

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

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**Context:** The advent of Web-based sports injury surveillance via programs such as the High School Reporting Information Online system and the National Collegiate Athletic Association Injury Surveillance Program has aided the acquisition of data for girls' and women's field hockey injuries.

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

**Design:** Descriptive epidemiology study.

**Setting:** Online injury surveillance from field hockey teams in high school girls (annual average = 61) and collegiate women (annual average = 14).

**Patients or Other Participants:** Girls' and women's field hockey players who participated in practices and competitions during the 2008–2009 through 2013–2014 high school academic years and the 2004–2005 through 2013–2014 collegiate academic years.

**Main Outcome Measure(s):** Athletic trainers collected time-loss ( $\geq 24$  hours) injury and exposure data. Injury rates per 1000 athlete-exposures (AEs), injury rate ratios (IRRs) with 95%

confidence intervals (CIs), and injury proportions by body site and diagnosis were calculated.

**Results:** The High School Reporting Information Online system documented 983 time-loss injuries during 569 551 AEs; the National Collegiate Athletic Association Injury Surveillance Program documented 996 time-loss injuries during 185 984 AEs. The injury rate from 2008–2009 through 2013–2014 was higher in college than in high school (3.25 versus 1.73/1000 AEs; IRR = 1.89; 95% CI = 1.63, 2.18). Most injuries occurred during practices in high school (52.0%) and college (60.7%). Injury rates were higher during competitions than practices in high school (IRR = 2.00; 95% CI = 1.76, 2.26) and college (IRR = 1.96; 95% CI = 1.73, 2.23). At both levels, injuries most commonly occurred to the lower extremity and head/face and resulted in muscle/tendon strains and contusions. However, injury patterns varied between practices and competitions.

**Conclusions:** Injury rates and patterns varied across age groups and between practices and competitions, highlighting the need for development of targeted injury-prevention strategies at both levels of play.

**Key Words:** lower extremity, student-athletes, athletic injuries

## Key Points

- The injury rate was higher in collegiate women's field hockey than in high school girls' field hockey.
- Although most injuries occurred during practices at both the high school and collegiate levels, the injury rate was higher in competition.
- Most injuries affected the lower extremity and head/face and resulted in muscle/tendon strains and contusions.

Competitive women's field hockey began in 1975 under the Association for Intercollegiate Athletics for Women, before being shifted to the National Collegiate Athletic Association (NCAA) in the 1981–1982 academic year. More recently in 2014–2015, close to 6000 women participated in NCAA field hockey across divisions.<sup>1</sup> Over 60 000 high school athletes participate in field hockey.<sup>2</sup> The continued increase in participation may equate to a similar increase in the number of injuries occurring in the sport, warranting the need for continued injury surveillance and the development of prevention strategies.

The NCAA has used injury surveillance to acquire collegiate sports injury data since the 1980s. 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).<sup>3</sup> A year later, High School Reporting Information Online (HS RIO), a similar Web-based high school sports injury-surveillance system, was launched.<sup>4</sup>

Although field hockey is played with a hard, fast-moving projectile and a stick, athletes wear minimal protective equipment. Most of the attention in injury prevention has focused on the use of equipment for the face, particularly protective eyewear. As denoted in the van Mechelen et al<sup>5</sup> framework, injury prevention benefits from ongoing monitoring of injury incidence, and updated descriptive epidemiology is needed. A previous NCAA-ISP report<sup>6</sup> for the 1988–1989 through 2002–2003 academic years documented women's field hockey competition and practice injury rates of 7.87 and 3.70/1000 athlete-exposures (AEs), respectively. In addition, it is important to document injury incidence at the high school level and compare findings between the settings. The purpose of this article is to summarize the descriptive epidemiology of injuries sustained in girls' high school and women's collegiate field hockey during the first decade of Web-based sports injury surveillance (2004–2005 through 2013–2014 academic years).

## METHODS

### Data Sources and Study Period

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

An average of 61 high schools sponsoring girls' field hockey 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 14 NCAA member institutions (Division I = 7, Division III = 7) sponsoring women's field hockey participated in the NCAA-ISP during the 2004–2005 through 2013–2014 academic years. The methods of HS RIO and NCAA-ISP are summarized in the following sections. 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.<sup>7</sup> In addition, earlier authors have described the sampling and data collection of HS RIO<sup>4,8</sup> and NCAA-ISP<sup>3</sup> in depth.

### The High School RIO

The 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 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).

The 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 other sports of interest (eg, boys' ice hockey, lacrosse; girls' field hockey, 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.<sup>9</sup> 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 because of 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 in the first panel (those enrolled in the original random sample) chose to report for more than the original 9 sports of interest, and ATs at some of the schools from the second panel reported for some of the original 9 sports as well as the additional sports of interest. Data originated from those schools in the original and convenience samples that had collected data from girls' field hockey.

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

### The NCAA-ISP

The NCAA-ISP depends on a convenience sample of teams with ATs voluntarily reporting injury and exposure data.<sup>3</sup> 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 compe-

tion. A description of data collection for the 2004–2005 through 2013–2014 academic years follows.

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.<sup>3</sup> 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 or 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 as part of their daily clinical practice, as opposed to asking them to report injuries solely to participate 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.

To calculate national estimates of the number of injuries and AEs, we applied poststratification sample weights, based on sport, division, and academic year, to each reported injury and AE. Weights for all data were further adjusted to correct for underreporting, consistent with Kucera et al,<sup>10</sup> 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<sup>-1</sup>). In-depth information on the formula used to calculate national estimates can be found in the previously published methodologic article.<sup>7</sup>

## Definitions

**Injury.** A reportable *injury* in both HS RIO and 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 time 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 earlier) 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 in 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 SAS 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 among these surveillance systems, caution must be taken when interpreting these results.

