

# A Comparison of High School Boys' and Girls' Lacrosse Injuries: Academic Years 2008–2009 Through 2015–2016

Keegan Warner, MS, ATC\*; Jennifer Savage, MS, ATC\*;  
Christopher M. Kuenze, PhD, ATC\*; Alexandria Erkenbeck, AN†;  
R. Dawn Comstock, PhD†; Tracey Covassin, PhD, ATC, FNATA\*

\*Michigan State University, East Lansing; †Colorado School of Public Health, Aurora

**Context:** The sex-based differences in the structure and rules of boys' and girls' lacrosse result in very different styles of play, which may have significant implications for the rates and patterns of injuries.

**Objective:** To compare the epidemiology of injuries sustained by boys' and girls' lacrosse players.

**Design:** Descriptive epidemiology study.

**Setting:** Web-based online surveillance system.

**Patients or Other Participants:** The High School Reporting Information Online database was used to analyze injuries reported by certified athletic trainers from 2008–2009 through 2015–2016.

**Main Outcome Measure(s):** Practice and competition injury rates, body site, diagnosis, and mechanism.

**Results:** Boys had a higher injury rate than girls (20.9 versus 15.7 per 10 000 athlete-exposures, respectively; rate ratio = 1.3, 95% confidence interval = 1.2, 1.4). The most commonly injured body sites for boys and girls, respectively, were the lower extremities (38.0%, 56.4%) and the head/neck (28.3%, 29.8%). More specifically, the most frequently diag-

nosed injuries for both boys and girls, respectively, in competitions were concussions (23.1%, 25.6%), ankle ligament sprains (7.8%, 15.3%), upper leg strains (4.8%, 6.7%), and knee ligament sprains (4.2%, 6.7%). The most cited mechanism of injury overall was contact with another player (22.0%); among boys, it was contact with a stick (14.8%) and among girls, the most frequent mechanisms were overuse (25.0%) and contact with a stick (14.7%).

**Conclusions:** Injury rates and mechanisms of injuries differed between high school boys' and girls' lacrosse players. Boys had a higher rate of injury, with the most common mechanism of injury being contact with another player compared with overuse in girls. However, similarities were seen between sexes for the most frequently injured body sites and injury diagnoses. Future authors should continue to compare differences in injury rates, equipment upgrades, and rule changes in boys' and girls' lacrosse.

**Key Words:** sex differences, injury rates, injury surveillance

## Key Points

- High school boys' lacrosse players had a higher injury rate than high school girls' lacrosse players.
- The most commonly injured body parts for boys and girls overall were the lower extremities and the head/neck.
- The most frequent mechanisms of injury in boys' competition were contact with another player and contact with a stick. In girls' competition, the most cited mechanisms were overuse and contact with a stick.

Lacrosse is one of the fastest growing sports in the United States. National participation in lacrosse continues to increase rapidly,<sup>1</sup> with more than 800 000 players on organized teams and high school participation at 300 000 for the first time in 2015.<sup>2</sup> Concurrent with this rapid growth in participants, the number of lacrosse injuries has also increased steadily.<sup>3,4</sup> Although boys' and girls' lacrosse share a sport name, they are considered different sports due primarily to rule variations regarding allowed levels of athlete-athlete contact and required protective equipment. In addition, the actual crosses (sticks) are fundamentally different, resulting in various levels of ball control and strategies. The sex-based differences in the structures and rules of boys' and girls' lacrosse result in very diverse styles of play, which may have significant implications for the rates and patterns of injuries.

Boys' lacrosse is a full-contact sport that allows both body and stick checking, which permits a greater amount of physical contact between players and requires them to wear protective equipment: helmets, shoulder pads, elbow pads, mouth guards, and gloves. The equipment protects the players from stick checks to the body and shots at the goal cage at higher speeds. It is important to note that the helmet does not prevent concussion but disperses blows, thereby decreasing the severity of injuries to the skull and face.

