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

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1 Introduction

Sport-related concussions (SRC) are a concern for male and female athletes who participate in a wide range of contact and non-contact sports, including football, hockey, soccer and gymnastics (Cheng et al., 2019). SRC can alter cognitive and behavioural function (Koerte et al., 2020), affecting an athlete's short-term and long-term wellbeing. That kind of impact makes it essential to understand how to best prevent and manage these injuries. Such an understanding includes gaining a deeper understanding of how factors like biological sex and gendered behaviour can influence SRC risk and recovery outcomes.

An individual's biological 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; Mollayeva et al., 2018). In this review, when referring to biological sex, the terms male and female will be used. In contrast, when exploring the influence of gendered behaviours on SRC, the terms man, woman, girl, or boy will be used.[1]

While significantly more SRC research has focused on male athletes than female athletes, evidence suggests that biological sex and gender influence how SRC are experienced (Covassin et al., 2017; Koerte et al., 2020; Mollayeva et al., 2018). As a case in point, 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 everyone.

2 Purpose and objectives

This review's purpose was to explore how biological sex and gendered behaviour influence SRC, with a focus on implications for women and girls in sport. The information found in this review can then be used by sport organizations, coaches, parents or guardians, and clinicians to help inform educational initiatives and decisions around SRC management (for example: return-to-sport decisions).

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

- The incidence and mechanisms of SRC
- SRC symptom burden
- SRC risk factors

[1] It should be noted that the literature shows some inconsistency with the use of these terms. In some instances, we were unable to determine if a paper was studying biological sex, gender or a combination of both gender and biological sex.

- SRC reporting behaviours

3 Search strategy

First, we searched for titles of articles in Google Scholar, in July 2019, using the search terms "concussion" AND "sport" AND "sex differences" OR "gender differences." We performed a secondary search of Google Scholar and 3 other databases (PubMed, Medline and Web of Science) in January 2021 using the terms "concussion" OR "mild traumatic brain injury" AND "sport" AND "sex differences" OR "gender differences" OR "biological sex" OR "gendered behaviour." Next, we identified additional articles by manually searching the reference lists of key articles included in the review. We included studies in the review if they were peer-reviewed and published in English between 2015 and 2021. In total, we identified 33 articles to include in this review.

4 Summary of findings

4.1 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 up to a two times greater risk of sustaining an SRC compared to male athletes participating in comparable sports (Bretzin et al., 2021; Kerr et al., 2019).

SRC incidence appears to be particularly high for female athletes 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 female and male athletes sustain SRC vary. Evidence suggests that male athletes are more likely to sustain an SRC through player-to-player contact (a body check or tackle), while female athletes are more likely to sustain an SRC through contact with equipment (a soccer ball) or the playing surface (a goal post) for a sport (for example: Bretzin et al., 2021; Cheng et al., 2019; Lin et al., 2017; O'Connor et al., 2017). Further research is required to confirm how and why the mechanisms of injury vary between male and female athletes.

4.2 Symptoms

In addition to having an increased risk of SRC, researchers have suggested that female athletes often experience a greater symptom burden (that is, more symptoms and more severe symptoms) compared to their male counterparts (Covassin et al., 2018; Iverson et al., 2017; Lin et al., 2018, Mollayeva et al., 2018; Resch et al., 2017). Interestingly, the types of symptoms male and female participants report post-injury may also differ (Koerte et al., 2020). For example, female participants appear to be more likely than male participants to report drowsiness, sensitivity to light, headaches and difficulty concentrating post-SRC (Bunt et al., 2020, Covassin et al., 2018; Koerte et al., 2020). Understanding how symptoms differ between male and female athletes may help individuals better detect and manage SRC in the different 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 male athletes (Bretzin et al., 2021; Covassin et al., 2018). Increased recovery times may be related to the increased number of symptoms that female participants 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 female athletes may be at an increased risk of suffering from SRC symptoms lasting greater than 3 months, that is, post-concussive syndrome (Covassin et al., 2018). With this in mind, individuals working with female athletes may consider taking a more conservative approach to SRC management to ensure that female athletes don't return to play too soon after their injury.

Longer recovery times in female athletes may have implications when it comes to return-to-play progression. Researchers have suggested that post-injury, female athletes take longer to return to sport compared to sport-matched males (Bretzin et al., 2021; Stone et al., 2016; Tamura et al., 2020). For example, Bretzin and colleagues (2021) noted that female soccer players typically took 2 days longer (that is, 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 happen because female athletes take longer than male athletes to return to baseline scores post-SRC. It's worth noting that female participants often present with higher symptom scores at baseline than male participants (Merritt et al., 2019; Resch et al., 2017), highlighting the importance of baseline testing. To help anyone involved with SRC management (that is, coaches, parents or guardians, trainers) in tailoring their management plans to female athletes, it is important to communicate that female athletes may require more time to return to sport safely.

