Journal of Athletic Training 2019;54(1):42–54
doi: 10.4085/1062-6050-201-17

www.natajournals.org

The First Decade of Web-Based Sports Injury Surveillance: Descriptive Epidemiology of Injuries in US High School Girls' Lacrosse (2008–2009 Through 2013–2014) and National Collegiate Athletic Association Women's Lacrosse (2004–2005 Through 2013–2014)

Lauren A. Pierpoint, MS*; Shane V. Caswell, PhD, ATC†; Nina Walker, MA, LAT, ATC‡; Andrew E. Lincoln, ScD, MS§; Dustin W. Currie, MPH*; Sarah B. Knowles, PhD, MPH||; Erin B. Wasserman, PhD¶; Thomas P. Dompier, PhD, LAT, ATC#; R. Dawn Comstock, PhD; Stephen W. Marshall, PhD††‡‡; Zachary Y. Kerr, PhD, MPH‡‡§§**

*Department of Epidemiology, Colorado School of Public Health, University of Colorado Anschutz, Aurora; †Sports Medicine Assessment, Research & Testing (SMART) Laboratory, George Mason University, Manassas, VA; ‡Department of Sports Medicine, ††Department of Epidemiology, ‡‡Injury Prevention Research Center, and §§Department of Exercise and Sport Science, University of North Carolina at Chapel Hill; §MedStar Sports Medicine Research Center, Baltimore, MD; ||Palo Alto Medical Foundation Research Institute, CA; ¶Datalys Center for Sports Injury Research and Prevention, Inc, Indianapolis, IN; #Department of Athletic Training, Lebanon Valley College, Annville, PA; **Department of Pediatrics, University of Colorado School of Medicine, Aurora

Context: The advent of Web-based sports injury surveillance via programs such as the High School Reporting Information Online (HS RIO) system and the National Collegiate Athletic Association Injury Surveillance Program (NCAA-ISP) has aided the acquisition of girls' and women's lacrosse injury data.

Objective: To describe the epidemiology of injuries sustained in high school girls' lacrosse in the 2008–2009 through 2013–2014 academic years and collegiate women's lacrosse in the 2004–2005 through 2013–2014-academic years using Web-based sports injury surveillance.

Design: Descriptive epidemiology study.

Setting: Online injury surveillance from high school girls' (annual average = 55) and collegiate women's (annual average = 19) lacrosse teams.

Patients or Other Participants: Female lacrosse players who participated in practices or competitions during the 2008–2009 through 2013–2014 academic years for high school or the 2004–2005 through 2013–2014 academic years for college.

Main Outcome Measure(s): Athletic trainers collected time-loss injury (≥24 hours) and exposure data. We calculated injury rates per 1000 athlete-exposures (AEs), injury rate ratios (IRRs) with 95% confidence intervals (CIs), and injury proportions by body site and diagnosis.

Results: High school RIO documented 700 time-loss injuries during 481 687 AEs; the NCAA-ISP documented 1027 time-loss injuries during 287 856 AEs. The total injury rate during 2008–2009 through 2013–2014 was higher in college than in high school (2.55 versus 1.45/1000 AEs; IRR = 1.75; 95% CI = 1.54, 1.99). Most injuries occurred during competitions in high school (51.1%) and practices in college (63.8%). Rates were higher during competitions compared with practices in high school (IRR = 2.32; 95% CI = 2.00, 2.69) and college (IRR = 2.38; 95% CI = 2.09, 2.70). Concussion was the most common diagnosis among all high school and most collegiate player positions, and the main mechanism of contact was with a playing apparatus (eg, stick, ball). Ligament sprains were also common (HS RIO practices = 22.2%, competitions = 30.3%; NCAA-ISP practices = 25.5%, competitions = 30.9%).

Conclusions: Rates of injury were higher in college versus high school female lacrosse players and in competitions versus practices. Injury-prevention strategies are essential to decrease the incidence and severity of concussions and ligament sprains.

Key Words: injury surveillance, females, concussion

Key Points

- The rate of injury in collegiate women's lacrosse exceeded that of high school girls' lacrosse.
- Competition injury rates were higher than practice injury rates.
- Concussion was a common injury during competitions, representing 35.0% and 21.2% of all injuries at the high school and collegiate levels, respectively.

Girls' and women's lacrosse in high school and college has increased in popularity over the past decade. Participation at the collegiate level increased from 264 teams and 5746 players in 2004–2005 to 443 teams and 10 330 players in 2013–2014, corresponding to a 67.8% increase in the number of teams and a 79.8% increase in the number of players.[1] Similarly, at the high school level, girls' lacrosse participation increased from 108 079 players in 2004–2005 to 188 689 players in 2013–2014, a 74.6% increase.[2,3] As participation continues to increase, it is important to research injury rates and patterns in both age groups so as to drive effective and targeted injury-prevention efforts.

The National Collegiate Athletic Association (NCAA) has used injury surveillance since the 1980s to acquire collegiate sports injury data to assist in the development of evidence-based injury-prevention strategies. Although this NCAA-based surveillance system has had several names, we herein denote it as the *NCAA Injury Surveillance Program* (ISP). Since the 2004–2005 academic year, the NCAA has used a Web-based platform to collect collegiate sports injury and exposure data via athletic trainers (ATs).[4] A year later, High School Reporting Information Online (HS RIO), a similar Web-based high school sports injury-surveillance system, was launched.[5]

As denoted in the van Mechelen et al[6] framework, injury prevention benefits from ongoing monitoring of injury incidence, and updated descriptive epidemiology is needed. Furthermore, over the past decade, rule changes have been enforced to help reduce the incidence of injury. Lastly, prior researchers have mainly focused on injuries occurring within age groups, and few comparisons exist for the injury epidemiology of lacrosse injuries across the age spectrum. The purpose of this article is to summarize the descriptive epidemiology of injuries sustained in high school girls' and collegiate women's lacrosse during the first decade of Web-based sports injury surveillance (2004–2005 through 2013–2014 academic years).

METHODS

Data Sources and Study Period

We used data collected by HS RIO and the NCAA-ISP, sports injury-surveillance programs for the high school and collegiate levels, respectively. Use of HS RIO data was approved by the Nationwide Children's Hospital Subjects Review Board (Columbus, OH). Use of the NCAA-ISP data was approved by the Research Review Board at the NCAA.

An average of 55 high schools sponsoring girls' lacrosse participated in HS RIO during the 2008–2009 through 2013–2014 academic years (2008–2009 was the first year HS RIO collected data for the sport). An average of 19 NCAA member institutions (Division I = 9, Division II = 1, Division III = 9) that sponsored women's lacrosse participated in the NCAA-ISP during the 2004–2005 through 2013–2014 academic years. The methods of HS RIO and the NCAA-ISP are summarized in the following paragraphs. In-depth information on the methods and analyses for this special series of articles on Web-based sports injury surveillance can be found in the previously published methodologic article.[7] In addition, previous publications have described in depth the sampling and data collection of HS RIO[5,8] and the NCAA-ISP.[4]

High School RIO

High School RIO consists of a sample of high schools with 1 or more National Athletic Trainers' Association–affiliated ATs with valid e-mail addresses. The ATs from participating high schools reported injury incidence and athlete-exposure (AE) information weekly throughout the academic year using a secure Web site. For each injury, the AT completed a detailed report on the injured athlete (age, height, weight, etc), the injury (site, diagnosis, severity, etc), and the injury event (activity, mechanism, etc). Throughout each academic year, participating ATs were able to view and update previously submitted reports as needed with new information (eg, time loss).

High School RIO has 2 data-collection panels: a random sample of 100 schools recruited annually since 2005–2006 that report data for the 9 original sports of interest (boys' baseball, basketball, football, soccer, and wrestling, and girls' basketball, soccer, softball, and volleyball) and an additional convenience sample of schools recruited annually since 2008–2009 that report data for the additional sports of interest (eg, boys' ice hockey and lacrosse, girls' field hockey and lacrosse). For the first panel, high schools were recruited into 8 strata based on school population (enrollment $\leq$1000 or $>$1000) and US Census geographic region.[9] If a school dropped out of the system, a replacement from the same stratum was selected. For the second panel, it was impossible to approximate a nationally representative random sample due to strong regional variations in sport sponsorship (eg, ice hockey). As a result, exposure and injury data for the schools in the second panel represent a convenience sample of US high schools. Athletic trainers at some schools from the first panel, those enrolled in the original random sample, choose to report for more than the original 9 sports of interest, and ATs at some of the schools from the second panel report for some of the original 9 sports as well as the additional sports of interest. Those schools' data provided the original and convenience samples from girls' lacrosse.

National Estimates. National injury estimate weights were not created for girls' lacrosse, and thus, national estimates could not be computed.

National Collegiate Athletic Association Injury Surveillance Program

The NCAA-ISP depends on a convenience sample of teams with ATs voluntarily reporting injury and exposure data.[4] Participation in the NCAA-ISP, although voluntary, is available to all NCAA institutions. For each injury event, the AT completes a detailed event report on the injury or condition (eg, site, diagnosis) and the circumstances (eg, activity, mechanism, event type [ie, competition or practice]). The ATs are able to view and update previously submitted information as needed during the course of a season. In addition, ATs also provide the number of student-athletes participating in each practice and competition. Data collection for the 2004–2005 through 2013–2014 academic years is described in the next paragraph.