We examined injury counts, national estimates (for college only), and distributions by event type (practice or competition), 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), school size in high school ( $\leq 1000$  and  $> 1000$  students), division in college (Division I or III), and time in season (preseason, regular season, or postseason). For the IRR comparing high school and collegiate athletes, because HS RIO had data available only for 2008–2009 through 2013–2014, we considered only the NCAA-ISP data from that time period. All IRRs with 95% confidence intervals (CIs) not containing 1.0 were considered statistically significant.

Last, we used linear regression to analyze linear trends across time for injury rates 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 conducted 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 983 time-loss injuries in high school girls' field hockey (Table 1). During the 2004–2005 through 2013–2014 academic years, ATs reported a total of 996 injuries in collegiate women's field hockey. The total injury rate for high school girls' field hockey was 1.73/1000 AEs (95% CI = 1.62, 1.83). The total injury rate for collegiate women's field hockey was 5.36/1000 AEs (95% CI = 5.02, 5.69). The total injury rate during 2008–2009 through 2013–2014 was higher in college than in high school (3.25 versus 1.73/1000 AEs; IRR = 1.89; 95% CI = 1.63, 2.18).

**Table 1. Injury Rates by School Size or Division and Type of Athlete-Exposure in High School Girls' and Collegiate Women's Field Hockey<sup>a</sup>**

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	Practice	210 (49.1)	171 754	1.22 (1.06, 1.39)
	Competition	218 (50.9)	77 901	2.80 (2.43, 3.17)
	Total	428 (100.0)	249 655	1.71 (1.55, 1.88)
>1000 students	Practice	301 (54.2)	217 759	1.38 (1.23, 1.54)
	Competition	254 (45.8)	102 137	2.49 (2.18, 2.79)
	Total	555 (100.0)	319 896	1.73 (1.59, 1.88)
Total	Practice	511 (52.0)	389 513	1.31 (1.20, 1.43)
	Competition	472 (48.0)	180 038	2.62 (2.39, 2.86)
	Total	983 (100.0)	569 551	1.73 (1.62, 1.83)
NCAA-ISP (2004–2005 through 2013–2014)				
Division I	Practice	272 (58.7)	83 339	3.26 (2.88, 3.65)
	Competition	191 (41.3)	25 871	7.38 (6.34, 8.43)
	Total	463 (100.0)	109 210	4.24 (3.85, 4.63)
Division III	Practice	333 (62.5)	56 603	5.88 (5.25, 6.51)
	Competition	200 (37.5)	20 171	9.92 (8.54, 11.29)
	Total	533 (100.0)	76 774	6.94 (6.35, 7.53)
Total	Practice	605 (60.7)	139 942	4.32 (3.98, 4.67)
	Competition	391 (39.3)	46 041	8.49 (7.65, 9.33)
	Total	996 (100.0)	185 984	5.36 (5.02, 5.69)

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

<sup>a</sup> 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. No Division II schools participated in the NCAA-ISP. 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 the totals because of rounding error.

### School Size and Division

In high school girls' field hockey, the total injury rate did not differ between high schools with ≤1000 students and high schools with >1000 students (IRR = 0.99; 95% CI = 0.87, 1.12; Table 1). In collegiate women's field hockey, total injury rates varied by division. The total injury rate was higher in Division III than in Division I (IRR = 1.64; 95% CI = 1.45, 1.85).

### Event Type

The majority of injuries occurred during practices in both high school (52.0%) and college (60.7%; Table 1). The competition injury rate was higher than the practice injury rate in high school (IRR = 2.00; 95% CI = 1.76, 2.26) and in college (IRR = 1.96; 95% CI = 1.73, 2.23).

At the high school level, decreases were found in the annual injury rates for practices (annual average change = -0.05/1000 AEs; 95% CI = -0.10, -0.01) and competitions (annual average change = -0.11/1000 AEs; 95% CI = -0.19, -0.03; Figure). At the collegiate level, decreases occurred in the 2004–2005 through 2008–2009 academic years for practices (annual average change = -1.23/1000 AEs; 95% CI = -1.76, -0.69) and competitions (annual average change = -0.92/1000 AEs; 95% CI = -1.55, -0.30); a decrease was also present in the 2009–2010 through 2013–2014 academic years for practices (annual average change = -0.60/1000 AEs; 95% CI = -1.00, -0.19) but not for competitions (annual average change = -0.12/1000 AEs; 95% CI = -1.57, 1.32).

### Time in Season

In both high school (70.8%) and college (60.1%), most injuries occurred during the regular season (Table 2). In college, the preseason had a higher injury rate than the regular season (IRR = 1.53; 95% CI = 1.34, 1.74) and postseason (IRR = 2.92; 95% CI = 2.08, 4.10). In addition, the injury rate was higher in the regular season than in the postseason (IRR = 1.91; 95% CI = 1.37, 2.67). Injury rates by time in season could not be calculated for high school as AEs were not stratified by time in season.

