Epidemiology of Injuries in Women's Lacrosse: Implications for Sport-, Level-, and Sex-Specific Injury Prevention Strategies

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Abstract

Objective: By the end of 2013, the United States had an estimated 278 000 female lacrosse players, with half of those participating at the youth level. The effects of the sport's rapid growth on injury rates have yet to be determined. The purpose of this clinical review is to synthesize the available published data on injuries that have occurred in the sport of women's lacrosse. Of particular interest was the risk of injury based on the level of play and position. **Data Sources:** A comprehensive literature search was performed in PubMed, High Wire Press, SPORTDiscus, Google Scholar, and Ovid using the keywords "Lacrosse Injuries," "Epidemiology Lacrosse Injuries," "Lacrosse Injury," "Lacrosse," and "Injury." **Study Selection:** The electronic search included material published during or after 1950. In addition, all bibliographies of electronically found sources were cross-referenced to identify any additional publications that were not produced in the electronic searches. **Data Extraction:** All articles with data on women's injury rates were categorized by overall injury rates, rates by session (competition vs practice), nature of injury, location, type, severity, and player position. **Data Synthesis:** Injury rates increase with age: from youth leagues to high school and finally to the collegiate level. Rates of injury varied from 0.03 to 3.9 injuries/100 athletes. Women's game injury rates are consistently higher than practice injury rates (ranging from 0.2 to 7.1 vs 0.01 to 3.3). Injuries occur most frequently from stick-to-player or player-to-ball contact, rather than player-to-player contact. Women sustain a higher percentage of head and facial injuries relative to male lacrosse players. The most common types of injuries for women are concussions, sprains, contusions, and lacerations. More than half of all injuries are in the mild category resulting in players missing practice and games for 1 to 7 days. Offensive players had the most injuries, followed by defensive players and then midfielders, with goalies having the fewest number of injuries. **Conclusions:** In women's lacrosse, the rules and equipment used are substantially different than for the men's game. Face and hand injuries are more prevalent for women when compared with men, and ankle injuries are most prevalent in female youth. Medical professionals who treat lacrosse players can benefit from an improved understanding of the types and rates of the injuries they are likely to encounter. Improved awareness of lacrosse-specific injuries can assist these professionals to be more prepared to treat these athletes, which may lead to improved care and outcomes.

Key Words: lacrosse, epidemiology, athlete, injury

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INTRODUCTION

Background

Lacrosse began as a Native American tradition and is now one of the fastest growing sports in the United States.[1,2] Modern women's lacrosse began in 1890 in Scotland and was brought to the United States in 1926, with first recorded play occurring at the collegiate level.[3] By the end of 2013, the United States had an estimated 278 000 female lacrosse players, with half of those participating at the youth level.[4] For the youth players, this represents a 43% increase in 5 years. Thus, lacrosse is the fastest growing team sport for girls, and female participation at the high school level has increased 126.6% in the last 10 years.[4] Not surprisingly, the explosive growth at the youth level has led to increased collegiate play. Four hundred sixteen colleges and universities now sponsor women's lacrosse as a team sport (38.2% growth from 2008 to 2013). In 2013, US Lacrosse experienced record numbers of members and regional chapter applicants.[4] Expanding media coverage will also likely add to the sport's popularity and participation.[5]

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Problem

The growth in women's lacrosse participation has in turn increased the total number of lacrosse-related injuries.[6] Indeed, although the women's game only allows stick-to-stick contact and minimal incidental body contact, injury rates are still on the rise. Dick et al[7] showed that at the women's collegiate level, game injury rates had substantially increased from 1988/1989 to 2003/2004 (a 16-year period).

Overview

The purpose of this clinical literature review is to aggregate and analyze the existing literature relating to injuries associated with women's lacrosse participation. Women's injury data were collected at the youth, high school, and collegiate levels and were organized to compare injury rates, location, type, severity, setting (game vs practice), and player position. This detailed analysis of cumulative lacrosse injury data helped identify injury risk factors in the women's game and has implications for injury prevention efforts.

METHODS

Literature Search Strategy

A comprehensive literature search was performed in PubMed, High Wire Press, SPORTDiscus, Google Scholar, and Ovid using the keywords "Lacrosse Injuries," "Epidemiology Lacrosse Injuries," "Lacrosse Injury," "Lacrosse," and "Injury." The electronic search included material published during or after 1950. In addition, all bibliographies of electronically found sources were cross-referenced to identify any additional publications that were not produced in the electronic searches. All articles with data on women's injury rates were categorized by overall injury rates, rates by session (competition vs practice), nature of injury, location, type, severity, and player position.

