capture), hosted at the University of Toronto. REDCap is a secure, web-based digital project management application that allows investigators to build data collection instruments, electronically capture data, and organize and manage data easily (Harris et al., 2009).

4.3.3 Measures

The data were organized by one continuous variable (age), and seven categorical variables (mechanism of injury, specific activity at time of injury, diagnosing individual, time lost due to injury, activity type, location, and seasonal training phase). The seasonal training phase was determined for each concussion from the reported date of injury. All possible categories for each variable can be viewed in Table 1.

4.3.4 Procedure

Participants completed an online questionnaire. If a participant indicated that they had sustained any concussions due to synchronized swimming, they were asked several questions about the circumstances surrounding their injuries. Participants were instructed to respond to the questions for each concussion. For athletes aged 15 years and younger, consent was obtained from their
parent/guardian, and the parent/guardian was asked to complete the survey for their child. Athletes aged 16 years and older gave their own consent and were asked to complete the survey themselves. The data were exported into Microsoft Excel (Microsoft Office Professional Plus 2016, Version 16.0.4738.1000) with any identifying information removed.

4.3.5 Analysis

Descriptive statistics were calculated for all variables. Chi square goodness-of-fit tests were calculated for all categorical variables. This test is used to determine if the observed distribution of a categorical variable is the same or different than an expected distribution (Cressie & Read, 1984). In this case the observed distribution was compared to an expected equal distribution among cells, as would occur by chance. This was done to ensure any differences between the observed frequencies in the categories of each variable were statistically significant. Significance was set at $\alpha=.05$. Statistical analyses were conducted with IBM SPSS Statistics for Windows (IBM Corp, Version 24).

4.4 Results

4.4.1 Descriptive Statistics

Of the 263 respondents, 262 (99.6%) consented to participate. Incomplete responses (n=32) were removed from the data set. Of the remaining 230 respondents, 106 (46%) reported that they had sustained a diagnosed concussion directly due to synchronized swimming. Of those participants, 79 completed the entire survey, reporting 107 concussions. Thirty-three of those concussions occurred when participants were either younger than 11 or older than 18, and an additional 5 were sustained when respondents were not registered in the competitive category. These incidents were excluded from analysis, leaving 69 concussions reported by 50 athletes eligible for the study (Figure 1).
The mean age of athletes at the time of SRC was 13.93 (±1.97) years. Frequency tables for the categorical variables are displayed in Table 1. The most frequent mechanism of injury was
contact with another athlete (81.2%), and performing highlights (37.7%) and pattern transitions (30.4%) were the most frequently reported specific activities at time of injury. Family doctors typically diagnosed concussions (39.1%), followed by sport medicine specialists (30.4%). Time lost due to injury was most frequently reported at more than four weeks (34.8%). Concussions occurred almost exclusively during in-pool training (94.2%), and occurred most frequently in the deep-end of the pool (78.3%). Concussions most frequently occurred in the specific preparation (33.3%) and general competition (34.8%) training phases, which span from November to March.

<table>
<thead>
<tr>
<th>Seasonal Training Phase</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>General preparation</td>
<td>12</td>
<td>17.4%</td>
</tr>
<tr>
<td>Specific preparation</td>
<td>23</td>
<td>33.3%</td>
</tr>
<tr>
<td>General competition</td>
<td>24</td>
<td>34.8%</td>
</tr>
<tr>
<td>Specific competition</td>
<td>10</td>
<td>14.5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanism of Injury</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact with other athlete</td>
<td>56</td>
<td>81.2%</td>
</tr>
<tr>
<td>Contact with object</td>
<td>13</td>
<td>18.8%</td>
</tr>
<tr>
<td>Non-contact trauma</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Not sure</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>0</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Specific Activity</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pattern transitions</td>
<td>21</td>
<td>30.4%</td>
</tr>
<tr>
<td>Highlights</td>
<td>26</td>
<td>37.7%</td>
</tr>
<tr>
<td>Swimming warm-up</td>
<td>11</td>
<td>15.9%</td>
</tr>
<tr>
<td>Dryland Training</td>
<td>2</td>
<td>2.9%</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>1.4%</td>
</tr>
<tr>
<td>Choreography</td>
<td>8</td>
<td>11.6%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activity Type</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competition: Warm-Up</td>
<td>1</td>
<td>1.4%</td>
</tr>
<tr>
<td>Competition: Event</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Training: In pool</td>
<td>65</td>
<td>94.2%</td>
</tr>
<tr>
<td>Training: Dryland</td>
<td>2</td>
<td>2.9%</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>1.4%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow-end of the pool</td>
<td>12</td>
<td>17.4%</td>
</tr>
<tr>
<td>Deep-end of the pool</td>
<td>54</td>
<td>78.3%</td>
</tr>
<tr>
<td>Pool Deck</td>
<td>3</td>
<td>4.3%</td>
</tr>
<tr>
<td>Dryland Gym</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency room doctor</td>
<td>18</td>
<td>26.1%</td>
</tr>
<tr>
<td>Sport medicine doctor</td>
<td>21</td>
<td>30.4%</td>
</tr>
</tbody>
</table>
4.4.2 Chi-Square Analysis

Chi-square goodness-of-fit tests were significant (p<0.05) for all categorical variables (Table 2). Concussions were significantly more common (p<0.05) in the specific preparation and general competition phases than in the general preparation and specific competition phases. Contact with another athlete was significantly more frequent (p<0.01) as the mechanism of injury than contact with an object, non-contact trauma, and other. Concussions occurred significantly more frequently (p<0.01) during pattern transitions and highlights than in warm-up, dry-land training, or choreography. In-pool training had significantly more concussions occur (p<0.01) than dry-land training, competition event or competition warm-up. Concussions were significantly more common (p<0.01) in deep water than in the shallow-end of the pool, on the pool deck, or in a dryland training area. Finally, athletes missed more than four weeks of artistic swimming participation significantly more often (p<0.05) than less than a week, one to two weeks, or three to four weeks.

| Family doctor | 27 | 39.1% |
| Nurse practitioner | 1 | 1.4% |
| Other | 2 | 2.9% |
| **Missed Time** | | |
| Less than 1 week | 10 | 14.5% |
| 1-2 weeks | 12 | 17.4% |
| 3-4 weeks | 23 | 33.3% |
| More than 4 weeks | 24 | 34.8% |

Table 2

| Table 2 | Chi-Square Goodness-of-fit Statistics |
| Seasonal Training | 9.203 | 3 | .027* |
| Mechanism of Injury | 26.797 | 1 | ≤.001** |
| Specific Activity | 44.652 | 5 | ≤.001** |
| Activity Type | 176.275 | 3 | ≤.001** |
| Location | 64.435 | 2 | ≤.001** |
| Missed Time | 9.203 | 3 | .027* |

Note. *p < 0.05, **p < 0.01.
4.5 Discussion

To our knowledge, this is the first study to examine sport-specific concussion factors in artistic swimmers. It is an important starting point for further examination of concussion rates and factors in this sport. AS is commonly thought of as a non-contact sport; therefore, it is not given the same attention and study as more traditional contact sports. There is a large amount of athlete-to-athlete contact during the execution of routines in AS; hence, there is a potential for injuries (Mountjoy, 2009). In order to begin to reduce the risk of concussions in AS, it is important to describe the associated factors.

4.5.1 Injury Factors

The most common mechanism of injury was athlete-to-athlete contact (81.2%) during the execution of highlights (37.7%). Highlights are the powerful throws, stands, and flips executed by the team forming a base under the water and propelling one or two athletes up out of the water with force. These are considered to be very “high risk” moves and typically only occur a handful of times within a routine. However, the chance for contact between the athletes is increased as a failed highlight may fall on a team member, or collisions may occur under the water while the team is swimming into or out of the base positions. A similar pattern is seen in cheerleading, where it has been reported that “stunts” are responsible for 60% of all injuries and 96% of concussions and closed head injuries (Shields, Fernandez & Smith, 2009).

Concussions were more frequently diagnosed by a family doctor (39.1%). Primary care providers may not have training in the diagnosis and management of concussions (Zonfrillo et al., 2012), and the findings suggest that injured artistic swimmers are attending general practitioners more often than emergency physicians or sports medicine specialists. The most frequently reported time loss due to injury was more than four weeks (34.8%). The 2017 Concussion in Sport Group consensus statement indicates the expected duration of symptoms is up to 4 weeks in children (McCrory et al., 2017), indicating the athletes from this study are taking longer than expected to recover. Evidence suggests that female athletes take longer to recover from concussion than their male counterparts (Stone, Lee, Garrison, Blueitt & Creed, 2016). This is one possible explanation for why the athletes in this study lost more than four weeks to injury. The sample was solely comprised of female adolescents. In addition, the fact that family doctors diagnosed 39% of concussions may have had some influence on the longer
time to recover. A family doctor may not have the same level of concussion management training as a sports medicine specialist, and may prescribe longer rest, as has been the traditional standard in concussion management (Silverberg & Iverson, 2013).

Concussions occurred almost exclusively during in-pool training (94.2%), contrary to findings from most other sports that incidence rates of SRCs are higher in games than in practices (Dompier et al., 2015; Gessel et al., 2007; O’Connor et al., 2017). Artistic swimmers train their routine numerous times prior to competition. Once in competition, the routine has been rehearsed well enough to avoid mistakes that might lead to highlights failing, collisions under the water, and other unplanned contact between athletes. Again, this is similar to findings from competitive cheerleading, in which it has been reported that 85% of injuries sustained by US cheerleaders during a one year period happened during training (Shields & Smith, 2009).

Concussions were more likely to occur in deep water (78.3%), likely because most AS training takes place in deep rather than shallow water. Further, concussions were more common during the specific preparation (33.3%) and general competition (34.8%) seasonal phases. These seasonal phases tend to have the highest training volume along with lower levels of proficiency, which could lead to errors resulting in injury.

4.5.2 Limitations

There are a number of limitations associated with this research. First, the study was retrospective and thus participants’ answers were subject to recall bias. Only concussions from within the last five years were included, in an effort to balance accuracy of recall and representativeness of the sample (Fadnes, Taube & Tylleskär, 2009). Second, the study uses self-report, which may lead to social desirability bias. This is when a desire to appear in a positive light influences one’s answers on a survey or questionnaire, which in turn can confound observed relationships in the results (Ganster, Hennessey & Luthens, 1983). Third, the title of the survey instrument, “Past Concussions in Ontario Synchronized Swimmers”, may have contributed to a sample bias in that those who participated were those who felt the survey was relevant to them. Even though all members were invited to participate, regardless of whether they had sustained a concussion or not, it is probable that people were more likely to respond if they had been concussed. Consequently, this limits the interpretation of the results. Addressing
these methodological limitations (e.g. prospective method, data collection without self-report, non-volunteer sample) would be beneficial in future research.

### 4.6 Conclusion and Clinical Implications

Findings of this preliminary work elucidate the context in which concussions are occurring in artistic swimming. Contact with other athletes during highlights was identified as the main mechanism of injury. Future prospective research with more diverse data collection methods would help to clarify the picture of concussions in this sport. Future research can inform safety guidelines, prevention policies, and clinical management. Clinicians working with artistic swimmers should be aware that contact between athletes is a primary mechanism of injury. The findings emphasize the importance of family physicians as a frontline in the management of concussion in these young athletes.
Chapter 5
Study Two

5 Incidence of Concussion in Youth Artistic Swimmers in Ontario: A Prospective Study

5.1 Abstract

Objective: To measure the incidence of concussion in youth artistic swimmers in a competitive season and describe the contexts in which these concussions occurred.

Design: Prospective cohort study.

Setting: Club-level competitive artistic swimmers in Ontario who participated in the 2017-2018 competitive season.

Participants: Competitive artistic swimmers registered in the national, provincial, or novice categories in Ontario in the 2017-2018 competitive season.

Independent Variables: Seven variables (age, mechanism of injury, competitive category, specific activity at time of injury, location, activity type, and seasonal training phase) were examined.

Outcome Measures: Incidence proportion (risk) and clinical incidence of concussions were calculated. Mechanism of injury and activity at the time of injury were described.

Results: The mean age of concussed athletes was 12.80 (±2.53) years. Twenty-two concussions occurred during the season, for a clinical incidence of 0.02. The risk of sustaining a concussion was 1.91%. Contact with another athlete was the most frequently reported mechanism of injury (72.7%) and pattern transitions were the most frequently reported activity at the time of concussion (31.8%).

Conclusions: This study is the first to measure the incidence of concussion in artistic swimmers and the first to prospectively examine injuries over a competitive artistic swimming season. It is
an important starting point for sport-specific concussion tracking and prevention. More comprehensive study of concussions in artistic swimmers is warranted.

5.2 Introduction

Despite its origins in theatrical performance, artistic swimming (AS)—formerly synchronized swimming—has evolved into a contact sport with high physical demands (FINA, 2015). A recent retrospective study of concussions in artistic swimming suggested the most frequent mechanism of injury is contact between athletes during highlights (dynamic acrobatic maneuvers involving lifting or throwing team members up out of the water). Furthermore, concussions typically resulted in more than 4 weeks’ time lost from the sport (McClemont & Mainwaring, unpublished). These findings indicate that there is a risk of athlete contact resulting in concussions in artistic swimming, and further investigation is warranted to explore the scope of the problem and any risk factors for concussions in the sport. Mountjoy (2009) was the first to report the risk of traumatic injuries including concussion from contact between athletes in AS.

Females and aesthetic sports are underrepresented in concussion research. Compared to males, females have higher concussion rates at both the high school and collegiate levels (Gessel et al., 2007; Kerr et al., 2017). Females have a higher symptom burden following a concussion and may take longer to recover than males (Broshek et al., 2005; Chiang Colvin et al., 2009). In cheerleading concussion rates have been measured in youth, high school and collegiate levels (Shields, Fernandez & Smith, 2009). There are a handful of studies describing concussions in dance (Kish & Koutures, 2016; Roberts, Nelson & McKenzie, 2013; Stein et al., 2014), and one study reporting on concussion in theater personnel (Russell & Daniell, 2018). Studying concussion in artistic swimmers would be an important step in addressing this gap in our knowledge of sport-related concussions in female athletes.

AS represents an unstudied female population with respect to sport concussion. Incidence data on concussions in AS would inform concussion management guidelines and sport-specific safety policies. The main purpose of this study was to examine the incidence of concussions in youth competitive artistic swimmers in Ontario over the 2017-2018 season. The secondary purpose was to describe the situational factors associated with concussions in this cohort. To our knowledge
this is the first study to measure the incidence of concussion in artistic swimming and the first study to prospectively describe the situational factors associated with concussion in artistic swimmers.

5.3 Method

5.3.1 Study Design and Participants

This prospective cohort study was approved by the University of Toronto Research Ethics Board (Protocol #34507). The data were collected using the injury tracking system used by Synchro Swim Ontario (SSO), developed by the PlaySafe Initiative (Sunnybrook Office of Injury Prevention). SSO is the provincial governing body of AS in Ontario and requires that any and all injuries sustained by its members during any SSO-sanctioned event (practices, competitions, training camps, etc.) be reported to the organization through this system.

The principal investigator received the injury reports from SSO with all names removed. There were 123 injury reports filed over the 2017-2018 competitive season. Reported injuries sustained by athletes not in a competitive stream (n=17) and by competitive athletes outside the included age range (n=1) were removed, leaving a sample of 105 injuries. Inclusion criteria were: registered athlete with SSO, competing in national, provincial, or novice stream, 17 years of age or younger, and injury was sustained directly from participation in artistic swimming. The participant flowchart is displayed in Figure 2.
5.3.2 Materials and Procedure

The data were collected with the PlaySafe Injury Tracker (Sunnybrook Office for Injury Prevention, 2017), a web-based survey application free to use for sport organizations for injury surveillance. In collaboration with SSO board members and administrators, the principal investigator developed questions specific to AS to include in the survey. This customized version of the tracker was reviewed for face and content validity. The injury tracker form can be found in Appendix C.

A link to the Injury Tracker was available on the SSO website. Coaches were directed to complete a report as soon as possible after any injury that resulted in disruption and/or modification of an athlete’s training. Completed injury reports were received and compiled by the SSO Sport Development Manager. Any reports indicating a blow to the head or face were
flagged as a possible concussion. The SSO Sport Development Manager performed six week follow-ups with the coach filing the report for all flagged head impacts. Concussion status was recorded in the report after the follow-up.

5.3.3 Study Variables and Definitions

Three variables were extracted from the injury tracker and examined: AS age at time of injury, mechanism of injury and the specific artistic swimming activity at the time of injury.

AS age at time of injury was defined as age on December 31, 2018 and was determined from the athlete’s date of birth. Mechanism of injury was categorized by five possibilities: contact with another athlete, contact with a stationary object, non-contact trauma, overuse, or other. Specific activity at time of injury was categorized by six possibilities: 1) pattern transitions, 2) highlights, 3) choreography, 4) swimming laps, 5) dryland, or 6) other. Concussion diagnosis was categorized into Yes (concussion) or No (musculoskeletal injury). Concussions were only considered to be a “Yes” if they had been diagnosed by a medical doctor.

5.3.4 Analysis

Descriptive statistics were calculated for all variables.

