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Understanding Gender Differences in Sports-related Concussions Among High School Athletes: Implications for Diagnosis, Treatment, and Management

Abstract

Growing research on both the immediate and long-term effects of sports-related concussions (SRCs) in professional athletes has called attention not only to understanding the impact of concussions in high school athletes, but has also focused on understanding how SRCs may impact female athletes differently than male athletes (Covassin & Elbin, 2011; Kirkwood, Yeates, & Wilson, 2006). There are many studies that have highlighted the neurocognitive, academic, and socioemotional implications of these brain injuries on developing youth, but there are few studies that focus on gender differences in adolescent athletes (Daneshvar, Nowinski, McKee, & Cantu, 2011; Kirkwood, et al., 2006). Understanding how sports-related concussions impact males and females differently can be crucial in approaching diagnosis, treatment, and recovery. The purpose of this paper is to give an overview of these issues, outline considerations for the field, provide recommendations for treatment providers, and share some case illustrations.

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A DOCTORAL PAPER
PRESENTED TO THE FACULTY OF THE
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IN PARTIAL FULFILLMENT
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DOCTOR OF PSYCHOLOGY

BY
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June 30, 2017

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Understanding Gender Differences in Sport-Related Concussions among High School Athletes: Implications for Diagnosis, Treatment, and Management.

Growing research on both the immediate and long-term effects of sports-related concussions (SRCs) in professional athletes has called attention not only to understanding the impact of concussions in high school athletes, but has also focused on understanding how SRCs may impact female athletes differently than male athletes (Covassin & Elbin, 2011; Kirkwood, Yeates, & Wilson, 2006). There are many studies that have highlighted the neurocognitive, academic, and socioemotional implications of these brain injuries on developing youth, but there are few studies that focus on gender differences in adolescent athletes (Daneshvar, Nowinski, McKee, & Cantu, 2011; Kirkwood, et al., 2006). Understanding how sports-related concussions impact males and females differently can be crucial in approaching diagnosis, treatment, and recovery. The purpose of this paper is to give an overview of these issues, outline considerations for the field, provide recommendations for treatment providers, and share some case illustrations.

While much of the research on SRCs has focused on college age or adult athletes, most athletes participating in organized sports are pediatric athletes; for example, more than half of high school students across the country are athletes (Kirkwood, et al., 2006). SRCs can impact younger athletes differently than adult athletes because younger athletes' brains are still developing (Kirkwood & Yeates, 2012). About nine percent of injuries in high school athletes involve SRCs, and about twenty five percent of the pediatric athletes who have presented to the emergency department with concussions report that these injuries occurred during an athletic activity (Meehan, Taylor, & Proctor, 2011). Not all athletes who suffer from a concussion seek emergency department treatment, so 25 percent could be an underrepresentation (Meehan et al., 2011). This suggests that the rate of high school athletes who have experienced a concussion is

likely higher. Additionally, pediatric athletes who did not present to the emergency department may not have accessed the appropriate medical care, potentially impacting their physical, cognitive, and emotional health.

Since the implementation of Title IX, the population of female high school athletes has rapidly grown. From 1990 to 2010, the number of high school female athletes increased from 1.9 million to 3.2 million, and during this same period, participation in high school girls' soccer tripled (Zuckerman et al., 2012). Female athletes present with the highest incident rate of SRCs in soccer, while football produces the highest rate of SRCs in male athletes (Broshek, Kaushik, Freeman, Erlanger, Webbe, & Barth, 2005). Other sports with high rates of SRCs between both genders, include wrestling, lacrosse, basketball, and cheerleading (Broshek et. al 2005).

The impact an SRC might have on neurocognitive functioning depends upon the number and severity of the concussion(s) and the length of time since the injury occurred (Kirkwood et al., 2006). Not every concussive injury will look the same, so it is important to approach each athlete with an individual treatment plan.

Concussions are a form of Traumatic Brain Injury (TBI) that can impact many different areas of functioning. The Centers for Disease Control Heads UP program describes a concussion as:

> …caused by a bump, blow, or jolt to the head or by a hit to the body that causes the head and brain to move rapidly back and forth. This sudden movement can cause the brain to bounce around or twist in the skull, stretching and damaging the brain cells and creating chemical changes in the brain. (Center for Disease Control and Prevention, National Center for Injury Prevention and Control, Division of Unintentional Injury Prevention, https://www.cdc.gov/headsup/basics/concussion_whatis.html.)