RESULTS

Injury Rates

The data gathered on injury rates in women's lacrosse are summarized in Table 1. Rates of injury varied from 0.03 to 3.9 injuries/100 athletes. Several studies examined anterior cruciate ligament (ACL) injury rates in women's lacrosse and other sports and found that women's lacrosse had lower incidence rates (0.18) than women's soccer (0.32) and basketball (0.28).[8–10] Cantu et al[11] looked at fatalities and catastrophic injuries in college and high school sports over a 15-year period. The researchers found that the relative incidence level of suffering a catastrophic injury or fatality in lacrosse is much lower than for other collision sports.[11]

Injury Rates by Age

Injury rates increase with age: from youth leagues to high school and finally to the collegiate level.[12,13] The increased injury rates are likely due to multiple factors, including more intense play and anthropometric differences between players.[12]

Game Versus Practice Injury Rates

Athlete exposures (AEs) are units of susceptibility to injury which is defined as one athlete participating in one game or practice in which she is exposed to the possibility of athletic injury. The game and practice injury rates for women's lacrosse are summarized in Table 2. Women's game injury rates are consistently higher than practice injury rates (ranging from 0.2 to 7.1 vs 0.01 to 3.3). Yard and Comstock[14] did not differentiate between men and women or practice and game at the youth level. Lincoln et al, Goldenberg and Hossler,[15] Matz and Nibbelink,[16] Hootman et al,[17] and Covasin et al[18] all found increased rates of injury during game activity.[15–19] McCulloch and Bach[2] did not study game injury numbers, showed a higher rate per 1000 AEs during games (11.5/6.1) when compared with practice injury rates. The disparity between practice and game sessions could be due to different intensity of competition, as practice sessions tend to involve less aggressive play, more frequent breaks, and fewer collisions.

Nature/Mechanism of Injury

Not much empirical information is available on the nature of lacrosse injuries. Women's lacrosse is classified as an incidental contact sport.[20] Purposeful body-to-body contact is not allowed, and the playing field is larger than that of the men's game (120 yards long and 70 yards wide), which creates more open space and likely reduces the probability of contact. For these reasons, injuries in the women's game occur most frequently from stick-to-player or player-to-ball contact, rather than player-to-player contact.[7,12,20,21]

Because of the lower collision rates compared with men's lacrosse, minimal protective equipment is required in the women's game. Women wear mouth guards and protective eyewear mandated in 2004. However with the exception of goalies, neither helmets nor padding are worn.[22] Light protective gloves are optional but are infrequently worn. Soft headgear is allowed.

Contusions, fractures, lacerations, concussions, sprains, and strains were the most common injuries recorded.[23] Injuries displayed as gradual onset included overuse injuries and stress fractures, but were seldom listed. Kang et al[24] studied stress fractures, which would likely account for a larger gradual onset (7) than sudden onset (0).

Injury Site Location (Body Area)

There is an abundance of information provided in the literature on injury site location, as displayed in **Supplemental Digital Content 1** and **2** (see **Tables S1A** and **S1B**, http://links.lww.com/JSM/A144 and http://links.lww.com/JSM/A145). Most data provided on women have centered on head and facial injuries. Women sustain a higher percentage of head and facial injuries relative to male lacrosse players.[19,25] Risk factors for these injuries may be attributed to 3 categories: (1) lack of protective equipment, (2) improper use of equipment, and (3) lack of enforcement of the rules.[15,26,27] Women are required to wear eye protection (mandated at all levels in 2004) and mouth guards, but helmets, body padding, and hand protection are not mandated for non-goalie female players.[22]

In the youth game, the most common injuries for females are to the ankle (26%), hand (24%), and face (21%).[14] Goldenberg showed that the largest number of injuries occur to the lower extremities (56%) in female high school lacrosse players.[15] The lack of mandatory protective glove

TABLE 1. Injury Rates

Study	Total No. of Injuries	Duration	Design	Female Participants	Female No. of Teams	Female No. of Injuries	I. P. R.	Incidence Rate Total Injuries/1000 AEs
High school								
Hinton et al (2005)	986	3 yrs	Prospective		23	371		2.54
Lincoln et al (2007)*	228	4 yrs	Prospective	3566	23	114	1.42	0.54
Cantu et al (1999)†	3	15 yrs	Retrospective	150 547			0.0000068	
Goldenberg et al (1995)*	1383	3 yrs	Prospective	7263	63	1383		3.9
Marar et al (2012)‡		2 yrs	Retrospective			60		0.86
Lincoln et al (2012)*	949	10 yrs	Retrospective		25	949		1.8
Lincoln et al (2011)‡	358	11 yrs	Retrospective		25	114		0.2
Caswell et al (2012)§	39	2 sns	Retrospective	2500	50	25	0.016¶	0.030¶
Lincoln et al. (2013)	86	2 sns	Retrospective				0.050¶	
Kerr et al (2013)‖		1 yr	Retrospective					82
College								
Diamond et al (2001)	1727	10 yrs	Retrospective	336				0.77
Lincoln et al (2007)*	400	4 yrs	Prospective		64	268	1.76	0.77
Matz et al (2004)	104	2 sns	Prospective		18	104	3.8	3.8
Waicus (2002)	125	2 Dys	Retrospective	667	34	125		
Decoster et al (1999)	134	1 sn	Prospective	163	10	111	2.29	1.76
Covassin et al (2003)	128	3 yrs	Prospective		112	48		
Mihata et al (2006)**		15 yrs	Retrospective		552	146		0.18
Cantu et al (1999)†	5	15 yrs	Retrospective	47 235			0.00004	
Prodromos et al (2007)**			Retrospective				1.06	0.18
Dick et al (2007)††	4845	16 yrs	Retrospective					
Dick et al (2007)‡‡	3392	16 yrs	Retrospective		42	3392		
Bowers et al (2010)§§	351	16 yrs	Retrospective			75		0.11