During the 2004–2005 through 2008–2009 academic years, ATs used a Web-based platform launched by the NCAA to track injury and exposure data.[4] This platform integrated some of the functional components of an electronic medical record, such as athlete demographic information and preseason injury information. During the 2009–2010 through 2013–2014 academic years, the Datalys Center for Sports Injury Research and Prevention, Inc (Datalys Center, Indianapolis, IN), introduced a common data element (CDE) standard to improve process flow. The CDE standard allowed data to be gathered from different electronic medical record and injury-documentation applications, including the Athletic Trainer System (Keffer Development, Grove City, PA), Injury Surveillance Tool (Datalys Center), and Sports Injury Monitoring System (FlanTech, Iowa City, IA). The CDE export standard allowed ATs to document injuries as they normally would during their daily clinical practice, as opposed to asking them to report injuries solely for the purpose of participation in an injury-surveillance program. Data were deidentified and sent to the Datalys Center, where they were examined by data quality-control staff and a verification engine.

National Estimates. To calculate national estimates of the number of injuries and AEs, poststratification sample weights, based on sport, division, and academic year, were applied to each reported injury and AE. Weights for all data were further adjusted to correct for underreporting, according to the findings of Kucera et al,[10] who estimated that the NCAA-ISP captured 88.3% of all time-loss medical-care injury events. Weighted counts were scaled up by a factor of (0.883^{-1}).

Definitions

Injury. A reportable *injury* in both HS RIO and the NCAA-ISP was defined as an injury that (1) occurred as a result of participation in an organized practice or competition, (2) required medical attention by a certified AT or physician, and (3) resulted in restriction of the student-athlete's participation for 1 or more days beyond the day of injury. Since the 2007–2008 academic year, HS RIO has also captured all concussions, fractures, and dental injuries, regardless of time loss. In the NCAA-ISP, multiple injuries occurring from 1 injury event could be included, whereas in HS RIO, only the principal injury was captured. Beginning in the 2009–2010 academic year, the NCAA-ISP also began to monitor all non–time-loss injuries. A *non–time-loss injury* was defined as any injury that was evaluated or treated (or both) by an AT or physician but did not result in restriction from participation beyond the day of injury. However, because HS RIO captures only time-loss injuries (to reduce the burden on high school ATs), for this series of publications, only time-loss injuries (with the exception of concussions, fractures, and dental injuries as noted) were included.

Athlete-Exposure. For both surveillance systems, a reportable *AE* was defined as 1 student-athlete participating in 1 school-sanctioned practice or competition during which he or she was exposed to the possibility of athletic injury, regardless of the time associated with that participation. Preseason scrimmages were considered practice exposures, not competition exposures.

Statistical Analysis

Data were analyzed using Enterprise Guide software (version 5.4; SAS Institute Inc, Cary, NC). Because the data collected from HS RIO and the NCAA-ISP are similar, we opted to recode data when necessary to increase the comparability between high school and collegiate student-athletes. We also opted to ensure that categorizations were consistent among all sport-specific articles within this special series. Because methodologic variations may lead to small differences in injury reporting between these surveillance systems, the results must be interpreted with caution.

We examined injury counts, national estimates (for college only), and distributions by event type (practices and competitions), time in season (preseason, regular season, postseason), time loss (1–6 days, 7–21 days, more than 21 days, including injuries resulting in a premature end to the season), body part injured, diagnosis, mechanism of injury, activity during injury, and position.

We also calculated injury rates per 1000 AEs and injury rate ratios (IRRs). The IRRs focused on comparisons by level of play (high school and college), event type (practice and competition), size of high school ($\leq$1000 and $>$1000 students), division in college (Divisions I, II, and III), and time in season (preseason, regular season, and postseason). For the IRR comparing high school and college, because HS RIO only had data available for 2008–2009 through 2013–2014, we considered only the NCAA-ISP data from that time period as well. All IRRs with 95% confidence intervals (CIs) not containing 1.0 were considered statistically significant.

Lastly, we used linear regression to analyze linear trends of injury rates across time and compute average annual changes (ie, mean differences). Because of the 2 data-collection methods for the NCAA-ISP during the 2004–2005 through 2008–2009 and 2009–2010 through 2013–2014 academic years, linear trends were analyzed separately for each time period. All mean differences with 95% CIs not containing 0.0 were considered statistically significant.

RESULTS

Total Injury Frequency and Injury Rates

During the 2008–2009 through 2013–2014 academic years, ATs reported a total of 700 time-loss injuries among high school girls' lacrosse players (Table 1). During the

Table 1. Injury Rates by School Size or Division and Type of Athlete-Exposure in High School Girls' and Collegiate Women's Lacrosse[a]

Surveillance System and School Size or Division	Exposure Type	Injuries in Sample, No. (%)	Athlete-Exposures	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
HS RIO (2008–2009 through 2013–2014)				
≤1000 students	Practices	139 (47.6)	135 130	1.03 (0.86, 1.20)
	Competitions	153 (52.4)	58 259	2.63 (2.21, 3.04)
	Total	292 (100.0)	193 389	1.51 (1.34, 1.68)
>1000 students	Practices	203 (49.8)	196 765	1.03 (0.89, 1.17)
	Competitions	205 (50.2)	91 533	2.24 (1.93, 2.55)
	Total	408 (100.0)	288 298	1.42 (1.28, 1.55)
Total	Practices	342 (48.9)	331 895	1.03 (0.92, 1.14)
	Competitions	358 (51.1)	149 792	2.39 (2.14, 2.64)
	Total	700 (100.0)	481 687	1.45 (1.35, 1.56)
NCAA-ISP (2004–2005 through 2013–2014)				
Division I	Practices	368 (65.9)	150 007	2.45 (2.20, 2.70)
	Competitions	190 (34.1)	31 908	5.95 (5.11, 6.80)
	Total	558 (100.0)	181 915	3.07 (2.81, 3.32)
Division II	Practices	23 (62.2)	9033	2.55 (1.51, 3.59)
	Competitions	14 (37.8)	2180	6.42 (3.06, 9.79)
	Total	37 (100.0)	11 213	3.30 (2.24, 4.36)
Division III	Practices	264 (61.1)	73 310	3.60 (3.17, 4.04)
	Competitions	168 (38.9)	21 419	7.84 (6.66, 9.03)
	Total	432 (100.0)	94 728	4.56 (4.13, 4.99)
Total	Practices	655 (63.8)	232 350	2.82 (2.60, 3.03)
	Competitions	372 (36.2)	55 507	6.70 (6.02, 7.38)
	Total	1027 (100.0)	287 856	3.57 (3.35, 3.79)

Abbreviations: HS RIO, High School Reporting Information Online; NCAA-ISP, National Collegiate Athletic Association Injury Surveillance Program.

[a] High school data originated from HS RIO surveillance data, 2008–2009 through 2013–2014; collegiate data originated from NCAA-ISP surveillance data, 2004–2005 through 2013–2014. Injuries included in the analysis were those that (1) occurred during a sanctioned practice or competition; (2) were evaluated or treated (or both) by an athletic trainer, physician, or other health care professional; and (3) restricted the student-athlete from participation for at least 24 hours past the day of injury. All concussions, fractures, and dental injuries were included in the analysis, regardless of time loss. Data may include multiple injuries that occurred at 1 injury event. The athlete-exposures may not sum to totals due to rounding error.

2004–2005 through 2013–2014 academic years, ATs reported a total of 1027 time-loss injuries in collegiate women's lacrosse. The total injury rate for high school girls' lacrosse was 1.45/1000 AEs (95% CI = 1.35, 1.56), and the total injury rate for collegiate women's lacrosse was 3.57/1000 AEs (95% CI = 3.35, 3.79). The total injury rate during 2008–2009 through 2013–2014 was higher in college than in high school (2.55 versus 1.45/1000 AEs; IRR = 1.75; 95% CI = 1.54, 1.99).

School Size and Division

Among high school athletes, the total injury rates for schools with ≤1000 students and schools with >1000 students did not differ (IRR = 1.07; 95% CI = 0.92, 1.24; Table 1). At the collegiate level, Division III had a higher total injury rate than Division I (IRR = 1.49; 95% CI = 1.31, 1.69). However, injury rates did not differ between Divisions I and II (IRR = 0.93; 95% CI = 0.67, 1.30) or Divisions II and III (IRR = 0.72; 95% CI = 0.52, 1.01).

Event Type

The majority of injuries occurred during competitions in high school (51.1%) and practices in college (63.8%; Table 1). The competition injury rate was higher than the practice injury rate in both high school (IRR = 2.32; 95% CI = 2.00, 2.69) and in college (IRR = 2.38; 95% CI = 2.09, 2.70).

