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The First Decade of Web-Based Sports Injury Surveillance: Descriptive Epidemiology of Injuries in US High School Boys' Baseball (2005–2006 Through 2013–2014) and National Collegiate Athletic Association Men's Baseball (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 boys' and men's baseball injury data.

Objective: To describe the epidemiology of injuries sustained in high school boys' baseball in the 2005–2006 through 2013–2014 academic years and collegiate men's baseball in the 2004–2005 through 2013–2014 academic years using Web-based sports injury surveillance.

Design: Descriptive epidemiology study.

Setting: Online injury surveillance from baseball teams in high school boys (annual average = 100) and collegiate men (annual average = 34).

Patients or Other Participants: Boys' or men's baseball players who participated in practices and competitions during the 2005–2006 through 2013–2014 academic years in high school or the 2004–2005 through 2013–2014 academic years in college, respectively.

Main Outcome Measure(s): Athletic trainers collected time-loss injury and exposure data. Injury rates per 1000 athlete-exposures (AEs) were calculated. Injury rate ratios (IRRs) with 95% confidence intervals (CIs) compared injury rates by school size or division, time in season, event type, and competition level.

Results: The High School Reporting Information Online system documented 1537 time-loss injuries during 1 573 257 AEs; the National Collegiate Athletic Association Injury Surveillance Program documented 2574 time-loss injuries during 804 737 AEs. The injury rate was higher in college than in high school (3.20 versus 0.98/1000 AEs; IRR = 3.27; 95% CI = 3.07, 3.49). The competition injury rate was higher than the practice injury rate in high school (IRR = 2.27; 95% CI = 2.05, 2.51) and college (IRR = 2.32; 95% CI = 2.15, 2.51). Baseball players at the high school and collegiate levels sustained a variety of injuries across the body, with the most common injuries reported to the upper extremity. Many injuries also occurred while fielding or pitching.

Conclusions: Injury rates were greater in collegiate versus high school baseball and in competition versus practice. These findings highlight the need for injury-prevention interventions focused on reducing the incidence of upper extremity injuries and protecting batters from pitches and fielders from batted balls.

Key Words: athletes, injury incidence, pitching, fielding

Key Points

- The rate of injury in collegiate men's baseball exceeded that of high school boys' baseball.
- Competition injury rates were higher than practice injury rates.
- Most reported injuries affected the upper extremity.

Participation in boys' and men's baseball is popular at the high school and collegiate levels. In the 2013–2014 academic year, baseball was the fourth most common sport among high school males, played by 11% of male high school athletic participants.[1] The sport is even more popular at the collegiate level. In the National Collegiate Athletic Association (NCAA), baseball had the second largest number of male student-athletes participating; baseball players made up 12% of all NCAA male student-athletes.[2] The popularity and high levels of participation have remained consistent since 2004–2005, despite the emerging popularity of other sports, such as lacrosse.

Injuries are an inherent potential risk of sport participation. Baseball involves contact and requires repetitive, high-demand activities, which can lead to injury. In boys' high school baseball, the overall time-loss injury rate has been reported as 1.26/1000 athlete-exposures (AEs), with most injuries resulting in time loss of less than 7 days.[3] In men's collegiate baseball, injury rates reported[4] for practices (1.85/1000 AEs) and competitions (5.78/1000 AEs) suggested a relatively low injury risk. However, 25% of injuries resulted in time loss of at least 10 days.

As denoted in the van Mechelen et al[5] framework, injury prevention benefits from ongoing monitoring of injury incidence, and so updated descriptive epidemiology is needed. Further, despite potentially significant differences in athlete maturity and intensity of play, previous authors have not compared the epidemiology of injuries between high school boys' and collegiate men's baseball players. 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).[6] A year later, the High School Reporting Information Online system (HS RIO), a similar Web-based high school sports injury-surveillance system, was launched.[7] The purpose of this article is to summarize the descriptive epidemiology of injuries sustained in high school boys' and collegiate men's baseball players 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, OH). Use of the NCAA-ISP data was approved by the Research Review Board at the NCAA.

An average of 100 high schools sponsoring boys' baseball provided data to the HS RIO random sample during the 2005–2006 through 2013–2014 academic years (2005–2006 was the first year HS RIO collected data). An average of 43 NCAA member institutions (Division I = 14, Division II = 7, Division III = 13) sponsoring men's baseball participated in the NCAA-ISP during the 2004–2005 through 2013–2014 academic years. The methods of HS RIO and the NCAA-ISP are summarized in the following 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.[8] In addition, previous publications have described the sampling and data collection of HS RIO[7,9] and the NCAA-ISP[6] 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 who had 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).

Data for HS RIO during the 2005–2006 through 2013–2014 academic years originated from a random sample of 100 schools that were recruited annually. Eligible schools were randomly selected from 8 strata (12 or 13 per stratum) based on school population (enrollment $\leq$1000 or $>$1000) and US Census geographic region.[10] The ATs from these schools reported data for the 9 sports of interest (boys' baseball, basketball, football, soccer, and wrestling and girls' basketball, soccer, softball, and volleyball). If a school dropped out of the system, a replacement from the same stratum was selected.

In HS RIO, national injury estimates were calculated from injury counts obtained from the sample. A weighting algorithm based on the inverse probability of participant schools' selection for the study (based on geographic location and high school size) was applied to individual case counts in order to calculate the national injury estimates.

The NCAA-ISP

The NCAA-ISP depends on a convenience sample of teams with ATs voluntarily reporting injury and exposure data.[6] Participation in the NCAA-ISP, although 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. Data collection for the 2004–2005 through 2013–2014 academic years is described in the following paragraph.

During the 2004–2005 through 2008–2009 academic years, ATs used a Web-based platform launched by the NCAA to track injury and exposure data.[6] 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), the 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 the purpose of participation in an injury-surveillance program. Data were deidentified and sent to the Datalys Center, where they were examined by data quality-control staff and a verification engine.

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. Poststratification sample weights were calculated using the formula

$$\text{Weight}_{ijk} = \left(\frac{\text{Number of teams participating in ISP}_{ijk}}{\text{Number of teams in NCAA}_{ijk}}\right)^{-1}$$

where $weight_{ijk}$ is the weight for the ith sport of the jth division in the kth year. Weights for all data were further adjusted to correct for underreporting, according to the findings of Kucera et al,[11] 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}).

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 captured only time-loss injuries (to reduce the burden on high school ATs), for this series of publications, only time-loss injuries (with the exception of concussions, fractures, and dental injuries as noted 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 were similar, we opted to recode them 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, and distributions by event type (practice, competition), time in season (preseason, regular season, postseason), time loss (1–6 days; 7–21 days; >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), high school size ($\leq$1000 and >1000 students), division in college (I, II, and III), and time in season (preseason, regular season, and postseason). The following is an example of an IRR comparing competition and practice injury rates:

$$\text{IRR} = \frac{\left(\frac{\sum \text{Competition injuries}}{\sum \text{Competition AEs}}\right)}{\left(\frac{\sum \text{Practice injuries}}{\sum \text{Practice AEs}}\right)}$$

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 the 2009–2010 through 2013–2014 academic years, linear trends were examined separately for each period. All mean differences with 95% CIs not containing 0.0 were considered statistically significant.

RESULTS

Total Injury Frequency, National Estimates, and Injury Rates

Between 2004–2005 and 2013–2014, ATs reported a total of 4111 injuries in boys' and men's baseball (high school = 1537, college = 2574; Table 1). This equated to a national estimate of 494 793 high school injuries (annual average = 54 977) and 68 997 collegiate injuries (annual average = 6900). The total injury rate for high school boys' baseball was 0.98/1000 AEs (95% CI = 0.93, 1.03). The total injury rate for collegiate men's baseball was 3.20/1000 AEs (95% CI = 3.07, 3.32). The total injury rate was higher in college than in high school (IRR = 3.27; 95% CI = 3.07, 3.49).