In comparison, girls' lacrosse allows only stick checking, which intentionally limits contact, and players are only required to wear protective eyewear and a mouth guard (gloves and soft-shell helmets are optional equipment). Requiring protective eyewear in girls' lacrosse has achieved the desired goal of reducing eye injuries, with a concomitant decrease in head/face injuries.<sup>5</sup> Studies of

girls' lacrosse have shown higher rates of head, face, and eye injuries, most likely because of the lack of any required head/face protection other than a mouth guard at the time.<sup>6</sup>

Although similar to a number of sports, such as football and soccer, the potential level of physical contact coupled with rapid deceleration and cutting involved in competitive lacrosse may predispose participants to a variety of injuries. Based on the recent increase in participation, especially among young individuals,<sup>2</sup> and the specific demands of the sports, it is important to understand the most common mechanisms of injury, types of diagnosed injuries, and injured body parts. By understanding the specific demands and characteristics of the sports, we can potentially develop and institute suggested guidelines specific to rule and equipment changes aimed at protecting high school athletes. Literature is available regarding the characteristics of lacrosse injuries in high school athletes, but research addressing potential sex disparities in injury characteristics is limited or nonexistent.

The characteristics of lacrosse injuries were similar at the high school and collegiate levels. At the collegiate level, the most frequently reported injuries in men's and women's lacrosse were muscle strains, ankle sprains, internal knee derangements, and concussions.<sup>3,4</sup> At the high school level, the most frequently reported injuries in boys' and girls' lacrosse were sprains/strains and concussions.<sup>6</sup> At the high school level, both sexes were more likely to sustain an injury during a game than during a practice.<sup>6</sup> In boys' lacrosse, the most common mechanism of injury was contact with another person, including activities such as general play and body checking by another person.<sup>6-8</sup> This was in contrast to girls' lacrosse, in which the most frequent mechanisms of injury were noncontact and contact with equipment (ie,rosse [stick] and ball).<sup>6-8</sup>

Although the rules are significantly different between the sports, both versions of lacrosse have the same objectives: to use the lacrosse stick to catch, cradle, and pass the ball and score by shooting the ball into an opponent's goal past the goalie. As lacrosse game rules evolve and equipment properties change, the patterns of musculoskeletal injuries may change over time.<sup>1</sup> As a result, updated injury data are needed to help drive targeted injury-prevention efforts in boys' and girls' lacrosse players. Therefore, the purpose of our study was to examine sex differences in injury rates and patterns among high school boys' and girls' lacrosse.

## METHODS

### Procedures

We analyzed data from the National High School Sports-Related Injury Surveillance System, High School Reporting Information Online (HS RIO), a large, multiyear longitudinal surveillance system that has monitored injuries among US high school athletes since the 2005–2006 academic year. The HS RIO system has collected injury and exposure data for athletes participating in 9 US high school sports (boys' baseball, basketball, football, soccer, and wrestling and girls' basketball, soccer, softball, and volleyball).<sup>9</sup> Annually, 100 high schools with certified athletic trainers (ATs) who volunteered to report data were selected for the original study sample based on a scheme intended to provide a nationally representative sample in terms of

geographic location and school enrollment ( $\leq 1000$  or  $> 1000$  students).<sup>9,10</sup> Beginning in 2008–2009, HS RIO was expanded to include 13 additional sports, including boys' and girls' lacrosse. In this expansion, any high schools offering any of the newly added sports with a certified AT willing to report data were included in a convenience sample.<sup>10</sup> To obtain the largest sample possible, schools selected into the original sample were allowed to report for any of the newly added 13 sports as well as the original 9 sports. The lacrosse data reported from schools participating in either the original or the expanded sample were included in this study. This sampling method resulted in a large, nationally dispersed convenience sample of US high schools reporting data on injuries sustained by boys' and girls' lacrosse players.<sup>10</sup>

Participating ATs receive weekly e-mails via HS RIO reminding them to complete weekly exposure reports capturing the number of athlete competitions and athlete practices, as well as the number of injuries for each sport in session at their school. For each reportable injury, ATs complete a standardized injury report capturing detailed information about the injured player, the injury, and the injury event. The ATs were able to view and update previously submitted forms as needed throughout the academic year.

### Operational Definitions

**Athlete-Exposure.** In HS RIO, an *athlete-exposure* (AE) is defined as 1 athlete participating in 1 school-sanctioned practice or competition.<sup>10</sup> The total number of AEs was calculated as the sum of the total number of practices and competitions.

