

The roles of biological sex and gendered behaviour in sport-related concussions: A review and synthesis of the literature

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Introduction

Sport-related concussions (SRC) are a concern for male and female athletes participating in a wide range of contact and non-contact sports, including, but not limited to, football, hockey, soccer and gymnastics (Cheng et al., 2019). SRC can alter cognitive and behavioural function (Koerte et al., 2020), impacting an athlete's short and long-term wellbeing. To that end, it is essential to understand how to best prevent and manage these injuries, which includes gaining a deeper understanding of how factors like biological sex and gendered behaviour impact SRC risk and recovery outcomes.

An individual's sex is determined based on biology (for example, chromosomes and genes), whereas their gender is based on socially assigned behaviours and attitudes (Koerte et al., 2020; Molloyeva et al., 2018). In SRC research, there is inconsistency with the use of these terms.

While significantly more SRC research has focused on male athletes than female athletes (D'Lauro et al., 2022), evidence suggests that sex and gender influence how SRC is experienced (Covassin et al., 2017; Koerte et al., 2020; Mollayeva et al., 2018). For example, researchers have identified that biological sex and gendered behaviour can influence the incidence, mechanisms, symptoms, and outcomes related to SRC (for example, Covassin et al., 2017). As such, members of the sport and rehabilitation communities must be aware of these differences so that they can better facilitate the management and prevention of SRC for all athletes.

Purpose and Objectives

The purpose of this review was to explore how sex and gendered behaviour influence SRC, with a focus on implications for females in sport. The information found in this review can then be used by sport organizations, coaches, parents, and clinicians to help inform educational initiatives and decisions around SRC management (for example, return to play decisions).

Specifically, the objectives of this review were to explore how biological sex and gendered behaviour influence:

- 1) SRC incidence and mechanisms
- 2) SRC symptom burden
- 3) SRC risk factors, and
- 4) SRC reporting behaviours

Search Strategy

Articles were first searched through Google Scholar in July 2019 using the search terms "concussion" AND "sport" AND "sex differences" OR "gender differences." A second and third search was performed in June 2021 and November 2023 using the same search terms and two additional databases (PubMed and Web of Science). Studies were included if they were peerreviewed, contained original data, and published in English or French. In total, 33 articles were included in this review.

Summary of Findings

Incidence and Mechanisms

Researchers have identified that female athletes, at both the high school and university levels, are at an increased risk of sustaining an SRC compared to their male counterparts (Black et al., 2017; Bretzin et al., 2021; O'Connor et al., 2017; Solominto et al., 2019; Tsushima et al., 2019; Zuckerman et al., 2015). In fact, researchers have suggested that female athletes may be at upwards of a two times greater risk of sustaining a SRC compared to males participating in comparable sports (Bretzin et al., 2021; Kerr et al., 2019).

The incidence of SRC appears to be particularly high for females participating in soccer, basketball, hockey and rugby (Black et al., 2017; Bretzin et al., 2021; Cheng et al., 2019; O'Connor et al., 2017; Tsushima et al., 2019; Zuckerman et al., 2015). For example, in a Canadian study, researchers noted that female rugby and ice hockey players had the highest incidence of SRC compared to all other female varsity sports (Black et al., 2018). In sports like hockey and rugby where the risk of SRC is high, efforts should be made to increase SRC awareness and prevention.

Interestingly, it appears that the mechanisms by which females and males sustain SRC vary. For example, evidence suggests that male athletes are more likely to sustain a SRC through player to player contact (e.g., a body check or a tackle), while female athletes are more likely to sustain SRC through contact with equipment (e.g., a soccer ball) or the playing surface (e.g., a goal post: Bretzin et al., 2021; Cheng et al., 2019; Lin et al., 2017; O'Connor et al., 2017). In addition to these differences, it is crucial to consider variations in impact rates. A recent study revealed that young males exhibited significantly higher impact rates compared to young females of the same sports (Huber et al., 2021). There remains a need for further research to confirm how and why the mechanisms of injury vary between male and female athletes.

Symptoms

In addition to having an increased risk of SRC, researchers have suggested that young and adult females often experience a greater symptom burden (meaning, more symptoms and more severe symptoms) compared to their male counterparts (Alsalaheen et al., 2021; Bailey et al., 2022; Covassin et al., 2018; Iverson et al., 2017; Lin et al., 2018, Mihalik et al., 2022; Molloyeva et al., 2018; Resch et al., 2017; Starkey et al., 2022; Stephenson et al., 2023; Teramoto et al., 2022). Interestingly, the types of symptoms males and females report post-injury may also differ (Koerte et al., 2020). For example, some studies suggest that females are more likely than males to report drowsiness, sensitivity to light, headaches and difficulty concentrating post-SRC

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(Bunt et al., 2020, Covassin et al., 2018; Koerte et al., 2020). Moreover, a recent study indicates that females report more emotional symptoms, energy and sleep disturbances, headaches and numbness post-concussion (Race et al., 2023). Understanding how symptoms differ between males and females may help individuals better detect and manage SRC in different athlete populations.