School Size and Division

In high school, the total injury rate was higher in schools with $\leq$1000 students than in schools with >1000 students (IRR = 1.38; 95% CI = 1.25, 1.52; Table 1). In college, Division I had a higher total injury rate than Division II (IRR = 1.28; 95% CI = 1.15, 1.42) and Division III (IRR = 1.18;

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

Surveillance System and School Size or Division	Exposure Type	Injuries in Sample, No. (%)	National Estimates, No. (%)	Athlete-Exposures	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
HS RIO (2005–2006 through 2013–2014)					
≤1000 students	Practice	318 (44.0)	147 952 (44.2)	403 008	0.79 (0.70, 0.88)
	Competition	404 (56.0)	186 778 (55.8)	212 246	1.90 (1.72, 2.09)
	Total	722 (100.0)	334 731 (100.0)	615 254	1.17 (1.09, 1.26)
>1000 students	Practice	369 (45.3)	74 019 (46.2)	614 555	0.60 (0.54, 0.66)
	Competition	446 (54.7)	86 043 (53.8)	343 448	1.30 (1.18, 1.42)
	Total	815 (100.0)	160 062 (100.0)	958 003	0.85 (0.79, 0.91)
Total	Practice	687 (44.7)	221 971 (44.9)	1 017 563	0.68 (0.62, 0.73)
	Competition	850 (55.3)	272 822 (55.1)	555 694	1.53 (1.43, 1.63)
	Total	1537 (100.0)	494 793 (100.0)	1 573 257	0.98 (0.93, 1.03)
NCAA-ISP (2004–2005 through 2013–2014)					
Division I	Practice	536 (42.3)	10 970 (42.8)	210 928	2.54 (2.33, 2.76)
	Competition	730 (57.7)	14 680 (57.2)	145 218	5.03 (4.66, 5.39)
	Total	1266 (100.0)	25 650 (100.0)	356 147	3.55 (3.36, 3.75)
Division II	Practice	192 (38.8)	6654 (39.1)	121 590	1.58 (1.36, 1.80)
	Competition	303 (61.2)	10 370 (60.9)	56 171	5.39 (4.79, 6.00)
	Total	495 (100.0)	17 024 (100.0)	177 761	2.78 (2.54, 3.03)
Division III	Practice	422 (51.9)	13 467 (51.2)	192 185	2.20 (1.99, 2.41)
	Competition	391 (48.1)	12 857 (48.8)	78 643	4.97 (4.48, 5.46)
	Total	813 (100.0)	26 323 (100.0)	270 828	3.00 (2.80, 3.21)
Total	Practice	1150 (44.7)	31 091 (45.1)	524 704	2.19 (2.07, 2.32)
	Competition	1424 (55.3)	37 906 (54.9)	280 033	5.09 (4.82, 5.35)
	Total	2574 (100.0)	68 997 (100.0)	804 737	3.20 (3.07, 3.32)

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

[a] High school data originated from the HS RIO surveillance data, 2005–2006 through 2013–2014; collegiate data originated from the 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. The data may include multiple injuries that occurred at 1 injury event. National estimates and athlete-exposures may not sum to totals due to rounding error.

95% CI = 1.08, 1.29). However, total injury rates in Divisions II and III did not differ (IRR = 0.93; 95% CI = 0.83, 1.04).

Event Type

In both high school and college, the majority of injuries occurred during competitions (both 55.3%; Table 1). The competition injury rate was higher than the practice injury rate in both high school (IRR = 2.27; 95% CI = 2.05, 2.51) and college (IRR = 2.32; 95% CI = 2.15, 2.51).

No linear trends were found for the annual injury rates for high school practices (annual average change of –0.02/1000 AEs; 95% CI = –0.05, 0.01) or competitions (annual average change of –0.04/1000 AEs; 95% CI = –0.09, 0.02; Figure). Decreases were present in the 2004–2005 through 2008–2009 academic years for practices (annual average change of –0.24/1000 AEs; 95% CI = –0.47, –0.01) and competitions (annual average change of –0.34/1000 AEs; 95% CI = –0.57, –0.10). A linear trend was noted in the 2009–2010 through 2013–2014 academic years for competitions (annual average change of –0.32/1000 AEs; 95% CI = –0.47, –0.17) but not for practices (annual average change of 0.04/1000 AEs; 95% CI = –0.12, 0.20).

Time in Season

Among both high school and collegiate athletes, most injuries occurred during the regular season (high school = 74.6%, college = 65.9%; Table 2). In college, injury rates in the preseason and regular season did not differ (IRR = 0.96; 95% CI = 0.89, 1.05). However, when restricting analyses to practices, injury rates in the preseason were higher than those in the regular season (IRR = 2.24; 95% CI = 1.97, 2.54). Compared with the postseason, injury rates were higher in the preseason (IRR = 1.69; 95% CI = 1.30, 2.18) and the regular season (IRR = 1.75; 95% CI = 1.36, 2.26). 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

For both high school and collegiate athletes, more than half of reported injuries resulted in time loss of at least 1 week (Table 3). In both high school and collegiate competitions, approximately one-quarter of all reported injuries resulted in time loss of more than 3 weeks. In practices, 19.6% of reported high school injuries and 30.9% of collegiate injuries resulted in time loss of more than 3 weeks.

Body Parts Injured and Diagnoses

High School. The most commonly injured body parts were the shoulder/clavicle (18.5%) and head/face (17.6%) in practices and the head/face (18.7%) and hand/wrist (15.4%) in competitions (Table 4). The most frequent injury

