

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

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**Context:** 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 efforts to collect data on ice hockey injuries.

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

**Design:** Descriptive epidemiology study.

**Setting:** Online injury surveillance of ice hockey teams of high school boys (annual average = 34), collegiate men (annual average = 20), and collegiate women (annual average = 11).

**Patients or Other Participants:** Boys', men's, and women's ice hockey players who participated in practices and competitions during the 2008–2009 through 2013–2014 high school academic years or 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. 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:** The High School Reporting Information Online system documented 831 boys' ice hockey time-loss injuries during 356 997 AEs; the National Collegiate Athletic Association Injury Surveillance Program documented 2611 men's ice hockey time-loss injuries during 552 642 AEs and 752 women's ice hockey injuries during 232 051 AEs. Injury rates were higher in collegiate men than in high school boys during 2008–2009 through 2013–2014 (4.38 versus 2.33/1000 AEs; IRR = 1.88; 95% CI = 1.73, 2.05) and collegiate women during 2004–2005 through 2013–2014 (IRR = 1.46; 95% CI = 1.34, 1.58). Most injuries occurred during competitions (boys = 80.0%, men = 66.9%, women = 55.3%); injury rates were higher in competitions than in practices for boys (IRR = 8.14; 95% CI = 6.87, 9.65), men (IRR = 6.58; 95% CI = 6.06, 7.13), and women (IRR = 3.63; 95% CI = 3.14, 4.19). At all levels, most injuries occurred to the head/face and shoulder/clavicle and resulted in concussions, contusions, or ligament sprains.

**Conclusions:** Injury rates varied across sports but were consistently higher in competitions than in practices. In competitions, concussions were common injuries, highlighting the need for continued development of injury-prevention strategies.

**Key Words:** musculoskeletal injuries, concussions, ligament sprains, injury rate

## Key Points

- Men's ice hockey had the highest overall injury rate among the cohorts investigated.
- Checking may have led to higher injury rates in boys' ice hockey compared with men's ice hockey.
- Of all women's ice hockey competition injuries, 38% resulted from contact with another person, even though body checking was illegal.

Participation in collegiate men's and women's ice hockey has steadily increased over the last 3 decades.<sup>1</sup> The growth in women's collegiate ice hockey has been tremendous, with a nearly 7-fold increase in participation.<sup>1</sup> At the high school level, almost 36 000 boys currently participate in ice hockey.<sup>2</sup> The growth in participation may be associated with an increase in the number of injuries related to the sport. Thus, in order to develop injury-prevention interventions, we need data on the incidence of ice hockey injuries.

Even though ice hockey is a full-contact activity in the boys' and men's sports and unintentional contact can occur in the women's sport, recent epidemiologic data from the high school and collegiate settings are lacking, with most researchers<sup>3,4</sup> focusing on these age groups in international samples. Previous reports examining ice hockey injury data from the National Collegiate Athletic Association (NCAA) showed injury rates of 16.27/1000 athlete-exposures (AEs) in men's ice hockey in the 1988–1999 through 2003–2004 academic years<sup>5</sup> and 12.60/1000 AEs in women's ice hockey in the 2001–2002 through 2003–2004 academic years.<sup>6</sup> As denoted in the van Mechelen et al<sup>7</sup> framework, injury prevention benefits from ongoing monitoring of injury incidence, and updated descriptive epidemiologic data are needed. Further, few comparisons exist on the injury epidemiology of ice hockey injuries across levels. Such differences in age and sex must also be considered when developing targeted and effective injury-prevention strategies.

Since the 1980s, the NCAA has used injury surveillance 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).<sup>8</sup> A year later, High School Reporting Information Online (HS RIO), a similar Web-based sports injury-surveillance system, was launched.<sup>9</sup> The purpose of this article is to summarize the descriptive epidemiology of injuries sustained in boys' high school ice hockey and men's and women's collegiate ice 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 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 34 high schools sponsoring boys' ice 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). During the 2004–2005 through 2013–2014 academic years, an average of 20 NCAA member institutions (Division I = 9, Division

II = 2, Division III = 9) sponsoring men's ice hockey and an average of 11 NCAA member institutions (Division I = 4, Division II = 1, Division III = 6) sponsoring women's ice hockey participated in the NCAA-ISP. 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 a previously published methodologic article.<sup>10</sup> In addition, previous publications have described the sampling and data collection of HS RIO<sup>9,11</sup> and the NCAA-ISP<sup>8</sup> in depth.

### 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 AE information weekly throughout the academic year using a secure Web site. For each injury, the AT completed a detailed report on the 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 with new information (eg, time loss) as needed.

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, 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>12</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 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. The ATs at some schools from 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. Those schools' data represented the original and convenience samples that had collected data from boys' ice hockey.

**National Estimates.** National injury estimate weights were not created for boys' ice 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>8</sup> Participation in the NCAA-ISP, while voluntary, is available to all NCAA institutions. For each injury event, the AT completes a detailed 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. A description of the 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>8</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 and injury-documentation applications, including the Athletic Trainer System (Keffer Development, Grove City, PA), Injury Surveillance Tool (Datalys Center), and the 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 purposes 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 engineer.

**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,<sup>13</sup> who estimated that the ISP captured 88.3% of all time-loss medical-care injury events. Weighted counts were scaled up by a factor of  $(0.883^{-1})$ . In-depth information on the formula used to calculate national estimates can be found in the previously published methodologic article.<sup>10</sup>

## 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 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-Exposures.** 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 were similar, we opted to recode data when necessary in order 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, caution must be taken when interpreting these results.

We examined injury counts, national estimates (for college only), and distributions by event type (practice and 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 first focused on comparisons of high school boys' versus collegiate men's ice hockey and collegiate men's versus women's ice hockey. Comparisons within sport were then performed by event type (practice and competition), school size in 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 IRRs comparing high school boys and collegiate men, because HS RIO had data available only for 2008–2009 through 2013–2014, we analyzed the NCAA-ISP data only from that time period as well. 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 of 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 831 time-loss injuries in high school boys' ice hockey (Table 1). During the 2004–2005 through 2013–2014 academic years, ATs reported a total of 2611 and 752 injuries in collegiate men's and women's ice hockey, respectively. The total injury rate for high school