**Injury.** In HS RIO, a reportable *injury* had to meet the following criteria: (1) occurred in a sanctioned practice or competition, (2) required attention from a medical professional (eg, AT or physician), and (3) resulted in restriction from participation for at least 1 day beyond the day of injury or, beginning in 2008–2009, was any fracture, concussion, or dental injury, regardless of whether it resulted in restriction of the student-athlete's participation.<sup>10</sup>

The developers of HS RIO exported the boys' and girls' lacrosse data from an 8-year period (2008–2009 through 2015–2016) to researchers at Michigan State University. Michigan State University's Institutional Review Board determined that the de-identified data from HS RIO used for these analyses were exempt from review.

### Data Analysis

Descriptive statistics (mean  $\pm$  standard deviation) were reported for all injuries incurred by boys' and girls' lacrosse players. Injury rates were calculated as the number of injuries in a particular category divided by the number of AEs in that category and presented as rates per 10 000 AEs. The boys' lacrosse injury rate was calculated as

$$\begin{aligned} & \text{Injury rate per 10 000 AEs} \\ & = \left( \frac{\text{No. of Boys' Lacrosse Injuries}}{\text{Total No. Boys' Lacrosse AEs}} \right) \times 10\,000. \end{aligned}$$

Rate ratios (RRs) were calculated to compare injury rates between boys and girls and between competitions and

**Table 1. Demographic Information for Injured Boys' and Girls' High School Lacrosse Athletes, High School Reporting Information Online, 2008–2009 Through 2015–2016**

Characteristic	Mean ± SD	
	Males	Females <sup>a</sup>
Age, y	16.2 ± 1.3	16.0 ± 1.2
Height, cm	175.3 ± 11.9	164.7 ± 8.4
Weight, kg	74.0 ± 11.9	60.1 ± 8.3

<sup>a</sup> Data from 2 athletes were deleted due to impossible values for weight (25 kg and 552 kg).

practices. Rate ratios with 95% confidence intervals (CIs) not including 1.00 were considered statistically significant. The RR comparing boys' and girls' lacrosse injury rates was calculated as

$$RR = \frac{(\text{Rate of Girls' Lacrosse Injuries})}{(\text{Rate of Boys' Lacrosse Injuries})}$$

All data analyses were conducted using SAS (version 9.4; SAS Institute Inc, Cary, NC).

## RESULTS

### Demographics

A total of 3020 lacrosse injuries were included in the analyses. Demographic information for the injured athletes is presented in Table 1. During the study period, 1950 injuries were reported in boys' lacrosse: 1211 (62.1%) were competition and 739 (37.9%) were practice injuries during 933 165 AEs (competitions = 285 299, practices = 647 866), for an overall injury rate of 20.9/10 000 AEs. Among boys, the competition injury rate (42.4/10 000 AEs) was higher than the practice injury rate (11.4/10 000 AEs, RR = 3.7, 95% CI = 3.4, 4.1). Girls' lacrosse athletes sustained a total of 1070 injuries: 555 (51.9%) from competitions and 515 (48.1%) from practices during 683 183 AEs (competitions = 211 885, practices = 471 298), for an overall injury rate of 15.7/10 000 AEs. Among girls, the competition injury rate (26.2/10 000 AEs) was higher than the practice injury rate (10.9/10 000 AEs, RR = 2.1, 95% CI = 2.1, 2.7).

### Body Part Injured and Injury Diagnosis

Among boys, the lower extremity was the most commonly injured body part overall (38.0% of all injuries) and during practices (50.2%); however, the head/neck was the most often injured body part during competitions (34.9%; Table 2). Among girls, the lower extremity was the most frequently injured body part overall (56.4%) and during practices (67.0%) and competitions (46.7%).

More specifically, the most typical injuries among boys were concussions during both competitions (29.3%) and practices (13.0%), whereas the most common injuries among girls during competitions were concussions (35.0%) and during practices were ankle ligament sprains (15.4%; Table 3).

