



Original Contribution

A comparison of head injuries in male and female lacrosse participants seen in US emergency departments from 2005 to 2016[☆]



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ABSTRACT

Introduction: In the United States there has been a large increase in participation in lacrosse for both males and females. The purpose of this study was to analyze the number of head injuries, injury rates (calculated using the reported number of participants) and types of head injuries that are seen in emergency departments in the United States.

Methods: We compared injuries between male and female lacrosse participants. This was a retrospective study using a publicly available database produced by the US Consumer Product Safety Commission and information about lacrosse participation from US Lacrosse.

Results: A linear regression was performed and showed a positive correlation between number of head injuries to males and time from 2002 to 2010 ($R^2 = 0.823$; $p = 0.001$). While the number of injuries to the head in female lacrosse participants was not significant. There was a negative correlation between the number of head injuries to males from 2010 to 2016 ($R^2 = 0.800$; $p = 0.007$), but again, there was no significance for female injury count ($R^2 = 0.417$; $p = 0.117$). Other significant differences between head injuries in males and females included the mechanism of injury and the type of injury recorded.

Conclusion: The most recent data from 2010 to 2016, suggest that both males and females have had a decrease in injury rate. However the total number of female head injuries is not significantly decreasing and as the sport continues to grow there will likely be more total head injuries and visits to the emergency department.

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1. Introduction

Recently, sports have been under much scrutiny due to the frequency of head injuries and their lasting effects. According to the Centers for Disease Control and Prevention (CDC), a concussion is defined as a blow to the head that causes the head and brain to move back and forth rapidly. Individuals who get concussions can display many different symptoms including amnesia, loss of consciousness, confusion, nausea and vomiting, headache, blurred vision, difficulty concentrating, balance issues and many other non-specific symptoms [1]. These concussions also may lead to the accumulation of neurodegenerative proteins that permanently alter the composition of the brain and lead chronic traumatic encephalopathy [2].

Much of the research emphasis has been on collegiate athletes and boys' football; however, head injuries occur in many other sports, including boys' and girls' lacrosse. Lacrosse is a sport played between two teams using a small, dense rubber ball and a long-handled stick. The rules for lacrosse differ for male and female athletes. For male participants, the sport is considered full contact where body and stick checks are allowed. Male athletes are required to wear helmets with facemasks, mouth guards, shoulder pads, arm pads and gloves. Lacrosse is considered a "non-contact" sport for female participants and female athletes are only required to wear mouth guards and eye protection. The effects of requiring eye protection for female lacrosse athletes have been previously examined [3,4]. One study collected injury data from 25 schools in Virginia and compared the rates and types of injuries that occurred before and after the implementation of eye protection [3]. They found that there was a statistically significant decrease in eye injuries following the implementation of protective eye equipment. Another study conducted by Webster et al. showed a significant decrease in facial injuries especially to the ocular and forehead region with athletes wearing eye protection [4].

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Despite women's lacrosse being labeled non-contact, incidental contact does occur. A 2000 study conducted by Diamond et al. examined head injuries in men's and women's lacrosse over a ten year time period and found that women were at risk of serious injury to the head and face region even though they are not required to wear a helmet or face protection [5]. The head and face region was the most common area injured (20.4%). Injuries to the head and face were significantly more prevalent among females than males in their study [5]. Closed head injuries represented 5.6% of all lacrosse-related injuries and were slightly more prevalent among females according to the study [5]. A recent national study examined concussions to high school athletes in the US [6]. In this study, the authors collected data on sport-related concussion (SRC) for 20 sports over three years, including the number of SRCs and athletic exposures (AE) [6]. During games, girls' lacrosse had the second highest concussion rate for all girls' sports (8.6 SRC per 10,000 AEs). However, when competition and practice were combined, girls' lacrosse had the highest SRC rate. These injuries were most often caused by contact between the player and equipment (player/stick, player/ball). However, player-to-player contact was the cause of 28% of the SRCs, despite the non-contact rules. They also found that there was no statistical difference in concussion rates between boys and girls [6]. A 2014 study by Vincent et al. found that women experienced fewer concussions but more facial fractures when compared to men. The study also found that injuries to women involving foot/ankle, head, face, wrist and hand more often require surgery [7]. A 2007 study by Lincoln et al. analyzed over one million athletic exposures in men's and women's lacrosse at the high school and college level and found that the incidence of injury to the head, face and eyes were significantly higher in the women's game than in the men's game [8].

