Sport-related concussion (SRC) management and prevention: A review and synthesis of the literature

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1 Introduction

Sport-related concussions (SRC) are a growing health concern due to their high prevalence in Canadian athletes, of all ages and across all sport types (Avedisian et al., 2020). SRCs can happen in organized and unorganized sporting events. A hit to the head or body that applies biomechanical forces to the brain causes SRCs (Avedisian et al., 2020; Bazarian et al., 2020; Ellis et al., 2018; Waltzman & Sarmiento, 2019).

SRC can result in a wide range of short- and long-term symptoms, which can affect an athlete's motor, cognitive and behavioural function (Bazarian et al., 2020; Ellis et al., 2018; Waltzman & Sarmiento, 2019). With SRCs' potential to have negative short- and long-term effects on an athlete's wellbeing, it's essential that individuals working in the sport community are aware of proper SRC prevention and management strategies. These strategies should be consistent throughout Canada to guarantee all athletes receive the best care.

The Sport Information Resource Centre (SIRC) is a partner with leading SRC experts, including Parachute Canada, Sport Canada, and the Public Health Agency of Canada. With these partners, SIRC is working to support Canada's Concussion Harmonization Project. Harmonization's purpose is to ensure protocols are consistent nationally and aligned with the best available evidence. This helps to ensure that while concussion protocols can be individualized, each concussion plan will follow the same core principles.

2 Purpose and objectives

This literature review's purpose is to support and build on evidence that underpins Canada's harmonized approach to SRC. This approach is highlighted in the Canadian Guideline on Concussion in Sport, a fundamental document created in 2017 by Canadian experts based on global expertise. By synthesizing research that explores SRC management and prevention strategies, this literature review will support the Canadian Guideline on Concussion in Sport.

2.1 Part 1: SRC management

The primary objective of Part 1 is to provide an overview of concussion management strategies. This part of the review focuses on the 4 Rs of concussion management: recognize, remove, refer and return. SIRC has previously used the 4 Rs and for consistency will use them in this review. This part also explores novel considerations for concussion management, including how biological sex and age influence SRC outcomes.

2.2 Part 2: SRC prevention

The primary objective of Part 2 is to identify strategies for change in sport to support SRC prevention. This section explores the potential roles of protective equipment, education, rule changes and neck strengthening on reducing SRC occurrences.

3 Search Strategy

3.1 Part 1: SRC management

To review the literature focused on concussion management, we performed searches using 3 databases (PubMed, DOAJ and Elsevier Science Direct). For the first search, we used the terms “concussion” AND “sport” AND “management” OR "recovery" OR "recognition." Through the next search, we gathered more information about novel considerations for SRC management. The terms for this search were “concussion” AND “sport” AND “biological sex” OR "athletes with disabilities." We limited searches to peer-reviewed articles published in English from 2015 to 2020. We excluded articles that didn't focus directly on SRC management, biological sex-based differences, or SRC in athletes with disabilities. We also excluded studies that had poor methodological quality. To supplement these searches, we performed an additional search using Google Scholar and the same search terms as earlier.

3.2 Part 2: SRC prevention

To review the literature focused on SRC prevention, we conducted 2 searches using 3 databases: PubMed, DOAJ and Elsevier ScienceDirect. We performed the first search to gain a broad overview of SRC prevention and risk reduction, using the terms “concussion” AND “sport” AND “prevention” OR "risk reduction." The second search looked specifically at sub-topics that weren't addressed in detail in the initial search. We used the terms “concussion” AND “sport” AND “neck strength” OR "protective equipment." Both searches's results were limited to peer-reviewed articles published in English between 2015 and 2020. We excluded articles that didn't focus directly on prevention or risk reduction in SRC, or that had poor methodological quality.

In total, we identified 29 articles to include in this review.

4 Summary of findings

4.1 Part 1: SRC management

In this section, we summarize the literature focused on the 4 Rs of concussion management: recognize, remove, refer and return. Next, we present a brief review of the research focused on novel considerations for concussion management, including biological sex, age, disability, sleep and mental health.