The incidence proportion (risk) and clinical incidence of diagnosed concussions were calculated. Concussion risk was calculated using the following formula:

\[
\text{Concussion Risk} = \frac{\sum \text{Concussed Athletes}}{\sum \text{Athletes}}, \quad \sum \text{Athletes}=\text{number of eligible registered athletes}
\]

Clinical incidence (CI) was calculated using the formula:

\[
\text{CI} = \frac{\sum \text{Concussions}}{\sum \text{Athletes}}
\]

Statistical analyses were conducted with IBM SPSS Statistics for Windows (IBM Corp, Version 24), with significance set at \( \alpha=0.05 \).
5.4 Results

5.4.1 Descriptive Statistics

There were a total of 105 injury reports filed for athletes meeting the inclusion criteria (n=1151). Of those, 62 (59%) were flagged as potential concussions, with 22 (21%) diagnosed concussions, 27 (25.7%) classified as musculoskeletal injuries, and 13 incomplete follow-ups. The athletes lost to follow-up were excluded from the analysis. The mean age of concussed athletes was 12.80 (±2.53) years, with a range of 9-17, and was not significantly different from the mean age of musculo-skeletal injured athletes (12.41 ± 2.57 years). The most frequent mechanism of injury of concussions was contact with another athlete (72.7%). Concussions occurred most frequently in the specific preparation and general competition (36.4% each) seasonal phases. Pattern transition (31.8%) was the most commonly reported activity at the time of injury. All but one concussion happened during training (95.5%), and the majority were sustained in the deep-end of the pool (90.9%). The majority of concussions (72.7%) were reported by athletes competing in the Provincial stream. Concussions represented 21% of all injury reports. Demographic characteristics of the concussed athletes are reported in Table 3.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Concussion (n=22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (±SD)</td>
<td>12.80 (±2.53)</td>
</tr>
<tr>
<td>Range</td>
<td>9-17</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Competitive Stream</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td>3 (13.6%)</td>
<td></td>
</tr>
<tr>
<td>Provincial</td>
<td>16 (72.7%)</td>
<td></td>
</tr>
<tr>
<td>Novice</td>
<td>3 (13.6%)</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Demographic characteristics of concussed athletes.

5.4.2 Incidence

There were 22 diagnosed concussions reported during the season. The risk of sustaining a concussion was 1.91%. The clinical incidence of concussion in competitive athletes was 1.91 per 100 athletes.
5.5 Discussion

5.5.1 Incidence and Situational Factors

To our knowledge, this study is the first epidemiological study of concussions in artistic swimming. Concussions represented 21% of all reported injuries, which is higher than reports from other sports. Two epidemiological studies of sport-related injuries in male and female athletes in 100 US high schools reported only 8.9% (Gessel et al., 2007) and 9.1% (Rechel, Yard & Comstock, 2008) of injuries were concussions. Schulz and colleagues (2004) reported 7.49% of injuries sustained by high school athletes were concussions, while Meehan, d’Hemecourt, Collins and Comstock (2011) reported that concussions represented 14.6% of the injuries in a sample of US high school athletes. The higher proportion of concussions observed in this study could be due to a coach being more likely to sit an athlete out and file a report for a possible concussion than for a chronic overuse injury.

The single-season concussion risk was 1.91%, which is much greater than findings of 0.9% and 1.3% in female high school soccer and lacrosse, respectively (Marshall, Guskiewicz, Shankar, McCrea & Cantu, 2015).

The majority (93.75%) of concussions occurred in training. Reports from most other sports report higher concussion rates in competition at the middle school (Kerr et al., 2017), high school (Schulz et al., 2004) and collegiate level (Zuckerman et al., 2015). This is perhaps due to the aesthetic nature of AS and the manner in which athletes compete against one another. Numerous repetitions of routines are performed in practice, so by the time athletes compete the routine mistakes resulting in unplanned contact between the athletes are unlikely. Higher concussion incidence in training has also been reported in cheerleading (Marar et al., 2012; Schulz et al., 2004), another aesthetic sport. It is important to note that artistic swimmers typically spend a lot more time training than they do competing, and without a reliable method of collecting athlete exposure data for the present study it remains uncertain whether the concussion rate in training truly is higher than in competition.

The most frequent mechanism of injury was athlete-athlete contact (75%). This is consistent with findings from both male and female youth athletes in other sports (Gessel et al., 2007; Marar et al., 2012; Meehan, d’Hemecourt & Comstock, 2010). Chi-square analysis found a
significant relationship between injury type and athlete-athlete contact. It is important that AS be recognized as a contact sport, and the risk of traumatic injury due to contact between artistic swimmers be acknowledged. Clinicians working with artistic swimmers should be aware of the possibility of athlete-to-athlete contact and alert for injuries, in particular concussions, to ensure these injuries are properly managed.

5.5.2 Limitations

The study population was comprised solely of competitive club-level artistic swimmers from a single Canadian province. This limits the generalizability of the findings to other levels of athletes and athletes from other provinces and countries. In addition, limited study resources prohibited the collection of athlete exposure data and therefore the calculation of concussion incidence rate. Measuring the incidence rate of concussion in this cohort would have allowed for comparisons to other sports, which could have been valuable to help contextualize concussion incidence in artistic swimming.

The injury reports were filled out by coaches, and were based on coach observation of the events. It is possible that coaches may not have had a completely accurate interpretation of the events that occurred leading to injury, and thus, there may be some error in the reports. Furthermore, the reported incidence proportion and clinical incidence may be lower than the true rates due to potential under-reporting and the unknown concussion status of the athletes lost to follow-up. Under-reporting has been identified as a serious issue in concussion research (Kerr, Register-Mihalik, Kroshus, Baugh & Marshall, 2016; Kroshus, Garnett, Hawrilenko, Baugh & Clazo, 2015). In addition, there may have been under-reporting of more mild musculoskeletal injuries, as they may have been less salient to coaches and therefore not have had injury reports filled out for them. This could lead to an overestimation of the proportion of injuries that were concussions. Additional variables (e.g., time lost due to injury, symptom profiles, recurrent concussions) were outside the scope of this study.

5.6 Conclusion

This study is the first to describe the incidence of concussion in a population of artistic swimmers. The findings are comparable to previous reported incidence from other female
athletes of similar age, and suggest that concussions may comprise a greater proportion of injuries as compared to other sports. Similar to findings from other sports, athlete-athlete contact is the most common mechanism of injury. Sport officials and medical clinicians need to be aware of the possibility of artistic swimmers to sustain injuries, in particular concussions, from contact with another athlete. This study lays an important foundation for future work by providing a framework for injury surveillance in AS, measuring incidence of concussions in a population of artistic swimmers, and identifying the primary mechanism of injury. More comprehensive epidemiological study of concussions in artistic swimmers is warranted with larger study populations, athlete exposure data and additional variables of interest.
Chapter 6
Study Three

6 Building a Concussion Safety Program with a Provincial Sport Organization: A Community-Based Participatory Research Approach

6.1 Abstract

The province of Ontario recently enacted Rowan’s Law (2018). This legislation requires all sport organizations to have concussion protocols and education. Ontario Artistic Swimming (OAS) is the provincial sport organization that oversees the sport of artistic swimming in Ontario. This paper describes the collaboration between an academic research team from University of Toronto and members of Ontario Artistic Swimming in the design, implementation, and evaluation of a sport-specific concussion safety program using a qualitative study. This partnership is discussed in terms of a community-based participatory research approach. The lessons learned from the collaboration, both positive and negative, are highlighted.

6.2 Introduction

Artistic swimming, formerly called synchronized swimming, is a predominately female aesthetic sport. It has grown from theatrical water ballet to become a fast-paced, contact sport. With the increase in contact between athletes comes a concomitant increase in the potential for traumatic injuries, including concussions (Mountjoy, 2010).

Concussions have been estimated to be responsible for close to 35 000 pediatric emergency department and physician office visits in Ontario in 2013 (Zemek et al., 2017). Sport related concussion is a traumatic brain injury caused by a direct blow to the head, face, or neck, or an indirect blow to the body that results in force being transmitted to the head, sustained through participation in sport or physical activity. It results in functional disturbance of the brain as well as clinical signs and symptoms.
Recently, the Government of Ontario has recognized the importance of managing sport-related concussions properly and promoting concussion safety within schools and community sport organizations. This was enacted in the wake of the death of a young athlete, Rowan Stringer, following multiple concussions. Rowan’s Law (2018) requires sport organizations to have a concussion code of conduct, removal from sport protocol, return to sport protocol, and require members to read concussion awareness resources. These requirements present a practical problem for many community sport organizations that may lack the knowledge and resources to implement a concussion safety program that fulfills all of the conditions set forth in Rowan’s Law. Ontario Artistic Swimming (OAS), formerly Synchro Swim Ontario (SSO), is the provincial governing body of artistic swimming in Ontario. Recognizing a need for data-driven, sport-specific concussion resources, a partnership was formed between the principal investigator (LMS) and OAS to assist in addressing the requirements of Rowan’s Law and develop a sound concussion safety program that would help to protect athlete health and safety moving forward. The concussion safety program did not exist prior to the formation of the collaborative partnership, and all of the program components were the result of the work of the principal investigator with the community representatives. The program consists of an organizational concussion policy (Appendix D), concussion education sessions, concussion management guidelines and a sport-specific return to sport protocol (Appendix E), a return to sport progress tracking tool for coaches (Appendix F), a concussion information guide for athletes and parents (Appendix G), and an injury tracking program. The entire suite of resources is illustrated in Figure 4. A detailed description of the documents can be found in section 6.4.1, information about the education initiatives in section 6.4.2, and a description of the injury tracking program in section 6.4.3. This paper describes the design, implementation, and initial evaluation of the OAS concussion safety program, through the collaboration of the provincial sport organization and a university-based researcher.
6.3 Program Design

6.3.1 The Parties

The partnership was formed between two parties: the research team and the community sport organization. The research team, based out of the University of Toronto, consisted of the primary investigator (LMS) and a research supervisor (LMM). There were three individuals from Ontario Artistic Swimming that were centrally involved in the concussion safety program:
the executive director (MD), the sport development manager (RK), and the president of the board of directors (RB).

6.3.2 Definition of Roles and Scope

A key first step in the collaboration process between OAS and LMS was the clarification of the roles that each party would take in the different stages of the process. Clear roles were important for the efficiency of the design phase of the program. As the principal investigator, LMS was primarily responsible for identifying the components of the program and the content for same, under the supervision of LMM. OAS provided the technical support and the access to the study population, as well as some input into the content of the program and its resources. It was recognized that each party’s roles would be dynamic and could change from beginning to end of the process.

It was also important to clearly define the scope of the concussion safety program, and how each party’s roles related to that. It was agreed that the program would aim to provide resources for identifying and managing concussions sustained during OAS-sanctioned events and the collection and analysis of data on same, and concussion education for all members within the province of Ontario.

6.3.2.1 Role and Perspectives of the Principal Investigator

As the principal investigator, I (LMS) was primarily bringing a researcher role to the table in the partnership. However, my extensive experience in the sport allowed me to bring other perspectives. I was a club athlete for 17 years, including 6 years as a National team athlete. Having experience at all levels of competition has given me an understanding of the needs of athletes at different levels. In addition, I sustained multiple concussions before retiring from artistic swimming. Living the experience of sport-related concussion gave me an understanding of the injury from an athlete’s perspective before I understood it from a scholar’s perspective. Furthermore, I have experience as a certified Competition Development coach (the second-highest coaching certification level in artistic swimming in Canada) and have worked with athletes at all different levels, including Novice stream, Provincial stream and National stream competitive athletes, as well as an athlete with a disability (AWAD). Again, this experience has provided me with insight into the needs of coaches at various levels.
This combination of perspectives, from researcher to athlete to coach, made me uniquely situated to be able to carry out this research. The ability to adopt different viewpoints guided me in the conceptualization and execution of this research. My experience with concussions as an athlete has instilled a strong drive to understand these injuries and work to prevent concussions in this generation of athletes. I was able to use my experience as both an athlete and a coach to assist in choosing which variables to measure in the empirical studies. As a researcher and scholar I could bring a level of scientific rigor to the investigation of concussions in my sport. Drawing on these multiple perspectives allowed me to execute this research within the community setting and strengthened both the program and the partnership by engendering trust and buy-in with the community sport organization.

6.3.3 Identifying Goals

It was vital to set clear and finite goals for the concussion safety program (Ahmed & Palermo, 2010). These goals would guide not only the content of the program components, but also the design of the documents and the delivery of the program resources. The goals of the concussion safety program were as follows:

1. Create and enact an organization-wide concussion policy to be followed by all OAS member clubs.
2. Create and disseminate concussion management guidelines and a return to sport protocol that is specific to the sport of artistic swimming.
3. Create and disseminate concussion information documents for coaches and officials, and athletes and parents, specific to the sport of artistic swimming.
4. Hold sport-specific concussion education sessions for coaches, officials, administrators, parents, and athletes.
5. Develop and implement an injury tracking system to track all injuries incurred by OAS members during participation in artistic swimming, including concussions.

We defined ‘create’ to mean develop and author the respective documents. In the case of the first goal, we defined ‘enact’ the policy to mean that the OAS board of directors would approve it and OAS would officially adopt it. As part of officially adopting the policy, OAS distributed it to all member clubs and made it available online. We defined ‘disseminate’ as ensuring the
respective documents were readily available to OAS membership, as well as providing regular communication about their existence and where they could be accessed.

These goals were selected to guide us to our overall objective: build and implement a system to objectively monitor injuries sustained while participating in OAS-sanctioned activities, which will provide a basis for health and safety policy decisions in the future. It was important that both parties agreed on the global objective of the program and the stepping stones to achieving it, so that there was buy-in on both sides (Goodman & Sanders Thompson, 2017).

6.4 Program Implementation

6.4.1 Document Development

The partners determined that the various components of the program would need to be rolled out sequentially to ensure clarity and avoid overwhelming users with information. It was recognized that the organizational concussion policy document should be first in order to establish a rationale for adopting some of the other components. The policy is renewed every four years and is intended to guide the organization’s approach to concussion safety and provide a basis for member clubs to write their own concussion policy. A OAS board member with experience in policy writing was the primary author and developer of the policy document. Once the policy was ratified by the board of directors, it was provided to the member clubs and made publicly available on the OAS website. Written in to the policy document was the expression of intent to develop and provide additional sport-specific and organization-specific concussion materials.

The information guide for athletes/parents was developed and written by the research team, and contains practical information for managing concussions at home and instructions on returning to daily activities following a concussion. The content for these documents was based on the Concussion in Sport Group’s 2012 consensus statement (McCrory et al., 2013) and was subsequently updated to reflect the latest consensus statement from the Berlin conference (McCrory et al., 2017). In addition, a sports medicine physician familiar with artistic swimming provided input into the “at home” and “return to school” sections of the athlete and parent concussion information guide.
The concussion management guidelines and sport-specific return to sport protocol were also based on the 2012 consensus statement (McCrory et al., 2013). The research team was tasked with displaying the consensus statement content in the artistic swimming context, using sport-specific terminology and examples to illustrate the concussion management principles. It was important to preserve the scientific soundness of the documents while adapting them to be of the most use for the target audience, OAS members. A key objective of this stage was to put the management principles into easy to understand language and an easily consumable format. Therefore, the management guidelines and return to sport protocol were both purposely designed to be concise, streamlined and easy to read. These documents are intended for use by coaches who suspect an athlete has sustained a concussion or who have an athlete with a diagnosed concussion.

The return to sport progress tracking tool for coaches was developed following a request from a coach in the OAS community. The tool was requested to facilitate a coach’s management of an athlete through the return to sport protocol. It maps directly on to the sport-specific return to sport protocol and is intended for use as a companion piece to the protocol document.

Each of the documents of the concussion safety program were designed with a user-friendly approach, in order to balance a scientific basis with a streamlined design. With the exception of the return to sport progress tracking tool, each of the program components can be read and used in isolation; however, they were designed as a suite of resources that complement one another.

6.4.2 Education Initiatives

Both parties acknowledged the importance of, and need for, education for all OAS members (athletes, coaches, officials, parents, and volunteers). In order to address this need, four separate education outreach sessions were conducted with members over the period of three years (September 2014, October 2015, October 2016 and September 2017). The audience for the first two sessions consisted of club head coaches and club presidents, the third session audience was primarily administrators and officials, and the latest education session was conducted as part of a continuing education series for coaches. The content of these sessions included education about what a concussion is and how it occurs, concussion recognition, and sport-specific concussion management. The content of these education sessions was based on the Concussion in Sport group consensus statements (McCrory et al., 2013; McCrory et al., 2017) as well as other
selections from the sport concussion literature (DiFazio et al., 2015; Giza & Hovda, 2014; Mainwaring et al., 2010; Silverberg & Iverson, 2013). Furthermore, these education sessions were used to introduce, explain, and promote the use of the concussion program resources as they were developed and introduced to the membership. A key part of the education initiatives was clear communication with members around the objectives of the program, the purpose of each of the program components, and the practicalities of how to use the different tools. This was vital to fostering buy-in from the membership and to help promote the adoption and use of the program components at the ground level.

To date, the forms that education has taken has been mostly limited to lecture-style presentations at OAS conferences and events. The face to face approach, as opposed to simply distributing the information, was chosen in order to really connect with the membership and provide a forum for questions and discussion. In fact, the concept for the progress tracking tool was born out of a discussion session at the end of one of the education sessions. This tactic has been effective in reaching the members who already take an interest in the topic and are ready and willing to participate in safe concussion management and injury surveillance. However, there is a large gap in reaching those members who may not have the same interest level or previous knowledge of the importance of concussion safety. More diverse education and communication methods need to be employed to enhance membership engagement in the program.

