Abstract

Introduction
The annual incidence of sport related concussion ranges from 1.6 to 3.8 million concussions per year representing a common injury in sports. Lacrosse is a rapidly growing sport for both men and women and these athletes are at risk for concussion. The mechanism of injury for concussion in the men’s and women’s game are different as are the rules and equipment requirements.

Objectives
To report the epidemiology, pathophysiology, presentation, management of sport related concussion and to highlight recent rule changes for men’s and woman’s lacrosse in regards to concussion prevention.

Methods
PubMed and Scopus databases were searched. All levels of evidence (I-IV) pertaining to concussions in men’s and women’s lacrosse players were analyzed and presented in this narrative review.

Results
For all high school boys’ sports, lacrosse ranks number 3 for sports with the highest prevalence of concussions. Concussions most frequently result from athlete-to-athlete contact which represents 66.4% of the recorded concussions. For all high school girls’ sports, lacrosse ranks number 2 for sports with the highest prevalence of concussions. In women’s lacrosse, stick or ball contact with the athlete’s head is the most common mechanism of concussion, accounting for 72.7% of the recorded concussions.

Conclusion
Both men’s and women’s lacrosse players are at risk for concussion, even though there are different mechanisms for this injury between the two games. Sports medicine providers should be knowledgeable on diagnosis, management and prevention when caring for lacrosse players. Protective equipment and rule changes are potential means to continue to protect these athletes and still need further investigation.

Patient Consent Statement
There are no patient consent documents associated with this narrative review on concussion in lacrosse athletes.

Introduction

Despite the COVID pandemic, approximately 75% of American youth ages 6-17 continue to participate in individual or team sports.¹ Lacrosse is one of the fastest growing sports in the United States at both the youth and NCAA level. Per the National Collegiate Athletic Association (NCAA) Sports Participation and Sponsorship report, the number of women’s lacrosse teams nearly doubled between 2003 and 2018, rising 97% from 256 teams to 505 teams. Men’s lacrosse experienced a 61% increase over the same period, fielding 380 teams by 2018.² Participation in organized sports offers a great opportunity for athletes to develop life skills such as leadership, teamwork, and communication. It can also improve physical and emotional well-being as well as academic success.³ Despite these benefits, sports participation can also place athletes at risk for sports related injuries, including sport related concussion (SRC). In 2017, 2.5 million high school student athletes reported sustaining at least one sport or activity related concussion within the last year.⁴ Based data provided by the NCAA injury surveillance program, athletes sustain a concussion at a rate of 4.5 per 10,000 athlete exposures (AE) in men’s lacrosse and a rate of 5.07 per 10,000 AE in women’s lacrosse.⁴

Providers caring for lacrosse athletes should be well versed in how to diagnose and manage concussion. Providers should also be aware of the differences between the two games, including the mechanism of injury for concussions, equipment requirements, and rule enforcement. In this narrative review, we will outline the epidemiology, pathophysiology, diagnosis, management, and treatment of concussions in men’s’ and women’s’ lacrosse players. We will also highlight recent rule changes for men’s and woman’s lacrosse in regard to concussion prevention.
Methods

PubMed and Scopus databases were searched. All levels of evidence (I-IV) pertaining to concussions in men’s and women’s lacrosse players were analyzed and presented in this narrative review.

Epidemiology

The Center for Disease Control estimates that the annual incidence of concussion range from 1.6 to 3.8 million concussions per year.\(^5\) Data suggests a trend of increased annual concussion rates over the last decade, likely because of increased awareness, identification, and reporting.\(^29\)

Female athletes suffer concussions about twice as often as male participants in the same sport.\(^6\)

A study comparing concussion rates across 20 high school sports found that among boys’ sports, lacrosse had the third highest concussion rate following football and ice hockey. Among youth girls’ sports, lacrosse had the second highest concussion rate just below soccer.\(^7\) Warner et al. found that while concussion rates were slightly higher in youth boy’s compared to youth girls’ lacrosse (4.8 per 10,000 vs 4.0, RR = 1.2, 95% CI 1.0–1.4), concussions represented a slightly greater percentage of all injuries in youth girls’ lacrosse (23.1 vs. 25.6%) (Warner et al. 2018).