All data were taken directly from the references unless otherwise noted.
** Lincoln et al (2007), Lincoln et al (2012), and Goldenberg et al only studied head, face, and eye injuries.*
† Cantu et al only studied catastrophic injuries.
‡ Marar et al and Lincoln et al (2011) only studied concussions.
§ Caswell et al only studied head injuries.
¶ Number is calculated using data reported in reference.
‖ Kerr et al only studied exertional heat illness.
*** Prodromos et al and Mihata et al only studied ACL injuries.*
†† Dick et al. J Athl Training. *2007;42:255–261.*
‡‡ Dick et al. J Athl Training. *2007;42:262–269.*
§§ Bowers et al only studied injuries of the thumb, fingers, and metacarpals.
I.P.R., incidence proportion rate (no. of injured athletes/total number of athletes).

wear increases their risk for injuries to the hands and fingers; although as mentioned earlier, some players choose to wear light fabric gloves that offer substantially less protection than the padded gloves common to the men's game. Many accidental injuries are also likely due to lack of skill development and unfamiliarity with the sport, leading to poor control of stick check and movement. Novice players especially should wear additional protective equipment.

Lincoln et al[19] compared the rate of head injuries at the high school level between boys and girls over a 4-year period, for 46 teams (23 males and 23 females) and found that girls had significantly higher rate of injury (0.54/1000 AE) than did boys (0.38/1000 AE). Goldenberg[15] showed a high rate of injury to the eye (1.3 per 100 athletes), but this study was done in 1995, before the mandatory use of protective eyewear implemented for the women's game in 2004.[15] Lincoln et al[28] compared eye injury rates in girls' scholastic lacrosse before and after the eyewear rule change and found a reduction from 0.10/1000 AE to 0.016/1000 AE (See **Tables S1A** and **S1B, Supplemental Digital Content 1** and **2**, http://links.lww.com/JSM/A144 and http://links.lww.com/JSM/A145).

The women's game does not currently use helmets for nongoalie players. However, women tend to carry the head of the stick closer to their heads and faces during cradling as a result of the technique needed for maximum ball control with sticks that lack a pocket in the mesh. Holding their stick close to their face while possessing the ball may increase the probability of injury to face and head from purposeful or incidental contact. In the women's game, most injuries occur to the head and facial areas, which are left exposed, except for the mandated protective eyewear.[22] The regulation for head and face protection in the women's game continues to be an evolving improvement process. US Lacrosse (the national governing body of lacrosse) is currently working with leading

TABLE 2. Game Versus Practice Injury Rates

Study	No. of Injuries	Duration	Design	No. of Subjects	Injury Rate	
					Practice	Game
					P/1000 AE	G/1000 AE
High school						
Lincoln et al (2007)†	114	4 yrs	Prospective	3566	0.26	1.33
Mayer et al (1987)	2		Retrospective	2	2‡	
Goldenberg et al (1995)†	1383	3 yrs	Prospective	7263	1.8§	3.5§
Marar et al (2012)	60	2 yrs	Retrospective		0.13¶	0.86¶
Caswell et al (2012)	39	2 sns	Retrospective	2500	0.011‖	0.019‖
Lincoln et al (2013)		2 sns	Retrospective			
Kerr et al (2013)*		1 yr	Retrospective		118‖	0
College						
Lincoln et al (2007)†	268	4 yrs	Prospective		0.53	1.98
Matz et al (2004)	104	2 sns	Prospective		2.75	8.65
Hootman et al (2007)	960	16 yrs	Retrospective		3.3	7.2
Waicus et al (2002)	125	2 d	Retrospective	667	41‡	38‡
Covassin et al (2003)	48	3 yrs	Prospective		0.22**	1.06**
Livingston, et al (2003)	1		Retrospective	1	1‡	
Lapidus et al (1992)	6		Retrospective	3	6‡	
McCulloch et al (2007)	Zero		Retrospective	Zero		6.1
Dick et al (2007)††		16 yrs	Retrospective			
Dick et al (2007)‡‡	3392	16 yrs	Retrospective		3.3	7.15