### Mechanism of Injury

Among boys, the most common mechanism of injury was contact with another player during competitions (45.7% of

**Table 2. Percentages of Competition and Practice Injuries by Body Part Injured, High School Reporting Information Online, 2008–2009 Through 2015–2016**

Body Part Injured <sup>a,b</sup>	Sex	No. (%)		
		Competitions	Practices	Overall
Lower extremity	Boys	370 (30.7)	371 (50.2)	741 (38.0)
	Girls	259 (46.7)	345 (67.0)	604 (56.4)
Head/neck	Boys	423 (34.9)	128 (17.3)	551 (28.3)
	Girls	216 (38.9)	103 (20.0)	319 (29.8)
Upper extremity	Boys	238 (19.7)	134 (18.1)	372 (19.1)
	Girls	60 (10.8)	22 (4.3)	82 (7.6)
Trunk/back	Boys	168 (13.9)	91 (12.3)	259 (13.3)
	Girls	15 (2.7)	37 (7.2)	52 (4.9)
Other	Boys	8 (0.7)	15 (2.0)	23 (1.2)
	Girls	3 (0.5)	7 (1.4)	10 (1)
All body parts <sup>c</sup>	Boys	1211 (62.1)	739 (37.9)	1950 (100.0)
	Girls	555 (51.9)	515 (48.1)	1070 (100.0)

<sup>a</sup> Lower extremity includes thigh/upper leg, knee, lower leg, ankle, foot/toe. Head/neck includes head/face, neck/cervical spine, and mouth/teeth. Upper extremity includes shoulder, upper arm, elbow forearm, wrist, hand/finger. Trunk/back includes chest/thoracic spine/pelvis, abdomen, lower back/lumbar spine/pelvis, hip. Other includes other and male genitalia.

<sup>b</sup> Table is organized by most to least common body part injured.

<sup>c</sup> Due to a small number of records with missing data for body part, data may not sum to the totals for each sex.

all competition injuries) and overuse during practices (28.3%), whereas the most frequent mechanism of injury among girls was contact with the crosse during competitions (24.2%) and overuse during practices (42.8%; Table 4).

### Injury Rates by Sex

Overall, boys (20.9/10 000 AEs) had a higher injury rate than girls (15.7/10 000 AEs, RR = 1.3, 95% CI = 1.2, 1.4). This sex difference was even greater during competitions (boys = 42.4/10 000 AEs, girls = 26.2/10 000 AEs, RR = 1.6, 95% CI = 1.5, 1.8); a similar but nonsignificant trend was observed during practices (boys = 11.4/10 000 AEs, girls = 10.9, RR = 1.0, 95% CI = 0.9, 1.2; Table 3). More specifically, boys had higher rates of concussions (RR = 1.2, 95% CI = 1.0, 1.4), hand fractures (RR = 4.0, 95% CI = 2.3, 6.8), low back strains (RR = 2.7, 95% CI = 1.2, 5.8), clavicle fractures (RR = 18.7, 95% CI = 4.5, 76.7), lower leg contusions (RR = 3.7, 95% CI = 1.4, 9.6), hip muscle strains (RR = 2.1, 95% CI = 1.0, 4.4), and shoulder ligament sprains (RR = 6.1, 95% CI = 1.8, 20.2) than girls. Boys and girls had similar rates of knee ligament sprains (RR = 0.8, 95% CI = 0.6, 1.1) and upper leg muscle-tendon strains (RR = 1.0, 95% CI = 0.7, 1.3). Girls were more likely to sustain ankle ligament sprains (RR = 0.7, 95% CI = 0.5, 0.8) and to develop knee tendinitis (RR = 0.3, 95% CI = 0.2, 0.7).

### Injury Rates by Type of Activity

When comparing competition with practice injury rates, we found that competition injury rates among boys were higher for concussions (12.4 versus 1.5 injuries/10 000 AEs, RR = 8.4, 95% CI = 6.7, 10.5), knee ligament sprains (1.9 versus 0.4/10 000 AEs, RR = 4.8, 95% CI = 3.0, 7.7), ankle ligament sprains (3.0 versus 1.0/10 000 AEs, RR = 3.0, 95%

**Table 3. Specific Injury Diagnoses, Rates, and Rate Ratios for Competitions Versus Practices and Boys' Versus Girls' Injuries, High School Reporting Information Online, 2008–2009 Through 2015–2016**