6.4.3 Injury Tracking

The fifth goal of the concussion safety program was to develop and implement an injury tracking program for use province-wide. The purpose of the injury tracker is to document injuries of all types, for organizational insurance coverage and to collect data to use as a basis for athlete health and safety decisions. OAS expressed a strong interest in extending the concussion safety program beyond member education and management resources into injury prevention. A key component of injury prevention efforts is identifying risk factors for injury (van Mechelen, 1997). If these factors can be modified, they are reasonable targets for prevention strategies. The injury tracking program was designed to gather data on the rate and contexts of concussion injuries in order to lay the groundwork for future concussion prevention. It was decided that it would be valuable and important to collect data on all injury types. The two main reasons for this were to provide a basis for comparison for the concussion injury context data, as well as to
enable future research focus on different injury types. For example, OAS members have expressed interest in further study of hip injuries in artistic swimmers.

The tool used for data collection was the PlaySafe Injury Tracker, a free to use online sports injury tracking tool that sport organizations can customize to fit their needs. The PlaySafe Injury Tracker was developed by the PlaySafe Initiative, part of the Sunnybrook Office for Injury Prevention. The tracking and prevention component of the concussion safety program is still quite new, however; it is important to establish this kind of monitoring in order to have objective data. The results can be used to both identify injury prevention targets and assess the impact of education and prevention initiatives.

The injury tracking program was specifically set up as part of the prospective cohort study of concussion incidence and injury factors in artistic swimming (Chapter 5 in this document). The study outcomes include the first measurement of concussion incidence in artistic swimming, and a description of the contexts in which concussions are occurring in artistic swimming. These important findings lay the groundwork for continuing the tracking program in future seasons, in order to continue to measure the incidence of concussion in this population as well as begin to isolate targets for intervention with a view to concussion prevention.

6.5 Program Evaluation

6.5.1 Evaluation Methods and Defining Success

Both the research team and OAS noted the importance of evaluating the concussion safety program through multiple avenues. A significant first step of evaluation was coming to a definition of program success. We defined success as to what degree the program goals were met, positive user feedback, and interest from other artistic swimming provincial sport organizations in adopting the program.

The Centers for Disease Control and Prevention’s (CDC) Framework for Program Evaluation in Public Health was used to guide the evaluation process (CDC, 1999). There are six steps in the framework: (1) engage stakeholders, (2) describe the program, (3) focus the evaluation design, (4) gather credible evidence, (5) justify conclusions and (6) ensure use and lessons learned.
When these steps are followed, evaluations are viewed as being more ‘culturally competent’; that is, they are conducted through a culturally-appropriate lens and are relevant to the culture of the population that the program is serving (CDC, 1999). A key component of the framework are the evaluation standards. The standards are utility, feasibility, propriety and accuracy, and are intended as the “benchmarks” for program evaluations using this framework (Gill, Kuwahara & Wilce, 2016). The evaluation process used by the U of T and OAS partnership followed the steps of the CDC framework. Furthermore, the partners strived to apply the evaluation standards to the evaluation of the concussion safety program to ensure the integrity and accuracy of the evaluation.

Multiple types of evaluation were used to measure how well the concussion safety program met our definition of success. To assess how well we met our goals, we held a series of critical review meetings throughout the process with representatives from both parties (LMS, MD and RB). The team engaged in some honest self-reflection of both the concussion safety program and the research partnership, to explore and define what was successful and what could be improved in the future. In addition, coaches who had used the injury tracker were interviewed to obtain user feedback on the effectiveness and usefulness of the tracker and their perceptions of the concussion safety program as a whole. General results of the evaluation process can be found in the Lessons Learned section. Specific findings from the meetings can be found below, and findings from a qualitative study with the users (coaches) can be found in Chapter 7.

6.5.1.1 Self-Evaluation

The self-evaluation process was conducted throughout a series of meetings between LMS from the research team and RB, MD and RK from OAS. The purpose of these meetings was to provide updates in terms of findings as data were collected and analyzed, and to reflect on the program to date and the process used to develop and roll out the resources. The meetings provided a forum for both sides to offer insights and feedback. Meetings were conducted in person and were held between December 2017 and December 2018. The representatives from OAS indicated that their satisfaction with the program and its components was overall very high. Components that were the most positively regarded were the sport-specific management guidelines, the return-to-sport protocol, and the injury tracking program. The SSO team members identified that trust between the partners, open communication, and common goals
were the biggest facilitators to the success of the partnership. Three key areas in which to improve the program were acknowledged as: seeking input from the national sport organization to ensure that the PSO policy and guidelines were aligned with national ones, continuing to monitor the requirements of Rowen’s Law as it is updated to ensure compliance with provincial government regulations, and the addition of some questions to the injury tracker to expand the injury data collected. OAS proposed that it would be useful to collect data on the education level of the coach overseeing the athlete at the time of injury, and LMS proposed that it could be important to know the point in time during the training session or competitive event (first third, middle third, or last third) that the injury occurred. Both of these additions were discussed by the partners and agreed upon. The coaching level question was adopted mid-season during the 2017-2018 competitive season, and the time point question was added to the tracker prior to the beginning of the 2018-2019 season.

The progress of the partnership was compared to the definitions of success that had been previously identified. All five program goals (see Section 6.3.3) were considered to be met. The partnership is in the process of setting new goals; for example, expanding the injury tracker to a national level to widen the study population and capture more data. The feedback from the users of the concussion safety program was largely positive. An important area for improvement that was identified through user feedback was that members are much more aware of the injury tracker than of the other sport-specific concussion resources. Based on this feedback, both partners agreed that better communication to the members of the existence and purpose of the other program resources was needed. A more in-depth examination of user feedback can be found in Section 6.5.2. Lastly, two other provinces expressed interest in the Ontario program resources, with one province officially adopting the sport-specific management guidelines and return-to-sport protocol. With all three definitions of success fulfilled, the partners mutually agreed that this important program be continued and improved upon, and that the partnership be preserved moving forward. This can be achieved through the setting of new goals, maintaining open communication, and continuing to support mutual input into the program.

6.5.2 Challenges

There were a few challenges encountered in both the program design and implementation phases. The first challenge encountered in the design stage was the balancing of the wishes of the
organization with what is possible using a sound scientific approach. Understandably, OAS wanted recommendations immediately for rule and/or policy changes to reduce concussions. However, it wasn’t possible to produce these kind of recommendations so early in the research portion of the project. It is vital that any guidelines or changes are based on objective, sport-specific data, as well as current sport concussion guidelines. In order to collect enough data to inform any recommendations, the injury surveillance component needs to continue for additional seasons. In a community-academic partnership it is important to consider the organization’s input into the research objectives, while maintaining scientific integrity.

The implementation phase included the injury surveillance study. The data were hosted by a separate organization and had to be obtained by OAS to redact the names before being handed over to the researchers for analysis. The multiple steps to obtain the data created delays in the analysis process which made it difficult to adhere to our timelines. Another challenge encountered in the implementation phase was the increased workload on the OAS staff member in charge of some of the practical tasks associated with the project (RK). These practical tasks included receiving the incident report data and redacting the identifying information before transferring the data to LMS. While having the organization directly responsible for some tasks within the project was mostly beneficial in that it engendered a sense of ownership and investment in the project, it also placed demands on RK above and beyond her regular job. This further contributed to timeline delays.

Despite the challenges encountered, the concussion safety project—and the partnership that created and produced it—was generally perceived in a positive manner by both the partners and the coaches who were interviewed. The difficulties identified present opportunities for improvement for future collaboration.

6.6 Discussion

The OAS concussion safety program was an effective partnership between university-based researchers from the University of Toronto and the community sport organization Ontario Artistic Swimming. The success of this project has important implications for protecting athlete safety while participating in artistic swimming in Ontario. The most fruitful aspects of the
working relationship between the partners were the clear and continuous communication between the parties, the mutual input into the objectives of the project, and the sharing of the roles and responsibilities of the project implementation. Goodman and Sanders Thompson (2017) have described a spectrum of stakeholder involvement in Community Engagement in Research (CER). According to their classification, our partnership would be classified as “Collaboration” which is part of the “Engaged Participation” category. In collaboration both parties have an active contribution in the design and execution of the research and analysis of the findings with mutual benefit and a balance of power (Goodman & Sanders Thompson, 2017).

The guiding principles behind our partnership are aligned with the values of CER outlined by the National Institute of Health (NIH). Namely, our research relationship involves a strong researcher-community partnership, clear and relevant research goals, mutual benefit and equal respect for both parties, and the translation of the findings into policies and programs (Ahmed & Palermo, 2010).

This collaboration between the university-based research team and the provincial sport organization representing the artistic swimming community in Ontario is an excellent example of community-based participatory research (CBPR). CBPR enhances the creation and translation of knowledge by directly involving communities in projects (Cornwall & Jewkes, 1995). Main benefits of this research approach include community-supported interventions, expanding of research discourse beyond academia and into the “real world”, and sustaining programs and long-term relationships between partners of mutual benefit (Wallerstein & Duran, 2010).

The partnership between University of Toronto researchers and OAS exemplified many aspects of the Revised CBPR Conceptual Model (Belone at al., 2016). This model was adapted to describe the partnership by preserving the constructs that applied to this situation and explaining how each is applicable. Constructs that were not relevant to the collaboration experience were not included. In the model, group dynamics work within contexts to produce intervention and research, which leads to outcomes. Many aspects of the Contexts construct matched with the experience of our collaboration. The enactment of Rowan’s Law pushed ahead the creation of organizational policy and the awareness of the need for resources. Members of OAS involved in the concussion safety project brought specialized skills and experience that were important in the creation of many of the program components. Similarly, the primary investigator (LMS) brought
a unique combination of scientific research skills and a deep knowledge of the sport of artistic (synchronized) swimming. This greatly facilitated the design and creation of the concussion safety program and its components. In addition, the perceived importance of the health issue at hand, sport-related concussion, was quite high amongst the partners and the community. There was overlap between the Group Dynamics construct and our partnership as well. The partnership has existed for several years, which facilitates trust between the partners. Both parties had high motivation to participate in the program, and there were pre-existing personal relationships between members of the partners, which collectively increased buy-in from both sides. Furthermore, LMS was in the position to act as a bridge person between both parties given her role as the principal investigator and her reputation amongst the OAS community as a coach and a former athlete. The use of flexible dialogue and participatory decision-making, along with the willingness on both sides to engage in mutual learning and self-reflection, strengthened the relational dynamics of the partnership. Likewise, the use of—and recognition of the importance of doing so—language specific to the sport and to the OAS community helped to reinforce the relationship between the parties. Lastly, these aspects were reflected in the intervention and research components of the concussion safety program, which has directly led to new policies and resources and an increase in capacity of both parties. In time, this should lead to improved health outcomes in the form of a decreased risk of concussions. An adapted version of the Revised CBPR Conceptual Model can be found in Figure 5.
Figure 4. Map of OAS-researcher partnership on to the Revised CBPR Conceptual Model (adapted from Belone et al., 2016).

Sharing the power of decision-making and responsibilities of the project amongst both parties, and maintaining consistent communication, allowed for the growth and evolution of the concussion safety project beyond what could have been accomplished alone. That being said, there is still room to grow. The main lessons that were taken away from this collaborative partnership experience are presented below.

6.7 Lessons Learned

This partnership, the design of the OAS concussion safety project, and the development of the project components, have provided some important lessons for future CBPR projects with community sport organizations. The main take-away lessons from this project are as follows:
• **Trust and Respect Amongst Parties**: The strength of the relationship between the academic research team and Ontario Artistic Swimming was bolstered by mutual trust and respect between the partners. This was fostered in multiple ways. First, there was a pre-existing relationship between the principal investigator, LMS, and some members of the OAS project team. This was beneficial as it facilitated the dialogue between partners, especially in the earlier phases of the project. Second, both parties had input into the scope of the project, the number and type of resources created as part of the project, and the content of some of the project components. The opportunity to have input allowed the community partner to feel that their ideas were valued and respected by the academic research team. Third, a regular flow of communication allowed each partner to trust that the other was meeting their responsibilities to the project, which in turn engendered trust between the parties. This is discussed further in the next lesson.

• **Consistent Communication**: Communication was maintained continuously throughout the design, implementation, and evaluation of the concussion safety project. This was vital to the project’s success. Strong communication affords efficiency and promotes the achievement of research objectives by stimulating the flow of work on the project. In addition, roles can be clearly maintained as both parties stay on the same page. Communication was sustained through electronic mail and regular meetings. As mentioned above, regular check-ins assist in the building and maintenance of trust between the research partners.

• **Community Contribution**: The Ontario artistic swimming community was involved in the project both through OAS representing them as their governing body, and via direct feedback from community members to the research team. This feedback was gathered through both formal and informal processes. The formal evaluation process involved interviewing members of the OAS community—head coaches of OAS member clubs—to elicit feedback on the resources developed through the concussion safety program. This feedback is being used to evolve the concussion safety program. Informally, feedback was gathered during some of the education sessions put on as part of the program. The most significant incorporation of informal feedback was the development of the progress tracker at the request of coaches who had managed concussed athletes. Listening to the community and considering their
feedback creates a feeling of investment in the project in the community members which in turn enhances their participation in the research arm of the concussion safety program and their use of the program resources.

- **Data Collection/Hosting**: A crucial part of the concussion safety program is the injury tracking research program. This tracking program was greatly facilitated by a collaboration with the PlaySafe Initiative, based out of Sunnybrook Health Sciences Centre in Toronto, Canada. This organization has produced a tool called the PlaySafe Injury Tracker, a web-based application customizable for sports organizations to collect data on any injuries that occur in the course of participating in sport. Access to the PlaySafe Injury Tracker greatly shortened the time it took to launch the research arm of the program as it provided an established tool with which to collect the injury data. However, there was a significant drawback to using the PlaySafe tool, and that was the data storage location. All the data collected using the PlaySafe Injury Tracker is hosted on the Sunnybrook servers, and neither the university-based researchers nor the OAS team had direct access to the data. The involvement of a third party created difficulties in accessing the data. The analysis was performed by LMS in the University of Toronto Concussion Lab, but the data had to be transferred from PlaySafe to OAS where the names were redacted, and then on to LMS. Delays were created by the data having to pass through multiple hands. Future research by community-academic partnerships should carefully consider how and where data is being stored, and who will have access to the data. Privacy and protection of participant identifying information should be protected, while efficiency of data access should be maximized.

- **Task Burden on Organization**: One of the contributors to the success of the concussion safety program was the high level of involvement by the community organization. This enhanced investment in the project through a feeling of ownership facilitated progress, however; it placed a burden on the staff members involved. Tasks associated with the program competed with the duties associated with their regular jobs. This resulted in both strain on the team members, and decreased efficiency in completing program objectives. The burden on each partner should be considered in a community-academic collaboration, and steps taken to minimize strain on team members due to tasks associated with research and programming.
6.8 Conclusion

The collaboration between academic researchers from University of Toronto and the community sport organization Ontario Artistic Swimming was an overall success. Valuable program resources, an important line of research, and a lasting partnership between the parties were born out of this collaboration. The resources developed as part of the concussion safety program are all still in use by OAS and its membership. In addition, some program components have been adopted by other provincial artistic swimming organizations. Important lessons from the collaborative experience are potentially useful for future collaborative partnerships between academic researchers and community sport organizations.
Chapter 7
Study Four

7 Coach Perceptions of Concussion Resources

7.1 Abstract

Through a collaborative partnership between Ontario Artistic Swimming (OAS) and researchers from the University of Toronto, a program of sport-specific concussion resources was developed and implemented. A crucial part of the evaluation process was gathering feedback from the end users of the program, the member coaches. In order to achieve this, a qualitative study was employed to examine coaches’ perceptions of the injury tracker. Important findings on coaches’ attitudes towards injury reporting and surveillance are reported, as well as specific implications for enhancing injury tracker use. Recommendations for facilitating coaches’ use of the tracker, and the OAS sport-specific concussion resources, are presented.

7.2 Introduction

Athletic injury can have negative consequences on an athlete’s physical, mental and emotional health (Dawes & Roach, 1997; Leddy, Lambert & Ogles, 1994; Russell, Tracey, Wiese-Bjornstal & Canzi, 2018; Von Rosen, Kottorp, Fridén, Frohme & Heijne, 2018). Furthermore, previous injury can increase the likelihood that an athlete will incur a subsequent injury (Giroto, Hespanhol Junior, Gomes & Lopes, 2017; Hägglund, Waldén & Ekstrand, 2006; Whittaker, Small, Maffey & Emery, 2015).

Injury prevention is a key part of protecting athletes’ health and well-being. The ‘sequence of prevention’ of sports injuries is composed of four stages: establishing the extent of the problem, establishing the injury etiology and mechanisms, introducing preventative measures and assessing the effectiveness of those measures, specifically through repeating the first step (van Mechelen, Hlobil & Kemper, 1992). Application of the ‘sequence of prevention’ requires an injury surveillance system, ideally one that is able to support all the stages in the sequence (van Mechelen, 1997). Given the specificity of injury types and etiologies in different sports, oftentimes a sport-specific system is warranted (van Mechelen, 1997).
With this in mind, the partners in the Ontario Artistic Swimming (OAS) concussion safety program determined that a sport-specific injury surveillance program was needed to track injuries to artistic swimming athletes in the province. The collaborative partnership behind the OAS concussion safety program consisted of three administrators from OAS (RB, MD and RK) and two researchers from the University of Toronto (LMS and LMM). The principal investigator was LMS. The aim of the program was to develop sport-specific concussion resources. The program consists of a concussion policy, an information guide for athletes and parents, concussion management guidelines and return-to-pool protocol, a return to sport progress tracking tool for coaches, concussion education sessions for coaches and administrators, and an injury tracking program. While the injury tracker was developed as part of the concussion safety program, it is intended to track and record all injuries sustained as a result of artistic swimming participation and not just concussions. The questions in the tracker were reviewed for face and content validity during the development process. Following the implementation of the resources in the OAS community, the partners began an evaluation process to assess the utility and effectiveness of the concussion safety program, particularly the injury tracking component.