While the findings of individual studies are mixed, researchers have suggested that female athletes appear to have longer recovery times post-injury compared to males (Bretzin et al., 2021; Covassin et al., 2018). Increased recovery times may be related to the increased number of symptoms that females report (Ono et al., 2016), but at least one study found that recovery times were longer even when a similar number of symptoms were reported (Gallagher et al., 2018). In line with this, researchers have suggested that females are at an increased risk of suffering from post-concussive syndrome (meaning, SRC symptoms lasting greater than four weeks; Covassin et al., 2018; Martens et al., 2023).

Findings vary among studies when it comes to return to play. Some studies suggest that females take longer to return to sport post injury compared to sport-matched males (Bretzin et al., 2021; Bretzin et al., 2018; Stone et al., 2016; Tamura et al., 2020). On one hand, Bretzin and colleagues (2021) noted that female soccer players typically took two days longer (meaning, 12 days compared to 10 days) to return to play than their male counterparts. Tamura and colleagues (2020) further supported these findings and noted that prolonged return to play times in females may occur because female athletes take longer than male athletes to return to baseline scores post-SRC. In another study, the authors found that females had a higher number of days to return to sport, but the difference was not significant (Churchill et al., 2021). Females also often present with higher symptom scores at baseline than males (Merritt et al., 2019; Resch et al., 2017), highlighting a potential benefit of baseline testing.

On the other hand, a recent study by Bretzin and colleagues (2022) found that even though females experienced a longer median time for symptom resolution, it did not result in a delayed return to sport (Bretzin et al., 2022). This finding was supported by another study that found no sex difference in the time taken to return to play among a sample of Japanese collegiate and non-collegiate athletes (Tanaka et al., 2023). That being said, females might return to play while symptomatic, it should be communicated to all individuals involved with SRC management (for example, coaches, parents, trainers) in order for them to interact appropriately with female athletes following SRC and offer appropriate care to ensure their safety. Finally, researchers found that there was a significant difference between male and females in recovery time when analyzing level of contact in sports (Master et al., 2021). Indeed, females participating in contact sports had longer recovery time compared to their male counterparts (Master et al., 2021). Interestingly, females in non-contact sport (for example, swimming) had longer recoveries than athletes in limited contact and contact sports (Master et al., 2021). As highlighted in the most recent consensus statement on SRC (Patricios et al., 2023), more research is needed to better understand the possible differences in various aspects of SRC, including recovery time, in different types of sports.

Additionally, it is important for individuals involved in sport to recognize that SRC recovery may be a more overwhelming process for young females than it is for young males (Clair et al., 2020). Researchers have noted that young females often express more frustration and negative emotions during their recovery (Clair et al., 2020). Working to normalize these feelings and finding ways to support females early on and throughout their recovery may help them cope with their SRC (Clair et al., 2020).

Risk Factors

The reasons behind the biological sex-based differences in SRC risk and recovery outcomes require further investigation. However, researchers have suggested that sex-based differences in hormone levels, neck strength, and brain anatomy as well as gender differences in SRC reporting may all be contributing factors.

Hormone Levels

Researchers have suggested that differences in symptom burden and recovery times may be attributable to hormonal changes associated with the menstrual cycle (Brown et al., 2015). The research in this area is still in the early stages. However, researchers postulate that changes in progesterone levels may impact SRC recovery outcomes (Chen et al., 2020; Molleyeva et al., 2018; Resch et al., 2017).

Progesterone may have protective effects on SRC, meaning that higher progesterone levels have been associated with better recovery outcomes (Chen et al., 2020). Researchers have suggested that females in the luteal stage of their cycle (meaning, the last phase before menstruation) may experience worse recovery outcomes than females in different phases of their cycle (Resch et al., 2017). This is because females in their luteal stage appear to experience a significant drop or "withdrawal" in progesterone levels following a SRC (Resch et al., 2017). Consequently, these females are no longer exposed to the protective effects of progesterone, which may increase their symptom burden post SRC (Gallagher et al., 2018: Resch et al., 2017).

Interestingly, females who use hormonal contraceptives (i.e., birth control) report less severe symptoms than females who do not use hormonal contraceptives (Gallagher et al., 2018). This may occur because females who use hormonal contraceptives have more stable hormone levels and therefore may not experience a "withdrawal" of progesterone post SRC (Gallagher et al., 2018).

Neck Strength

When compared to males, females often have lower neck strength, smaller neck girth, and lower neck muscle mass (Covassin et al., 2018; Gallo et al., 2022; Koerte et al., 2020; Lin et al., 2018; Nutt et al., 2022). For example, researchers found that females rugby and football athletes had significantly weaker neck strength compared to aged-matched males (Nutt et al.,

2022) and that males had 17,55 % greater neck girth than females (Gallo et al., 2022). As a result of lower neck strength, females may experience more significant head motion (for example, acceleration) during an impact, which may, in turn, increase SRC risk (Cheng et al., 2019; Resch et al., 2017). Interestingly, Honda et al. (2018) noted that female soccer players with stronger neck muscles had a lower SRC risk than those who had weaker neck muscles. These findings suggest the potential for neck strengthening to reduce SRC risk. However, more research is needed to determine the relationship between neck strengthening and SRC risk reduction in female athletes.