All data were taken directly from the references, unless otherwise noted.
** Kerr et al only studied exertional heat illness.*
† Lincoln et al and Goldenberg et al only studied head, face, and eye injuries.
‡ Either (a) not given sufficient data to calculate or (b) athletes' self-reported injuries on survey or (c) no athletic exposure data reported.
§ Numbers are per 100, rather than per 1000 AEs.
¶ Numbers are calculated based on reported numbers for injuries per 10 000 AEs.
‖ Number is calculated using data reported in reference.
*** Numbers are calculated averages for the 3 individual years.*
†† Dick et al. J Athl Training. *2007;42:255–261.*
‡‡ Dick et al. J Athl Training. *2007;42:262–269.*

manufacturers to develop lacrosse-specific head protection. New protective equipment for women needs to specifically address common injury mechanisms of women's lacrosse and not merely adopt currently available protective equipment from the men's game or other similar sports.[21]

Injury Type

The most common types of injuries for women are (in order from most frequent to least frequent) concussions, sprains, contusions, and lacerations. These injuries are summarized in Table 3. Males experienced more concussions (nearly 2:1) in all studies, whereas females experienced contusions, abrasions, sprains, and strains in greater numbers. For women, the lack of protective equipment is perhaps the number one cause of contusions and lacerations. Studies on concussion injuries have provided the overall number of concussion occurrences, but most studies have not listed the severity or time lost from each concussion.[29] Similarly, regarding sprains, current research lists only the number of sprains, but future data collection could improve research by including the area of the body where the sprain occurred (specific: ie, ACL, MCL, and ATF; or general: ie, ankle or knee). More detailed data on injury type are warranted for future lacrosse studies.

Injury Severity

The severity of injuries in women's lacrosse varies in the literature. According to the current literature, more than 50% of injuries are in the mild category resulting in players missing practice and games for 1 to 7 days.[12,16,30,31] Table 4 summarizes the data on injury severity. The most common injuries in the mild category were contusions and lacerations.[32] The moderate category involves player absence from 8 to 21 days, with the primary injuries being ankle sprains and muscle strains.[12,16,30,31] The severe category requiring 22 or more days lost was attributed to ACL injuries and was documented by Hinton et al[12] and Matz and Nibbelink.[12,16]

The definition of a catastrophic injury in the literature ranges from the loss of one or more vital functions to the complete loss of life.[2,16] Commotio cordis, a sudden cardiac episode secondary to blunt, nonpenetrating but forceful chest blows are very rare in sports. There have been recorded incidents of commotio cordis in baseball, hockey, and lacrosse, with and without protective equipment over the heart area.[14,33] There are approximately 18 cases of lacrosse-related commotio cordis in the literature, all of which come from the high school or collegiate levels. Of

TABLE 3. Injury Type

Study	Design	Duration	No. of Subjects	No. of Injuries	Contusions/ Abrasions	Concussions	Dislocations	Fracture	Lacerations	Sprain	Strain	Other
High school												
Lincoln et al (2007)	P	4 yrs	3566	114	38	45		16	8			4
Hinton et al (2005)	P	3 yrs		615	69	14	10	33	5	170		
Caswell et al (2012)	R	2 sns	2500	39	4	35						
College												
Hootman et al (2007)	R	16 yrs		960		213				602		145
Mihata et al (2006)	R	15 yrs		146						146		
Covassin et al (2003)	P	3 yrs		48		48						
Dick et al (2007)	R	16 yrs		3392	65	213	292	212	14	649	864	127
Lincoln et al (2007)	P	4 yrs		268	64	111		56	25			12
Bowers et al (2010)	R	16 yrs		75	27		0	31	5	9		3

All data were taken directly from the references, unless otherwise noted. Caswell only studied head injuries; Hootman only reported data for injuries to ankle ligament, ACL, and concussion; Bowers only studied injuries to the thumb and hand.

these 18 cases, half occurred in goalies who were wearing chest protection.[11,16,32]

Injury by Position

The injury-by-position data are presented in Table 5. Offensive players had the most injuries, followed by defensive players and then midfielders.[24,31,34] Goalies had fewer injuries, which may be due to the rules which limit players' ability to make physical contact with the goalie.[15] Risk seems to be greater for players who do more ball handling (more exposure to body and stick contact) and who perform more running, cutting, and stopping maneuvers, compared with goalies. Further research should include player position when documenting injuries to better track what types of injuries are associated with particular field positions. These data can help researchers, officials, coaches,

