

# The First Decade of Web-Based Sports Injury Surveillance: Descriptive Epidemiology of Injuries in US High School Girls' Volleyball (2005–2006 Through 2013–2014) and National Collegiate Athletic Association Women's Volleyball (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 in the acquisition of girls' and women's volleyball injury data.

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

**Design:** Descriptive epidemiology study.

**Setting:** Online injury surveillance from high school girls' (annual average = 100) and collegiate women's (annual average = 50) volleyball teams.

**Patients or Other Participants:** Girls' and women's volleyball players who participated in practices and competitions during the 2005–2006 through 2013–2014 academic years in high school and the 2004–2005 through 2013–2014 academic years in college.

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

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

**Results:** The High School Reporting Information Online system documented 1634 time-loss injuries during 1 471 872 AEs; the National Collegiate Athletic Association Injury Surveillance Program documented 2149 time-loss injuries during 563 845 AEs. The injury rate was higher in college than in high school (3.81/1000 versus 1.11/1000 AEs; IRR = 3.43; 95% CI = 3.22, 3.66), and higher in high schools with  $\leq 1000$  students than in those with  $> 1000$  students (IRR = 1.35; 95% CI = 1.23, 1.49). Injury rates did not vary by collegiate division. The injury rate was higher during competitions than practices for high school (IRR = 1.23; 95% CI = 1.12, 1.36) but not for college (IRR = 1.01; 95% CI = 0.92, 1.10). Ankle sprains were common in both the high school and collegiate setting. However, libero had a high incidence of concussion.

**Conclusions:** Injury rates were higher among collegiate than high school players. However, injury rates differed by event type in high school, unlike college. Concussion injury patterns among liberos varied from those for other positions. These findings highlight the need for injury-prevention interventions specific to setting and position.

**Key Words:** athletics, competition, females

## Key Points

- The rate of injury in collegiate women's volleyball exceeded that in high school girls' volleyball.
- Ankle sprains were common injuries at both the high school and collegiate levels.
- During competitions, the most frequent injury among liberos was concussion.

The number of female volleyball players at the high school and collegiate levels has increased in the past decade. Compared with the 2003–2004 academic year, the number of high school girls'

volleyball student-athletes in the 2013–2014 academic year increased 8.4% to 429 634.<sup>1</sup> Similarly, in the National Collegiate Athletic Association (NCAA), compared with the 2003–2004 academic year, the number of

collegiate women's volleyball student-athletes in the 2013–2014 academic year increased 25.1% to 16 657.<sup>2</sup> The continued increase in participation may equate with a similar increase in the number of injuries occurring in the sport, warranting the need for continued injury surveillance and development of injury-prevention strategies.

The NCAA has used injury surveillance to acquire collegiate sports injury data since the 1980s. Although this NCAA-based surveillance system has had several names, we herein denote it as the *NCAA Injury Surveillance Program* (ISP). A previous NCAA-ISP report<sup>3</sup> for the 1988–1989 through 2003–2004 academic years documented women's volleyball competition and practice injury rates of 4.58 and 4.10 per 1000 athlete-exposures (AEs), respectively. This report also noted the high incidence of ankle sprains, highlighting the need for focused injury prevention.<sup>3</sup> As denoted in the van Mechelen et al<sup>4</sup> framework, injury prevention benefits from the ongoing monitoring of injury incidence, and updated descriptive epidemiology is needed. In addition, it is important to document injury incidence at the high school level and compare findings between settings.

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>5</sup> A year later, High School Reporting Information Online (HS RIO), a similar Web-based high school sports injury-surveillance system, was launched.<sup>6</sup> The purpose of this article is to summarize the descriptive epidemiology of injuries sustained in high school girls' and collegiate women's volleyball 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 girls' volleyball 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 50 NCAA member institutions (Division I = 19, Division II = 10, Division III = 21) sponsoring women's volleyball participated in the NCAA-ISP during the 2004–2005 through 2013–2014 academic years. The methods of HS RIO and the NCAA-ISP are summarized in the following paragraphs. In-depth information on the methods and analyses for this special series of articles on Web-based sports injury surveillance can be found in the previously published methodologic article.<sup>7</sup> In addition, previous publications have described the sampling and data collection of HS RIO<sup>6,8</sup> and the NCAA-ISP<sup>5</sup> in depth.

## The High School RIO

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

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) on the basis of school population (enrollment either  $\leq 1000$  or  $>1000$ ) and US Census geographic region.<sup>9</sup> Athletic trainers 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 into the study (based on geographic location and high school size) was applied to individual case counts 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.<sup>5</sup> Participation in the NCAA-ISP 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.<sup>5</sup> This platform integrated some of the functional components of an electronic medical record, such as athlete demographic 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), 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. Weights for all data were further adjusted to correct for underreporting, according to the findings of Kucera et al,<sup>10</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<sup>-1</sup>). In-depth information on the formula used to calculate national estimates can be found in the previously published methodologic article.<sup>7</sup>

## Definitions

**Injury.** A reportable *injury* in both HS RIO and the NCAA-ISP was defined as an injury that (1) occurred as a result of participation in an organized practice or competition; (2) required medical attention by a certified AT or physician; and (3) resulted in restriction of the student-athlete's participation for 1 or more days beyond the day of injury. Since the 2007–2008 academic year, HS RIO has also captured all concussions, fractures, and dental injuries, regardless of time loss. In the NCAA-ISP, multiple injuries occurring from 1 injury event could be included, whereas in HS RIO, only the principal injury was captured. Beginning in the 2009–2010 academic year, the NCAA-ISP also began to monitor all non-time-loss injuries. A *non-time-loss injury* was defined as any injury that was evaluated or treated (or both) by an AT or physician but did not result in restriction from participation beyond the day of injury. However, because HS RIO captures only time-loss injuries (to reduce the burden on high school ATs' time), 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 data when necessary to increase the comparability between high school and collegiate student-athletes. We also opted to ensure that categorizations were consistent among all sport-specific articles within this special series. Because methodologic variations may lead to small differences in injury reporting among these surveillance systems, caution must be taken when interpreting these results.

We examined injury counts, national estimates, 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 focused on comparisons by level of play (high school and college), event type (practice and competition), school size in high school ( $\leq 1000$  and  $> 1000$  students), collegiate division (I, II, and III), and time in season (preseason, regular season, and postseason). 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 examined separately for each time period. All mean differences with 95% CIs not containing 0.0 were considered statistically significant.

## RESULTS

### Total Injury Frequency, National Estimates, and Injury Rates

During the 2005–2006 through 2013–2014 academic years, ATs reported a total of 1634 time-loss injuries in high school girls' volleyball (Table 1). During the 2004–2005 through 2013–2014 academic years, ATs reported a total of 2149 injuries in collegiate women's volleyball. These raw data counts represent overall national estimates of 561 709 high school injuries (annual average of 62 412) and 46 449 collegiate injuries (annual average of 4645). The total injury rate for high school girls' volleyball was 1.11/1000 AEs (95% CI = 1.06, 1.16). The total injury rate for collegiate women's volleyball was 3.81/1000 AEs (95% CI = 3.65, 3.97). The total injury rate was higher in college than in high school (IRR = 3.43; 95% CI = 3.22, 3.66).