At the high school level, evidence for a decrease in injury rates was found for practices (annual average change of –0.07/1000 AEs; 95% CI = –0.14, –0.01) but not for competitions (annual average change of –0.14/1000 AEs; 95% CI = –0.31, 0.04; Figure). A decrease in practice injury rates was also noted for college in 2004–2005 through 2008–2009 (annual average change of –0.50/1000 AEs; 95% CI = –0.77, –0.22) but not for 2009–2010 through 2013–2014 (annual average change of –0.23/1000 AEs; 95% CI = –0.52, 0.05). No linear trends were found for collegiate competition injury rates in 2004–2005 through 2008–2009 (annual average change of –0.43/1000 AEs; 95% CI = –1.47, 0.60) or 2009–2010 through 2013–2014 (annual average change of –0.26/1000 AEs; 95% CI = –1.10, 0.58).

Time in Season

For both high school and collegiate athletes, most injuries occurred during the regular season (high school = 76.6%, college = 60.8%; Table 2). At the collegiate level, injury rates in the preseason and the regular season did not differ (IRR = 1.07; 95% CI = 0.94, 1.22). However, the injury rate was higher in the preseason than in the postseason (IRR = 2.37; 95% CI = 1.67, 3.37) and in the regular season than in the postseason (IRR = 2.22; 95% CI = 1.57, 3.13). Injury rates by time in season could not be calculated for high schools as AEs were not stratified by the time in the season.

Time Loss From Participation

At the high school level, the largest proportion of injuries resulted in time loss of less than 1 week from practices

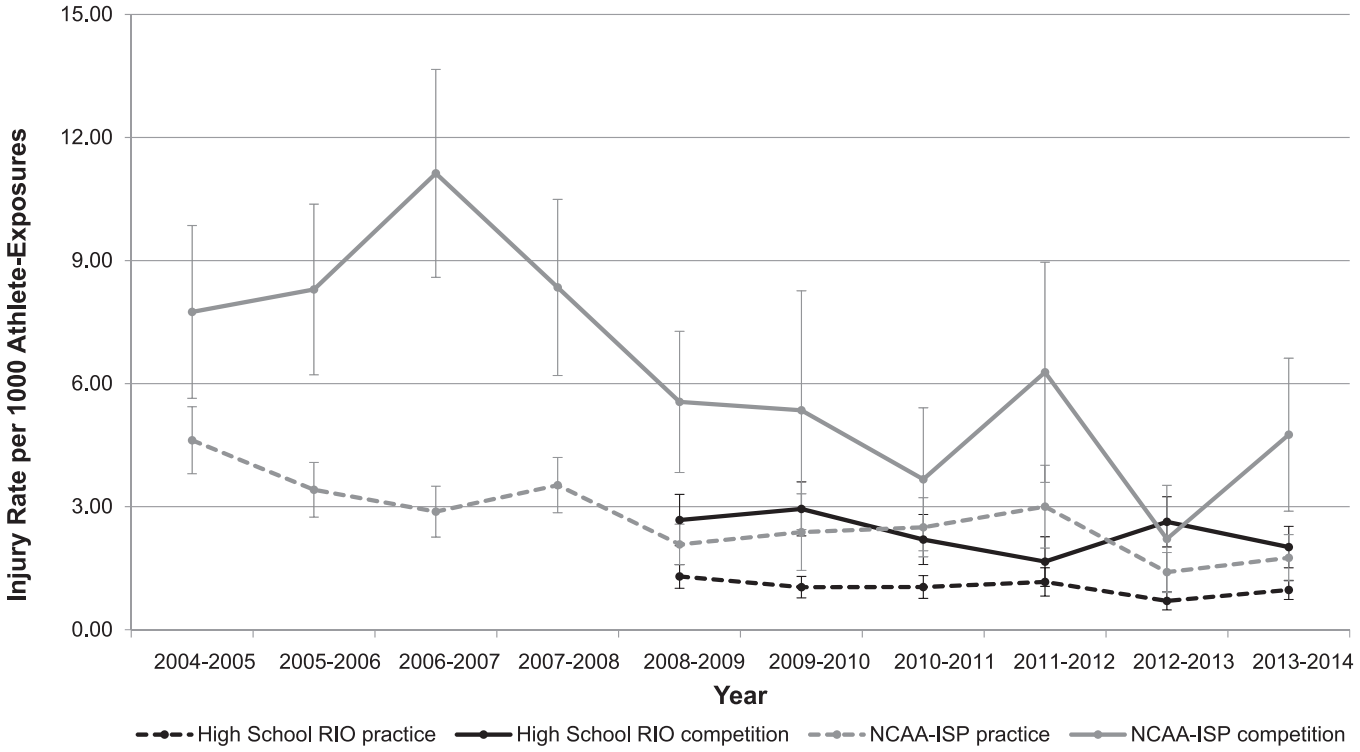

Figure. Injury rates by year and type of athlete-exposure (AE) in high school girls' and collegiate women's lacrosse. Note: Annual average changes for linear trend test for injury rates are as follows: High School Reporting Information Online (RIO; practices = –0.07/1000 AEs, 95% confidence interval [CI] = –0.14, –0.01; competitions = –0.14/1000 AEs, 95% CI = –0.31, 0.04); National Collegiate Athletic Association Injury Surveillance Program (NCAA-ISP) 2004–2005 through 2008–2009 (practices = –0.50/1000 AEs, 95% CI = –0.77, –0.22; competitions = –0.43/1000 AEs, 95% CI = –1.47, 0.60); NCAA-ISP 2009–2010 through 2013–2014 academic years (practices = –0.23/1000 AEs, 95% CI = –0.52, 0.05; competitions = –0.26/1000 AEs, 95% CI = –1.10, 0.58). A negative rate indicates a decrease in the annual average change between time spans, and a positive rate indicates an increase in the annual average change. The 95% CIs including 0.00 are not significant.

(44.6%) and 1 to 3 weeks from competitions (36.7%; Table 3). At the collegiate level, the majority of injuries resulted in time loss of less than 1 week (practices = 50.3%, competitions = 53.2%).

Body Parts Injured and Diagnoses

High School. Commonly injured body parts in practices and competitions were the head/face (practices = 17.9%, competitions = 38.8%) and ankle (practices = 21.4%, competitions = 16.9%; Table 4). Other body parts injured most often were the hip/thigh/upper leg (17.9%) in practices and the knee (17.7%) in competitions. The most frequent injury diagnoses from practices and competitions were muscle/tendon strains (practices = 24.9%, competitions = 11.5%), ligament sprains (practices = 22.2%, competitions = 30.3%), and concussions (practices = 15.2%, competitions = 35.0%; Table 5).

College. The most commonly injured body parts during practices and competitions were the hip/thigh/upper leg (practices = 19.9%, competitions = 15.1%), knee (practices = 18.9%, competitions = 21.8%), ankle (practices = 17.1%, competitions = 16.1%), and head/face (practices = 13.4%, competitions = 25.3%; Table 4). The most frequent injury diagnoses from practices and competitions were ligament sprains (practices = 25.5%, competitions = 30.9%), muscle/tendon strains (practices = 19.7%, competitions = 16.1%), and concussions (practices = 10.2%, competitions = 21.2%; Table 5).

Mechanisms of Injury and Activities

High School. The mechanism of injury cited most often during practices and competitions was no contact (practices = 31.1%, competitions = 25.6%; Table 6). Other common mechanisms of injury were overuse/chronic (28.7%) during practices and contact with the stick (25.0%) and contact with another person (23.3%) during competitions. The most frequent activity during injury in practices and competitions was general play (practices = 38.5%, competitions = 37.2%; Table 7). Other activities during which injury occurred were conditioning (28.4%) in practices and defending (16.3%) and ball handling (15.1%) in competitions.

College. The most common mechanism of injury during practices and competitions was no contact (practices = 48.4%, competitions = 36.9%; Table 6). Other typical mechanisms of injury were overuse/chronic (17.4%) during practices and contact with another person (28.7%) and contact with the stick (15.7%) in competitions. The most frequent activities during injury in practices and competitions were general play (practices = 42.7%, competitions = 30.7%) and defending (practices = 16.2%, competitions = 27.9%; Table 7). Other activities being performed when injury occurred were conditioning (15.0%) during practices and ball handling (16.1%) during competitions.

Position-Specific Injuries During Competitions

During competitions at the high school and collegiate levels, the most common injury among all positions was

Table 2. Injury Rates by Time in Season and Type of Athlete-Exposure in High School Girls' and Collegiate Women's Lacrosse[a]

Surveillance System and Time in Season	Event Type	Injuries in Sample, No. (%)	Athlete-Exposures	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
HS RIO (2008–2009 through 2013–2014)				
Preseason	Practices	123 (86.6)		
	Competitions	19 (13.4)		
	Total	142 (100.0)		
Regular season	Practices	211 (39.6)		
	Competitions	322 (60.4)		
	Total	533 (100.0)		
Postseason	Practices	7 (33.3)		
	Competitions	14 (66.7)		
	Total	21 (100.0)		
NCAA-ISP (2004–2005 through 2013–2014)				
Preseason	Practices	364 (98.6)	94 325	3.86 (3.46, 4.26)
	Competitions	5 (1.4)	761	6.57 (0.81, 12.33)
	Total	369 (100.0)	95 086	3.88 (3.48, 4.28)
Regular season	Practices	270 (43.3)	121 597	2.22 (1.96, 2.49)
	Competitions	354 (56.7)	50 381	7.03 (6.29, 7.76)
	Total	624 (100.0)	171 978	3.63 (3.34, 3.91)
Postseason	Practices	21 (61.8)	16 428	1.28 (0.73, 1.83)
	Competitions	13 (38.2)	4365	2.98 (1.36, 4.60)
	Total	34 (100.0)	20 793	1.64 (1.09, 2.18)

Abbreviations: HS RIO, High School Reporting Information Online; NCAA-ISP, National Collegiate Athletic Association Injury Surveillance Program.