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

Sport/Surveillance System and School Size or Division	Exposure Type	Injuries in Sample, No. (%)	Athlete-Exposures	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
<b>Boys' ice hockey—HS RIO (2008–2009 through 2013–2014)</b>				
≤1000 students	Practice	102 (18.1)	148 813	0.69 (0.55, 0.82)
	Competition	463 (81.9)	72 143	6.42 (5.83, 7.00)
	Total	565 (100.0)	220 956	2.56 (2.35, 2.77)
>1000 students	Practice	64 (24.1)	90 420	0.71 (0.53, 0.88)
	Competition	202 (75.9)	45 621	4.43 (3.82, 5.04)
	Total	266 (100.0)	136 041	1.96 (1.72, 2.19)
Total	Practice	166 (20.0)	239 233	0.69 (0.59, 0.80)
	Competition	665 (80.0)	117 764	5.65 (5.22, 6.08)
	Total	831 (100.0)	356 997	2.33 (2.17, 2.49)
<b>Men's ice hockey—NCAA-ISP (2004–2005 through 2013–2014)</b>				
Division I	Practice	380 (31.0)	203 999	1.86 (1.68, 2.05)
	Competition	847 (69.0)	63 769	13.28 (12.39, 14.18)
	Total	1227 (100.0)	267 768	4.58 (4.33, 4.84)
Division II	Practice	87 (28.3)	47 059	1.85 (1.46, 2.24)
	Competition	220 (71.7)	14 422	15.25 (13.24, 17.27)
	Total	307 (100.0)	61 480	4.99 (4.43, 5.55)
Division III	Practice	398 (37.0)	171 788	2.32 (2.09, 2.54)
	Competition	679 (63.0)	51 606	13.16 (12.17, 14.15)
	Total	1077 (100.0)	223 394	4.82 (4.53, 5.11)
Total	Practice	865 (33.1)	422 846	2.05 (1.91, 2.18)
	Competition	1746 (66.9)	129 796	13.45 (12.82, 14.08)
	Total	2611 (100.0)	552 642	4.72 (4.54, 4.91)
<b>Women's ice hockey—NCAA-ISP (2004–2005 through 2013–2014)</b>				
Division I	Practice	84 (40.0)	67 271	1.25 (0.98, 1.52)
	Competition	126 (60.0)	23 092	5.46 (4.50, 6.41)
	Total	210 (100.0)	90 363	2.32 (2.01, 2.64)
Division II	Practice	56 (49.6)	18 330	3.06 (2.25, 3.86)
	Competition	57 (50.4)	6 629	8.60 (6.37, 10.83)
	Total	113 (100.0)	24 959	4.53 (3.69, 5.36)
Division III	Practice	196 (45.7)	87 390	2.24 (1.93, 2.56)
	Competition	233 (54.3)	29 339	7.94 (6.92, 8.96)
	Total	429 (100.0)	116 729	3.68 (3.33, 4.02)
Total	Practice	336 (44.7)	172 992	1.94 (1.73, 2.15)
	Competition	416 (55.3)	59 059	7.04 (6.37, 7.72)
	Total	752 (100.0)	232 051	3.24 (3.01, 3.47)

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. 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 due to rounding error.

boys' ice hockey was 2.33/1000 AEs (95% CI=2.17, 2.49). The total injury rates for collegiate men's and women's ice hockey were 4.72/1000 AEs (95% CI = 4.54, 4.91) and 3.24/1000 AEs (95% CI = 3.01, 3.47), respectively. The total injury rate during 2008–2009 through 2013–2014 was higher in collegiate men than in high school boys (4.38 versus 2.33/1000 AEs; IRR = 1.88; 95% CI = 1.73, 2.05). The total injury rate during 2004–2005 through 2013–2014 was higher in collegiate men than in collegiate women (IRR = 1.46; 95% CI = 1.34, 1.58).

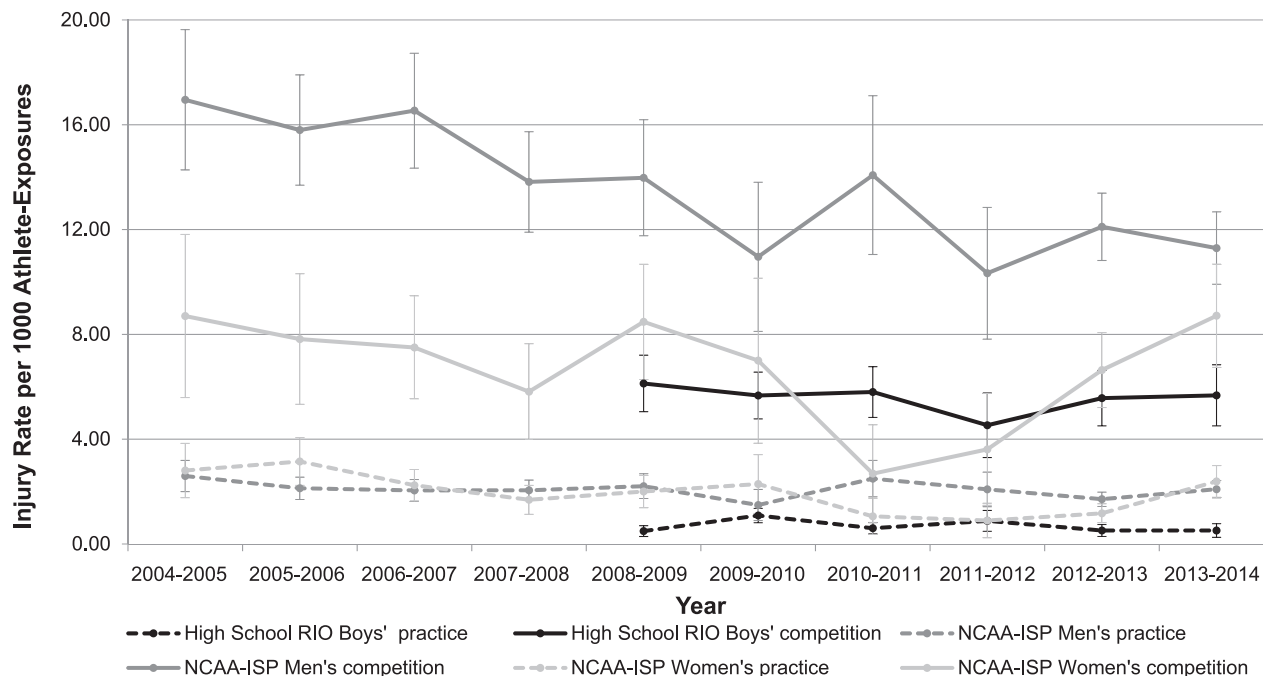
>1000 students (IRR = 1.31; 95% CI = 1.13, 1.51; Table 1). In men's ice hockey, total injury rates did not differ by division (I versus II: IRR = 0.92, 95% CI = 0.81, 1.04; I versus III: IRR = 0.95, 95% CI = 0.88, 1.03; II versus III: IRR = 1.04, 95% CI = 0.91, 1.18). In women's ice hockey, Division II had a higher total injury rate than Division I (IRR = 1.95; 95% CI = 1.55, 2.45) and Division III (IRR = 1.23; 95% CI = 1.00, 1.52); also, Division III had a higher total injury rate than Division I (IRR = 1.58; 95% CI = 1.34, 1.87).