Mechanism of injury appears to differ between girls’/women’s lacrosse and boys’/men’s lacrosse. For men’s lacrosse, a full contact/collision sport, athlete-athlete contact was the most commonly reported mechanism of concussion accounting for 66.4% of all concussions, while stick or ball contact accounted for 23.5%.\(^8\) Caswell et al conducted a study investigating boy’s lacrosse which found that midfielders experience 46.7% of all player impacts, which is highest the of any position group in men’s lacrosse.\(^9\) This study also found that, head to head contact occurred 58.4% of the time.\(^9\) This group also determined that most contact was initiated when a player’s team was attacking and players who received contact were often not expecting contact .\(^31\) For women’s lacrosse, which is not considered a contact/collision sport and in which checking
is prohibited, stick or ball contact was the most common mechanism of concussion accounting for 72.7% of all concussions, while athlete-athlete contact accounted for 19.8%. A second study by Caswell investigating girls’ lacrosse, found that 48.3% of head impacts for girls lacrosse occurred from a direct strike to the head, most often from a stick. They additionally found that midfielders experienced the highest percentage of player to player impacts at 48.3%, and that more than half of the impacts, occurred in the attack area of the field.

Same Goal but Different Rules and Tools

The overall objective of both men’s and women’s lacrosse is the same with many similar physical components of play including acceleration, deceleration, dynamic directional changes and throwing and catching a high velocity projective. However, there are substantial rule and equipment differences between the sports.

As mentioned above, men’s lacrosse is a full contact/collision sport which permits body checking and stick checking. Whereas, in women’s lacrosse, body checking is prohibited, but stick checking is allowed. In women’s lacrosse there is also a “halo” rule that defines a sphere of 7 in. surrounding the player’s head in all directions that is not to be breached by an opponent’s stick. However, this rule is not always enforced. One study found that illegal stick and body contacts to the head in women’s lacrosse games rarely resulted in a penalty.

In men’s lacrosse, body contact and stick checking are both legal, and being body checked, cross checked, or stick checked are the most common activities that result in injuries. Men’s lacrosse had the largest percentage of concussions resulting from checking and being checked (39.1% and 43.8%, respectively) compared with the percentage of concussions from intentional contact mechanisms in both football and ice hockey. There is also a stark contrast in required equipment for men’s and women’s lacrosse. Men are required to wear hard shell helmets with full face masks, mouth guards, upper extremity protection, and padded gloves. Women, except for the goalkeeper, are only required to wear mouth guards and protective eyewear and are explicitly prohibited from wearing the hard shell,
full face masked helmet mandated in men’s lacrosse.\textsuperscript{16,17} The only style of helmet women’s lacrosse players are permitted to wear, are those that meet the F3137 standard in which the headgear is flexible enough to prevent injury to other players not wearing headgear if collision occurs, yet covers the entire head. This style of headwear includes integrated eyewear that all player’s are required to wear.\textsuperscript{17} In women’s lacrosse, eye protection has been mandatory since 2004 to reduce the number of eye injuries. A study performed by Lincoln et al, found that protective eye equipment reduced the rate of eye injuries from 0.10 injuries per 1000 athlete exposures to 0.016 injuries per 1000 athlete exposures, but had no effect on the number of concussions.\textsuperscript{18}

Women’s lacrosse rules prohibit body checking and are thought to provide protection against head injury. As a result, the women are required to only wear mouth guards, protective eyewear and are explicitly prohibited from wearing the hard shell, full face masked helmet mandated in men’s lacrosse.\textsuperscript{19}

Mechanism of Injury and Pathophysiology

A concussion is a traumatically induced transient disturbance in brain function. Concussions occur after external forces acting on the head and neck are transferred to the brain.\textsuperscript{6} These forces can occur following a direct impact from an object or surface or indirectly from rapid changes in position of the torso.\textsuperscript{20} Resultant acceleration, deceleration, or rotational forces cause acute cellular injury which in turn starts a metabolic cascade of events. This results in an energy mismatch between an increased need for glucose and decreased cerebral blood flow.\textsuperscript{21,22} The exact pathophysiology is not completely understood, nor is how this translates into development of symptoms.
Clinical Presentation

