Sports-Specific Issues in Men's and Women's Lacrosse

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Abstract

Boys'/men's and girls'/women's lacrosse are the fastest-growing sports at the high school and college levels and are team sports with unique medical issues and injuries. The rules of the game are very different for the women's game compared with those for the men's game. Youth rules include modifications that take into account physical and cognitive maturational differences. Given the unique rules of the game between genders, the equipment requirements also are different. The most common injuries in lacrosse for both genders across all ages are lower extremity injuries and, primarily, ankle and knee sprains, followed by head injuries. Concussion has received a lot of recent attention, and education, comprehensive management, and prevention efforts remain the most critical issues. A unique medical concern in lacrosse is commotio cordis, which requires immediate identification and management and underscores the importance of sideline preparedness. This article will review the sport-specific medical and musculoskeletal issues in lacrosse.

Introduction

Lacrosse is the fastest-growing sports in the United States, with every segment of the game showing growth and more than half of the players competing at the youth level (aged 15 years or below) (54). Over the last 5 years, there are 34.2% and 36.2% more high schools sponsoring boys' and girls' lacrosse and 33.5% and 38.2% more colleges sponsoring men's and women's National Collegiate Athletics Association (NCAA) lacrosse (54). There are increasing opportunities to participate in professional lacrosse for men and for postcollegiate club and international play for both men and women.

Lacrosse is a unique team sport with physiological demands including endurance, speed, strength, agility, and sport-specific skills. It is a sport where players across a range of physical attributes can excel. The stick is an extension of the upper extremity in throwing the ball and creates additional demands related to carrying the ball, shooting, passing, and picking up ground balls. The history of the game dates back to its roots as a Native American form of stickball (54). There are basic differences in the sport of lacrosse for men and women, with significantly different rules and, thus, equipment requirements (54) (Table). There are also some differences in the youth game versus the adult game (54). For example, in the boys' game, checking is not allowed in youth play.

In the men's game, body contact is permissible and stick checking is a component of the game, both of which create the potential for additional injuries. In the girls'/women's game, no intentional contact to the head or body is allowed, and penalties for slashing, dangerous propelling, or follow-through and checks to the head result in mandatory cards. In addition, there is a 7-inch "bubble" around the head that cannot be invaded by an opponent, the "pocket" of the stick must be substantially shallower than the men's, making it easier for the ball to be dislodged, and it is illegal to cradle the ball close to the face such that it is within the "bubble." In the women's game, protective eyewear has been mandated since 2004 and mouth guards are the only required personal equipment for field players. Hard helmets are illegal in the women's game for field players but are required equipment for goalies, who also are required to wear chest and thigh protectors. Soft headgear and soft fitted gloves are permitted for women's field players, although no standard exists for either at the present time. The men's game, due to the contact nature of the sport, requires protective equipment including a mouth guard, a hard helmet that meets certification standards, gloves, and elbow and shoulder pads.

Equipment and Biomechanical Issues

All sport helmet standards, including the National Operating Committee on Standards for Athletic Equipment (NOCSAE) standard for men's lacrosse helmets, are formulated

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Table.

Equipment and rule comparison for men's and women's lacrosse (reprinted with permission from U.S. Lacrosse (51); updated July 14, 2014).