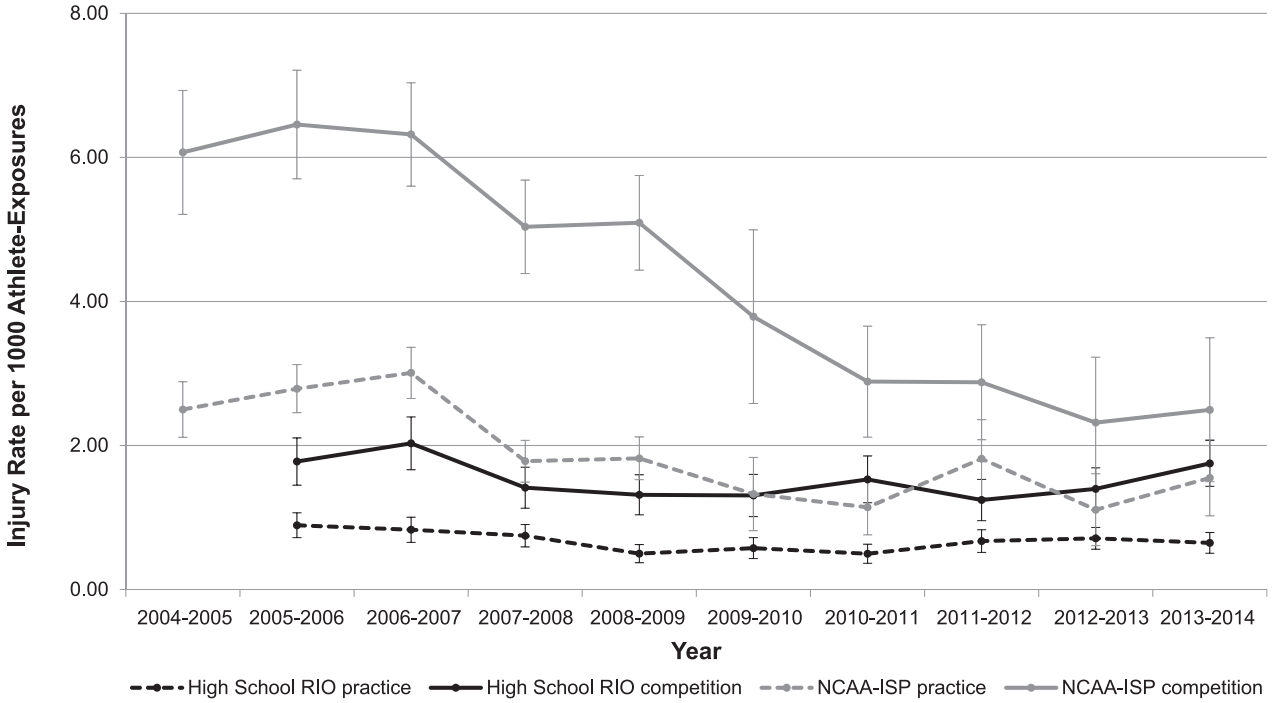

Figure. Injury rates by year and type of athlete-exposure (AE) in high school boys' and collegiate men's baseball. Annual average changes for linear trend test for injury rates are as follows: High School Reporting Information Online (RIO; practices = –0.02/1000 AEs, 95% confidence interval (CI) = –0.05, 0.01; competitions = –0.04/1000 AEs, 95% CI = –0.09, 0.02); National Collegiate Athletic Association Injury Surveillance Program (NCAA-ISP) 2004–2005 through 2008–2009 (practices = –0.24/1000 AEs, 95% CI = –0.47, –0.01; competitions = –0.34/1000 AEs, 95% CI = –0.57, –0.10); NCAA-ISP 2009–2010 through 2013–2014 academic years (practices = 0.04/1000 AEs, 95% CI = –0.12, 0.20; competitions = –0.32/1000 AEs, 95% CI = –0.47, –0.17). 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.

diagnoses from practices and competitions were muscle/tendon strains (practices = 25.0%, competitions = 19.9%) and ligament sprains (practices = 18.8%, competitions = 19.4%; Table 5). Other common injury diagnoses were fractures/avulsions (12.9%) in practices and contusions (17.5%) and fractures/avulsions (16.1%) in competitions.

College. The most commonly injured body parts in practices and competitions were the shoulder/clavicle

Table 2. Injury Rates by Time in Season and Type of Athlete-Exposure in High School Boys' and Collegiate Men's Baseball[a]

		HS RIO (2005–2006 Through 2013–2014)		NCAA-ISP (2004–2005 Through 2013–2014)			
Time in Season	Exposure Type	Injuries in Sample, No. (%)	National Estimates, No. (%)	Injuries in Sample, No. (%)	National Estimates, No. (%)	Athlete-Exposures	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
Preseason	Practice	288 (86.8)	99 145 (87.3)	793 (97.2)	21 703 (97)	254 577	3.11 (2.90, 3.33)
	Competition	44 (13.2)	14 469 (12.7)	23 (2.8)	683 (3.1)	2698	8.52 (5.04, 12.01)
	Total	332 (100.0)	113 614 (100.0)	816 (100.0)	22 385 (100.0)	257 274	3.17 (2.95, 3.39)
Regular season	Practice	388 (34.0)	118 013 (32.7)	349 (20.6)	9074 (20.3)	250 579	1.39 (1.25, 1.54)
	Competition	754 (66.0)	242 584 (67.3)	1347 (79.4)	35 652 (79.7)	264 008	5.10 (4.83, 5.37)
	Total	1142 (100.0)	360 597 (100.0)	1696 (100.0)	44 726 (100.0)	514 587	3.30 (3.14, 3.45)
Postseason	Practice	8 (14.0)	2993 (18.1)	8 (12.9)	315 (16.7)	19 648	0.41 (0.13, 0.69)
	Competition	49 (86.0)	13 537 (81.9)	54 (87.1)	1571 (83.3)	13 327	4.05 (2.97, 5.13)
	Total	57 (100.0)	16 530 (100.0)	62 (100.0)	1886 (100.0)	32 975	1.88 (1.41, 2.35)

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

[a] High school data originated from the HS RIO surveillance data, 2005–2006 through 2013–2014; collegiate data originated from the 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. The data may include multiple injuries that occurred at 1 injury event. Excluded were 6 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. National estimates and athlete-exposures may not sum to totals because of rounding error.

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

Surveillance System and Time-Loss Category	Practices			Competitions		
	Injuries in Sample, No. (%)	National Estimates, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)	Injuries in Sample, No. (%)	National Estimates, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
HS RIO (2005–2006 through 2013–2014)						
1 d to <1 wk	326 (48.9)	103 942 (48.1)	0.32 (0.29, 0.36)	367 (44.7)	111 449 (42.3)	0.66 (0.59, 0.73)
1 to 3 wk	210 (31.5)	66 658 (30.9)	0.21 (0.18, 0.23)	257 (31.3)	86 104 (32.7)	0.46 (0.41, 0.52)
>3 wk[b]	131 (19.6)	45 401 (21.0)	0.13 (0.11, 0.15)	197 (24.0)	66 144 (25.1)	0.35 (0.31, 0.40)
NCAA-ISP (2004–2005 through 2013–2014)						
1 d to <1 wk	457 (41.0)	12 691 (43.0)	0.87 (0.79, 0.95)	581 (42.1)	15 860 (44.1)	2.07 (1.91, 2.24)
1 to 3 wk	313 (28.1)	8599 (29.1)	0.60 (0.53, 0.66)	424 (30.7)	10 977 (30.5)	1.51 (1.37, 1.66)
>3 wk[b]	345 (30.9)	8254 (27.9)	0.66 (0.59, 0.73)	375 (27.2)	9106 (25.3)	1.34 (1.20, 1.47)

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

[a] High school data originated from the HS RIO surveillance data, 2005–2006 through 2013–2014; collegiate data originated from the 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. The data may include multiple injuries that occurred at 1 injury event. Excluded were 49 injuries reported in HS RIO and 79 injuries reported in the NCAA-ISP because of missing data for time loss. Percentages may not add to 100.0 because of rounding error.

[b] 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.

(practices = 21.1%, competitions = 16.2%), arm/elbow (practices = 15.5%, competitions = 14.7%), hip/thigh/upper leg (practices = 13.2%, competitions = 15.3%), and hand/wrist (practices = 10.0%, competitions = 14.4%; Table 4). The most frequent injury diagnoses in practices and competitions were muscle/tendon strains (practices = 23.7%, competitions = 23.2%) and ligament sprains (practices = 17.7%, competitions = 18.4%; Table 5). Also, 15.9% of injuries in competitions were contusions.

Mechanisms of Injury and Activities

High School. The most common mechanism of injury during practices and competitions was no contact (practices = 31.2%, competitions = 24.3%; Table 6). Other frequent mechanisms of injury were overuse/chronic (18.3%), contact with the playing surface (14.2%), and contact with batted ball (10.6%) in practices and contact with another person (16.3%), contact with the playing surface (13.7%), and contact with pitch (11.2%) in competitions. Common activities that resulted in injury in practices and competitions were fielding (practices = 24.6%, competitions = 20.9%) and pitching (practices = 17.5%, competitions = 14.3%; Table 7). Also, 19.3% and 16.6% of injuries during competitions occurred while running bases and batting, respectively.

College. The most frequent mechanisms of injury during practices and competitions were no contact (practices = 44.3%, competitions = 39.7%) and overuse/chronic (practices = 25.3%, competitions = 11.0%; Table 6). Common activities associated with injury in practices and competitions were pitching (practices = 24.3%, competitions = 21.4%), fielding (practices = 16.2%, competitions = 19.5%), and batting (practices = 11.1%, competitions = 17.4%; Table 7). Also, 20.3% of injuries sustained during competitions occurred while running bases.