TABLE 4. Injury Severity

Study	No. of Injuries	Duration	Design	Participants	Rate		
					Injuries/1000 AEs (1-7 Days)	Injuries/1000 AEs (8-21 Days)	Inj/1000 AEs (22 + Days Lost)
High school							
Luckstead et al (2002)	91*	18 yrs	Retrospective				
Hinton et al (2005)	986	3 yrs	Prospective		193	21	11
Mayer et al (1987)	2	na	Retrospective	2			2
Marar et al (2012)	153	2 yrs	Retrospective		9	33	5
Cantu et al (1999)	3	14 yrs	Retrospective	150 547			
College							
Luckstead et al	37†	18 yrs	Retrospective				
Matz et al (2004)	104	2 sns	Retrospective		73.4	17	9.6
Waicus et al (2002)	125	2 d	Retrospective	667	79	9	Zero
Decoster et al (1999)	134	1 sn	Prospective	163			
Cantu et al (1999)	5	14 yrs	Retrospective	47 256			

Marar only studied concussions.
All data were taken directly from the references, unless otherwise noted.
** Includes all catastrophic injuries for all High school spring season sports.*
† Includes all catastrophic injuries for all college spring sports.
na, not applicable.

TABLE 5. Injury by Position

Study		Duration	Design	Participants	No. of Teams	No. of Injuries	Goalie	Defense	Offense	Midfield
High school										
Goldenberg et al (1995)*	F	3 yrs	Prospective	7263	63	1383	5	125	189	
Caswell et al (2012)	F	2 sns	Retrospective	2500	50	39		5	6	2
College										
Waicus et al (2002)	F	2 d	Retrospective	667	34	125	na	27	41	22
Kang et al (2005)	F	6 yrs	Retrospective	7*	1	7		1	3	3
Livingston et al (2003)	F	1 yr	Retrospective	1†	1	1				1
High school and college combined										
Carter et al (2013)	F	5 yrs	Retrospective			96	3	22	31	40

** Kang retrospectively reviewed 7 cases of femoral shaft fracture.*
† Livingston reported 1 case of thump entrapment.

and medical professionals develop improved protective equipment and regulations for gameplay to decrease injury risk.

Risk Factors for Injury During Lacrosse Participation

Risk factor data are displayed in Table 6 and are divided into intrinsic and extrinsic risk factors. Intrinsic risk factors for youth and collegiate players include hypermobility of joints, age, skill level, and sex.[35,36] Extrinsic risk factors include rules of the game (body and stick contact),[18,29] equipment (or lack thereof for females),[9,25,34,37] position played,[15] and game versus practice participation.[17]

DISCUSSION

This clinical review of women's lacrosse-related literature is intended to offer insight to the types of injuries that a provider of medical services to lacrosse players may expect. Women tend to have injuries to the lower extremity and exposed body parts of the hand and face because of limited protective equipment coverage and incidental stick and body contact.[7,12,13,15,16,19] The overall women's lacrosse injury rate is lower compared with other female collision sports such as soccer, but it is higher than the rate for basketball.[7,14,17]

Facemasks and goggles limit the exposure of the face to the stick and ball, so as to reduce injuries to the eyes, nose, and mouth. Rule enforcers should continue to ensure that players are using protective equipment appropriately to cover at-risk body areas, despite the effects on mobility. In addition, officials and rule makers can continue to improve the safety of the game by developing and enforcing rules to limit players' risk to injury while still maintaining the integrity of the game. Specifically, continuing research on developing effective

TABLE 6. Injury Risk Factors

	Design	Duration	Description
Intrinsic risk factors			
Youth			
Yard et al (2006)	Retrospective	13 yrs	Children 2-9 yrs of age sustained more injuries to the head and face
McGuine (2006)	Retrospective	10 yrs	Sex, age/grade, experience, previous history, and body size were considered
College			
Brown et al	Observational	1 yr	Sex differences (females more susceptible to injuries, concussions, ACL, etc.)
Decoster (1999)	Prospective	1 season	Hypermobility of joints
Extrinsic risk factors			
Youth			
Yard (2006)	Retrospective	13 yrs	Rule enforcement
High school			
Lapidus et al (1992)	Retrospective	—	Lack of eye protection (women)
Hinton (2005)	Prospective	3 yrs	Lack of rule enforcement and effectiveness of protective gear
Goldenberg et al (1995)	Prospective	3 yrs	Field position, midfield play more prone to injury
College			
Hootman and Agel (2007)	Retrospective	16 yrs	Increase in participation, higher rate of injury in game vs practice
Livingston (2003)	Retrospective	—	Lack of equipment protection, gloves (women)
Lapidus et al (1992)	Retrospective	—	Lack of eye protection (women)
Shermondy (2006)	Retrospective	1 yr	Lack of equipment
Mihata (2006)	Retrospective	15 yrs	Rules and style of play, sex

All data were taken directly from the references, unless otherwise noted.