	Women's Rules	Men's Rules	Rationale
Equipment	No pocket in stick is allowed. Shallow pocket rule allows for easier ball dislodgement. Mesh pockets are not allowed.	Deeper pocket rule requires more aggressive checking.	Pockets impact the ease at which the ball will dislodge from the stick (when shooting or passing or after being checked) and the speed the ball travels.
	The length of stick is defined and is the same for all field players.	The length of the stick is different for positions.	The stick/shaft is not used the same way in men's/women's lacrosse. Cross-checking is not allowed in women's lacrosse, and the stick cannot be used to hold, hit, or detain other players in women's lacrosse. In men's lacrosse, stick-on-body play is permitted as long as the player is in the act of passing, shooting, or attempting to scoop the ball.
	Protective eyewear and mouth guards are required.	Mouth guards are required.	Eyewear is required in the women's game to prevent orbital eye injuries, where the helmet and face mask provide the same function in the men's game. Properly fitted mouth guards covering the top set of teeth are required to prevent serious dental injuries.
	Soft headgear is optional.	Men's lacrosse helmets certified to the NOCSAE standard are required.	While there is currently no performance specification for women's lacrosse soft headgear, soft headgear is allowed to prevent facial and head lacerations. Because contact to the head or body is illegal in the women's game, and catastrophic head injuries have not been an issue, hard helmets have not been required or deemed necessary. In women's lacrosse, a field player would not be permitted to wear a men's lacrosse helmet because the women's rules prohibit it based on the concerns that it would be deemed dangerous to other nonhelmeted players on the field due to the fact that a hard shell helmet has parts that protrude (face mask). A men's lacrosse helmet standard was developed to address the types of head injuries seen in full-contact men's lacrosse: skull fractures, contusions, and other catastrophic head injuries. The most common types of head injuries in women's lacrosse are caused by stick or ball to head impacts, rather than collision/contact, and catastrophic head injuries have not been documented. Given the emphasis of safety and limited contact in rules of the women's game, it is believed that allowing helmets would place athletes at greater risk of bodily injury. In men's lacrosse, body contact and collision are part of the game, and because of this, protective helmets and equipment are necessary.
	Soft fitted gloves are allowed.	Arm pads, shoulder pads, and heavy gloves are required.	
	Goalie: helmets certified to the NOCSAE standard, chest protectors, mouth guards, gloves, and shin pads are required.	Goalie: helmets certified to the NOCSAE standard, chest protectors, mouth guards, gloves, and shin pads are required.	
Contact	Aggressive stick checking and body contact are illegal.	Aggressive stick checking and body contact are legal.	
	Cross-checking is illegal.	Cross-checking is illegal.	
	Any contact with the head from a stick will result in a yellow or red card (time loss) penalty.	A player shall not initiate contact to an opponent's head or neck with a cross-check or with any part of his body. Any follow-through that makes contact with the head or neck is also a rule violation, resulting in a 2- or 3-min nonreleasable penalty.	
	Body checks and slashes are major fouls and will result in a yellow or red card (time loss) penalty.	High hits or any contact initiated by the head will result in an automatic 2- or 3-min nonreleasable penalty.	

specifically to mitigate the risk of skull fracture and subdural hematomas but do not address the risk of concussion. Since skull fractures and traumatic brain injuries are not a recorded concern in girls' or women's lacrosse, many feel that helmets are inappropriate and there is controversy regarding whether adding a helmet might cause unanticipated consequences (*e.g.*, false sense of protection or increase in injury by increasing surface area or weight).

The ball used in lacrosse also has been under scrutiny, and in January 2014, all three governing bodies for lacrosse in the United States, the NCAA, U.S. Lacrosse, and National High School Federation, decided to mandate the use of a ball meeting the NOCSAE standard (54). Having a standard ensures uniformity and, ideally, safety.

An important aspect of lacrosse is advancing the ball by carrying it using a circular motion of the stick or "cradling" it. Cradling stabilizes the ball within the stick pocket, increasing the force that an opposing player needs to dislodge the ball. In men's lacrosse, dislodgement of the opponents' ball is achieved by stick and body checks, while in women's lacrosse, it is limited to stick checks. The construction and design of the head of the lacrosse stick evolved from originally wooden to plastic in the 1970s, to modern designs of alloyed metals, and the evolution to a narrow or "bulb"-shaped head. With this design evolution, the modern head greatly increases the player's ability to stabilize the ball and subsequently require more forceful checks to dislodge the ball (35). Some early modern head designs worked so well that the ball would not be dislodged until extremely violent checks were laid. A scientific approach to qualify the relationship between head design and ball stability is surprisingly challenging, so sport-governing bodies have turned to restrict the design characteristics and shape of the heads. Rules regarding both head and stick designs are now in place and are specific to gender and the level of play.

The evolution of and the gender differences in stick design also are associated with increased shot speeds. While rigorous scientific evidence demonstrating increased shot speeds are associated with higher incidence and severity of injury does not exist, governing bodies often respond conservatively to changes in stick design that are associated with increased shot speed. Livingston (35) examined the effects of stick design on ball speed in a video study of a single player and 24 different lacrosse stick models. Livingston's (35) findings supported the general belief that stick design influences ball speed; shot speed was lowest for wooden sticks, increased for sticks with plastic heads, and increased even further with the more contemporary plastic head design. A recent study to determine whether the lacrosse stick performs as a passive extension of the player's hands during the shot or whether the stick contributes a "whipping action" that further increases the ball shot found that both men's and women's stick "whipped" the ball faster than predicted, but the increase with the men's stick ($3.5\ m{\cdot}s^{-1}$ (7.8 mph)) was substantially faster than the increase with the women's stick ($0.7\ m{\cdot}s^{-1}$ (1.5 mph)) (10). Given that the stick shafts were of similar mechanical stiffness, the difference in sticks performance was associated with the head of the sticks, it was postulated that it was most likely due to the difference in pockets; the men's pocket is substantially deeper, allowing the release of the ball at a higher speed.

