

[Athletic Training]



A Comparison of Women's Collegiate and Girls' High School Volleyball Injury Data Collected Prospectively Over a 4-Year Period

Jonathan C. Reeser, MD, PhD,^{*†} Andrew Gregory, MD,[‡] Richard L. Berg, MS,[†] and R. Dawn Comstock, PhD[§]

Background: There is a relative paucity of research examining the sport-specific injury epidemiology of high school and collegiate volleyball athletes. Moreover, differences in study methodology frequently limit our ability to compare and contrast injury data collected from selected populations.

Hypothesis: There are differences between the injury patterns characteristic of high school and collegiate female volleyball athletes.

Study Design: Retrospective clinical review.

Level of Evidence: Level 3.

Methods: We statistically analyzed injury incidence and outcome data collected over a 4-year interval (2005-2006 to 2008-2009) by 2 similar injury surveillance systems, the National Collegiate Athletic Association's Injury Surveillance System (NCAA ISS) and the High School Reporting Injuries Online (HS RIO). We compared diagnoses, anatomic distribution of injuries, mechanisms of injury, and time lost from training or competition between high school and collegiate volleyball athletes.

Results: The overall volleyball-related injury rate was significantly greater among collegiate athletes than among high school athletes during both competition (injury rate ratio, 2.9; 95% CI, 2.5-3.4) and practice (injury rate ratio, 3.5; 95% CI, 3.1-3.9). Collegiate athletes had a higher rate of ankle sprain, knee injury, and shoulder injury. Concussions represented a relatively high percentage of injuries in both populations (5.0% of total NCAA ISS injuries vs 4.8% of total HS RIO injuries, respectively).

Conclusion: The data suggest that although similar, there were distinct differences between the injury patterns of the 2 populations. Compared with high school volleyball players, collegiate athletes have a higher rate of acute time loss injury as well as overuse time loss injury (particularly patellar tendinosis). Concussions represented a significant and worrisome component of the injury pattern for both study populations.

Clinical Relevance: The injury data suggest that important differences exist in the injury patterns of female high school compared with collegiate volleyball athletes. Consideration of the specific injury patterns may be helpful in future prevention efforts.

Keywords: volleyball; injury surveillance; injury patterns; high school athletes; collegiate athletes

From [†]Marshfield Clinic Research Foundation, Marshfield, Wisconsin, [‡]Vanderbilt Sports Medicine Medical Center East, Nashville, Tennessee, and [§]Colorado School of Public Health, Epidemiology University of Colorado School of Medicine, Pediatrics, Pediatric Injury Prevention, Education, and Research (PIPER) Program, Aurora, Colorado

*Address correspondence to Jonathan C. Reeser, MD, PhD, Marshfield Research Foundation, 1000 North Oak Avenue, Marshfield, WI 54449 (email: jreeser@charter.net).

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During the 2013-2014 academic year, 429,634 girls participated in competitive volleyball at the high school level in the United States,¹⁶ making volleyball the third most popular participation sport among the female high school demographic, trailing only basketball and outdoor track and field. In addition, between 2009-2010 and 2013-2014, participation in girls' high school volleyball increased by 6%, compared with a decline of 1.4% in girls' basketball and a decline of 2.1% in outdoor track and field.¹⁶ Despite the growing popularity of volleyball among high school girls, a detailed understanding of the sport-specific injury pattern characteristic of this population has yet to be achieved. Part of the reason for this may be a relative disinterest on the part of injury epidemiologists, since volleyball has traditionally been considered a rather safe sport. Furthermore, methodological differences between studies have hampered efforts to make meaningful comparisons between the injury data collected on female high school^{5,8,14,17,25} and collegiate volleyball^{1-3,11,20,26} athletes.

The National Collegiate Athletic Association's Injury Surveillance System (NCAA ISS)^{2,11,12} has been collecting comprehensive epidemiologic data on women's collegiate sports injuries (including volleyball) annually since its inception in 1982. The High School Reporting Injuries Online (HS RIO) project is part of the High School Sports-Related Injury Surveillance System, which since 2005 has prospectively collected data on injuries that occur to high school athletes participating in a variety of sports.^{6,10,14,22,24,25,27}

The data collected by these 2 distinct injury surveillance systems have yet to be used to compare the injury pattern characteristic of female volleyball athletes at the high school and collegiate skill levels and age ranges. Our goal was to compare the volleyball-specific injury data collected by these 2 independent surveillance systems during a 4-year period beginning with 2005-2006 to determine whether substantive relative differences existed in the injury patterns characteristic of the 2 volleyball populations under surveillance.