Symptoms of concussion are nonspecific, and their recognition should be a team effort between the athletic training staff, physical therapist, coaches, parents, athlete, and the sports medicine physician. Many times, athletes have non-specific complaints which may overlap with other medical conditions. Additionally, symptom onset may be delayed or unrecognized by the athlete, coaches, or parents. Making a concussion diagnosis relies on reporting by the athlete and is limited by a lack of validated, objective diagnostic tests. Clinical manifestations of a sports-related concussion can present as one or a combination of the following symptoms categories, vestibular, ocular, headache, cognitive, mood, and fatigue.23

Diagnosis

If an athlete experiences an injury during a game or practice, the athlete should be immediately withdrawn from play. Once on the sideline, a concussion screening tool such as the SCAT5 can be used to assess for and establish baseline signs and symptoms of concussion. If the athlete’s concussion screen is abnormal and/or an athlete is symptomatic, they should not return to the game or practice.

In office, or off-field concussion evaluation should begin with a comprehensive history regarding the mechanism, location of impact, presence or absence of loss of consciousness, as well as anterograde or retrograde amnesia.21 The examining provider should also inquire about recent medication use, typical sleep patterns, and history of prior concussions.24 In addition to the history, a self-reported symptom score, such as the Sport Concussion Assessment Tool or Post Concussion Scale, should be obtained at initial presentation and during each follow up visit to monitor recovery.25

Physical examination of a concussed patient should start with the collection of orthostatic vitals to screen for autonomic dysfunction and postural tachycardia.26 Following this, the head and neck should be inspected for areas of pain, ecchymosis, otorrhea and rhinorrhea. The cervical spine and upper thoracic spine should be palpated to identify muscle spasms which may contribute to the patient’s symptoms. Cervical spine range of motion should also be assessed.
The patient’s mental status, myotomes, dermatomes, and cranial nerves should be tested to identify any focal deficits. The patient's balance and vestibular systems can be assessed by validated tools like the Balance Error Scoring System or Vestibular Ocular Motor Screening.27,28

Treatment

For each athlete, concussion management should be customized to their unique symptom presentation. Many times, treatment may require a multidisciplinary approach for optimal recovery. Symptoms of concussion may present as changes in vestibular function, ocular changes, headache, cognitive difficulties, mood disturbances, and fatigue. In all cases of concussion, sleep optimization and stress management should be recommended. Typically, management starts with a 24-48 hour period of rest which is then followed by a symptom-limited reintroduction of activities.28

Symptoms like dizziness, balance difficulties, and nausea/vomiting following a concussion may suggest that the vestibular system is involved. Clinically this can be assessed by performing Vestibular Ocular Motor Screening.27 If vestibular changes are appreciated, referral to a trained vestibular physical therapist may be helpful for vestibular habitation and balance retraining.26

Light sensitivity, blurry vision, and difficulty reading and focusing are common ocular symptoms associated with concussion. If this is identified, visual modifications like decreased screen time, increased font size, and use of sunglasses can be recommended.21 If a patient reports vision loss or painful vision they should be referred to an ophthalmologist.

Headaches, the most common symptom, can be one of the most difficult symptoms to treat as there are often multifactorial.21 Headaches can be treated with a short course of nonsteroidal anti-inflammatory drugs and may also be improved by focusing on good sleep hygiene and stress mitigation. Physical therapy specifically focused on cervical treatment modalities may also be helpful in headache management.21
Fatigue and decreased activity tolerance is a common presenting symptom of a concussion. Early sub-symptomatic activity has been shown to decrease recovery time and symptom severity. Early supervised cardiovascular exercise that does not provoke symptoms such as treadmill walking, or stationary cycling can be performed four days post-concussion.

In many cases physical therapists and/or vestibular or ocular rehabilitation specialists are utilized to help address balance, vestibular or ocular deficits, improve cervical spine strengthening, and help facilitate a graded return to exertional training.

Cognitive and academic performance changes can present as difficulty with concentration, difficulty with recall memory, and decreased performance in academic activities. Cognitive rest and return to learn protocols can be used to reduce these symptoms. Mood disturbances in athletes who experienced a concussion are more common in athletes who have underlying anxiety and depression. A multidisciplinary approach to managing mood changes should be incorporated.