[a] Excluded 4 injuries reported in HS RIO due to missing data for time in season. Injury rates by time in season could not be calculated for high school as athlete-exposures were not stratified by time in season. The athlete-exposures may not sum to totals due to rounding error. High school data originated from HS RIO surveillance data, 2008–2009 through 2013–2014; collegiate data originated from NCAA-ISP surveillance data, 2004–2005 through 2013–2014. Injuries included in the analysis were those that (1) occurred during a sanctioned practice or competition; (2) were evaluated or treated (or both) by an athletic trainer, physician, or other health care professional; and (3) restricted the student-athlete from participation for at least 24 hours past the day of injury. All concussions, fractures, and dental injuries were included in the analysis, regardless of time loss. Data may include multiple injuries that occurred at 1 injury event.

concussion (Table 8). Knee sprains and ankle sprains were also frequent injuries. However, the injury mechanisms cited most often (contact with the stick, the ball, and another player) varied by level and position.

DISCUSSION

Lacrosse is one of the fastest growing sports at both the high school and collegiate levels.[1,3] As opposed to boys' and men's lacrosse players, who are required to wear

Table 3. Number of Injuries and Injury Rates by Time Loss and Type of Athlete-Exposure in High School Girls' and Collegiate Women's Lacrosse[a]

	Practices		Competitions	
Surveillance System and Time-Loss Category	Injuries in Sample, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)	Injuries in Sample, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
HS RIO (2008–2009 through 2013–2014)				
1 d to <1 wk	145 (44.6)	0.44 (0.37, 0.51)	111 (32.8)	0.74 (0.60, 0.88)
1 to 3 wk	112 (34.5)	0.34 (0.27, 0.40)	124 (36.7)	0.83 (0.68, 0.97)
>3 wk[b]	68 (20.9)	0.20 (0.16, 0.25)	103 (30.5)	0.69 (0.55, 0.82)
NCAA-ISP (2004–2005 through 2013–2014)				
1 d to <1 wk	316 (50.3)	1.36 (1.21, 1.51)	194 (53.2)	3.50 (3.00, 3.99)
1 to 3 wk	186 (29.6)	0.80 (0.69, 0.92)	89 (24.4)	1.60 (1.27, 1.94)
>3 wk[b]	126 (20.1)	0.54 (0.45, 0.64)	82 (22.5)	1.48 (1.16, 1.80)

Abbreviations: HS RIO, High School Reporting Information Online; NCAA-ISP, National Collegiate Athletic Association Injury Surveillance Program.

[a] Excluded 37 injuries reported in HS RIO and 34 injuries reported in the NCAA-ISP due to missing data for time loss. Percentages may not add up to 100.0 due to rounding error. High school data originated from HS RIO surveillance data, 2008–2009 through 2013–2014; collegiate data originated from NCAA-ISP surveillance data, 2004–2005 through 2013–2014. Injuries included in the analysis were those that (1) occurred during a sanctioned practice or competition; (2) were evaluated or treated (or both) by an athletic trainer, physician, or other health care professional; and (3) restricted the student-athlete from participation for at least 24 hours past the day of injury. All concussions, fractures, and dental injuries were included in the analysis, regardless of time loss. Data may include multiple injuries that occurred at 1 injury event.

[b] Included injuries that resulted in time loss >3 weeks, medical disqualification, the athlete choosing not to continue, the athlete being released from the team, or the season ending before the athlete returned to activity.

Table 4. Number of Injuries and Injury Rates by Body Part Injured and Type of Athlete-Exposure in High School Girls' and Collegiate Women's Lacrosse[a]

Surveillance System and Body Part Injured	Practices		Competitions	
	Injuries in Sample, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)	Injuries in Sample, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
HS RIO (2008–2009 through 2013–2014)				
Head/face	61 (17.9)	0.18 (0.14, 0.23)	138 (38.8)	0.92 (0.77, 1.07)
Neck	3 (0.9)	0.01 (0.00, 0.02)	3 (0.8)	0.02 (0.00, 0.04)
Shoulder/clavicle	2 (0.6)	<0.01 (0.00, 0.01)	7 (2.0)	0.05 (0.01, 0.08)
Arm/elbow	3 (0.9)	0.01 (0.00, 0.02)	6 (1.7)	0.04 (0.01, 0.07)
Hand/wrist	10 (2.9)	0.03 (0.01, 0.05)	29 (8.2)	0.19 (0.12, 0.26)
Trunk	13 (3.8)	0.04 (0.02, 0.06)	4 (1.1)	0.03 (0.00, 0.05)
Hip/thigh/upper leg	61 (17.9)	0.18 (0.14, 0.23)	25 (7.0)	0.17 (0.10, 0.23)
Knee	36 (10.6)	0.11 (0.07, 0.14)	63 (17.7)	0.42 (0.32, 0.52)
Lower leg	48 (14.1)	0.14 (0.10, 0.19)	14 (3.9)	0.09 (0.04, 0.14)
Ankle	73 (21.4)	0.22 (0.17, 0.27)	60 (16.9)	0.40 (0.30, 0.50)
Foot	26 (7.6)	0.08 (0.05, 0.11)	5 (1.4)	0.03 (0.00, 0.06)
Other	5 (1.5)	0.02 (0.00, 0.03)	2 (0.6)	0.01 (0.00, 0.03)
NCAA-ISP (2004–2005 through 2013–2014)				
Head/face	88 (13.4)	0.38 (0.30, 0.46)	94 (25.3)	1.69 (1.35, 2.04)
Neck	2 (0.3)	0.01 (0.00, 0.02)	2 (0.5)	0.04 (0.00, 0.09)
Shoulder/clavicle	15 (2.3)	0.06 (0.03, 0.10)	9 (2.4)	0.16 (0.06, 0.27)
Arm/elbow	9 (1.4)	0.04 (0.01, 0.06)	5 (1.3)	0.09 (0.01, 0.17)
Hand/wrist	15 (2.3)	0.06 (0.03, 0.10)	15 (4.0)	0.27 (0.13, 0.41)
Trunk	38 (5.8)	0.16 (0.11, 0.22)	19 (5.1)	0.34 (0.19, 0.50)
Hip/thigh/upper leg	130 (19.9)	0.56 (0.46, 0.66)	56 (15.1)	1.01 (0.74, 1.27)
Knee	124 (18.9)	0.53 (0.44, 0.63)	81 (21.8)	1.46 (1.14, 1.78)
Lower leg	62 (9.5)	0.27 (0.20, 0.33)	16 (4.3)	0.29 (0.15, 0.43)
Ankle	112 (17.1)	0.48 (0.39, 0.57)	60 (16.1)	1.08 (0.81, 1.35)
Foot	48 (7.3)	0.21 (0.15, 0.27)	14 (3.8)	0.25 (0.12, 0.38)
Other	12 (1.8)	0.05 (0.02, 0.08)	1 (0.3)	0.02 (0.00, 0.05)

Abbreviations: HS RIO, High School Reporting Information Online; NCAA-ISP, National Collegiate Athletic Association Injury Surveillance Program.

[a] Excluded 3 injuries reported in HS RIO due to missing data for body part. Percentages may not add up to 100.0 due to rounding error. High school data originated from HS RIO surveillance data, 2008–2009 through 2013–2014; collegiate data originated from NCAA-ISP surveillance data, 2004–2005 through 2013–2014. Injuries included in the analysis were those that (1) occurred during a sanctioned practice or competition; (2) were evaluated or treated (or both) by an athletic trainer, physician, or other health care professional; and (3) restricted the student-athlete from participation for at least 24 hours past the day of injury. All concussions, fractures, and dental injuries were included in the analysis, regardless of time loss. Data may include multiple injuries that occurred at 1 injury event.

extensive protective gear, female lacrosse players are only required to wear a mouth guard and protective eyewear. Full body contact is not allowed, and stick checking is allowed only if it is directed away from the opponent.[11] Players must be both skilled technically (eg, passing, quick changes in direction of play, competition for the ball without body checking) and physically fit to excel at the game. The combination of these skills and the use of equipment (lacrosse stick and hard ball) produce unique injury patterns compared with many other high school and collegiate sports.[12–14] Given the increased popularity of the sport at both levels of play and the potential for apparatus-related injury, it is essential to focus on injury prevention for these athletes. To our knowledge, this was the first study to directly compare rates and patterns of injury among girls' high school and women's collegiate lacrosse players using comparable surveillance systems.