TABLE 7. Lacrosse INJURY Prevention Strategies

Administrative
Support coaching and official certification: All lacrosse organizations should support the current efforts of US Lacrosse in requiring national, standardized certification of coaches and official at all levels of play. Such certification is the foundation to a safe play environment and has been designated by US Lacrosse as the top health and safety priority for the game.
Adopt youth specific rules: All lacrosse organizations should adopt and promote recently developed youth specific rules for boys and girls' lacrosse. These national, standardized rules have been developed in recognition of the unique psychological and physical characteristic of the young player. The goal is to promote a positive game experience while enhancing health and safety among the game's youngest players.
Develop an emergency action plan: All lacrosse organization should have a well-developed emergency action plan to deal with routine injuries, catastrophic events, weather-related emergencies, and player transport/contacts.
Promote a positive game environment: All lacrosse organizations and administrators must recognize that the priority for the vast majority of lacrosse athletes is to have fun and learn life's lessons on the field of play. A conscious effort must be made to promote a positive game experience and limit secondary gain issues. Such efforts serve to prevent mental burnout, limit physical overuse, and promote a safer play environment.
Acknowledge one sport—2 games: The lacrosse and general sporting community must recognize that although they are both called lacrosse, the men's and women's games each have their own unique histories, rules, equipment, and styles of play. These differences are purposeful and must be recognized as an integral part of game's integrity. These differences also necessitate game-specific injury prevention strategies and interventions.
Promote health and safety rules: Make sure all parties prioritize the implementation and enforcement of safety-related rules which limit contact to the unprotected player, discourage body shielding of the goal or shot path, limit crowding about the goal area, limit stick contact to specific areas of the opponents' stick or body area, promote "heads up play," and encourage the appropriate utilization of protective equipment.
Player and Family
Maintain open communication: Discuss your lacrosse goals and health concerns with your lacrosse organization and coaches. Offer to volunteer and support the team in a positive manner. Do not just drop your kids and run. Be an active part of your children's lacrosse experience.
Respect the game: Although men's lacrosse is a collision sport, it is a game which prioritizes skill and fines. Unprotected, takeout hits have no place in the game. For women, rules which promote a free style of play and limit purposeful body contact must be adhered to by all.
Stay in shape—but take a break: Lacrosse is a high speed change of direction sport. Players should maintain a core strength and flexibility base throughout the year. Always warm up well and incorporate an active stretching program. Lacrosse is not a game which lends itself to playing yourself into shape or starting cold. To stay mentally and physical fresh, take at least 2 mo away from the sport each year.
Wear the right equipment: Protective equipment must be appropriately sized and maintained. Do not modify mouthpieces or glove for comfort.
Report all injuries: Head injuries of any severity and any injury which causes lost or modified play time must be reported to your coach, trainer, or parents. Hiding or ignoring injuries will eventually lead to missed game time and extended recovery periods.
Healthcare Providers
Stay current: Stay abreast of the growing body of lacrosse-specific sports medicine knowledge which deals with the unique mechanisms, types, and prevention of lacrosse-specific injuries and conditions.
Get involved: Work with your local lacrosse community regarding education and development of emergency action plans, injury prevention programs, and appropriate injury rehabilitation and performance enhancement efforts.

protection for those at risk for commotio cordis is urgently needed to reduce the chances of this catastrophic injury to players of lacrosse and other collision sports.[11,38,39]

A summary of recommended injury prevention suggestions is provided in Table 7. These suggestions range from wearing the right equipment, adopting youth specific rules, and promoting health and safety rules. However, the largest focus on injury prevention must be on the education of officials, coaches, players, parents, and the community concerning rules, game integrity, and sportsmanship. An extensive certification process for coaches and officials is available through US Lacrosse (http://www.uslacrosse.org/participants/coaches/coaching-education-program.aspx and http://www.uslacrosse.org/participants/officials/womens-officials-information/womens-training-and-certification-process.aspx). US Lacrosse spent numerous years focused on developing rules specific to youth lacrosse. These rules are available through US Lacrosse and were developed with a multidisciplinary panel with best practices and consideration of physiology, growth and development, injury prevention, and functional status based on age. They significantly limit contact, prioritize skills and team development concepts, focus on sportsmanship, game integrity, and positive game experience.[20,40]

Rule changes have been implemented for injury prevention. US Lacrosse emphasizes injury prevention through adequately educating and certifying coaches and officials to ensure that the rules are known, understood, and enforced and to instruct youth on the ethics of the game.