Chest protectors, worn by both male and females goalies, have been designed to reduce the risk of musculoskeletal injuries from ball shots. No standard for design or performance exists for chest protectors in lacrosse or other sports. Manufacturers have developed chest protectors that perform extremely well to mitigate the risk of musculoskeletal injuries. As will be discussed later, chest protectors tragically do not prevent commotio cordis (CC), which occurs when a blunt nonpenetrating blow to the chest at a critical time in the cardiac cycle can lead to fatal arrhythmia.

Specific Injuries in Lacrosse

The top three game injuries at the college level for both male and female players are ankle sprains, knee ligament internal derangements, and concussions. Ankle sprains, muscle tendon strains, and knee internal derangements are the most common practice injuries (12,13,22). Although less common, upper extremity injuries such as acromioclavicular sprains and fractures to the hand and thumb also are significant, especially in the men's game where contact and checking are components of the game. Medical issues are not captured as easily in the literature, and less frequent but serious concerns related to lacrosse include heat-related illness, nutritional requirements, and CC. These issues are especially important in the youth player, given the increased risk for heat illness, increased nutritional requirements of youth players, and increased pliability of the chest wall and, therefore, increased likelihood of CC in youths.

Ankle sprain injuries in lacrosse are not unique in terms of their mechanism, management, or prevention (23). These injuries are typically due to noncontact cutting, dodging, or torsion activities (22). Although common, they are typically not severe in terms of time loss or complications. Injury prevention strategies include evaluating for preexisting ankle instability during the preparticipation examination, complete rehabilitation and recovery, and initiating taping or bracing and rehabilitation to protect the athlete from further injury (16,23).

Knee internal derangements, specifically anterior cruciate ligament (ACL) injuries, are significant injuries in lacrosse (12,13,22). Treatment of ACL injury can be surgical with rehabilitation afterwards or rehabilitation by itself, and a Cochrane Review has concluded that more quality randomized trials are necessary in order to determine which is preferred (34) The management of these injuries should be individualized and consider the individuals' occupation, sports activities, and associated injuries (50). If high-risk activities such as return to competitive sport with cutting and pivoting demands or a concomitant repairable meniscus injury are present, then surgical treatment is preferred (50). No matter the initial management decision, the time loss after ACL injury is significant.

The mechanism of ACL injury in lacrosse at all levels and both genders appear to be similar: noncontact or indirect mechanism injuries (12,13,22) most likely due to the cutting and pivoting. Several risk factors that may predispose an athlete to ACL injury have been presented (3,9,21,43,50). A full discussion of these risk factors is beyond the scope of this review.

Several studies have demonstrated an increase in ACL injury incidence in women's sports compared with that in their male counterparts (23,50). Although women's lacrosse

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has a higher incidence of ACL injury compared with that in field hockey, it remains significantly lower than that in women's basketball, soccer, and gymnastics (23,50). Mihata et al. (41) compared injury incidence in lacrosse as well as soccer and basketball, and although the incidence was higher in women for soccer and basketball compared with that in their male counterparts, the incidence in lacrosse was equal between genders. In a meta-analysis, Prodromos et al. concluded the same (47).

Among female athletes, field hockey athletes experience a lower incidence of ACL injury compared with that in other sports, and some have attributed this to the bent over positioning that players have while using a stick to move the ball on the ground in field hockey versus carrying a stick up above the head in lacrosse (4). A recent study supports this by demonstrating a decreased knee flexion angle during landing in female lacrosse players compared with that in field hockey players (4).

ACL injury prevention is important, and several programs have been developed, which incorporate balance training, plyometrics, strengthening, and feedback to alter biomechanical and neuromuscular variables (42,46,53). Several programs have been shown to reduce ACL injury (25,36,43,56), and these ideally should be initiated in youth players as part of their prepractice regimen.

Head and Eye Injuries/Concussion

Head injuries and concussion are important injuries in lacrosse at all levels of play. Significant attention has been paid to this injury in the sport, especially as it relates to the women's game and the concern for head protection.

Recent efforts have identified the risk of concussion in men's and women's game at the collegiate, scholastic, and youth levels of play (12,13,27,29,30). At the college level, the incidence of concussion in women's lacrosse is well below women's ice hockey and soccer but slightly higher than that in women's field hockey, basketball, softball, and volleyball, and on the men's side, the incidence is just below football but higher than men's ice hockey, wrestling, and soccer (44). These rankings by concussion rates are similar at the high school level (24,44). In the men's game, the mechanism of concussive injury is attributed to player-to-player contact, whereas in the women's game, it is primarily incidental contact with the stick (6,12,13,29,30). Despite different mechanisms of injury, the importance of education, medical management, and return to play issues of the concussed athlete is otherwise no different in lacrosse and other sports.