Position-Specific Injuries in Competitions

During competitions, the most frequent injury depended on position (Table 8). For example, concussions were the most often reported injury for high school batters (11.4%) and catchers (14.8%). The most common injury for both high school and collegiate pitchers was arm/elbow sprain (high school = 13.5%, college = 17.3%). Last, hip/thigh/upper leg strains were the most frequent injury for high school outfielders (12.0%) and collegiate base runners (34.4%), catchers (14.1%), infielders (13.3%), and outfielders (14.5%).

DISCUSSION

Given the popularity of baseball among male student-athletes, examination of the injury incidence among high school boys' and collegiate men's baseball is important. Although a multitude of researchers have examined baseball injuries, the majority focused on upper extremity injuries among pitchers. No investigators have described and compared the injury rates and injury characteristics among both high school and collegiate baseball players. Findings from these analyses can drive injury-prevention interventions specific to baseball and level of play, especially those related to overuse, which was the second most common mechanism of injury during practices at both the high school and collegiate levels. Additionally, although the proportion of severe injuries was similar between high school and college in competitions, a much larger proportion of severe practice injuries occurred in college compared with high school. Furthermore, our findings can inform care providers about which injuries they can expect to treat, such as overuse injuries, which were prevalent at both levels but particularly at the collegiate level. However, our results also highlight the

Table 4. Number of Injuries, National Estimates, and Injury Rates by Body Part Injured and Type of Athlete-Exposure in High School Boys' and Collegiate Men's Baseball[a]

	Practices			Competitions		
Surveillance System and Body Part Injured	Injuries in Sample, No. (%)	National Estimates, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)	Injuries in Sample, No. (%)	National Estimates, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
HS RIO (2005–2006 through 2013–2014)						
Head/face	121 (17.6)	35 484 (16.0)	0.12 (0.10, 0.14)	159 (18.7)	51 966 (19.1)	0.29 (0.24, 0.33)
Neck	6 (0.9)	2225 (1.0)	0.01 (0.00, 0.01)	8 (0.9)	2322 (0.9)	0.01 (0.00, 0.02)
Shoulder/clavicle	127 (18.5)	47 241 (21.3)	0.12 (0.10, 0.15)	100 (11.8)	34 095 (12.5)	0.18 (0.14, 0.22)
Arm/elbow	84 (12.2)	25 741 (11.6)	0.08 (0.06, 0.10)	101 (11.9)	29 201 (10.7)	0.18 (0.15, 0.22)
Hand/wrist	85 (12.4)	24 681 (11.1)	0.08 (0.07, 0.10)	131 (15.4)	43 674 (16.0)	0.24 (0.20, 0.28)
Trunk	40 (5.8)	12 053 (5.4)	0.04 (0.03, 0.05)	34 (4.0)	11 179 (4.1)	0.06 (0.04, 0.08)
Hip/thigh/upper leg	60 (8.8)	19 043 (8.6)	0.06 (0.04, 0.07)	101 (11.9)	31 902 (11.7)	0.18 (0.15, 0.22)
Knee	50 (7.3)	17 034 (7.7)	0.05 (0.04, 0.06)	74 (8.7)	22 893 (8.4)	0.13 (0.10, 0.16)
Lower leg	29 (4.2)	8747 (4.0)	0.03 (0.02, 0.04)	29 (3.4)	9 768 (3.6)	0.05 (0.03, 0.07)
Ankle	66 (9.6)	22 670 (10.2)	0.06 (0.05, 0.08)	93 (11.0)	30 724 (11.3)	0.17 (0.13, 0.20)
Foot	14 (2.0)	5562 (2.5)	0.01 (0.01, 0.02)	11 (1.3)	2893 (1.1)	0.02 (0.01, 0.03)
Other	4 (0.6)	1156 (0.5)	<0.01 (0.00, 0.01)	8 (0.9)	2109 (0.8)	0.01 (0.00, 0.02)
NCAA-ISP (2004–2005 through 2013–2014)						
Head/face	70 (6.1)	2518 (8.1)	0.13 (0.10, 0.16)	149 (10.5)	3266 (8.6)	0.53 (0.45, 0.62)
Neck	8 (0.7)	166 (0.5)	0.02 (0.00, 0.03)	12 (0.8)	321 (0.9)	0.04 (0.02, 0.07)
Shoulder/clavicle	243 (21.1)	6241 (20.1)	0.46 (0.40, 0.52)	231 (16.2)	6077 (16.0)	0.82 (0.72, 0.93)
Arm/elbow	178 (15.5)	5120 (16.5)	0.34 (0.29, 0.39)	209 (14.7)	5828 (15.4)	0.75 (0.65, 0.85)
Hand/wrist	115 (10.0)	3103 (10.0)	0.22 (0.18, 0.26)	205 (14.4)	5467 (14.4)	0.73 (0.63, 0.83)
Trunk	111 (9.7)	3232 (10.4)	0.21 (0.17, 0.25)	90 (6.3)	1837 (4.9)	0.32 (0.25, 0.39)
Hip/thigh/upper leg	152 (13.2)	3985 (12.8)	0.29 (0.24, 0.34)	218 (15.3)	5813 (15.3)	0.78 (0.68, 0.88)
Knee	80 (7.0)	1813 (5.8)	0.15 (0.12, 0.19)	92 (6.5)	2457 (6.5)	0.33 (0.26, 0.40)
Lower leg	39 (3.4)	961 (3.1)	0.07 (0.05, 0.10)	51 (3.6)	1408 (3.7)	0.18 (0.13, 0.23)
Ankle	102 (8.9)	2682 (8.6)	0.19 (0.16, 0.23)	107 (7.5)	3504 (9.2)	0.38 (0.31, 0.45)
Foot	31 (2.7)	733 (2.4)	0.06 (0.04, 0.08)	48 (3.4)	1239 (3.3)	0.17 (0.12, 0.22)
Other	21 (1.8)	536 (1.7)	0.04 (0.02, 0.06)	12 (0.8)	690 (1.8)	0.04 (0.02, 0.07)

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

[a] High school data originated from the HS RIO surveillance data, 2005–2006 through 2013–2014; collegiate data originated from the 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. The data may include multiple injuries that occurred at 1 injury event. Excluded were 2 injuries reported in HS RIO because of missing data for body part. Percentages may not add to 100.0 because of rounding error.

need for further in-depth research into specific injuries and areas of the sport.

Comparison of Injury Rates With Previous Research

The high school injury rates reported in these analyses were lower than those previously observed. In this analysis, the overall rate in high school boys' baseball was 0.98/1000 AEs, whereas the overall injury rate from the HS RIO data for the 2005–2007 seasons was 1.26/1000 AEs.[3] Powell and Barber-Foss[12] reported high school boys' baseball injury rates from the 1995–1997 seasons of 2.8/1000 AEs overall, 1.8/1000 AEs during practices (compared with 0.68/1000 AEs in our sample), and 5.6/1000 AEs during competitions (compared with 1.53/1000 AEs in our sample). During the 2009 season, Shanley et al[13] demonstrated a high school baseball injury incidence rate of 4.0/1000 AEs, which is higher than both HS RIO rates and those reported by Powell and Barber-Foss,[12] but this value included both time-loss and non–time-loss injuries. This is an important methodologic difference among studies, given that more than 80% of sport-related injuries are reported to be non–time-loss injuries.[14] Although injury rates did not drop from 2005–2006 through 2013–2014, the lower injury rates observed in this analysis compared with other studies may reflect efforts to prevent injuries through changes to playing rules and an overall emphasis on injury prevention (described in a subsequent section).