Most lacrosse protective equipment comes in varying shapes and models that provide a range of body protection.[5] Many players will sacrifice the protection provided by large, heavier equipment for greater ranges of motion and less resistance facilitated by smaller, lighter equipment that offers less protection. However, choosing to use minimal equipment places athletes' bodies at greater risk for contact injuries. Likewise, for the sake of enhanced mobility and speed, many players elect to not use optional equipment such as rib pads. Most women's mandated equipment is lighter than male counterparts. Women are only required to wear a mouth guard and protective eye goggles. Goalies in women's lacrosse are required to wear throat protectors and chest pads. No protective equipment is mandated for the back, chest, ribs, abdomen, hips, or lower extremities for all nongoalie players. Mandating the use of protective equipment for all lacrosse players may help mitigate injury risk to these areas. However, women may be against more equipment mandates. Finally, game and duration may pose injury risk factors as a result of play intensity and exposure to

injury risk. Tournament play may present a higher level of risk because of fatigue and greater exposure to risk.

CONCLUSION

With current increasing trends of participation in lacrosse at all levels of play, efforts to enhance safety and decrease potential injury risk are warranted. Improvements to rules, equipment, and gameplay that consider the well-being of participants can have a tremendous positive influence on players' health, our healthcare system, and future generations of lacrosse players. Healthcare professionals are in a position to improve athletes' well-being by making recommendations to the sport's governing body to address limitations in rules or equipment to reduce injury risk. Although the rate of injury in lacrosse is lower than the rates in many other collision sports, stricter rules on contact and protective equipment are recommended as the sport grows. Also, we need to ensure appropriate development of fundamental movement skills for youth players before being allowed to check or make stick-to-stick contact in a competitive environment. In addition, ongoing monitoring of the types and rates of injury can help to determine the efficacy of rules and equipment and to recommend modifications to improve safety for participants.

Suggestions for Further Research

Further research is warranted to better classify and predict lacrosse injury factors and mechanisms. More complete and thorough data are needed for women to classify injuries based on position, age, level of play, type of injury, severity of injury, mechanism of injury, and time point in game/practice when injury occurred. Injury data among females at the postcollegiate levels, including amateur, professional, and international play, should be collected, as well as injury data distinguished by cause, either intrinsic or extrinsic factors. Longitudinal studies and meta-analyses to assess lacrosse injuries across all levels of play are recommended. Researchers are advised to implement thorough statistical analyses and conduct more epidemiological studies across all levels of play. In future research, it would be helpful if documentation of the onset of injuries was included to further glean the incidence of injury patterns, especially given the exponential growth in participation.