We recognized that coaches would play an important role in the implementation and evaluation of the injury tracker. The relationship between youth athletes and their coaches has been described as potentially the most significant relationship with an adult in these athletes’ lives (Gervis & Dunn, 2004). Previous research has recognized the critical role that a coach can play in an athlete’s injury management and rehabilitation (Bianco, 2001; Johnston & Carroll, 1998). Due to their important position on the frontlines of injury management, we believed that a crucial part of the evaluation process would be to hear the coaches’ perceptions of the injury tracker. In order to capture the amount of detail we believed was necessary to describe the coach perspective, and to allow the voices of the coaches to be heard, a qualitative approach was deemed to be the most appropriate manner in which to investigate.

Qualitative research methods are useful for gathering descriptive data in participants’ own voices (Taylor, Bogdan & DeVault, 2015). Qualitative methods have been used previously in program evaluation in various fields including special education and disability (Bogdan & Taylor, 1990), early childhood mental health (Williams, Joyner, Matic & Lakatos, 2019), physician training (Neff et al., 2017) and childbirth support (Richards & Lanning, 2019). Adopting a qualitative
approach to evaluation allows the researcher to move beyond collecting facts about the program to incorporate human and contextual aspects that are important in understanding a user’s perspective (Guba & Lincoln, 1989).

7.3 Method

7.3.1 Paradigmatic Position and Researcher Perspective

The purpose of this study was to evaluate coaches’ perspectives of the usefulness and effectiveness of the concussion safety program resources, primarily the online injury tracker. In order to achieve this, a qualitative study was conducted from a post-positivist paradigmatic position. A paradigm is a set of beliefs that represent a worldview from which the researcher defines the world and their place in it (Guba & Lincoln, 1994). Post-positivism is an evolution of the positivist paradigm, which asserts that truth can only be obtained through verified and replicable findings of directly observable processes (Clark, 1998). Positivism assumes an objective reality completely apart from the observer, and centers on the desire of the researcher to explain and control phenomena (Guba & Lincoln, 1994). It has long been criticized for its reductionist and deterministic approach (Guba & Lincoln, 1994; Keat, 1980). Where post-positivism differs is the researcher, and their associated beliefs and perceptions, are recognized as being connected to investigation rather than completely disconnected from reality (Clark, 1998). In terms of epistemology, which is concerned with the nature of knowledge and the assumptions and beliefs we have of that nature, post-positivism takes a modified dualist/objectivist approach in the sense that while it is recognized that true dualism is likely not possible, an objective approach is considered ideal (Guba & Lincoln, 1994). In terms of ontology, which is concerned with the nature of reality and our assumptions and beliefs about reality, post-positivism has a critical realism, which assumes that a distinct objective reality exists but that our ability to understand it is inherently influenced by our own biases and thus reality can only be known imperfectly (Guba & Lincoln, 1994).

Working from this perspective, my goal as the principal investigator (PI) was to understand the coaches’ perceptions of the tracker as a representation of the real usefulness and ease of use of the tracker. My own beliefs and lived experiences would have interacted with and influenced
how I conducted the study and how I interpreted the data, leading to an imperfect understanding of the coaches’ reality. My aim was to understand enough to be able to generate recommendations for ways to modify the tracker that would improve coaches’ perceptions of it and ultimately increase its use within the community. As a fellow coach and member of the community, my position as a participant-observer allowed me to have a better and closer understanding of the other coaches’ experiences. By ‘speaking the same language’ as my participants, I was able to develop a degree of trust with them that an outsider to the community would not have been able to within the same time frame. This trust and understanding allowed the participants to feel more comfortable in sharing their perspectives and allowed me a closer understanding of their reality than I otherwise would have had.

7.3.2 Participants

Feedback was sought from coaches in the province that had experience with the injury tracker. A convenience sample of three coach participants represented clubs from three of the four competitive regions in Ontario (East, Central and West). Inclusion criteria for coaches was as follows: coach-of-record of competitive athletes during the 2017-2018 season, and had used the injury tracker at least once in the last year.

The three participants, designated as C1, C2, and C3 were all from different competitive clubs in different regions. C1 is the head coach of a large club from the Central competitive region. She primarily coaches Junior level athletes; however, as the head coach she is involved to a certain degree with all competitive athletes in the club. She holds her NCCP Level IV and is also an accomplished mental performance skills consultant. At the time of interview, C1 had used the online tracker several times, including once for a concussion. C2 is a competitive coach at a large club in the West competitive region. She did not coach a team in the 2017-2018 season but was the coach of record for competitive athletes in extra routines (i.e. solos and duets). As of the time of study participation, she had used the injury tracker twice. C3 is the Lead Competitive coach of a large club in the East competitive region. At the time of her interview, she had filled out the injury tracker numerous times, including multiple times for concussions. C2 and C3 are both CAC Competition Development certified. Due to the relatively small size of the community, no other demographic information is reported in order to protect participants’ anonymity.
7.3.3 Interviews

This study was approved by the University of Toronto Research Ethics Board (Protocol #34507). Participants were recruited through the investigator directly. Semi-structured interviews were conducted, and the guide for these interviews can be found in Appendix H. Questions focused on the coaches’ perceptions of the injury tracker as well as their and their athletes’ concussion knowledge. Their attitudes towards injury tracking in general were also explored. Informed consent was obtained before each of the interviews began. The consent form can be found in Appendix I. The interviews were audio-recorded using the Voice Recorder application for iPhone (2018), and the recordings were transcribed verbatim by the PI. Notes on the emphasis and focus of the participants’ answers were taken during each interview. The text of the transcripts were analyzed using content analysis in the method described below.

7.3.4 Analysis

In order to address the stated purpose of the study, a qualitative content analysis of semi-structured interviews was conducted. Content analysis originated from communication sciences, where it started as a quantitative method for analyzing large amounts of text (Mayring, 2004). The fundamental idea of content analysis is that a greater amount of text can be organized and collapsed down into a fewer number of categories (Weber, 1990). The way these categories are interpreted and presented depends on the goal of the researcher. Whereas a quantitative content analysis organizes the text into pre-determined categories through explicit counts of codes, a qualitative content analysis is more concerned with interpreting the latent meanings of the communication (Kondracki, Wellman & Amundson, 2002). The text being analyzed can be obtained through various methods, including participant interviews.

The interviews were analyzed with an inductive content analysis approach by the principal investigator (LMS). This approach was selected as it is appropriate for describing a phenomenon when existing literature is limited (Hsieh & Shannon, 2005) and allows the researcher to make valid inferences from the data to provide an insight into or representation of the phenomenon under investigation (Elo & Kyngäs, 2008). In a conventional qualitative content analysis, data codes are derived from the data itself rather than pre-conceived before analysis begins, as is the case with directive and summative approaches (Hsieh & Shannon, 2005). This has the benefit of
resulting in themes that develop from the data rather than themes being imposed on the data (Hsieh & Shannon, 2005).

The analysis process followed the steps outlined by Elo and Kyngas (2008) and Hsieh and Shannon (2005). First, the transcripts were read through like a story to get an overall sense of the participants’ perspectives. The transcripts were then read through again in a more focused manner and parsed into meaning units. Next, codes were given to the meaning units and recorded in the margins. Codes were transferred to coding sheets and grouped into clusters in a meaningful way. These groups were the themes that flowed from the data.

This approach was considered inductive in the sense that analysis was not guided by a theoretical framework or by existing literature. Some qualitative researchers question the extent to which the process described above is truly inductive. Cassidy (2019) points out that most qualitative research involves both inductive and deductive processes, and viewing induction and deduction as completely binary is limiting. Some researchers advocate for an ‘abductive’ approach to analysis, in which there is movement back and forth between inductive and deductive processes to relate observations to theory (Ryba, Haapanen, Mosek & Ng, 2012). Schwandt (1997) notes that qualitative analysis usually involves all three forms of analytic approaches. For the purposes of classifying the analytic approach, this study can be considered to be inductive in its analysis insofar as themes were generated directly from the participant responses, while acknowledging that deductive processes did come into play in terms of the selected interview questions which were derived from the study’s stated purpose.

7.4 Results

Overall perceptions of the program by the coaches were very positive and afforded important information for improving the injury tracker. Although all three coaches stated some minimal awareness of the other OAS sport-specific concussion resources, they did not feel familiar enough with them to provide any feedback. This was an important result in and of itself. As collaborating partners we felt that we had communicated effectively with the community about the other resources. Given the results of these interviews, our communication needs to improve to bring more awareness of the additional OAS resources to the community.
Four main themes were developed from the interview data: injury reporting, importance of injury tracking, facilitators to using the tracker, and barriers to using the tracker. Each of these themes and their corresponding sub-themes are described below. Quotes from the participants are included to illustrate some of the sub-themes and provide voice to the participants.

### 7.4.1 Injury Reporting

Coaches reported that prior to the OAS injury tracker, their clubs attempted to keep track of athletes’ injuries through paper reports completed as part of facility requirements. All three participants identified instances of chronic injuries that were not reported in the OAS injury tracker, however; they felt that acute injuries were being captured quite well. Three common reasons for not reporting chronic injuries were identified: (1) unaware that chronic injuries should be logged in the tracker, (2) lack of clarity as to what constitutes an actual injury, and (3) disagreement with the expectation that all chronic injuries should be logged.

Coaches all reported being very aware of the need to report traumatic injuries, especially any blow to the head or suspected concussion. However, awareness of needing to use the system for chronic injuries was lower:

> “I’m going to be honest, the only time I would fill it out is if it’s a new like traumatic, ‘getting pulled out of the water’ injury. If it’s a chronic, over-use, tired… it’s not even on my radar to fill it in right now.” C1

Participants also identified the difficulty in making the judgement call of when to call a chronic condition an actual injury, and which chronic problems should or shouldn’t be reported. Participants were unsure of what a reasonable ‘threshold’ for reporting a problem as an injury should be:

> “It’s hard to say because with chronic injuries, sometimes they aren’t even happening at the pool, they’re just sort of coming up. So it’s hard to identify, because there’s no big moment.” C3

> “The last one I did was a chronic illness, and she’s already been seeking medical attention but she was like collapsed in the bathroom. So I was like ‘this has to be reported’, but it’s a chronic condition…that one I didn’t really know if I was supposed to.
I think I remember during that [report] being like ‘I don’t know if I should be reporting this or not.’”  

“...something would have to be done. Or the other marker, is any time they have to go to a doctor. Although I have to be honest, I’m not doing that now either.”  

There was also a feeling amongst the coaches that reporting each and every little problem was too onerous and an unrealistic expectation for a coach. This tied into the concept of a lack of clarity around the threshold for reporting:

“I’m just trying to think about the sheer volume. Like if we have 100 swimmers [in the club], and every one of them has at least one incident a year, of overuse and tiredness, and some people up to 6, you’re looking at us potentially filling in that [tracker] up to 600 times for chronic overuse...that’s a lot of time spent filling out stuff. Is that a reasonable ask of the coaching staff of Ontario? I don’t think so.”

Despite a positive regard for the injury tracker, coaches are not reporting all injuries to OAS. This appears to stem from both feelings of confusion around what constitutes a reportable incident, and disagreement about the threshold for reporting an incident and the potential burden on a coach.

**7.4.2 Importance of Injury Tracking**

In contrast to their feelings around reporting chronic injuries, all three coaches reported that keeping track of injuries in general was important to them as a coach and in line with their personal coaching philosophy. Two of the participants identified group insurance coverage through the provincial sport organization as a reason that tracking was important:

“Super important, not only because everything should be recorded, but even for something like insurance purposes. Like if it did happen at a competition or at a practice, that could be covered by Synchro Ontario’s insurance, and that could help because some parents don’t have that.”
All three coaches felt that tracking injuries would encourage follow up and proper recovery by enhancing communication between coaches and healthcare professionals. There was also a perception that injury tracking could improve athlete safety and keep athletes participating in sport longer:

“It’s just, you can always go back to it, it’s there and it’s monitored. Then the coach can be on top of following up, and the parents are identified…it’s just good communication.” C2

“I would say I put a pretty high [importance], especially with having athletes that are there all the time, it’s important to know what steps we’re at and following up with physicians too when need be. Some of our kids are definitely injury-prone and work a lot with physio and stuff, so it’s good to know where we’re at and what we need to adjust in training, to keep them in the sport longer.” C3

Coaches reported belief in the importance of collecting information about injuries in their athletes, which appears to conflict with their behaviour of letting some injuries go unreported.

7.4.3 Facilitators to User Friendly Tracking

The overall impression of the online injury tracker was very positive, with all three coaches describing it as “easy to use” and user-friendly. The participants identified the following as facilitating the use of the injury tracker: (1) online access, (2) comprehensive list of answer options, (3) option to enter additional explanation/information, and (4) makes the medical bye process easier:

“The fact that it’s online, it’s easy to just pull it up. Very rarely am I struggling to input anything. It seems to be pretty fast and efficient, and it makes it easier to go through the medical bye process later if needed, because that step has already been taken.” C3

“I think the new system is way speedier, just in terms of the options going through, it’s a bit more accessible just to find exactly what you’re looking for especially based on the length, and where it was, and what happened, I think there is like every option at this point, and I’ve yet to have to click the other button.” C3
“You know it’s a good mix of having check boxes and having a space that I could write stuff out. I liked having that space to write out, because there were times that I didn’t really know what to do, but I can explain more in depth in the boxes where it allows me to. Super easy. It is convenient and doesn’t take that much time.”  

C2

Participants identified several logistical aspects of the tracker that increase its ease of use. It is important to recognize the facilitators to using the tracker, so that OAS can maintain and enhance those features.

7.4.4 Barriers to Injury Tracker Use

The participating coaches identified the following barriers to using the injury tracker: (1) the link to the tracker was difficult to find the first time it was used, (2) some of the information asked for wasn’t always on hand (e.g. birthdates), (3) not mobile friendly, and (4) no option to save and continue later:

“All the communication comes through the head coach. I don’t recall seeing it obvious on the website, like not right on the first page.”  

C2

“It was a bit hard at first. Like we knew it was a thing but the links weren’t quite there all the time or it wasn’t as easy to access, it wasn’t on the home page right away so that made it a bit harder. I also think just going off of a paper system was a bit of a different change, rather than just relying on the pool but making sure everything is followed through on that.”  

C3

“Probably the hardest part is birthdates, depending on what it is, generally you can’t pull that up, and you don’t have that… that would make it the most challenging I think.”  

C3

As with the facilitators to using the tracker, the coaches focused on logistics when discussing the barriers to using it. It is equally important to recognize the barriers to use, so that OAS can begin to address them and enable more coaches to use the tracker.
7.5 Discussion

The coaches who participated in the interviews provided valuable information about their perceptions of the OAS injury tracker. The four main themes that described the data were as follows: injury reporting, importance of injury tracking, facilitators to using the tracker and barriers to using the tracker. The process used to arrive at these themes was inductive in the sense that no outside theories or models were imposed. However, it is important to note that there is an element of deduction in the sense that participant responses were guided by the interview questions, which likely influenced the manner in which they answered the questions and how I interpreted the answers. Nevertheless, given that the main purpose of this study was to examine coaches’ perceptions of the OAS concussion resources and especially the injury tracker, the structured nature of the responses is appropriate given the applied nature of the research.

The coaches interviewed were all quite aware of and comfortable with using the online injury tracker resource. However, their awareness of the other OAS concussion safety program resources was very low by comparison. This indicates the need for more frequent and effective communication from OAS to the membership about the sport-specific concussion resources available, as well as how to use them and where to find them.

All of the participants described being aware of instances when injuries, particularly chronic injuries, occurred in their athletes or athletes in their club that were not recorded in the injury tracker. This indicated a need for greater clarity and communication around when/what to report through the injury tracker. Under-reporting of injuries in sports has been studied previously (Chrisman, Quitiquit & Rivara, 2013; Sanderson, Weathers, Snedaker & Gramlich, 2017; Wiese-Bjornstal, 2010), however the majority of work has been examining under-reporting from an athlete perspective. The fact that all three coaches, each from a different club, knew about unreported incidents suggests that this is a pervasive problem in the community. Discussion of unreported incidents led into questions around what the appropriate ‘threshold’ for reporting an injury is, and what a reasonable expectation is in terms of the logistical demands of injury reporting on coaches. Youth sport coaches wear many hats and tend to have numerous responsibilities outside the pool or playing field associated with their role, and injury reporting may take a backseat to other duties like scheduling and parent communication. It would be ideal
to have additional personnel, such as athletic trainers, to report injuries to the surveillance program. Yard, Collins and Comstock (2009) found that high school coaches participating in an injury surveillance program only submitted 55 injury reports and 36.5% of expected exposures, as compared to 338 reports and 96.7% of expected exposures submitted by athletic trainers. In the National Football League (NFL) and National Hockey League (NHL) athletic trainers review video feed and act as “spotters”, which takes responsibility of reporting out of the athletes’ and coaches’ hands (Davis et al., 2018). Unfortunately, due to the limited resources of OAS clubs, it is not feasible to have an athletic trainer to act as a spotter or manage injury reporting.