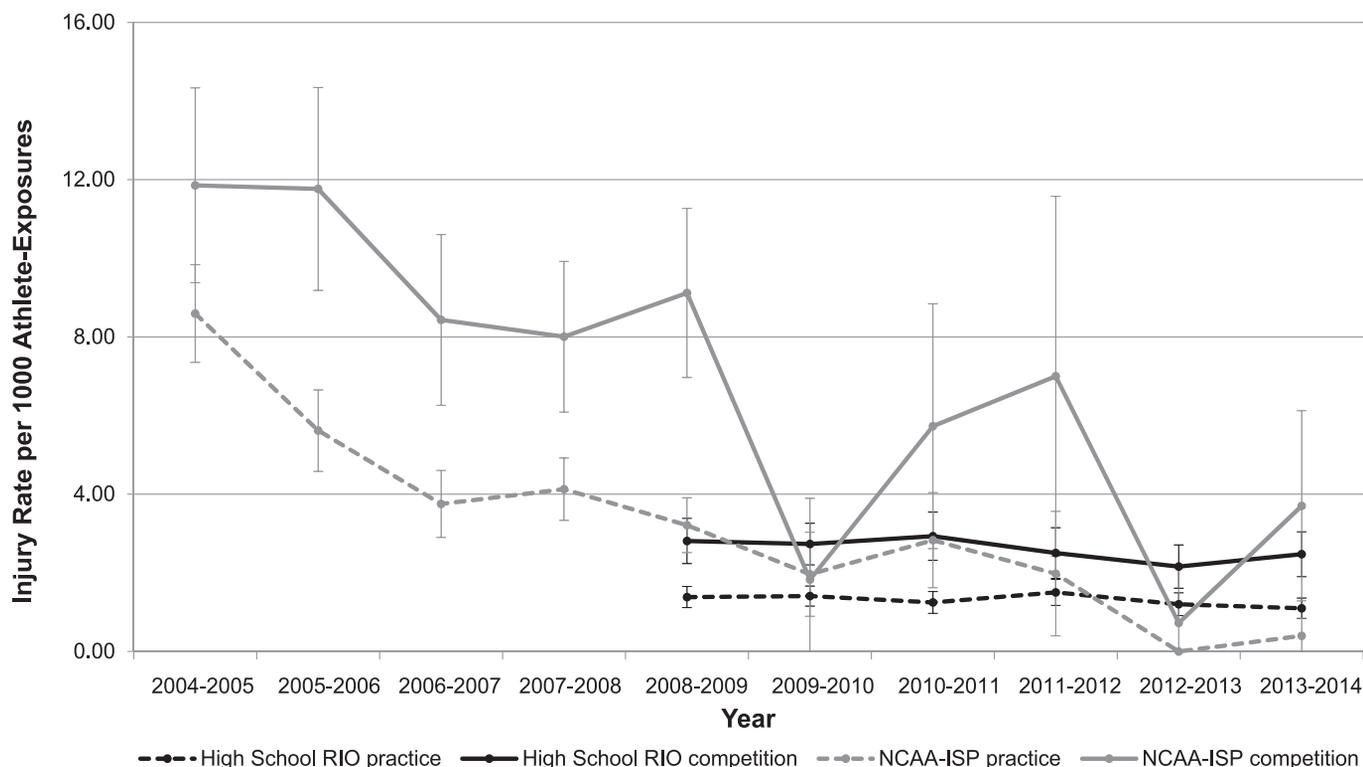
### Time Loss From Participation

In both high school and college, the largest proportion of injuries resulted in time loss of less than 1 week, ranging from 49.5% for injuries in high school competitions to 71.6% for injuries in collegiate competitions (Table 3).

### Body Parts Injured and Diagnoses

**High School.** The most commonly injured body parts were the hip/thigh/upper leg (23.6%) and head/face (15.4%) during practices and the head/face (36.0%) and hand/wrist (17.2%) during competitions (Table 4). The most frequent diagnoses were muscle/tendon strains (31.8%) and ligament sprains (15.7%) during practices and concussions (22.7%) and contusions (21.9%) during competitions (Table 5).

**College.** The body parts injured most often were the hip/thigh/upper leg (27.4%) and knee (15.5%) during practices and the head/face (27.6%) and hand/wrist (15.4%) during



**Figure.** Injury rates by year and type of athlete-exposure (AE) in high school girls' and collegiate women's field hockey. Note: Annual average changes for linear trend test for injury rates are as follows: High School Reporting Information Online (RIO; practices =  $-0.05/1000$  AEs, 95% confidence interval [CI] =  $-0.10, -0.01$ ; competitions =  $-0.11/1000$  AEs, 95% CI =  $-0.19, -0.03$ ); National Collegiate Athletic Association Injury Surveillance Program (NCAA-ISP) 2004–2005 through 2008–2009 (practices =  $-1.23/1000$  AEs, 95% CI =  $-1.76, -0.69$ ; competitions =  $-0.92/1000$  AEs, 95% CI =  $-1.55, -0.30$ ); NCAA-ISP 2009–2010 through 2013–2014 (practices =  $-0.60/1000$  AEs, 95% CI =  $-1.00, -0.19$ ; competitions =  $-0.12/1000$  AEs, 95% CI =  $-1.57, 1.32$ ). A negative rate indicates a decrease in the annual average change; 95% CIs that include 0.00 are not significant.

competitions (Table 4). The most common diagnoses were muscle/tendon strains (29.7%) and ligament sprains (14.7%) during practices and contusions (25.1%) and ligament sprains (14.6%) during competitions (Table 5).