4.1.1 The 4 Rs of concussion management

a) Recognizing SRCs

Recognizing signs and symptoms of an SRC is the first and perhaps most essential step in SRC management. An SRC should be suspected if an athlete sustains a hit to their head or body that causes an acceleration of their head (Avedesian et al., 2020; Schneider et al., 2019). In some cases, an SRC is obvious because an athlete shows signs of injury, such as taking a long time to right themselves or appearing dazed and confused (Schneider et al., 2019). However, in many cases, the signs of an SRC are less clear and can be missed (Bazarian et al., 2020). Tools such as the Concussion Recognition Tool Fifth Edition (CRT5) can be used by coaches, players, parents and officials to familiarize themselves with SRC symptoms. These tools can also be used to support decisions for SRC assessments (Schneider et al., 2019). In sports where there's a high risk of SRC, designated "spotters" may be beneficial (Schneider et al., 2019). These individuals watch for potentially harmful impacts and identify athletes who may have suffered an SRC (Schneider et al., 2019).

If an athlete is suspected of having an SRC, they should undergo a sideline concussion assessment performed by a licensed healthcare practitioner (Halstead et al., 2018; Schneider et al., 2019; Scorza & Cole, 2019). When possible, it's recommended that the practitioner is familiar with the athlete, because they may be more sensitive to changes in the athlete's behaviour and better able to detect the occurrence of an SRC (Halstead et al., 2018; Jackson & Starling, 2019). An SRC assessment can be performed using the Sport Concussion Assessment Tool Fifth Edition (SCAT-5: Jackson & Starling, 2019; Schneider et al., 2019; Scorza & Cole, 2019). This tool contains several tests, including Maddocks Questions and a modified version of the Balance Error Scoring System (BESS: Jackson & Starling, 2019;

Schneider et al., 2019; Scorza & Cole, 2019). For youth ages 5 to 12 years, you can use the Child SCAT-5 (Schneider et al., 2019; Scorza & Cole, 2019).

SRC can result in a diverse range of symptoms that aren't always present immediately after an injury (Jackson & Starling, 2019; Scorza & Cole, 2019). As a result, it's essential to perform repeated SRC testing in the acute timeframe post-injury, unless the assessing practitioner is confident that no injury occurred (Halstead et al., 2018). The assessing practitioner should be aware of an athlete's medical history, because symptoms an athlete reports may be attributable to underlying health conditions rather than an SRC (Halstead et al 2018; Jackson & Starling, 2019). The use of baseline testing can help support SRC assessments by allowing a practitioner to compare an athlete's performance to their pre-injured state (Jackson & Starling, 2019).

Lastly, when assessing an athlete for an SRC, a practitioner needs to check for signs or “red flags” of a more severe cognitive injury (Halstead et al., 2018; Jackson & Starling, 2019; Schneider et al., 2019). The SCAT-5 tool provides a comprehensive list of red flags, which include seizures, neck pain and vomiting. If an athlete exhibits any red flags, they should be taken immediately to a medical facility.

Resources to explore
• Concussion Recognition Tool Fifth Edition (CRT-5) • Sport Concussion Assessment Tool Fifth Edition (SCAT-5) • Child Sport Concussion Assessment Tool Fifth Edition (Child SCAT-5)

b) Removing an athlete from play

If an athlete has a suspected SRC, they need to be removed from play immediately and should not return until a licensed healthcare professional has ruled out an SRC or given the athlete clearance to return to play (Halstead et al., 2018; Schneider et al., 2019; Scorza & Cole, 2019). Individuals who aren't removed from play immediately after a SRC may be at an increased risk of suffering from a secondary injury, likely due to impairments associated with the primary injury (Jackson & Starling, 2019).