In the collegiate setting, the overall injury rates observed from 2004–2005 through 2013–2014 were similar to those reported in the collegiate setting from 1988–1989 through 2003–2004. Dick et al[4] noted a competition injury rate of 5.78/1000 AEs (compared with 5.09/1000 AEs in our sample) and a practice injury rate of 1.85/1000 AEs (compared with 2.19/1000 AEs in our sample). When examining injury rates by division, we found similar rates during practices and competitions. In comparison with Powell and Dompier's[15] estimates for the 2000–2001 and 2001–2002 academic years, the injury rates we found were lower for Division I (3.55/1000 AEs in our study versus 6.2/1000 AEs in Powell and Dompier[15]), higher for Division II (2.78 versus 1.5/1000 AEs), and similar for Division III (3.00 versus 3.5/1000 AEs). Finally, McFarland and Wasik[16] measured the injury rates in a single Division I collegiate baseball team over 3 seasons (1991–1993) and identified an overall injury rate of 5.83/1000

Table 5. Number of Injuries, National Estimates, and Injury Rates by Diagnosis and Type of Athlete-Exposure in High School Boys' and Collegiate Men's Baseball[a]

	Practices			Competitions		
Surveillance System and Diagnosis	Injuries in Sample, No. (%)	National Estimates, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)	Injuries in Sample, No. (%)	National Estimates, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
HS RIO (2005–2006 through 2013–2014)						
Concussion	35 (5.1)	10 405 (4.7)	0.03 (0.02, 0.05)	74 (8.8)	25 445 (9.4)	0.13 (0.10, 0.16)
Contusion	68 (9.9)	21 145 (9.5)	0.07 (0.05, 0.08)	148 (17.5)	45 694 (16.9)	0.27 (0.22, 0.31)
Dislocation[b]	14 (2.0)	3785 (1.7)	0.01 (0.01, 0.02)	31 (3.7)	10 146 (3.8)	0.06 (0.04, 0.08)
Fracture/avulsion	88 (12.9)	27 599 (12.5)	0.09 (0.07, 0.10)	136 (16.1)	43 777 (16.2)	0.24 (0.20, 0.29)
Laceration	30 (4.4)	7176 (3.2)	0.03 (0.02, 0.04)	35 (4.1)	9708 (3.6)	0.06 (0.04, 0.08)
Ligament sprain	129 (18.8)	42 466 (19.2)	0.13 (0.10, 0.15)	164 (19.4)	53 904 (19.9)	0.30 (0.25, 0.34)
Muscle/tendon strain	171 (25.0)	56 909 (25.7)	0.17 (0.14, 0.19)	168 (19.9)	52 491 (19.4)	0.30 (0.26, 0.35)
Other	150 (21.9)	52 097 (23.5)	0.15 (0.12, 0.17)	89 (10.5)	29 327 (10.8)	0.16 (0.13, 0.19)
NCAA-ISP (2004–2005 through 2013–2014)						
Concussion	28 (2.5)	950 (3.1)	0.05 (0.03, 0.07)	63 (4.4)	1467 (3.9)	0.22 (0.17, 0.28)
Contusion	108 (9.4)	2870 (9.3)	0.21 (0.17, 0.24)	227 (15.9)	5183 (13.7)	0.81 (0.71, 0.92)
Dislocation[b]	16 (1.4)	328 (1.1)	0.03 (0.02, 0.05)	32 (2.3)	837 (2.2)	0.11 (0.07, 0.15)
Fracture/avulsion	71 (6.2)	2254 (7.3)	0.14 (0.10, 0.17)	137 (9.6)	4039 (10.7)	0.49 (0.41, 0.57)
Laceration	10 (0.9)	301 (1.0)	0.02 (0.01, 0.03)	43 (3.0)	1014 (2.7)	0.15 (0.11, 0.20)
Ligament sprain	203 (17.7)	5285 (17.0)	0.39 (0.33, 0.44)	262 (18.4)	7716 (20.4)	0.94 (0.82, 1.05)
Muscle/tendon strain	271 (23.7)	7510 (24.2)	0.52 (0.45, 0.58)	330 (23.2)	8918 (23.5)	1.18 (1.05, 1.31)
Other	438 (38.3)	11 505 (37.1)	0.83 (0.76, 0.91)	330 (23.2)	8733 (23.0)	1.18 (1.05, 1.31)

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

[a] High school data originated from the HS RIO surveillance data, 2005–2006 through 2013–2014; collegiate data originated from the 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. The data may include multiple injuries that occurred at 1 injury event. Excluded were 7 injuries reported in HS RIO and 5 injuries reported in the NCAA-ISP because of missing data for diagnosis. Percentages may not add to 100.0 because of rounding error.

[b] Included separations.

AEs, which was higher than our observed rate of 3.55/1000 AEs in Division I.

Comparisons with previous research should be made carefully, as the compositions of the samples may vary by school size and division. Additionally, injury definitions and reporting methods varied across these studies. Nevertheless, it is encouraging that high school baseball injury rates were lower than those previously reported. Further research is needed to determine why injury rates do not appear to be different in collegiate baseball in this sample compared with 1988–1989 through 2003–2004.

Comparisons Between and Within High School Boys' and Collegiate Men's Baseball

Injury Rates. The injury rates observed in collegiate men's baseball were more than 3 times those seen in high school boys' baseball (IRR = 3.27). This finding was consistent across practices and competitions. Many explanations are possible for the large difference in rates. Although intensity of play is likely higher at the collegiate level, rates may also vary because of the differential availability of athletic training resources at the high school and collegiate levels. Collegiate student-athletes often have more consistent and greater access to an AT, which may increase the reporting of injuries.[17–19] In many colleges, an AT is dedicated primarily to baseball or to only a few sports. By contrast, the majority of high schools have 1 AT reporting data for all sports. These additional AT resources at the collegiate level could lead to higher levels of injury reporting because of these ATs' greater familiarity with and access to the athletes. Fatigue and increased workload are also of greater concern in the collegiate setting. In college, practice and training are more likely to occur year round, though specialization is increasing in high school.[20,21] Year-round practice and training may increase overuse injuries and injuries due to fatigue.[22,23] In collegiate men's baseball, 25% of injuries were due to an overuse/chronic mechanism and 44% were due to no contact, as compared with 18% due to overuse/chronic and 31% due to no contact in high school boys' baseball. The intensity of activities may also be greater overall in college than in high school.

Event Type. In both high school and college, the competition injury rate was more than twice the practice injury rate (high school IRR = 2.27, college IRR = 2.32). This is consistent with previous results in baseball and data reported from other sports. Although we cannot determine the reason for a higher injury rate during games than practices from these data, we can speculate that this is in part due to a greater intensity of play in competitions. To win in a competition, athletes are less likely to refrain from an activity, such as running into a wall or running or throwing faster or harder. During practice, injury prevention may be of greater concern, and athletes may hold back on certain potentially injury-inducing activities.