Specific Injury Diagnosis	Sex	Injuries, No. (%)				Rate per 10 000 Athlete-Exposures			Rate Ratio (95% Confidence Interval)		
		Competitions	Practices	Total	Competitions	Practice	Total	Competitions Versus Practices	Boys Versus Girls (Total Injuries)		
		354 (29.3)	96 (13.0)	450 (23.1)	12.4	1.5	4.8	8.4 (6.7, 10.5)	1.2 (1.0, 1.4)		
Concussion	Boys	194 (35.0)	79 (15.4)	273 (25.5)	9.2	1.7	4.0	5.5 (4.2, 7.1)	NA		
	Girls	85 (7.0)	67 (9.1)	152 (7.8)	3.0	1.0	1.6	3.0 (2.1, 4.0)	0.7 (0.5, 0.8)		
Ankle ligament sprain	Boys	80 (14.4)	84 (16.4)	164 (15.3)	3.8	1.8	2.4	2.1 (1.6, 2.9)	NA		
	Girls	41 (3.4)	53 (7.2)	94 (4.8)	1.4	0.8	1.0	1.8 (1.2, 2.6)	1.0 (0.7, 1.3)		
Upper leg muscle or ligament strain	Boys	20 (3.6)	51 (9.9)	71 (6.7)	0.9	1.1	1.0	0.9 (0.5, 1.5)	NA		
	Girls	55 (4.5)	26 (3.5)	81 (4.2)	1.9	0.4	0.9	4.8 (3.0, 7.7)	0.8 (0.6, 1.1)		
Knee ligament sprain	Boys	61 (11.0)	10 (2.0)	71 (6.7)	2.9	0.2	1.0	13.6 (7.0, 26.5)	NA		
	Girls	42 (3.5)	35 (4.7)	77 (4.0)	1.5	0.5	0.8	2.7 (1.7, 4.3)	4.0 (2.3, 6.8)		
Hand fracture	Boys	12 (2.2)	4 (0.8)	16 (1.5)	0.6	0.1	0.2	6.7 (2.2, 20.7)	NA		
	Girls	34 (2.8)	17 (2.3)	51 (2.6)	1.2	0.3	0.5	4.5 (2.5, 8.1)	18.7 (4.5, 76.7)		
Clavicle fracture	Boys	1 (0.2)	1 (0.2)	2 (0.2)	0.0	0.0	0.0	NA	NA		
	Girls	13 (1.1)	16 (2.2)	29 (1.5)	0.5	0.2	0.3	1.8 (0.9, 3.8)	2.1 (1.0, 4.4)		
Hip muscle strain	Boys	4 (0.7)	6 (1.2)	10 (0.9)	0.2	0.1	0.1	1.5 (0.4, 5.3)	NA		
	Girls	12 (1.0)	17 (2.3)	29 (1.5)	0.4	0.3	0.3	1.6 (0.8, 3.4)	2.7 (1.2, 5.8)		
Low back muscle or tendon strain	Boys	1 (0.18)	7 (1.4)	8 (0.8)	0.0	0.1	0.1	NA	NA		
	Girls	23 (1.9)	4 (0.5)	27 (1.4)	0.8	0.1	0.3	13.0 (4.5, 37.8)	0.05 (0.02, 1.0)		
Chest contusion	Boys	2 (0.4)	0 (0.0)	2 (0.2)	0.1	0.0	0.0	NA	NA		
	Girls	20 (1.7)	10 (1.3)	25 (1.3)	0.7	0.2	0.3	4.5 (2.1, 9.7)	6.1 (1.8, 20.2)		
Shoulder ligament sprain	Boys	2 (0.4)	1 (0.2)	3 (0.3)	0.1	0.0	0.0	NA	NA		
	Girls	1 (0.1)	8 (1.1)	9 (0.5)	0.0	0.1	0.1	0.3 (0.0, 2.3)	0.3 (0.2, 0.7)		
Knee tendinitis	Boys	1 (0.2)	19 (3.7)	20 (1.9)	0.0	0.4	0.3	0.1 (0.02, 0.9)	NA		
	Girls	20 (1.7)	5 (0.7)	25 (1.3)	0.7	0.1	0.3	0.5 (0.2, 1.2)	3.7 (1.4, 9.6)		
Lower leg contusion	Boys	4 (0.7)	1 (0.2)	5 (0.5)	0.2	0.0	0.1	NA	NA		
	Girls	1211 (62.1)	739 (37.9)	1950	42.4	11.4	20.9	3.7 (3.4, 4.1)	1.3 (1.2, 1.4)		
Overall	Boys	555 (51.9)	515 (48.1)	1070	26.2	10.9	15.7	2.1 (2.1, 2.7)	NA		

Abbreviation: NA, not available.