### Mechanisms of Injury and Activities

**High School.** The most frequent mechanisms of injury were no contact (31.1%) and overuse/chronic (28.7%) during practices and contact with stick (25.9%) and contact

**Table 2.** Injury Rates by Time in Season and Type of Athlete-Exposure in High School Girls' and Collegiate Women's Field Hockey<sup>a</sup>

Time in Season	Event Type	HS RIO (2008–2009 Through 2013–2014)		NCAA-ISP (2004–2005 Through 2013–2014)	
		Injuries in Sample, No. (%)	Injuries in Sample, No. (%)	Athlete-Exposures	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
Preseason	Practice	231 (88.5)	346 (96.1)	47 478	7.29 (6.52, 8.06)
	Competition	30 (11.5)	14 (3.9)	930	15.05 (7.17, 22.94)
	Total	261 (100.0)	360 (100.0)	48 408	7.44 (6.67, 8.21)
Regular season	Practice	271 (39.0)	246 (41.1)	82 023	3.00 (2.62, 3.37)
	Competition	423 (61.0)	353 (58.9)	41 005	8.61 (7.71, 9.51)
	Total	694 (100.0)	599 (100.0)	123 028	4.87 (4.48, 5.26)
Postseason	Practice	8 (32.0)	13 (35.1)	10 441	1.25 (0.57, 1.92)
	Competition	17 (68.0)	24 (64.9)	4 107	5.84 (3.51, 8.18)
	Total	25 (100.0)	37 (100.0)	14 548	2.54 (1.72, 3.36)

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

<sup>a</sup> Excluded 3 injuries reported in HS RIO because of 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. 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.

**Table 3. Number of Injuries and Injury Rates by Time Loss and Type of Athlete-Exposure in High School Girls' and Collegiate Women's Field Hockey<sup>a</sup>**

Surveillance System and Time-Loss Category	Practice		Competition	
	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	262 (53.3)	0.67 (0.59, 0.75)	222 (49.5)	1.23 (1.07, 1.40)
1 to 3 wk	156 (31.8)	0.40 (0.34, 0.46)	146 (32.6)	0.81 (0.68, 0.94)
>3 wk <sup>b</sup>	73 (14.9)	0.19 (0.14, 0.23)	80 (17.9)	0.44 (0.35, 0.54)
NCAA-ISP (2004–2005 through 2013–2014)				
1 d to <1 wk	350 (63.1)	2.50 (2.24, 2.76)	250 (71.6)	5.43 (4.76, 6.10)
1 to 3 wk	157 (28.3)	1.12 (0.95, 1.30)	80 (22.9)	1.74 (1.36, 2.12)
>3 wk <sup>b</sup>	48 (8.7)	0.34 (0.25, 0.44)	19 (5.4)	0.41 (0.23, 0.60)

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

<sup>a</sup> Excluded 44 injuries reported in HS RIO and 92 injuries reported in the NCAA-ISP because of missing data for time loss. Percentages may not add up to 100.0 because of 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.

<sup>b</sup> Includes injuries that resulted in time loss >3 wk, 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.

with ball (24.4%) during competitions (Table 6). The most often cited activities associated with injury were conditioning (32.0%) and general play (29.9%) during practices and defending (33.2%) and general play (20.2%) during competitions (Table 7).

**College.** The most common mechanisms of injury were no contact (49.1%) and overuse/chronic (17.2%) during practices and contact with ball (27.2%) and no contact (23.8%) during competitions (Table 6). The most frequent activities associated with injury were general play (47.4%) and conditioning (20.7%) during practices and general play (47.8%) and defending (24.8%) during competitions (Table 7).

### Position-Specific Injuries in Competitions

During high school competitions, concussion was the injury incurred most often among all positions, although the most common mechanism of injury varied by position (Table 8). Concussions were also the most frequent injuries among all collegiate forwards, midfielders, and defenders, but knee injuries most often affected goalkeepers in competitions. Furthermore, ankle sprains and hip/thigh/upper leg strains were also common across positions.

## DISCUSSION

We are the first to directly compare injury rates and patterns across high school and collegiate female field hockey players over multiple seasons in the United States. Although several injury patterns were similar between the 2 age cohorts, such as higher injury rates during competitions than during practices, important differences were identified that may allow for the development of more effective injury-prevention strategies targeted to the level of play. Overall, collegiate female field hockey players had higher injury rates than their high school counterparts, and injury

mechanisms and activities during which injury occurred varied by age group.

Previous authors<sup>6</sup> have reported data originating between 1988–1989 and 2002–2003 from the NCAA Injury Surveillance System. The injury rates observed in our study were higher than those previously reported during competitions (8.49 versus 7.87/1000 AEs) and practices (4.32 versus 3.70/1000 AEs). However, the most commonly injured body part remained stable between studies (lower extremity), and the most frequent mechanisms of injury were similar (contact with ball and no contact). Many factors could have affected this increase, including additional training time, nutritional and conditioning changes, or reporting discrepancies between the 2 study periods. Overall, we caution against interpretation of the different injury rates, as participation rates in our current study were smaller than in the previous dataset: an average of 40 programs participated annually from 1988–1989 through 2002–2003, whereas an average of 13 programs participated from 2004–2005 through 2013–2014. To obtain valid and reliable estimates of injury incidence in collegiate field hockey for driving injury-prevention efforts, existing programs must participate in injury-surveillance efforts. The most generalizable data will help to ensure that data-driven rule changes and decisions to increase student-athlete safety and health are appropriately enacted.