Despite the acknowledged under-reporting of injuries, all of the participants felt that injury tracking was important to them as a coach. This dichotomy between supporting the idea of injury tracking and knowingly letting injuries go unreported highlights the importance of determining the facilitators and barriers to coaches using the tracker, and translating this feedback into actual modifications to the system. The participants indicated that the online access, comprehensive list of answer options, option to enter additional information and the expedition of the medical bye process all facilitated their use of the tracker. The four barriers to using the tracker were identified as: the visibility of the link, limited access to some of the information requested, the inability to use it on a mobile device and the lack of an option to save and return to it later. Any changes that can be made to the tracker to make it as logistically easy for coaches as possible should be implemented to encourage its use. Time and logistical considerations have been cited in other injury prevention research as barriers for coaches (Joy et al., 2013; Norcross, Johnson, Bovbjerg, Koester & Hoffman, 2016; Saunders et al., 2010). Facilitating the logistics of using the tracker will hopefully serve to increase reporting, as coaches have indicated their belief in the importance of the program and their concern for their athletes’ health and well-being.

As with all studies, there were limitations to this qualitative study. First, the sample size of three coaches falls below what has historically been considered necessary to achieve saturation, with researchers recommending sample sizes between 5 and 36 depending on the type of qualitative inquiry (Guest, Bunce & Johnston, 2006). However, approaching this from the perspective of data saturation rather than theoretical saturation indicates that saturation can be thought of as the repetition of responses (Fusch & Ness, 2015) or the redundancy of responses (Grady, 1998). From that perspective, saturation was reached in this study in that there were no new themes that
developed after the third participant’s transcript was analyzed. Second, due to practical considerations a convenience sample was taken. Interpretation of the findings is potentially more limited than if purposeful or critical case sampling was used, in which a wider range of perspectives may have been accessed. Third, only coaches who had used the injury tracker were included in the sample. Hearing from those coaches that did not sue the tracker may have provided valuable insight and feedback into the true barriers to using the program. Nevertheless, this study reports important information about how the OAS injury tracker is perceived by the main users of the system. This information is valuable in modifying and improving the tracker to encourage its use by the coaches in Ontario.

7.6 Conclusion and Implications

Coaches in Ontario are the ‘end-users’ of the online injury tracker and many of the OAS concussion safety program resources. General impressions of the online injury tracker were very positive, and coaches reported that the tool is very easy to use, primarily due to the online access and the comprehensive nature of the options. Findings from the coach interviews suggest that more communication is needed to the SSO membership about the variety and breadth of sport-specific concussion resources that are available, and more clarity is needed around what constitutes a ‘reportable’ chronic condition and what a reasonable threshold is for doing so.

It is important to continue to collect feedback data in order to further enhance the program, as well as ensure that the resources are accessible, user-friendly and effective. This will serve to promote their use within the community, and assist in keeping the athletes healthy and safe. Future evaluation of the tracker and the other OAS resources should employ different sampling strategies, and ideally should include those coaches that have not used the tracker in order to better our understanding of barriers to using it. Future studies would also benefit from increasing the sample size to hear from more coaches and potentially gain some new perspectives.

Based on the findings from this study, I have made the following recommendations to OAS for improving the injury tracker and the concussion program resources:
• Create a clear guideline for reporting chronic injuries and communicate that to the community
• Consult with coaches from the community to determine a reasonable threshold for determining a reportable incident and communicate that to the membership
• Continue to host the injury tracker online and dovetail it into the medical bye process
• Upgrade the software hosting the tracker to be mobile-friendly
• Provide an option for a user to save their progress and continue at a later time
• Move the link to the tracker to the OAS homepage
• Increase communication to the community about the breadth of sport-specific concussion resources available through OAS and where they can be accessed

Results from this study indicate that artistic swimming coaches value injury-reporting and care about their athletes’ health and safety. By implementing improvements to the OAS injury tracking program, we can harness the coaches’ desire to protect athletes’ well-being and increase injury reporting in the community.
Chapter 8
General Discussion

8 Discussion

8.1 Chapter Summaries

This section summarizes the previous chapters and discuss the results of the program of research within the context of the current literature. Each of the three studies are summarized followed by a discussion of the relevant literature. Literature for comparison will include concussion incidence in amateur youth sports, descriptive epidemiology of concussion in youth sports, and community engaged research.

8.1.1 Chapter 4: Concussions in Youth Artistic Swimmers: A Retrospective Descriptive Study

The purpose of the retrospective descriptive study of concussion in Ontario amateur artistic swimmers was to describe and characterize the injury contexts in which these concussions are occurring. To date, there are no known studies of concussions in this population. The main research objective of this study was to determine which aspects of artistic swimming were more likely to lead to a concussion. To address this objective, data were collected on the following factors related to concussions sustained while participating in artistic swimming: (1) the mechanism of injury, (2) the seasonal training phase in which it occurred, (3) the location in which it occurred, (4) the competitive age group the athlete was in at the time of the injury, (5) the type of activity the athlete was participating in when the injury occurred, (6) the specific aspect of training in which the athlete was engaged at the time of injury, and (7) the time-loss participating in sport due to the injury. Participants were also asked who diagnosed their concussion as a quality check to ensure data reflected concussions diagnosed by medical doctors.

Data on the injury contexts were collected through an on-line survey tool. An invitation to participate in the survey was sent to all SSO member clubs via email, with instructions that the invitation be forwarded to their membership. The invitation was also posted on SSO’s social media pages. Inclusion criteria for the study were current or former artistic swimmers between 11 and 18 years old, and registered in a competitive category in Ontario. Of 230 respondents, 106 (46%) reported that they had sustained a concussion directly due to participation in artistic
swimming. Once inclusion criteria had been applied, 69 concussions reported by 50 athletes were eligible for analysis. If a participant indicated that they had sustained any concussions during their participation in synchronized swimming, they were asked several questions about the circumstances surrounding their injuries. Participants were instructed to respond to the questions for each concussion. The data were exported into Microsoft Excel with any identifying information removed. Descriptive statistics were calculated for all variables. Chi square goodness-of-fit tests were calculated for all categorical variables. Significance was set at $\alpha=.05$. Statistical analyses were conducted with IBM SPSS Statistics for Windows, v.24 (IBM Corp, Armonk, NY).

The mean age of athletes at the time of SRC was 13.93 (±1.97) years. The most common mechanism of injury was contact with another athlete, and the most common specific activity at the time of injury was highlights. Concussions most commonly occurred in the specific preparation and general competition seasonal phases, and during in-water training. The deep end of the pool was the most commonly reported location of concussions. Athletes diagnosed with a concussion were most commonly in the 13-15 Provincial competitive category, and concussed athletes most commonly missed more than four weeks of participation in artistic swimming. Chi-square goodness-of-fit tests were significant for all categorical variables.

This preliminary work is important as it identifies and characterizes the contexts (previously unknown) in which concussions occur in Ontario artistic swimmers. It lays the foundation for future epidemiological study of concussions in artistic swimmers, and suggests that artistic swimming is a contact sport.

8.1.2 Chapter 5: Incidence of Concussion in Youth Artistic Swimmers in Ontario

The purpose of the prospective study in Chapter 5 was to determine the incidence of concussions in youth artistic swimmers in Ontario over the 2017-2018 competitive season, and the injury factors associated with them. Data were collected using an online injury surveillance system developed with the assistance of the PlaySafe Initiative. Coaches were directed to fill out an incident report with the online tracker whenever their athletes suffered an injury that necessitated a disruption in artistic swimming participation.
There were 123 injury reports filed over the 2017-2018 competitive season, 105 of which were filed for competitive stream athletes within the age range specified by the inclusion criteria. Inclusion criteria were set as follows: registered athlete with SSO, competing in national, provincial, or novice stream, 17 years of age or younger, and injury was sustained directly from participation in artistic swimming. Any reports indicating a blow to the head or face were flagged as a possible concussion. The SSO Sport Development Manager performed six week follow-ups with the coach filing the report for all flagged head impacts. Concussion status was recorded in the report after the follow-up.

Eight injury context variables were examined: (1) artistic swimming age at time of injury, (2) mechanism of injury, (3) competitive category, (4) seasonal training phase, (5) activity type, (6) specific activity at time of injury, (7) location and (8) concussion diagnosis. Concussion diagnosis was categorized into Yes (concussion) or No (musculoskeletal injury). Concussions were only considered to be a “Yes” if they had been diagnosed by a medical doctor. The injury risk (incidence risk) and clinical incidence of diagnosed concussions were calculated. Descriptive statistics were calculated for all variables.

Of the 105 eligible injury reports, 62 (59%) were flagged as potential concussions, with 22 (21%) diagnosed concussions and 13 incomplete follow-ups. The mean age of concussed athletes was 12.80 (±2.53) years, with a range of 9-17. The majority of concussions (72.7%) and musculoskeletal injuries (65.7%) were reported by athletes competing in the Provincial stream. The most frequent mechanism of injury of concussions was contact with another athlete (72.7%). Concussions occurred most frequently in the specific preparation and general competition (36.4% each) seasonal phases. Pattern transitions (31.8%) was the most commonly reported activity at the time of injury. All but one concussion happened during training (95.5%), and the majority were sustained in the deep-end of the pool (90.9%). Concussions represented 21% of all injury reports.

The risk of sustaining any injury was 9.12%, and the risk of sustaining a concussion was 1.91%. The clinical incidence of concussion in this population was 1.91 per 100 athletes.

This study was significant as the first known study to measure the incidence of concussion in a population of artistic swimmers. Furthermore, this study builds on the findings of the retrospective study in illuminating the contextual factors of concussions in these athletes. These
results indicate that concussions are occurring in artistic swimming at a rate similar to other sports, and that further monitoring of concussion incidence, as well as the factors surrounding these injuries, is warranted.

8.1.3 Chapter 6: Building a Concussion Safety Program with a Provincial Sport Organization: A Case of Community-Based Participatory Research

The purpose of Chapter 6 was to describe the design, implementation, and evaluation of the suite of sport-specific concussion resources developed in collaboration with Synchro Swim Ontario. These resources are collectively referred to as the concussion safety program. The components developed were: an organizational concussion policy, concussion information document for athletes and parents, concussion education sessions, concussion management guidelines, a sport-specific return to sport protocol, return to sport progress tracking tool for coaches, and an injury tracking program.

The first step in the design phase was the identification of the roles of each member of the partnership and the scope of the project. The next step was delineating the goals of the concussion safety project. The implementation phase involved the development of document resources and education initiatives, and the setting up of the injury tracking research program. The evaluation phase consisted of defining success and identifying measures of same. Both self-reflection and user feedback were incorporated into the evaluation of the concussion safety program.

Five main take-away messages from the partnership and collaboration experience were: (1) trust and respect among parties, (2) consistent communication, (3) community contribution, (4) data host location and (5) task burden on team members. These lessons can be applied to continued collaboration between the University of Toronto research team and SSO or to other university-community research partnerships.

8.1.4 Chapter 7: Coach Perceptions

The purpose of this qualitative study was to explore coaches’ perceptions of the injury tracker developed as part of the Ontario Artistic Swimming concussion safety program, in order to identify ways in which the tracker could be improved. Three coaches were interviewed about
their perceptions of the injury tracker and the OAS concussion resources as well as their attitudes towards injury reporting and injury tracking. The interview transcripts were analyzed according to an inductive content analysis approach.

Overall perceptions of the injury tracker were positive. Awareness of the other resources was very limited; an important finding that indicated the need for increased communication about the resources to the membership. Four main themes flowed from the data: injury reporting, importance of injury tracking, facilitators to using the tracker, and barriers to using the tracker.

The participants reported being aware of instances of injuries that were not recorded in the tracker, but also reported viewing injury tracking as being important to them as coaches. This interesting dichotomy suggests that more clarity is needed around what coaches should report and what a reasonable threshold for reporting chronic injuries is. Increased communication to the membership around the importance of reporting chronic as well as acute injuries may also be warranted. Additional recommendations for logistical improvements to the tracker that could enhance its use within the community were also developed from the results.

8.2 Context

This section will discuss the main outcomes from the research program in relation to the existing literature. Specifically, the findings will be discussed in terms of the concussion incidence, concussion injury context, and community engaged research literatures.

8.2.1 Concussion Incidence

The cumulative incidence of concussion in competitive Ontario artistic swimmers during the 2017-2018 season was 1.91%. Cumulative incidence is the number of new cases of a condition (in this case concussion) that develop within the population of interest over a specific period of time (Bhopal, 2016). This is a measure of the absolute risk of concussion, in other words the probability that an athlete would sustain a concussion over the season (Bhopal, 2016).
Estimates of concussion in the general pediatric and adolescent population have been reported. Zhang, Sing, Rugg, Feeley and Senter (2016) examined the incidence of concussion in different age groups in the United States general population, using data from a large private health insurance group. From 2007 to 2014, the incidence of concussion in the 15 to 19 age group and the 10 to 14 age group was the equivalent of 1.65% and 1.05%, respectively (Zhang et al., 2016). A Canadian estimate using data from the 1996-1997 Canadian National Population Health Survey found a prevalence of concussion in children ages 0-14 years of 200 per 100,000 population (Gordon, Dooley & Wood, 2006). A population-based study of concussion-related doctor visits in Ontario children aged 3-18 years reported an incidence equivalent to 0.34% in 2003 and 0.6% in 2010 (Macpherson, Fridman, Scolnik, Corallo & Guttmann, 2014). This suggests that the incidence of concussion in artistic swimming may be higher than in the general population, however there are limitations to the comparisons that can be drawn between these studies.

Measures of cumulative incidence have also been reported in sport populations. A study of children treated for gymnastics-related injuries in emergency departments in the United States between 1990 and 2005 reported the incidence of head and neck injuries to be the equivalent of 0.98% in 6-11 year olds and 1.75% in 12-17 year olds (Singh, Smith, Fields & McKinzie, 2008). Looking at concussions in nine different youth (4-13 years) sports, Buzas, Jacobsen and Morawa (2014) found the incidence of concussion to be 3.85% in girls’ sports over an 11 year study period. A prospective cohort study of concussions in seven US high school and collegiate sports reported an average single-season concussion risk for all athletes of 1.8% (Marshall, Guskiewicz, Shankar, McCrea & Cantu, 2015). In a descriptive epidemiology of concussions in 13 high school sports in Michigan, Covassin and colleagues (2018) calculated an overall concussion incidence of 2.36%. Cheerleading (male and female) had a concussion incidence of 1.73% (Covassin, 2018). Among female athletes, the incidence of concussion was reported as 3.04% in women’s soccer, 2.92% in women’s basketball, 1.09% in women’s volleyball, 1.08% in women’s lacrosse and 1.07% in softball (Covassin, 2018). Taken together, these reports seem to indicate that the risk of concussion in artistic swimming is on a par with the risk in other sports. If that is the case, there is a need to continue to measure concussions in this sport and to expand to include athletes from other provinces. Injuries in artistic swimming are essentially unstudied,
and if the risk of concussion is comparable to that of other sports, it stands to reason that it deserves comparable investigation.

Nonetheless, there are some limitations to the comparisons that can be drawn between the artistic swimming incidence and the literature. First, the reported incidences from other sports are taken from the United States, while the artistic swimming incidence is from a Canadian population. Most of the research from the US is reporting on student athletes from high school or middle school sports. Whereas these athletes are the same age range as the ones in this study, the US school sports system is different from a Canadian club system. The majority of the injuries in the American studies were reported by athletic trainers dedicated to each team and trained to recognize and treat injuries. In the artistic swimming study the athletes’ coaches were charged with the responsibility of filling out the injury reports. It’s likely that many didn’t have the same training in recognizing injuries nor the time to fill out the reports every single time. In addition, the study population, and in turn the number of injuries, were much higher in the American studies. Some of these injury surveillance studies were performed over periods of several years. In order to make more accurate comparisons with the literature, the artistic swimming study needs to be extended beyond a single season.

8.2.2 Concussion Injury Contexts

The most frequent mechanism of injury for concussions in the artistic swimmers in the present studies was contact with another athlete. This has also been reported as the most frequent mechanism of injury in football, boys’ and girls’ soccer, boys’ and girls’ basketball, boys’ ice hockey, boys’ lacrosse, and cheerleading (Currie, Fields, Patterson, & Comstock, 2016; Marar et al., 2012; Marshall et al., 2015). Traditionally, artistic swimming hasn’t been viewed as a contact sport. It is important to recognize that these athletes are sustaining injuries, including concussions, from contact with other athletes. Furthermore, this mechanism of injury is the same as other sports considered to be contact or collision sports, like football and ice hockey. This parallel is important as it further supports the notion that artistic swimming should receive a similar level of focus and attention in terms of concussion research.

The most frequent activity at the time of injury was highlights in the retrospective study and pattern transitions in the prospective study. It was hypothesized that highlights would be the most frequent activity at time of injury in both studies. However, in the prospective study
highlights were only the third most frequently reported activity at the time of injury. This was counter to expectations as stunts (the cheerleading equivalent to highlights) have been reported as the most frequent activity at the time of concussion injury in cheerleading (Currie et al., 2016; Marar et al., 2012; Schulz et al., 2004), and cheerleading and artistic swimming have many parallels. Collecting more injury context data will provide a more accurate picture of the sport-specific activities that are more likely to lead to concussion in artistic swimming.

The most frequently reported seasonal training phases in which concussions occurred were the specific preparation and general competition phases, in both the retrospective and prospective studies. The specific preparation phase is November to December and the general competition phase is January to March. The entire season runs from September to June, meaning that the majority of concussions are occurring in the middle of the season. This could be because this time in the season is typically when the athletes’ routines are completed and the training volume increases dramatically. This increase in repetitions is occurring before the athletes have perfected the routine, and it is likely that mistakes are occurring that are leading to contact which is in turn leading to concussions. There are limited reports from other sports of which times of the season concussions are more likely to happen. A recent surveillance study of sport-related concussion in New Jersey high school students from multiple sports found the majority of concussions occurred in the fall (Shendell, Listwan, Gonzalez, & Panchella, 2018). However, artistic swimming was not among the sports included in the study; therefore, comparison between the findings of Shendell et al. (2018) and the current study is limited.

