

Hand and Wrist Injuries Among US High School Athletes: 2005/06–2015/16

Bernadette K. Johnson, MD,^{a,b} Lina Brou, MPH,^{a,b} Sarah K. Fields, JD, PhD,^c Alexandria N. Erkenbeck, MPH,^d R. Dawn Comstock, PhD^{b,d,e}

abstract

BACKGROUND: The risk of hand/wrist injuries is present across various sports. Little is known about the epidemiology of such injuries. The objective of this study was to calculate the rates of hand/wrist injuries and investigate injury patterns among high school athletes.

METHODS: Athlete exposure (AE) and hand/wrist injury data were collected during 11 academic years, 2005/06 through 2015/16, from a large sample of US high schools as part of the National High School Sports-Related Injury Surveillance Study.

RESULTS: There were 6723 hand/wrist injuries sustained during 40 195 806 AEs, a rate of 1.7 per 10 000 AEs. The rate of injury in competition (3.3) was higher than in practice (1.1) (95% confidence interval: 2.8–3.1). Rates of hand/wrist injuries varied by sport, with the highest rates in football (4.3), boys' lacrosse (1.9), girls' softball (1.9), wrestling (1.8), girls' field hockey (1.7), boys' ice hockey (1.7), and girls' basketball (1.7). The most common injuries were fracture (45.0%), contusion (11.6%), and ligament sprain (9.0%). Athletes most frequently returned to play in <7 days (45.7%), but 12.4% of injuries kept athletes out ≥3 weeks.

CONCLUSIONS: High school athletes are at risk for hand/wrist injuries. Such injuries can keep athletes out of play and many require substantial medical treatment. Stick and ball or puck sports and full contact sports have high rates of hand/wrist injuries relative to other sports, which is indicative of a need for sport-specific prevention efforts.

^aChildren's Hospital Colorado, Aurora, Colorado; ^bSection of Emergency Medicine, Department of Pediatrics, School of Medicine, ^cDepartment of Communication, College of Liberal Arts and Sciences, University of Colorado Denver, Denver, Colorado; ^dDepartment of Epidemiology, Colorado School of Public Health, University of Colorado Anschutz, Aurora, Colorado; and ^ePediatric Injury Prevention, Education, and Research Program, Aurora, Colorado

Dr Johnson conceptualized and designed the study and drafted the initial manuscript; Ms Brou conducted the initial analyses and reviewed and revised the manuscript; Dr Fields critically reviewed and revised the manuscript; Ms Erkenbeck conducted data analyses to update the manuscript and reviewed the manuscript; Dr Comstock designed the data collection instruments, coordinated and supervised data collection, and critically reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

DOI: <https://doi.org/10.1542/peds.2017-1255>

Accepted for publication Sep 11, 2017

Address correspondence to Bernadette K. Johnson, MD, Department of Pediatrics, University of Colorado Denver, 13123 E 16th Ave, B251, Aurora, CO 80045. E-mail: bernadette.johnson@childrenscolorado.org

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

Copyright © 2017 by the American Academy of Pediatrics

WHAT'S KNOWN ON THIS SUBJECT: High school sports participation has many benefits. However, sports participation is the most common cause of hand fractures in pediatric patients. Considering all sports-related fractures, hand and wrist injuries require surgery more frequently than fractures of other sites.

WHAT THIS STUDY ADDS: The authors describe the injury patterns of hand and wrist injuries in high school athletes, including differences by sport, sex, and in injury severity. The authors take an in-depth look at injuries in stick sports, identifying areas for future prevention efforts.

To cite: Johnson BK, Brou L, Fields SK, et al. Hand and Wrist Injuries Among US High School Athletes: 2005/06–2015/16. *Pediatrics*. 2017;140(6):e20171255

Participation in high school sports in the United States has nearly doubled over the last 4 decades, with 7.9 million students competing in high school sports during the 2015/16 academic year.¹ The health benefits of organized sports as part of a physically active lifestyle are undeniable; however, athletes are at risk for sustaining a wide variety of injuries. In particular, hand and wrist injuries, which reportedly account for 17% of all injuries in pediatric and adolescent sports,² can result in large direct and indirect costs and time loss from sports, in addition to impairing students' ability to write, type, or otherwise complete school work. The authors of one study of hand/wrist injuries across age groups ranked hand/wrist injury as the most expensive category of injuries in regard to health care and productivity costs: higher than knee injuries, lower limb fractures, and skull-brain injury costs.³

Injuries requiring surgery can be particularly burdensome in regard to recovery-time and monetary costs. In pediatric patients, sports participation has been reported to be the most common cause of hand fracture in both boys and girls.⁴ Additionally, sports and recreation were shown to be most commonly associated with pediatric wrist injuries.⁵ Additionally, of all sports-related fractures requiring surgery, those to the hand and wrist required surgery more frequently than fractures to other body sites.⁶

In addition to the potential economic and academic burdens associated with hand/wrist injuries, such injuries also affect sports participation, and, thus, student athletes' quality of life must be considered. Time to return to play varies widely by the type of injury, care decisions after the injury, and sport and position played.⁷⁻¹⁰ The authors of a previous study found that in 5 boys' sports (baseball, basketball, ice hockey, track and

field, and wrestling) and 2 girls' sports (softball and field hockey), hand or wrist fracture was 1 of the most common reasons for medical disqualification (MDQ), either for the season or for the athlete's career.¹¹ Despite these concerns, the literature on hand/wrist injuries has largely consisted of case reports, and, to date, little has been published to examine the rates and patterns of hand/wrist injuries among US high school athletes.^{12,13} Elucidating the epidemiology of hand/wrist injuries will not only help clinicians assess the impact of such injuries on sports participation but should also help drive more effective injury prevention efforts.