Compared to athletes who are removed at the time of injury, athletes who aren't removed from play immediately following an SRC (that is, those who participate in immediate post-injury exercise) are more likely to report more severe SRC symptoms (Jackson & Starling, 2019). Additionally, those athletes may experience a longer recovery time, because increased symptom severity and diversity during the acute time frame post-injury correlates to an increased time to recovery (Iverson et al., 2017). With this in mind, it's important to be cautious and remove an athlete from play immediately after any impact that may have resulted in an SRC.

c) Referring an athlete

When a sideline assessment isn't possible, an athlete should be taken to an emergency room (ER) or their family doctor within 72 hours of the potential injury (Jackson & Starling, 2019). It's the role of the initial assessor, whether an ER doctor or sideline assessor, to refer the athlete to a specialist or a primary caregiver who can help them manage their recovery (Bazarian et al., 2020). The treating physician should also educate the athlete about SRC and direct them to SRC management tools. Those tools include the return-to-school and return-to-sport strategies developed by Parachute Canada. Educating athletes on their symptoms and their likelihood for full recovery has been shown to have a positive impact on recovery outcomes (Bazarian et al., 2020). If an athlete experiences a complicated or elongated SRC recovery, the athlete may benefit from a referral to a multidisciplinary team of SRC experts, who can work together to create a comprehensive symptom-directed plan for recovery (Ellis et al., 2018; Jackson & Starling, 2019).

d) Returning an athlete to school and sport

After 24 to 48 hours of cognitive and physical rest, an athlete may begin to reintroduce activities of daily living in a gradual and controlled manner (Jackson & Starling, 2019; Schneider et al., 2019; Scorza & Cole, 2019). An athlete may begin their return-to-school and return-to-sport protocols simultaneously. However, a full return to school should happen before an athlete returns to contact sports or competitions (Jackson & Starling, 2019; Schneider et al., 2019; Scorza & Cole, 2019).

When returning to school, an athlete with an SRC may require academic accommodations to help reduce the onset and exasperation of their symptoms (Schneider et al., 2019). These accommodations may include a lighter workload, a shorter school day, and frequent breaks from their studies (Jackson & Starling, 2019; Schneider et al., 2019). A stepwise return-to-school protocol should be followed to ensure a safe re-entry into the school environment. This protocol is comprised of 4 steps: 1) light cognitive activity, 2) school-type work or light physical activity, 3) part-time school, and 4) full-time return to school (Schneider et al., 2019). When returning to school, an athlete should consider providing their school with a medical letter highlighting their required accommodations, because this may help ease the transition back to the school environment (Schneider et al., 2019).

In terms of return to sport, an integral part of the recovery process is the gradual reintroduction of exercise following SRC. That gradual reintroduction can also help combat some of the deficits associated with the injury (Jackson & Starling, 2019; Schmidt et al., 2018). For example, the reintroduction of physical activity may assist with SRC sleep problems, as physical activity helps with the maintenance of an individual's sleep-wake cycle (Morse & Kothare, 2018).

Previous guidance suggested that athletes should rest for prolonged periods following SRC. Now, it's widely accepted that extended periods of rest could have detrimental effects on SRC recovery prognoses (Leddy et al., 2018). An extended removal from physical activity has been associated with increased symptom reporting and increased symptom length in the athlete population (Leddy et al., 2018; Schmidt et al., 2018; Scorza & Cole, 2019). An additional

concern is the potential for extended rest to cause physical deconditioning and mental health illnesses in athletes, including the onset of anxiety and depression (Leddy et al., 2016; Leddy et al., 2018; Schmidt et al., 2018;).

Since athletes recover at varying speeds, an individualized approach should be taken when creating a return-to-sport plan (Scorza & Cole, 2019). Practitioners can prescribe an athlete's exercise "dose" by determining an athlete's symptom threshold and then prescribing activities that fall below that threshold (De Wandel et al., 2019; Leddy et al., 2019). In the early stages of recovery, aerobic exercises such as walking or biking are safe, if they're done at low intensity (De Wandel et al., 2019; Leddy et al 2019). Guidelines such as Parachute Canada's return-to-sport strategy can assist athletes and practitioners in the return-to-activity process. In addition, many sports organizations offer resources to help inform sport-specific, return-to-activity protocols.