There are both similarities and key differences between the findings from this study on concussions in artistic swimmers and reported findings from other sports. These are all indications that further research into concussions in this sport is warranted. More data will assist in clarifying the injury contexts surrounding the concussions in these athletes, as well as help to calculate a more accurate estimate of the concussion incidence in this population.

### 8.2.3 Community Engaged Research

Community-engaged research (CER) is an approach that values and emphasizes the participation of representatives from the community in which the research is based. Traditionally, research in a community setting is unidirectional, that is the academic research team performs research on community members without their involvement. The researchers design the study, collect data
from the community and decide what those data are telling them. Sometimes the research findings are not readily available to the community after the research is concluded. CER aims to make the research process bidirectional. In this approach, the academic research team performs research with, rather than on, the community. Representatives from the community are involved in various aspects of the design and implementation of projects, to mutual benefit of both the community and the academic researchers.

There are several different models of CER (Ahmed & Palermo, 2010). Participatory rapid appraisal, or rapid rural appraisal, uses qualitative research techniques to understand a situation, with three key aspects: (1) more than one researcher is involved, (2) researcher interaction is an important part of the methodology, and (3) results are produced much more quickly (Beebe, 1995). This approach enables local members to share their knowledge, and to take part in planning and action within their community (Chambers, 1995). However, rapid rural appraisal is still largely extractive in the sense that data is collected and used based on the goals of the researchers (Cavestro, 2003).

Participatory action research (PAR) is a methodology that seeks to improve health outcomes in participants through direct involvement and participant action. There are three main aspects in which PAR diverges from traditional research techniques: (1) the focus of research is enabling action through self-reflection, (2) power is shared between the researchers and the researched, and (3) as the name suggests, PAR involves the active participation of those on which the research is being conducted (Baum, MacDougall & Smith, 2006). There is an important distinction to be made in PAR between participation—the ownership of knowledge production and practical improvements—and mere involvement, which can lead to exploitation of participants for the benefit of others (McTaggart, 1991).

Empowerment evaluation is a collaborative process by which a group engages in cycles of reflection and action for the purpose of self-determination (Fetterman, 2001), with a focus on program improvement through the empowerment of the people involved (Miller & Campbell, 2006). A guiding principle of empowerment evaluation is the honest understanding of a situation through a participant’s own perspective (Fetterman, 2001).

Viewed as the most well-known of CER approaches (Centers for Disease Control and Prevention, 2011), community-based participatory research (CBPR) is rooted in the equal
involvement of all parties in the study of a topic that is important to the community, combining knowledge and action to improve community health outcomes (Minkler & Wallerstein, 2008). The foundation of CBPR is a repetitive process of action, reflection, and experiential learning (Faridi, Grunbaum, Gray, Franks & Simoes, 2007). CBPR is often used with groups with social or health disadvantages, to give them a say and thereby increase the success of interventions and improve outcomes (Wallerstein & Duran, 2010). The CBPR Conceptual Model was developed to describe the partnership dynamics, their contexts, and their effect on research and outcomes (Wallerstein et al., 2008). Belone and colleagues (2016) validated and expanded the original CBPR Conceptual model through focus groups with six CBPR partnerships to create the Revised CBPR Conceptual Model. The revised model has four dimensions: context, group dynamics, intervention/research, and outcomes. According to the revised model, group dynamics operate within contexts to produce outcomes. An adapted version of this model can be found in Figure 5 on page 66.

Constructs in the revised model fit quite well with the experience of collaboration with SSO on the concussion safety project. The contexts dimension describes social, historic and structural aspects of the partnering organizations. Policy trends, community capacity, university capacity and perceived severity of health issue all played a role in this partnership. The relatively recent enacting of Rowan’s Law in Ontario, which requires sport organizations to have concussion protocols and education for their members, was a significant impetus to SSO being on board with the concussion safety project. There were some unique aspects about both the community organization and the university team that contributed to the success of the partnership as well. From SSO, RB and RK had skill sets that increased the efficiency of the design and implementation of some program resources. RB’s experience in policy writing assisted greatly in the development of the SSO concussion policy resource. RK’s organizational and communication expertise were instrumental in the implementation of various program resources. Finally, the perceived severity of the issue (sport concussion) was very high, lending motivation to both parties to complete the project. The group dynamics dimension has three sub-categories: structural dynamics, individual dynamics and relational dynamics. The length of time the parties were engaged in the partnership (an aspect of structural dynamics) was a factor in the success of the project. The partnership first started in 2013, and has been established for several years. This history has provided the time necessary for trust to be built between the partners, which had
a critical role in the success of the project. Trust was also facilitated through the personal relationships between some members of the project team. LMS and RB knew each other in a non-professional capacity, as LMS had coached RB’s daughter in the past. As an artistic swimming coach in Ontario and the lead investigator of the university research team, LMS was in the unique position to act as a bridge person between the two partners. In addition, the community reputation of the PI as a coach assisted in building trust and engagement in the project within the artistic swimming community. The research partnership also exemplified the relational dynamics of participatory decision-making, self and collective reflection, flexible dialogue, task roles and communication, and community voice and community language. The importance of using community language rather than expert language in research and intervention has been noted (Belone et al., 2016).

A spectrum of community involvement in research has been described by Goodman and Sanders-Thompson (2017). According to the classifications of stakeholder engagement, the collaboration with SSO falls under the category of “Collaboration”, which is a dimension of the highest category of engagement (Engaged Participation), and is marked by the active involvement of both partners in the design, implementation, and interpretation phases of the project and mutual benefit to both parties (Goodman & Sanders-Thompson, 2017).

The research collaboration between the University of Toronto research team and SSO has been an excellent example of success in CBPR. To date, the partnership has been very fruitful and has led to the development of 8 concussion safety program components, including member resources, concussion education, and injury surveillance research. There has been mutual benefit to both parties and strong motivation on both sides for the partnership to continue. Strong involvement in the project by the community going forward will ensure the program is sustained and the research aspect, the implications of which are significant for furthering the understanding of concussions in artistic swimming, will continue. By incorporating the lessons learned through evaluation of the concussion safety program and the partnership to date, the collaboration can grow and continue to improve and augment the program.
8.3 Limitations

The research program represents a significant step forward in terms of artistic swimming research. It is the first known empirical study of concussions in artistic swimmers, including the first known measure of the incidence of concussion in this sport and of the injury contexts surrounding same. Despite the important contribution, this work has some limitations.

Study One was a retrospective survey study. As such, it is subject to recall bias and self-report bias. In addition, the title of the data collection instrument may have introduced sample bias in terms of who decided to participate. Furthermore, there was no measure of the size of the study population and thus no way to calculate response rate or concussion rate.

Study Two was a prospective cohort study. Whereas it avoided some of the biases associated with Study One, there was a relatively small study population which limited the measurements and calculations that could be performed. Furthermore, it relied on coach observation of the events surrounding the injury. There is also the chance that the incidence risk and rate estimates are lower than the true incidence measures, due to the possibility of under-reporting.

Both empirical studies were limited to artistic swimmers from a single province. This limits the generalizability of the results. In addition, the injury context factors measured were chosen arbitrarily. There was an effort to include a range of contextual aspects; however, an important one may have been missed. The chosen factors were subject to the principal investigator’s own bias as well.
9 Conclusion

The purpose of this program of research was two-fold. The first purpose was to measure the incidence of concussions in youth artistic swimmers in Ontario, and define and describe the contexts within which these concussions occurred. The second was to do so using a community-based research approach. The specific question that guided the research was as follows: What is the frequency and context of concussions among youth female synchronized swimmers in Ontario? There were five associated research objectives to assist in answering the research question:

a) To determine the incidence of concussion in this population in a single competitive season

b) To determine the seasonal training phase in which concussions are more likely to occur

c) To determine if concussions are more common in any of the competitive age groups

d) To describe which injury context factors are associated with a concussion sustained during artistic swimming participation

e) To develop sport-specific concussion resources for the Ontario artistic swimming community

Two empirical studies, one using a retrospective and one using a prospective approach, were employed to address the first four objectives and are described in Chapters 4 and 5, respectively. The fifth objective was met through a collaboration between the university-based principal investigator and the community-based sport organization. A description of the process of this collaboration can be found in Chapter 6, and a qualitative examination of one of the resources is described in Chapter 7.
9.1 Results Summary

Each of the research objectives were met. Main findings are summarized below:

a) Objective 1: The incidence risk of concussion in competitive youth artistic swimmers in Ontario over the 2017-2018 competitive season was 1.91%. The clinical incidence was 1.91 per 100 athletes.

b) Objective 2: Findings from both empirical studies demonstrated that concussions occurred most frequently in the specific preparation and general competition seasonal training phases. This corresponds to the period from November through March. This supports the hypothesis that more concussions would occur in the specific preparation phase; however, it also suggests that the period in which concussions are more frequent extends beyond a single training phase.

c) Objective 3: Study One found that concussions occurred more frequently in the 13-15 FINA competitive age group, and Study Two found concussions occurred more frequently in the 13-15 Provincial competitive age group. The mean age of concussed athletes in Study One was 13.93 years, and in Study Two was 12.80 years. This suggests that around age 13 athletes may be more vulnerable to concussion. This partially supports the hypothesis that more concussions would occur in the 13-15 age group. Conflicting findings of concussions occurring more frequently in the FINA versus Provincial stream indicates more data are needed to fully answer this question.

d) Objective 4: Findings from both empirical studies demonstrate that the most common mechanism of injury is contact with another athlete. Concussions occurred much more frequently in training than in competition in both studies, and also occurred most frequently in the deep end of the pool. Highlights (Study One) and pattern transitions (Study Two) were the most common activities at the time of concussion. Similar to the hypothesis associated with Objective 3, the hypothesis that more concussions would be sustained during highlights and pattern transitions is partially supported. Again, different findings from the retrospective and prospective studies indicates more data are needed to clarify
which specific activities of artistic swimming are more frequently associated with concussion. Furthermore, different research methods using an external observer could help to elucidate which activity is more commonly associated with concussions.

e) Objective 5: A suite of seven sport-specific concussion resources was developed in collaboration with Synchro Swim Ontario as part of the concussion safety program. The program components are: (1) an organizational concussion policy, (2) a concussion information document for athletes and parents, (3) concussion education sessions, (4) concussion management guidelines, (5) a sport-specific return to sport protocol, (6) a return to sport progress tracking tool for coaches, and (7) an injury tracking program. All of the resources developed as part of this program are currently in use by Synchro Swim Ontario and its members.

Meeting these objectives produced important information and implications for future research, artistic swimming officials in Ontario tasked with promoting safe sport and athlete safety, and medical clinicians working with artistic swimmers who may not be aware of the risk of concussions in the sport.

In addition to these main findings, there were secondary findings from this research. The research was conducted within the community through the formation of a collaborative partnership with the provincial governing body for artistic swimming in Ontario. Study One and Study Two were part of the larger collaborative project, the concussion safety project, which developed and implemented the program of sport-specific concussion resources described above. This community-engaged research approach afforded the opportunity to perform studies that were meaningful and important to the community. There were five main take-away lessons from the program development process and the partnership itself. First, a vital part of the success of the partnership was the foundation of trust and respect among the partners. Second, consistent communication was key to maintaining progress as well as ensuring the community felt a sense of contribution. Third, the community contribution was two-fold, both through the involvement of SSO and through the participation of community members in the research components. Lastly, practical lessons in data hosting and task burden were also acknowledged. In addition, community feedback from coaches assisted in the improvement of the injury tracker resource.
These lessons may be of value to other academic-community partnerships, especially in the area of sport injury resources.

9.2 Clinical Implications and Future Directions

The results of this novel work can inform next steps in terms of practical applications and further research on this topic. In terms of medical personnel that may be in contact with injured artistic swimmers, such as sport medicine specialists and athletic therapists, it is important to raise awareness that artistic swimming is a contact sport and there is a risk of traumatic injury, including concussion. Such information could assist medical professionals in diagnosing and treating artistic swimmers more effectively. The findings of this research program also have implications for artistic swimming organizations and officials. For example, the findings that the most frequent mechanism of injury is contact with another athlete, and concussions are more frequent between November and March in the specific preparation and general competition training phases, have important implications for coach education. It is imperative that artistic swimming be recognized as a contact sport, not just by those outside the sport but also by those involved in it. Contact needs to be taken more seriously and strategies for introducing and teaching contact should be developed and provided to coaches. Concussion risk during certain training phases should be included in the coach education topics of training and periodization. Other artistic swimming organizations (i.e., other provincial governing bodies and the national organization) would benefit from adopting these or developing their own sport-specific concussion resources. These resources could benefit officials, coaches, and athletes alike.

This program of research and its results are an important first step in the investigation of concussions in artistic swimming, and demonstrate the need for further investigation. The reported incidence of concussions is the first known empirical measurement of the number of concussions in this sport; however, a larger data set would give a more accurate estimate. The findings indicate that artistic swimmers are at a moderate risk of concussion as compared to other sports. This underlines the importance of continuing to investigate concussions in artistic swimming. It will be important to expand data collection to future competitive seasons and beyond Ontario to include athletes from other provinces, or even better the country as a whole. In addition, some of the findings in terms of injury factors were inconsistent between the two
studies. This demonstrates that further study of the injury contexts surrounding concussions in artistic swimming is warranted, preferably with a data collection method that is more independent and removed from the situation. For example, using video analysis or a neutral observer could provide a higher degree of objectivity. Having objective data will assist in the formulation of concussion safety guidelines and should be used as the basis for any rule changes or other administrative actions. Furthermore, it will be important to continue to collect concussion data going forward to measure the effects of any recommendations or guidelines implemented by artistic swimming organizations. It may also be valuable to examine those flagged head impacts that were not diagnosed as concussions, both in terms of what might be differentiating these situations from those that result in a concussion diagnosis, and in terms of the possible effects on the athletes of obtaining a diagnosis versus being left without a label for their injury. Further investigation will aid in the protection of athlete health and safety, and assist artistic swimmers in staying involved in their sport for life.

In conclusion, this program of research has provided several main findings related to concussion in artistic swimming, as well as secondary lessons in academic-community partnership. Several practical resources were developed and implemented within the Ontario artistic swimming community. The research program was embedded in the community through a community-engaged research approach. Future research would benefit from continuing this community-based approach to promote participation and investment by the community members. The findings from this research program contribute to the evolving knowledge on sport-related concussions by beginning to address the gaps in the literature on artistic swimming and concussion in female athletes.
References


System in identifying acute concussion. *Annals of Biomedical Engineering, 45*(9), 2135-2145. doi: 10.1007/s10439-017-1856-y


Appendices

Appendix A: Consent Form for Retrospective Survey

CONSENT FORM

University of Toronto

Principal Investigator: Laura McClemont Steacy

Supervisor: Dr. Lynda Mainwaring

1. TITLE OF PROJECT

Concussions in Ontario synchronized swimmers: a retrospective study.

2. GOAL OF THE STUDY

The purpose of this study is to determine the aspects of synchronized swimming training that may be more likely to lead to a concussion.

3. PROCEDURES

Participation in this study consists of the one-time completion of a survey questionnaire about your injury experiences in competitive synchronized swimming. This will take 10-15 minutes.

5. ADVANTAGES OF THE STUDY

By participating in this study you will be contributing to important and valuable research into the contexts and mechanisms of synchro-related concussion injuries.

6. DISADVANTAGES OF THE STUDY
There is a possibility that recounting some of your experiences may cause you to focus on your injury experience and cause some discomfort. If this is the case you may contact the principal researcher for some resources.

7. CONFIDENTIAL NATURE OF THIS STUDY

Data will be stored anonymously and confidentially. Only the researcher directly in charge of the study will have access to the data.

Any potentially identifying data will be kept separately and destroyed after a period of one (1) year. The anonymous data will be kept for a period of three (3) years after study completion.

All data and results will be reported anonymously.

8. WITHDRAWAL FROM THE STUDY

Please know that participation is entirely voluntary, and you are free to withdraw at any point during the study with no consequence.

9. COMPENSATION

Upon completion of the survey, you will be entered into a draw to win one of 2 $50 Team Aquatic Supply gift cards.

10. QUESTIONS

If you have any further questions, we can be reached using the following information:

Laura McClemont Steacy
Department of Exercise Science
Email: laura.mcclemont@mail.utoronto.ca

Dr. Lynda Mainwaring
Department of Exercise Science
Email: lynda.mainwaring@utoronto.ca
DECLARATION OF CONSENT

The investigator has explained all the aspects of this study to me and my questions have been answered to my satisfaction. I _________________________ (Participant) have read the above description with the investigator, ___________________________ (Investigator). I fully understand the procedures, advantages and disadvantages of the study, which have been explained to me. I freely and voluntarily consent to participate in this study entitled “Concussions in Ontario synchronized swimmers: a retrospective study.”

A copy of this consent form has been given to the participant named below.