Comparison With Previous Research and Trends Over Time

In previous studies[15,16] at the high school level, girls' lacrosse had the third highest injury rates among girls' sports behind soccer and basketball. We found an overall injury rate of 1.45/1000 AEs, which was lower than in work[11] conducted from 1999 through 2001 (2.54/1000 AEs) but similar to more recent research[16] that showed an injury rate of 1.57/1000 AEs. At the collegiate level, injury rates during practices and competitions were slightly lower than earlier rates[17] (2.82 versus 3.30/1000 AEs in practice, 6.70 versus 7.15/1000 AEs in competitions). The differences in injury rates over time may be explained by the many rule changes pertaining to player safety implemented during the past decade.[18] For example, rule changes introduced penalties for stick-to-head contact.[19] Also, the mandatory use of protective eyewear was associated with a dramatic reduction in eye injuries and a decrease in head/face injuries in high school lacrosse.[20] At the same time, governing bodies such as US Lacrosse emphasized safety education for coaches and officials with the goal of minimizing injury incidence and severity.[21] Because we were unable to assess the specific effects of such policies and programming in conjunction with the study data, future research is warranted.

In contrast, few linear trends were present in high school and collegiate injury rates during our study period. Our findings highlight that, despite evidence of longitiduinal

Table 5. Number of Injuries and Injury Rates by Diagnosis and Type of Athlete-Exposure in High School Girls' and Collegiate Women's Lacrosse[a]

Surveillance System and Diagnosis	Practices		Competitions	
	Injuries in Sample, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)	Injuries in Sample, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
HS RIO (2008–2009 through 2013–2014)				
Concussion	52 (15.2)	0.16 (0.11, 0.20)	125 (35.0)	0.83 (0.69, 0.98)
Contusion	15 (4.4)	0.05 (0.02, 0.07)	30 (8.4)	0.20 (0.13, 0.27)
Dislocation[b]	3 (0.9)	0.01 (0.00, 0.02)	4 (1.1)	0.03 (0.00, 0.05)
Fracture/avulsion	16 (4.7)	0.05 (0.02, 0.07)	20 (5.6)	0.13 (0.08, 0.19)
Laceration	1 (0.3)	<0.01 (0.00, 0.01)	7 (2.0)	0.05 (0.01, 0.08)
Ligament sprain	76 (22.2)	0.23 (0.18, 0.28)	108 (30.3)	0.72 (0.59, 0.86)
Muscle/tendon strain	85 (24.9)	0.26 (0.20, 0.31)	41 (11.5)	0.27 (0.19, 0.36)
Other	94 (27.5)	0.28 (0.23, 0.34)	22 (6.2)	0.15 (0.09, 0.21)
NCAA-ISP (2004–2005 through 2013–2014)				
Concussion	67 (10.2)	0.29 (0.22, 0.36)	79 (21.2)	1.42 (1.11, 1.74)
Contusion	46 (7.0)	0.20 (0.14, 0.26)	42 (11.3)	0.76 (0.53, 0.99)
Dislocation[b]	2 (0.3)	0.01 (0.00, 0.02)	0	0.00
Fracture/avulsion	16 (2.4)	0.07 (0.04, 0.10)	15 (4.0)	0.27 (0.13, 0.41)
Laceration	4 (0.6)	0.02 (0.00, 0.03)	6 (1.6)	0.11 (0.02, 0.19)
Ligament sprain	167 (25.5)	0.72 (0.61, 0.83)	115 (30.9)	2.07 (1.69, 2.45)
Muscle/tendon strain	129 (19.7)	0.56 (0.46, 0.65)	60 (16.1)	1.08 (0.81, 1.35)
Other	224 (34.2)	0.96 (0.84, 1.09)	55 (14.8)	0.99 (0.73, 1.25)

Abbreviations: HS RIO, High School Reporting Information Online; NCAA-ISP, National Collegiate Athletic Association Injury Surveillance Program.

[a] Excluded 1 injury reported in HS RIO due to missing data for diagnosis. Percentages may not add up to 100.0 due to rounding error. High school data originated from HS RIO surveillance data, 2008–2009 through 2013–2014; collegiate data originated from NCAA-ISP surveillance data, 2004–2005 through 2013–2014. Injuries included in the analysis were those that (1) occurred during a sanctioned practice or competition; (2) were evaluated or treated (or both) by an athletic trainer, physician, or other health care professional; and (3) restricted the student-athlete from participation for at least 24 hours past the day of injury. All concussions, fractures, and dental injuries were included in the analysis, regardless of time loss. Data may include multiple injuries that occurred at 1 injury event.

[b] Included separations.

decreases compared with previous investigations, continued development and refinement of injury-prevention interventions may be needed to further decrease injury incidence.

Injury Rates in College Versus High School

Injury rates were higher in collegiate lacrosse compared with high school during the 2008–2009 through 2013–2014 academic years (IRR = 1.75; Table 1). This is consistent with prior investigations[22,23] in other sports that suggested the intensity and skill level were greater for sports played at the collegiate level. Also, collegiate athletes may spend more time practicing during the week, allowing more time to sustain injuries. Additionally, competitions at the collegiate level are divided into 30-minute halves compared with 25-minute halves at the high school level. Because AEs are defined equivalently at both levels, the higher rates in college could reflect increased playing time. Furthermore, the NCAA recommends that an AT be present at all collegiate practices and competitions, whereas not every AT at the high school level can cover every practice. Thus, some injuries at the high school level may go unreported.

Event Type

Injury rates were higher during competitions than during practices at both levels; this finding is well-described in the literature across many sports.[24–27] In high school, most injuries occurred during competitions (51.1%), whereas in college, most injuries occurred during practices (63.8%). Differences may exist in the composition of drills as well as in the tempo and intensity of practice sessions. Because the surveillance systems did not collect data on such aspects of practice sessions, future researchers may focus on identifying specific aspects of practice that are associated with an increased injury incidence.

School Size and Division

Whereas injury rates did not vary by school size for high school girls' lacrosse, Division III had the highest injury rate in collegiate women's lacrosse players. Factors related to school size and division have seldom been examined in lacrosse injury-surveillance data but may be warranted. Past results[22,28–30] among other sports were mixed, and conflicting hypotheses suggested that highly skilled players may play with increased intensity and thus be more at risk for injury and that less skilled players may have a lower fitness level and thus be more at risk for injury. Previous authors[31] have hypothesized a preselection effect in which higher-level teams may not include athletes whose previous injuries inhibited their ability to play at those levels. Our findings may indicate a higher injury incidence among lower-division lacrosse athletes at the collegiate level; however, additional research is needed to validate our results and explore factors associated with such differences.

Concussions

For both high school and collegiate lacrosse athletes, concussion was the most common specific diagnosis for every field position. Prior studies[32–35] have also shown that

Table 6. Number of Injuries and Injury Rates by Mechanism of Injury and Type of Athlete-Exposure in High School Girls' and Collegiate Women's Lacrosse[a]

Surveillance System and Mechanism Of Injury	Practices		Competitions	
	Injuries in Sample, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)	Injuries in Sample, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
HS RIO (2008–2009 through 2013–2014)				
Contact with another person	18 (5.4)	0.05 (0.03, 0.08)	80 (23.3)	0.53 (0.42, 0.65)
Contact with playing surface	44 (13.3)	0.13 (0.09, 0.17)	46 (13.4)	0.31 (0.22, 0.40)
Contact with ball	47 (14.2)	0.14 (0.10, 0.18)	29 (8.4)	0.19 (0.12, 0.26)
Contact with goal	1 (0.3)	<0.01 (0.00, 0.01)	0	0.00
Contact with stick	14 (4.2)	0.04 (0.02, 0.06)	86 (25.0)	0.57 (0.45, 0.70)
Contact with other playing equipment	1 (0.3)	<0.01 (0.00, 0.01)	2 (0.6)	0.01 (0.00, 0.03)
Contact with out of bounds object	0	0.00	0	0.00
No contact	103 (31.1)	0.31 (0.25, 0.37)	88 (25.6)	0.59 (0.46, 0.71)
Overuse/chronic	95 (28.7)	0.29 (0.23, 0.34)	13 (3.8)	0.09 (0.04, 0.13)
Illness/infection	8 (2.4)	0.02 (0.01, 0.04)	0	0.00
NCAA-ISP (2004–2005 through 2013–2014)				
Contact with another person	68 (10.5)	0.29 (0.22, 0.36)	106 (28.7)	1.91 (1.55, 2.27)
Contact with playing surface	36 (5.6)	0.15 (0.10, 0.21)	23 (6.2)	0.41 (0.25, 0.58)
Contact with ball	67 (10.4)	0.29 (0.22, 0.36)	24 (6.5)	0.43 (0.26, 0.61)
Contact with goal	0	0.00	0	0.00
Contact with stick	30 (4.7)	0.13 (0.08, 0.18)	58 (15.7)	1.04 (0.78, 1.31)
Contact with other playing equipment	2 (0.3)	0.01 (0.00, 0.02)	0	0.00
Contact with out-of-bounds object	0	0.00	1 (0.3)	0.02 (0.00, 0.05)
No contact	312 (48.4)	1.34 (1.19, 1.49)	136 (36.9)	2.45 (2.04, 2.86)
Overuse/chronic	112 (17.4)	0.48 (0.39, 0.57)	19 (5.2)	0.34 (0.19, 0.50)
Illness/infection	18 (2.8)	0.08 (0.04, 0.11)	2 (0.5)	0.04 (0.00, 0.09)

Abbreviations: HS RIO, High School Reporting Information Online; NCAA-ISP, National Collegiate Athletic Association Injury Surveillance Program.