The management of athletes with sport-related concussion (SRC) is comprehensive and includes preseason planning, education, initial evaluation, postinjury assessment, disposition, return to play decisions, and consideration of long-term neurological health. Several recent publications have addressed sports concussion management using the best available evidence (17,18,40,48) and will not be discussed in detail. Preseason planning includes incorporating questions regarding modifiers of concussion (49) and a baseline assessment of athletes' symptoms, cognitive function, and postural stability (*e.g.*, Sideline Concussion Assessment Tool (SCAT) 3, National Football League sideline tool (45,52)). This baseline assessment then can be compared with an athletes' postinjury assessment if a concussive injury occurs, and the SCAT2, and thus SCAT3, has been shown to be useful in evaluating SRC (49). The use of computerized or paper-and-pencil neurocognitive testing also can be included and is beneficial as part of the baseline and/or postinjury assessment, although not required (17,18,40,50). The management of sports concussion has evolved rapidly over the past several years, facilitated by a greater understanding of the potential for both short- and long-term sequelae. Early recognition and comprehensive management is important, with emphasis on education, prevention, and gradual stepwise return to play (17,18,40,48).

Having a concussion plan as part of the emergency action plan (EAP) is important for lacrosse. Although such events are rare, being prepared for more serious head injury such as an intracranial bleed, skull fracture, or cervical spine injury is an important part of sideline preparedness (20). The return to play progression should include an incremental increase both in exertion and risk for contact (17,18,40). The rate of progression is individualized, taking into account the players' history of concussion, emotional readiness, and other modifiers (18,40).

Several efforts have been in place to address concussion in lacrosse. Injury prevention efforts include evaluating playing environment and behaviors, coaching techniques, officiating, rule enforcement, education, and protective equipment. U.S. Lacrosse has partnered with the U.S. Centers for Disease Control and Prevention to develop lacrosse-specific educational information for youth (8) and has developed educational videos and additional resources (54) specific to the sport lacrosse.

Rules in men's lacrosse that illegalize hits to the head and blows to the body that follow through to the head are important modifications at the college level (44) that can make a difference in preventing injury. Rule modifications and enforcement and promoting fair play can make a difference in reducing head exposures (2). U.S. Lacrosse has developed initiatives to remove checking in youth play by making it a penalty and developing the "Compete with Class & Honor the Game" program that encourages playing behaviors that promote safety and avoid injury (54).

When considering sports-related concussion, it is critical to understand how protective equipment may mitigate injury risk and severity as well as the limitations of this equipment in preventing injury. No helmet prevents all concussions, and, although mouth guards are effective in preventing dental injury, there is no conclusive data that they prevent concussions. Recent findings suggest that helmet design may limit impact forces and risk of concussion in football and lacrosse (51,7). Whether this can translate to men's lacrosse is unclear.

Protective eyewear has been mandated in the women's game since 2004 due to the risk of significant eye injury. An evaluation of the eyewear showed an 84% reduction (incident rate ratio, 0.16; 95% confidence interval, 0.06–0.42) in eye injuries during the years following the mandate compared with the years that preceded it (28). While similar results were found for protective eyewear in high school field hockey players (26), more research is needed to determine the role of headgear and protective equipment in preventing head and facial injuries.

Medical Issues in Lacrosse

Medical issues specific to lacrosse include CC, nutrition issues, and heat-related illness. The sport-specific demands

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pose nutritional requirements that may be increased when environmental issues such as altitude or heat are encountered. Understanding the role of nutrition in performance, especially in situations where athletes are playing multiple games on consecutive days, is important for the team physician (19).

Heat illness is an important issue for all athletes but raises concern for lacrosse, and especially in youth among whom thermoregulation can be impaired, tournament play is frequent, and in male players where protective equipment can impede heat loss. Due to the prolonged nature of play and the nutritional demands, heat issues can be exacerbated when fluid and electrolyte loss and subsequent dehydration occur. In addition, when athletes are exposed to heat over several hours and/or days, such as in a tournament setting, there is a cumulative effect and the risks of heat illness are increased. Heat illness remains an issue for all sports, especially in settings where dehydration, poor acclimatization, and significant heat and humidity occur. Several measures can prevent heat illness, including proper hydration, acclimatization to heat, use of ice towels during practices, scheduled periods of time-out, and, if heat illness occurs, rapid cooling using immersion and cooling fans (1).