There are likely sex- and sport-specific differences in the risk of hand and wrist injury. Football, which has historically accounted for the majority of various sports-related injuries,^{6,14-16} has also been noted for high numbers of wrist and hand injuries.¹⁶ Furthermore, the authors of previous studies have highlighted that hand and wrist injuries occur more frequently in boys than in girls.^{4,5,14,16-18} However, high school athletes' injuries may have distinct features and consequences; thus, investigating their specific epidemiology is important. The objective of this study was to describe the rates and patterns of hand/wrist injury among high school athletes. Specifically, the aims were to (1) report injury rates by sport, (2) compare injury rates in sex-comparable sports, (3) describe common types of injury, and (4) report outcomes of injury, in terms of both time loss from sport and the proportion of injuries treated with surgical repair.

METHODS

Data from the National High School Sports-Related Injury Surveillance Study for the 2005/06 through 2015/16 academic years were used.

All US high schools with National Athletic Trainers' Association (NATA)-affiliated certified athletic trainers (ATs) who were willing to report data via the Internet-based surveillance system, High School RIO (Reporting Information Online), were eligible. Among eligible schools, a 3-stage sampling methodology was used to select study schools. In the first stage, all schools were categorized into 8 sampling strata by geographic location and school size (enrollment ≤ 1000 or >1000 students). Participant schools were then randomly selected from each stratum to obtain 100 study schools assigned to report for each of the 9 sports included in the original High School RIO (boys' football, boys' and girls' soccer, girls' volleyball, boys' and girls' basketball, boys' wrestling, boys' baseball, and girls' softball). In the second stage, all previously unselected schools with NATA-affiliated certified ATs willing to report for any of the more rarely offered sports included in the expansion of High School RIO (girls' gymnastics, girls' field hockey, boys' and girls' lacrosse, boys' ice hockey, and boys' volleyball) were selected for the convenience sample to obtain as large a sample as possible. In the third stage, a sample of all previously unselected schools with NATA-affiliated certified ATs willing to report for any of the remaining sports of interest (boys' and girls' track and field, swimming and diving, cross country, tennis, and the coeducational sport of cheerleading) were selected in an attempt to ensure that at least 100 schools had ATs reporting for each of the sports. This 3-step sampling methodology resulted in a large, nationally dispersed convenience sample of US high schools.

Participating ATs received weekly e-mails throughout the study period reminding them to enter their school's data into the High School RIO surveillance system. An athlete

exposure (AE) was defined as 1 athlete participating in 1 school-sanctioned practice, competition, or performance. An injury was defined as an injury that (1) occurred during participation in a school-sanctioned competition, practice, or performance; (2) required medical attention from an AT or physician; and (3) resulted in the restriction of an athlete's participation for ≥ 1 day beyond the day of injury or, beginning in the 2007/08 academic year, resulted in any fracture, concussion, or dental injury, regardless of whether it resulted in restriction of the student-athlete's participation. For each injury, the AT reported detailed information about the injured player, the injury, and the injury event. In this study, we evaluated only hand/wrist injuries.

Data were analyzed by using SAS version 9.4 (SAS Institute Inc, Cary, NC). Injury rates were calculated as the ratio of case counts per 10 000 AEs and were compared by using rate ratios (RRs) with 95% confidence intervals (CIs). An RR > 1.00 suggests a risk association, whereas an RR < 1.00 suggests a protective association. CIs not including 1.00 were considered statistically significant. Linear regression was used to assess rates of hand/wrist injuries over time. Statistical significance was set at $P < .05$. This study was approved by the institutional review board at Nationwide Children's Hospital and the Colorado Multiple Institutional Review Board.

RESULTS

Injury Rates

Among schools participating in High School RIO in the 2005/06 through 2015/16 academic years, there were 6723 hand/wrist injuries sustained during 40 195 806 AEs, resulting in a rate of 1.7 injuries per 10 000 AEs (Table 1). Approximately half of the hand/wrist injuries were sustained during competition

($n = 3394$; 50.5%), and half were sustained during practice ($n = 3315$; 49.3%). Additionally, 14 hand/wrist injuries (0.2%) were sustained during cheerleading performances. Rates of hand/wrist injuries were significantly higher in competition (3.3 injuries per 10 000 competition AEs) than in practice (1.1 injuries, RR: 3.0, 95% CI: 2.8–3.1). Rates of hand/wrist injury decreased slightly among the 9 original sports under surveillance from 2005/06 through 2015/16 (boys' baseball, basketball, football, soccer, and wrestling and girls' basketball, soccer, softball, and volleyball), overall and in practice, whereas competition rates did not change significantly (Fig 1).

Hand/wrist injuries accounted for 8.5% of all injuries reported to High School RIO from 2005/06 through 2015/16 ($n = 78\,937$). Overall, football (4.3 per 10 000 AEs), boys' lacrosse (1.9), softball (1.9), wrestling (1.8), girls' field hockey (1.7), boy's ice hockey (1.7), and girls' basketball (1.7) had the highest rates of hand/wrist injuries (Table 1). For all sports except girls' gymnastics, boys' volleyball, girls' tennis, and cheerleading, hand/wrist injury rates were higher in competition than in practice. For most sex-comparable sports (volleyball, baseball and softball, basketball, track and field, tennis, soccer, and cross country), girls' sports had a higher or equivalent hand/wrist injury rate compared with boys' sports (RR: 1.08, 95% CI: 1.07–1.08). More specifically, in baseball and softball (RR: 1.4, 95% CI: 1.4–1.5), basketball (RR: 1.2, 95% CI: 1.1–1.2), and tennis (RR: 4.0 95% CI: 1.2–13.9), injury rates were significantly higher in girls than in boys. In lacrosse, girls had a significantly lower injury rate than boys (RR: 0.4, 95% CI: 0.4–0.4).