### School Size and Division

In high school girls' volleyball, the total injury rate was higher for high schools with  $\leq 1000$  students than for high schools with  $> 1000$  students (IRR = 1.35; 95% CI = 1.23, 1.49; Table 1). In collegiate women's volleyball, total injury rates did not vary among divisions.

### Event Type

The majority of injuries occurred during practices in both high school (60.9%) and college (70.5%; Table 1). The competition injury rate was higher than the practice injury rate in high school (IRR = 1.23; 95% CI = 1.12, 1.36) but not in college (IRR = 1.01; 95% CI = 0.92, 1.10).

Among high school players, a decrease was found in the annual injury rates for practices (annual average change =  $-0.07/1000$  AEs; 95% CI =  $-0.10$ ,  $-0.04$ ) but not competitions (annual average change =  $-0.05/1000$  AEs; 95% CI =  $-0.12$ ,  $0.01$ ; Figure). Among collegiate players, decreases were found in the 2004–2005 through 2008–2009 academic years for practices (annual average change =



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

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	434 (59.6)	235 513 (61.2)	362 389	1.20 (1.08, 1.31)
	Competition	294 (40.4)	149 386 (38.8)	186 538	1.58 (1.40, 1.76)
	Total	728 (100.0)	384 899 (100.0)	548 927	1.33 (1.23, 1.42)
≤1000 students	Practice	561 (61.9)	111 977 (63.3)	605 378	0.93 (0.85, 1.00)
	Competition	345 (38.1)	64 831 (36.7)	317 567	1.09 (0.97, 1.20)
	Total	906 (100.0)	176 809 (100.0)	922 945	0.98 (0.92, 1.05)
Total	Practice	995 (60.9)	347 491 (61.9)	967 767	1.03 (0.96, 1.09)
	Competition	639 (39.1)	214 218 (38.1)	504 105	1.27 (1.17, 1.37)
	Total	1634 (100.0)	561 709 (100.0)	1 471 872	1.11 (1.06, 1.16)
NCAA-ISP (2004–2005 through 2013–2014)					
Division I	Practice	632 (71.9)	10 691 (70.3)	174 315	3.63 (3.34, 3.91)
	Competition	247 (28.1)	4 523 (29.7)	63 408	3.90 (3.41, 4.38)
	Total	879 (100.0)	15 214 (100.0)	237 723	3.70 (3.45, 3.94)
Division II	Practice	317 (67.9)	8 126 (65.7)	83 476	3.80 (3.38, 4.22)
	Competition	150 (32.1)	4 249 (34.3)	34 917	4.30 (3.61, 4.98)
	Total	467 (100.0)	12 375 (100.0)	118 393	3.94 (3.59, 4.30)
Division III	Practice	567 (70.6)	13 451 (71.3)	140 538	4.03 (3.70, 4.37)
	Competition	236 (29.4)	5 410 (28.7)	67 091	3.52 (3.07, 3.97)
	Total	803 (100.0)	18 861 (100.0)	207 629	3.87 (3.60, 4.13)
Total	Practice	1516 (70.5)	32 268 (69.5)	398 429	3.80 (3.61, 4.00)
	Competition	633 (29.5)	14 181 (30.5)	165 416	3.83 (3.53, 4.12)
	Total	2149 (100.0)	46 449 (100.0)	563 845	3.81 (3.65, 3.97)

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, 2005–2006 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. National estimates and athlete-exposures may not sum to totals due to rounding error.

–0.53/1000 AEs; 95% CI = –0.77, –0.29) and competitions (annual average change = –0.51/1000 AEs; 95% CI = –0.79, –0.24). However, linear trends were not seen in the 2009–2010 through 2013–2014 academic years for practices (annual average change = –0.03/1000 AEs; 95% CI = –0.14, 0.07) or competitions (annual average change = –0.18/1000 AEs; 95% CI = –0.45, 0.09).

### Time in Season

For both high school and collegiate athletes, the majority of injuries occurred during the regular season (high school = 72.6%, college = 57.4%; Table 2). Among collegiate players, the preseason had a higher injury rate than the regular season (IRR = 1.87; 95% CI = 1.72, 2.04) and postseason (IRR = 2.79; 95% CI = 2.12, 3.69). In addition, the injury rate was higher in the regular season than in the postseason (IRR = 1.49; 95% CI = 1.13, 1.97). Injury rates by time in season could not be calculated for high school because AEs were not stratified by time in season.

### Time Loss From Participation

For both high school and collegiate athletes, the largest proportion of injuries resulted in time loss of less than 1 week, ranging from 45.3% of injuries in high school competitions to 61.4% of injuries in collegiate practices (Table 3).