In response to these injuries, the Florida High School Athletic Association began the process of implementing a new requirement that female participants wear helmets in high school competition. However, US Lacrosse (the leading governing body of the sport in the United States) strongly disagreed with this new mandate. They believed that the state of Florida was requiring women to wear helmets without any evidence to justify the need. Despite their position, the mandate of hard headgear will go into be implemented in the 2018 season and is the first state in the country to do so [9].

In the United States there has been a large increase in participation in lacrosse for both males and females. According to US Lacrosse, it is the fastest growing sport in the United States. US Lacrosse estimates that there were 253,931 people playing organized lacrosse at the end of 2001. Since then the number has grown 325% to 826,033 participants in 2016 [10]. As the number of participants increases, the number of injuries may also increase. The purpose of this study was to analyze the number of head injuries, injury rates (calculated using the reported number of participants) and types of head injuries that are seen in emergency departments in the United States. We compared injuries between male and female lacrosse participants.

2. Methods

This was a retrospective study using a publicly available database produced by the US Consumer Product Safety Commission. The database, National Electronic Injury Surveillance System (NEISS) is a national probability sample of hospitals in the United States [11]. Each NEISS hospital Emergency Department reports patient injury information involving an injury associated with specific products. From this data, the total number of product-related injuries nationwide can be estimated. The NEISS database uses information obtained from approximately 100 hospitals across the United States. Inclusion criteria are: hospitals with 6+ beds and an emergency department while psychiatric and penal institutions are excluded. The hospitals are broken down further into five strata (four strata based on size and one consisting of children's hospital). Data is then collected from these hospitals and given a specific weight based on strata. Adjustments are made to these weights due to non-response and hospital mergers [11].

To quantify the number of injuries, we queried the NEISS database from January 2002 to December 2016 for lacrosse related injuries (product code 1215) and looked at all diagnoses that involved the head region. The comments section of each case was examined and cases were excluded if the comments indicated that the patient was not playing lacrosse at the time of injury. Some examples of exclusions were fans getting hit with lacrosse balls not participating in the game and individuals getting injured with lacrosse equipment while not playing or practicing.

We used the US Lacrosse Participation Census data from 2006 to 2016 to gauge the number of active participants in the US. US Lacrosse was founded in 1998 and is consider the national governing body of men's and women's lacrosse in the US. US Lacrosse publishes a participation survey yearly to monitor participation in the sport throughout the country. The survey only includes participation on organized lacrosse teams collected from regional chapters. Each chapter reports participation at the youth, high school, collegiate and post-collegiate levels. According to US Lacrosse the data is also obtained from US Lacrosse membership records, the National Collegiate Athletic Association and the National Federation of State High School [10].

Combining both the NEISS and US Lacrosse data we were able to compile injury rates. Data reported include the number of head injuries to males and females from 2002 to 2016 and the injury rate for males and females from 2006 to 2016 per 10,000 participants. We also examined the mechanism of injury by examining the comments section. Injury mechanisms were categorized as ground-to-head, stick-to-head, ball-to-head, head-to-head, player collision/body-to-head and other. Examples of "other" included collision with the goal post, cleats to the head and player's own gear cutting him/herself.

A simple linear regression was calculated to predict number of injuries and injury rate based on year for males and females. This analysis was completed for two data ranges – up to 2010 and from 2010 to