METHODS

Prior to implementation, this descriptive epidemiologic study was reviewed and approved by the Marshfield Clinic Research Foundation Institutional Review Board. HS RIO collects surveillance data on sports injuries from 100 high schools annually, selecting them from a pool of interested applicant institutions.^{6,10,15,19,24,25,29} Athletic trainers (ATs) from each school submit weekly reports on 9 different sports, including girls' volleyball. Data include information on athlete demographics, exposures, diagnoses, and injury outcomes. These data are similar (if not identical) in focus to the sport-specific injury incidence and outcome data collected by NCAA member colleges and universities from across all 3 divisions that choose to participate in the NCAA ISS.

For 4 consecutive years beginning in 2005-2006, the injury definition and data collection methodology utilized by HS RIO

and the NCAA ISS^{11,12} were extremely similar. During this period, both systems employed the same definition of injury, that is, any condition resulting in the loss of at least 1 day of training or competition. In addition, both surveillance systems defined an athlete exposure (AE) as 1 athlete's participation in 1 competition or practice without regard for the duration of participation. Finally, both systems relied on ATs to report and describe the injuries using an Internet-based reporting system during this time. The 2 surveillance systems therefore provided methodologically comparable data with respect to the descriptive epidemiology of volleyball injuries among their respective populations from 2005-2006 through 2008-2009. The study interval ended in 2009, when the NCAA introduced changes to the surveillance software,¹² renamed the ISS the Injury Surveillance Program (ISP), and contracted the management of the ISP to The Datalys Center.

Data Analysis

Confidence intervals (CIs) for injury rates and the ratios of injury rates between the 2 surveillance systems were based on standard, large-sample normal approximations. Statistical comparisons were based on chi-square tests, and the observed significance levels (*P* values) are reported. Results of statistical tests were deemed significant at the 5% level (*P* < 0.05), without formal adjustment for multiple outcomes.

RESULTS

Throughout the 4-year study interval, 792 time-loss injuries were recorded by HS RIO during 637,786 total AEs, resulting in a girls' high school volleyball injury rate of 12.4 injuries per 10,000 AEs. By comparison, the NCAA ISS recorded 1380 injuries during 339,753 total practice and competition exposures, resulting in a women's collegiate volleyball injury rate of 40.6 per 10,000 AEs (Table 1 in Appendix, available at <http://sph.sagepub.com/content/by/supplemental-data>). The overall college injury rate was therefore more than 3 times the high school injury rate during the study interval (rate ratio, 3.3; 95% CI, 3.0-3.6). In addition, the overall injury rate declined proportionately in both populations during the study interval (Figure 1). The ankle sprain, knee, and shoulder injury rates declined during the study interval in both the high school and collegiate populations (Figure 2, a-c). By contrast, the HS RIO and NCAA ISS rate of concussion remained stable or increased slightly over the 4-year study interval (Figure 2d).

Ligament sprain injury was the most common diagnosis made during the study interval (Table 1): 49.2% of HS RIO injuries and 28.8% of NCAA ISS injuries. However, the sprain injury rate was higher among the collegiate population than it was for the high school population (NCAA ISS, 11.7 per 10,000 AE; HS RIO, 6.1 per 10,000 AE; injury rate ratio, 1.9; 95% CI, 1.7-2.2).

Muscle strains represented the second most common diagnosis in both study populations. Other diagnoses common to both populations included overuse injury, fracture, contusion, and concussion. Fracture was diagnosed twice as frequently in

Table 1. Most frequent injury diagnoses, HS RIO (high school) vs NCAA ISS (college) 2005-2006 through 2008-2009

Type of Injury	Practice				Competition				Overall			
	High School		College		High School		College		High School		College	
	n	%	n	%	n	%	n	%	n	%	n	%
Sprain	227	45.9	251	25.3	160	54.8	147	37.9	387	49.2	398	28.8
Strain	107	21.6	230	23.2	44	15.1	62	16.0	151	19.2	292	21.2
Concussion	15	3.0	44	4.4	23	7.9	25	6.4	38	4.8	69	5
Contusion	15	3.0	36	3.6	23	7.9	33	8.5	38	4.8	69	5
Fracture	23	4.6	20	2	10	3.4	9	2.3	33	4.2	29	2.1
Tendinopathy	26	5.3	93	9.4	4	1.4	18	4.6	30	3.8	111	8
All other	82	16.6	318	32.1	28	9.6	94	24.2	110	14	142	29.9

HS RIO, High School Reporting Injuries Online; NCAA ISS, National Collegiate Athletic Association's Injury Surveillance System.