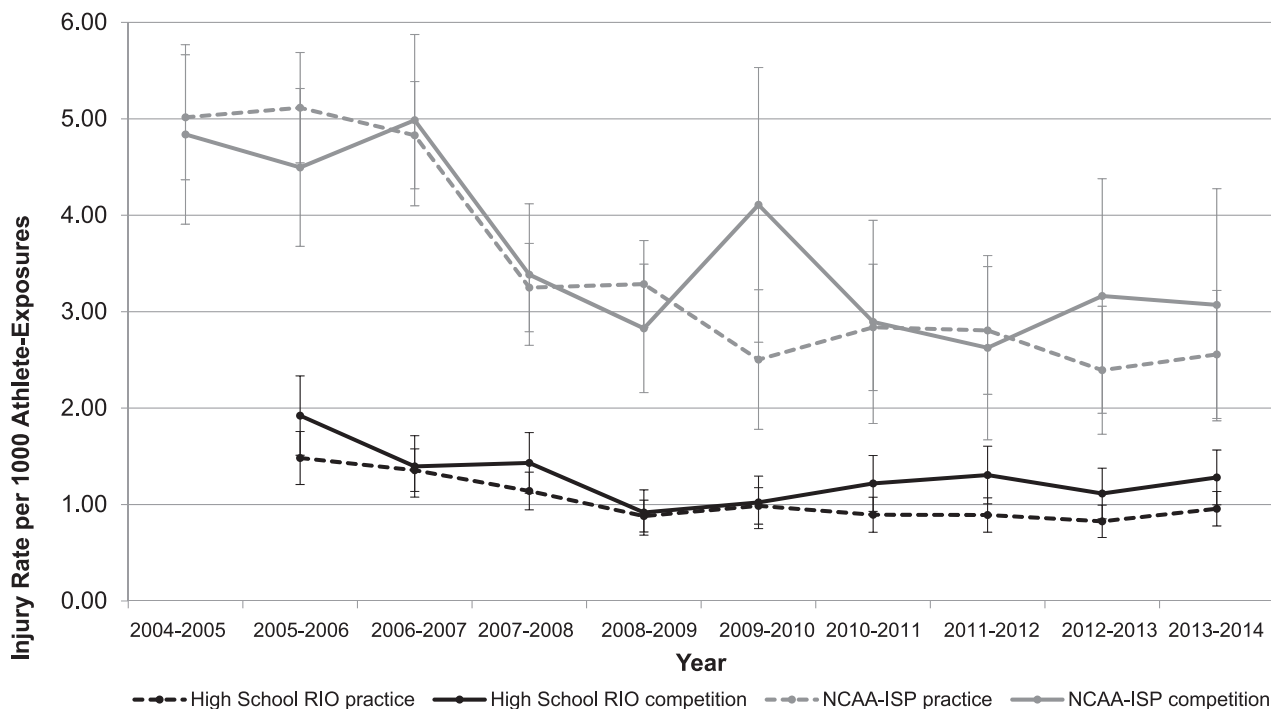
### Body Parts Injured and Diagnoses

**High School.** Commonly injured body parts during both practices and competitions were the ankle (practices = 37.4%, competitions = 34.9%) and the knee (practices = 10.2%, competitions = 13.0%; Table 4). The head/face (17.1%) and the hand/wrist (14.1%) were also frequently injured body parts in competitions. Often reported diagnoses for both practices and competitions were ligament sprains (practices = 44.2%, competitions = 51.1%) and muscle/tendon strains (practices = 18.3%, competitions = 12.5%; Table 5). Concussion was also a common diagnosis in competitions (15.1%).

**College.** Frequently injured body parts for both practices and competitions were the ankle (practices = 16.6%, competitions = 25.8%) and the knee (practices = 13.6%, competitions = 15.6%; Table 4). Common diagnoses for both practices and competitions were ligament sprains (practices = 25.6%, competitions = 37.7%) and muscle/tendon strains (practices = 22.8%, competitions = 15.8%; Table 5).

### Mechanisms of and Activities During Injury

**High School.** The most often reported mechanism of injury for both practices and competitions was contact with the playing surface (practices = 25.0%, competitions = 31.5%), followed by no contact (practices = 24.1%, competitions = 20.3%) and contact with another person (practices = 21.7%, competitions = 25.6%; Table 6). Overuse/chronic mechanisms also accounted for 13.4% of



**Figure.** Injury rates by year and type of athlete-exposure (AE) for high school girls' and collegiate women's volleyball. **Note:** Annual average changes in the linear trend test for injury rates are as follows: High School Reporting Information Online (RIO; practices =  $-0.07/1000$  AEs, 95% confidence interval (CI) =  $-0.10, -0.04$ ; competitions =  $-0.05/1000$  AEs, 95% CI =  $-0.12, 0.01$ ); National Collegiate Athletic Association Injury Surveillance Program (NCAA-ISP) 2004–2005 through 2008–2009 (practices =  $-0.53/1000$  AEs; 95% CI =  $-0.77, -0.29$ ; competitions =  $-0.51/1000$  AEs, 95% CI =  $-0.79, -0.24$ ); NCAA-ISP 2009–2010 through 2013–2014 academic years (practices =  $-0.03/1000$  AEs, 95% CI =  $-0.14, 0.07$ ; competitions =  $-0.18/1000$  AEs, 95% CI =  $-0.45, 0.09$ ). 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.

injuries during practices. The most frequent activities during injury for both practices and competitions were blocking (practices = 25.4%, competitions = 27.0%), general play (practices = 24.8%, competitions = 17.5%), and digging (practices = 12.9%, competitions = 24.7%; Table 7).

**College.** The most common mechanism of injury for both practices and competitions was no contact (practices = 36.5%, competitions = 35.8%), followed by contact with another person (practices = 14.7%, competitions = 25.2%) and contact with the playing surface (practices = 11.3%,

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

Time in Season	Exposure Type	HS RIO (2005–2006 Through 2013–2014)		NCAA-ISP (2004–2005 Through 2013–2014)			Injury Rate/1000 Athlete-Exposures (95% Confidence Interval)
		Injuries in Sample, No. (%)	National Estimates, No. (%)	Injuries in Sample, No. (%)	National Estimates, No. (%)	Athlete-Exposures	
Preseason	Practice	361 (91.2)	121 583 (90.4)	849 (98.5)	17 673 (99.0)	144 055	5.89 (5.50, 6.29)
	Competition	35 (8.8)	12 956 (9.6)	13 (1.5)	174 (1.0)	2375	5.47 (2.50, 8.45)
	Total	396 (100.0)	134 540 (100.0)	862 (100.0)	17 847 (100.0)	146 430	5.89 (5.49, 6.28)
Regular season	Practice	603 (51.0)	211 375 (52.5)	645 (52.3)	14 109 (51.4)	235 848	2.73 (2.52, 2.95)
	Competition	579 (49.0)	190 963 (47.5)	589 (47.7)	13 326 (48.6)	156 408	3.77 (3.46, 4.07)
	Total	1182 (100.0)	402 338 (100.0)	1234 (100.0)	27 435 (100.0)	392 256	3.15 (2.97, 3.32)
Postseason	Practice	28 (56.0)	13 625 (59.4)	22 (41.5)	486 (41.6)	18 529	1.19 (0.69, 1.68)
	Competition	22 (44.0)	9324 (40.6)	31 (58.5)	681 (58.4)	6633	4.67 (3.03, 6.32)
	Total	50 (100.0)	22 949 (100.0)	53 (100.0)	1167 (100.0)	25 162	2.11 (1.54, 2.67)

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

<sup>a</sup> Excluded were 6 injuries reported in HS RIO due to missing data for time in season. High school data originated from HS RIO surveillance data, 2005–2006 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. Injury rates by time in season could not be calculated for high school because athlete-exposures were not stratified by time in season. National estimates and athlete-exposures may not sum to totals due to rounding error.

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

Surveillance System and Time Loss Category	Practice			Competition		
	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	497 (52.2)	182 300 (54.6)	0.51 (0.47, 0.56)	276 (45.3)	92 368 (44.8)	0.55 (0.48, 0.61)
1 to 3 wk	334 (35.1)	110 637 (33.1)	0.35 (0.31, 0.38)	212 (34.8)	70 307 (34.1)	0.42 (0.36, 0.48)
>3 wk <sup>b</sup>	121 (12.7)	40 938 (12.3)	0.13 (0.10, 0.15)	121 (19.9)	43 488 (21.1)	0.24 (0.20, 0.28)
NCAA-ISP (2004–2005 through 2013–2014)						
1 d to <1 wk	892 (61.4)	19 405 (62.4)	2.24 (2.09, 2.39)	341 (57.1)	7212 (53.8)	2.06 (1.84, 2.28)
1 to 3 wk	379 (26.1)	7783 (25.0)	0.95 (0.86, 1.05)	166 (27.8)	3337 (24.9)	1.00 (0.85, 1.16)
>3 wk <sup>b</sup>	183 (12.6)	3925 (12.6)	0.46 (0.39, 0.53)	90 (15.1)	2864 (21.4)	0.54 (0.43, 0.66)

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

<sup>a</sup> Excluded were 73 injuries reported in HS RIO and 98 injuries reported in the NCAA-ISP due to missing data for time loss. High school data originated from HS RIO surveillance data, 2005–2006 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 one injury event. Percentages may not add up to 100.0 due to rounding error.