### School Size and Division

In boys' ice hockey, the total injury rate was higher in high schools with ≤1000 students than in high schools with

### Event Type

The majority of injuries occurred during competitions in boys' ice hockey (80.0%), men's ice hockey (66.9%), and



**Figure.** Injury rates by year and type of athlete-exposure (AE) in high school boys', collegiate men's, and collegiate women's ice hockey. **Note:** Annual average changes for linear trend test for injury rates are as follows: High School Reporting Information Online (RIO) boys (practices =  $-0.04/1000$  AEs, 95% confidence interval [CI] =  $-0.14, 0.06$ ; competitions =  $-0.11/1000$  AEs, 95% CI =  $-0.32, 0.10$ ); National Collegiate Athletics Association Injury Surveillance Program (NCAA-ISP) men 2004–2005 through 2008–2009 (practices =  $-0.09/1000$  AEs, 95% CI =  $-0.19, 0.02$ ; competitions =  $-0.79/1000$  AEs, 95% CI =  $-1.20, -0.39$ ); NCAA-ISP men 2009–2010 through 2013–2014 (practices =  $0.04/1000$  AEs, 95% CI =  $-0.17, 0.25$ ; competitions =  $-0.13/1000$  AEs, 95% CI =  $-0.93, 0.66$ ); NCAA-ISP women 2004–2005 through 2008–2009 (practices =  $-0.31/1000$  AEs, 95% CI =  $-0.50, -0.12$ ; competitions =  $-0.25/1000$  AEs, 95% CI =  $-0.84, 0.35$ ); NCAA-ISP women 2009–2010 through 2013–2014 ( $0.03/1000$  AEs, 95% CI =  $-0.37, 0.43$ ; competitions =  $0.74/1000$  AEs, 95% CI =  $-0.49, 1.97$ ). A negative rate indicates a decrease in the annual average change between years and a positive rate indicates an increase in the annual average change. Any 95% CIs that include 0.00 are not significant.

women's ice hockey (55.3%; Table 1). The competition injury rate was higher than the practice injury rate in boys' ice hockey (IRR = 8.14; 95% CI = 6.87, 9.65), men's ice hockey (IRR = 6.58; 95% CI = 6.06, 7.13), and women's ice hockey (IRR = 3.63; 95% CI = 3.14, 4.19).

No linear trends were found in the annual injury rates for high school practices (annual average change of  $-0.04/1000$  AEs; 95% CI =  $-0.14, 0.06$ ) or competitions (annual average change of  $-0.11/1000$  AEs; 95% CI =  $-0.32, 0.10$ ; Figure). In collegiate men's ice hockey, a decrease was present in the 2004–2005 through 2008–2009 academic years for competitions (annual average change of  $-0.79/1000$  AEs; 95% CI =  $-1.20, -0.39$ ) but not practices (annual average change of  $-0.09/1000$  AEs; 95% CI =  $-0.19, 0.02$ ). No linear trends were noted in the 2009–2010 through 2013–2014 academic years for practices (annual average change of  $0.04/1000$  AEs; 95% CI =  $-0.17, 0.25$ ) or competitions (annual average change of  $-0.13/1000$  AEs; 95% CI =  $-0.93, 0.66$ ). In collegiate women's ice hockey, a decrease occurred in the 2004–2005 through 2008–2009 academic years for practices (annual average change of  $-0.31/1000$  AEs; 95% CI =  $-0.50, -0.12$ ) but not for competitions (annual average change of  $-0.25/1000$  AEs; 95% CI =  $-0.84, 0.35$ ). No linear trends were observed in the 2009–2010 through 2013–2014 academic years for practices (annual average change of  $0.03/1000$  AEs; 95% CI =  $-0.37, 0.43$ ) or competitions (annual average change of  $0.74/1000$  AEs; 95% CI =  $-0.49, 1.97$ ).

### Time in Season

The majority of injuries occurred during the regular season in boys' (90.2%), men's (85.8%), and women's (84.7%; Table 2) ice hockey. In men's ice hockey, the injury rate was higher in the regular season than in the preseason (IRR = 1.17; 95% CI = 1.03, 1.33) and postseason (IRR = 2.11; 95% CI = 1.73, 2.59); also, the injury rate was higher in the preseason than in the postseason (IRR = 1.80; 95% CI = 1.43, 2.27). In women's ice hockey, the injury rate was higher in the regular season than in the preseason (IRR = 1.32; 95% CI = 1.05, 1.66) and postseason (IRR = 1.58; 95% CI = 1.10, 2.27); however, injury rates in the preseason did not differ from those in the postseason (IRR = 1.20; 95% CI = 0.79, 1.81). Injury rates by time in season could not be calculated for high school athletes as the AEs were not stratified by time in season.

### Time Loss From Participation

In boys', men's, and women's ice hockey, the largest proportion of injuries resulted in time loss of less than 1 week (Table 3); the 1 exception was competitions in boys' ice hockey, in which the largest proportion of injuries resulted in time loss of 1 to 3 weeks.

### Body Parts Injured and Diagnoses

**Boys.** The most commonly injured body part in practices and competitions was the head/face (practices = 24.1%, competitions = 36.1%; Table 4). Other frequently injured

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

Sport/Surveillance System and Time in Season	Exposure Type	Injuries in Sample, No. (%)	Athlete-Exposures	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
<b>Boys' ice hockey—HS RIO (2008–2009 through 2013–2014)</b>				
Preseason	Practice	40 (64.5)		
	Competition	22 (35.5)		
	Total	62 (100.0)		
Regular season	Practice	126 (16.8)		
	Competition	623 (83.2)		
	Total	749 (100.0)		
Postseason	Practice	0 (0.0)		
	Competition	19 (100.0)		
	Total	19 (100.0)		
<b>Men's ice hockey—NCAA-ISP (2004–2005 through 2013–2014)</b>				
Preseason	Practice	224 (82.4)	61 882	3.62 (3.15, 4.09)
	Competition	48 (17.6)	1854	25.89 (18.57, 33.21)
	Total	272 (100.0)	63 736	4.27 (3.76, 4.77)
Regular season	Practice	604 (27.0)	329 147	1.84 (1.69, 1.98)
	Competition	1637 (73.0)	118 426	13.82 (13.15, 14.49)
	Total	2241 (100.0)	447 573	5.01 (4.80, 5.21)
Postseason	Practice	37 (37.8)	31 817	1.16 (0.79, 1.54)
	Competition	61 (62.2)	9517	6.41 (4.80, 8.02)
	Total	98 (100.0)	41 334	2.37 (1.90, 2.84)
<b>Women's ice hockey—NCAA-ISP (2004–2005 through 2013–2014)</b>				
Preseason	Practice	84 (100.0)	31 989	2.63 (2.06, 3.19)
	Competition	0	296	0.00
	Total	84 (100.0)	32 285	2.60 (2.05, 3.16)
Regular season	Practice	235 (36.9)	130 031	1.81 (1.58, 2.04)
	Competition	402 (63.1)	55 457	7.25 (6.54, 7.96)
	Total	637 (100.0)	185 488	3.43 (3.17, 3.70)
Postseason	Practice	17 (54.8)	10 972	1.55 (0.81, 2.29)
	Competition	14 (45.2)	3305	4.24 (2.02, 6.45)
	Total	31 (100.0)	14 277	2.17 (1.41, 2.94)