Injury Types

The most common hand/wrist injury categories were fracture (45.0%),

contusion (11.6%), and ligament sprain (9.0%) (Table 2). Fractures accounted for more than half of all hand/wrist injuries in boys' lacrosse (62.3%), ice hockey (62.5%), and boys' soccer (59.8%) and for $> 40\%$ of injuries in football, softball, wrestling, girls' field hockey, girls' and boys' basketball, baseball, and girls' soccer.

Mechanism of Injury

Hand/wrist injuries occurred most frequently as a result of contact with another player (40.9%), contact with a playing apparatus (30.3%), or contact with the playing surface (25.1%) (other or unknown mechanisms accounted for 3.8%) (Table 3). Football was the only sport in which player-player contact resulted in over half of all injuries (61.0%). Player-apparatus contact resulted in at least half of all injuries in 6 girls' sports (field hockey [81.0%], lacrosse [69.2%], softball [67.7%], gymnastics [66.7%], volleyball [62.2%], and basketball [51.4%]), but similar proportions were evident in only 3 boys' sports (volleyball [60.0%], lacrosse [51.5%], and baseball [51.9%]).

Injury Severity

In nearly half (45.7%) of all hand/wrist injuries, athletes returned to play in < 7 days (Table 4). However, in 12.4% of injuries, athletes did not return to play for ≥ 3 weeks, and 5.6% of injuries resulted in MDQ. Injuries that resulted in ≥ 3 weeks' time loss were most frequently in the fracture (85.2% of all injuries resulting in ≥ 3 weeks' time loss) or sprains and/or strains categories (5.3%). Injuries that resulted in MDQ were most frequently in the fracture (83.6% of all injuries resulting in MDQ) or sprains and/or strains categories (8.6%). In all sports studied, athletes most frequently returned to play in < 7 days.

Among all hand/wrist injuries with information about surgery

TABLE 1 Number and Rate of Hand/Wrist Injuries by Sport, US National High School Sports-Related Injury Surveillance Study, 2005/06 Through 2015/16 Academic Years

Sport	No. Hand/Wrist Injuries			Rate of Hand/Wrist Injuries per 10 000 AEs			RR (95% CI)	Percentage of All Injuries
	Overall	Competition	Practice	Overall	Competition	Practice		
Football	3268	1583	1685	4.3	12.0	2.6	—	10.4
Boys' lacrosse	175	106	69	1.9	3.7	1.1	—	9.0
Softball	359	201	158	1.9	3.0	1.3	—	15.1
Wrestling	444	145	299	1.8	2.3	1.6	—	7.6
Girls' field hockey	126	99	27	1.7	4.3	0.5	—	10.1
Boys' ice hockey	80	60	20	1.7	3.8	0.6	—	7.7
Girls' basketball	454	250	204	1.7	3.0	1.1	—	8.6
Boys' basketball	491	244	247	1.4	2.4	1.0	—	9.2
Baseball	344	213	131	1.3	2.4	0.8	—	13.4
Girls' volleyball	314	149	165	1.2	1.7	1.0	—	10.4
Girls' gymnastics ^a	9	1	8	1.1	0.7	1.2	—	5.9
Boys' volleyball ^b	5	1	4	0.9	0.5	1.1	—	12.2
Boys' soccer	241	149	92	0.9	1.7	0.5	—	4.7
Girls' lacrosse	53	41	12	0.8	1.9	0.3	—	5.0
Girls' soccer	186	125	61	0.8	1.7	0.4	—	3.0
Girls' tennis ^c	9	2	7	0.7	0.5	0.8	—	14.0
Cheerleading ^d	109	6	89	0.6	0.5	0.7	0.4	8.7
Boys' tennis ^e	2	1	1	0.2	0.3	0.1	—	8.0
Boys' track and field	25	11	14	0.1	0.3	0.1	—	1.6
Girls' track and field	20	4	16	0.1	0.1	0.1	—	1.1
Girls' swimming and diving	4	1	3	0.05	0.1	0.0	—	1.6
Boys' swimming and diving	3	1	2	0.04	0.1	0.0	—	2.0
Girls' cross country ^e	1	1	0	0.02	0.1	0.0	—	0.2
Boys' cross country ^e	1	0	1	0.02	0.1	0.0	—	0.3
Overall	6723	3394	3315	1.7	3.3	1.1	0.4	8.5

The table is organized by the overall rate of hand/wrist injuries from highest to lowest. —, not applicable.

^a Includes 4 y of data (2008/09 through 2011/12 academic years).

^b Includes 3 y of data (2009/10 through 2011/12 academic years).

^c Includes 2 y of data (2013/14 through 2015/16 academic years.)

^d Includes 7 y of data (2009/10 through 2015/16 academic years).

^e Includes 4 y of data (2012/13 through 2015/16 academic years).