**Table 4. Mechanism of Injury During Competitions and Practices for Boys' and Girls' Lacrosse, High School Reporting Information Online, 2008–2009 Through 2015–2016, No. (%)**

Mechanism of Injury	Sex	Competitions	Practices	Total
Contact with player	Boys	542 (45.7)	159 (22.1)	701 (22.0)
	Girls	105 (19.6)	16 (3.3)	121 (11.8)
Overuse	Boys	73 (6.2)	204 (28.3)	277 (14.5)
	Girls	47 (8.8)	210 (42.8)	257 (25.0)
Contact with stick	Boys	210 (17.7)	72 (10.0)	282 (14.8)
	Girls	130 (24.2)	21 (4.3)	151 (14.7)
Inversion/rotation around planted foot	Boys	124 (10.5)	96 (13.3)	220 (11.5)
	Girls	108 (20.1)	86 (17.5)	194 (18.9)
Contact with ball	Boys	61 (5.1)	80 (11.1)	141 (7.4)
	Girls	54 (10.1)	76 (15.5)	130 (12.7)
Other	Boys	91 (7.7)	55 (7.7)	146 (7.7)
	Girls	45 (10.1)	32 (6.5)	77 (7.5)
Stepped on/fell on/kicked	Boys	61 (5.1)	24 (3.3)	85 (4.5)
	Girls	33 (6.2)	19 (3.9)	52 (5.1)
Uneven playing surface	Boys	24 (2.0)	27 (3.8)	51 (2.7)
	Girls	15 (2.8)	30 (6.1)	45 (4.4)
Contact with goal	Boys	1 (0.1)	3 (0.4)	4 (0.2)
	Girls	0 (0.0)	1 (0.2)	1 (0.1)
Total	Boys	1187 (62.2)	720 (37.8)	1907 (100.0)
	Girls	537 (52.2)	491 (47.8)	1028 (100.0)

CI = 2.1, 4.0), chest contusions (0.8 versus 0.1/10 000 AEs, RR = 13.0, 95% CI = 4.5, 37.8), hand fractures (1.5 versus 0.5/10 000 AEs, RR = 2.7, 95% CI = 1.7, 4.3), clavicle fractures (1.2 versus 0.3/10 000 AEs, RR = 4.5, 95% CI = 2.5, 8.1), and upper leg muscle-tendon strains (1.4 versus 0.8/10 000 AEs, RR = 1.8, 95% CI = 1.2, 2.6; Table 3). Competition injury rates among girls were higher for knee ligament sprains (2.9 versus 0.2 injuries/10 000 AEs, RR = 13.6, 95% CI = 7.0, 26.5), concussions (9.2 versus 1.7, RR = 5.5, 95% CI = 4.2, 7.1), and ankle ligament sprains (3.8 versus 1.8, RR = 2.1, 95% CI = 1.6, 2.9).

## DISCUSSION

Injury rates and patterns varied between high school boys' and girls' lacrosse players. For example, boys had higher injury rates overall, during competitions, and during practices, while also having higher rates of several specific injuries: concussions, shoulder sprains, and hand fractures. Additionally, the mechanisms of injuries differed, with boys most likely to be injured due to contact with another athlete during both competitions and practices, while girls were most likely to be injured by contact with a crosse during competitions and by overuse during practices. These trends are consistent with the diverse styles of play that result from the differences in rules and required versus allowed protective equipment.

The majority of injuries among both boys' and girls' high school lacrosse occurred during competitions compared with practices. These findings are similar to those of previous authors<sup>5,10</sup> who reported that both boys and girls were more likely to sustain injuries during competitions. Competition injury rates were likely higher due to the increase in player intensity and the length of continuous play in game situations compared with practices.<sup>11</sup> The intensity of play is less during practices because of the drills and scrimmages that are similar to game conditions and noncontact drills, instruction, and conditioning.<sup>11</sup> Injury rates may also be higher during competitions because players are more aggressive.<sup>11</sup> Although this factor

has not been clearly described in lacrosse, similar trends in the disparity between practice and competition injury rates were evident in soccer players.<sup>12,13</sup> Future researchers examining the specific aspects or actions during which injuries occur in practices versus competitions may provide integral information for developing injury-prevention strategies targeted at lacrosse athletes.