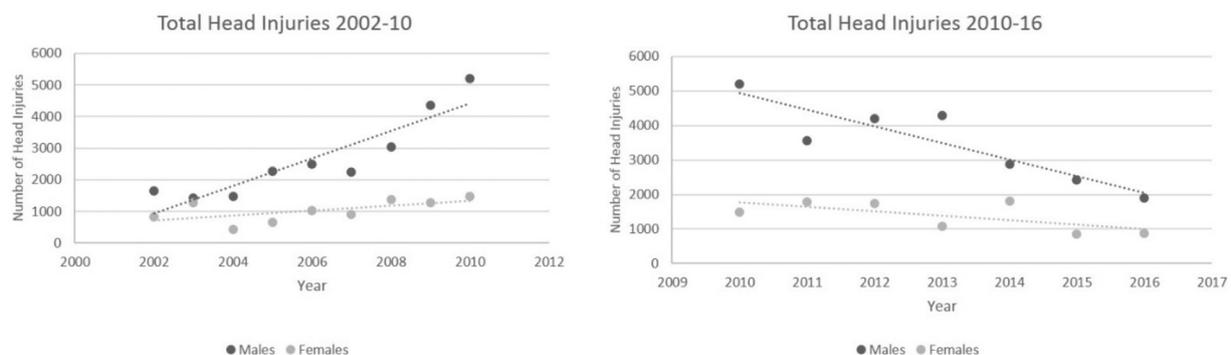


Fig. 1. Total number of lacrosse related head injuries from 2002 to 2010 and 2010 to 2016. For males from 2002 to 2010, $R^2 = 0.823$, $p = 0.001$; for females over the same period, $R^2 = 0.375$, $p = 0.08$. For males from 2010 to 2016, $R^2 = 0.800$, $p = 0.007$; for females over the same period, $R^2 = 0.417$, $p = 0.117$. Results considered significant if $p < 0.05$.

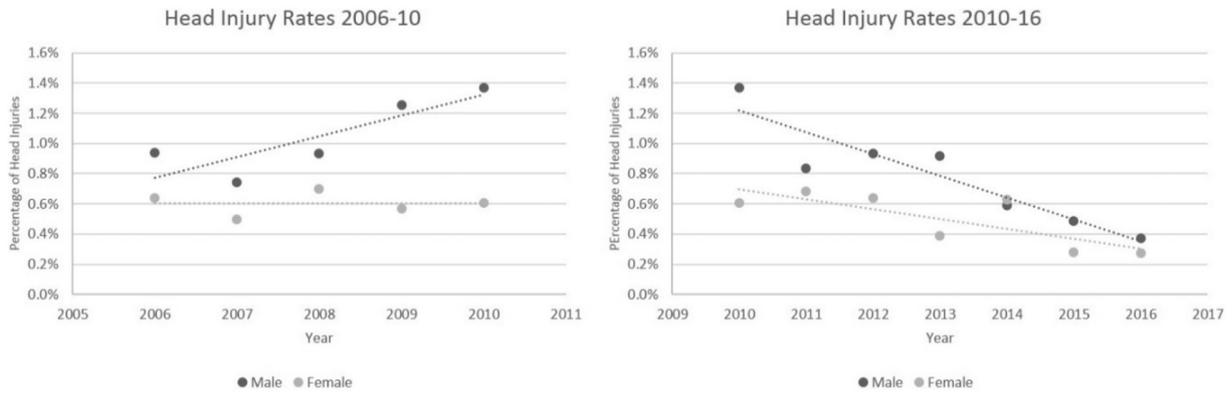


Fig. 2. Lacrosse related head injury rates per 10,000 participants from 2002 to 2010 and 2010 to 2016. For males from 2006 to 2010, $R^2 = 0.712$, $p = 0.072$; for females over the same period, $R^2 = 0.00$, $p = 0.991$. For males from 2010 to 2016, $R^2 = 0.854$, $p = 0.003$; for females over the same period $R^2 = 0.606$, $p = 0.039$. Results considered significant if $p < 0.05$.

2016. Data were also stratified by diagnosis and descriptive information is reported for concussion, laceration and closed head injury numbers. A chi-square analysis was conducted to examine the frequency of these injuries for males and females. Additional descriptive information reported includes disposition and cause of injury (stick, ground, collision, etc.). All statistics were computed using SPSS 24.0. Data were considered significant if $p < 0.05$.

3. Results

Between 2006 and 2016 there were a total of 7,178,136 lacrosse participants of which 4,448,512 were male and 2,729,636 female. From 2006 to 2016 there were an estimated total of 50,743 lacrosse related head injuries reported to US emergency departments. Head related injuries consisted of concussion, closed head injury, and facial/head lacerations. Of the 50,743 head injuries, 36,534 were to males and 14,208 were to females. The age range of the injured patients was 6–55 years.