Name of Participant Signature Date

Name of Person Conducting the Informed Consent Discussion

Name Signature Date
Appendix B: Retrospective Survey Questions  
Past Concussions in Amateur Ontario Synchronized Swimmers

Q1. How many synchronized swimming related concussions have you had? (please fill out separate surveys for each concussion)
   **Multiple Choice**
   a. 1
   b. 2
   c. 3 or more

Q2. What was the date of the injury?
   **Date Field**

Q3. How old were you when the injury occurred?
   **Single text field**

Q4. What competitive level were you at when the injury occurred?
   **Multiple Choice**
   a. 11-12 Provincial
   b. 11-12 FINA
   c. 13-15 Provincial
   d. 13-15 FINA
   e. 16-20 Provincial
   f. Junior FINA

Q5. What was the exact location of the incident?
   **Drop-down list**
   - Shallow-end of the pool
   - Deep-end of the pool
   - Pool Deck
   - Change Room
   - Gym/Dryland Area
   - Other: please specify

Q6. What type of activity were you participating in at the time of the injury?
   **Multiple Choice**
   - Meet: During competitive event
   - Meet: During warm-up
   - Practice: During in-pool time
   - Practice: During dry-land time
   - Camp
   - Other: please specify
Q7: What was the cause of the injury?

Check box list
- Contact: with other athlete
- Contact: with static object (e.g. side of pool)
- Non-contact trauma (e.g. fast sharp movement)
- Other: please specify

Q8: What was the specific activity at the time of the injury?

Check box list
- Pattern change/transition
- Highlight
- Swimming laps/warm-up
- Dryland: please specify
- Other: please specify

Q9. Are there any other details related to sustaining the injury that you feel are important and wish to share?

Paragraph text field

Q10. Following the incident, were you diagnosed with a concussion by a physician?

Multiple Choice
- a) Yes
- b) No

Q11. How much time away from training did you miss due to this injury?

Multiple Choice
- a. Less than 1 week
- b. 1-2 weeks
- c. 3-4 weeks
- d. More than 4 weeks

Q12. Would you like to be entered in a draw to win a $50 Team Aquatic Supplies gift card?
Appendix C: SSO Online Injury Tracker Questions

Synchro Swim Ontario Injury Tracker

Part 1: Participant Information

In this section, please tell us about the injured person.

1. Name of the injured person:

   

2. Birthday of the injured person:

   DD  MM  YYYY

   Birthday:

3. The injured person is:

   - Female
   - Male
   - Prefer not to disclose

4. The injured person is a:

   - Athlete
   - Coach
   - Official
   - Other (please specify)

5. If the injured person is an athlete, please select the level of swimming:

   - 1 Competitive – National/FINA Stream
   - 2 Competitive – Provincial Stream
   - 3 Competitive – AWD
   - 4 Competitive – Masters
   - 5 Limited (Novice) Competitive
   - 6 Recreational Swimmer
   - 7 Recreational Swimmer – AWD
   - 8 Recreational Swimmer – Masters
   - 9 Recreational Swimmer – Short-term (camp or program of <6 weeks)
   - 0 Not an athlete

6. Please select the club to which the injured person is officially registered:

   

Synchro Swim Ontario Injury Tracker

Part 2: Injury Event Details

In this section, please tell us about the injury.

7. Date of Injury:
   Date and Time

8. Venue / Facility where Injury occurred (if applicable):

9. Exact location of injury incident:
   - Shallow-end of the pool
   - Deep-end of the pool
   - Change room
   - Pool deck
   - Other (please specify)

10. Was the event in which the injury occurred sanctioned by SSO?
   - Yes
   - No
   - Other (please specify)

11. Type of activity at time of Injury:
   - Practice / Training - During In-Pool time
   - Practice / Training - During Dry-land time
   - Camp
   - Meet / Competition - During event
   - Meet / Competition - During warm-up
   - Other sanctioned activity, please describe below
   - Other (please specify)

12. Specific activity at time of injury:
   - Pattern change/transition
   - Highlight
   - Swimming laps/warm-up
   - Breath control-related
   - Dry land, please specify below
   - Other (please specify)
13. Injured body part:
- Face (incl. eye, ear, nose)
- Head (skull, scalp, brain)
- Neck / cervical
- Thoracic spine / upper back
- Sternum / ribs
- Lumbar spine / lower back
- Abdomen
- Pelvis / sacrum / buttock
- Shoulder / clavicle
- Upper arm
- Elbow
- Forearm
- Other (please specify)

14. Type of injury:
- Abrasion / graze / blister
- Amputation
- Bruise / contusion
- Concussion
- Cut / open wound / laceration
- Crush injury
- Dental injury / broken tooth
- Dislocation / subluxation
- Other (please specify)

15. What is the status of this injury?
- New injury (Acute)
- Aggravated / exacerbated of an existing injury (Chronic)
- Recurrent injury (Previous but not chronic)
- Other (please specify)

16. Cause of Injury:
- Overuse (gradual)
- Overuse (sudden onset)
- Non-contact trauma (e.g. quick movement)
- Contact: with another athlete
- Contact: stagnant object (e.g. bottom/side of pool)
- Other (please specify)
17. Contributing to cause of injury:
- [] Pool conditions (crowded, shallow)
- [] Equipment failure
- [] Athlete state (e.g. nutrition, substance, sleep, hydration, emotion)
- [] Athlete ability not matched to activity / competition
- [] Other (please specify)

18. Please use the space below if you would like to share more detail about how the injury incident occurred:

19. Were there additional witnesses to the injury?
- [] Yes, please include name/role of witness:
  - [ ]

---

Synchro Swim Ontario Injury Tracker

Part 3: Treatment of Injury

In this section, please tell us about what happened after the injury occurred or was identified.

20. Initial treatment provided:
- [] None given (not required)
- [] None given (referred elsewhere)
- [] Removal from activity
- [] Stretch / exercises
- [] Taping only
- [] Dressing / bandage
- [] RICER (Rest, ice, Compression, Elevation, Referral)
- [] Sling / splint
- [] Crutches
- [] CPR
- [] Other (please specify)
  - [ ]
21. Immediate referral:
- No referral
- Medical practitioner
- Physiotherapist
- Athletic therapist
- Hospital: by ambulance transport
- Hospital: by personal transport
- Other (please specify)

22. Immediate advice given:
- Immediate return, unrestricted activity
- Able to return with restriction
- Unable to return at the present time
- Able to return but athlete (or parent) chose not to
- Referred for further assessment before returning to activity
- Other (please specify)

23. Treating person if on-site care was provided:
- Coach
- Official
- Lifeguard
- First Responder
- Medical practitioner
- Other (please specify)
Synchro Swim Ontario Injury Tracker

Part 4: Administration

In this final section, please let us know who is completed this form.

24. Please tell us who completed this form?
   - Athlete
   - Coach
   - Official
   - Trainer
   - Parent
   - Chief Referee
   - Other (please specify): 

25. For follow-up purposes, please provide your contact information:
   - Name: 
   - Email: 
   - Phone: 
Appendix E: OAS (SSO) Concussion Policy

### Definitions

In this Policy:

1. “Concussion” refers to a type of traumatic brain injury caused by a bump, blow or jolt to the head, face, neck or body that causes the head and brain to move rapidly back and forth and can alter the way the brain normally functions;

2. “Concussion awareness resources” refer to information or materials on concussion prevention, detection, reporting and management;

3. “Including” means including but not limited to;

4. “Medical professional” means a family physician, pediatrician, emergency room physician, sports-medicine physician, neurologist or nurse practitioner;

5. “Members” mean The Regional Training Centre, Ontario and any Competitive, Recreational, Scholastic, University synchronized swimming club or Trillium awards program provider registered with SSO;

6. “Most Responsible Person or MRP” refers to the person assigned to have final decision-making authority to remove an athlete who is suspected of having sustained a concussion;

7. “Officials” means all judges, including practice judges, referees and scorers;

8. “Parents” refers to parents or guardians of athletes under 18 years of age;

9. “Registrant” means any Member or individual that has fulfilled the requirements of registration as required by SSO and has paid any associated registration fees to SSO;

10. “SSO” means Synchro Swim Ontario;

11. “SSO Activity” means all SSO business and activities over which SSO has jurisdiction; and

12. “SSO Participants” means all persons engaged in any paid or volunteer capacity with SSO or otherwise under the jurisdiction of SSO.

### Purpose

The purpose of this Policy is to contribute to a safe and positive sport environment through education and training and by making SSO Participants aware of synchro-specific concussion awareness resources to assist in recognizing and managing a concussion injury.
Renewal
This Policy will be reviewed every four (4) years to coincide with the International Consensus on Concussion in Sport.

Application of This Policy
This Policy applies to all SSO Participants including:
1. All SSO Members or Registrants;
2. SSO directors, officers, committee members and volunteers;
3. SSO employees and persons under contract with SSO;
4. All athletes eligible for selection to, or forming part of, any team or routine participating in competitions, events or activities over which SSO has jurisdiction; and
5. All persons working with those teams or athletes, including coaches and other support persons.

This Policy applies at all times, wherever the SSO Activity takes place, which includes the SSO offices as well as external locations in Canada and abroad and includes all sanctioned activities over which SSO has jurisdiction. SSO Activity includes:
1. SSO hosted conferences or clinics;
2. Participation in provincial or national competitions including related training and organized group travel;
3. All SSO hosted meets; and
4. All SSO hosted selection and assessment processes and regular training or practice time, whether inside or outside Canada.

Responsibilities
SSO has made the following concussion awareness resources available to Members and SSO Participants on its public website at http://synchroontario.com/member-resources/concussion-resources/:
1. SSO Synchro-specific Concussion Guidelines including:
   a. SSO Removal-from-sport Protocol
   b. SSO Synchro-specific Concussion Return-to-sport Protocol
   c. Concussion Recognition Tool
   d. SSO Return-to-synchro Concussion Progress Tracker
2. SSO Injury Tracker
3. SSO Concussion Information and Guidelines for Athletes and Parents.

SSO will:
1. Ensure all SSO Activity is properly supervised, including the use of certified lifeguards in aquatic environments;
2. Assign the Most Responsible Person for all SSO hosted meets, selection and assessment processes and teams (e.g., Chief Referee or Head Coach for provincial teams);
3. Maintain a system for collecting and analyzing concussion injury data reported by Members during the season;
4. Assess changes in concussion rates over seasons and make recommendations on training or routine elements that put athletes in a position of high risk for concussion injury;
5. Provide annual concussion education for Members, coaches, officials and other SSO Participants at its Journey to Excellence conferences and other SSO hosted conferences, clinics or calls;
6. Develop concussion awareness resources for Members, officials, coaches, athletes and their parents;
7. Provide a copy of the SSO Synchro-specific Concussion Guidelines to all officials and confirm that they have reviewed the resource by no later than October 15 of each year;
8. Ensure that Members provide a copy of the SSO Synchro-specific Concussion Guidelines to all coaches and confirm that coaches have reviewed the resource by no later than October 15 of each year;
9. Ensure that Members provide a copy of the SSO Synchro-specific Concussion Guidelines to all new and returning athletes and, for athletes under 18 years of age, their parents and that they have confirmed they have reviewed the resource prior to registration; and
10. Review its concussion awareness resources every four (4) years to coincide with the International Consensus on Sport in Concussion.

All Members have responsibility to:
1. Ensure all activities are properly supervised, including the use of certified lifeguards in aquatic environments;
2. Provide a copy of the SSO Synchro-specific Concussion Guidelines to all new and returning athletes and, for athletes under 18 years of age, their parents and confirm that the athlete or parent, as appropriate, has reviewed the resource prior to registration;
3. Provide a copy of the SSO Synchro-specific Concussion Guidelines to their coaches and confirm that they have reviewed the resource by no later than October 15 of each year;
4. Ensure their coaches are familiar with their responsibilities under the SSO Synchro-specific Concussion Guidelines including how to recognize, report and manage a concussion injury;
5. Keep a copy of the Concussion Recognition Tool on deck and available to coaches;
6. Assign the Most Responsible Person for removing an athlete with a suspected concussion (e.g., Head Coach or lead team coach);
7. Submit an incident report through the SSO Injury Tracker for all instances of suspected or confirmed concussion injury sustained during synchro activity;
8. Implement SSO Synchro-specific Return to Play Protocol for all instances of concussion injury; and
9. Modify or limit training or routine elements that put athletes in a position of high risk for concussion injury based on SSO analysis and recommendations.

All Members are encouraged to establish their own Concussion Policy consistent with the responsibilities described above. These policies can strengthen, but cannot weaken, the responsibilities set out in this Policy. Failure to abide by this Policy and the protocols contained in the SSO Synchro-specific Concussion Guidelines may result in disciplinary action in accordance with SSO’s Discipline and Complaint’s Policy.

The Most Responsible Person (MRP) has responsibility to:
1. Remove an athlete who is suspected of having sustained a concussion from further training, practice or competition;
2. Call 911 immediately if any Red Flag symptoms are present (see Concussion Recognition Tool);
3. For athletes under 18 years of age, inform the parent or guardian of the removal and remain with the athlete until discharged to a parent, guardian or other trusted adult or EMS. For athletes over 18 years of age, the MRP should contact their emergency contact person;
4. Communicate to the athlete’s parent or guardian the need for immediate medical assessment by a medical professional when Red Flag symptoms are not present but other concussion symptoms are reported or observed;
5. Complete an incident report through the SSO Injury Tracker immediately after a concussion is suspected;
6. For Members, ensure medical clearance is provided prior to beginning Step 2 of the SSO Synchro-specific Return to Play Protocol; and
7. For Members, ensure the SSO Synchro-specific Return to Play Protocol is implemented for all instances of concussion injury.

The MRP may delegate any of the above responsibilities to another official or coach, as appropriate. Final decision-making authority to remove an athlete who is suspected of having sustained a concussion rests with the MRP.
Appendix F: SSO Concussion Management Guidelines and Return to Sport Protocol

SSO Synchro-specific Concussion Guidelines, 2018

These guidelines were developed from the latest Consensus Statement by the Concussion in Sport Group (McCrory et al., 2017) and research from the University of Toronto Concussion Lab. They are intended for use by synchronized swimming coaches and officials to assist in recognizing and managing a concussion injury. They are not intended to take the place of direct advice from a medical professional. When in doubt, contact a medical professional.

1. SSO Removal-from-sport Protocol

What to do if you suspect a concussion?

1. Immediately remove athlete from the pool. Remove cap and goggles.
2. Go through a brief symptom checklist:
   - Headache (differentiate between headache and pain at the impact site)
   - Nausea
   - Dizziness
   - Confusion
   - Light and noise sensitivity
   - Balance problems
   - Feeling “not right”
   - Please see the attached Concussion Recognition Tool (Appendix A) for more
3. If athlete has any of these symptoms, cease all activity immediately and inform lifeguard. Call parent or guardian to pick up the athlete and advise they should be taken to see a medical professional immediately.
4. Remain with the athlete until discharged to a parent, guardian or other trusted adult or EMS. For swimmers over 18 years of age, contact their emergency contact person;
5. Complete facility incident report and SSO Injury Tracker.
6. If athlete does not have any symptoms, allow them to remain poolside but not actively engaged in activity. Continue to monitor the athlete for symptoms every 10-15 minutes. Symptoms can set in gradually over time.
7. If athlete has no symptoms at the end of the training session, inform the parent or guardian that an impact occurred and advise them to continue monitoring the athlete.

*If an athlete has a suspected concussion, it is the parent or guardian’s responsibility to take the athlete to see a medical professional immediately. This includes a family physician, pediatrician, emergency room physician, sports-medicine physician, neurologist or nurse practitioner. Documentation from any other source will not be acceptable.

SSO Synchro-specific Concussion Guidelines, 2018
for symptoms at home. If symptoms develop at any point, the athlete should be taken to a medical professional.

If the athlete loses consciousness at any time, immediately remove the athlete from the pool and inform lifeguards. Conduct appropriate emergency procedures.
2. SSO Synchro-specific Concussion Return-to-sport Protocol

Each stage should be performed sequentially. Medical clearance* is required to progress from Stage 1 to Stage 2. Within each stage, activity should be introduced and increased gradually. The athlete should be symptom-free for at least 24 hours before progressing to the next stage. If symptoms return at any time, revert back to the previous stage until symptom-free for at least 24 hours. Every concussion is different; therefore, each synchronized swimmer may move through the protocol at a different pace. Communication between the coaching staff and the healthcare provider(s) in charge of the athlete’s care is important and should be emphasized. A sample Return to Synchro Concussion Progress Tracker form is attached (Appendix B).

Adolescent athletes may take longer to return to full activity. The Concussion in Sport Group recommends that student-athletes make a full return to school before starting a return to sport protocol.

Stage 1 Limited Physical and Cognitive Activity

- Physical and cognitive rest
- Avoid exposure to bright lights and loud noises
- Avoid all use of screens (phones, computers, tablets, televisions, etc.)
- Perform passive flexibility and breathing exercises.

Medical Clearance to Exercise

Stage 2 Light Aerobic Exercise

- Begin re-introducing light physical activity. Keep cognitive load low (e.g. no learning of new routines). Very limited water time, no inversions
- Perform aerobic activity up to 70% of maximum heart rate, avoiding excessive head movement (i.e., no shaking or extensive bouncing of the head, no sharp head movements). Start with 15 minutes and gradually increase duration of activity
  - Walking
  - Stationary bicycle
  - Kick with a board (cease if aggravates the neck)
- Continue to avoid bright light and loud noise. Wear sunglasses and earplugs to the pool when attending practice

*Medical clearance to exercise must be provided by a medical professional. This includes a family physician, pediatrician, emergency room physician, sports-medicine physician, neurologist or nurse practitioner. Documentation from any other source will not be acceptable.
• Limit use of screens (<30 min/day)
• Continue passive flexibility exercises. Re-introduce active flexibility and extension exercises.