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

4.3 Risk factors

The reasons behind 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 may all be contributing factors.

4.3.1 Hormone levels

Researchers have suggested that differences in symptom burden and recovery times may be attributable to hormonal changes associated with menstrual cycles (Brown et al., 2015). The research in this area is still in the early stages. However, researchers believe that changes in progesterone levels may impact SRC recovery outcomes (Chen et al., 2020; Mollayeva 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 female participants in the luteal stage of their cycle (that is, the last phase before menstruation) may experience worse recovery outcomes than those who are in different phases of their cycle (Resch et al., 2017). This is because during the luteal stage, female participants appear to experience a significant drop or “withdrawal” in progesterone levels after an SRC (Resch et al., 2017). Consequently, these female participants are no longer exposed to the protective effects of progesterone, which may increase their post-SRC symptom burden (Gallagher et al., 2018: Resch et al., 2017).

Interestingly, female participants who use hormonal contraceptives (that is, birth control) report less severe symptoms than females who don't 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).

4.3.2 Neck strength

When compared to male participants, female participants often have lower neck strength, smaller neck girth and lower neck muscle mass (Covassin et al., 2018; Koerte et al., 2020; Lin et al., 2018). As a result of lower neck strength, female participants 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.

4.3.3 Brain anatomy

Male and female brains aren't the same (Covassin et al., 2018). For example, researchers have found that female brains have smaller axons than male brains do (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. So, damage to axons can alter brain function, resulting in symptoms and impairments observed following an SRC, such as troubles concentrating on a task (Dolle et al., 2018: Shafi et al., 2020). Interestingly, researchers have noted that post-SRC alterations to brain function may differ in males and females (Shafi et al., 2020)[2]. Meaning that similar symptoms that present in males and females may be driven by different functional impairments (Shafi et al., 2020). More research is needed to understand how biological sex influences brain function and structure and its relationship to SRC risk and recovery outcomes.

4.4 Reporting behaviours

Female participants are more likely to report an SRC than their male counterparts (Kroshus et al., 2017; Lin et al., 2018; 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; Pennock et al., 2020). For example, in one study, researchers found that only a 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 between male and female high-school athletes' SRC symptom knowledge (Wallace et al., 2017) or rationale for not reporting an SRC, such as not wanting to leave the game (Miyashita et al., 2016). Interestingly, one study showed that their differences primarily resided in intentions to report SRC symptoms (Weber et al., 2019). But these intentions didn't translate into significant differences in actual reporting behaviours among male and female collegiate athletes (Weber et al., 2019). Another study found that gendered behaviour, rather than biological sex, may play a larger role in determining SRC safety and behaviours (Kroshus et al., 2017).

Together these studies highlight the importance of working to improve SRC reporting behaviours in all athletes. Efforts to improve SRC reporting must go beyond just improving education, because education alone doesn't seem to effectively improve reporting behaviours (Pennock et al., 2020). Instead, efforts should focus on reducing risk-taking culture and de-emphasizing the win-at-all-cost mentality that often surrounds sport (Kroshus et al., 2017).

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

5 Conclusion

This review provides people in sport and rehabilitation settings with information that can help them to better understand how biological sex and gendered behaviour can or may influence an individual's SRC risk and recovery outcomes. Special considerations may need to be made to effectively manage and prevent SRC among girls and women, because of the differences in how biological sex and gendered behaviour influence SRC incidence, mechanisms, symptoms, risk factors and reporting behaviour.

According to the research, female athletes are at an increased risk of sustaining an SRC compared to sport-matched males. More research is needed to fully understand why and how female athletes are at an increased risk of SRC. However, the 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 female participants often experience longer recovery times and a greater symptom burden (that is, number and severity of symptoms) than their male counterparts. Individuals working with female athletes may consider taking a more conservative approach to SRC management to ensure that their athletes don't return to play too soon after an injury.

Lastly, researchers have noted that female athletes are more likely to report an SRC compared to their male counterparts. However, SRC reporting in female athletes remains relatively low. To improve SRC reporting in both male and female athletes, initiatives should go beyond education to target attitudes and behaviours (that is, risk-taking behaviours).

Takeaway points
• Female athletes are at increased risk of SRC compared to sport-matched male athletes. • Female athletes often experience a greater number of symptoms and more severe symptoms compared to their male counterparts. • Female athletes may take longer to safely return to play following an SRC. • Sex-based differences in SRC may be attributed to differences in hormone levels, neck strength and brain anatomy. • SRC reporting remains low in both male and female participants. As such, there's a need for initiatives targeted at improving reporting behaviours.

6 References

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