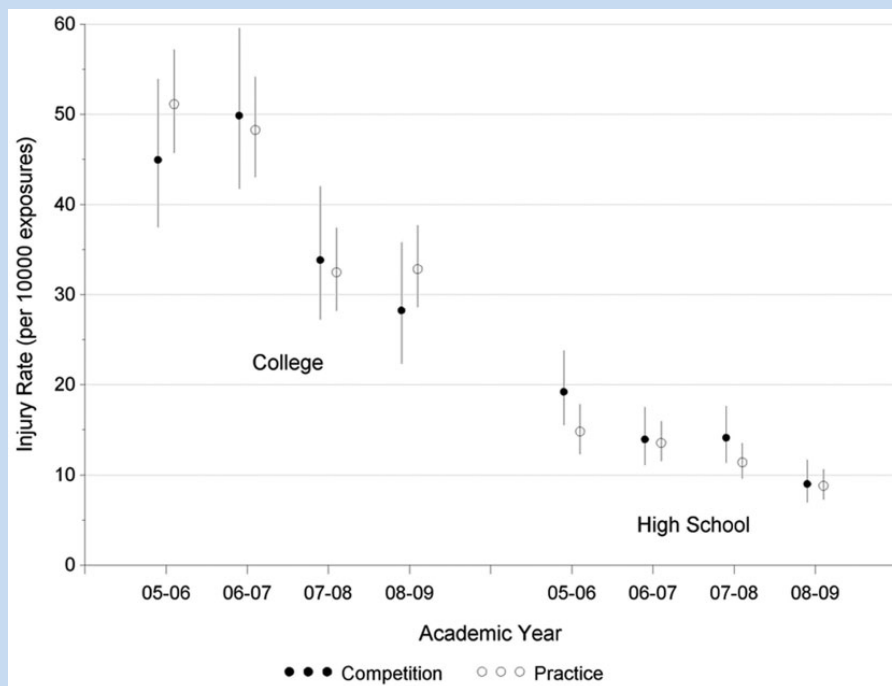


Figure 1. Graphic representation of the annualized overall injury incidence rate ($\pm 95\%$ CI) for volleyball-related injuries recorded by HS RIO and the NCAA ISS during the 4-year study interval (2005-2006 through 2008-2009). HS RIO, High School Reporting Injuries Online; NCAA ISS, National Collegiate Athletic Association's Injury Surveillance System.

high school athletes as collegiate athletes. Concussion represented the fourth most frequent diagnosis among the NCAA ISS population and the third most frequent in the HS RIO population. Tendinosis was the most common overuse condition recorded by both surveillance programs, occurring twice as frequently in collegiate athletes (NCAA ISS, 8.0% of the

total injuries recorded [$n = 111$]; HS RIO, 3.8% of the total injuries recorded [$n = 30$]; $P < 0.001$).

Acute lateral ankle sprain represented the most common diagnosis among both high school and collegiate athletes (Figures 2a and 3; Table 2 in Appendix, available at <http://sph.sagepub.com/content/by/supplemental-data>). The