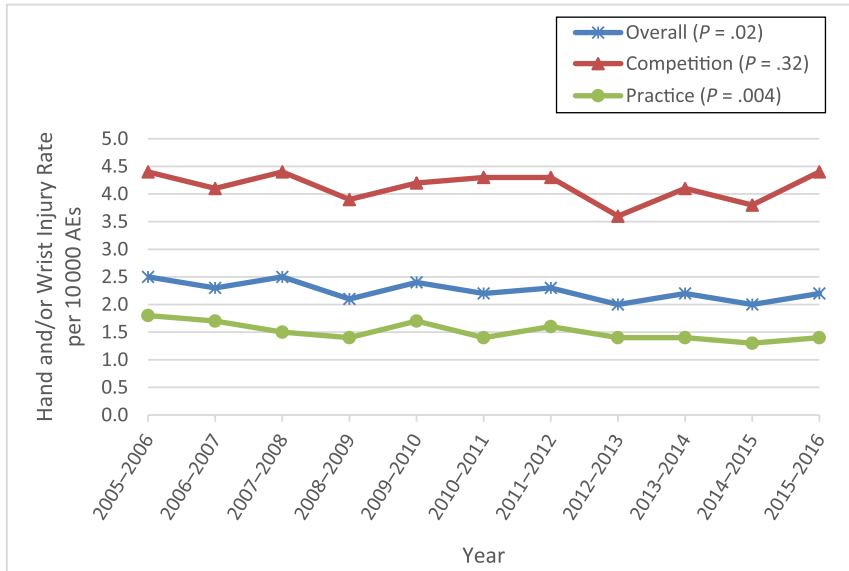


FIGURE 1

Trends over time in hand/wrist injury rate by type of exposure, US National High School Sports-Related Injury Surveillance Study, 2005 to 2006 through 2015 to 2016 academic years. Only the 9 original sports under continuous surveillance from 2005 to 2006 through 2015 to 2016 (boys' baseball, basketball, football, soccer, and wrestling and girls' basketball, soccer, softball, and volleyball) were included.

($n = 6558$), 7.6% injuries ($n = 498$) resulted in surgical repair; however, in 16.8% ($n = 70$) of those injuries with information on the timing of surgical repair ($n = 416$), the procedure was postponed until the athlete completed the season. Most injuries that resulted in delayed surgery were fractures of the hand (47.1%), and a physician cleared the majority of these athletes to return to play before they received surgery (68.3%). Variables most frequently associated with delayed surgery were playing on a varsity team (81.4% of all injuries with delayed surgery), playing football (60.0%), and being a senior in school (42.7%). Sports with the highest proportion of hand/wrist injuries repaired surgically were boys' track and field (20.0%), boys' ice hockey (18.2%), and boys' lacrosse (12.0%). Among all hand/wrist injuries, diagnostic tools most frequently used included radiograph imaging (77.6%), MRI (3.1%), and computed tomography scan (0.3%).

DISCUSSION

To our knowledge, this is the first study of hand/wrist injuries sustained by US high school athletes to compare injury rates and patterns by sex and across multiple sports. Because previous work has shown hand and wrist injuries to be common,² and because the vital need of hand/wrist dexterity for most daily functions is well recognized, gaining a broader understanding of the epidemiology of these injuries is meaningful. Understanding the epidemiology of these injuries is the first step in improving safety in athletics through focused injury prevention efforts.

Hand/wrist injuries accounted for 8.5% of all sports-related injuries in this study. Although there are a wide range of reports on the commonality of hand and wrist injuries, this percentage falls within the commonly cited 3% to 9% of all athletic injuries related to the hand or wrist.¹⁹ Despite known increases in sports participation over time, slight decreases in overall and practice

hand and wrist injury rates were observed during this 11-year study period, whereas the competition injury rate has remained relatively stable over time, indicating a steady increase in AEs and a similar, but slightly lower, increase in the absolute number of injuries occurring during the study period. These findings reveal a need for a renewed focus on identifying effective injury prevention programs. Sport-specific injury prevention efforts should be driven by the mechanisms of injury. For example, the variation in the proportion of injuries attributed to contact with a playing apparatus appeared to vary across sports with sticks and hard, quickly moving projectiles in correlation to the type of hand protection worn. Boys' ice hockey, the sport which requires players to wear the most protective of gloves, had the lowest proportion of injuries attributed to contact with a playing apparatus (27.9%); boys' lacrosse, which requires players to wear slightly less protective gloves, had the next lowest proportion (51.5%); and girls' lacrosse (69.2%) and field hockey (81.0%), which do not require protective gloves for any players other than goalies, had the highest proportion. On the basis of this data, future consideration should be given to revising the rules regarding protective gloves in girls' lacrosse and field hockey. Additionally, protective gloves offering higher protection against hand/wrist injury need to be designed.

In this study, hand/wrist injuries occurred at a significantly higher rate in competition than in practice in the majority of sports. This is consistent with the findings from multiple previous studies of sports-related injuries, which have revealed that both injury rates and the severity of injuries are greater in competition compared with practice.^{6,11,15,20,21} A common hypothesis proffered in those previous publications is that

TABLE 2 Type of Hand/Wrist Injury by Sport, US National High School Sports-Related Injury Surveillance Study, 2005/06 Through 2015/16 Academic Years