The lower body and head/face were the most commonly injured body parts for both girls' and boys' lacrosse participants. These results are similar to those of Xiang et al<sup>6</sup> in regard to injuries to the head/face (25.2%); however, they contrast with that study's findings regarding lower body injuries. We noted almost twice as many injuries to the lower extremity as Xiang et al<sup>6</sup> did. Higher rates of injuries to the lower extremity have been linked to uneven playing surfaces, high speeds, rapid cutting, and deceleration associated with game play.<sup>12</sup> In addition, the approach phase of a lacrosse shot results in rapid lower extremity deceleration on a planted leg, which is a common mechanism for knee and ankle joint sprains.<sup>13</sup> The similarities between lacrosse and other field-based cutting sports, such as football or soccer, provide a clear rationale for the higher rates of lower extremity sprains reported in this investigation as well as in previously published work.<sup>12,13</sup> Interventions such as neuromuscular training and movement feedback have been effective in reducing rates of lower extremity sprains among soccer athletes.<sup>13</sup> Thus, implementation of similar programs among lacrosse athletes may result in a reduction in lower extremity injuries.

We observed that boys' lacrosse athletes had higher injury rates than girls' lacrosse athletes. These results are similar to those of previous investigators,<sup>6</sup> who demonstrated that the majority of injuries occurred in high school boys' lacrosse compared with girls' lacrosse. In our study, boys were more likely to sustain concussions, shoulder sprains, and hand fractures than girls. This is because boys' lacrosse is a full-contact sport, whereas most contact is specifically prohibited in girls' lacrosse. Further explana-

tion of a higher number of injuries in boys' lacrosse players is provided by the most common mechanism of injury in both competition and injury being contact with another player, whereas girls were most likely to be injured by contact with the crosse in competitions and by overuse in practices.<sup>6</sup> The differences in rules result in different styles of play and speeds of each game. These findings indicate the need for targeted injury-prevention efforts (eg, strengthening the core and lower extremity, dynamic warm-up) to decrease the athletes' risk of a lower extremity injury.

Currently, the most debated injury-prevention topic in lacrosse is whether helmets should be required protective equipment in the girls' sport, and if so, what type of helmet is best.<sup>3,7,14-17</sup> The spring of 2017 marked the arrival of long-awaited new headgear designed specifically for girls' lacrosse. The Web site of US Lacrosse, the sport's governing body, stated, "The ASTM [American Society for Testing and Materials] standard is the first ever performance standard for women's lacrosse headgear, developed to help reduce impact forces associated with stick and ball contact in women's lacrosse."<sup>18(p1)</sup> Previous researchers<sup>1,19</sup> used video analysis to obtain an objective and comprehensive visual record for identifying the mechanisms of injury, game characteristics, and penalties associated with head injuries in high school girls' and boys' lacrosse. The absence of penalty calls on most of the plays suggests an area for exploration, such as the extent to which the current rules are enforced and the effectiveness of the existing rules for preventing head injury.<sup>19</sup> Further investigation of preventive measures, such as education of coaches and officials and enforcement of rules designed to prevent intentional head-to-head contact, is warranted to reduce the incidence of concussions in boys' lacrosse.<sup>19</sup> Future authors should evaluate the results of the Florida High School Athletic Association's decision to require soft-shell helmets in girls' lacrosse. In addition, examining future headgear mandates will be helpful in determining whether these measures affect reported head injuries or have unintended consequences for other types of injuries. In boys' lacrosse, it will be important to assess the effectiveness of new streamlined helmets in preventing concussions and new technology applied to stick shafts in preventing hand fractures. The effects of recent rule changes on player safety and game integrity should also be evaluated. For example, in 2013, US Lacrosse decreased the number of players in the draw circle for girls' lacrosse from 4 per team to 2; the effectiveness of this rule change has not yet been measured.

Our study had several limitations. First, the HS RIO database included only high schools that employed an AT; thus, these findings may not be generalizable to all high schools. Second, this dataset includes only time-loss injuries, concussions, fractures, and dental injuries that came to the attention of ATs. Therefore, the injury rates reported here are undoubtedly an underestimate of the true injury rates among high school boys' and girls' lacrosse players. Third, HS RIO captures only those injuries associated with high school-sanctioned practices and competitions. Hence, the injury rates and patterns presented here should not be generalized to other populations, such as younger age groups and club lacrosse programs. Finally, sex or activity comparisons of categories that had small

numbers of injuries (ie, lower leg contusions, hand fractures, and shoulder ligament sprains) resulted in unstable rate ratios. These findings should be interpreted with caution, as they could be misleading.