The American Academy of Pediatrics identified\s five major features of a concussion: (a) a direct blow to head, face, neck, or anywhere on the body with force to the head; (b) rapid onset of short-lived impairment to neurologic functioning that spontaneously resolves; (c) acute symptoms due to functional impairment rather than structural impairment; (d) results in a graded set of clinical syndromes that may or may not involve loss of consciousness; and (e) typically associated with grossly normal neuroimaging studies (Halstead, 2012).

Kutcher and Eckner (2010) found that athletes who have sustained one concussion can be up to three times more likely to sustain another within the same season, while athletes who have had a concussion with loss of consciousness can be up to six times more likely to sustain another. Overall, high school athletes tend to take longer than adults to recover from SRCs (Kirkwood et al., 2006). Also, concussions often present with a wide range of symptoms including physical, emotional, behavioral, and somatic; concussions can also disrupt sleep and impact the brain's cognitive functioning (Daneshvar et al. 2011; Kirkwood et al., 2006). Symptoms of a concussion generally resolve within one to two weeks, but some people can develop post-concussive symptoms that continue to persist well after the expected recovery period. Post-concussive symptoms are often divided into three areas of concern: physical, emotional and behavioral, and cognitive (Kirkwood et al., 2006).

Physical symptoms that an athlete can experience include headaches, nausea, vomiting, dizziness, loss of consciousness, fatigue, tinnitus, sensitivity to sound and light, and vision changes, but the most commonly reported symptom after a concussion is post-traumatic headache (Frommer, Gurka, Cross, Ingersoll, Comstock, & Saliba, 2011; Kirkwood et al., 2006). Additionally, post-concussive symptoms often are highlighted by changes in mood and personality.

Emotional symptoms include increased anxiety; low frustration tolerance; emotional lability; and symptoms of depression, such as low mood or sadness. Athletes can also experience changes in behavior such as increased impulsivity and difficulty maintaining attention and concentration (Covassin & Elbin, 2011; Kirkwood et al., 2006). Cognitive symptoms include feeling in a fog, difficulty problem-solving, slowed reaction times, and learning and memory changes (Covassin & Elbin, 2011).

Research that focuses specifically on the psychological impact of sports related concussions (especially when it comes to the variations between genders) is limited, but many studies have considered the impact of a mild traumatic brain injury on the emotional, social, and behavioral impact on pediatric patients. All athletes can experience significant changes in mood after an SRC; however, they differ in the type of symptomology they experience. Female athletes, for example, report experiencing increased symptoms of depression and anxiety after an SRC, and many high school athletes can experience increased levels of irritability, depression, and anxiety (Dick, 2009; Kirkwood et al., 2006). These symptoms are not only influenced by consequences of the SRC, but are also related directly to the injury itself (Gracey, 2002). Athletes may experience secondary stress caused by their inability to practice and play with their peers, frustration with their recovery process, or frustration with experiencing an increase in academic difficulties (Kirkwood et al., 2006). Male athletes experience more amnesia and confusion than female athletes (Frommer et al., 2011). Additionally, executive functioning difficulties are more common in both pediatric and adult male athletes (Niemeier, Marwitz, Lesher, Walker, and Bushnik, 2007).

Changes in routine and in social support can influence stress in relation to the injury as well (Gracey, 2002). Athletes can experience significant changes in their relationships with

family and peers and can also experience changes in roles and expectations. An athlete's parent or caregiver can also experience emotional distress because of an SRC, which can further impact the athlete's behavior. (Gracey, 2002). If an athlete develops post-concussive symptoms and is required to sit out from his or her sport for longer than expected, the athlete may feel lonely and isolated as he or she is not around his or her teammates.

Usually, the first professionals to have contact with athletes following an SRC are certified athletic trainers (Piebes et al., 2009). These trainers assess athletes for symptomology related to concussions, generally by conducting a series of sideline assessments. They should be able to interpret and understand the results of these objective evaluations because athletes may present differently on baseline—and post SRC—testing. (Piebes et al., 2009). It is recommended that baseline assessments for youth be completed at the beginning of the season, and it is important that these trainers be aware of any athlete's prior cognitive, learning, mood, or attentional difficulties that can impact results (Meehan et al., 2011). Trainers should also keep in mind that athletes might purposely exhibit poor performance at baseline testing (a phenomenon that will be discussed later) because it would make it more difficult to diagnose a concussion (Meehan et al., 2011).