Sport	Type of Injury			
	n (%)			
	Fracture	Contusion	Ligament Sprain	Other or Unknown
Football	1532 (46.9)	420 (12.9)	259 (7.9)	1057 (32.3)
Boys' lacrosse	109 (62.3)	28 (16.0)	5 (2.9)	33 (18.9)
Softball	153 (42.6)	85 (23.7)	30 (8.4)	91 (25.4)
Wrestling	203 (45.7)	10 (2.3)	54 (12.2)	177 (39.9)
Girls' field hockey	57 (45.2)	47 (37.3)	1 (0.8)	21 (16.7)
Boys' ice hockey	50 (62.5)	12 (15.0)	2 (2.5)	16 (20.0)
Girls' basketball	183 (40.3)	20 (4.4)	54 (12.2)	193 (42.5)
Boys' basketball	213 (43.4)	18 (3.7)	52 (10.6)	208 (42.4)
Baseball	159 (42.2)	60 (17.4)	28 (8.1)	97 (28.2)
Girls' volleyball	53 (16.9)	31 (9.9)	66 (21.0)	164 (52.2)
Girls' gymnastics ^a	3 (33.3)	0 (0.0)	4 (44.4)	2 (22.2)
Boys' volleyball ^b	0 (0.0)	1 (20.0)	0 (0.0)	4 (80.0)
Boys' soccer	144 (59.8)	13 (5.4)	16 (6.6)	68 (28.2)
Girls' lacrosse	20 (37.7)	15 (28.3)	0 (0.0)	18 (34.0)
Girls' soccer	84 (45.2)	12 (6.5)	30 (16.1)	60 (32.3)
Girls' tennis ^b	1 (11.1)	0 (0.0)	0 (0.0)	8 (88.9)
Cheerleading ^c	38 (34.9)	5 (4.6)	0 (0.0)	66 (60.6)
Boys' tennis ^b	0 (0.0)	1 (50.0)	0 (0.0)	1 (50.0)
Boys' track and field	10 (40.0)	0 (0.0)	0 (0.0)	15 (60.0)
Girls' track and field	6 (30.0)	2 (10.0)	0 (0.0)	12 (60.0)
Girls' swimming and diving	0 (0.0)	1 (25.0)	0 (0.0)	3 (75.0)
Boys' swimming and diving	1 (33.3)	1 (33.3)	0 (0.0)	1 (33.3)
Girls' cross country ^d	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)
Boys' cross country ^d	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)
Overall ^e	2310 (45.0)	782 (11.6)	605 (9.0)	3019 (34.4)

The table is organized by the overall rate of hand/wrist injuries by sport from highest to lowest.

^a Includes 4 y of data (2008/09 through 2011/12).

^b Includes 3 y of data (2009/10 through 2011/12).

^c Includes 7 y of data (2009/10 through 2015/16).

^d Includes 4 y of data (2012/13 through 2015/16).

^e Does not sum to 6723 because of missing information in a small number of injury reports.

injuries are more common during competition because of increased athlete-athlete contact and a higher intensity of play. However, future research is needed to confirm this presumption.

Football almost universally has the highest injury rate when compared with other sports in studies of all types of injuries, and this was also found to be true in this study. Additionally, fractures accounted for over 40% of all hand/wrist injuries sustained by football players, and playing football was the second most common variable associated with delaying surgery until after the athlete had completed the season. This concerning combination of high injury rates relative to other sports and the tendency to delay surgery, which could increase possible suboptimal outcomes, highlights the

importance of prevention of hand/wrist injuries in football.

Not surprisingly, aside from the full contact sports of football and wrestling, as well as girls' basketball (which appears to be an outlier in this study), the sports with the highest rates of hand/wrist injury were stick sports: boys' lacrosse, girls' softball, girls' field hockey, boys' ice hockey, and boys' lacrosse. Of note, not all stick sports had similar rates of injury. Intriguingly, the use of protective gloves does not seem to correlate well with the rate of hand/wrist injury. For example, of the 4 stick sports with the highest rates of hand/wrist injury, 2 of the sports require protective gloves (boys' lacrosse and boys' ice hockey), yet they still had high rates of hand/wrist injury. Conversely, girls' lacrosse does not require protective

gloves but had a lower rate of hand/wrist injury compared with other stick sports. Girls' field hockey, which does not require protective gloves, had a high rate of injury. The etiology of this lack of correlation may be related to the rules of these varied sports. Boys' lacrosse and ice hockey are full-contact sports, so it is not surprising that they have injury rates that are more similar to those in football and wrestling. The differences between girls' field hockey and girls' lacrosse are more intriguing. Because hand/wrist dexterity plays such an integral role in these sports, identifying protective equipment that is effective without being limiting is challenging.

A notable clinical finding is the higher rate of injury among girls in certain sex-comparable sports. Girls' softball and basketball had significantly

TABLE 3 Hand/Wrist Injuries by Sport and Injury Mechanism, US National High School Sports-Related Injury Surveillance Study, 2005/06 Through 2015/16 Academic Years