Resources to explore
• Return-to-school strategy • Medical assessment letter • Return-to-sport strategy

4.1.2 Novel considerations

a) Biological sex

Female athletes are at an increased risk of sustaining an SRC compared to age- and sport-matched males in various contact and non-contact sports, including ice hockey, soccer and basketball (Cheng et al., 2019; Resch et al., 2017). Interestingly, female athletes are more likely to experience an SRC from contact with equipment or the playing surface (Merritt et al., 2019). By contrast, male athletes often experience SRCs due to player-to-player contact (Merritt et al., 2019). This is an important consideration when it comes to recognizing SRC, because non-contact-related injuries may be harder to detect compared to those sustained from player-to-player contact.

In addition to differences in concussion mechanisms, female and male athletes often exhibit differences in concussion recovery prognoses (Koerte et al., 2020; Merritt et al., 2019; Resch et al., 2017). Specifically, female participants tend to have prolonged SRC recovery times, and they may take longer to return to normal activities following an injury (Merritt et al., 2019; Resch et al., 2017). This extended recovery time is often associated with increased severity and diversity of symptoms (Resch et al., 2017). For example, several reviews showed that female participants often present with more cognitive impairments, sleep difficulties, and emotional changes post SRC than their male counterparts (Covassin et al., 2017; Resch et al., 2017). As such, SRC management in female athletes should include close monitoring for these symptoms.

Researchers have also identified that female athletes present with more baseline SRC symptoms than males (Covassin et al., 2017; Merritt et al., 2019; Resch et al., 2017). This means that female athletes may not need to be completely asymptomatic before returning to play, they might just need to match their baseline testing scores (Resch et al., 2017). While the exact cause of biological sex-related differences in SRC remains largely unknown. It's suspected that differences in brain anatomy, hormone levels and injury biomechanics are all contributing factors (Gallagher et al., 2018; Iverson et al., 2017, Solomito et al., 2018). More research is needed to better understand concussion management in female athletes.

b) Age

Age can influence an athletes' SRC symptom severity and duration, so consider age when creating a management plan (Iverson et al., 2017; Scorza & Cole, 2019). Research indicates that teenagers are more vulnerable to SRC and more likely to experience prolonged SRC recovery times compared to youth (Iverson et al., 2017; Schneider et al., 2019; Scorza & Cole, 2019). However, these findings may be partially attributable to differences between the groups' ability to vocalize their symptoms (Iverson et al., 2017). Further research is needed to better understand the effects of SRC in children ages 13 and under and to identify the long-term implications of multiple SRCs in the developing brain (Scorza & Cole, 2019). Due to the number of unknowns, SRC management in youth and adolescents should be handled with extra caution (Scorza & Cole, 2019).

c) Disability

While it's known that SRCs happen in sports for persons with disabilities, such as para alpine skiing, wheelchair basketball, and para ice hockey, relatively little research has been done to explore the management and assessment of SRC in this population (Kissick & Webborn, 2018; Webborn, 2018). Traditional concussion assessment tools, such as the SCAT-5, include elements that may not be inclusive for athletes with diverse abilities (Kissick & Webborn, 2018; Webborn, 2018). For example, the BESS portion of the SCAT-5 requires the ability to stand. Thus, an alternative is required for people who use wheelchairs (Kissick & Webborn, 2018; Webborn, 2018). Wheelchair-specific tasks could be used to assess postural control post-injury. However, this technique has yet to be validated in the literature (Kissick & Webborn, 2018). Individuals with cognitive, speech or hearing impairments may also have difficulties with some elements of the SCAT-5 assessment (Kissick & Webborn, 2018).

Research shows that athletes with disabilities often have higher baseline scores for symptom severity compared to athletes without disabilities (Kissick & Webborn, 2018). For this reason, athletes with disabilities may require baseline testing, so that a more accurate SRC assessment can be performed. To properly identify an SRC, assessors must be aware of the signs and symptoms of SRC in people with disabilities (Kissick & Webborn, 2018; Webborn, 2018). More

research is needed to better understand how to manage and detect injuries among athletes with disabilities.