**Return to Learn and Return to Play Progression**

The return to learn and play progression starts after the first 24–48-hour rest period. The progression is advanced per the athlete’s symptoms. This is summarized in Table 1. An athlete must be asymptomatic with a full work/school/cognitive load before they can return fully to sport. Most concussions will resolve in a two-to-four-week period.

**Recent Changes and Future Directions**

Both men’s and women’s lacrosse have experienced recent changes to help protect athletes and to attempt to reduce the rate of concussions. The NCAA added a rule in 2011 in men’s lacrosse which prohibits players from targeting the head and neck and asked the referees to be more stringent on penalizing head and neck contact in attempt to emphasize the new rule change. In women’s lacrosse, there has been a continual effort to improve player safety and protect players from stick-on-body contact, but no major rule adjustments have occurred.
In attempt to develop means to protect men’s lacrosse athletes, the National Federation of State High School Associations previously implemented two lacrosse rule modifications to rule 5.4 and 5.3.5. Rule 5.4 stated that any intentional hits to the head would be deemed a higher foul, changing the previous penalty of 2 minutes to full-time–serving non-releasable fouls. The purpose of this rule was to minimize intentional contact to the head and neck of players. Rule 5.3.4 stated that a body check targeting a player in a defenseless position was illegal. The purpose of this rule was to reduce the use of body checking. Rule 5.4 was introduced during the 2012–2013 academic year to heighten the penalty for a head or neck hit to the head, face, or neck (HFN) and Rule 5.3.5 in the 2013–2014 academic year to minimize body checking.\(^{14}\) A study conducted by Comstock et al found that following both rule modifications concussion rates due to body checks, as well as overall injury risk from body checks, decreased. Concussion rates due to delivering body checks (IRR = 0.51, 95% CI = 0.29, 0.91) and overall injury risk due to being body checked (IRR = 0.72, 95% CI = 0.53, 0.97) also decreased.\(^{19}\)

In women’s lacrosse, instead of rule changes, more time has been spent debating changes to equipment to reduce risk of concussion. In 2015, the American Society for Testing and Materials (ASTM) released performance standard F3137–15, Standard Specification for Headgear Used in Women’s Lacrosse (excluding Goalkeepers).\(^{19}\) Following this, US Lacrosse released a statement on the new optional women’s lacrosse headgear which declared any headgear used after January 1, 2017, must meet the new ASTM standard, in an attempt to reduce head ball-to-head and stick-to-head impact forces in women’s lacrosse.\(^{19}\)

Studies have been performed to determine if mandated hard shell helmets in women’s lacrosse can cause a reduction in concussion. Baron et al conducted a prospective study which revealed that mandated use of F3137 headgear for women’s lacrosse players during the 2017 and 2018 seasons reduced concussion and injuries to the head and neck.\(^{31}\) In another study by Comstock et al, it was found that 44.7% of concussions in girls’ lacrosse could be prevented by wearing the same helmet as boy’s lacrosse.\(^{19}\) Caswell and colleagues found that ASTM International performance standard F3137 headgear is associated with a reduction in the magnitude of overall impacts but not a significant change in the rate of impacts, how they occur, or how penalties were administered for impacts sustained during competition.\(^{18}\)
There is an ongoing debate surrounding the use of hard-shell helmets in women’s lacrosse regarding the intended benefits and potential adverse consequences of women’s lacrosse headgear. Proponents of headgear mandates propose that required use will decrease the severity of impacts and decrease the risk of injury. Those in opposition cited the Peltzman and the Gladiator effect, which hypothesizes that with increased safety measures, at least some of their benefits will be offset by increased risky behavior. The state of Florida now mandates helmet use in girls lacrosse. Herman et al conducted a study to determine the effect of helmet use and concussion reduction in girls’ lacrosse players in the state of Florida and found that concussion rates among high school girls’ lacrosse players not wearing headgear was 59% higher than those wearing headgear.

The methods to reduce the number of concussions in both men’s and women’s lacrosse will continue to be a topic of debate in the lacrosse community. To improve how athletes are protected, research into helmet use and rule changes should be continued. Additionally, education and awareness training programs can be created to help parents’ players and teams better identify and manage concussions. Lastly, standardized education programs for coaches can be implemented to ensure safe techniques are taught to athletes.