## CONCLUSIONS

Differences in injury rates and patterns between boys' and girls' lacrosse players were evident. Boys' lacrosse allows body and stick checking and requires helmets with a face shield, shoulder pads, mouth guards, and gloves, whereas girls' lacrosse players are required to wear only protective eyewear and mouth guards and are allowed only minimal stick checking. Boys' lacrosse players sustained concussions, shoulder sprains, and hand fractures at higher rates than girls' lacrosse players. Despite differences in the rules, required protective equipment, and resultant styles of play, among both groups, the most commonly diagnosed injuries were concussions, ankle ligament sprains, upper leg strains, and knee ligament sprains, which were more likely to occur during competitions than practices. To promote safe participation in lacrosse for all high school athletes, differences and similarities in sex-based injury characteristics should be considered when developing injury-prevention efforts such as rules changes, coach and official education, and protective equipment.

## REFERENCES

1. Vincent HK, Zdziarski LA, Vincent KR. Review of lacrosse-related musculoskeletal injuries in high school and collegiate players. *Sports Health*. 2015;7(5):448-451.
2. Participation survey. US Lacrosse Web site. <http://www.uslacrosse.org/sites/default/files/public/documents/about-us-lacrosse/participation-survey-2015.pdf>. Accessed February 8, 2017.
3. Dick R, Lincoln AE, Agel J, Carter EE, Marshall SW, Hinton RY. 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(2):262-269.
4. Dick R, Romani WA, Agel J, Case JG, Marshall SW. Descriptive epidemiology of collegiate men's lacrosse injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. *J Athl Train*. 2007;42(2):255-261.
5. 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(3):611-614.
6. Xiang J, Collins CL, Liu D, McKenzie LB, Comstock RD. Lacrosse injuries among high school boys and girls in the United States: academic years 2008-2009 through 2011-2012. *Am J Sports Med*. 2014;42(9):2082-2088.
7. 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(2):207-215.
8. Hinton RY, Lincoln AE, Almquist JL, Douougih WA, Sharma KM. Epidemiology of lacrosse injuries in high school-aged girls and boys: a 3-year prospective study. *Am J Sports Med*. 2005;33(9):1305-1314.
9. Gessel LM, Fields SK, Collins CL, Dick RW, Comstock RD. Concussions among united states high school and collegiate athletes. *J Athl Train*. 2007;42(4):495-503.
10. 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(4):747-755.

11. Rechel JA, Yard EE, Comstock RD. An epidemiologic comparison of high school sports injuries sustained in practice and competition. *J Athl Train*. 2008;43(2):197–204.
12. Ekstrand J, Hägglund M, Waldén M. Epidemiology of muscle injuries in professional football (soccer). *Am J Sports Med*. 2011;39(6):1226–1232.
13. Rahnama N, Reilly T, Lees A. Injury risk associated with playing actions during competitive soccer. *Br J Sports Med*. 2002;36(5):354–359.
14. 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(6):537–544.
15. Otago L, Adamcewicz E, Eime R, Maher S. The epidemiology of head, face and eye injuries to female lacrosse players in Australia. *Int J Inj Contr Saf Promot*. 2007;14(4):259–261.
16. Lapidus CS, Nelson LB, Jeffers JB, Kay M, Schwarz DF. Eye injuries in lacrosse: women need their vision less than men? *J Trauma*. 1992;32(5):555–556.
17. Harmer P. Protective equipment in women's lacrosse: a conflict between the sanctity of the game and the safety of the players. *Sport Health*. 1993;11:14.
18. Kelley C. Womens lacrosse headgear FAQ. US Lacrosse Web site. <https://www.uslacrosse.org/safety/equipment/womens-lacrosse-headgear-faq>. Accessed February 12, 2017.
19. 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(4):756–761.

---

Address correspondence to Tracey Covassin, PhD, ATC, FNATA, Michigan State University, 105 IM Sports Circle, East Lansing, MI 48824. Address e-mail to [covassin@msu.edu](mailto:covassin@msu.edu).