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

<sup>a</sup> Excluded 1 injury 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 the 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.

body parts were the hip/thigh/upper leg (14.5%) and knee (13.2%) during practices and the shoulder (22.1%) during competitions. The most often reported injury diagnosis in practices and competitions was concussion (practices = 21.8%, competitions = 31.4%; Table 5). Other common diagnoses were contusions (21.2%) and muscle/tendon strains (20.0%) in practices and contusions (16.0%), fractures/avulsions (14.3%), and ligament sprains (13.6%) in competitions.

**Men.** The most frequently injured body parts were the hip/thigh/upper leg (21.5%) during practices and the shoulder/clavicle (22.1%) and head/face (19.5%) during competitions (Table 4). The most often reported injury diagnoses were muscle/tendon strains (23.5%), ligament sprains (18.8%), and contusions (17.3%) in practices and ligament sprains (31.4%), contusions (18.9%), and concussions (17.0%) in competitions (Table 5).

**Women.** The most commonly injured body parts were the hip/thigh/upper leg (17.3%) and head/face (16.4%)

during practices and the head/face (27.9%) and shoulder/clavicle (15.4%) during competitions (Table 4). The most frequent injury diagnoses in practices and competitions were muscle/tendon strains (practices = 21.8%, competitions = 14.2%), ligament sprains (practices = 16.4%, competitions = 19.7%), concussions (practices = 15.2%, competitions = 26.9%), and contusions (practices = 14.0%, competitions = 14.9%; Table 5).

### Mechanisms of Injury and Activities

**Boys.** The most often reported mechanisms of injury in practices and competitions were contact with another person (practices = 36.5%, competitions = 58.0%) and contact with the playing surface (practices = 22.6%, competitions = 21.6%; Table 6). The most common activities during injury in practices and competitions were general play (practices = 54.6%, competitions = 37.8%) and checking (practices = 27.7%, competitions = 52.4%; Table 7).

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

Sport/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)
Boys' ice hockey—HS RIO (2008–2009 through 2013–2014)				
1 d to <1 wk	73 (45.9)	0.31 (0.24, 0.38)	224 (35.5)	1.90 (1.65, 2.15)
1 to 3 wk	67 (42.1)	0.28 (0.21, 0.35)	256 (40.6)	2.17 (1.91, 2.44)
>3 wk <sup>b</sup>	19 (12.0)	0.08 (0.04, 0.12)	151 (23.9)	1.28 (1.08, 1.49)
Men's ice hockey—NCAA-ISP (2004–2005 through 2013–2014)				
1 d to <1 wk	470 (55.4)	1.11 (1.01, 1.21)	829 (48.7)	6.39 (5.95, 6.82)
1 to 3 wk	255 (30.1)	0.60 (0.53, 0.68)	561 (32.9)	4.32 (3.96, 4.68)
>3 wk <sup>b</sup>	123 (14.5)	0.29 (0.24, 0.34)	314 (18.4)	2.42 (2.15, 2.69)
Women's ice hockey—NCAA-ISP (2004–2005 through 2013–2014)				
1 d to <1 wk	217 (66.8)	1.25 (1.09, 1.42)	212 (53.0)	3.59 (3.11, 4.07)
1 to 3 wk	77 (23.7)	0.45 (0.35, 0.54)	138 (34.5)	2.34 (1.95, 2.73)
>3 wk <sup>b</sup>	31 (9.5)	0.18 (0.12, 0.24)	50 (12.5)	0.85 (0.61, 1.08)

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 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.

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

**Men.** The most frequent mechanism of injury in practices and competitions was contact with another person (practices = 29.5%, competitions = 55.4%; Table 6). Other often reported mechanisms of injury were no contact (24.1%) and contact with the puck (16.1%) during practices and contact with the boards (15.4%) during competitions. The most common activities during injury in practices and competitions were general play (practices = 69.9%, competitions = 62.9%) and checking (practices = 11.6%, competitions = 25.7%; Table 7).

**Women.** The most frequent mechanisms of injury were no contact (26.6%) and contact with another person (20.9%) during practices and contact with another person (37.8%), contact with the boards (17.4%), and contact with the playing surface (16.9%) during competitions (Table 6). Another often reported mechanism of injury was contact with the puck (12.7%) during practices. The most common activity during injury in practices and competitions was general play (practices = 73.3%, competitions = 83.6%; Table 7).

### Position-Specific Injuries During Competitions

During competitions in boys', men's, and women's ice hockey, concussion was the most frequent injury among almost all positions, with most concussions being due to contact with another person (Table 8). The 1 exception was men's goalkeepers, who more often had hip/thigh/upper leg strains. Other common injuries in competitions across boys', men's, and women's ice hockey were hip/thigh/upper leg strains and knee sprains, as well as injuries to the shoulder that resulted in sprains, dislocations, and fractures/avulsions.

## DISCUSSION

This study is the first to directly compare injury rates and patterns across high school and collegiate female ice 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 in competition than in practice, we found interesting trends when comparing men's ice hockey data with those of women's and boys' ice hockey and also when comparing these data with previously published ice hockey injury data. Also, collegiate men's ice hockey had the overall highest injury rate compared with boys' high school and women's collegiate ice hockey. These findings may allow for the development of effective injury-prevention strategies targeted to the level of play.