Table 6. Number of Injuries, National Estimates, and Injury Rates by Mechanism of Injury and Type of Athlete-Exposure in High School Boys' and Collegiate Men's Baseball[a]

Surveillance System and Mechanism of Injury	Practices			Competitions		
	Injuries in Sample, No. (%)	National Estimates, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)	Injuries in Sample, No. (%)	National Estimates, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
HS RIO (2005–2006 through 2013–2014)						
Contact with another person	41 (6.1)	12 752 (5.9)	0.04 (0.03, 0.05)	135 (16.3)	47 479 (17.9)	0.24 (0.20, 0.28)
Contact with playing surface	95 (14.2)	31 346 (14.5)	0.09 (0.07, 0.11)	114 (13.7)	37 428 (14.1)	0.21 (0.17, 0.24)
Contact with bases	21 (3.1)	6818 (3.2)	0.02 (0.01, 0.03)	69 (8.3)	21 870 (8.2)	0.12 (0.09, 0.15)
Contact with bat	9 (1.3)	2798 (1.3)	0.01 (0.00, 0.01)	5 (0.6)	1155 (0.4)	0.01 (0.00, 0.02)
Contact with outfield wall/dugout/foul fence	5 (0.8)	3200 (1.5)	<0.01 (0.00, 0.01)	4 (0.5)	1078 (0.4)	0.01 (0.00, 0.01)
Contact with batted ball	71 (10.6)	22 232 (10.3)	0.07 (0.05, 0.09)	81 (9.8)	26 458 (10.0)	0.15 (0.11, 0.18)
Contact with pitch	17 (2.5)	4270 (2.0)	0.02 (0.01, 0.02)	93 (11.2)	28 892 (10.9)	0.17 (0.13, 0.20)
Contact with thrown ball (not pitch)	44 (6.6)	10 665 (4.9)	0.04 (0.03, 0.06)	33 (4.0)	10 661 (4.0)	0.06 (0.04, 0.08)
Contact with other playing equipment	21 (3.1)	5571 (2.6)	0.02 (0.01, 0.03)	30 (3.6)	8626 (3.2)	0.05 (0.03, 0.07)
Contact with out of bounds object	5 (0.8)	1171 (0.5)	<0.01 (0.00, 0.01)	2 (0.2)	413 (0.2)	<0.01 (0.00, 0.01)
No contact	209 (31.2)	71 535 (33.1)	0.21 (0.18, 0.23)	202 (24.3)	61 815 (23.2)	0.36 (0.31, 0.41)
Overuse/chronic	123 (18.3)	41 919 (19.4)	0.12 (0.10, 0.14)	60 (7.2)	19 449 (7.3)	0.11 (0.08, 0.14)
Illness/infection	10 (1.5)	2117 (1.0)	0.01 (0.00, 0.02)	3 (0.4)	667 (0.3)	0.01 (0.00, 0.01)
NCAA-ISP (2004–2005 through 2013–2014)						
Contact with another person	42 (3.7)	889 (3.0)	0.08 (0.06, 0.10)	127 (9.0)	3621 (9.8)	0.45 (0.37, 0.53)
Contact with playing surface	75 (6.7)	2502 (8.5)	0.14 (0.11, 0.18)	118 (8.3)	3682 (10.0)	0.42 (0.35, 0.50)
Contact with bases	17 (1.5)	438 (1.5)	0.03 (0.02, 0.05)	74 (5.2)	2923 (7.9)	0.26 (0.20, 0.32)
Contact with bat	10 (0.9)	253 (0.9)	0.02 (0.01, 0.03)	18 (1.3)	352 (1.0)	0.06 (0.03, 0.09)
Contact with outfield wall/dugout/foul fence	16 (1.4)	383 (1.3)	0.03 (0.02, 0.05)	37 (2.6)	871 (2.4)	0.13 (0.09, 0.17)
Contact with batted ball	68 (6.0)	2048 (6.9)	0.13 (0.10, 0.16)	139 (9.8)	3173 (8.6)	0.50 (0.41, 0.58)
Contact with pitch	47 (4.2)	1318 (4.5)	0.09 (0.06, 0.12)	121 (8.6)	2882 (7.8)	0.43 (0.36, 0.51)
Contact with thrown ball (not pitch)	34 (3.0)	837 (2.8)	0.06 (0.04, 0.09)	38 (3.7)	791 (2.1)	0.14 (0.09, 0.18)
Contact with other playing equipment	13 (1.2)	368 (1.3)	0.02 (0.01, 0.04)	12 (0.9)	328 (0.9)	0.04 (0.02, 0.07)
Contact with out of bounds object	1 (0.1)	25 (0.1)	<0.01 (0.00, 0.01)	1 (0.1)	25 (0.1)	<0.01 (0.00, 0.01)
No contact	499 (44.3)	12 905 (43.7)	0.95 (0.87, 1.03)	561 (39.7)	13 352 (36.2)	2.00 (1.84, 2.17)
Overuse/chronic	285 (25.3)	7121 (24.1)	0.54 (0.48, 0.61)	156 (11.0)	4286 (11.6)	0.56 (0.47, 0.64)
Illness/infection	19 (1.7)	449 (1.5)	0.04 (0.02, 0.05)	13 (0.9)	587 (1.6)	0.05 (0.02, 0.07)

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

[a] High school data originated from the HS RIO surveillance data, 2005–2006 through 2013–2014; collegiate data originated from the 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. The data may include multiple injuries that occurred at 1 injury event. Mechanism of injury excluded 35 injuries reported in HS RIO and 33 injuries reported in the NCAA-ISP because of missing data or the athletic trainer reporting *Other* or *Unknown*. Percentages may not add to 100.0 because of rounding error.

Time in Season. We could not evaluate high school injury rates by time in season, but overall injury rates were lowest in the collegiate postseason. Additionally, the collegiate practice injury rates were highest in the preseason compared with the regular season and postseason. Preseason injury rates may be highest because of many factors. For example, in the preseason, student-athletes may play at higher intensity to gain a roster spot and subsequent scholarship or a starting position on the team. It could also be that, in the preseason, the players are less conditioned and are unready for the demands of preseason practices, though this is less likely in a collegiate setting where year-round training and practices occur. Future researchers should examine whether drills and other practice activities differ across seasons.

Time Loss From Participation. For competitions, the proportion of severe injuries (>3 weeks time loss) was similar between high school (24.0%) and college (27.2%; Table 3). However, only 20% of high school practice injuries were severe, compared with nearly a third of collegiate practice injuries (31%). For NCAA baseball from 1988–1989 through 2003–2004, the proportion of *severe injuries* (defined as 10+ days of time loss) was 25% for both practices and games.[4] The proportion of severe injuries was also larger than previously reported by McFarland and Wasik.[16] Although the overall injury rate in baseball was low, this large proportion of severe injuries, along with the fact that more than half of injuries resulted in at least 1 week of time loss, is notable and important to consider for clinical and resource purposes. Future investigators should examine the differences in practice injuries between the 2 levels of play and determine why a larger proportion of severe practice injuries occurred at the collegiate level.

Body Parts Injured and Diagnoses. Approximately twice the proportion of high school boys' baseball injuries was to the head/face and had a diagnosis of concussion compared with collegiate men's baseball injuries. However, the concussion incidence rate was lower in high school than in college. This is consistent with previous literature[24] indicating that concussion rates were higher in college than

Table 7. Number of Injuries, National Estimates, and Injury Rates by Activity During Injury and Type of Athlete-Exposure in High School Boys' and Collegiate Men's Baseball[a]