There was a significant positive correlation between the number of head injuries to males and time from 2002 to 2010 ($R^2 = 0.823$; $p = 0.001$). While the number of injuries to the head in female lacrosse participants fluctuated from year to year and was not significant during the same time period ($R^2 = 0.375$; $p = 0.08$) (Fig. 1). For injury rates per 10,000 participants during the same time period, there was no significance between year and injury rate for males ($R^2 = 0.712$; $p = 0.072$) or females ($R^2 = 0.00$; $p = 0.991$) (Fig. 2). There was a significant negative correlation ($R^2 = 0.800$; $p = 0.007$) for the number of male injuries from 2010 to 2016, but again, there was no significance for female injury count ($R^2 = 0.417$; $p = 0.117$) (Fig. 1). However, a significant negative correlation was found for both males ($R^2 = 0.854$; $p = 0.003$) and females ($R^2 = 0.606$; $p = 0.039$) when examining injury rate during that same time period (Fig. 2).

A chi-square test of independence was calculated for all head injuries comparing the frequency of concussion, closed head injury, concussion plus closed head injury and lacerations in male and female lacrosse participants from 2006 to 2016. A significant interaction was found in all four cases ($p < 0.004$). Males were more likely to have a concussion or laceration than females. Females were more likely to have a closed head injury than males (Table 1). Females were more likely to sustain head injury with ball to head (28.9%) and stick to head (28.2%) mechanisms. In contrast to males, ball to head (16.3%) and stick to head (21.7%) mechanisms were less (Fig. 3). Compared to females, males were more likely to sustain head injuries via head to head contact (10.1%) and body to head contact (12.4%), while female athletes sustained injuries due to these mechanisms 6.3% and 5.1%, respectively (Fig. 3).

4. Discussion

In general, the number of head injuries and injury rates increased from 2002 to 2010 and then decreased from 2010 to 2016. Although there were no changes in equipment for either sex in these time periods, there were significant rule changes in the high school game. The NFHS (National Federation of State High School Associations) made it illegal to body check a defenseless player and has continued to emphasize the enforcement of penalties for contact to the head and neck [12]. Crisco et al. recommended that strict enforcement of rules and implementation of rules to protect players’ heads would likely decrease head injuries. The authors noted that the National Football League, National Hockey League and NCAA Football have implemented significant fines and suspensions on players for direct hits to the head which ultimately decreased head injuries in the game without significantly altering the competitive nature of the game [13].

When comparing rates of head injuries to other sports, many of our results were similar. We found that approximately 72% of injuries occurred in males and 28% in women. A retrospective NEISS study from 2007 to 2011 looked at all causes of non-fatal head traumas [14]. The authors examined athletics, motor vehicle accidents, work related injuries and other incidents of head injuries. Their results for sports related injuries mirrored ours. They showed that 69% of their sport-related head injuries occurred in males compared to 31% in women [14]. The highest incidence of head injuries for male athletes occurred in football and basketball and for female athletes, basketball and soccer [14].

Previous studies have shown that the implementation of eye protection has decreased the number of ocular injuries to female participants. Our data showed that the mechanism of head injury to female lacrosse athletes seen in the emergency department is most commonly caused by ball to head and stick to head which mirrors previous research [15,16]. Caswell et al. examined the mechanism of head injuries in junior varsity and varsity high school girls [15]. They found that stick to head contact was the most frequent cause of injury followed by body to head contact [15]. They also showed that the majority of injuries

Table 1

Chi square test of independence comparing the frequency of concussions, closed head injuries, concussions plus closed head injuries, and lacerations from 2006 to 2016 for participants who sustained head injuries. Frequency of concussion and laceration were higher with men; frequency of CHI and concussion + CHI were higher with women. $p < 0.004$ for all cases.

	Male	Female
Concussion	26.86%	24.22%
Closed head injury	27.91%	31.89%
Concussion + CHI	54.78%	56.11%
Laceration	24.61%	14.10%