Self-report questionnaires are also used when assessing symptoms. Some include samples from both high school and college age athletes, but they may not accurately represent the developmental factors of high school athletes. In most of these questionnaires, gender differences have neither been accounted for nor explored, yet there is a higher representation of male athletes normed on these measures (Kirkwood & Yeates, 2012). The Post-Concussive Scale is a self-report questionnaire that was originally designed for adults, but has since been adjusted and studied for the pediatric population (Kirkwood & Yeates, 2012). This questionnaire is notable

because it took gender differences into account, and so it is beneficial for assessing post-concussive symptoms. However, the norms include a mixture of high school and college age athletes, and because high school athletes are at a different developmental level than college athletes, it may not be an accurate questionnaire to use with the younger high school athletes. (Kirkwood & Yeates, 2012)

Neuropsychological assessments are more individualized. These assessments help in identifying the impact of an SRC on an athlete and in managing treatment. Most athletes who experience an SRC do not work with a neuropsychologist since their symptoms resolve within the expected time frame (Kirkwood & Yeates, 2012). However, for those athletes who continue to experience post-concussive symptoms, neuropsychological assessments can help identify an athlete's current cognitive, academic, and socioemotional functioning. These assessments can help identify the appropriate accommodations for school support and any other service that may be beneficial to the athlete's mental health—such as psychological therapy to assist with changes in mood or behavior, medication management, or creating an Individual Education Plan (IEP) to support cognitive, academic, or executive functioning difficulties (Echemendia et al., 2013; Kirkwood et al., 2006).

Given that athletes may not report concussive symptoms, and that loss of consciousness does not always occur, neuropsychological testing can be beneficial in identifying an athlete's current cognitive, academic, and social emotional functioning (Kirkwood et al., 2006). Traditional neuropsychological testing can be time consuming and expensive, but it is beneficial for athletes who continue to demonstrate symptoms of an SRC because the results could lead to the implementation of accommodations that would improve their well-being (Kirkwood et al., 2006).

A growing area of research in neuropsychological assessment has focused on validity testing with athletes diagnosed with a mild traumatic brain injury. An increasing number of neuropsychologists have begun to utilize validity testing with pediatric patients because it can identify if an athlete is faking or exaggerating his or her reported symptoms. (Connery, Peterson, Baker, and Kirkwood, 2016) Reasons for faking or exaggerating symptomology may include feeling overwhelmed with academic and sports demands potentially leading to anxiety or depression, attention seeking, or attempts to avoid school responsibilities (Connery et. al, 2016). There is minimal research on gender differences in validity testing outcomes, specifically with high school athletes diagnosed with an SRC. Further research on gender differences in validity testing could provide important information for how male versus female athletes handle academic and sport performance pressure.

In 2006, a survey was conducted with primary care physicians to assess their understanding of diagnosis and management of SRCs. Researchers identified that many of the physicians did not possess sufficient understanding of SRC management, which could significantly impact athletes' symptom recovery and place them at risk for re-injury if appropriate return to play procedures are not followed (Meehan et al., 2011). Some researchers have identified that isolation from teammates and their preferred sport can lead athletes to experience symptoms of anxiety and depression (Putukin & Echemendia, 2003).

There is little research focused on the impact of SRCs between genders. Much of the research has highlighted mixed results on these gender differences. There are a number of areas that research has focused on identifying differences within male and female high school athletes. These areas include the risk and rate of reporting of SRCs, physical and biological differences, and cognitive differences. Understanding differences within these areas can be beneficial in the

assessment, diagnosis, and management of SRCs in male and female athletes

Risk and Rate of Reporting

Player contact accounts for a higher percentage of SRCs experienced by male athletes while contact with a ball or surface explains a higher percentage of SRCs experienced by female athletes (Dick, 2009). When looking at the incidence rate of SRCs in high school athletes, female athletes demonstrate a higher risk and rate of occurrence when compared to males in similar sports (Covassin & Elbin, 2011). Additionally, a higher number of SRC-related symptoms have been reported by female athletes in some studies (Kutcher & Eckner, 2010). Culture factors may contribute to this difference in rate of occurrences. Many researchers have discussed how male athletes are encouraged to play through injuries leading to lower reporting rates and a higher risk for long-term damage (e.g., Covassin & Elbin 2011; Lincoln et al., 2011). Female athletes demonstrate more concern for their future health, which influences their tendency to report injury (Dick, 2009). Female athletes have also demonstrated a higher willingness to delay their return to play (Yard & Comstock, 2009).