Surveillance System and Activity During Injury	Practices			Competitions		
	Injuries in Sample, No. (%)	National Estimates, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)	Injuries in Sample, No. (%)	National Estimates, No. (%)	Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
HS RIO (2005–2006 through 2013–2014)						
Batting	48 (7.5)	14 197 (6.9)	0.05 (0.03, 0.06)	134 (16.6)	39 203 (15.3)	0.24 (0.20, 0.28)
Catching	47 (7.4)	12 966 (6.3)	0.05 (0.03, 0.06)	60 (7.5)	17 512 (6.9)	0.11 (0.08, 0.14)
Conditioning	35 (5.5)	11 845 (5.7)	0.03 (0.02, 0.05)	2 (0.2)	341 (0.1)	<0.01 (0.00, 0.01)
Fielding	157 (24.6)	52 553 (25.5)	0.15 (0.13, 0.18)	168 (20.9)	57 374 (22.4)	0.30 (0.26, 0.35)
General play	55 (8.6)	21 940 (10.6)	0.05 (0.04, 0.07)	29 (3.6)	9178 (3.6)	0.05 (0.03, 0.07)
Pitching	112 (17.5)	36 598 (17.7)	0.11 (0.09, 0.13)	115 (14.3)	36 988 (14.5)	0.21 (0.17, 0.24)
Running bases	83 (13.0)	22 547 (10.9)	0.08 (0.06, 0.10)	155 (19.3)	49 920 (19.5)	0.28 (0.24, 0.32)
Sliding	27 (4.2)	9132 (4.4)	0.03 (0.02, 0.04)	101 (12.5)	31 968 (12.5)	0.18 (0.15, 0.22)
Throwing ball	75 (11.7)	24 671 (12.0)	0.07 (0.06, 0.09)	41 (5.1)	13 320 (5.2)	0.07 (0.05, 0.10)
NCAA-ISP (2004–2005 through 2013–2014)						
Batting	123 (11.1)	3346 (11.5)	0.23 (0.19, 0.28)	241 (17.4)	5683 (15.6)	0.86 (0.75, 0.97)
Catching	57 (5.2)	1109 (3.8)	0.11 (0.08, 0.14)	54 (3.9)	1144 (3.2)	0.19 (0.14, 0.24)
Conditioning	103 (9.3)	3011 (10.4)	0.20 (0.16, 0.23)	10 (0.7)	167 (0.5)	0.04 (0.01, 0.06)
Fielding	179 (16.2)	4883 (16.9)	0.34 (0.29, 0.39)	269 (19.5)	7300 (20.1)	0.96 (0.85, 1.08)
General play	97 (8.8)	2565 (8.9)	0.18 (0.15, 0.22)	66 (4.8)	1975 (5.4)	0.24 (0.18, 0.29)
Pitching	269 (24.3)	6895 (23.8)	0.51 (0.45, 0.57)	295 (21.4)	7315 (20.1)	1.05 (0.93, 1.17)
Running bases	107 (9.7)	2623 (9.1)	0.20 (0.17, 0.24)	280 (20.3)	8164 (22.5)	1.00 (0.88, 1.12)
Sliding	23 (2.1)	460 (1.6)	0.04 (0.03, 0.06)	79 (5.7)	2136 (5.9)	0.28 (0.22, 0.34)
Throwing ball	147 (13.3)	4079 (14.1)	0.28 (0.23, 0.33)	88 (6.4)	2459 (6.8)	0.31 (0.25, 0.38)

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

[a] High school data originated from the HS RIO surveillance data, 2005–2006 through 2013–2014; collegiate data originated from the 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. The data may include multiple injuries that occurred at 1 injury event. *Activity* excluded 93 injuries reported in HS RIO and 87 injuries reported in the NCAA-ISP because of missing data or the athletic trainer reporting *Other* or *Unknown*. Percentages may not add to 100.0 because of rounding error.

in high school. It may be that injuries to other body parts and other diagnoses are less common in high school than in college, making the relative proportion of injuries that are concussions larger in high school than in college.

The proportion of high school athletes' injuries that were fractures/avulsions was larger than that for collegiate athletes. Across all sports in the HS RIO system over a 2-year period, fractures accounted for 9.9% of all injuries and occurred at an overall rate of 1.82 fractures per 10 000 AEs.[25] A hand/wrist fracture/avulsion was one of the most common diagnoses for high school infielders, but this was not the case for collegiate infielders. It is possible that high school student-athletes were less skilled than collegiate student-athletes in avoiding contact with batted, thrown, or pitched balls, which are frequent mechanisms of fractures and avulsions. Some of these fractures may be due to worse field conditions in high school than in college or balls that take a bad bounce and induce a fracture when the fields are in poor condition. This finding is also consistent with previous research[25] showing that the proportion of injuries that were fractures decreased with increasing age, though this work only addressed high school athletes. Future researchers should determine the mechanisms of injury and activities associated with fractures among high school boys' baseball student-athletes to develop interventions to prevent fractures.

In high school, the body parts injured most commonly during practices were the shoulder/clavicle (18.5%) and the head/face (17.6%), whereas the body parts injured most commonly during competitions were the head/face (18.7%) and hand/wrist (15.4%). This result differs from earlier reported HS RIO baseball injury data,[3] in which the shoulder and the ankle were the most frequently injured body parts. In collegiate athletes, for both practices and competitions, the most often injured body parts were the shoulder/clavicle (21.1% in practices, 16.2% in competitions) and the arm/elbow (15.5% in practices, 24.7% in competitions). These findings are consistent with previous collegiate research, which indicated that 46.4% of practice and 44.6% of competition injuries were to the upper extremity.[4]

Mechanism of Injury and Activities. Compared with college, a larger proportion of high school injuries occurred because of contact with the playing surface. This again may be due to greater experience among collegiate student-athletes than high school student-athletes in navigating the field and base running but may also be due to greater upkeep and better conditions of fields and base paths in college than in high school.

Common Injuries and Injury Prevention

Shoulder/Clavicle and Pitching Injuries. The large proportion of shoulder/clavicle injuries, especially during

Table 8. Most Common Injuries Associated With Position in Competitions in High School Boys' and Collegiate Men's Baseball[a]

	HS RIO (2005–2006 Through 2013–2014)			NCAA-ISP (2004–2005 Through 2013–2014)		
Position	Most Common Injuries	% of Injuries Within Position	Most Frequent Mechanism of Injury for This Injury Within Position	Most Common Injuries	% of Injuries Within Position	Most Frequent Mechanism of Injury for This Injury Within Position
Base runner	Ankle sprain	24.4	Contact with base	Hip/thigh/upper leg strain	34.4	No contact
	Hip/thigh/upper leg strain	14.8	No contact	Ankle sprain	11.5	No contact
Batter	Concussion	11.4	Hit by pitch	Arm/elbow contusion	10.9	Hit by pitch
	Hand/wrist fracture/avulsion	10.5	Hit by pitch	Hand/wrist fracture/avulsion	10.4	Hit by pitch
Catcher	Concussion	14.8	Hit by pitch	Hip/thigh/upper leg strain	14.1	No contact
	Hand/wrist sprain	9.9	Contact with another person	Hand/wrist fracture/avulsion	11.3	Hit by batted ball
Infielder	Ankle sprain	10.4	Contact with base	Hip/thigh/upper leg strain	13.3	No contact
	Hand/wrist fracture/avulsion	10.4	Contact with another person	Ankle sprain	9.0	Contact with base
Outfielder	Hip/thigh/upper leg strain	12.0	No contact	Hip/thigh/upper leg strain	14.5	No contact
	Concussion	9.5	Contact with another person	Ankle sprain	8.6	No contact
Pitcher	Arm/elbow sprain	13.5	No contact	Arm/elbow sprain	17.3	No contact
				Shoulder strain	7.5	No contact

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

[a] High school data originated from the HS RIO surveillance data, 2005–2006 through 2013–2014; collegiate data originated from the 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. The data may include multiple injuries that occurred at 1 injury event. Excluded were 35 competition injuries reported in HS RIO and 121 competition injuries reported in the NCAA-ISP because the position was not indicated. The Table should be read as follows: for the base runner position in high school, ankle sprains made up 24.4% of all competition injuries for that position. The most common mechanism of injury for this specific injury for this specific position was contact with the base.

practices, is likely due to pitching overuse injuries. The larger proportion of injuries to the shoulder during practices than during competitions is also consistent with overuse, as repetitive-motion injuries are more often reported as occurring during practices than competitions and more repetition over time is performed during practices. In high school, 17.5% of practice injuries occurred while pitching, and in college, 24% of practice injuries occurred while pitching. In high school, this was the second most common activity associated with practice injuries, and in college, this was the most common activity associated with practice injuries. Of increasing concern are elbow injuries among baseball pitchers. For competition injuries, arm/elbow sprains were the most frequent injuries to pitchers in both high school and college, and the arm/elbow was the second most often injured body part in college.