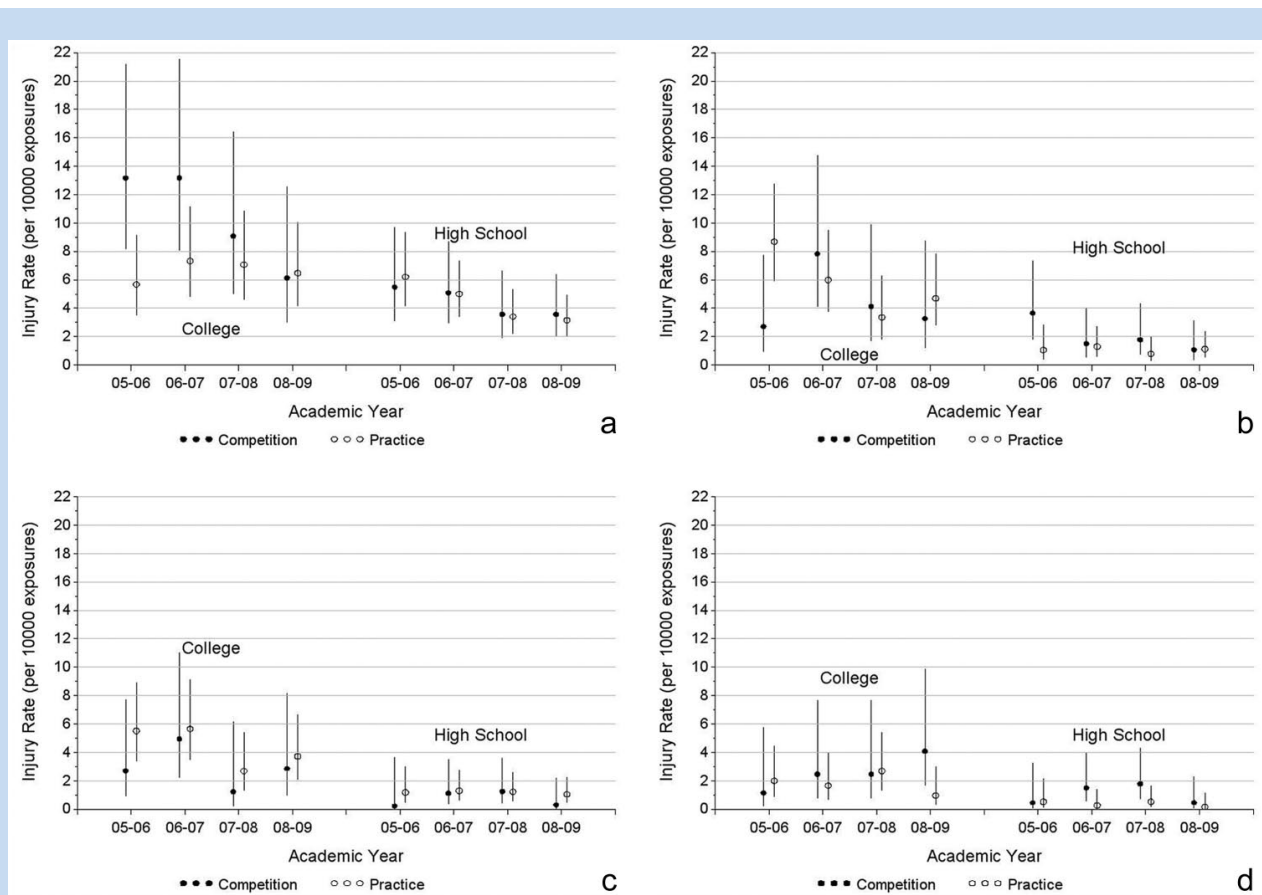


Figure 2. Graphic representation of the annualized incidence rates ($\pm 95\%$ CI) for volleyball-related (a) ankle sprain, (b) knee, and (c) shoulder injuries as well as (d) concussion rates reported to the HS RIO and NCAA ISS injury surveillance systems during a 4-year period (2005-2006 through 2008-2009). HS RIO, High School Reporting Injuries Online; NCAA ISS, National Collegiate Athletic Association's Injury Surveillance System.

ankle sprain rate was greater among collegiate athletes than among high school athletes during both competition (NCAA ISS, 10.4 per 1000 AEs; HS RIO, 4.3 per 10,000 AEs) and practice (NCAA ISS, 6.6 per 1000 AEs; HS RIO, 4.3 per 10,000 AEs). The severity of the ankle sprains was similar in each population, with approximately 70% of athletes losing 9 or fewer days of competition and/or training. Ankle sprains occurred most often while blocking, particularly among high school athletes. Player-to-player contact was the most common immediate mechanism of injury leading to ankle sprains for both high school and collegiate athletes.

The second most frequently injured body part among both populations was the knee (Figures 2b and 3; Table 3 in the Appendix, available at <http://sph.sagepub.com/content/by/supplemental-data>). The practice knee injury rate among collegiate athletes was over 5 times greater than the practice knee injury rate among high school athletes (injury rate ratio, 5.3; 95% CI, 3.8-7.4) and more than twice as great in competition (injury rate ratio, 2.4; 95% CI, 1.5-3.6).

Acute time loss knee injuries were more common among high school girls. Eight of the 86 documented HS RIO knee injuries

(9.3%) involved the ACL, compared with only 4.4% of collegiate knee injuries. Only 15.1% ($n = 13$) of high school knee injuries were related to overuse, compared with 38.1% ($n = 69$) of collegiate knee injuries. The leading knee injury diagnosis among college volleyball athletes was patellar tendinosis, accounting for 19.3% ($n = 35$) of collegiate knee injuries, compared with only 5.8% ($n = 5$) of high school knee injuries. The majority of severe knee injuries (defined as injuries resulting in 10 or more days of lost time) in high school occurred during competition, while the majority of severe knee injuries in college occurred during practice. Making a defensive play ("digging") was the most commonly reported activity leading to knee injury among high school athletes, while no single antecedent activity predominated among collegiate athletes with knee injuries.