In contrast to the collegiate findings, previously reported high school girls' field hockey injury rates from the mid-1990s<sup>11</sup> for practice and competition (3.2 and 4.9/1000 AEs, respectively) were higher than our practice and competition injury rates (1.31 and 2.62/1000 AEs, respectively). Several drivers of the decrease in injury rates have been hypothesized. The decrease may be associated with advances in injury prevention, although the advances would have been effective only at the high school level, given the increase in collegiate injury rates over time. Alternatively,

**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 Field Hockey<sup>a</sup>**

Surveillance System and Body Part Injured	Practice		Competition	
	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	78 (15.4)	0.20 (0.16, 0.24)	169 (36.0)	0.94 (0.80, 1.08)
Neck	1 (0.2)	<0.01 (0.00, 0.01)	3 (0.6)	0.02 (0.00, 0.04)
Shoulder/clavicle	4 (0.8)	0.01 (0.00, 0.02)	7 (1.5)	0.04 (0.01, 0.07)
Arm/elbow	4 (0.8)	0.01 (0.00, 0.02)	5 (1.1)	0.03 (0.00, 0.05)
Hand/wrist	20 (3.9)	0.05 (0.03, 0.07)	81 (17.2)	0.45 (0.35, 0.55)
Trunk	38 (7.5)	0.01 (0.07, 0.13)	17 (3.6)	0.09 (0.05, 0.14)
Hip/thigh/upper leg	120 (23.6)	0.31 (0.25, 0.36)	39 (8.3)	0.22 (0.15, 0.28)
Knee	74 (14.6)	0.12 (0.09, 0.16)	61 (13.0)	0.34 (0.25, 0.42)
Lower leg	52 (10.2)	0.13 (0.10, 0.17)	18 (3.8)	0.10 (0.05, 0.15)
Ankle	56 (11.0)	0.14 (0.11, 0.18)	50 (10.6)	0.28 (0.20, 0.35)
Foot	33 (6.5)	0.08 (0.06, 0.11)	16 (3.4)	0.09 (0.05, 0.13)
Other	28 (5.5)	0.07 (0.05, 0.10)	4 (0.9)	0.02 (0.00, 0.04)
NCAA-ISP (2004–2005 through 2013–2014)				
Head/face	62 (10.3)	0.44 (0.33, 0.55)	108 (27.6)	2.35 (1.90, 2.79)
Neck	1 (0.2)	0.01 (0.00, 0.02)	5 (1.3)	0.11 (0.01, 0.20)
Shoulder/clavicle	11 (1.8)	0.08 (0.03, 0.13)	12 (3.1)	0.26 (0.11, 0.41)
Arm/elbow	7 (1.2)	0.05 (0.01, 0.09)	6 (1.5)	0.13 (0.03, 0.23)
Hand/wrist	36 (6.0)	0.26 (0.17, 0.34)	60 (15.4)	1.30 (0.97, 1.63)
Trunk	46 (7.6)	0.33 (0.23, 0.42)	14 (3.6)	0.30 (0.14, 0.46)
Hip/thigh/upper leg	166 (27.4)	1.19 (1.01, 1.37)	39 (10.0)	0.85 (0.58, 1.11)
Knee	94 (15.5)	0.67 (0.54, 0.81)	56 (14.3)	1.22 (0.90, 1.53)
Lower leg	56 (9.3)	0.40 (0.30, 0.50)	22 (5.6)	0.48 (0.28, 0.68)
Ankle	70 (11.6)	0.50 (0.38, 0.62)	43 (11.0)	0.93 (0.65, 1.21)
Foot	33 (5.5)	0.24 (0.16, 0.32)	17 (4.4)	0.37 (0.19, 0.54)
Other	23 (3.8)	0.16 (0.10, 0.23)	9 (2.3)	0.20 (0.07, 0.32)

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

<sup>a</sup> Excluded 5 injuries reported in HS RIO because of missing data for body part. Percentages may not add up to 100.0 because of 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.

with increased participation,<sup>2</sup> high school student-athletes may be receiving better coaching and developing better skills, which may decrease the injury risk. The contrasting findings between the high school and collegiate levels, in comparison with previous findings, warrant additional research to fully understand age-specific injury risk factors.

Several other reports of various cohorts have been published. Comparisons are difficult, however, because of the differences in study methods. Murtaugh<sup>12</sup> described a mixed cohort of high school, collegiate, and national-level female field hockey players. One interesting discrepancy is Murtaugh's<sup>12</sup> conclusion that 42% of game and practice injuries were caused by an impact with the ball. Our data suggested that fewer than 28% of injuries in games or practices at the high school or collegiate level resulted from ball impact. Additional studies of men's and women's senior international field hockey<sup>13</sup> and men's junior international field hockey<sup>14</sup> also have been conducted. These reports are compelling and provide further evidence regarding field hockey injuries, but direct comparisons are difficult because of methodologic and cohort differences. Standardizing injury definitions and data-collection methods would help improve our overall understanding of the

epidemiology of field hockey injuries and the relative burden and risk factors across various playing cohorts.

### Comparisons Between and Within High School and Collegiate Field Hockey Players

Interesting differences were noted between female high school and collegiate field hockey players. Injury rates were higher in collegiate than in high school players. Several factors may account for this difference. Overall, the collegiate game is played at a faster pace by bigger and stronger women. Thus, player-to-player contact and ball-to-player contact may occur with greater force and therefore be more likely to injure collegiate women as compared with the same mechanisms in high school girls' field hockey. Field conditions may also contribute to differences between the age cohorts. High school players often play on grass fields, which may be of poor quality, leading to unpredictably bouncing balls and a resulting increased risk of injury. Conversely, though, collegiate players may more commonly play on turf, which could also affect their injury risk. As we were unable to assess the effect of field type on injury

**Table 5. Number of Injuries and Injury Rates by Diagnosis and Type of Athlete-Exposure in High School Girls' and Collegiate Women's Field Hockey<sup>a</sup>**