Sport	Injury Mechanism			
	n (%)			
	Player-Player	Player-Apparatus	Player-Surface	Other or Unknown
Football	164 (61.0)	566 (17.6)	633 (19.7)	60 (1.9)
Boys' lacrosse	55 (31.8)	89 (51.5)	27 (15.6)	2 (1.2)
Softball	35 (9.8)	241 (67.7)	50 (14.0)	30 (8.4)
Wrestling	191 (43.8)	8 (1.8)	208 (47.7)	29 (6.7)
Girls' field hockey	3 (2.4)	102 (81.0)	17 (13.5)	4 (3.2)
Boys' ice hockey	27 (34.2)	22 (27.9)	27 (34.2)	3 (3.8)
Girls' basketball	93 (20.9)	229 (51.4)	107 (24.0)	17 (3.8)
Boys' basketball	117 (24.2)	181 (37.4)	170 (35.1)	16 (3.3)
Baseball	59 (17.3)	177 (51.9)	83 (24.3)	22 (6.5)
Girls' volleyball	18 (5.8)	194 (62.2)	82 (26.3)	18 (5.8)
Girls' gymnastics ^a	0 (0.0)	6 (66.7)	1 (11.1)	2 (22.2)
Boys' volleyball ^b	0 (0.0)	3 (60.0)	2 (40.0)	0 (0.0)
Boys' soccer	59 (24.8)	64 (26.9)	110 (46.2)	5 (2.1)
Girls' lacrosse	2 (3.9)	36 (69.2)	12 (23.1)	2 (3.9)
Girls' soccer	41 (22.2)	76 (41.1)	65 (35.1)	3 (1.6)
Girls' tennis ^c	0 (0.0)	0 (0.0)	2 (22.2)	7 (77.8)
Cheerleading ^d	50 (45.9)	0 (0.0)	39 (35.8)	20 (18.4)
Boys' tennis ^c	0 (0.0)	0 (0.0)	1 (50.0)	1 (50.0)
Boys' track and field	0 (0.0)	7 (28.0)	15 (60.0)	3 (12.0)
Girls' track and field	1 (5.0)	6 (30)	10 (50.0)	3 (15.0)
Girls' swimming and diving	1 (25.0)	1 (25.0)	0 (0.0)	2 (50.0)
Boys' swimming and diving	0 (0.0)	1 (33.3)	2 (66.7)	0 (0.0)
Girls' cross country ^e	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)
Boys' cross country ^e	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)
Overall ^f	2716 (40.9)	2009 (30.3)	1664 (25.1)	250 (3.8)

The table organized is by the overall rate of hand/wrist injuries by sport from highest to lowest.

^a Includes 4 y of data (2008/09 through 2011/12).

^b Includes 3 y of data (2009/10 through 2011/12).

^c Includes 2 y of data (2013/14 through 2015/16).

^d Includes 7 y of data (2009/10 through 2015/16).

^e Includes 4 y of data (2012/13 through 2015/16).

^f Does not sum to 6723 because of missing information in a small number of injury reports.

higher rates of hand/wrist injury in comparison with the respective boys' sport. Girls' softball and boys' baseball injuries were most commonly fractures occurring during contact with a playing apparatus. However, a greater proportion of hand/wrist injuries attributed to contact with a playing apparatus occur because of contact with the ball in girls' softball (79.9%) than in boys' baseball (62.5%). This may be caused by the difference in size between a softball and a baseball. A larger size may make the ball more difficult to catch and may transfer more force during impact, which could explain the difference in injury rates. Although the patterns of girls' and boys' basketball hand/wrist injuries were relatively similar, only

34.9% of boys' basketball injuries were attributed to contact with the ball, as opposed to 51.3% of girls' basketball injuries. However it seems unlikely that the small difference in basketball size would explain this disparity in injury rates. Some other, as yet unidentified biomechanical explanation may exist for the sex differences in injury rates in basketball. Given these intriguing findings, efforts to elucidate the causes of sex differences in hand/wrist injury rates should be an area of additional future research.

Return to play, the need for surgery, and the diagnostic mechanisms used represent both important clinical outcomes and financial burdens to the family. Although almost half of the injured participants returned

to sports in <1 week, a large proportion, 12.4%, had restricted participation for ≥3 weeks, and another 5.6% received an MDQ for the season. In addition, more than 80% of injuries required some type of medical imaging, and 7.6% required surgical repair. Time away from play can have a considerable impact on the student athlete from a psychological perspective, and diminished hand/wrist dexterity can impact school performance. Given this study's findings that the majority of those who delayed surgery were seniors and varsity athletes, the decision to delay surgery may be based on several factors, including social pressure, perceived financial pressure, and clinical assurances that the athlete

TABLE 4 Hand/Wrist Injury by Sport and Severity, US National High School Sports-Related Injury Surveillance Study, 2005/06 Through 2015/16 Academic Years

Sport	Time Loss				
	n (%)				
	<7 d	1–3 wk	≥3 wk	MDQ ^a	Other ^b
Football	1588 (48.6)	727 (22.6)	356 (11.0)	181 (5.5)	413 (12.6)
Boys' lacrosse	54 (30.9)	29 (16.6)	22 (12.6)	18 (10.3)	52 (29.7)
Softball	138 (38.4)	93 (25.9)	54 (14.0)	18 (5.0)	56 (15.6)
Wrestling	134 (30.2)	104 (23.4)	94 (21.2)	45 (10.1)	67 (15.1)
Girls' field hockey	65 (51.6)	25 (19.8)	15 (11.9)	4 (3.2)	17 (13.5)
Boys' ice hockey	25 (31.3)	20 (25.0)	16 (20.0)	8 (10.0)	11 (13.8)
Girls' basketball	209 (46.0)	118 (26.0)	45 (9.9)	17 (3.7)	65 (14.3)
Boys' basketball	213 (43.4)	100 (20.4)	88 (17.9)	25 (5.1)	65 (13.2)
Baseball	129 (37.5)	69 (20.1)	57 (16.6)	28 (8.1)	61 (17.7)
Girls' volleyball	176 (56.1)	80 (25.5)	24 (7.6)	4 (1.3)	30 (9.6)
Girls' gymnastics ^c	5 (55.6)	0 (0.0)	3 (33.3)	0 (0.0)	1 (11.1)
Boys' volleyball ^d	4 (80.0)	1 (20.0)	0 (0.0)	0 (0.0)	0 (0.0)
Boys' soccer	121 (50.2)	52 (21.6)	21 (8.7)	12 (5.0)	35 (14.5)
Girls' lacrosse	28 (52.8)	10 (18.9)	4 (7.6)	0 (0.0)	11 (20.8)
Girls' soccer	108 (58.1)	35 (18.8)	14 (7.5)	7 (3.8)	22 (11.8)
Boys' tennis ^d	1 (50.0)	1 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)
Cheerleading ^e	41 (37.6)	32 (29.4)	17 (15.6)	2 (1.8)	17 (15.6)
Girls' tennis ^d	7 (77.8)	2 (22.2)	0 (0.0)	0 (0.0)	0 (0.0)
Boys' track and field	10 (40.0)	6 (24.0)	2 (8.0)	3 (12.0)	4 (16.0)
Girls' track and field	10 (50.0)	3 (15.0)	1 (5.0)	2 (10.0)	4 (20.0)
Girls' swimming and diving	3 (75.0)	1 (25.0)	0 (0.0)	0 (0.0)	0 (0.0)
Boys' swimming and diving	2 (66.7)	0 (0.0)	0 (0.0)	0 (0.0)	1 (33.3)
Girls' cross country ^f	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Boys' cross country ^f	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Overall ^g	3073 (45.7)	1508 (22.4)	836 (12.4)	374 (5.6)	932 (13.9)