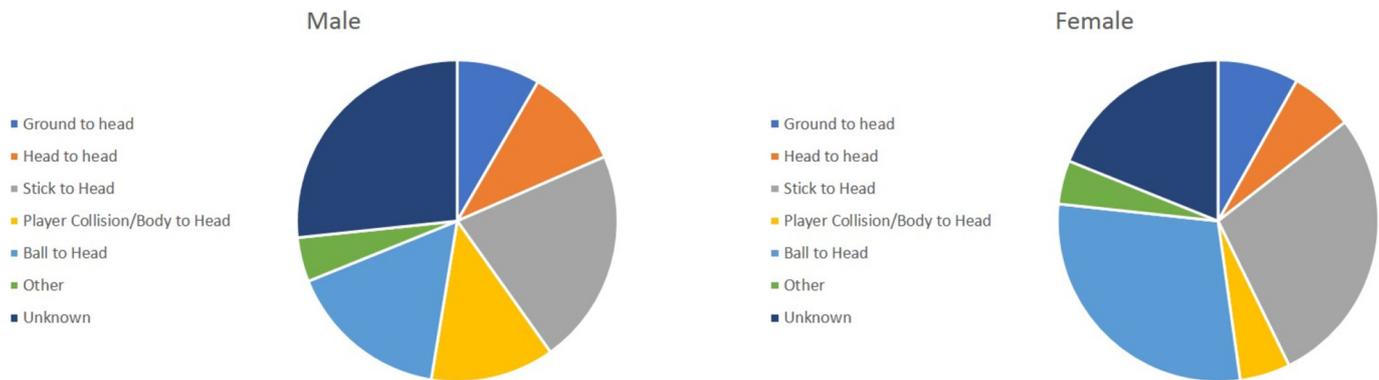


Fig. 3. Mechanism of head injury for males and females.

occurred in close proximity to the goal [15]. A similar study, by Lincoln et al. analyzed the mechanisms of injury in the high school men's game [17]. They found that the most common mechanism of injury was player to player contact on unanticipated contact or a defenseless player which occurred when athletes were attempting to recover loose balls [17]. If the addition of eye protection decreased the number of eye injuries, this raises the question that if female lacrosse players were to wear head protection, would the rates of these injuries decrease.

According to a laboratory study conducted by Clark et al., there were three incidents in women's lacrosse (when played within the rules of the game) that could produce enough linear and angular acceleration to cause concussions. The three mechanisms were falls, high velocity ball impacts and high velocity stick impacts [16]. We showed that women are at a significantly higher risk than their male counterparts of receiving head injuries due to the ball hitting the head (28.9%) and stick impacts to the head (28.2%). A study by Crisco et al. analyzed commercially available protective helmets to determine whether they would provide any reduction in linear and angular head acceleration. They found that 3 out of 4 commercially available men's helmets significantly reduced the peak linear and angular acceleration and could lead to a reduction in concussions. However, soft headgear is currently the only head protection available to female lacrosse athletes [16]. A laboratory study by Rodowicz et al. showed that soft headgear did not offer the same reduction in head acceleration as helmets for male athletes. While soft headgear provided protection against low velocity ball impacts, it did not provide protection against high velocity ball impacts where concussions typically occur [18]. Indicating that mandated soft headgear use may function differently than mandated eye protection use.

A concerning cohort study by Sandel et al. looked at 112 male and 112 female athletes ages 13–17 that were diagnosed with concussions. It showed that the after effects of an acute concussion on female athletes were significantly worse than males when comparing neurocognitive test results. Female athletes also had a greater number of symptoms when compared to males [19]. This indicates that concussion prevention in this population is an important goal.

Oponents to helmet use in girls' lacrosse state that they will alter the mindset of players and increase injury rates [20]. They believe that players may believe they are protected more and therefore play more aggressively [20], which is referred to as the "gladiator effect" [21]. In our literature search we found no peer-reviewed studies that state that this "gladiator effect" exists and that personal protective equipment would lead to more aggressive play. However, it is possible that in some circumstances, this could be the case.

There were several limitations to our study. First, this study only examined head injuries due to lacrosse seen in emergency departments. It is likely that additional head injuries occurred in this time period that were seen by an athletic trainer, family physician or pediatrician. Additionally, some athletes could have been injured multiple times in one year. Another limitation was our use of the US Lacrosse data as our

denominator. Many research studies that report injury rates, report their results as number of injuries per 10,000 athletic exposures (defined as games and practices played). However, these studies often examined several specific high schools or universities [6]. We used the number of people reportedly playing organized lacrosse. By using this number as our denominator, we were able to examine all ages of participants in the United States.

5. Conclusion

Our study showed that females were likely to sustain a closed head injury that were caused by ball to head or stick to head contact. Males in contrast were more likely to sustain concussions and lacerations by head to head and body to head contact. The most recent data from 2010 to 2016, suggest that both males and females have had a decrease in injury rate. However the total number of female head injuries is not significantly decreasing and as the sport continues to grow there will likely be more total head injuries and visits to the emergency department. Future studies should examine whether or not the addition of protective headgear could decrease the number of head injuries in female athletes. Previous research has shown that when personal protective equipment such as goggles were mandated, the number of ocular injuries decreased. While male and female lacrosse athletes play the sport with different rule sets, there is still an opportunity to further decrease head injury in women's lacrosse. It is not uncommon to see some of these head injured players for initial evaluation and multiple subsequent follow up visits in the ED for management of post-concussive symptoms and/or suture removal. Reducing these visits to already overburdened US emergency departments are imperative.