CC is a life-threatening injury that can occur as a result of a blunt nonpenetrating blow to the chest (over the heart) at a critical time in the cardiac cycle, causing an often fatal arrhythmia. CC has been reported as the second leading cause of death in young athletes and is more likely to occur when the chest wall is pliable, with those aged 12 to 15 years being at greatest risk (37). No cases have been reported in girls' or women's lacrosse. Cases of CC reported in the United States typically involve small projectiles, such as baseballs, hockey pucks, and lacrosse balls that strike the chest. In other parts of the world, CC has been reported in sports such as soccer and cricket, suggesting that it may not be limited to small projectiles (38). What appears to be consistent is a blow to the chest at a vulnerable period in the cardiac cycle, 10 to 20 ms prior to the peak of the T wave (31,32). Using an animal model, Link et al. (31,32) demonstrated that the blow often occurs over the cardiac silhouette at an optimal velocity of 40 mph, with ventricular fibrillation as the most common arrhythmia. CC is difficult to recognize, but if an athlete sustains a blow to the chest and subsequently drops to the ground, it should be considered and the EAP should be initiated with emphasis on early access to defibrillation (15).

In the reported cases of CC in the United States, the overall survival is poor at 16% (37). In those cases where cardiopulmonary resuscitation was initiated and defibrillation occurred, the survival rate is higher (41%), but overall, the outcome is disappointing, with emergency measures within and after 3 min associated with 25% and 3% survival rate, respectively (37). In the swine model of CC, early defibrillation after experimentally reproduced induction of ventricular fibrillation (VF) was associated with a significantly improved outcome (33). In those situations where the animal model produced ventricular fibrillation and an automated external defibrillator (AED) was placed within 2 min, over 90% of the animals survived, whereas at 4 min, the survival rate dropped to 40% (33). Translating the animal model directly to clinical application is not possible, but this research underscores the importance of having an emergency plan that includes access to early defibrillation in arrhythmias to maximize the potential for survival.

Prevention of CC includes education, emergency planning, and equipment considerations. Recognizing CC can be difficult, and in reviewing the EAP with players, parents, coaches, and administrators, reviewing the presentation of CC is useful (5). In addition, rehearsing the EAP with health care providers and emergency personnel should include scenarios such as CC.

The use of current chest protectors in sports such as lacrosse and baseball has not been shown to be effective in preventing CC in both a swine model of CC and the clinical reports of CC in humans (14,37,55). Additional research to develop chest protectors for lacrosse (11) and sports such as hockey and baseball is needed. The use of safety baseballs has been associated with a decrease in the occurrence of ventricular defibrillation in an animal model of CC (32). At 40 mph, the softest safety balls triggered ventricular fibrillation in 11% of balls using an experimental model compared with 19% and 22% of harder safety balls and 69% of standard baseballs (32). This represents a promising area of research in lacrosse to prevent CC.

Education efforts are important not only in recognizing potential CC events, initiating the EAP, and early defibrillation but also because it relates to playing behaviors in preventing CC, in particular deliberately attempting to block shots with the body. A review of CC in lacrosse identified 23 sudden death events at the high school and college levels between 1980 and 2007, with 10 sustaining a blow to the chest prior to their collapse and without evidence of underlying structural disease (39). Four of these were in goalkeepers wearing chest protection. In some, athletes were attempting actively to block a shot on goal. The overall mortality was no different in lacrosse compared with that in other sports in this study, but the propensity of CC to occur was felt to be higher in lacrosse than that in hockey and baseball (39). Youth players should be discouraged actively, by coaches and program administrators, to participate in shot blocking.

Conclusions

Men's and women's lacrosse are distinct team sports that involve running, cutting, agility, and sport-specific skills. They are governed by drastically different rules and, therefore, equipment needs. Ankle sprains, knee internal derangement, and head injuries are the most common game injuries, and ACL injuries are the most severe injuries based on time loss. The mechanism for concussion is different in the men's and women's games, and additional research is needed to evaluate the management and prevention of these injuries. Lacrosse is the fastest-growing sport at the high school and college level for both boys/men and girls/women, and efforts to prevent injury and illness that can make the game safer are under way. Attention to youth rules and efforts to educate athletes, coaches, parents, and administrators regarding the importance of recognizing signs and symptoms of concussion and CC is useful in avoiding significant morbidity and mortality. Efforts to implement injury prevention strategies, such as ACL prevention programs and emergency action planning, can make the game safer.

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