

Epidemiology of Clavicle Fractures Among US High School Athletes, 2008-2009 Through 2016-2017

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Background: Little is known about the epidemiology of clavicle fractures in United States (US) high school athletes. Sports participation among high school students has increased steadily, placing increased numbers at risk of sports-related injury.

Purpose: To describe the epidemiology of clavicle fractures among high school athletes, including injury rates by sex, sport, and type of play and trends in operative versus nonoperative treatment.

Study Design: Descriptive epidemiology study.

Methods: The study data set included all athlete-exposure (AE) and clavicle fracture data collected from 2008-2009 through 2016-2017 from a large sample of US high schools as part of the National High School Sports-Related Injury Surveillance Study for students participating in boys' football, boys'/girls' soccer, boys'/girls' basketball, boys'/girls' volleyball, boys' wrestling, boys' baseball, girls' softball, girls' field hockey, boys' ice hockey, boys'/girls' lacrosse, boys'/girls' swimming and diving, boys'/girls' track and field, girls' gymnastics, girls' cheerleading, boys'/girls' tennis, and boys'/girls' cross-country.

Results: Overall, 567 clavicle fractures were reported during 31,520,765 AEs, an injury rate of 1.80 per 100,000 AEs. Injury rates varied by sport, with the highest rates in the boys' full-contact sports of ice hockey (5.27), lacrosse (5.26), football (4.98), and wrestling (2.21). Among girls' sports, the highest rates were in soccer (0.92), lacrosse (0.26), and basketball (0.25). In sex-comparable sports, injury rates were still significantly higher among boys (1.03) than girls (0.35) (rate ratio, 2.91; 95% CI, 1.97-4.30). Injury rates were significantly higher in competition (4.58) as compared with practice (0.87) (rate ratio, 5.27; 95% CI, 4.44-6.26). Most injuries were treated conservatively (82.7%) rather than operatively (17.3%). Time to return to sports varied, with a greater proportion of medical disqualifications among those treated operatively (40.0%) as compared with those treated conservatively (22.6%) (injury proportion ratio, 1.77; 95% CI, 1.31-2.39).

Conclusion: Although clavicle fracture rates are relatively low, they vary by sport, sex, and activity. Understanding such differences should drive more effective, targeted injury prevention efforts. Increased time loss from sports with surgical versus conservative treatment may have been influenced by factors including injury severity and its timing relative to the season's progress.

Keywords: pediatric sports medicine; shoulder; clavicle; epidemiology

Sports participation among high school students in the United States (US) has increased over the past 3 decades, with a record 7,963,535 student-athletes documented as participating in sport in 2017.¹⁷ Clavicle fractures remain the most common pediatric long-bone fracture and are among the most common fractures sustained in the adolescent and high school patient populations.²⁶ Unfortunately, relatively little is known about clavicle fractures in relation to sport or sex differences, return-to-play time, treatment modalities, or mechanism of injury in high school athletes.

Given the increase in the number of high school students participating in sport, this information would be helpful for clinicians as well as athletes and their families.

While previous studies have investigated the epidemiology of clavicle fractures in the pediatric and adolescent patient populations,^{2,9,20,21,26} there are limited data pertaining to the incidence of clavicle fractures among high school athletes. As discussed by Bartley et al,¹ high school-aged adolescents are at greater risk for injury than children because of their increased size, strength, and velocity in sport. Previous studies have identified clavicle fracture patterns, treatment trends, outcomes after pediatric clavicle fractures, and risks for fracture nonunions among the pediatric population.⁸ However, there remains

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a gap in the literature regarding these topics in the high school athlete.

Fortunately, the data set captured by the National High School Sports-Related Injury Surveillance Study allows for the examination of injury rates (IRs), treatment trends, return to play, and mechanism of injury for high school athletes' sports-related injuries. Given the gap in knowledge regarding these injuries in high school athletes, the purpose of this study was to determine the epidemiology of clavicle fractures among US high school athletes with this data set. The specific aims were to (1) describe rates of clavicle fracture by sex, sport, and type of athletic activity; (2) evaluate time loss from sport by operative and nonoperative treatment modality; and (3) examine mechanism of injury. We anticipated a higher incidence of clavicle fractures in males over females and in contact-sport athletes versus noncontact-sport athletes.