Surveillance System and Diagnosis	Practice		Competition	
	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	45 (8.8)	0.12 (0.08, 0.15)	107 (22.7)	0.59 (0.48, 0.71)
Contusion	41 (8.1)	0.11 (0.07, 0.14)	103 (21.9)	0.57 (0.46, 0.68)
Dislocation <sup>b</sup>	0	0.00	7 (1.5)	0.04 (0.01, 0.07)
Fracture/avulsion	15 (3.0)	0.04 (0.02, 0.06)	55 (11.7)	0.31 (0.22, 0.39)
Laceration	17 (3.3)	0.04 (0.02, 0.06)	39 (8.3)	0.22 (0.15, 0.28)
Ligament sprain	80 (15.7)	0.21 (0.16, 0.25)	82 (17.4)	0.46 (0.36, 0.55)
Muscle/tendon strain	162 (31.8)	0.42 (0.35, 0.48)	46 (9.8)	0.26 (0.18, 0.33)
Other	149 (29.3)	0.38 (0.32, 0.44)	32 (6.8)	0.18 (0.12, 0.24)
NCAA-ISP (2004–2005 through 2013–2014)				
Concussion	26 (4.3)	0.19 (0.11, 0.26)	52 (13.3)	1.13 (0.82, 1.44)
Contusion	63 (10.5)	0.45 (0.34, 0.56)	98 (25.1)	2.13 (1.71, 2.55)
Dislocation <sup>b</sup>	0	0.00	2 (0.5)	0.04 (0.00, 0.10)
Fracture/avulsion	23 (3.8)	0.16 (0.10, 0.23)	45 (11.5)	0.98 (0.69, 1.26)
Laceration	15 (2.5)	0.11 (0.05, 0.16)	22 (5.6)	0.48 (0.28, 0.68)
Ligament sprain	88 (14.7)	0.63 (0.50, 0.76)	57 (14.6)	1.24 (0.92, 1.56)
Muscle/tendon strain	178 (29.7)	1.27 (1.09, 1.46)	44 (11.3)	0.96 (0.67, 1.24)
Other	207 (34.5)	1.48 (1.28, 1.68)	71 (18.2)	1.54 (1.18, 1.90)

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

<sup>a</sup> Excluded 3 injuries reported in HS RIO and 5 injuries reported in the NCAA-ISP because of missing data for diagnosis. Percentages may not add up to 100.0 because of 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.

<sup>b</sup> Includes separations.

rates in this study, future data-collection procedures should capture this potentially important variable.

High school injury rates did not differ between large and small schools, but differences were noted between Division I and Division III colleges. At the collegiate level, this may reflect the higher perceived performance demands experienced by Division I players. More pressure on Division I participants may push players to play through injuries, resulting in fewer injuries reported to the collegiate ATs. Alternatively, the higher level of play in Division I may coincide with a higher skill level, which would be expected to minimize injury rates. Unfortunately, our data are not sufficient to determine the specific reasons for divisional differences. Understanding divisional injury-rate differences across all college sports is important and should be a focus of future research efforts, as the findings could contribute to more effective, targeted injury-prevention efforts.

### Common Injuries and Injury Prevention

Consistent with a previous report,<sup>6</sup> among women's collegiate field hockey players, the injury rates were higher in the preseason than in the regular season and postseason. Conditioning was identified as a common activity during which injury occurred to both high school (30%) and collegiate (21%) athletes. Together, these results could have important injury-prevention implications. Coaches, strength and conditioning specialists, and ATs could tailor

preseason conditioning regimens to reduce the injury risk. For example, better off-season programs may help maintain appropriate conditioning levels, leading to a decreased injury risk when the preseason begins. A gradual introduction of high-level activity during the preseason may also help to decrease the injury risk. Well-designed intervention studies are needed to evaluate the effectiveness of such prevention programs.

Additionally, performing exercises throughout the season that improve proprioception and sensorimotor abilities may also help to decrease the injury incidence in youth and collegiate athletes. As early as 1996, Caraffa et al<sup>15</sup> demonstrated the efficacy of a proprioceptive training program among soccer players. Since then, numerous authors<sup>16–18</sup> have touted the efficacy of these neuromuscular regimens. Although no consensus exists on the specific elements that must be included, these protocols generally aim to decrease landing forces and improve landing posture with hamstrings and gluteus muscle strengthening and plyometric exercises. Today, popular programs include the “Prevent Injury and Enhance Performance” program<sup>19</sup> and the Fédération Internationale de Football Association 11+ program.<sup>20</sup> These programs have not been studied specifically in the sport of field hockey, but their ability to decrease the incidence of injuries,<sup>20–22</sup> including anterior cruciate ligament tears, in female athletes generally makes them a logical option for further study and possible inclusion in this sport's training protocol.