High school athletic teams often do not have access to the trainers or resources necessary to perform appropriate assessments when an athlete experiences a potential SRC (Meehan, et al., 2011). Without access to these resources, SRCs may go undiagnosed. Male athletes may also experience immediate emotional and academic struggles that go untreated or unsupported, leading to adjustment difficulties. Moreover, this can impact how the treatment team approaches diagnosis in these athletes. If medical professionals are aware that female athletes are more likely to experience a SRC, medical professionals may be more focused on the symptom presentation in females rather than males.

Females appear to be at a higher risk of concussions than males, and studies suggest that

this increased risk may be related to different biomechanics of male and female bodies as well a performance difference on baseline testing between male and female athletes (Broshek et al., 2005; Covassin and Elbin 2011; Dick, 2009). Female athletes also take about seven days longer than male athletes to recover from symptomology related to SRCs (Covassin and Elbin 2011). It is important for coaches, parents, and medical professionals to be aware of this difference as it may impact return to play decisions.

Research highlights that male and female high school athletes with SRCs present with differences across all three domains of cognitive, emotional and behavioral, and physical functioning. Given all these factors, when considering sex, it is unclear if the differences of risk and rate of occurrences of SRCs are due to cultural factors, biological factors, or some combination of the two.

Physical and Biological Differences

Certain physical and biomechanical differences between male and female athletes likely contribute to the difference in incidence rates of SRCs. Female athletes generally have less head-segment neck mass, and less neck mass can increase the acceleration to the head after impact (Covassin & Elbin 2011; Dick, 2009). For every pound in neck strength, the risk of concussion decreases by five percent (Collins et al., 2014.) Therefore, it is likely that females who have weaker and smaller necks are at an increased risk to sustain a concussion. In soccer specifically, female athletes have a smaller head-to-ball ratio than male athletes (Covassin & Elbin, 2011), and given that soccer is one of the most popular sports for female athletes, this presents an increased risk for females to experience a SRC.

Additionally, researchers identified that females can have larger areas of unmyelinated neuronal processes (neuropils), a higher rate of cerebral blood flow, and higher rates of glucose

metabolism, all of which make it harder for their brains to respond to injury (Covassin & Elbin, 2011). These differences from male athletes are thought to possibly cause an increased neurometobolic cascade (Covassin & Elbin, 2011). When an athlete experiences a concussion, the brain releases neurotransmitters. This leads to a depolarization of neurons with an efflux of potassium and influx of calcium, an ionic shift that changes cellular physiology. The sodium-potassium pump works overtime, causing a jump in glucose metabolism; the discrepancy between glucose supply and demand makes the brain less able to respond to injury. (Covassin & Elbin, 2011). The differences in biomechanics between females and males incurs an increased risk of symptoms and longer recovery times in female athletes with SRCs.

To further understand differences in SRCs between male and female athletes, researchers focused on how hormone levels may impact SRCs by using animal models. Covassin and Elbin (2011) found that estrogen treatment given to rats prior to induced brain injury was detrimental for female rats but protective for male rats. Other researchers, have however, observed the opposite effect, with female rats demonstrating better outcomes than male mice (Broshek, et al., 2005; Covassin and Elbin 2001). With such conflicting results, it is unclear whether estrogen plays a protective or detrimental role when it comes to mild traumatic brain injuries.

However, progesterone has been shown to positively affect recovery from both traumatic brain injury and other CNS injuries (e.g., Stein, 2008). Progesterone has a neuroprotective effect, and it could be used as a potential treatment for those who experience brain injuries (Stein, 2008). These results suggest that female athletes may have an improved recovery from SRCs, which contradicts the research that shows that females have a higher risk of brain injury and longer recovery times. This area could benefit from additional research on the roles that both estrogen and progesterone play in the outcome of SRCs and in treatment of brain injury.

Cognitive Differences

Research on the cognitive differences between genders following a SRC has focused largely on populations of collegiate athletes. This research shows that, when tested within 10 days of experiencing an SRC, adult female athletes have larger neuropsychological deficits than adult male athletes (Dougan et al., 2013). In fact, Broshek et al (2005) reported that within a cohort of high school and college age athletes, female athletes were twice as likely to demonstrate negative changes in cognitive functioning. Female athletes have more difficulty with visual memory tasks and have slower reaction times following an SRC (Broshek et al., 2005; Covassin & Elbin, 2011; Dick, 2009). These cognitive changes indicate that following a concussion, female athletes may experience more difficulty learning and integrating new information in the classroom. It's important to keep in mind that while some of this research focused on collegiate athletes, cognitive traits are generally stable, so this information can be applied to high school-aged athletes as well.