d) Sleep

Sleep is an essential component of SRC recovery, particularly in the acute phase post-injury (Morse & Kothare, 2018; Schneider et al., 2019). However, up to 50% of individuals' who suffer from SRC experience difficulties sleeping, such as problems falling to sleep or staying asleep (Schneider et al., 2019). During SRC recovery, poor sleep quality may result in a more diverse range of symptoms, including fatigue, depression, anxiety and irritability (Morse & Kothare, 2018). Reduced sleep quality and quantity may also contribute to increased cognitive and functional impairments post-injury (Morse & Kothare, 2018). Consequently, SRC management should include strategies to address sleep difficulties, such as consuming less caffeine before bed and limiting naps throughout the day (Morse & Kothare, 2018; Schneider et al., 2019; Vitale et al., 2019). Athletes with chronic sleep difficulties may also be referred to a sleep specialist for more targeted management (Schneider et al., 2019).

e) Mental health

Individuals who experience an SRC often report feeling irritable, sad and anxious (Schneider et al., 2019). Many of these symptoms are associated with SRC. However, in some cases they can also indicate the development of mental illness, including depression and anxiety (Rice et al., 2018). The post-SRC development of depression has been associated with symptoms lasting for a prolonged length of time, that is, more than 4 weeks (Iverson et al., 2017; Rice et al., 2018). Additionally, researchers noted that pre-existing depression may contribute to an extended SRC symptom burden and the appearance of post-SRC depression and anxiety (Rice et al., 2018). Further research is needed to gain a more complete understanding of the effects of SRC on depression and other mental illnesses. The potential for an SRC to lead to mental health challenges highlights the importance of including mental health monitoring as a part of SRC management (Rice et al., 2018).

Takeaway points
• If an athlete has a suspected SRC, they should be removed from play and assessed by a healthcare practitioner. • Return-to-play protocols should be followed to reduce the likelihood of an athlete suffering from a secondary injury or a prolonged SRC recovery. • Following an SRC, athletes should be monitored for the development of mental health conditions and sleep disorders, as both can impact an athletes' recovery prognosis. • Practitioners must consider factors such as age and gender when creating an SRC management plan. • Concussion assessment tools may need to be adapted to assess concussions in athletes with diverse abilities. • Concussion management can't take a one-size-fits-all approach.

4.2 Part 2: SRC prevention

This section provides an overview of several strategies designed to promote SRC prevention, including education, rule changes, protective equipment and neck strengthening.

4.2.1 Education

Education may play an important role in SRC prevention by encouraging athletes to adhere to the rules and by reducing aggressive playing styles (Scorza & Cole, 2019). For example, one Canadian study found that youth hockey players were less likely to use aggressive behaviour (such as cross-checking and checking from behind) when exposed to the "Smart Hockey" video by the ThinkFirst Foundation of Canada (Enniss et al., 2018). This study exemplifies the potential for educational initiatives to encourage safer play, which may in turn reduce SRC occurrences (Waltzman & Sarmiento, 2019). Accordingly, there has been a push for increased SRC education throughout Canada. In Ontario, for instance, Rowan's Law mandates that sport organizations ensure that all participants, including trainers, officials, coaches, and athletes, have reviewed Ontario's Concussion Awareness Resources.

4.2.2 Rule changes

Changing sport rules may be an effective way to reduce the occurrence of SRC. Player-to-player contact is the primary cause of SRC in several sports, including hockey, football, soccer and lacrosse (Waltzman & Sarmiento, 2019). As such, rule changes should focus on identifying ways to minimize player-to-player contact (Halstead et al., 2018; Schneider et al., 2019). Ways to reduce player-to-player contact include removing kickoffs in football and soccer. Other strategies include eliminating body contact such as body checking and tackling in hockey and football, respectively (Schneider et al., 2019; Scorza & Cole, 2019; Waltzman & Sarmiento, 2019). Sport-specific rule changes such as changing the age of heading in soccer may also help to prevent SRC (Halstead et al., 2018).

While further research is needed to determine the potential for rule changes to prevent SRC, the preliminary evidence is promising. For example, the elimination of body contact in Canadian youth hockey has led to more than a three-fold reduction in SRC occurrences (Waltzman & Sarmiento, 2019). As sports organizations find creative ways to enhance brain safety, it becomes even more critical that officials work to enforce the rules of play.