<sup>b</sup> Includes 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.

competitions = 17.7%; Table 6). Overuse/chronic mechanisms also accounted for 21.2% of injuries during practices. The most often reported activities during injury for both practices and competitions were general play (practices = 32.9%, competitions = 26.7%), spiking (practices = 17.0%, competitions = 19.5%), digging (practices = 15.0%, competitions = 20.6%), and blocking (practices = 14.8%, competitions = 20.8%; Table 7).

### Position-Specific Injuries in Competitions

In competitions at the high school level, ankle sprains were the most frequent injury to middle blockers (43.0%), opposite players (21.2%), outside hitters (35.5%), and setters (43.0%). Concussions were the most common injury to liberos (31.4%; Table 8). In competitions at the collegiate level, ankle sprains were the most often reported injury to middle blockers (36.4%), outside hitters (25.7%), and setters (21.9%). Hand/wrist sprains were the most frequent injury to opposite players (21.1%), whereas concussions were the most common injury to liberos (22.9%).

## DISCUSSION

Our study examined injuries sustained in the past decade among a sample of high school girls' and collegiate women's volleyball players and demonstrated variations in the incidence of injury. Over the past decade, participation in volleyball among high school and collegiate females has increased.<sup>1,2</sup> As of the 2013–2014 academic year, more than 15 672 high schools and 95.6% of all NCAA member institutions sponsored girls' or women's volleyball.<sup>1,2</sup> Given the large population of players at both levels of competition, it is essential to acquire up-to-date information to both help clinicians identify the most prevalent injuries that athletes may present and to drive the timely

development of injury-prevention interventions specific to the sport. We found variations in injury rates by level of competition as well as position-specific differences related to common injuries, particularly in liberos.

### Comparison of Injury Rates With Previous Research

The high school injury rates varied from those in previous research<sup>11</sup> conducted for the 1995–1997 seasons. Whereas our competition injury rate was slightly higher (1.27/1000 versus 1.2/1000 AEs), our practice injury rate was lower (1.03/1000 versus 2.8/1000 AEs). At the collegiate level, overall injury rates were lower than those previously reported by Powell and Dompier<sup>12</sup> for Divisions I through III in the 2000–2001 through 2001–2002 academic years (range of time-loss injury rates = 4.1–5.4/1000 AEs). In an earlier iteration of the NCAA-ISP during the 1988–1989 through 2003–2004 academic years, reported competition and practice injury rates were 4.58/1000 and 4.10/1000 AEs, respectively,<sup>3</sup> which were higher than those in our study (3.83/1000 and 3.80/1000 AEs, respectively). Comparisons with previous research should be performed with caution because the composition of the samples may vary by division, school size, and resources such as the size of the team medical staff or staff-to-athlete ratio and consequently confound reported injury rates.<sup>13</sup> Nevertheless, the higher injury rates in earlier research, coupled with our finding that injury rates have decreased over time during the study period, may highlight the potential benefits of continued implementation of injury-prevention interventions aimed at reducing the incidence of injury (some of which are described in more depth in the following paragraphs). Although future investigators should continue examining how such interventions may benefit female volleyball athletes, it is important for clinicians who recommend their use to also consider the feasibility of

**Table 4. Number of Injuries, National Estimates, and Injury Rates by Body Part Injured and Type of Athlete-Exposure in High School Girls' and Collegiate Women's Volleyball<sup>a</sup>**

Surveillance System and Body Part Injured	Practice			Competition		
	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	85 (8.6)	23 998 (6.9)	0.09 (0.07, 0.11)	109 (17.1)	33 710 (15.8)	0.22 (0.18, 0.26)
Neck	6 (0.6)	1539 (0.4)	0.01 (0.00, 0.01)	5 (0.8)	1371 (0.6)	0.01 (0.00, 0.02)
Shoulder/clavicle	84 (8.5)	28 435 (8.2)	0.09 (0.07, 0.11)	28 (4.4)	8220 (3.9)	0.06 (0.03, 0.08)
Arm/elbow	20 (2.0)	7202 (2.1)	0.02 (0.01, 0.03)	19 (3.0)	6067 (2.8)	0.04 (0.02, 0.05)
Hand/wrist	95 (9.6)	30 767 (8.9)	0.10 (0.08, 0.12)	90 (14.1)	28 284 (13.2)	0.18 (0.14, 0.22)
Trunk	73 (7.4)	27 055 (7.8)	0.08 (0.06, 0.09)	37 (5.8)	14 678 (6.9)	0.07 (0.05, 0.10)
Hip/thigh/upper leg	53 (5.3)	19 573 (5.6)	0.05 (0.04, 0.07)	16 (2.5)	5894 (2.8)	0.03 (0.02, 0.05)
Knee	101 (10.2)	35 832 (10.3)	0.10 (0.08, 0.12)	83 (13.0)	29 761 (13.9)	0.16 (0.13, 0.20)
Lower leg	40 (4.0)	14 804 (4.3)	0.04 (0.03, 0.05)	13 (2.0)	3778 (1.8)	0.03 (0.01, 0.04)
Ankle	371 (37.4)	135 828 (39.2)	0.38 (0.34, 0.42)	222 (34.9)	78 189 (36.6)	0.44 (0.38, 0.50)
Foot	45 (4.5)	15 244 (4.4)	0.05 (0.03, 0.06)	9 (1.4)	2417 (1.1)	0.02 (0.01, 0.03)
Other	20 (2.0)	6589 (1.9)	0.02 (0.01, 0.03)	6 (0.9)	1328 (0.6)	0.01 (0.00, 0.02)
NCAA-ISP (2004–2005 through 2013–2014)						
Head/face	95 (6.3)	2346 (7.3)	0.24 (0.19, 0.29)	65 (10.3)	1683 (11.9)	0.39 (0.30, 0.49)
Neck	11 (0.7)	215 (0.7)	0.03 (0.01, 0.04)	10 (1.6)	185 (1.3)	0.06 (0.02, 0.10)
Shoulder/clavicle	158 (10.4)	3018 (9.4)	0.40 (0.33, 0.46)	50 (7.9)	1061 (7.5)	0.30 (0.22, 0.39)
Arm/elbow	25 (1.7)	549 (1.7)	0.06 (0.04, 0.09)	16 (2.5)	348 (2.5)	0.10 (0.05, 0.14)
Hand/wrist	113 (7.5)	2513 (7.8)	0.28 (0.23, 0.34)	63 (10.0)	1277 (9.0)	0.38 (0.29, 0.47)
Trunk	197 (13.0)	4233 (13.1)	0.49 (0.43, 0.56)	70 (11.1)	1441 (10.2)	0.42 (0.32, 0.52)
Hip/thigh/upper leg	196 (12.9)	4230 (13.1)	0.49 (0.42, 0.56)	35 (5.5)	735 (5.2)	0.21 (0.14, 0.28)
Knee	206 (13.6)	4359 (13.5)	0.52 (0.45, 0.59)	99 (15.6)	2798 (19.7)	0.60 (0.48, 0.72)
Lower leg	97 (6.4)	1752 (5.4)	0.24 (0.20, 0.29)	30 (4.7)	570 (4.0)	0.18 (0.12, 0.25)
Ankle	252 (16.6)	5379 (16.7)	0.63 (0.55, 0.71)	163 (25.8)	3329 (23.5)	0.99 (0.83, 1.14)
Foot	80 (5.3)	1673 (5.2)	0.20 (0.16, 0.24)	21 (3.3)	585 (4.1)	0.13 (0.07, 0.18)
Other	86 (5.7)	2001 (6.2)	0.22 (0.17, 0.26)	11 (1.7)	170 (1.2)	0.07 (0.03, 0.11)