Male athletes experience more amnesia and confusion than female athletes (Frommer et al., 2011), which could make it difficult for male athletes to learn and integrate new information in the classroom. Additionally, executive functioning difficulties are more common in both pediatric and adult male athletes, leading to increased impulsivity, poor planning, and difficulty with emotion regulation (Niemeier, Marwitz, Lesher, Walker, and Bushnik, 2007). This may lead male athletes to present as emotionally labile with problems following expectations at school and/or in the home. Executive functioning impairments are also associated with Attention Deficit Hyperactivity Disorder (ADHD), but it is important to recognize that while male athletes may present with symptoms similar to ADHD, these symptoms are likely due to cognitive changes from the SRC and not the disorder itself. Without understanding that these marked cognitive

changes can take place following an SRC, male athletes are also at risk to be misdiagnosed or even experience unhelpful disciplinary actions from parents or teachers.

It is imperative that treatment teams and parents both recognize and monitor each athlete's individual symptomology and understand the cognitive differences between genders following an SRC. This would allow them to identify the appropriate recommendations for teachers and coaches, including academic accommodations and return to play decisions. Both male and female athletes can experience cognitive changes following an SRC that can lead to academic and behavioral difficulties potentially requiring academic accommodations that might vary from case to case (Kirkwood et al., 2006).

Reported Symptoms

In addition to the biological, physical, and cognitive differences identified between male and female athletes, there are also a number of differences in observed and experienced symptoms reported by each gender. Regarding symptomology reported by male athletes, a study by Zuckerman et al. (2012) found that males more often report amnesia, confusion and disorientation. Females with SRCs have a higher frequency of somatic symptoms. Specifically, female athletes report dizziness, headache (including migraines), and fatigue more often than male athletes (Covassin & Elbin 2011; Dick, 2009). Of note, migraines have been found to increase recovery time from a SRC (Lau, Lovell, Collins, & Pardini, 2009). With the higher rate of reporting somatic symptoms, female athletes risk misdiagnosis, as symptoms can be attributed to other stressors such as anxiety or depression (Frommer et al., 2011).

Overall, the most commonly reported symptom after a concussion is post-traumatic headache (Frommer et al., 2011). Pediatric patients diagnosed with post-traumatic headaches experience uncomfortable physical symptoms such as nausea and vomiting that lead to an

inability to participate in extracurricular activities, spend time with friends, and even attend school (Piebes et al., 2009). This can lead athletes to experience psychological changes affecting emotional, behavioral, and social well-being.

Emotional, Behavioral, and Social Impact

If an athlete has experienced many SRCs and is no longer able to participate in competitive athletics, he or she may experience a change in identity, causing increased distress (Gracey, 2002). Female athletes, who appear to have an increased risk for experiencing an SRC, could encounter this situation more often. Male athletes, who are less likely than female athletes to report injury, could be less likely to report distress related to psychosocial changes (Covassin et al., 2012). This suggests that male athletes must be closely watched for any signs of psychological changes following a hit to the head, even if they are not diagnosed with an SRC or report experiencing symptomology.

Assessment and Diagnosis

During baseline assessments, female athletes demonstrated a higher number of reported symptoms concerning somatic complaints, difficulty concentrating, and feeling emotional (Zuckerman et al., 2012). It can be hypothesized that because male athletes are less likely to report concussive symptoms, and females demonstrate more concern for their health and well-being, male athletes may be more likely to attempt poor performance on baseline testing. Additional research might determine if there are gender differences in throwing performance of baseline testing, the act of which might impact the report rate and incidence of SRCs between males and females.

There are only a handful of measures that have been created specifically for the use with pediatric athletes, and within these measures, none of have explored gender differences

(Kirkwood & Yeates, 2012). The questionnaires that have focused on gender differences were originally created for adults. While adjusted and normed on high school athletes, there may be important developmental impacts that the questionnaires do not account for (Kirkwood & Yeates, 2012). The lack of data alone should inspire a push for creating measures that are a) designed for high school athletes, b) normed solely on high school athletes, and c) considering gender differences between high school athletes.