Rule changes in action
• Figure skating now allows athletes to be removed from the ice for SRC evaluation during a competition, without incurring a penalty. • Rugby Ontario has introduced a "blue card." The blue card allows referees to remove players who may have experienced an SRC from the game.

4.2.3 Protective equipment

There's inconclusive evidence to suggest that helmets, headgear and mouthguards can protect against SRC (Halstead et al., 2018). Evidence from several sports, including hockey, football, skiing, snowboarding, cycling and equestrian, shows that helmets can reduce severe head trauma. However, they haven't been consistently shown to protect against SRC (Enniss et al., 2018; Halstead et al., 2018). Research in soccer and rugby has also shown mixed findings on the effectiveness of headgear for SRC prevention (Schneider et al., 2019). Finally, there's some evidence to suggest that mouthguards can prevent SRC, but they're more commonly known for their ability to protect against orofacial injuries (Knapik et al., 2019; Waltzman & Sarmiento, 2019). In general, the use of protective equipment to prevent SRC requires additional research. Nonetheless, in certain sports, properly fitted protective equipment should be used to prevent other serious injuries.

4.2.4 Neck strengthening

Neck strength is one factor that may influence an athlete's SRC risk (Enniss et al., 2018; Halstead et al., 2018; Hrysomallis, 2016; Waltzman & Sarmiento, 2019). The neck muscles work to stabilize the head. During an impact, the neck muscles help to reduce head acceleration (Enniss et al., 2018). This may decrease the kinematic force applied to the brain and reduce the risk of SRC (Enniss et al., 2018; Halstead et al., 2018; Hrysomallis, 2016; Waltzman & Sarmiento, 2019). Smaller neck circumference and lower-neck strength have been associated with an increased risk of SRC (Enniss et al., 2018; Hrysomallis, 2016). For example, a study noted that for every additional pound of neck strength an athlete had, their odds of sustaining an SRC decreased by 5% (Collins et al., 2014).

While there's evidence to support that athletes with stronger necks have a lower risk of SRC (Collins et al., 2014) and that neck-strengthening programs improve neck strength (Hrysomallis, 2016), the research is limited when it comes to exploring the link between neck-strengthening programs and SRC. Thus, neck strengthening may be a promising practice, but more research is needed to understand its role in SRC prevention.

Takeaway points
• Educating athletes on SRC may reduce aggressive playing styles and promote rule adherence. • It's unknown whether protective equipment such as helmets and mouthguards can prevent SRC, but they're important for the prevention of other head and face injuries. • Altering sport rules to reduce player-to-player contact may help reduce occurrences of SRC. • Neck strengthening may contribute to a lower risk of SRC, but more research is needed before we'll know for sure.

Conclusion

This literature review's purpose was to support and build on evidence that underpins Canada's harmonized approach to SRC, including the Canadian Guideline on Concussion in Sport. This was done by synthesizing research focused on SRC management and prevention.

From an SRC management perspective, this review's findings clearly identified the importance of following the 4 Rs of SRC management. A large body of evidence indicates that athletes who don't follow proper SRC management protocols are more likely to experience a prolonged recovery. Individuals suffering from sleep disturbances or mental illness may also experience a prolonged recovery, highlighting the importance of closely monitoring athletes suffering from SRC and referring them to specialists as needed. In addition, characteristics such as age and biological sex can influence SRC outcomes. For example, female athletes and adolescents often exhibit more SRC symptoms and a longer SRC recovery time than male or youth athletes.

In terms of SRC prevention, this review's findings highlighted the potential for education and rule changes to reduce the incidence of SRC. Neck strength may also be a modifiable risk factor for SRC, because greater neck strength may be associated with a reduced SRC risk. In contrast, it's unknown if equipment such as helmets and mouthguards can protect against SRC. However such protective gear is important for preventing other injuries. Future research is needed to explore SRC prevention and management in a wider range of sports and in underrepresented populations (that is, youth, women and girls and athletes with disabilities).

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