**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 Field Hockey<sup>a</sup>**

Surveillance System and Mechanism of Injury	Practice		Competition	
	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	30 (6.0)	0.08 (0.05, 0.10)	81 (17.3)	0.45 (0.35, 0.55)
Contact with playing surface	40 (8.0)	0.10 (0.07, 0.13)	45 (9.6)	0.25 (0.18, 0.32)
Contact with stick	27 (5.4)	0.07 (0.04, 0.10)	121 (25.9)	0.67 (0.55, 0.79)
Contact with ball	64 (12.8)	0.16 (0.12, 0.20)	114 (24.4)	0.63 (0.52, 0.75)
Contact with goal	1 (0.2)	<0.01 (0.00, 0.01)	1 (0.2)	0.01 (0.00, 0.02)
Contact with other playing equipment	5 (1.0)	0.01 (0.00, 0.02)	5 (1.1)	0.03 (0.00, 0.05)
No contact	155 (31.1)	0.40 (0.34, 0.46)	83 (17.8)	0.46 (0.36, 0.56)
Overuse/chronic	143 (28.7)	0.37 (0.31, 0.43)	14 (3.0)	0.08 (0.04, 0.12)
Illness/infection	34 (6.8)	0.09 (0.06, 0.12)	3 (0.6)	0.02 (0.00, 0.04)
NCAA-ISP (2004–2005 through 2013–2014)				
Contact with another person	34 (5.7)	0.24 (0.16, 0.32)	67 (17.4)	1.46 (1.11, 1.80)
Contact with playing surface	22 (3.7)	0.16 (0.09, 0.22)	23 (6.0)	0.50 (0.30, 0.70)
Contact with stick	22 (3.7)	0.16 (0.09, 0.22)	72 (18.7)	1.56 (1.20, 1.93)
Contact with ball	92 (15.5)	0.66 (0.52, 0.79)	105 (27.2)	2.28 (1.84, 2.72)
Contact with goal	2 (0.3)	0.01 (0.00, 0.03)	2 (0.5)	0.04 (0.02, 0.10)
Contact with other playing equipment	1 (0.2)	0.01 (0.00, 0.02)	0 (0.0)	0.00
No contact	291 (49.1)	2.08 (1.84, 2.32)	92 (23.8)	2.00 (1.59, 2.41)
Overuse/chronic	102 (17.2)	0.73 (0.59, 0.87)	15 (3.9)	0.33 (0.16, 0.49)
Illness/infection	27 (4.6)	0.19 (0.12, 0.27)	10 (2.6)	0.22 (0.08, 0.35)

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

<sup>a</sup> Mechanism of injury excluded 17 injuries reported in HS RIO and 17 injuries reported in the NCAA-ISP because of missing data or athletic trainer reporting *Other* or *Unknown*. Percentages may not add up to 100.0 because of 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.

During games, at least 50% of the injuries at both levels were due to contact with the stick or ball. Although these injury mechanisms may be hard to avoid given the nature of the sport, continuing efforts should be made to ensure that appropriate injury-prevention strategies are in place. Better skill instruction and rule enforcement may help to decrease these injuries. Padded gloves for field players are allowed but may not always be worn by players; we did not examine the specific use of such equipment. Increased adoption of such protective equipment may help mitigate the incidence of ball- or stick-strike injuries. However, future researchers should examine the benefits and feasibility of protective gloves as well as protective equipment for other areas of the body.

In field hockey, equipment aimed at protecting the head/face has been considered extensively, resulting in variations in rules and mandates regarding such equipment between the high school and collegiate levels. For example, field players at both levels are required to wear mouth guards (mandated by some states for high school players); however, for goalkeepers, mouth guards are required at the high school level and only recommended at the collegiate level.<sup>23</sup> Face masks are not allowed at the high school level but may be worn at the collegiate level when defending the penalty corner<sup>23</sup> as long as athletes are not using the equipment in a dangerous manner against other athletes.<sup>24</sup> The use or lack of protective eyewear has

garnered much debate. In 2011, high school field hockey players were mandated to wear protective eyewear; however, this rule does not apply to collegiate players.<sup>23</sup> It is logical that facial and eye injuries will be minimized with protective eyewear, yet critics of the rule change have expressed concerns that concussions may increase because of collisions due to reduced visibility.<sup>25</sup> However, Kriz et al<sup>26</sup> refuted that theory by noting that the incidence of eye and orbital injuries was lower during time periods in states with the mandate enacted, whereas concussion rates did not differ between time periods in states with and without the mandate. Boden et al<sup>27</sup> recently reported a 52% reduction in the eye-injury rate after the rule change. However, this reduction was not statistically significant, and caution should be used when interpreting these results because of the small overall number of eye injuries (6 before the rule change, 3 after). Despite this evidence, opponents of protective eyewear continue to raise concerns regarding potential unintended consequences. Given the opposition to rule changes requiring protective equipment in field hockey, well-designed studies will be needed to evaluate the effectiveness of equipment-related rule changes and policies across levels of competition.

Concussions were common injuries in both cohorts. Among high school goalkeepers, concussions accounted for more than one-third of all injuries. Overall, concussions accounted for almost one-quarter of all competition injuries

**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 Field Hockey<sup>a</sup>**

Surveillance System and Activity During Injury	Practice		Competition	
	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	39 (8.4)	0.10 (0.07, 0.13)	58 (13.0)	0.32 (0.24, 0.41)
Blocking shot	6 (1.3)	0.02 (0.00, 0.03)	21 (4.7)	0.12 (0.07, 0.17)
Conditioning	149 (32.0)	0.38 (0.32, 0.44)	0 (0.0)	0.00
Defending	38 (8.2)	0.10 (0.07, 0.13)	148 (33.2)	0.82 (0.69, 0.95)
General play	139 (29.9)	0.36 (0.30, 0.42)	90 (20.2)	0.50 (0.40, 0.60)
Goaltending	23 (5.0)	0.06 (0.03, 0.08)	16 (3.6)	0.09 (0.05, 0.13)
Loose ball	35 (7.5)	0.09 (0.06, 0.12)	59 (13.2)	0.33 (0.24, 0.41)
Passing	8 (1.7)	0.02 (0.01, 0.03)	19 (4.3)	0.11 (0.06, 0.15)
Receiving pass	13 (2.8)	0.03 (0.02, 0.05)	21 (4.7)	0.12 (0.07, 0.17)
Shooting	15 (3.2)	0.04 (0.02, 0.06)	14 (3.1)	0.08 (0.04, 0.12)
NCAA-ISP (2004–2005 through 2013–2014)				
Ball handling	34 (5.9)	0.24 (0.16, 0.32)	25 (6.5)	0.54 (0.33, 0.76)
Blocking shot	3 (0.5)	0.02 (0.00, 0.05)	23 (6.0)	0.50 (0.30, 0.70)
Conditioning	119 (20.7)	0.85 (0.70, 1.00)	2 (0.5)	0.04 (0.00, 0.10)
Defending	35 (6.1)	0.25 (0.17, 0.33)	95 (24.8)	2.06 (1.65, 2.48)
General play	272 (47.4)	1.94 (1.71, 2.17)	183 (47.8)	3.97 (3.40, 4.55)
Goaltending	51 (8.9)	0.36 (0.26, 0.46)	19 (5.0)	0.41 (0.23, 0.60)
Loose ball	11 (1.9)	0.08 (0.03, 0.13)	14 (3.7)	0.30 (0.14, 0.46)
Passing	9 (1.6)	0.06 (0.02, 0.11)	6 (1.6)	0.13 (0.03, 0.23)
Receiving pass	15 (2.6)	0.11 (0.05, 0.16)	8 (2.1)	0.17 (0.05, 0.29)
Shooting	25 (4.4)	0.18 (0.11, 0.25)	8 (2.1)	0.17 (0.05, 0.29)