[a] Mechanism of injury excluded 25 injuries reported in HS RIO and 13 injuries reported in the NCAA-ISP due to missing data or the athletic trainer reporting *Other* or *Unknown*. Percentages may not add up to 100.0 due to rounding error. High school data originated from HS RIO surveillance data, 2008–2009 through 2013–2014; collegiate data originated from NCAA-ISP surveillance data, 2004–2005 through 2013–2014. Injuries included in the analysis were those that (1) occurred during a sanctioned practice or competition; (2) were evaluated or treated (or both) by an athletic trainer, physician, or other health care professional; and (3) restricted the student-athlete from participation for at least 24 hours past the day of injury. All concussions, fractures, and dental injuries were included in the analysis, regardless of time loss. Data may include multiple injuries that occurred at 1 injury event.

concussions were a concern in girls' and women's lacrosse. In college, women's lacrosse had the seventh highest concussion rate of 25 men's and women's sports at 0.52/1000 AEs, whereas in high school, girls' lacrosse had the fourth highest rate of 20 boys' and girls' sports at 0.35/1000 AEs.[14,34] A continued focus on efforts to decrease the incidence of concussion, increasing athletes' self-reporting of symptoms, and improving access to resources to assist in management and recovery is needed. As of 2014, all 50 states and the District of Columbia had enacted concussion-related legislation for high school sports; however, the content within each state varies.[36] In April 2010, the NCAA Executive Committee adopted a new concussion policy[37] mandating that each member institution's concussion-management plan include the following: (a) annual concussion education for athletes, (b) immediate removal from play if a concussion is suspected, (c) elimination of same-day return to play of a concussed athlete, and (d) a process for clearance by a medical professional for return to play.[37,38]

In our study, for most positions at both levels of play, the most frequent mechanism of concussion was contact with the stick, followed by contact with the ball. This is in line with a previous study[35] showing that girls' and women's lacrosse injuries were driven by contact with playing apparatuses, most likely because player-to-player contact is limited in the sport. In particular, 1 group[39] used video footage of high school girls' lacrosse players and found that most of the 14 examined head injuries (11 concussions) were from contact with the stick (n = 8). Reducing player contact with equipment, particularly with the stick, may help to reduce the incidence of concussions. Recently, concussion-prevention efforts have focused on coaching techniques, officiating, education, rule changes, and protective equipment to address all potential mechanisms of injury.[19]

A controversial topic in girls' and women's lacrosse is the introduction of protective headgear. Extensive protective equipment, including helmets, is used in boys' and men's lacrosse because these sports are full contact, whereas girls' and women's lacrosse is not, and consequently, they do not have such extensive equipment requirements. Although headgear is currently optional for female lacrosse players, the "ASTM [American Society for Testing and Materials] International F3137-15: Standard Specification for Headgear Used in Women's Lacrosse (Excluding Goalkeepers)" aims to standardize soft headgear currently allowed in women's lacrosse and to help reduce stick contact to the head.[40,41] Headgear worn after January 1, 2017, must meet the ASTM standard. It is possible that the use of headgear may reduce the number of head injuries due to contact with equipment.

Table 7. Number of Injuries and Injury Rates by Activity During Injury and Type of Athlete-Exposure in High School Girls' and Collegiate Women's Lacrosse[a]

Surveillance System and Activity During Injury	Practices		Competitions	
	Injuries in Sample, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)	Injuries in Sample, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
HS RIO (2008–2009 through 2013–2014)				
Ball handling	12 (4.1)	0.04 (0.02, 0.06)	50 (15.1)	0.33 (0.24, 0.43)
Blocking	4 (1.4)	0.01 (0.00, 0.02)	3 (0.9)	0.02 (0.00, 0.04)
Conditioning	84 (28.4)	0.25 (0.20, 0.31)	0	0.00
Defending	24 (8.1)	0.07 (0.04, 0.10)	54 (16.3)	0.36 (0.26, 0.46)
Faceoff	0	0.00	3 (0.9)	0.02 (0.00, 0.04)
General play	114 (38.5)	0.34 (0.28, 0.41)	123 (37.2)	0.82 (0.68, 0.97)
Goaltending	11 (3.7)	0.03 (0.01, 0.05)	14 (4.2)	0.09 (0.04, 0.14)
Loose ball	11 (3.7)	0.03 (0.01, 0.05)	35 (10.6)	0.23 (0.16, 0.31)
Passing	10 (3.4)	0.03 (0.01, 0.05)	16 (4.8)	0.11 (0.05, 0.16)
Receiving pass	21 (7.1)	0.06 (0.04, 0.09)	23 (7.0)	0.15 (0.09, 0.22)
Shooting	5 (1.7)	0.02 (0.00, 0.03)	10 (3.0)	0.07 (0.03, 0.11)
NCAA-ISP (2004–2005 through 2013–2014)				
Ball handling	44 (7.4)	0.19 (0.13, 0.25)	56 (16.1)	1.01 (0.74, 1.27)
Blocking	7 (1.2)	0.03 (0.01, 0.05)	7 (2.0)	0.13 (0.03, 0.22)
Conditioning	90 (15.0)	0.39 (0.31, 0.47)	1 (0.3)	0.02 (0.00, 0.05)
Defending	97 (16.2)	0.42 (0.33, 0.50)	97 (27.9)	1.75 (1.40, 2.10)
Faceoff	5 (0.8)	0.02 (0.00, 0.04)	5 (1.4)	0.09 (0.01, 0.17)
General play	256 (42.7)	1.10 (0.97, 1.24)	107 (30.7)	1.93 (1.56, 2.29)
Goaltending	23 (3.8)	0.10 (0.06, 0.14)	10 (2.9)	0.18 (0.07, 0.29)
Loose ball	20 (3.3)	0.09 (0.05, 0.12)	40 (11.5)	0.72 (0.50, 0.94)
Passing	16 (2.7)	0.07 (0.04, 0.10)	3 (0.9)	0.05 (0.00, 0.12)
Receiving pass	8 (1.3)	0.03 (0.01, 0.06)	2 (0.6)	0.04 (0.00, 0.09)
Shooting	33 (5.5)	0.14 (0.09, 0.19)	20 (5.7)	0.36 (0.20, 0.52)

Abbreviations: HS RIO, High School Reporting Information Online; NCAA-ISP, National Collegiate Athletic Association Injury Surveillance Program.

[a] Activity excluded 73 injuries reported in HS RIO and 80 injuries reported in the NCAA-ISP due to missing data or the athletic trainer reporting *Other* or *Unknown*. Percentages may not add up to 100.0 due to rounding error. High school data originated from HS RIO surveillance data, 2008–2009 through 2013–2014; collegiate data originated from NCAA-ISP surveillance data, 2004–2005 through 2013–2014. Injuries included in the analysis were those that (1) occurred during a sanctioned practice or competition; (2) were evaluated or treated (or both) by an athletic trainer, physician, or other health care professional; and (3) restricted the student-athlete from participation for at least 24 hours past the day of injury. All concussions, fractures, and dental injuries were included in the analysis, regardless of time loss. Data may include multiple injuries that occurred at 1 injury event.

However, one of the main arguments against headgear in girls' and women's lacrosse is that such use will result in more aggressive play due to the so-called "gladiator effect," or risk-compensation theory.[42,43] In other sports, little evidence[42] has shown that introducing a piece of protective equipment objectively increased either the aggressiveness of the sport or the number of injuries sustained. In some cases, athletes self-reported more risk-taking behaviors when they wore helmets, but few studies had measurable objective outcomes, and those that did demonstrated no measurable increases in injury rates.[44–46] Furthermore, the percentage of injuries in collegiate women's lacrosse due to contact with another player may have increased over time,[17] suggesting that the game is already becoming more physical and that (1) rules regarding player contact should be strictly enforced and (2) further consideration of protective headgear is warranted. If athletes abide by the rules when they compete and the rules are enforced, aggressiveness should not increase when headgear is worn, and the headgear could offer substantial protection against concussions due to contact with the ball or the stick. Our results indicate the need for an evidence-based discussion on the benefits and drawbacks of introducing headgear at each level of play.

Other Lacrosse-Related Injuries

Although concussions receive considerable attention, we found that sprains and strains to various parts of the body, particularly the knee and ankle, occurred frequently. Sprains can result in significant time loss for athletes; 41.8% of high school and 35.7% of collegiate athletes who sustained ligament sprains during competitions took longer than 3 weeks to return to play. Lacrosse requires quick changes of direction and constant acceleration and deceleration, which may explain why most ligament sprains in lacrosse result from contact with the playing surface or noncontact (ie, rotation around a planted foot).[47,48] Risk factors for sustaining ligament sprains include sex and prior injury. Previous authors[47,49] showed that females sustained sprains more frequently than males and that more than 10% of knee and ankle sprains were recurrent. Strategies for reducing the incidence and severity of sprains should include both primary and secondary prevention (ie, consideration of prophylactic bracing, conditioning, and drills[50–52]). As US Lacrosse evaluates the effectiveness of its LaxPrep program (a warm-up and exercise program that aims to decrease the risk of lower extremity injury),[53] attention to the unique physical demands of lacrosse and specifically targeting females is warranted.