Following an SRC, athletes will often work with their primary care physician. As previously discussed, physician knowledge around SRCs is variable. With the higher rate of reporting somatic symptoms, female athletes could be at a high risk of misdiagnosis as symptoms can be attributed to another stressor such as anxiety or depression. For example, if a female athlete presents with somatic symptoms following an SRC, a doctor may misattribute this symptom with anxiety, especially if some of these somatic symptoms were present at baseline (Frommer et al., 2011). Additionally, female athletes tend to have longer recovery periods which could potentially impact physicians' return to play decisions (Covassin & Elbin, 2011). By understanding this difference between sexes, medical professionals can have a better understanding of what symptomology they should continue to assess. Physician knowledge around the management of SRCs in high school athletes should continue to be assessed to ensure that appropriate care is provided to these athletes. Further education around gender differences can also be beneficial in helping physicians diagnose SRCs.

Management

As previously mentioned, research has highlighted that many primary care physicians are unaware of how to appropriately manage an athlete's SRC (Meehan et al., 2011). Physicians can vary in their knowledge and understanding of symptomology and management of SRCs. This is

notable because treatment is often reliant on each physician's understanding of SRCs. This suggests that medical providers may vary on decisions such as return to play or how long they recommend an athlete to refrain from school work, reading, or other similar stimulations.

Younger athletes take longer to recover when compared to adult athletes, so more conservative return to play decisions should be used when transitioning high school athletes back into athletic activity (Meehan et al., 2011). As previously discussed, female athletes are more likely to experience cognitive deficits after an SRC (Broshek et al., 2005; Covassin & Elbin, 2011; Dick, 2009), so they may need more support in the classroom and with their academic work. This requires that teachers and school personnel work closely with the athlete's physicians to ensure that they're getting the help they need.

It is important to recognize that female athletes also tend to report more symptoms at baseline (Zuckerman et al., 2012). Baseline testing can highlight the symptoms that a female athlete may have been experiencing before her SRC that may not be directly related to the SRC. If there was not baseline testing, the managing professional could delay a return to play decision because a female athlete continues to report symptoms, even though the symptoms may have been present before the SRC. This could lead to potential misdiagnosis or misunderstanding of the etiology of these symptoms. As previously discussed, the inability to participate in the sport and isolation from teammates can lead to symptoms of anxiety and depression (Putukian & Echemendia, 2003). Given this, a delayed return to play decision may place female athletes at further risk of adjustment difficulties as they are unable to be active participants in their sports. Additionally, it would be difficult to identify the impact of the SRC on these baseline symptoms without having an initial measure of its prevalence and severity.

These potential situations highlight some of the complexity in identifying, diagnosing,

and managing SRCs and their related symptoms. The management of SRCs may involve several professionals—including physicians, coaches, educators, neuropsychologists and at times, individual psychotherapists—working together as a team to support an injured athlete. Not only is it important for each of these professions to understand the impacts of SRCs, but it is important for them to recognize the gender differences that can impact the management of SRCs.

Case Example 1

Jason (name and demographic data have been changed), a 17-year-old male, completed a neuropsychological evaluation about 6 months after a sports-related concussion while playing soccer. After this concussion, Jason reported experiencing headaches, dizziness, and decreased endurance. He began having trouble sustaining attention and concentration and remaining focused in the classroom. Additionally, he became easily distractible and struggled to shift his attention. Jason also demonstrated a significant increase in impulsive behavior and decision making.

Jason experienced changes in mood and behavior following his SRC. He demonstrated little frustration tolerance, irritability, and angry outbursts, including physical and verbal aggression. He was observed easily losing his temper and becoming argumentative. Further, he engaged in more oppositional behaviors, defying rules within the home and deliberately annoying others. In addition to feeling angry and irritable, Jason also reported feeling down, apathetic, and experiencing low self-worth at times. His symptoms did not resolve within the expected time frame, so Jason was referred for a neuropsychological evaluation to better understand his cognitive, academic and emotional functioning.

During his evaluation, Jason demonstrated average cognitive and academic abilities. He performed within normal limits on activities measuring verbal, auditory, and visual memory.

Additionally, his immediate attention and concentration abilities fell within the average range. However, he did illustrate some difficulty with sustained attention, particularly when he was presented with tasks that required more complex problem solving skills.

The neuropsychological testing identified that Jason experienced affect, mood, and behavioral difficulties. This is consistent with research that determined that these same changes (behavioral, mood, and affect) can occur after a mild traumatic brain injury. Further, the increased externalized behaviors that Jason experienced (the anger, aggression, mood lability, and impulsivity) happen more frequently with male athletes. He had trouble with sustained attention, and his low frustration tolerance made it more challenging for him to solve complex problems. It is notable that Jason did not have difficulties with visual memory, which is a common strength for males.