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

<sup>a</sup> Excluded were 4 injuries reported in HS RIO due to missing data for body part. High school data originated from HS RIO surveillance data, 2005–2006 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. Percentages may not add up to 100.0 due to rounding error.

actual implementation and adherence within their respective communities.

### Comparisons Between and Within High School Girls' and Collegiate Women's Volleyball

Collegiate injury rates were higher than high school injury rates. The reasons for this difference may be multiple. The intensity at which collegiate volleyball is played may be higher than that of high school volleyball, which may augment the injury risk. This difference may also be related to previous injury, which has been postulated to place athletes at greater risk for reinjury.<sup>14,15</sup> Thus, the higher injury rates in collegiate players may be due to a longer exposure to the sport and greater likelihood of previous injury. At the same time, the prevalence of more multipractice days in the collegiate setting may increase the volume load and, therefore, the injury risk as well. Given that preseason injury rates were higher than those during the regular season in collegiate volleyball, limiting the number of 2- and 3-a-day practices, monitoring jump loads, and increasing strength-training sessions should all be considered. Furthermore, the

scheduling of sport-related activities at the high school and collegiate levels may vary. Whereas the high school season may be more finite, training for the collegiate season may occur across the academic year. At the same time, season lengths may vary between levels. Last, varying injury rates may be a function of coverage differences between high school and collegiate sports. The *NCAA Sports Medicine Handbook* advocated for “an adequate number of athletic trainers who are able to provide for the safety and well-being of student-athletes across all sports.”<sup>16(p9)</sup> Only 37% of US high school athletic programs had at least 1 full-time AT.<sup>17</sup> Part-time AT coverage at the high school level could result in underreporting of injuries, although recent researchers<sup>13</sup> did not find a difference in time-loss football injury rates between high school programs with full-time versus outreach ATs. Because injury surveillance seldom includes in-depth data on individual-, team-, and school-level characteristics, more in-depth studies are warranted. For example, further study is needed to better understand the gameplay intensity and skill levels of high school and collegiate female volleyball players, as well as how these



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

Surveillance System and Diagnosis	Practice			Competition		
	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	77 (7.8)	20 303 (5.9)	0.08 (0.06, 0.10)	96 (15.1)	28 664 (13.5)	0.19 (0.15, 0.23)
Contusion	41 (4.1)	13 510 (3.9)	0.04 (0.03, 0.06)	38 (6.0)	12 981 (6.1)	0.08 (0.05, 0.10)
Dislocation <sup>b</sup>	22 (2.2)	6 744 (2.0)	0.02 (0.01, 0.03)	8 (1.3)	2 181 (1.0)	0.02 (0.00, 0.03)
Fracture/avulsion	40 (4.0)	15 451 (4.5)	0.04 (0.03, 0.05)	36 (5.7)	11 248 (5.3)	0.07 (0.05, 0.09)
Laceration	4 (0.4)	2 474 (0.7)	<0.01 (0.00, 0.01)	6 (0.9)	1 532 (0.7)	0.01 (0.00, 0.02)
Ligament sprain	438 (44.2)	154 822 (44.7)	0.45 (0.41, 0.49)	324 (51.1)	114 606 (53.9)	0.64 (0.57, 0.71)
Muscle/tendon strain	181 (18.3)	66 265 (19.2)	0.19 (0.16, 0.21)	79 (12.5)	25 595 (12.0)	0.16 (0.12, 0.19)
Other	189 (19.1)	66 541 (19.2)	0.20 (0.17, 0.22)	47 (7.4)	15 802 (7.4)	0.09 (0.07, 0.12)
NCAA-ISP (2004–2005 through 2013–2014)						
Concussion	75 (5.0)	1 914 (6.0)	0.19 (0.15, 0.23)	54 (8.5)	1 468 (10.4)	0.33 (0.24, 0.41)
Contusion	55 (3.7)	1 088 (3.4)	0.14 (0.10, 0.17)	43 (6.8)	872 (6.2)	0.26 (0.18, 0.34)
Dislocation <sup>b</sup>	9 (0.6)	201 (0.6)	0.02 (0.01, 0.04)	7 (1.1)	216 (1.5)	0.04 (0.01, 0.07)
Fracture/avulsion	37 (2.5)	894 (2.8)	0.09 (0.06, 0.12)	20 (3.2)	542 (3.8)	0.12 (0.07, 0.17)
Laceration	6 (0.4)	85 (0.3)	0.02 (0.00, 0.03)	3 (0.5)	38 (0.3)	0.02 (0.00, 0.04)
Ligament sprain	384 (25.6)	8 510 (26.6)	0.96 (0.87, 1.06)	238 (37.7)	5 480 (38.7)	1.44 (1.26, 1.62)
Muscle/tendon strain	342 (22.8)	7 237 (22.6)	0.86 (0.77, 0.95)	100 (15.8)	2 231 (15.8)	0.60 (0.49, 0.72)
Other	593 (39.5)	12 099 (37.8)	1.49 (1.37, 1.61)	167 (26.4)	3 315 (23.4)	1.01 (0.86, 1.16)

<sup>a</sup> Excluded were 8 injuries reported in HS RIO due to missing data for diagnosis. High school data originated from HS RIO surveillance data, 2005–2006 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. Percentages may not sum to 100.0 due to rounding error.

<sup>b</sup> Includes separations.

factors, coupled with previous injury, may be associated with injury risk.