Table 8. Most Common Injuries Associated With Position in Competitions in High School Girls' and Collegiate Women's Lacrosse[a]

Surveillance System and Position	Most Common Injuries	Injuries Within Position, %	Most Frequent Mechanism of Injury for This Injury Within Position
HS RIO (2008–2009 through 2013–2014)			
Attacker	Concussion	26.7	Contact with stick
	Ankle sprain	20.0	No contact
	Knee sprain	14.3	No contact
Defense	Concussion	42.3	Contact with stick
	Ankle sprain	9.9	No contact
Goalkeeper	Concussion	50.0	Contact with ball
Midfielder	Concussion	38.0	Contact with stick
	Ankle sprain	16.1	No contact
	Knee sprain	12.4	No contact
NCAA-ISP (2004–2005 through 2013–2014)			
Attacker	Concussion	21.1	Contact with stick
	Ankle sprain	19.3	No contact
	Knee sprain	11.0	No contact
Defense	Concussion	20.0	Contact with stick
	Ankle sprain	15.0	Contact with another person
	Knee sprain	13.0	No contact
Goalkeeper	Concussion	31.3	Contact with ball
	Knee sprain	12.5	No contact
Midfielder	Concussion	21.5	Contact with another person
	Hip/thigh/upper leg strain	16.5	No contact
	Ankle sprain	12.4	Contact with another person

Abbreviations: HS RIO, High School Reporting Information Online; NCAA-ISP, Ntional Collegiate Athletic Association Injury Surveillance Program.

[a] Excluded 27 competition injuries reported in HS RIO and 26 competition injuries reported in the NCAA-ISP due to position not being indicated. The table reads as follows: for the attacker position in high school, concussions comprised 26.7% of all competition injuries to that position. The most common mechanism of injury for this specific injury for this specific position was contact with the stick. High school data originated from HS RIO surveillance data, 2008–2009 through 2013–2014; collegiate data originated from NCAA-ISP surveillance data, 2004–2005 through 2013–2014. Injuries included in the analysis were those that (1) occurred during a sanctioned practice or competition; (2) were evaluated or treated (or both) by an athletic trainer, physician, or other health care professional; and (3) restricted the student-athlete from participation for at least 24 hours past the day of injury. All concussions, fractures, and dental injuries were included in the analysis, regardless of time loss. Data may include multiple injuries that occurred at 1 injury event.

Common Injury Mechanisms

Although a small proportion of injuries in practices were due to contact with another player, 23.3% (high school) and 28.7% (college) of competition injuries were due to athlete-to-athlete contact (Table 6). Given that only incidental contact is allowed in girls' and women's lacrosse, it is concerning that many injuries were the result of such contact. This represents an opportunity for injury prevention by enforcing the rules of the game. Investigators[17] found that 18.6% of injuries to collegiate women's lacrosse players that occurred during lacrosse competitions were due to player-to-player contact, which may indicate an increase in the physicality of the game over the past decade. However, the percentage of injuries due to contact with another player during practices has remained similar (8.0% in 1989–2004 compared with 10.5% in 2004–2013).[17] Coaches and officials should be aware of the amount and type of player contact in the competition setting and (1) regulate contact appropriately, (2) consider additional protective equipment, or (3) introduce rule changes to impose harsher punishments for intentional contact.

We also noted that most injuries (>50% during practices) at the high school and collegiate levels were noncontact or overuse/chronic. In the adolescent population, overuse injuries can have long-term physical consequences and negatively affect growth and development.[54,55] Similar to our results, a previous report[56] showed that rates of overuse injuries were higher in college, possibly due to increased training or the fact that collegiate athletes have participated in their sport for longer than high school athletes. Most overuse injuries occur (or present) during practices, so ATs can play a pivotal role in recognizing and managing the injuries.[56] Close supervision of athletic activity, early detection, and encouragement from coaches and ATs for athletes to report these injuries could aid in reducing their incidence and severity and potentially avoid the associated long-term sequalae.[55,57]

LIMITATIONS

Our findings may not be generalizable to other playing levels, such as youth, middle school, and professional programs, nor to collegiate programs at non-NCAA institutions, nor to high schools without National Athletic Trainers' Association–affiliated ATs. Furthermore, we were unable to account for factors potentially associated with injury occurrence, such as AT coverage, implemented injury-prevention programs, and athlete-specific characteristics (eg, previous injury, functional capabilities). Also, although HS RIO and the NCAA-ISP are similar injury-surveillance systems, it is important to consider the variations between the systems. In addition, differences may exist between high school and college in regard to the length of the season in total, as well as the preseason, regular season, and postseason; the potentially longer collegiate season may increase the injury risk. We calculated injury rates using AEs, which may not be as precise an at-risk exposure measure as minutes, hours, or total number of game plays across a season. However, collecting such exposure data is more laborious than collecting AE data and may be too burdensome for ATs participating in HS RIO and the NCAA-ISP. We also caution against comparisons of injury distributions between the high school and collegiate levels as high school data were not available for the 2004–2005 through 2007–2008 academic years.

Although our study is one of few to examine injury incidences across multiple levels of play (eg, high school versus college and competitions versus practices), we were unable to examine differences between starters and nonstarters for competitions; analyses that group both types of players may confound and thus weaken the possible exposure-outcome association for some known injury risk factors. Differences may also exist among the freshmen, junior varsity, and varsity teams due to differences in

maturation status. Playing positions may vary in physical demands and in the resulting injury risk. Athlete-exposures were not collected by position, preventing the calculation of position-specific injury rates.

CONCLUSIONS

We identified several potential areas for injury prevention at both levels of play. We also demonstrated similarities and differences between age groups, which would not be possible without comparable surveillance system methods used by HS RIO and the NCAA-ISP. Although rates of injury were higher overall and for most specific injuries in collegiate compared with high school players, a greater proportion of injuries resulted in more than 3 weeks of time loss at the high school level. Many injuries were due to overuse/noncontact and occurred during practices, particularly at the collegiate level. The conversation surrounding protective headgear for girls' and women's lacrosse athletes should continue because (1) the proportion of injuries due to player-to-player contact appears to have increased over time and (2) most concussions were due to contact with the playing apparatus. To help reduce the incidence of concussions among girls' lacrosse players, particularly at the high school level, protective equipment and enforcement of the rules preventing most types of player-to-player contact may be beneficial. Many of the areas for injury prevention identified in this study would not have been possible without the use of surveillance systems. Continued monitoring of rates and patterns of injury is essential for developing targeted injury-prevention efforts and evaluating their effectiveness.

ACKNOWLEDGMENTS

The NCAA-ISP data were provided by the Datalys Center for Sports Injury Research and Prevention, Inc. The NCAA-ISP was funded by the NCAA. Funding for HS RIO was provided in part by the Centers for Disease Control and Prevention grants R49/CE000674-01 and R49/CE001172-01 and the National Center for Research Resources award KL2 RR025754. We also acknowledge the research funding contributions of the National Federation of State High School Associations (Indianapolis, IN), National Operating Committee on Standards for Athletic Equipment (Overland Park, KS), DonJoy Orthotics (Vista, CA), and EyeBlack (Potomac, MD). The content of this report is solely the responsibility of the authors and does not necessarily represent the official views of the funding organizations. We thank the many ATs who have volunteered their time and efforts to submit data to HS RIO and the NCAA-ISP. Their efforts are greatly appreciated and have had a tremendously positive effect on the safety of high school and collegiate student-athletes.