The table is organized by the overall rate of hand/wrist injuries by sport from highest to lowest.

^a The MDQ category includes MDQ for the remainder of the season and MDQ for the athlete's career.

^b The other category included AEs for athletes who discontinued participation despite no MDQ, AEs for athletes released from the team for nonmedical reason, permanent paralysis, fatalities, and unknown or unreported exposures.

^c Includes 4 y of data (2008/09 through 2011/12).

^d Includes 3 y of data (2009/10 through 2011/12).

^e Includes 7 y of data (2009/10 through 2015/16).

^f Includes 4 y of data (2012/13 through 2015/16).

^g Does not sum to 6723 because of missing information in a small number of injury reports.

will not be risking further damage if play is continued. There is scant research on the potential long-term impacts of delaying surgical repair for hand/wrist injuries in the adolescent population, indicating another need for future research.

The limitations of this study are largely associated with the limitations of High School RIO. First, only schools with NATA-affiliated ATs were eligible to participate. Although this may limit the generalizability of results, it increases data quality. Also, the only exposure denominator captured by this surveillance system is AE. More discrete measures of exposure (eg, hours or

minutes played) are not available because of the intense time burden recording such detailed information for each athlete in each sport would pose for reporting high school ATs. Additionally, participating ATs were only able to report injuries they were aware of; therefore, data presented here likely represent an underestimation of the actual number of hand/wrist injuries sustained by high school athletes. Finally, detailed clinical information (eg, subclassification of fracture site, fracture type, and type of surgical repair) that can be reported in smaller clinic-based studies is not captured by this large, national surveillance study. Despite these limitations, we

believe that this study is the most comprehensive evaluation of hand/wrist injuries sustained by US high school athletes to date.

In this study, we demonstrated that high school athletes are at risk for hand/wrist injuries. Rates and patterns of hand/wrist injury varied widely by sport and sex, but the observed relative stability in injury trends over time reveals that more needs to be done to prevent these injuries. Understanding sport-specific differences should help drive more effective targeted prevention efforts. Although some observed differences lend themselves readily to suggestions for preventive efforts (eg, introducing protective gloves

in girls' field hockey and lacrosse), other observed differences are more puzzling and, as such, will require further study (eg, the sex differences in basketball). Overall, up to one-half of all sports-related injuries among children may be preventable.²² Given the prevalence of hand/wrist injuries in this population, as well as the potential negative

effects of these injuries, including time loss from play, financial costs, and academic challenges, more concerted efforts should be made to prevent sports-related hand/wrist injuries. Although there is a risk of hand and wrist injuries in all sports, the positive effects of sports participation likely continue to outweigh the risks.

ABBREVIATIONS

AE: athlete exposure
 AT: athletic trainer
 CI: confidence interval
 MDQ: medical disqualification
 NATA: National Athletic Trainers' Association
 RR: rate ratio

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Funded in part by the Centers for Disease Control and Prevention grants R49/CE000674-01 and R49/CE001172-01. The content of this report is solely the responsibility of the authors and does not necessarily represent the official views of the Centers for Disease Control and Prevention. We acknowledge the generous research funding contributions of the National Federation of State High School Associations, the National Operating Committee on Standards for Athletic Equipment, and DonJoy Orthotics.