In the management of Jason's SRC, there were several factors that needed to be addressed. It was helpful to recognize his mood lability, impulsivity, anger, and frustration as these changes were likely due to his SRC rather than other changes in his life. This could not only help Jason, his parents, the treatment team, and school personnel understand the etiology of his difficulties, it could also help them to address these symptoms and help him manage and adjust to these overall personality changes rather than dismissing his behavior as "bad" or "disrespectful." The testing also highlighted some difficulties with complex problem solving and sustained attention which allowed his caregivers and teachers to understand that appropriate academic accommodations should be put into place.

Recommendations in Jason's treatment plan included consultation with a psychiatrist to identify potential benefits of utilizing medication to address his mood changes and psychotherapy provided by a psychologist to help him learn how to manage his irritable and low

frustration tolerance and improve his overall mood.

Additionally, a number of academic accommodations were warranted in this case to assist Jason with sustained attention and problem solving skills. Accommodations included having information provided visually, as visual memory is a strength for him, allowing Jason to audio record class lectures, and extended time when completing assignments and tests.

Jason's case highlights the benefit of neuropsychological assessment when symptoms do not resolve. It also illustrates the necessity of a team approach in management. In addition to Jason's medical doctor, a psychiatrist and psychologists are also crucial team members in SRC management. Jason's teachers also play a vital role in management to support his academic success

Case Example 2

Mary (name and demographic data have been changed), a 17-year-old female, completed a neuropsychological evaluation 18months after experiencing a SRC during a cheerleading event. After this concussion, Mary reported experiencing dizziness, headaches, fatigue, sensitivity to light, pain, and changes in mood and stamina. Additionally, she reported having trouble with memory. Mary also reported experiencing changes in her mood and affect. She noted becoming more easily frustrated, experiencing feelings of anxiety, difficulty concentrating, and low self-esteem. These symptoms were impacting Mary's social, emotional, and academic functioning. This continued difficulty following her SRC prompted her family to seek comprehensive neuropsychological testing.

Testing indicated that Mary's cognitive and academic abilities fell into the average range. Her ability to sustain attention and concentration as well as executive functioning abilities fell within normal limits. Mary's verbal, visual, and auditory memory abilities were also in the

average range. Mary demonstrated mood and affect concerns as well as many somatic complaints. She reported experiencing irritability, a lower frustration tolerance, symptoms of anxiety and depression, and low self-esteem. Additionally, she reported experiencing many somatic complaints, such as dizziness, headaches, pain, and fatigue. Further, she noted continued sensitivity to light and sounds.

As research highlights, female athletes with SRCs tend to experience and report more symptoms of anxiety, depression and somatic complaints. This is consistent with Mary's case. It is important to understand this difference in symptom presentation to help with differential diagnosis. By understanding common symptoms presentation of SRCs in female athletes, medical providers may be less likely to dismiss the somatic symptoms that Mary experiences as related to anxiety and depression but recognize them as a result of her SRC. Further, it is also important to recognize that female athletes tend to take a longer time to recover and have an increased risk of experiencing another concussion. Understanding this research can impact return to play decisions for Mary. Since testing indicated that Mary's executive functioning and other cognitive skills were within the average range, the difficulty Mary is experiencing at school was probably not due to cognitive abilities but more likely a combination of somatic symptoms and increase in negative mood.

Similar to Jason's case, there were a number of approaches required to adequately manage Mary's recovery from the SRC. It was recommended that she consult with a psychiatrist to discuss medication to address her changes in mood, and that she work with a psychologist in individual psychotherapy to learn relaxation strategies and mood management skills. Even though Mary did not exhibit cognitive difficulties, her academic functioning had been impacted by her emotional and somatic changes, indicating that she could benefit from school

accommodations. Such accommodations included teaching information in chunks, taking frequent breaks, and reviewing guides for tests and class lectures. This case again highlights the necessity for a team approach in management of SRCs and the importance of understanding gender differences in SRC symptoms.

These cases illustrate the gender differences present in high school athletes who have experienced a SRC. A number of professionals were involved in the diagnosis and management of these athletes highlighting the importance of educating these providers on the effects of SRCs and how they may differ between male and female athletes.

Summary and Recommendations

Understanding the overall symptomology of sport-related concussions is important in providing care for high school athletes who may experience this form of brain injury. SRCs are a complex and layered issue that can impact athletes in different ways. Factors to consider include the number and the severity of the concussion/s. Further, understanding gender differences can have clear implications on the approach to diagnosis and treatment. Understanding these differences between male and female athletes is important for medical providers to recognize so that accurate concussion management is implemented.