### Comparison of Injury Rates With Previous Research

Men's collegiate ice hockey practice injury rates in the current investigation were nearly identical to previously published rates, but the competition injury rate we reported (13.45/1000 AEs) appears to be lower than a previous estimate (16.27/1000 AEs).<sup>5</sup> Similarly, the women's ice hockey competition injury rate was lower in the current investigation (7.04/1000 AEs) than in previously published data (12.60/1000 AEs).<sup>6</sup> It is difficult to say whether our results can identify a true decrease in injury incidence. It is also possible that methodologic changes, including but not limited to improved epidemiologic capture methods between the study periods, contributed to the differences reported here. Further, although there is some evidence of decreases in collegiate

**Table 4. Number of Injuries and Injury Rates by Body Part Injured and Type of Athlete-Exposure in High School Boys', Collegiate Men's, and Collegiate Women's Ice Hockey<sup>a</sup>**

Sport/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)
<b>Boys' ice hockey—HS RIO (2008–2009 through 2013–2014)</b>				
Head/face	40 (24.1)	0.17 (0.12, 0.22)	240 (36.1)	2.04 (1.78, 2.30)
Neck	2 (1.2)	0.01 (0.00, 0.02)	11 (1.7)	0.09 (0.04, 0.15)
Shoulder/clavicle	18 (10.8)	0.08 (0.04, 0.11)	147 (22.1)	1.25 (1.05, 1.45)
Arm/elbow	6 (3.6)	0.03 (0.01, 0.05)	30 (4.5)	0.25 (0.16, 0.35)
Hand/wrist	18 (10.8)	0.08 (0.04, 0.11)	50 (7.5)	0.42 (0.31, 0.54)
Trunk	14 (8.4)	0.06 (0.03, 0.09)	43 (6.5)	0.37 (0.26, 0.47)
Hip/thigh/upper leg	24 (14.5)	0.10 (0.06, 0.14)	47 (7.1)	0.40 (0.29, 0.51)
Knee	22 (13.3)	0.09 (0.05, 0.13)	52 (7.8)	0.44 (0.32, 0.56)
Lower leg	4 (2.4)	0.02 (0.00, 0.03)	15 (2.3)	0.13 (0.06, 0.19)
Ankle	10 (6.0)	0.04 (0.02, 0.07)	22 (3.3)	0.19 (0.11, 0.26)
Foot	5 (3.0)	0.02 (0.00, 0.04)	6 (0.9)	0.05 (0.01, 0.09)
Other	3 (1.8)	0.01 (0.00, 0.03)	2 (0.3)	0.02 (0.00, 0.04)
<b>Men's ice hockey—NCAA-ISP (2004–2005 through 2013–2014)</b>				
Head/face	110 (12.7)	0.26 (0.21, 0.31)	341 (19.5)	2.63 (2.35, 2.91)
Neck	15 (1.7)	0.04 (0.02, 0.05)	33 (1.9)	0.25 (0.17, 0.34)
Shoulder/clavicle	116 (13.4)	0.27 (0.22, 0.32)	385 (22.1)	2.97 (2.67, 3.26)
Arm/elbow	20 (2.3)	0.05 (0.03, 0.07)	48 (2.7)	0.37 (0.27, 0.47)
Hand/wrist	85 (9.8)	0.20 (0.16, 0.24)	144 (8.2)	1.11 (0.93, 1.29)
Trunk	90 (10.4)	0.21 (0.17, 0.26)	122 (7.0)	0.94 (0.77, 1.11)
Hip/thigh/upper leg	186 (21.5)	0.44 (0.38, 0.50)	235 (13.5)	1.81 (1.58, 2.04)
Knee	85 (9.8)	0.20 (0.16, 0.24)	251 (14.4)	1.93 (1.69, 2.17)
Lower leg	13 (1.5)	0.03 (0.01, 0.05)	25 (1.4)	0.19 (0.12, 0.27)
Ankle	75 (8.7)	0.18 (0.14, 0.22)	111 (6.4)	0.86 (0.70, 1.01)
Foot	43 (5.0)	0.10 (0.07, 0.13)	36 (2.1)	0.28 (0.19, 0.37)
Other	27 (3.1)	0.06 (0.04, 0.09)	15 (0.9)	0.12 (0.06, 0.17)
<b>Women's ice hockey—NCAA-ISP (2004–2005 through 2013–2014)</b>				
Head/face	55 (16.4)	0.32 (0.23, 0.40)	116 (27.9)	1.96 (1.61, 2.32)
Neck	9 (2.7)	0.05 (0.02, 0.09)	19 (4.6)	0.32 (0.18, 0.47)
Shoulder/clavicle	21 (6.3)	0.12 (0.07, 0.17)	64 (15.4)	1.08 (0.82, 1.35)
Arm/elbow	10 (3.0)	0.06 (0.02, 0.09)	16 (3.8)	0.27 (0.14, 0.40)
Hand/wrist	22 (6.5)	0.13 (0.07, 0.18)	34 (8.2)	0.58 (0.38, 0.77)
Trunk	46 (13.7)	0.27 (0.19, 0.34)	40 (9.6)	0.68 (0.47, 0.89)
Hip/thigh/upper leg	58 (17.3)	0.34 (0.25, 0.42)	31 (7.5)	0.52 (0.34, 0.71)
Knee	47 (14.0)	0.27 (0.19, 0.35)	48 (11.5)	0.81 (0.58, 1.04)
Lower leg	7 (2.1)	0.04 (0.01, 0.07)	9 (2.2)	0.15 (0.05, 0.25)
Ankle	18 (5.4)	0.10 (0.06, 0.15)	25 (6.0)	0.42 (0.26, 0.59)
Foot	12 (3.6)	0.07 (0.03, 0.11)	9 (2.2)	0.15 (0.05, 0.25)
Other	31 (9.2)	0.18 (0.12, 0.24)	5 (1.2)	0.08 (0.01, 0.16)

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

<sup>a</sup> 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.

practices in the 2004–2005 through 2008–2009 academic years, no additional linear trends were detected. Our findings warrant the continued use of consistent methods to better detect and verify the possibility of longitudinal decreases in injury incidence in ice hockey.

Previous men's<sup>5</sup> and women's<sup>6</sup> collegiate ice hockey epidemiology reports are the most feasible for comparison given the similar methods, but investigations of elite ice hockey players have been conducted. Our overall women's competition injury rate (7.04/1000 AEs) was comparable with but slightly higher than the rates

reported during the International Ice Hockey Federation World Women's Championship, World Women's under-18 Championship, and Olympic Winter Games tournaments for women (5.7/1000 AEs) and youth girls (6.4/1000 AEs).<sup>3</sup> Our reported men's collegiate ice hockey competition injury rate (13.45/1000 AEs) is similar to that documented for men's international ice hockey competitions over a 7-year period (14.2/1000 AEs).<sup>4</sup> These findings are interesting given the sample differences. Further, rule and rink differences in international ice hockey compared with American collegiate hockey do