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

<sup>a</sup> Excluded 72 injuries reported in HS RIO and 39 injuries reported in the NCAA-ISP because of missing data or athletic trainer reporting *Other* or *Unknown*. Percentages may not add up to 100.0 because of 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.

among high school players. At the collegiate level, concussions accounted for over 13% of all competition injuries. The mechanisms for these concussions varied greatly between cohorts and among positions within each cohort. Contact-related mechanisms (ie, with another player, ball, or stick) were associated with competition concussions. Mechanisms involving contact with the stick are of concern because high sticking is illegal. Our results are similar to those previously reported by Gardner<sup>28</sup> in her 2015 analysis of NCAA field hockey head injuries. Further enforcement of existing competition rules, such as high sticking, the air-ball rule (ie, the ball can only be lifted as long as it cannot potentially hit or injure another player), and those involving player contact, may help to limit the number of concussions. Although some have suggested consideration of protective headgear in the sport, the high incidence of concussions among goalies (the only field hockey position currently protected with a hard helmet) suggests that more investigation is needed.

### Limitations

Our findings may not be generalizable to other playing levels, such as youth, middle school, and professional programs or to collegiate programs at non-NCAA institutions or high schools without National Athletic Trainers'

Association-affiliated ATs. This is particularly true for NCAA Division II women's field hockey programs, which had no representation in the current study. Furthermore, we were unable to account for factors potentially associated with injury occurrence, such as AT coverage, implemented injury-prevention programs, playing surface, and athlete-specific characteristics (eg, previous injury, functional capabilities). Also, although HS RIO and NCAA-ISP are similar injury-surveillance systems, it is important to consider the differences 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 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 we are among the few to examine injury incidence across multiple levels of play (eg, high school

**Table 8. Most Common Injuries Associated With Position in Competitions in High School Girls' and Collegiate Women's Field Hockey<sup>a</sup>**

Position	HS RIO (2008–2009 Through 2013–2014)			NCAA-ISP (2004–2005 Through 2013–2014)		
	Most Common Injuries	Injuries Within Position, %	Most Frequent Mechanism of Injury for This Injury Within Position	Most Common Injuries	Injuries Within Position, %	Most Frequent Mechanism of Injury for This Injury Within Position
Defense	Concussion	17.7	Contact with ball	Concussion	17.5	Contact with another player
	Head/face laceration	9.7	Contact with stick, contact with ball (tied)	Head contusion	9.3	Contact with ball
Forward	Concussion	19.8	Contact with another player	Ankle sprain	8.3	Contact with another player
				Concussion	9.6	Contact with ball
				Hip/thigh/upper leg strain	9.6	No contact
Goalkeeper	Concussion	36.4	Contact with playing surface	Ankle strain	8.9	No contact
				Knee sprain	20.0	No contact
				Concussion	15.0	Contact with another player
Midfielder	Concussion	24.1	Contact with another player	Hip/thigh/upper leg strain	15.0	No contact
				Concussion	13.2	Contact with stick
				Ankle sprain	7.9	No contact

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

<sup>a</sup> Excluded 30 competition injuries reported in HS RIO and 25 competition injuries reported in the NCAA-ISP because of position not being indicated. The table reads as follows: for the defense position in high school, concussions composed 17.7% of all competition injuries to that position. The most common mechanism of injury for this specific injury for this specific position was contact with ball. 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.

versus college and competition versus practice), we were unable to examine differences between starters and nonstarters in 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 freshman, junior varsity, and varsity teams because of differences in maturation status. Playing positions may vary in physical demands and the resulting injury risk. Athlete-exposures were not collected by position, preventing the calculation of position-specific injury rates.

## CONCLUSIONS

Female field hockey participation continues to increase at the high school and collegiate levels. Injury rates were higher in college than in high school. However, the collegiate injury rates we presented were higher than those previously reported, whereas the high school injury rates were lower than those previously reported. Concussion appears to be one of the most frequent injuries at both levels of play, and this may be modifiable with rule and policy changes along with better enforcement of existing rules. A large percentage of injuries in both cohorts occurred during preseason and were attributed to conditioning. Modifying preseason training to ensure the gradual introduction of high workloads may result in a lower injury rate. Additionally, high school and collegiate programs should consider more-structured offseason programs that better prepare athletes for the rigors of the preseason. Further study in this area is needed, as we reported on a fairly small number of injuries. These data combined with similar injury-epidemiology studies across the age spectrum can greatly inform athlete safety.

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