In late 2016, the National Federation of State High School Associations (NFHS) approved a rule requiring each NFHS member to create a pitch-count–restriction policy based on the number of pitches thrown in a game and a required rest period.[26] As of 2017, only 2 states that sponsor baseball did not have pitch-count rules; one of these had day-based rest restrictions without pitch limits, but the rules varied.[27] In a national survey of youth pitchers aged 9 through 18 years, self-reported pitching on back-to-back days was associated with 4 times the odds of arm tiredness while pitching and twice the odds of arm pain while pitching compared with not pitching on back-to-back days. Pitching multiple games on the same day was also associated with increased odds of arm pain when pitching.[28] Further research is needed to address the effect of changing high school pitch-count restrictions on shoulder and other pitching injuries. Currently no pitch-count restrictions exist in NCAA baseball.

Overuse and Noncontact Injuries. Overuse and noncontact mechanisms resulted in a large proportion of injuries among both high school and collegiate players. During high school practices, the most common mechanisms of injury in practices were no contact and overuse; during competitions, the most frequent mechanism of injury was no contact, followed by contact with another person. In college, noncontact and overuse mechanisms were most often reported for both practices and competitions. In college, team-sanctioned year-round practicing and playing are more typical than in high school, and more games are usually played during the collegiate competitive season than during the high school competitive season. A study[29] of 11 NCAA baseball pitchers showed that pitching kinematics during competitions worsened over the course of the season and with increasing fatigue during games. These worsened biomechanics may lead to increased injuries in pitchers. Authors of another study[30] of adolescent baseball players observed that those who pitched competitively for more than 8 months of the year had 5 times the odds of sustaining an arm injury than players who pitched less than 8 months of the year. Furthermore, pitching-related arm tiredness and pain were associated with increased injury risk, and as pitching progressed

through a game, fatigue and pain were greater and velocity was lower.[28,31,32] Pitching in warm-weather areas, where the activity can more easily be done year round, without sufficient breaks for recovery, has also been associated with undergoing ulnar collateral ligament reconstruction and a shorter time to reconstruction.[33] Our findings in conjunction with the current body of literature suggest the need for closely monitoring pitching at all levels to reduce fatigue and ultimately reduce overuse injuries among baseball pitchers. Further work is needed on overuse injuries among players other than pitchers.

Head/Face Injuries and Concussions. As discussed previously, injuries to the head/face and injuries diagnosed as concussions were more common among high school than collegiate players. During competitions, concussions were the most common injury to high school batters, with the most frequent mechanism being hit by a pitch. The same was true for high school catchers and for outfielders, with the most often reported mechanism being contact with another player. All of this indicates a lower skill level at the high school than the collegiate level: pitchers may be less accurate in their throwing, making it more likely a batter will be hit in the head, or batters and catchers may be less aware of their surroundings or less able to move out of the way of a pitch to avoid injury than collegiate batters and catchers. Similarly, high school outfielders may have less positional awareness or ability to communicate with each other and be more likely to run into each other.

The large proportion of reported injuries diagnosed as concussions across both settings may be due to increased awareness and reporting. All 50 US states and the District of Columbia have passed laws to increase concussion education and improve management and reporting; in most cases, these are implemented at the high school athletic level.[34] Additionally, many groups, including the NCAA, have established guidelines with best practices for identifying and managing concussions.[35] Some literature[36] indicates that these changes in legislation and specific concussion guidelines may be responsible, at least in part, for the increased number of identified concussions.

Bat Standards. Over the course of data collection for this study, the standards for bats have changed in both high school and college. In 2011, the NCAA instituted a new restriction on bats. Instead of using batted-ball exit speed to determine whether a bat could be used, it instituted restrictions based on the batted-ball coefficient of resolution, which determines how much energy is lost when the bat makes contact with the ball. The baseball bat must have a batted-ball coefficient of resolution $\leq$0.500, which is similar to that of a wooden bat.[37] The same standards were put in place by the NFHS for the 2010–2011 academic year.[38] Although these changes were made primarily to limit the offense, they could also have an effect on batted-ball injuries, which made up approximately 10% of all injuries in both practices and competitions in high school and 6% and 10% of collegiate practice and competition injuries, respectively.

Limitations

Because these analyses were limited to time-loss injuries, we cannot draw conclusions about the differences between high school and collegiate baseball injuries for non–time-loss injuries. These analyses may also not be generalizable to all high school and collegiate programs. Only schools with ATs who chose to participate in the surveillance programs were included in the high school and collegiate samples, and high schools without ATs were unable to provide data to HS RIO. Furthermore, HS RIO only collects injuries and exposures for school-affiliated teams. Therefore, injuries from competitive club team play are not included in the high school data. Additionally, past researchers have shown that injury rates in NCAA-affiliated programs are different from those in collegiate athletics programs not affiliated with the NCAA. For example, in the 2000–2001 through 2001–2002 seasons, baseball injury rates in the National Association of Intercollegiate Athletics and National Junior College Athletic Association were generally lower than those observed in the NCAA.[15] Also, the NCAA data are from a small convenience sample and therefore should be interpreted with caution.

Although HS RIO and the NCAA-ISP are similar injury-surveillance systems, it is important to consider the differences between them; this is most evident in the fact that HS RIO relied on a random sample, whereas the NCAA-ISP relied on a convenience sample. In addition, differences may exist between high school and college in the length of the season, as well as the preseason, regular season, and postseason; the potentially longer collegiate season may increase the injury risk. Data regarding injuries for specific positions and activities should also be interpreted cautiously, as these were reported by the AT using his or her best judgment based on the athlete's position and activity at the time of the injury. Therefore, some injuries may be difficult to classify, such as "running bases" versus "sliding" or "pitcher" versus "fielder" when a pitcher is fielding a batted ball. We were unable to calculate some rates, such as the rate per season in HS RIO and position-specific injury rates, because limited exposure information was collected.

CONCLUSIONS

The injury rate for collegiate men's baseball was higher than that for high school boys' baseball. Additionally, it appears that the competition injury rate in baseball is decreasing over time. Clinicians should be aware that a large proportion of injuries are due to no contact and overuse mechanisms, and these mechanisms are more prevalent in collegiate players. Our findings suggest the need for closely monitoring pitching at all levels to reduce overuse injuries among baseball pitchers, and further work is needed on overuse injuries among players other than pitchers. Furthermore, despite the low injury rate in baseball compared with other sports, a large proportion of injuries at both levels resulted in time loss of $>$3 weeks, indicating that baseball players sustained severe injuries that may be resource intensive. Resources should also be allocated for preventing and treating upper extremity injuries, especially those to the shoulder, more often than lower extremity injuries. In particular, there is a need to reduce repetitions and improve biomechanics in baseball players, especially pitchers, in both high school and college. Athletic trainers should monitor or assist in monitoring pitchers' pain and fatigue. Our results highlight

the need for injury-prevention interventions specific to the level of competition and position. For example, further examination regarding ways to protect pitchers from overuse and shoulder injuries is required. Also, further research into prevention measures for reducing injuries in high school players due to being hit by pitches and batted balls is necessary. Such interventions would ensure that baseball players can continue to participate in their sport while reducing their injury risk.

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