The shoulder represented the third most frequently injured body part among collegiate volleyball athletes, and ranked fourth among high school athletes (Figures 2c and 3; Table 4 in the Appendix, available at <http://sph.sagepub.com/content/by/supplemental-data>). The rate of shoulder injury was greater in college than high school for both practice (injury rate ratio, 3.7; 95% CI, 2.6-5.2)

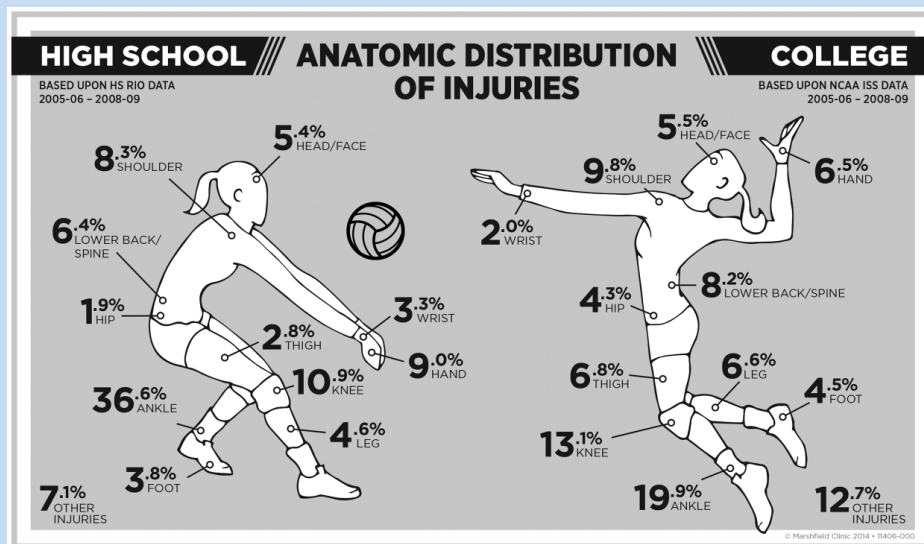


Figure 3. Anatomic frequency distribution of volleyball-related time-loss injuries reported to HS RIO and the NCAA ISS over a 4-year interval (2005-2006 through 2008-2009). HS RIO, High School Reporting Injuries Online; NCAA ISS, National Collegiate Athletic Association's Injury Surveillance System.

and competition (injury rate ratio, 4.0; 95% CI, 2.2-7.3) (see Table 4 in the Appendix). Shoulder injuries included rotator cuff tendinosis, musculolotendinous strain, and glenohumeral subluxation/dislocation. In both the NCAA ISS and HS RIO, the majority of shoulder injuries required 3 to 9 days before returning to training or competition. Both populations identified spiking as the predominant shoulder injury-inciting activity (college, 37.8%; high school, 39.1%). Shoulder symptoms were reported due to overuse in 53.3% of college and 33.3% of high school athletes.

The incidence and severity of concussions (Figures 2d and 3; Table 5 in the Appendix, available at <http://sph.sagepub.com/content/by/supplemental-data>) was perhaps greater than anticipated for a noncontact sport, both in the collegiate population (NCAA ISS, 2.0 per 10,000 AEs; $n = 69$) and in the high school population studied (HS RIO, 0.6 per 10,000 AEs; $n = 38$). Concussions were 3.4 times more likely to occur in a collegiate volleyball player than in a high school player (injury rate ratio, 3.4; 95% CI, 2.3-5.1). Concussion rates were greater during competition than during practice for both collegiate (NCAA ISS competition, 2.5 per 10,000 AEs; NCAA ISS practice, 1.8 per 10,000 AEs) and high school (HS RIO competition, 1.1 per 10,000 AEs; HS RIO practice, 0.4 per 10,000 AEs) athletes. The average severity of game-related concussion was similar for both the NCAA ISS and HS RIO: 88.1% of affected collegiate athletes were absent for 3 or more days, whereas 83.3% of concussed high school athletes were absent for 3 or more days ($P = 0.35$). In both populations, the most frequent mechanism of injury was player-surface contact (college, 42.0%; high school, 65.8%). Just over half the competition-related concussions in both college (56.0%) and high school (60.9%) occurred while digging/making a defensive play.