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

REFERENCES

- National Federation of State High School Associations. 2015–16 high school athletics participation survey. 2016. Available at: www.nfhs.org/ParticipationStatistics/PDF/2015-16_Sports_Participation_Survey.pdf. Accessed February, 2017
- Caine D, Purcell L. *Injury in Pediatric and Adolescent Sports: Epidemiology, Treatment and Prevention*. Cham, Switzerland: Springer; 2016
- de Putter CE, Selles RW, Polinder S, Panneman MJ, Hovius SE, van Beeck EF. Economic impact of hand and wrist injuries: health-care costs and productivity costs in a population-based study. *J Bone Joint Surg Am*. 2012;94(9):e56
- Liu EH, Alqahtani S, Alsaaran RN, Ho ES, Zuker RM, Borschel GH. A prospective study of pediatric hand fractures and review of the literature. *Pediatr Emerg Care*. 2014;30(5):299–304
- Shah NS, Buzas D, Zinberg EM. Epidemiologic dynamics contributing to pediatric wrist fractures in the United States. *Hand (NY)*. 2015;10(2):266–271
- Swenson DM, Henke NM, Collins CL, Fields SK, Comstock RD. Epidemiology of United States high school sports-related fractures, 2008-09 to 2010-11. *Am J Sports Med*. 2012;40(9):2078–2084
- Almekinders LC, Tao MA, Zarzour R. Playing hurt: hand and wrist injuries and protected return to sport. *Sports Med Arthrosc Rev*. 2014;22(1):66–70
- Schroeder NS, Goldfarb CA. Thumb ulnar collateral and radial collateral ligament injuries. *Clin Sports Med*. 2015;34(1):117–126
- Werner BC, Hadeed MM, Lyons ML, Gluck JS, Diduch DR, Chhabra AB. Return to football and long-term clinical outcomes after thumb ulnar collateral ligament suture anchor repair in collegiate athletes. *J Hand Surg Am*. 2014;39(10):1992–1998
- Gaston RG, Loeffler BJ. Sports-specific injuries of the hand and wrist. *Clin Sports Med*. 2015;34(1):1–10
- Tirabassi J, Brou L, Khodae M, Lefort R, Fields SK, Comstock RD. Epidemiology of high school sports-related injuries resulting in medical disqualification: 2005-2006 through 2013-2014 academic years. *Am J Sports Med*. 2016;44(11):2925–2932
- Gustafsson M, Persson LO, Amilon A. A qualitative study of stress factors in the early stage of acute traumatic hand injury. *J Adv Nurs*. 2000;32(6):1333–1340
- Johnston LH, Carroll D. The psychological impact of injury: effects of prior sport and exercise involvement. *Br J Sports Med*. 2000;34(6):436–439
- Wood AM, Robertson GA, Rennie L, Caesar BC, Court-Brown CM. The epidemiology of sports-related fractures in adolescents. *Injury*. 2010;41(8):834–838
- Kerr ZY, Collins CL, Fields SK, Comstock RD. Epidemiology of player–player contact injuries among US high school athletes, 2005-2009. *Clin Pediatr (Phila)*. 2011;50(7):594–603
- Cotterell IH, Richard MJ. Metacarpal and phalangeal fractures in athletes. *Clin Sports Med*. 2015;34(1):69–98
- de Putter CE, van Beeck EF, Looman CW, Toet H, Hovius SE, Selles RW. Trends in wrist fractures in children and adolescents, 1997-2009. *J Hand Surg Am*. 2011;36(11):1810–1815.e2
- Macgregor DM. Don't save the ball! *Br J Sports Med*. 2003;37(4):351–353
- Rettig AC. Athletic injuries of the wrist and hand. Part I: traumatic injuries of the wrist. *Am J Sports Med*. 2003;31(6):1038–1048
- McGuine T. Sports injuries in high school athletes: a review of injury-risk and injury-prevention research. *Clin J Sport Med*. 2006;16(6):488–499
- Kerr ZY, Collins CL, Pommering TL, Fields SK, Comstock RD. Dislocation/separation injuries among US high school athletes in 9 selected sports: 2005-2009. *Clin J Sport Med*. 2011;21(2):101–108
- Micheli LJ, Smith AD. Sports injuries in children. *Curr Probl Pediatr*. 1982;12(9):1–54

Hand and Wrist Injuries Among US High School Athletes: 2005/06–2015/16
Bernadette K. Johnson, Lina Brou, Sarah K. Fields, Alexandria N. Erkenbeck and R.
Dawn Comstock
Pediatrics 2017;140;
DOI: 10.1542/peds.2017-1255 originally published online November 21, 2017;

Updated Information & Services	including high resolution figures, can be found at: http://pediatrics.aappublications.org/content/140/6/e20171255
References	This article cites 20 articles, 3 of which you can access for free at: http://pediatrics.aappublications.org/content/140/6/e20171255#BIBL
Subspecialty Collections	This article, along with others on similar topics, appears in the following collection(s): Injury, Violence & Poison Prevention http://www.aappublications.org/cgi/collection/injury_violence_-_poison_prevention_sub Sports Medicine/Physical Fitness http://www.aappublications.org/cgi/collection/sports_medicine:physical_fitness_sub
Permissions & Licensing	Information about reproducing this article in parts (figures, tables) or in its entirety can be found online at: http://www.aappublications.org/site/misc/Permissions.xhtml
Reprints	Information about ordering reprints can be found online: http://www.aappublications.org/site/misc/reprints.xhtml

American Academy of Pediatrics

DEDICATED TO THE HEALTH OF ALL CHILDREN™



PEDIATRICS®

OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

Hand and Wrist Injuries Among US High School Athletes: 2005/06–2015/16
Bernadette K. Johnson, Lina Brou, Sarah K. Fields, Alexandria N. Erkenbeck and R.
Dawn Comstock
Pediatrics 2017;140;
DOI: 10.1542/peds.2017-1255 originally published online November 21, 2017;

The online version of this article, along with updated information and services, is
located on the World Wide Web at:
<http://pediatrics.aappublications.org/content/140/6/e20171255>

Pediatrics is the official journal of the American Academy of Pediatrics. A monthly publication, it has been published continuously since 1948. Pediatrics is owned, published, and trademarked by the American Academy of Pediatrics, 141 Northwest Point Boulevard, Elk Grove Village, Illinois, 60007. Copyright © 2017 by the American Academy of Pediatrics. All rights reserved. Print ISSN: 1073-0397.

American Academy of Pediatrics

DEDICATED TO THE HEALTH OF ALL CHILDREN™