Brain Anatomy

There are differences in male and female brains (Covassin et al., 2018). For example, researchers have found that females have smaller axons than males (Dolle et al., 2018). As such, when exposed to a similar force (for example, a hit to the head), a female axon may be more vulnerable to injury (Dolle et al., 2018). This is important to recognize because axons play an essential role in brain communication and function. Therefore, damage to axons can alter brain function, resulting in the symptoms and impairments observed following a SRC (for example, troubles concentrating on a task: Dolle et al., 2018: Shafi et al., 2020). Interestingly, researchers have noted that alterations to brain function post SRC may differ in males and females (Shafi et al., 2020)¹. Meaning that similar symptom presentation in males and females may be driven by different functional impairments (Shafi et al., 2020). More research is needed to understand how sex influences brain function and structure and its relationship to SRC risk and recovery outcomes.

Reporting Behaviours

Females may be more likely to report a SRC than their male counterparts (Kroshus et al., 2017; Lin et al., 2018; McAllister et al., 2022; Miyashita et al., 2016; Prien et al., 2018; Wallace et al., 2017). That said, SRC reporting rates in female athletes remain low (Kroshus et al., 2017; McDonald et al., 2016; Ferdinand Pennock et al., 2020). For example, in one study, researchers found that only one-third of female high school athletes who suspected a concussion reported their symptoms (McDonald et al., 2016).

Despite differences in reporting behaviour, studies have shown no differences in the reasons why males and females choose not to report a SRC. The primary reasons include a reluctance to missing a game, followed by fear of losing playing time, as was documented by McAllister and colleagues (2022). Interestingly, within the same study, the authors recognized that athletes may sometimes fail to report SRCs due to a lack of understanding of the injury and its consequences. In fact, McAllister and colleagues (2022) found that while female athletes had significant higher knowledge regarding SRC and SRC symptoms, they were also more likely to

¹ For more information on the sex-based differences in brain structure and function, please see <u>Dr.</u> <u>Reema Shafi's video</u> from SIRC's 2021 Canadian Concussion in Sport Virtual Symposium.

report a suspected SRC. More research is needed to determine the relationship between SRC knowledge and SRC reporting.

Gender may have an impact on SRC reporting. As mentioned earlier, gender pertains to the socially expected behaviors and attitudes associated with masculinity and femineity. It is a social construct, meaning that it is created and influenced by the society in which one finds themselves (Roper, 2012). For decades in North America, there has been a prevailing perception that males are expected to embody qualities of strength, toughness, and bravery, whereas women are often associated with qualities of fragility and gentleness (Roper, 2012). These widely ingrained gender stereotypes may, in turn, have an influence on SRC reporting. For example, it is possible that males do not want to be perceived as "fragile" and therefore do not report SRC. Research on gender is needed in SRC research and will be crucial to get a better understanding of the impact on gender on SRC experience.

Together these studies highlight the importance of working to improve SRC reporting behaviours in athletes. Efforts to improve SRC reporting must go beyond just improving education, as education alone does not appear to effectively improve reporting behaviours (Ferdinand Pennock et al., 2020). Instead, efforts should focus on reducing risk-taking culture, challenging stereotypes and social norms, as well as de-emphasizing the win-at-all-cost mentality in sport (Kroshus et al., 2017; McAllister et al., 2022).

Conclusion

This review provides individuals in sport and rehabilitation settings with information that can help them to better understand how biological sex and gender influence an individual's SRC experience. According to published research, females are at an increased risk of sustaining a SRC compared to sport-matched males. More research is needed to fully understand why and how females are at an increased risk of SRC. Preliminary evidence suggests that hormone levels, neck strength and brain anatomy are all contributing factors. In addition to an increased risk of injury, researchers also identified that females often experience a greater symptom burden (meaning, symptom number and severity) and longer recovery times for symptom resolution than males. Individuals working with female athletes may consider taking a more conservative approach to SRC management to ensure that their athletes do not return to play too soon following SRC. Lastly, researchers have noted that female athletes are more likely to report a SRC compared to their male counterparts and that could be due to gender stereotypes. Yet, SRC reporting in females remains relatively low. To improve SRC reporting in both males and females, initiatives should go beyond education to target attitudes and behaviours (for example, risk-taking behaviours).

As described above, because there are sex differences related to SRC incidence and mechanisms, symptoms, risk factors and reporting behaviours and because most of the research on SRC has focused on male athletes, it is important that researchers involve female athletes in future investigations. This will allow efficient prevention and management strategies

regarding SRC in this athlete population. More research is needed regarding gender and SRC to better understand how it impacts athletes' experiences.

Take-Home Points

- Females are at an increased risk of SRC compared to sport-matched males.
- Females often experience a greater number of symptoms and a greater symptom severity compared to their male counterparts.
- Symptoms resolution may take longer in females, but it does not seem to affect their return to play timeline.
- Sex and gender differences in SRC may be attributable to differences in hormone levels, neck strength, brain anatomy, and SRC reporting.

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