METHODS

Data Collection

Data analyzed in this study were collected by the National High School Sports-Related Injury Surveillance Study with the internet-based High School Reporting Information Online (RIO) during academic years 2008-2009 through 2016-2017. High School RIO captures injury and athlete-exposure (AE) information from a large national sample of US high schools, with reports submitted weekly by National Athletic Trainers' Association-affiliated certified athletic trainers (ATs) with valid email addresses who are willing to participate in the study. A detailed description of the methodology has been published previously.^{4,22}

In brief, the surveillance study began during the 2005-2006 academic year with a nationally representative sample of 100 US high schools randomly selected from 8 strata and stratified by school size and geographic region. The original sample included 9 sports: boys' football, boys'/girls' soccer, boys'/girls' basketball, girls' volleyball, boys' wrestling, boys' baseball, and girls' softball. Beginning in 2008-2009, High School RIO expanded the list of sports for which data were collected, subsequently adding 15 sports: girls' field hockey, boys' ice hockey, boys'/girls' lacrosse, boys'/girls' swimming and diving, boys'/girls' track/field, girls' gymnastics, cheerleading, boys' volleyball, boys'/girls'

tennis, and boys'/girls' cross-country. Schools not selected for the original sample offering any of the 24 sports (the original 9 and the added 15) were enrolled in a convenience sample, with the goal of at least 100 schools reporting for each sport. For each reported injury, ATs completed a detailed injury report, including athlete demographics (ie, age, height, weight), injury information (ie, body part, general injury type, time missed from competition), and injury event information (ie, activity, mechanism). Throughout each academic year, submitted information could be reviewed and updated by the ATs if necessary. This sampling methodology resulted in a large, nationally diverse convenience sample of US high schools reporting data on injuries sustained by student-athletes and their AEs.

Definition of Exposure and Injury

In High School RIO, an AE was defined as 1 athlete participating in 1 school-sanctioned practice or competition. Reportable injuries were defined as ones that (1) occurred as a result of participation in practice or competition, (2) required medical attention from an AT or physician, and (3) either restricted the athlete's participation in the sport for at least 1 day beyond the date of injury or resulted in any fracture, concussion, dental injury, or heat illness regardless of whether it resulted in a restriction of the student-athlete's participation. For this study, analyses included only injury reports of clavicle fractures with information regarding treatment modality (ie, operative or nonoperative).

Statistical Analysis

Data were analyzed with SPSS software (v 22.0; IBM Corp). IRs were calculated as the number of injuries per 100,000 AEs. To evaluate subgroup differences, rate ratios (RRs) and injury proportion ratios (IPRs) were calculated with unweighted case counts, with 95% CIs that do not include the null value (= 1) used to evaluate statistical significance. The following is an example of the calculations:

$$IR = \frac{\# \text{ of clavicle fractures sustained by boys football athletes}}{\# \text{ of football AEs}} \times 100,000$$

$$RR = \frac{(\# \text{ of clavicle fractures among boys}) / (\# \text{ of AEs among boys})}{(\# \text{ of clavicle fractures among girls}) / (\# \text{ of AEs among girls})}$$

[§]References 2, 3, 5, 7, 10, 12, 16, 18, 19, 21, 24-28, 31.

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TABLE 1
Rate of Clavicle Fracture by Sport^a