Conflict of interest

The authors have no conflicts of interest to declare.

References

- [1] Viano DC, King AI, Melvin JW, Weber K. Injury biomechanics research: an essential element in the prevention of trauma. *J Biomech* 1989;22:403–17.
- [2] Martinez-Perez R, Paredes I, Munarriz PM, Paredes B, Alen JF. Chronic traumatic encephalopathy: the unknown disease. *Neurologia* 2017;32:185–91.
- [3] Lincoln AE, Caswell SV, Almquist JL, Dunn RE, Clough MV, Dick RW, et al. Effectiveness of the women's lacrosse protective eyewear mandate in the reduction of eye injuries. *Am J Sports Med* 2012;40:611–4.
- [4] Webster DA, Bayliss GV, Spadaro JA. Head and face injuries in scholastic women's lacrosse with and without eyewear. *Med Sci Sports Exerc* 1999;31:938–41.
- [5] Diamond PT, Gale SD. Head injuries in men's and women's lacrosse: a 10 year analysis of the NEISS database. National Electronic Injury Surveillance System. *Brain Inj* 2001;15:537–44.
- [6] Marar M, McIlvain NM, Fields SK, Comstock RD. Epidemiology of concussions among United States high school athletes in 20 sports. *Am J Sports Med* 2012;40:747–55.
- [7] Vincent HK, Zdziarski LA, Vincent KR. Review of lacrosse-related musculoskeletal injuries in high school and collegiate players. *Sports Health* 2015;7:448–51.

- [8] Lincoln AE, Hinton RY, Almquist JL, Lager SL, Dick RW. Head, face, and eye injuries in scholastic and collegiate lacrosse: a 4-year prospective study. *Am J Sports Med* 2007; 35:207–15.
- [9] Dusenbury W. FHSAA helmet rule reheats girls lacrosse safety debate. *SunSentinel*; 2017.
- [10] USLacrosse. 2016 US Lacrosse participation survey; 2016.
- [11] Schroeder T, Ault K. In: Commission USCPS, editor. The NEISS sample (design and implementation) 1997 to present; 2001.
- [12] McEwen P. Special report: have recent rule changes impacted lacrosse's concussion rate? *Inside Lacrosse*; 2015.
- [13] Crisco JJ, Greenwald RM. Let's get the head further out of the game: a proposal for reducing brain injuries in helmeted contact sports. *Curr Sports Med Rep* 2011;10: 7–9.
- [14] Gaw CE, Zonfrillo MR. Emergency department visits for head trauma in the United States. *BMC Emerg Med* 2016;16:5.
- [15] Caswell SV, Lincoln AE, Almquist JL, Dunn RE, Hinton RY. Video incident analysis of head injuries in high school girls' lacrosse. *Am J Sports Med* 2012;40:756–62.
- [16] Crisco JJ, Costa L, Rich R, Schwartz JB, Wilcox B. Surrogate headform accelerations associated with stick checks in girls' lacrosse. *J Appl Biomech* 2015;31:122–7.
- [17] Lincoln AE, Caswell SV, Almquist JL, Dunn RE, Hinton RY. Video incident analysis of concussions in boys' high school lacrosse. *Am J Sports Med* 2013;41:756–61.
- [18] Rodowicz KA, Olberding JE, Rau AC. Head injury potential and the effectiveness of headgear in women's lacrosse. *Ann Biomed Eng* 2015;43:949–57.
- [19] Sandel NK, Schatz P, Goldberg KB, Lazar M. Sex-based differences in cognitive deficits and symptom reporting among acutely concussed adolescent lacrosse and soccer players. *Am J Sports Med* 2017;45:937–44.
- [20] Schwarz A. A case against helmets in lacrosse. *New York Times*; 2011.
- [21] Miele L. Psychology of the “gladiator effect” and women's lacrosse psychology and injury prevention. *Psychology Today*; 2017.