REFERENCES

1. 1981–1982—2013–14 NCAA sports sponsorship and participation rates report. National Collegiate Athletic Association Publications Web site. http://www.ncaapublications.com/productdownloads/PR1314.pdf. Accessed March 5, 2018.
2. 2013–14 high school athletics participation survey. National Federation of State High School Associations Web site. http://www.nfhs.org/ParticipationStatics/PDF/2013-14_Participation_Survey_PDF.pdf. Published 2014. Accessed March 5, 2018.
3. 1969–2014 high school athletics participation survey results. National Federation of State High School Associations Web site. http://www.nfhs.org/ParticipationStatics/PDF/Participation%20Survey%20History%20Book.pdf. Accessed May 10, 2017.
4. Kerr ZY, Dompier TP, Snook EM, et al. National Collegiate Athletic Association Injury Surveillance System: review of methods for 2004–2005 through 2013–2014 data collection. *J Athl Train*. 2014;49(4):552–560.
5. Centers for Disease Control and Prevention (CDC). Sports-related injuries among high school athletes—United States, 2005–06 school year. *MMWR Morb Mortal Wkly Rep*. 2006;55(38):1037–1040.
6. van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries: a review of concepts. *Sports Med*. 1992;14(2):82–99.
7. Kerr ZY, Comstock RD, Dompier TP, Marshall SW. The first decade of web-based sports injury surveillance (2004–2005 through 2013–2014): methods of the National Collegiate Athletic Association Injury Surveillance Program and High School Reporting Information Online. *J Athl Train*. 2018;53(8):729–737.
8. 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.
9. Census regions of the United States. US Census Bureau Web site. http://www.census.gov/const/regionmap.pdf. Accessed March 6, 2018.
10. Kucera KL, Marshall SW, Bell DR, DiStefano MJ, Goerger CP, Oyama S. Validity of soccer injury data from the National Collegiate Athletic Association's Injury Surveillance System. *J Athl Train*. 2011;46(5):489–499.
11. Hinton RY, Lincoln AE, Almquist JL, Douoguih 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.
12. 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.
13. Comstock RD, Currie DW, Pierpoint LA. Convenience sample summary report: National High School Sports-Related Injury Surveillance Study, 2013–2014 school year. University of Colorado-Denver Web site. http://www.ucdenver.edu/academics/colleges/PublicHealth/research/ResearchProjects/piper/projects/RIO/Documents/2013-14%20Convenience%20Report.pdf. Accessed March 6, 2018.
14. Zuckerman SL, Kerr ZY, Yengo-Kahn A, Wasserman E, Covassin T, Solomon GS. Epidemiology of sports-related concussion in NCAA athletes from 2009–2010 to 2013-2014: incidence, recurrence, and mechanisms. *Am J Sports Med*. 2015;43(11):2654–2662.
15. Comstock RD, Currie DW, Pierpoint LA. Convenience sample summary report, National High School Sports-Related Injury Surveillance Study, 2012–2013 school year. University of Colorado-Denver Web site. http://www.ucdenver.edu/academics/colleges/PublicHealth/research/ResearchProjects/piper/projects/RIO/Documents/2012-13%20Convenience%20Sample.pdf. Accessed May 10, 2017.
16. Kerr ZY, Roos KG, Djoko A, Dompier TP, Marshall SW. Rankings of high school sports injury rates differ based on time loss assessments. *Clin J Sport Med*. 2017;27(6):548–551.
17. Dick R, Lincoln AE, Agel J, Carter EA, 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.
18. 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.
19. Putukian M, Lincoln AE, Crisco JJ. Sports-specific issues in men's and women's lacrosse. *Curr Sports Med Rep*. 2014;13(5):334–340.
20. 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.

21. Women's rules. US Lacrosse Web site. http://www.uslacrosse.org/rules/womens-rules.aspx. Accessed March 6, 2018.
22. Reeser JC, Gregory A, Berg RL, Comstock RD. A comparison of women's collegiate and girls' high school volleyball injury data collected prospectively over a 4-year period. *Sports Health*. 2015; 7(6):504–510.
23. Yard EE, Collins CL, Dick RW, Comstock RD. An epidemiologic comparison of high school and college wrestling injuries. *Am J Sports Med*. 2008;36(1):57–64.
24. Kerr ZY, Marshall SW, Dompier TP, Corlette J, Klossner DA, Gilchrist J. College sports-related injuries—United States, 2009–10 through 2013–14 academic years. *MMWR Morb Mortal Wkly Rep*. 2015;64(48):1330–1336.
25. Shankar PR, Fields SK, Collins CL, Dick RW, Comstock RD. Epidemiology of high school and collegiate football injuries in the United States, 2005–2006. *Am J Sports Med*. 2007;35(8):1295–1303.
26. 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.
27. Lincoln AE, Yeger-McKeever M, Romani W, Hepburn LR, Dunn RE, Hinton RY. Rate of injury among youth lacrosse players. *Clin J Sport Med*. 2014;24(4):355–357.
28. Hopper DM, Hopper JL, Elliott BC. Do selected kinanthropometric and performance variables predict injuries in female netball players? *J Sports Sci*. 1995;13(3):213–222.
29. Hosea TM, Carey CC, Harrer MF. The gender issue: epidemiology of ankle injuries in athletes who participate in basketball. *Clin Orthop Relat Res*. 2000;372:45–49.
30. Chomiak J, Junge A, Peterson L, Dvorak J. Severe injuries in football players: influencing factors. *Am J Sports Med*. 2000;28(suppl 5):S58–S68.
31. Giza E, Mithöfer K, Farrell L, Zarins B, Gill T. Injuries in women's professional soccer. *Br J Sports Med*. 2005;39(4):212–216.
32. 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.
33. 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.
34. 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.
35. Marshall SW, Guskiewicz KM, Shankar V, McCrea M, Cantu RC. Epidemiology of sports-related concussion in seven US high school and collegiate sports. *Inj Epidemiol*. 2015;2(1):13.
36. Green L. Legal perspectives, recommendations on state concussion laws. National Federation of State High School Associations Web site. https://www.nfhs.org/articles/legal-perspectives-recommendations-on-state-concussion-laws/. Published November 21, 2014. Accessed March 6, 2018.
37. 2014–15 NCAA Sports Medicine Handbook. National Collegiate Athletic Association Publications Web site. http://www.ncaapublications.com/DownloadPublication.aspx?download=MD15.pdf. Accessed March 6, 2018.
38. Baugh CM, Kroshus E, Daneshvar DH, Filali NA, Hiscox MJ, Glantz LH. Concussion management in United States college sports: compliance with National Collegiate Athletic Association concussion policy and areas for improvement. *Am J Sports Med*. 2015;43(1):47–56.
39. Caswell SV, Lincoln AE, Almquist JL, Dunn RE, Hinton RY. Video incident analysis of head injuries in high school girls' lacrosse. *Am J Sports Med*. 2012;40(4):756–762.
40. Standard specification for headgear used in women's lacrosse (excluding goalkeepers). American Society for Testing and Materials International Web site. http://www.astm.org/Standards/F3137.htm. Accessed March 6, 2018.
41. Women's lacrosse headgear FAQ. US Lacrosse Web site. http://www.uslacrosse.org/safety/equipment/womens-lacrosse-headgear-faq. Accessed March 6, 2018.
42. Hagel B, Meeuwisse W. Risk compensation: a "side effect" of sport injury prevention? *Clin J Sport Med*. 2004;14(4):193–196.
43. Hedlund J. Risky business: safety regulations, risks compensation, and individual behavior. *Inj Prev*. 2000;6(2):82–90.
44. Ruedl G, Abart M, Ledochowski L, Burtscher M, Kopp M. Self reported risk taking and risk compensation in skiers and snowboarders are associated with sensation seeking. *Accid Anal Prev*. 2012;48: 292–296.
45. Ružić L, Tudor A. Risk-taking behavior in skiing among helmet wearers and nonwearers. *Wilderness Environ Med*. 2011;22(4):291–296.
46. Ruedl G, Kopp M, Burtscher M. Does risk compensation undo the protection of ski helmet use? *Epidemiology*. 2012;23(6):936–937.
47. 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(6):899–904.
48. Swenson DM, Collins CL, Fields SK, Comstock RD. Epidemiology of U.S. high school sports-related ligamentous ankle injuries, 2005/06–2010/11. *Clin J Sport Med*. 2013;23(3):190–196.
49. Swenson DM, Yard EE, Fields SK, Comstock RD. Patterns of recurrent injuries among US high school athletes, 2005–2008. *Am J Sports Med*. 2009;37(8):1586–1593.
50. McCriskin BJ, Cameron KL, Orr JD, Waterman BR. Management and prevention of acute and chronic lateral ankle instability in athletic patient populations. *World J Orthop*. 2015;6(2):161–171.
51. McGuine TA, Brooks A, Hetzel S. The effect of lace-up ankle braces on injury rates in high school basketball players. *Am J Sports Med*. 2011;39(9):1840–1848.
52. Van Reijen M, Vriend I, Zuidema V, van Mechelen W, Verhagen EA. The "strengthen your ankle" program to prevent recurrent injuries: a randomized controlled trial aimed at long-term effectiveness. *J Sci Med Sport*. 2017;20(6):549–554.
53. LaxPrep. US Lacrosse Web site. http://www.uslacrosse.org/coaches/coaching-education-program/online-courses/laxprep. Accessed March 6, 2018.
54. Gerrard DF. Overuse injury and growing bones: the young athlete at risk. *Br J Sports Med*. 1993;27(1):14–18.
55. Valovich McLeod TC, Decoster LC, Loud KJ, et al. National Athletic Trainers' Association position statement: prevention of pediatric overuse injuries. *J Athl Train*. 2011;46(2):206–220.
56. Roos KG, Marshall SW, Kerr ZY, et al. Epidemiology of overuse injuries in collegiate and high school athletics in the United States. *Am J Sports Med*. 2015;43(7):1790–1797.
57. Brenner JS; American Academy of Pediatrics Council on Sports Medicine and Fitness. Overuse injuries, overtraining, and burnout in child and adolescent athletes. *Pediatrics*. 2007;119(6):1242–1245.

Address correspondence to Zachary Y. Kerr, PhD, MPH, Injury Prevention Research Center, Department of Exercise and Sport Science, University of North Carolina at Chapel Hill, 313 Woollen Gym, CB#8700, Chapel Hill, North Carolina 27599-8700. Address e-mail to zkerr@email.unc.edu.