Whereas injury rates were higher during competitions than practices for high school players, injury rates did not differ by event type in collegiate players. This finding also varies from previous research. During the 1988–1989 through 2003–2004 academic years, NCAA-ISP data revealed a slightly higher injury rate during competitions than practices (4.58/1000 versus 4.10/1000 AEs)<sup>3</sup>; high school data from the 1995–1997 seasons showed the injury rate to be higher during practices than competitions (2.8/1000 versus 1.2/1000 AEs), the only such instance among the 10 sports examined.<sup>11</sup> The intensity and composition of activities and specific drills that occur during practices may vary in women's volleyball compared with other collegiate sports.<sup>18</sup> This difference may also exist between the high school and collegiate levels, which may explain the variation in findings. Nevertheless, practices accounted for the largest proportions of both injuries and exposures. Developing injury-prevention strategies that target practices alongside competitions might provide additional opportunities to reduce the incidence of injury.<sup>18</sup> Despite lower practice injury rates than competition rates in high school, practices should still be observed by medical staff to determine whether safety concerns are present and confirm that proper injury-prevention techniques are being used. Because improper diving and blocking techniques have been identified as activities with a high injury risk, teaching proper diving and blocking techniques is important. Future research to better understand the composition of practice activities

that may increase the injury risk among female volleyball players is also warranted.

In addition, differences were observed between high school and collegiate players for school size and division. Smaller high schools had higher injury rates than larger high schools. Collegiate injury rates did not vary by division, which is similar to previous results.<sup>3</sup> In reality, school size may be a proxy for medical staff coverage, but in what manner is unknown. For example, smaller high schools may have less access to ATs, which contributes to less care and more injuries. On the other hand, athletes at smaller high schools with an AT may have more access because of the lower athlete-to-AT ratio, and consequently, they are able to receive more care, which results in the AT reporting more injuries to injury-surveillance programs. Mixed findings have also been noted in state-specific analyses of associations between high school size and medical staff coverage, but these were mostly relegated to football.<sup>19–21</sup> Future investigators should examine injury incidence and reporting in high school sport settings by AT coverage, particularly in settings without AT coverage, to fully demonstrate the potential benefits of AT coverage.

### Common Injuries and Injury Prevention

As seen in previous research,<sup>3,14,22–24</sup> ankle sprains are frequent injuries to women's volleyball players. Our findings by position suggest that the majority of these ankle sprains were from contact with another person, most likely when coming in contact with another player's foot, as posited by Agel et al.<sup>3</sup> Because players on opposite sides of



**Table 6. Number of Injuries, National Estimates, and Injury Rates by Mechanism of Injury and Type of Athlete-Exposure in High School Girls' and Collegiate Women's Volleyball<sup>a</sup>**

Surveillance System and Mechanism of Injury	Practice			Competition		
	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)
<b>HS RIO (2005–2006 through 2013–2014)</b>						
Contact with another person	211 (21.7)	75 718 (22.4)	0.22 (0.19, 0.25)	160 (25.6)	54 964 (26.1)	0.32 (0.27, 0.37)
Contact with playing surface	243 (25.0)	84 864 (25.0)	0.25 (0.22, 0.28)	197 (31.5)	69 321 (32.9)	0.39 (0.34, 0.45)
Contact with ball	113 (11.6)	36 479 (10.8)	0.12 (0.10, 0.14)	96 (15.4)	30 699 (15.6)	0.19 (0.15, 0.23)
Contact with standard/pole/net	5 (0.5)	1821 (0.5)	0.01 (0.00, 0.01)	3 (0.5)	788 (0.4)	0.01 (0.00, 0.01)
Contact with other playing equipment	12 (1.2)	2603 (0.8)	0.01 (0.01, 0.02)	12 (1.9)	2789 (1.3)	0.02 (0.01, 0.04)
Contact with out-of-bounds object	3 (0.3)	855 (0.3)	<0.01 (0.00, 0.01)	3 (0.5)	638 (0.3)	0.01 (0.00, 0.01)
No contact	234 (24.1)	80 456 (23.7)	0.24 (0.21, 0.27)	127 (20.3)	41 364 (19.6)	0.25 (0.21, 0.30)
Overuse/chronic	130 (13.4)	48 700 (14.4)	0.13 (0.11, 0.16)	22 (3.5)	8534 (4.1)	0.04 (0.03, 0.06)
Illness/infection	22 (2.3)	7353 (2.2)	0.02 (0.01, 0.03)	5 (0.8)	1626 (0.8)	0.01 (0.00, 0.02)
<b>NCAA-ISP (2004–2005 through 2013–2014)</b>						
Contact with another person	218 (14.7)	4901 (15.7)	0.55 (0.47, 0.62)	157 (25.2)	3286 (23.6)	0.95 (0.80, 1.10)
Contact with playing surface	168 (11.3)	3875 (12.4)	0.42 (0.36, 0.49)	110 (17.7)	2990 (21.5)	0.66 (0.54, 0.79)
Contact with ball	130 (8.8)	2772 (8.9)	0.33 (0.27, 0.38)	65 (10.4)	1322 (9.5)	0.39 (0.30, 0.49)
Contact with standard/pole/net	16 (1.1)	401 (1.3)	0.04 (0.02, 0.06)	3 (0.5)	38 (0.3)	0.02 (0.00, 0.04)
Contact with other playing equipment	3 (0.2)	88 (0.3)	0.01 (0.00, 0.02)	2 (0.3)	61 (0.4)	0.01 (0.00, 0.03)
Contact with out-of-bounds object	4 (0.3)	62 (0.2)	0.01 (0.00, 0.02)	6 (1.0)	130 (0.9)	0.04 (0.01, 0.07)
No contact	541 (36.5)	11 037 (35.3)	1.36 (1.24, 1.47)	223 (35.8)	4855 (34.9)	1.35 (1.17, 1.53)
Overuse/chronic	314 (21.2)	6199 (19.8)	0.79 (0.70, 0.88)	48 (7.7)	1100 (7.9)	0.29 (0.21, 0.37)
Illness/infection	89 (6.0)	1964 (6.3)	0.22 (0.18, 0.27)	9 (1.4)	124 (0.9)	0.05 (0.02, 0.09)

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

<sup>a</sup> Excluded were 36 injuries reported in HS RIO and 43 injuries reported in the NCAA-ISP due to missing data or the athletic trainer reporting *Other* or *Unknown*. High school data originated from HS RIO surveillance data, 2005–2006 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 one injury event. Percentages may not sum to 100.0 due to rounding error.

the net are allowed to stand on the line under the net, the chance of landing on another's foot is high. Thus, 1 possible rule change to mitigate the incidence of ankle injuries due to player contact would be to not allow players to step on the line. Also, ankle braces and balance training have been shown to reduce the risk of ankle sprains.<sup>25–27</sup> As stated earlier, clinicians recommending these prevention interventions should also consider that because research is typically performed in controlled and monitored environments, these findings may be not replicable in their settings unless factors that aid and hinder implementation and compliance are identified and addressed.<sup>28</sup>

Although ankle sprains were prevalent among all positions, the proportion of concussions was the highest among liberos in both high school and college. The most common injury mechanism for concussions in liberos was contact with the playing surface. The libero is a defensive player who is not allowed to play the front row. As a result, these players rely on diving plays, which may increase their risk of concussion due to hitting the surface. Diving and rolling should be the focus of injury prevention for liberos. Nevertheless, concussions are a frequent injury in volleyball players and highlight the need to ensure appropriate medical personnel are present to detect, diagnose, and manage the concussions that occur. At the high school level, all 50 states and

Washington, DC, have enacted concussion-related legislation.<sup>29</sup> In April 2010, the NCAA Executive Committee<sup>16</sup> adopted a new concussion policy focused on better identification and management. Still, future investigators need to develop interventions focused on primary concussion prevention (ie, reducing the actual occurrence). We recommend that clinicians ensure their settings develop, implement, and comply with policies that aim to better identify and manage such injuries.