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

Sport/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)
<b>Boys' ice hockey—HS RIO (2008–2009 through 2013–2014)</b>				
Concussion	36 (21.8)	0.15 (0.10, 0.20)	208 (31.4)	1.77 (1.53, 2.01)
Contusion	35 (21.2)	0.15 (0.10, 0.19)	106 (16.0)	0.90 (0.73, 1.07)
Dislocation <sup>b</sup>	4 (2.4)	0.02 (0.00, 0.03)	50 (7.5)	0.42 (0.31, 0.54)
Fracture/avulsion	14 (8.5)	0.06 (0.03, 0.09)	95 (14.3)	0.81 (0.64, 0.97)
Laceration	8 (4.9)	0.03 (0.01, 0.06)	26 (3.9)	0.22 (0.14, 0.31)
Ligament sprain	18 (10.9)	0.08 (0.04, 0.11)	90 (13.6)	0.76 (0.61, 0.92)
Muscle/tendon strain	33 (20.0)	0.14 (0.09, 0.19)	46 (6.9)	0.39 (0.28, 0.50)
Other	17 (10.3)	0.07 (0.04, 0.10)	42 (6.3)	0.36 (0.25, 0.46)
<b>Men's ice hockey—NCAA-ISP (2004–2005 through 2013–2014)</b>				
Concussion	87 (10.1)	0.21 (0.16, 0.25)	297 (17.0)	2.29 (2.03, 2.55)
Contusion	149 (17.3)	0.35 (0.30, 0.41)	330 (18.9)	2.54 (2.27, 2.82)
Dislocation <sup>b</sup>	17 (2.0)	0.04 (0.02, 0.06)	26 (1.5)	0.20 (0.12, 0.28)
Fracture/avulsion	57 (6.6)	0.13 (0.10, 0.17)	126 (7.2)	0.97 (0.80, 1.14)
Laceration	30 (3.5)	0.07 (0.05, 0.10)	45 (2.6)	0.35 (0.25, 0.45)
Ligament sprain	162 (18.8)	0.38 (0.32, 0.44)	548 (31.4)	4.22 (3.87, 4.58)
Muscle/tendon strain	203 (23.5)	0.48 (0.41, 0.55)	192 (11.0)	1.48 (1.27, 1.69)
Other	158 (18.3)	0.37 (0.32, 0.43)	182 (10.4)	1.40 (1.20, 1.61)
<b>Women's ice hockey—NCAA-ISP (2004–2005 through 2013–2014)</b>				
Concussion	51 (15.2)	0.29 (0.21, 0.38)	112 (26.9)	1.90 (1.55, 2.25)
Contusion	47 (14.0)	0.27 (0.19, 0.35)	62 (14.9)	1.05 (0.79, 1.31)
Dislocation <sup>b</sup>	3 (0.9)	0.02 (0.00, 0.04)	4 (1.0)	0.07 (0.00, 0.13)
Fracture/avulsion	12 (3.6)	0.07 (0.03, 0.11)	22 (5.3)	0.37 (0.22, 0.53)
Laceration	3 (0.9)	0.02 (0.00, 0.04)	5 (1.2)	0.08 (0.01, 0.16)
Ligament sprain	55 (16.4)	0.32 (0.23, 0.40)	82 (19.7)	1.39 (1.09, 1.69)
Muscle/tendon strain	73 (21.8)	0.42 (0.33, 0.52)	59 (14.2)	1.00 (0.74, 1.25)
Other	91 (27.2)	0.53 (0.42, 0.63)	70 (16.8)	1.19 (0.91, 1.46)

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, 2 injuries reported in the NCAA-ISP men's ice hockey, and 1 injury reported in the NCAA-ISP women's ice hockey 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.

<sup>b</sup> Included separations.

not seem to affect overall injury rates, although more in-depth future comparisons are needed as the incidence of specific types of injuries may be associated with variations in rules, rink sizes, and game play between international and American ice hockey.

Comparisons at the high school level are more challenging. Although 1 previous injury epidemiology study<sup>14</sup> was performed at the high school level, the observed time period overlaps significantly with the time period we report here, and the same injury-surveillance system was used. Thus, comparisons between our data and this previous report are not appropriate and are not presented here.

### Comparisons Among and Within High School Boys', Collegiate Men's, and Collegiate Women's Ice Hockey

Our data highlight differences among the 3 cohorts examined. Men's collegiate ice hockey had the highest

overall injury rate. The difference between the sexes at the collegiate level was not unexpected, as women's ice hockey players are not allowed to body check. However, the higher injury rate in collegiate men versus high school boys is interesting given that similar rules apply at both levels of play. Our results may suggest an increased injury risk due to a number of factors. First, the intensity of play may be greater in collegiate versus high school ice hockey, and collegiate players as a population possess greater body mass and speed, which may elevate the injury risk. In other sports, players at the collegiate level also have more exposure to participation, which may further increase their likelihood of having sustained previous injuries and being subsequently injured.<sup>15–17</sup> This may well support our finding that the injury rate in collegiate women also exceeded that of high school boys. Further research is needed to better understand the risk factors associated with injury in high school and collegiate ice hockey.

**Table 6. Number of Injuries and Injury Rates by Mechanism of Injury and Type of Athlete-Exposure in High School Boys', Collegiate Men's, and Collegiate Women's Ice Hockey<sup>a</sup>**