References

1. Lacrosse U. *US Lacrosse 2011 Participation Survey*. Sparks, MD: USA Lacrosse; 2011.
2. McCulloch PC, Bach BR Jr. Injuries in men's lacrosse. *Orthopedics*. 2007; 30:29–34.
3. Fisher DM. *Lacrosse: A History of the Game*. Baltimore, MD: Johns Hopkins University Press; 2002.
4. Lacrosse U. *US Lacrosse 2013 Participation Survey*. 2013 ed. Baltimore, MD: US Lacrosse; 2013.
5. Lacrosse U. *US Lacrosse 2007 Participation Survey*. Sparks, MD: USA Lacrosse; 2008.
6. Knowles SB, Marshall SW, Guskiewicz KM. Issues in estimating risks and rates in sports injury research. *J Athl Train*. 2006;41:207–215.
7. Dick R, Lincoln AE, Agel J, et al. Descriptive epidemiology of collegiate women's lacrosse injuries: national collegiate athletic association injury surveillance system, 1988-1989 through 2003-2004. *J Athl Train*. 2007;42:262–269.
8. Arendt EA, Agel J, Dick R. Anterior cruciate ligament injury patterns among collegiate men and women. *J Athl Train*. 1999;34:86–92.
9. Mihata LC, Beutler AI, Boden BP. Comparing the incidence of anterior cruciate ligament injury in collegiate lacrosse, soccer, and basketball players: implications for anterior cruciate ligament mechanism and prevention. *Am J Sports Med*. 2006;34:899–904.
10. Prodromos CC, Han Y, Rogowski J, et al. A meta-analysis of the incidence of anterior cruciate ligament tears as a function of gender, sport, and a knee injury-reduction regimen. *Arthroscopy*. 2007;23: 1320–1325.e6.
11. Cantu RC, Mueller FO. Fatalities and catastrophic injuries in high school and college sports, 1982-1997. *Phys Sportsmed*. 1999;27:35–48.
12. Hinton RY, Lincoln AE, Almquist JL, et al. Epidemiology of lacrosse injuries in high school-aged girls and boys: a 3-year prospective study. *Am J Sports Med*. 2005;33:1305–1314.
13. Sherman NW. Head injuries and protective eyewear in Women's lacrosse. *J Phys Educ Recreation Dance*. 2000;71:9.
14. Yard EE, Comstock RD. Injuries sustained by pediatric ice hockey, lacrosse, and field hockey athletes presenting to United States emergency departments, 1990-2003. *J Athl Train*. 2006;41:441–449.
15. Goldenberg MS, Hossler PH. Head and facial injuries in interscholastic women's lacrosse. *J Athl Train*. 1995;30:37–41.
16. Matz SO, Nibbelink G. Injuries in intercollegiate women's lacrosse. *Am J Sports Med*. 2004;32:608–611.
17. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *J Athl Train*. 2007;42:311–319.
18. Covassin T, Swanik CB, Sachs ML. Sex differences and the incidence of concussions among collegiate athletes. *J Athl Train*. 2003;38:238–244.
19. Lincoln AE, Hinton RY, Almquist JL, et al. Head, face, and eye injuries in scholastic and collegiate lacrosse: a 4-year prospective study. *Am J Sports Med*. 2007;35:207–215.
20. Lacrosse U. *Safety Issues in Girls and Womens Lacrosse*. Available at: www.uslacrosse.org. Accessed August 20, 2012.
21. Carter EA, Westerman BJ, Lincoln AE, et al. Common game injury scenarios in men's and women's lacrosse. *Int J Inj Contr Saf Promot*. 2010;17:111–118.
22. Committee ULSSaS. *Position Statement on Eye Protection in Women's Lacrosse*. Sparks, MD: USA Lacrosse, Committee ULSSaS; 2003.
23. Caine D, Caine C, Maffulli N. Incidence and distribution of pediatric sport-related injuries. *Clin J Sport Med*. 2006;16:500–513.
24. Kang L, Belcher D, Hulstyn MJ. Stress fractures of the femoral shaft in women's college lacrosse: a report of seven cases and a review of the literature. *Br J Sports Med*. 2005;39:902–906.
25. Lapidus CS, Nelson LB, Jeffers JB, et al. Eye injuries in lacrosse: women need their vision less than men? *J Trauma*. 1992;32:555–556.
26. 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;15:537–544.
27. Elkousy HA, Janssen H, Ferraro J, et al. Lacrosse goalkeeper's thumb. A preventable injury. *Am J Sports Med*. 2000;28:317–321.
28. Lincoln AE, Caswell SV, Almquist JL, et al. Effectiveness of the women's lacrosse protective eyewear mandate in the reduction of eye injuries. *Am J Sports Med*. 2012;40:611–614.
29. Caswell SV, Deivert RG. Lacrosse helmet designs and the effects of impact forces. *J Athl Train*. 2002;37:164–171.
30. Marar M, McIlvain NM, Fields SK, et al. Epidemiology of concussions among United States high school athletes in 20 sports. *Am J Sports Med*. 2012;40:747–755.
31. Waicus KM, Smith BW. Eye injuries in women's lacrosse players. *Clin J Sport Med*. 2002;12:24–29.
32. Luckstead EF, Patel DR. Catastrophic pediatric sports injuries. *Pediatr Clin North Am*. 2002;49:581–591.
33. Casazza BA, Rossner K. Baseball/lacrosse injuries. *Phys Med Rehabil Clin N Am*. 1999;10:141–157, vii.
34. Livingston LA, Forbes SL. Lacrosse stick entrapment injury to the thumb. *Br J Sports Med*. 2003;37:272–273.
35. Brown CN, Guskiewicz KM, Bleiberg J. Athlete characteristics and outcome scores for computerized neuropsychological assessment: a preliminary analysis. *J Athl Train*. 2007;42:515–523.
36. Decoster LC, Bernier JN, Lindsay RH, et al. To injury patterns among NCAA lacrosse players. *J Athl Train*. 1999;34:99–105.
37. Sherbondy PS, Hertel JN, Sebastianelli WJ. The effect of protective equipment on cervical spine alignment in collegiate lacrosse players. *Am J Sports Med*. 2006;34:1675–1679.
38. Committee ULSSaS. *Position Statement on Commotio Cordis*. Sparks, MD: USA Lacrosse, Committee ULSSaS; 2008.
39. Edlich RF Jr, Mayer NE, Fariss BL, et al. Commotio cordis in a lacrosse goalie. *J Emerg Med*. 1987;5:181–184.
40. Lacrosse U. *Youth Rules and Best Practices Guidebook for Girls*. Available at: http://content.yudu.com/web/y5b2/0A1v7bf/2015GuidebookForGirl/flash/resources/index.htm?referrerUrl=http%3A%2F%2Fcontent.yudu.com%2Fweb%2Fy5b2%2F0A1v7bf%2F2015GuidebookForGirl%2Findex.html. Accessed November 1, 2015.