### Limitations

Our findings may not be generalizable to other playing levels, such as youth, middle school, and professional programs; collegiate programs at non-NCAA institutions; or 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. This is most evident in the fact that HS RIO used a random sample, whereas the NCAA-ISP used a convenience sample. In addition, differences may exist between high school and college in regard to the length of the season, as well as the

**Table 7. Number of Injuries, National Estimates, and Injury Rates by Activity During Injury and Type of Athlete-Exposure in High School Girls' and Collegiate Women's Volleyball<sup>a</sup>**

Surveillance System and Activity During Injury	Practice			Competition		
	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)						
Blocking	237 (25.4)	90696 (27.5)	0.24 (0.21, 0.28)	160 (27.0)	52583 (26.1)	0.32 (0.27, 0.37)
Conditioning	72 (7.7)	30348 (9.2)	0.07 (0.06, 0.09)	0	0	0.00
Digging	120 (12.9)	33673 (10.2)	0.12 (0.10, 0.15)	147 (24.7)	42766 (21.3)	0.29 (0.24, 0.34)
General play	232 (24.8)	74227 (22.5)	0.24 (0.21, 0.27)	104 (17.5)	34319 (17.1)	0.21 (0.17, 0.25)
Passing	62 (6.6)	24705 (7.5)	0.06 (0.05, 0.08)	47 (7.9)	16943 (8.4)	0.09 (0.07, 0.12)
Serving	47 (5.0)	16458 (5.0)	0.05 (0.03, 0.06)	20 (3.4)	7314 (3.6)	0.04 (0.02, 0.06)
Setting	49 (5.3)	16944 (5.1)	0.05 (0.04, 0.06)	44 (7.4)	16751 (8.3)	0.09 (0.06, 0.11)
Spiking	115 (12.3)	43313 (13.1)	0.12 (0.10, 0.14)	73 (12.3)	30568 (15.2)	0.14 (0.11, 0.18)
NCAA-ISP (2004–2005 through 2013–2014)						
Blocking	212 (14.8)	4410 (15.0)	0.53 (0.46, 0.60)	126 (20.8)	2665 (19.7)	0.76 (0.63, 0.89)
Conditioning	115 (8.0)	2210 (7.5)	0.29 (0.24, 0.34)	5 (0.8)	152 (1.1)	0.03 (0.00, 0.06)
Digging	214 (15.0)	4182 (14.2)	0.54 (0.47, 0.61)	125 (20.6)	2912 (21.5)	0.76 (0.62, 0.89)
General play	471 (32.9)	9489 (32.3)	1.18 (1.08, 1.29)	162 (26.7)	3920 (28.9)	0.98 (0.83, 1.13)
Passing	86 (6.0)	1832 (6.2)	0.22 (0.17, 0.26)	35 (5.8)	669 (4.9)	0.21 (0.14, 0.28)
Serving	33 (2.3)	738 (2.5)	0.08 (0.05, 0.11)	9 (1.5)	137 (1.0)	0.05 (0.02, 0.09)
Setting	57 (4.0)	1168 (4.0)	0.14 (0.11, 0.18)	26 (4.3)	637 (4.7)	0.16 (0.10, 0.22)
Spiking	243 (17.0)	5384 (18.3)	0.61 (0.53, 0.69)	118 (19.5)	2450 (18.1)	0.71 (0.58, 0.84)

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

<sup>a</sup> Excluded were 105 injuries reported in HS RIO and 112 injuries reported in the NCAA-ISP due to missing data or the athletic trainer reporting *Other* or *Unknown*. High school data originated from HS RIO surveillance data, 2005–2006 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 one injury event. Percentages may not sum to 100.0 due to rounding error.

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

Position	HS RIO (2005–2006 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
Libero	Concussion	31.4	Contact with playing surface	Concussion	22.9	Contact with playing surface
	Ankle sprain	18.5	No contact	Ankle sprain	8.6	No contact
Middle blocker	Ankle sprain	43.0	Contact with another player	Ankle sprain	36.4	Contact with another player
	Concussion	10.1	Contact with playing surface	Trunk strain	4.6	No contact
Opposite player	Ankle sprain	21.2	Contact with playing surface	Hand/wrist sprain	21.1	Contact with playing surface
	Concussion	21.2	Contact with playing surface	Ankle sprain	18.4	Contact with another player
	Hand/wrist sprain	15.4	Contact with playing surface	Concussion	10.5	Contact with playing surface
Outside hitter	Ankle sprain	35.5	Contact with another player	Ankle sprain	25.7	Contact with another player
	Concussion	12.3	Contact with another player	Knee sprain	7.9	No contact
Setter	Ankle sprain	43.0	Contact with another player	Ankle sprain	21.9	Contact with another player
	Hand/wrist sprain	10.7	Contact with ball	Concussion	9.4	Contact with another player
	Concussion	10.1	Contact with another player			

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

<sup>a</sup> Excluded 48 competition injuries reported in HS RIO and 92 competition injuries reported in the NCAA-ISP due to position not being indicated. High school data originated from HS RIO surveillance data, 2005–2006 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 one injury event. The table reads as follows: for the libero position in high school, concussions comprised 31.4% of all competition injuries to that position. The most common mechanism of injury for this specific injury for this specific position was contact with playing surface.

preseason, regular season, and postseason; the potentially longer collegiate season may increase the injury risk. We calculated injury rates using AEs, which may not be as precise an at-risk exposure measure as minutes, hours, or total number of game plays across a season. However, collecting such exposure data is more laborious than collecting AE data and may be too burdensome for ATs reporting data for HS RIO and the NCAA-ISP.

Although our study is one of the few to examine injury incidences across multiple levels of play (eg, high school versus college and competitions versus practices), 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 status. The physical demands and resulting injury risk of playing positions may vary. The AEs were not collected by position, preventing calculation of position-specific injury rates.