Sport/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)
<b>Boys' ice hockey—HS RIO (2008–2009 through 2013–2014)</b>				
Contact with another person	58 (36.5)	0.24 (0.18, 0.30)	370 (58.0)	3.14 (2.82, 3.46)
Contact with playing surface	36 (22.6)	0.15 (0.10, 0.20)	138 (21.6)	1.17 (0.98, 1.37)
Contact with stick	1 (0.6)	<0.01 (0.00, 0.01)	16 (2.5)	0.14 (0.07, 0.20)
Contact with puck	16 (10.1)	0.07 (0.03, 0.10)	23 (3.6)	0.20 (0.12, 0.28)
Contact with skate	2 (1.3)	0.01 (0.00, 0.02)	1 (0.2)	0.01 (0.00, 0.03)
Contact with board	13 (8.2)	0.05 (0.02, 0.08)	59 (9.3)	0.50 (0.37, 0.63)
Contact with goal	0	0.00	0	0.00
Contact with other playing equipment	0	0.00	0	0.00
Contact with out-of-bounds object	0	0.00	0	0.00
No contact	24 (15.1)	0.10 (0.06, 0.14)	25 (3.9)	0.21 (0.13, 0.30)
Overuse/chronic	7 (4.4)	0.03 (0.01, 0.05)	4 (0.6)	0.03 (0.00, 0.07)
Illness/infection	2 (1.3)	0.01 (0.00, 0.02)	2 (0.3)	0.02 (0.00, 0.04)
<b>Men's ice hockey—NCAA-ISP (2004–2005 through 2013–2014)</b>				
Contact with another person	244 (29.5)	0.58 (0.50, 0.65)	955 (55.4)	7.36 (6.89, 7.82)
Contact with playing surface	51 (6.2)	0.12 (0.09, 0.15)	91 (5.3)	0.70 (0.56, 0.85)
Contact with stick	14 (1.7)	0.03 (0.02, 0.05)	58 (3.4)	0.45 (0.33, 0.56)
Contact with puck	133 (16.1)	0.31 (0.26, 0.37)	144 (8.3)	1.11 (0.93, 1.29)
Contact with skate	8 (1.0)	0.02 (0.01, 0.03)	14 (0.8)	0.11 (0.05, 0.16)
Contact with board	88 (10.6)	0.21 (0.16, 0.25)	265 (15.4)	2.04 (1.80, 2.29)
Contact with goal	6 (0.7)	0.01 (0.00, 0.03)	9 (0.5)	0.07 (0.02, 0.11)
Contact with other playing equipment	1 (0.1)	<0.01 (0.00, 0.01)	4 (0.2)	0.03 (0.00, 0.06)
Contact with out-of-bounds object	0	0.00	6 (0.3)	0.05 (0.01, 0.08)
No contact	199 (24.1)	0.47 (0.41, 0.54)	149 (8.6)	1.15 (0.96, 1.33)
Overuse/chronic	54 (6.5)	0.13 (0.09, 0.16)	24 (1.4)	0.18 (0.11, 0.26)
Illness/infection	29 (3.5)	0.07 (0.04, 0.09)	6 (0.3)	0.05 (0.01, 0.08)
<b>Women's ice Hockey—NCAA-ISP (2004–2005 through 2013–2014)</b>				
Contact with another person	66 (20.9)	0.38 (0.29, 0.47)	154 (37.8)	2.61 (2.20, 3.02)
Contact with playing surface	37 (11.7)	0.21 (0.14, 0.28)	69 (16.9)	1.17 (0.89, 1.44)
Contact with stick	9 (2.8)	0.05 (0.02, 0.09)	15 (3.7)	0.25 (0.13, 0.38)
Contact with puck	40 (12.7)	0.23 (0.16, 0.30)	28 (6.9)	0.47 (0.30, 0.65)
Contact with skate	0	0.00	3 (0.7)	0.05 (0.00, 0.11)
Contact with board	25 (7.9)	0.14 (0.09, 0.20)	71 (17.4)	1.20 (0.92, 1.48)
Contact with goal	4 (1.3)	0.02 (0.00, 0.05)	6 (1.5)	0.10 (0.02, 0.18)
Contact with other playing equipment	1 (0.3)	0.01 (0.00, 0.02)	3 (0.7)	0.05 (0.00, 0.11)
Contact with out-of-bounds object	3 (0.9)	0.02 (0.00, 0.04)	4 (1.0)	0.07 (0.00, 0.13)
No contact	84 (26.6)	0.49 (0.38, 0.59)	43 (10.5)	0.73 (0.51, 0.95)
Overuse/chronic	24 (7.6)	0.14 (0.08, 0.19)	8 (2.0)	0.14 (0.04, 0.23)
Illness/infection	23 (7.3)	0.13 (0.08, 0.19)	4 (1.0)	0.07 (0.00, 0.13)

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

<sup>a</sup> Mechanism of injury excluded 34 injuries reported in HS RIO, 59 injuries reported in the NCAA-ISP men's ice hockey, and 28 injuries reported in the NCAA-ISP women's ice hockey due to missing data or 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.

Differences were observed between large and small schools at the high school level and when comparing collegiate divisions. At the high school level, small schools reported higher overall injury rates than did big schools. Similarly, Division II and III women's collegiate ice hockey players had higher overall injury rates than those in Division I, whereas no division differences were seen in the men's collegiate game. Understanding injury rates across different school sizes and divisions may be

important to identify the development of appropriate rules to mitigate injury risk. Currently, research on this topic is minimal. Investigators should pursue more detailed studies in order to develop a better understanding of our reported differences.

In collegiate women's ice hockey competitions, 38% of all injuries resulted from contact with another person. This value appears to be lower than findings reported for high school boys (58%) and collegiate men (55%). However,

**Table 7. Number of Injuries and Injury Rates by Activity During Injury and Type of Athlete-Exposure in High School Boys', Collegiate Men's, and Collegiate Women's Ice Hockey<sup>a</sup>**

Sport/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)
<b>Boys' ice hockey—HS RIO (2008–2009 through 2013–2014)</b>				
Checking	39 (27.7)	0.16 (0.11, 0.21)	319 (52.4)	2.71 (2.41, 3.01)
Conditioning	0	0.00	0	0.00
Faceoff	0	0.00	1 (0.2)	0.01 (0.00, 0.03)
General play	77 (54.6)	0.32 (0.25, 0.39)	230 (37.8)	1.95 (1.70, 2.21)
Goaltending	11 (7.8)	0.05 (0.02, 0.07)	15 (2.5)	0.13 (0.06, 0.19)
Passing	3 (2.1)	0.01 (0.00, 0.03)	16 (2.6)	0.14 (0.07, 0.20)
Receiving pass	10 (7.1)	0.04 (0.02, 0.07)	19 (3.1)	0.16 (0.09, 0.23)
Shooting	1 (0.7)	<0.01 (0.00, 0.01)	9 (1.5)	0.08 (0.03, 0.13)
<b>Men's ice hockey—NCAA-ISP (2004–2005 through 2013–2014)</b>				
Checking	93 (11.6)	0.22 (0.18, 0.26)	434 (25.7)	3.34 (3.03, 3.66)
Conditioning	42 (5.2)	0.10 (0.07, 0.13)	4 (0.2)	0.03 (0.00, 0.06)
Faceoff	1 (0.1)	<0.01 (0.00, 0.01)	5 (0.3)	0.04 (0.00, 0.07)
General play	563 (69.9)	1.33 (1.22, 1.44)	1060 (62.9)	8.17 (7.68, 8.66)
Goaltending	59 (7.3)	0.14 (0.10, 0.18)	38 (2.3)	0.29 (0.20, 0.39)
Passing	8 (1.0)	0.02 (0.01, 0.03)	61 (3.6)	0.47 (0.35, 0.59)
Receiving pass	21 (2.6)	0.05 (0.03, 0.07)	51 (3.0)	0.39 (0.29, 0.50)
Shooting	18 (2.2)	0.04 (0.02, 0.06)	33 (2.0)	0.25 (0.17, 0.34)
<b>Women's ice hockey—NCAA-ISP (2004–2005 through 2013–2014)</b>				
Checking	3 (1.0)	0.02 (0.00, 0.04)	18 (4.6)	0.30 (0.16, 0.45)
Conditioning	33 (11.0)	0.19 (0.13, 0.26)	4 (1.0)	0.07 (0.00, 0.13)
Faceoff	0	0.00	1 (0.3)	0.02 (0.00, 0.05)
General play	220 (73.3)	1.27 (1.10, 1.44)	331 (83.6)	5.60 (5.00, 6.21)
Goaltending	29 (9.7)	0.17 (0.11, 0.23)	21 (5.3)	0.36 (0.20, 0.51)
Passing	5 (1.7)	0.03 (0.00, 0.05)	4 (1.0)	0.07 (0.00, 0.13)
Receiving pass	7 (2.3)	0.04 (0.01, 0.07)	6 (1.5)	0.10 (0.02, 0.18)
Shooting	3 (1.0)	0.02 (0.00, 0.04)	11 (2.8)	0.19 (0.08, 0.30)

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

<sup>a</sup> Activity excluded 81 injuries reported in HS RIO, 120 injuries reported in the NCAA-ISP men's ice hockey, and 56 injuries in NCAA-ISP women's ice hockey due to missing data or 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.

given that body checking is not allowed in women's ice hockey, the finding is alarming, particularly because a small percentage of injuries were attributed to checking (5%). Although it is possible that a proportion of these injuries were due to incidental player contact, current surveillance methods do not allow ATs to report injury mechanisms to this extent. More knowledge of how incidental and intentional contact may differ in their associations with injury risk may be warranted. Simultaneously, enforcing existing rules related to player contact in women's ice hockey can help mitigate the injury incidence.