Conclusion

Sport-related concussion is a complex brain injury which affects both men’s and women’s lacrosse players and can lead to significant time away from sport. The annual incidence of concussion ranges from 1.6 to 3.8 million concussions per year and both boys’ and girl’s high school lacrosse have high concussion rates, ranking 3rd and 2nd respectively among all high school sports. The style of game, rules and required equipment are different for men’s and women’s lacrosse even though both groups are at similar risk for injury. This difference in equipment and rules results in a unique difference in common mechanisms of injury for concussion in men and women lacrosse players. Men are at greater risk of concussion due to direct contact with another athlete, while women are at greatest risk for a concussion as a result of direct ball or stick contact with the athlete’s head.
Prompt evaluation and diagnosis of a concussion is essential for maintaining athlete safety. Diagnosing a concussion can be complicated as it relies on self-reported symptoms and there are no readily available objective diagnostic tests. Sideline evaluation may consist of SCAT5 examination, however this is still limited by athlete reporting.

Management of concussion typically consists of a rest period followed by a progressively graded return to activity for both for school and sport-related activities.

As more of a spotlight is put on the dangers of repeat concussions, further research regarding how to reduce concussions in lacrosse athletes is needed for this fast-growing sport. Areas of potential research could be focused on mandated hard-shell helmets in women’s lacrosse, changes to contact rules, and national education programs for coaches to raise awareness about concussions.

Table 1 Return to Learn and Return to Play Timelines

<table>
<thead>
<tr>
<th>Stage</th>
<th>Activity</th>
<th>Goal</th>
<th>Stage</th>
<th>Activity</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptom-limited activities</td>
<td>Introduce typical activities (reading, texting, screen time) Start with 5- to 15-min increments and increase as tolerated</td>
<td>Gradual return to typical activities without increasing symptoms</td>
<td>Symptom-limited activities</td>
<td>Gradual reintroduction of daily activities that do not provoke symptoms</td>
<td>Gradual reintroduction of activities</td>
</tr>
<tr>
<td>School activities</td>
<td>Homework, reading, other</td>
<td>Increase tolerance to cognitive</td>
<td>Light aerobic exercise</td>
<td>Talking or stationary cycling at slow to medium pace that does not increase heart rate</td>
<td></td>
</tr>
<tr>
<td>Categories outside of the classroom work</td>
<td>provoke symptoms for up to 30 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>----------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial school day or with increased breaks during the day</td>
<td>Increase academic activities</td>
<td>Continue stage 2 activities with goal of performing without symptoms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gradually progress school activities until a full day can be tolerated</td>
<td>Return to full academic activities and catch up on missed work</td>
<td>Once full school day is tolerated and symptoms have resolved, proceed to return to play stage 3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Noncontact training drills</th>
<th>Return to play/sport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate aerobic exercise</td>
<td>Juggling 15-20 min, agility drills, bodyweight training (eg, squats, lunges)</td>
<td>Normal game play</td>
</tr>
<tr>
<td>Add movement and increase activity tolerance</td>
<td>Exercise, coordination, and increased thinking</td>
<td></td>
</tr>
</tbody>
</table>

*Return to learn and return to play progression may start at similar timeframes, but contact activity should never start before full progression of return to learn.*

Conflict of Interest Statement
There are no conflicts of interest to report for this narrative review on concussions in lacrosse.

References


19. Comstock RD, Arakkal AT, Pierpoint LA, Fields SK. Are high school girls’ lacrosse players at increased risk of concussion because they are not allowed to wear the same helmet boys’ lacrosse players are required to wear? *Injury Epidemiology*. 2020;7(1). doi:10.1186/s40621-020-00242-5


29. McCrea M, Broglio S, McAllister T, et al. Return to play and risk of repeat concussion in collegiate football players: Comparative Analysis from the NCAA Concussion Study


39. Bennett BD, About the Author Doug BennettScience Writer, Writer S. Headgear significantly reduces girls' lacrosse concussions, Landmark UF Health Study finds. UF