Stage 3 Synchro-specific Exercise
• Re-introduce sport specific skills. Begin to increase cognitive load
• Continue aerobic activity, gradually increasing the duration and intensity, allow some head movement
  o Jogging
  o Swimming (all strokes) – no flipturns.
• Re-introduce some synchro-specific skills (no inversions)
  o Horizontal sculling
  o Ballet legs
  o Eggbeater and body boosts
  o Land-drill
• Athlete should not be in pattern
• Avoid resistance training and high-impact cardio
• Limit electronic use (<1 hour/day)
• Dampen light and sound exposure at the pool when possible (wear sunglasses and ear plugs)
• Continue flexibility and extension exercises.

Stage 4 Non-contact Synchro Training Drills
• Increase physical and cognitive load
• Resume full dryland training including resistance training
• Re-introduce inverted skills and whole-body movements
  o Technical drills, gradually increasing intensity
  o Figure parts
  o Routine sections
  o Flip turns
• Remain out of the pattern
• Re-introduce full light and sound stimulation at the pool
• Limited electronic use (<1 hour/day).

Stage 5 Full-contact Synchro Practice
• Resume normal training activity – full practice participation

SSO Synchro-specific Concussion Guidelines, 2018
Gradually re-introduce athlete into the pattern
  - Start with small sections at a time and build up to big parts
  - Increase electronics use (avoid screens for at least 1 hour before bed).

Stage 6 Full Return to Synchro
  - Full practice and competition participation

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www.concussion.utoronto.ca

References:
APPENDIX A

CONCUSSION RECOGNITION TOOL 5

To help identify concussion in children, adolescents and adults

STEP 1: RED FLAGS — CALL AN AMBULANCE

- Immediate loss of consciousness
- Severe headache
- Loss of memory for the event
- Severe vomiting
- Stiff neck
- Decreased alertness
- Blurred vision
- Dizziness
- Balance problems
- Difficulty speaking
- Slurred speech
- Numbness or weakness in arms or legs
- Seizures
- Eye injury
- Changes in behavior
- Passed out

If any of the above symptoms are present, it is important to seek medical attention immediately.

STEP 2: OBSERVABLE SIGNS

Visual clues that suggest possible concussion include:

- Loss of consciousness on the playing surface
- Slower to get up after a direct hit to the head
- Changes in behavior, mood or ability to concentrate
- Balance, gait, and coordination disturbances
- Dizziness or disorientation

Any athlete with a suspected concussion should be immediately removed from practice and play and not return to activity until medically cleared by an appropriate health care professional.

SSO Synchro-specific Concussion Guidelines, 2018
Appendix G: SSO Return to Sport Progress Tracking Tool
SSO Return-to-synchro Concussion Progress Tracker

Athlete Name: ___________________________     Date of Injury: ________

Stage One: Limited Physical and Cognitive Activity

Date Started: ________     Date Completed: ________

Comments: __________________________________________________________
_________________________________________________________________
_________________________________________________________________

Date of Medical Clearance to Exercise:¹ ________

Stage Two: Light Aerobic Exercise (<=70% Max HR)

Date Started: ________________     Date Completed: ________

Activity Checklist:

Stationary Cycling
☐ 15 min
☐ 20 min
☐ 25 min
☐ 30+ min

Walking
☐ 15 min
☐ 20 min
☐ 25 min
☐ 30+ min

¹ Medical clearance to exercise must be provided by a medical professional. This includes a family physician, pediatrician, emergency room physician, sports-medicine physician, neurologist or nurse practitioner. Documentation from any other source will not be acceptable.
Kick
☐ 200m
☐ 400m
☐ 500m

Comments: ____________________________________________________________
______________________________________________________________

Stage Three: Synchro-specific Exercise

Date Started: _______ Date Completed: _______

Activity Checklist:

☐ Jogging
☐ Swimming (no turns)
  ☐ Freestyle
  ☐ Backstroke
  ☐ Breaststroke
  ☐ Butterfly
☐ Horizontal sculling
☐ Ballet legs
☐ Eggbeater
☐ Body boosts
☐ Land drill (no heads)

Comments: ____________________________________________________________
______________________________________________________________

Stage Four: Non-contact Synchro Training Drills

Date Started: _______ Date Completed: _______
Activity Checklist:

☐ Flip turns
☐ Inverted Technical Drills
☐ Figure parts
☐ Routine parts (out of pattern)

Comments: ______________________________________________________
_____________________________________________________________

Stage Five: Full-contact Synchro Practice

Date Started:_________  Date Completed:_______

Activity Checklist:

☐ Whole figures
☐ Routine Swim-throughs
☐ Pattern Swimming
  ☐ Half laps
  ☐ Full laps
  ☐ Halves
  ☐ Full swim through

Comments: ______________________________________________________
_____________________________________________________________

Stage 6: Full Return to Synchro

Date Reached:_______
Appendix H: Concussion Information for Athletes and Parents

Synchro Swim Ontario Concussion Information and Guidelines for Athletes and Parents

Introduction
Concussions most commonly occur in organized contact sports such as football, wrestling, and soccer, but they can also occur in synchronized swimming. Since concussions can lead to serious health consequences, it is essential that synchronized swimmers, coaches, parents, and healthcare providers learn the signs and symptoms of concussion and what to do if a concussion occurs.

What is a Concussion?
A concussion is a type of mild traumatic brain injury (or mTBI) caused by a bump, blow, or jolt to the head or body that shakes the head and can alter the way the brain normally functions. Fewer than 10% of concussions involve a loss of consciousness. In synchronized swimming, common causes of concussion are from a collision with another synchronized swimmer, hitting the wall, falling from a lift, being hit or kicked in the head by an arm or a leg, etcetera. What ensues are a number of possible symptoms that may adversely affect the synchronized swimmer’s ability to perform daily mental and physical tasks, alter mood and personality, and reduce the ability to safely participate in synchronized swimming. Each concussion is unique and can affect the injured synchronized swimmer in a different way. Recognition and proper response to concussions when they first occur is imperative to help prevent further injury or even death.

How to Recognize Signs and Symptoms of a Concussion?
Keys to identifying concussion include an observed or reported forceful bump, blow or jolt to the head or body that results in rapid movement of the head AND any changes in the synchronized swimmer’s behavior, thinking, or physical function. It is important to remember that you can’t “see” a concussion and that not all synchronized swimmers will experience or report the symptoms right away. Some synchronized swimmers may wait for hours or even days after the injury to report a problem. The following is a list of common symptoms of concussion. Keep in mind that it is not uncommon to have some of the symptoms before an injury. For example, an athlete may feel tired and have a headache from overtraining, a cold or lack of sleep. A concussion would be an increase in the severity or number of symptoms.

<table>
<thead>
<tr>
<th>Signs Observed by Others</th>
<th>Symptoms Reported by Synchronized Swimmer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confusion</td>
<td>Headache or “pressure” in head</td>
</tr>
<tr>
<td>Foggy</td>
<td>Nausea, vomiting, numbness or tingling</td>
</tr>
<tr>
<td>Forgetful</td>
<td>Balance problems or dizziness</td>
</tr>
<tr>
<td>Disoriented</td>
<td>Double or blurry vision, ringing in the ears</td>
</tr>
<tr>
<td>Lack of coordination</td>
<td>Sensitivity to light and noise</td>
</tr>
<tr>
<td>Slow to respond</td>
<td>Increased emotional behavior or irritability</td>
</tr>
<tr>
<td>Brief unconsciousness</td>
<td>Concentration or memory problems</td>
</tr>
<tr>
<td>Mood, behavior or personality changes</td>
<td>Feeling sluggish, low energy, foggy or groggy</td>
</tr>
<tr>
<td>Inability to recall events prior to hit or fall</td>
<td>Confusion</td>
</tr>
<tr>
<td>Inability to recall events after hit or fall</td>
<td>Does not “feel right” or “feeling down”</td>
</tr>
<tr>
<td>Seizures immediately after hit or fall</td>
<td>Problems with insomnia or excessive sleep</td>
</tr>
</tbody>
</table>

SSO Concussion Information and Guidelines for Athletes and Parents
Management
Most individuals with a concussion will recover fully in a timely manner (7–10 days) given early and proper care. But for some individuals, signs and symptoms of concussion can last for days, weeks, or longer and may be present during daily functioning in addition to exercise or synchronized swimming activity. Research informs us that some aspects of cognition and the body’s balance system can be affected for months following concussion.

Concussion management includes both physical and cognitive (mental) rest until symptoms resolve to pre-injury levels for all activities of daily living prior to returning to synchronized swimming. If there is any question whether or not a synchronized swimmer should participate, current guidelines state: "When in doubt, sit them out.”

Important aspects of early-stage recovery:
- **Monitoring for mental or physical deterioration** over the initial few hours after injury is essential
- **Restful sleep and relaxation**. Like any injury, the injured body part (in this case the brain) needs rest from activity to promote the healing. This means rest from television, computers, reading, texting and even music
- **Acetaminophen** (Tylenol) can be taken safely
- **DO NOT** drink alcohol, take sleeping medication, aspirin or anti-inflammatory medication (e.g., Advil)
- **DO NOT** return to synchronized swimming the same day as the injury, even if symptoms resolve
- **DO** return to synchronized swimming only after being cleared by a licensed healthcare provider experienced in concussion management, which may include a variety of tests designed to assess brain function (neurocognitive tests)

Return to Activity:
The following is a guideline. The return to activity must be led by a health care provider who is trained and experienced in concussion management. It is recommended that the physician be able to communicate directly with the athlete and/or parent in directing return to sport and providing step-by-step guidance. Once the synchronized swimmer’s symptoms have resolved to pre-injury levels, the synchronized swimmer should follow a step-wise return to full activity. **Medical clearance is required to progress from Stage 1 to Stage 2.** Within each stage, activity is introduced and increased gradually. The athlete should be symptom free for 24 hours before progressing to the next stage. **If at any stage the synchronized swimmer experiences a recurrence of symptoms of concussion, he/she needs to return to the previous level of activity until the symptoms resolve and should not try to progress for at least 24 hours.** Each step may take a minimum of one day, depending on the duration or recurrence of symptoms. Synchronized swimmers will progress through the following stages at differing rates:

<table>
<thead>
<tr>
<th>Stage</th>
<th>Home Activity</th>
<th>School Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 No Activity</td>
<td>Rest quietly, nap and sleep as much as needed. Avoid bright light if bothersome. Use sunglasses/earplugs as needed. Drink plenty of fluids and eat healthy foods every 3-4 hours. Avoid &quot;screen time&quot; (text, computer, cell phone, TV, video games).</td>
<td>No school. No homework or take-home tests. Avoid reading and studying.</td>
</tr>
<tr>
<td>2 Introduce Light Activity</td>
<td>Allow 8-10 hours of sleep per night. Avoid napping. Drink lots of fluids and eat healthy foods every 3-4 hours. &quot;Screen time&quot; less than 1 hour a day. Spend limited social time with friends. Avoid bright light and loud noise. Use sunglasses/earplugs as needed.</td>
<td>No school. May begin easy tasks at home (e.g., drawing, baking, cooking). Soft music and ‘books on tape’ okay. Once your child can complete 60-90 minutes of light mental activity without a worsening of symptoms he/she may go to the next step.</td>
</tr>
</tbody>
</table>
### 3 Moderate Activity
- Allow 8-10 hours of sleep per night. Avoid napping. Drink lots of fluids and eat healthy foods every 3-4 hours. "Screen time" less than 1 hour a day. Spend limited social time with friends outside of school. Use sunglasses/earplugs as needed.
- Gradually return to school. Start with a few hours/half-a-day. Take breaks in the nurse’s office or a quiet room every 2 hours or as needed. Avoid loud areas (music, band, choir, shop class, locker room, cafeteria, loud hallway and gym). Use sunglasses/earplugs as needed. Sit in front of class. Use preprinted large font (18) class notes. Complete necessary assignments only. No tests or quizzes. Limit homework time. Multiple choice or verbal assignments are better than lots of long writing. Tutoring or help as needed. Stop work if symptoms increase.

### 4 Begin Return to Full Activity
- Allow 8-10 hours of sleep per night. Avoid napping. Drink lots of fluids and eat healthy foods every 3-4 hours. "Screen time" less than 1 hour a day. Spend limited social time with friends outside of school.
- Progress to attending core classes for full days of school. Add in electives when tolerated. No more than 1 test or quiz per day. Give extra time or untimed homework/tests. Tutoring or help as needed. Stop work if symptoms increase.

### 5 Full Activity
- Allow 8-10 hours of sleep per night. Avoid napping. Drink lots of fluids and eat healthy foods every 3-4 hours. Increase "screen time" but avoid screens for at least one hour before bed. Increase social time with friends.
- Return to full school program. If symptoms return, return to previous stage.

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**Who Might a Synchronized Swimmer Work with Following a Concussion?**

A synchronized swimmer may work with a number of licenced healthcare providers who will assist in his/her recovery including: sports medicine physicians, certified athletic trainers/therapists, physiotherapists, neuropsychologists, psychologists, and/or osteopaths.

**References:**

- http://www.nata.org/position-statements
- Concussion Tip Sheet from Taskforce on Dancer's Health Dance USA
- Pocket Concussion Recognition Tool, copyright Parachute Canada 2013
- 2015 California Interscholastic RTL Protocol

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SSO Concussion Information and Guidelines for Athletes and Parents
Appendix I: Coach Feedback Interview Guide

SSO Coach Feedback Interview Guide

1. What region is your club in?

2. Approximately how many competitive and novice athletes swim with your club?

3. Prior to the Online Injury Tracker, how did your club keep track of athlete injuries?

4. How many times did you use the Online Injury Tracker last season?

5. On average, how much time elapsed between an injury to an athlete and completion of the form?

6. Are you aware of any acute (short-term) injuries experienced by your athletes, or athletes at your club, were NOT logged in the injury tracker?

7. Are you aware of any chronic (long-term, ongoing) injuries experienced by your athletes, or athletes at your club, were NOT logged in the injury tracker?

8. How would you describe your level of awareness of the Injury Tracker?

9. How would you describe the communication from SSO about the Injury Tracker?

10. Please describe how easy or how difficult the Injury Tracker was to use.

11. In terms of your personal coaching philosophy, do you feel it is important to monitor injuries in your athletes?

12. What did you find were FACILITATORS to using the Online Injury Tracker?

13. What did you feel were BARRIERS to using the Online Injury Tracker?

14. Is there anything else you feel is important to add about the SSO Online Injury Tracker?
15. Please describe your level of awareness of the other SSO Concussion Resources.

16. How would you characterize your level of knowledge of concussions?

17. How would you characterize your athletes’ level of knowledge of concussions?

18. What would you as a coach find helpful in terms of resources or other support to help you manage concussions in your athletes?

19. What do you think your athletes would find helpful in terms of resources or other support?

20. Is there anything else you feel is important to add?
Appendix J: Coach Feedback Consent Form

CONSENT FORM

Principal Investigator: Laura McClemont Steacy

Supervisor: Dr. Lynda Mainwaring

1. TITLE OF PROJECT

Building a concussion safety program for Ontario synchronized swimmers: a case study of collaboration between a university-based research team and a community sport organization.

2. GOAL OF THE STUDY

The purpose of this study is to describe the design and implementation of a concussion safety and tracking program in Ontario synchronized swimming, and evaluate the first year of the program.

3. PROCEDURES

Participation in this study consists of a single interview with the principal investigator. During this interview you will be asked about your perceptions and opinions of the Synchro Swim Ontario Injury Tracker, and injury monitoring in general. You have been approached for an interview because you used the SSO Injury Tracker in the 2017-2018 competitive season.

4. ADVANTAGES AND RISKS OF PARTICIPATION

By participating in this study you will be contributing to the ongoing improvement of the injury tracking program by providing valuable feedback.

There are no anticipated risks to participating in this study. Signing this consent form does not waive any of your legal rights.
5. CONFIDENTIAL NATURE OF THIS STUDY

Data will be stored anonymously and confidentially. Only the researcher directly in charge of the study will have access to the data.

Any potentially identifying data will be kept separately and destroyed after a period of one (1) year. The anonymous data will be kept for a period of three (3) years after study completion.

All data will be reported anonymously.

6. WITHDRAWAL FROM THE STUDY

Please know that participation is entirely voluntary, and you are free to withdraw at any point during the study with no consequence. If you choose to withdraw, your data will also be withdrawn and destroyed and will not be reported.

7. QUESTIONS

If you have any further questions, we can be reached using the following information:

Laura McClemont Steacy, M.Sc.  Department of Exercise Science
Email: laura.mcclemont@mail.utoronto.ca

Lynda Mainwaring, PhD, C.Psych.  Department of Exercise Science
Email: lynda.mainwaring@utoronto.ca

If you have any questions about your rights as a participant, you may contact the Research Oversight and Compliance Office – Human Research Ethics Program at ethics.review@utoronto.ca or 416-946-3273.

DECLARATION OF CONSENT

The investigator has explained all the aspects of this study to me and my questions have been answered to my satisfaction. I _________________________ (Participant) have read the above description with the investigator, ___________________________ (Investigator). I fully understand the procedures, advantages and disadvantages of the study, which have been
explained to me. I freely and voluntarily consent to participate in this study entitled “Building a concussion safety program for Ontario synchronized swimmers: a case study of collaboration between a university-based research team and a community sport organization.”

A copy of this consent form has been given to the participant named below.

Name of Participant _______________

Signature                  Date

I, __________________________ (Participant) consent to an audio recording of my interview.

Signature                  Date

Name of Person Conducting the Informed Consent Discussion _______________

Signature                  Date