At the same time, the proportion of injuries related to checking appeared higher in boys than in men (52% versus 26%). These findings may suggest a need to examine how checking, which inherently involves player contact, can be made safer. Previous researchers have shown a reduced risk of injury in youth hockey leagues where checking was not allowed,<sup>18,19</sup> although it should be noted that not all findings agree.<sup>20</sup> Consequently, it is also possible that rules aimed at minimizing or eliminating checking may decrease

the injury incidence. Still, we caution readers' interpretations as ATs at the high school and collegiate levels may vary in how they enter injury activity in their respective injury-surveillance programs; this is evidenced by the far larger percentages of injuries denoted as occurring during general play in the NCAA-ISP (men = 63%; women = 84%) than in HS RIO (38%). Furthermore, even though eliminating or reducing checking at the boys' high school level may be appropriate, it is also important to understand the potential implications as high school players move on to the collegiate level.

### Concussions

Compared with the results of previous investigations involving the NCAA-ISP data,<sup>5,6</sup> concussion rates in our study varied; the rate among collegiate men was higher (2.29 versus 1.47/1000 AEs), whereas the rate among collegiate women was lower (1.90 versus 2.72/1000 AEs). It can be argued that both findings are promising, given the push by the NCAA to better detect, diagnose, and manage

**Table 8. Most Common Injuries Associated With Position in Competitions in High School Boys', Collegiate Men's, and Collegiate Women's Ice 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
<b>Boys'/men's ice hockey</b>						
Defense	Concussion	31.2	Contact with another person	Concussion	16.1	Contact with another person
	Shoulder dislocation <sup>b</sup>	5.8	Contact with another person	Shoulder sprain	13.8	Contact with another person
	Knee sprain	5.8	Contact with another person	Knee sprain	9.5	Contact with another person
Forward	Concussion	30.8	Contact with another person	Concussion	18.0	Contact with another person
	Shoulder fracture/avulsion	6.9	Contact with another person	Shoulder sprain	15.7	Contact with another person
Goalkeeper	Knee sprain	9.2	Contact with another person	Knee sprain	9.2	Contact with another person
	Concussion	23.5	Contact with another person	Hip/thigh/upper leg strain	26.1	No contact
	Trunk contusion	23.5	Contact with another person	Knee sprain	19.6	Contact with another person
	Hip/thigh/upper leg sprain	11.8	No contact	Ankle sprain	10.9	Contact with another person
<b>Women's ice hockey</b>						
Defense				Concussion	27.3	Contact with player
				Shoulder sprain	5.3	Contact with board
Forward				Concussion	25.4	Contact with another person
				Shoulder sprain	7.6	Contact with board
Goalkeeper				Concussion	28.6	Contact with another person
				Hip/thigh/upper leg strain	25.0	No contact
				Knee sprain	17.9	Contact with another person

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

<sup>a</sup> Excluded 39 competition injuries reported in HS RIO, 33 competition injuries reported in the NCAA-ISP men's ice hockey, and 20 competition injuries reported in the NCAA-ISP women's ice hockey due to position not being indicated. The table reads as follows: For the defense position in high school boys, concussions comprised 31.2% of all competition injuries to that position. The most common mechanism of injury for this specific injury for this specific position was contact with another person. 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> Included separations.

concussions.<sup>21,22</sup> The higher rate in men may be due to increased reporting after implementation of the new policy<sup>23</sup>; the decreased rate in women may be due to better education and prevention efforts. However, it is important to note that researchers<sup>24</sup> found minimal change in collegiate ice hockey players' knowledge of concussion. Additional investigation is needed to verify the utility of such guidelines at the collegiate level.

Compared with collegiate men, the concussion rate in high school boys was lower. It is not uncommon for collegiate men's ice hockey athletes to matriculate after playing in a competitive league such as the United States Hockey League. Thus, they may have more at-risk exposure time and therefore a greater likelihood of a history of concussion injuries. Authors<sup>25</sup> have noted that a previous concussion was associated with an increased risk of subsequent concussion in football players. Because the current injury-surveillance efforts do not collect data on previous at-risk exposure, further prospective investigation is needed to elucidate the association of such factors and the concussion incidence. Further study is also needed to

clarify the brain injury risk between cohorts, which could allow for improved rules and technique training at each level of play to minimize the incidence of concussions during competition.

## 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 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 (eg, slight variations in options from which participating ATs select for variables). 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. Our calculation of injury rates using AEs 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 for AE data and may be too burdensome for ATs participating in HS RIO and the NCAA-ISP. We also caution regarding 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 incidence across multiple levels of play (eg, high school versus college and competition versus practice), we were unable to assess differences between starters and nonstarters during 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 due to differences in maturation. Playing positions may vary in physical demands and resulting injury risk. Athlete-exposures were not collected by position, preventing the calculation of position-specific injury rates.

## CONCLUSIONS

Ice hockey is a popular sport that is continuing to grow in popularity, especially for women.<sup>1</sup> We report interesting between-cohorts differences that may have injury-prevention implications specific to each level of ice hockey. At the high school level, very little has been published detailing the overall injury burden or mechanisms leading to injury. The data provided herein give high school hockey ATs important information about injury and also allow for a baseline to be established, such that injury-prevention programs can now be created and implemented, and the results of these programs can be compared with these data. Along these lines, checking led to a higher rate of injury in boys' ice hockey than in men's ice hockey. This finding may have injury-prevention implications, which should be further explored. In general, future researchers should continue to explore ice hockey injury epidemiology but include studies that seek to intervene with rule and technique changes at the various levels to improve overall sport safety. As previous investigators<sup>26</sup> have posited, ice hockey has one of the higher injury rates, and AT coverage to properly identify and manage athletes with such injuries is warranted. Our findings also suggested higher injury rates in smaller high schools and lower NCAA divisions. This may highlight a need for AT coverage not only in high schools and colleges sponsoring ice hockey but particularly in smaller high schools and lower-division NCAA programs.

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