Overall, female athletes present with a higher risk and incidence of SRCs than male athletes (Covassin & Elbin, 2011). There are many potential reasons for this difference in risk and rate of occurrences that include cultural, physical, and neuroanatomical differences. Further research into these potential factors is warranted. With a better understanding of what contributes to the increased risk and rate for female athletes, researchers may be able to identify how to improve SRC prevention and management. Female athletes also report a higher number of experienced symptoms, including physical, cognitive, and emotional symptoms (Kutcher &

Eckner, 2010). Specifically, they report higher incidence of headaches, dizziness, visual spatial difficulties, and increased symptoms of depression (Covassin & Elbin 2011; Dick, 2009). Additionally, females take longer to recover than their male counterparts. Females are more likely than males to be misdiagnosed when experiencing a SRC given the high number of somatic symptoms they report (Covassin and Elbin 2011). This could lead medical providers to attribute these somatic symptoms as symptoms of anxiety or depression rather than a SRC, placing the athlete at increased risk to sustain another SRC before symptoms have abated. Difficulty with diagnosis indicates the necessity to implement baseline testing for all high school athletes to better understand cognitive and emotional functioning before a potential SRC. Many high schools do not have the resources either for testing materials or access to the professionals who can administer and interpret these assessments. Having a central location or provider for communities to utilize could be beneficial in opening access to this vital resource. Athletes are often required to obtain a physical before participating in sports which could give providers the opportunity to intervene with baseline testing. Future research should explore how to best create easier access to these measures and to professionals who can administer and interpret them.

Given the increased risk for SRCs in female athletes, coaches, parents, educators, and medical providers should closely observe female athletes following a hit to the head. Further, when making return to play decisions, medical providers should remember that female athletes may need a longer recovery period than male athletes (Covassin and Elbin 2011). This longer recovery period likely puts female athletes at an increased risk for symptoms of anxiety and depression because they will not be able to participate in their sport, spend time with their teammates, or they may experience a change in identity or role expectations.

Research in this area is still limited, and further studies need to be completed to better

understand sex differences in concussion management. Much of the research combines both the high school age and collegiate age populations, making it difficult to understand the implications on only high school students. Additionally, most studies use populations that included higher numbers of male participants than female which may have impacted the results. Future research should include larger sample sizes, equal numbers of male and female athletes, and it should be conducted solely with high school athletes.

Studies should also consider athletes diagnosed with Attention Deficit Hyperactivity Disorder or a learning disorder, because it is unclear how an SRC might impact these disorders. Athletes who had a previous diagnosis of anxiety or depression were also not included in many studies, and while there is some research on the psychological implications of sports-related concussions, the literature mostly focuses on neuropsychological and cognitive functioning. Further research in these areas could provide more evidence and understanding of the emotional and behavioral changes that may be experienced and observed in high school athletes. Future research should also focus on the potential impact of SRCs on premorbid psychological diagnosis and how these impacts may differ between male and female athletes. Gender, learning disorders, and ADHD could impact neuropsychological functioning, and these variables must be considered in baseline, sideline, and neuropsychological assessments (Covassin & Elbin 2011; Dick, 2009; Meehan et al. 2011).

There are some studies that are focused on the overall psychological impacts of SRCs, but they do not identify the gender differences in experienced symptomology. By furthering research in this area, there could be a better understanding of how psychological symptoms may present differently between sexes. This may help treatment providers to recognize specific symptomology in athletes and to have preventative supports in place for these athletes.

Because physicians' knowledge can vary regarding concussion symptomology and management, it would be beneficial to understand how varying approaches to concussion management might impact symptom recovery or prolonged symptom presentations. Research could examine any potential differences in how physicians approach SRC management between genders, and if their varying approaches impact the cognitive differences observed between male and female athletes diagnosed with an SRC. After obtaining a better understanding of different physicians' approach to diagnosis and management, it would be easier to assess the amount of education needed for providers to support their athletes.

Overall, further research could assist medical providers, school personnel, and families in improving their approach to diagnosis, treatment, and management of symptoms associated with SRCs. Given the different impacts of SRCs on male and female athletes, education around this injury is crucial, and treatment and management is best supported through an interdisciplinary team approach. As participation in high school level sports continues to grow, the need for further research grows as well.

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