In addition to demonstrating potentially significant differences in type, anatomic location, and mechanism of injury between the 2 study populations, these data also indicate that injury risk varies with the position played during both high school and collegiate volleyball competitions. For example, the majority of injuries suffered by outside hitters occurred while the athlete was positioned in the front row (see Table 1 in the Appendix). Not only are players in the 3 front-row positions at greatest risk for ankle injury, outside hitters sustained the highest proportion of competition-related shoulder injuries among both populations of volleyball athletes (NCAA ISS, 56.6%; HS RIO, 37.3%). However, front-row players are not the only positions at risk for injury, as the liberos (defensive specialists), along with outside hitters, sustained 57.1% of the volleyball-related concussions that occurred at the collegiate level; middle blockers and setters sustained more than half of the concussions (52.6%) at the high school level.

DISCUSSION

There is general agreement that the skill and intensity level in collegiate volleyball is greater than in high school. Collegiate athletes are also generally perceived to be more athletic compared with high school players. Thus, one might anticipate that with greater strength and body control, the rate of injuries might be lower in collegiate volleyball athletes than in high school athletes. However, collegiate volleyball athletes demonstrate a 3-fold greater rate of time loss injury than do high school volleyball players. Ankle sprains are the most common injury, particularly among those athletes positioned in the middle and right front row. This observation suggests that net play may be more aggressive in college compared with high

school and that the interaction between spiker and opposing blocker in the “conflict zone” remains a serious safety issue in volleyball.^{4,23,25,27} In addition, collegiate athletes may be at greater risk of ankle sprain due to a greater prevalence of ankle sprain earlier in their playing careers.¹⁷ The overwhelming number of ankle sprains among high school and collegiate volleyball players argues strongly for the integration of preventive instruction and intervention (bracing and balance training) into youth volleyball training programs.²⁸

The NCAA ISS data indicate that patellar tendinosis accounted for 19.3% of the overall time-loss knee injuries during the study interval, compared with just less than 6% of HS RIO time-loss knee injuries. It appears that age and sex factor into the overuse knee injury risk equation. The observed increase in the percentage of overuse knee and shoulder injuries in the collegiate cohort compared with the high school cohort clearly suggests some cumulative time- and/or load-dependent influence on the etiology of volleyball-related knee and shoulder injuries as athletes age and mature.^{7,9,13,21} It was concerning to note that although the rate of time-loss injuries to the ankles, knees, and shoulders declined slightly over the study interval, the rate of concussion increased slightly (Figure 2d; see Table 5 in the Appendix). One possible explanation for the slight increase detected in concussion incidence may have been increased awareness of the diagnosis on the part of team medical personnel. Gessel et al¹⁰ compared concussion rates among high school and collegiate athletes across a number of sports. They found that, as we did, the rate of concussion was higher among collegiate athletes, but that concussion represented a higher percentage of the injury total among high school athletes. Gessel's group proposed that the different rates of concussion may be due to the greater competitive intensity among collegiate athletes.²⁷ A history of prior concussion also increases an athlete's risk of subsequent head injury, and positional and style-of-play issues could also potentially contribute to concussion risk.¹⁸ For example, in an analysis of 18 years of volleyball-related injuries treated in US emergency departments, Pollard and colleagues¹⁷ concluded that most concussions occurred as a result of collision with a net pole, whereas our data suggest that digging and player contact with the playing surface may be the most common mechanisms of injury. We recommend that concussive injuries be closely monitored to better understand the sport- and age-specific risk factors for concussion and to determine whether changes to rules or coaching tactics might reduce the risk of these often problematic injuries.

As with any investigation, this study has design limitations that may affect the interpretation of the results. The NCAA ISS and HS RIO injury surveillance systems both suffer from the limited number of participating schools. The fact that some of the data utilized in this study were collected 10 years ago may mean it is not perfectly reflective of the most current injury trends. However, there have been no significant rule changes implemented since the closure of the study interval to dramatically alter the way in which the game is played, so we

suspect that the risk factors for injury that are intrinsic to the sport remain largely unchanged since the closure of the study interval.

Many other questions remain regarding the epidemiology and prevention of volleyball injuries among different age groups. With the growing youth participation rate, it is our hope that this characterization of the high school volleyball injury patterns may help medical professionals provide better, more informed coverage of volleyball events in which adolescent athletes are competing.

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