## CONCLUSIONS

From a clinical perspective, although the injury rates for high school girls' and collegiate women's volleyball were low, it is important to consider the differences between the sport settings. Injury rates were higher in collegiate women's volleyball than in high school girls' volleyball. However, although no differences were present by division or event type in collegiate players, variations in injury rates existed by school size and event type in high school players. Because the number of participants in high school girls' volleyball greatly exceeds that of collegiate women's volleyball and some high school sport settings lack AT staffing, it is important to advocate for increased coverage in the high school setting while assisting high schools in resolving barriers related to access. Such AT access would likely positively affect all sports sponsored by the school, not just girls' volleyball.

Ankle sprains were the most common injury for most players. Injury patterns in liberos, particularly for concussions, varied from other positions. These results highlight the need for injury-prevention interventions specific to the level of competition and position. Such interventions can include rule changes that focus on better protection of athletes at the net line, equipment such as ankle braces, prevention programs that include dynamic warmup and strength-training programs, and skill development that focuses on proper diving and blocking techniques. Equipping female volleyball players with the appropriate skills and techniques is important to enable them to withstand the loads and demands involved in their sport. Clinicians can serve an important role in advocating for the integration and evaluation of such interventions in their settings.

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## REFERENCES

1. Participation statistics 2016. National Federation of State High School Associations Web site. <http://www.nfhs.org/ParticipationStatistics/ParticipationStatistics.aspx/>. Accessed April 7, 2017.
2. Student-athlete participation: 1981–82 – 2014–15. National Collegiate Athletic Association Web site. <http://www.ncaa.org/sites/default/files/Participation%20Rates%20Final.pdf>. Accessed April 7, 2017.
3. Agel J, Palmieri-Smith RM, Dick R, Wojtys EM, Marshall SW. Descriptive epidemiology of collegiate women's volleyball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 through 2003–2004. *J Athl Train*. 2007;42(2):295–302.
4. Van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. *Sports Med*. 1992;14(2): 82–99.
5. Kerr ZY, Dompier TP, Snook EM, et al. National Collegiate Athletic Association Injury Surveillance System: review of methods for 2004–2005 through 2013–2014 data collection. *J Athl Train*. 2014; 49(4):552–560.
6. Centers for Disease Control and Prevention. Sports-related injuries among high school athletes—United States, 2005–06 school year. *MMWR Morb Mortal Wkly Rep*. 2006;55(38):1037–1040.
7. Kerr ZY, Comstock RD, Dompier TP, Marshall SW. The first decade of Web-based sports injury surveillance (2004–2005 through 2013–2014): methods of the National Collegiate Athletic Association Injury Surveillance Program and High School Reporting Information Online. *J Athl Train*. 2018;53(8):729–737.
8. Rechel JA, Yard EE, Comstock RD. An epidemiologic comparison of high school sports injuries sustained in practice and competition. *J Athl Train*. 2008;43(2):197–204.
9. Census regions of the United States. US Census Bureau Web site. <http://www.census.gov/const/regionmap.pdf>. Updated 2009. Accessed April 14, 2017.
10. Kucera KL, Marshall SW, Bell DR, DiStefano MJ, Goerger CP, Oyama S. Validity of soccer injury data from the National Collegiate Athletic Association's Injury Surveillance System. *J Athl Train*. 2011;46(5):489–499.
11. Powell JW, Barber-Foss KD. Injury patterns in selected high school sports: a review of the 1995–1997 seasons. *J Athl Train*. 1999;34(3): 277–284.
12. Powell JW, Dompier TP. Analysis of injury rates and treatment patterns for time-loss and non-time-loss injuries among collegiate student-athletes. *J Athl Train*. 2004;39(1):56–70.
13. Kerr ZY, Lynall RC, Mauntel T, Dompier TP. High school football injury rates and services by athletic trainer employment status. *J Athl Train*. 2016;51(1):70–73.
14. Bahr R, Bahr I. Incidence of acute volleyball injuries: a prospective cohort study of injury mechanisms and risk factors. *Scand J Med Sci Sports*. 1997;7(3):166–171.
15. Pollard KA, Shields BJ, Smith GA. Pediatric volleyball-related injuries treated in US emergency departments, 1990–2009. *Clin Pediatr*. 2011;50(9):844–852.

16. 2014–15 Sports Medicine Handbook. National Collegiate Athletic Association Web site. <http://www.ncaapublications.com/DownloadPublication.aspx?download=MD15.pdf>. Accessed March 16, 2017.
17. Pryor RR, Casa DJ, Vandermark LW, et al. Athletic training services in public secondary schools: a benchmark study. *J Athl Train*. 2015; 50(2):156–162.
18. Kerr ZY, Marshall SW, Dompier TP, Corlette J, Klossner DA, Gilchrist J. College sports-related injuries—United States, 2009–10 through 2013–14 academic years. *MMWR Morb Mortal Wkly Rep*. 2015;64(48):1330–1336.
19. Rutherford DS, Niedfeldt MW, Young CC. Medical coverage of high school football in Wisconsin in 1997. *Clin J Sport Med*. 1999;9(4): 209–215.
20. Aukerman DF, Aukerman MM, Browning D. Medical coverage of high school athletics in North Carolina. *South Med J*. 2006;99(2): 132–137.
21. Carek P, Dunn J, Hawkins A. Health care coverage of high school athletics in South Carolina: does school size make a difference? *J S C Med Assoc*. 1999;95(11):420–425.
22. Aagaard H, Scavenius M, Jrgensen U. An epidemiological analysis of the injury pattern in indoor and in beach volleyball. *Int J Sports Med*. 1997;18(03):217–221.
23. Bahr R, Karlsen R, Lian Ø, Øvreb RV. Incidence and mechanisms of acute ankle inversion injuries in volleyball: a retrospective cohort study. *Am J Sports Med*. 1994;22(5):595–600.
24. Verhagen E, Van der Beek AJ, Bouter L, Bahr R, Van Mechelen W. A one season prospective cohort study of volleyball injuries. *Br J Sports Med*. 2004;38(4):477–481.
25. Pedowitz DI, Reddy S, Parekh SG, Huffman GR, Sennett BJ. Prophylactic bracing decreases ankle injuries in collegiate female volleyball players. *Am J Sports Med*. 2008;36(2):324–327.
26. Stasinopoulos D. Comparison of three preventive methods in order to reduce the incidence of ankle inversion sprains among female volleyball players. *Br J Sports Med*. 2004;38(2):182–185.
27. Bahr R, Lian Ø, Bahr I. A twofold reduction in the incidence of acute ankle sprains in volleyball after the introduction of an injury prevention program: a prospective cohort study. *Scand J Med Sci Sports*. 1997;7(3):172–177.
28. Finch C. A new framework for research leading to sports injury prevention. *J Sci Med Sport*. 2006;9(1):3–9.
29. Kreck C. States address concerns about concussions in youth sports. Education Commission of the States Web site. <http://www.ecs.org/clearinghouse/01/11/61/11161.pdf>. Published March 2014. Accessed February 1, 2018.

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