Sport ^b	Competition			Practice			RR (95% CI)	Overall IR
	Injuries, n	AE, n	IR	Injuries, n	AE, n	IR		
Boys' ice hockey	25	173,992	14.37	2	338,711	0.590474	24.33 (5.76-102.7)	5.27
Boys' lacrosse	38	317,955	11.95	17	726,910	2.338666	5.11 (2.89-9.05)	5.26
Boys' football	205	1,169,965	17.52	136	5,678,905	2.394828	7.32 (5.89-9.09)	4.98
Boys' wrestling	21	557,894	3.76	27	1,618,724	1.66798	2.26 (1.28-3.99)	2.21
Boys' soccer	38	768,552	4.94	8	1,772,193	0.451418	10.95 (5.11-23.48)	1.81
Girls' soccer	18	668,669	2.69	2	1,504,669	0.13292	20.25 (4.7-87.27)	0.92
Boys' baseball	5	795,695	0.63	2	1,484,677	0.134709	4.67 (0.91-24.04)	0.31
Girls' lacrosse	1	238,367	0.42	1	530,786	0.1884	2.23 (0.14-35.59)	0.26
Girls' basketball	6	735,798	0.82	0	1,648,835	0	—	0.25
Boys' basketball	2	925,468	0.22	3	2,128,882	0.140919	1.53 (0.26-9.18)	0.16
Boys' track and field	2	470,208	0.43	2	1,987,666	0.100621	4.23 (0.60-30.01)	0.16
Cheerleading ^c	0	118,905	0.00	2	1,431,983	0.139666	—	0.13
Girls' softball	1	581,272	0.17	1	1,114,535	0.089724	1.92 (0.12-30.65)	0.12
Girls' track and field	0	387,841	0.00	2	1,642,708	0.12175	—	0.10
Total	362	7,910,581	4.58	205	23,610,184	0.868269	5.27 (4.44-6.26)	1.80
Overall sex comparison ^d								
Boys	336	5,179,729	6.49	197	15,736,668	1.25	5.18 (4.35-6.18)	2.55
Girls	26	2,730,852	0.95	8	7,873,516	0.1	9.37 (4.24-20.7)	0.32
Sex-comparable sports ^e								
Boys	85	3,277,878	2.59	32	8,100,328	0.4	6.56 (4.37-9.86)	1.03
Girls	26	2,611,947	1	6	6,441,533	0.09	10.69 (4.40-26.00)	0.35

^aAE, athlete-exposure; IR, injury rate (number of injuries per 100,000 AEs); RR, rate ratio (competition to practice).

^bOf the 24 sports included in the surveillance data set, 10 reported zero clavicle fractures and thus are not included in the table.

^cAlthough cheerleading is a co-ed sport in the United States, only girls in this study sustained clavicle fractures in cheerleading.

^dSex comparison includes the cheerleading in the "girls" category, as only girls sustained clavicle fractures in this sport.

^eSex-comparable sports include soccer, basketball, baseball/softball, lacrosse, and track and field.

$$IPR = \frac{\text{proportion of clavicle fractures treated operatively resulting in medical disqualification}}{\text{proportion of clavicle fractures treated nonoperatively resulting in medical disqualification}}$$

Mechanism of injury between patients who underwent operative and nonoperative treatment was compared with the chi-square test. Trends in IRs over time were assessed by means of a simple linear regression. For these analyses, statistical significance was set at $P < .05$.

RESULTS

Clavicle Fracture IRs

Of the 24 sports included in the surveillance data set, 10 (girls' field hockey and gymnastics and girls' and boys' cross-country, swimming and diving, tennis, and volleyball) had no clavicle fractures reported during the study period. A total of 567 clavicle fractures were sustained during 31,520,765 AEs, for an overall IR of 1.80 per 100,000 AEs by high school athletes participating in the remaining 14 school-sanctioned sports (Table 1).

IRs varied by sex, sport, and type of activity (Table 1). Overall IRs were significantly higher among boys (2.55) versus girls (0.32) (RR, 7.95; 95% CI; 5.29-11.24). However,

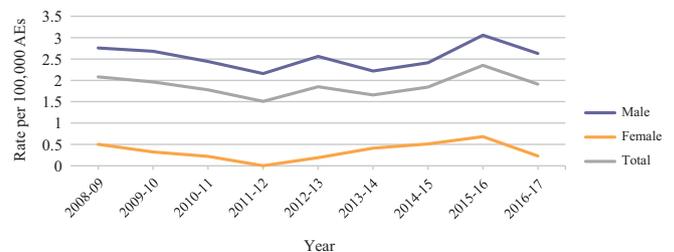


Figure 1. Trends in clavicle fracture rate over time. There was no significant change in injury rate over time for male ($P = .79$), female ($P = .57$), or total athletes ($P = .71$). AE, athlete-exposure.

IRs varied by sport, with the highest rates in the boys' full-contact sports of ice hockey (5.27), lacrosse (5.26), football (4.98) and wrestling (2.21), while among girls' sports, the highest rates were in soccer (0.92), lacrosse (0.26), and basketball (0.25).

When limited to sex-comparable sports, IRs were still significantly higher among boys (1.03) than girls (0.35) (RR, 2.91; 95% CI, 1.97-4.30). Overall IRs were significantly higher in competition (4.58) than in practice (0.87) (RR, 5.27; 95% CI, 4.44-6.26), and IRs were higher in competition than practice in 12 of the 14 individual sports. There were no significant trends over time in IRs among males ($P = .79$) or females ($P = .57$) (Figure 1).

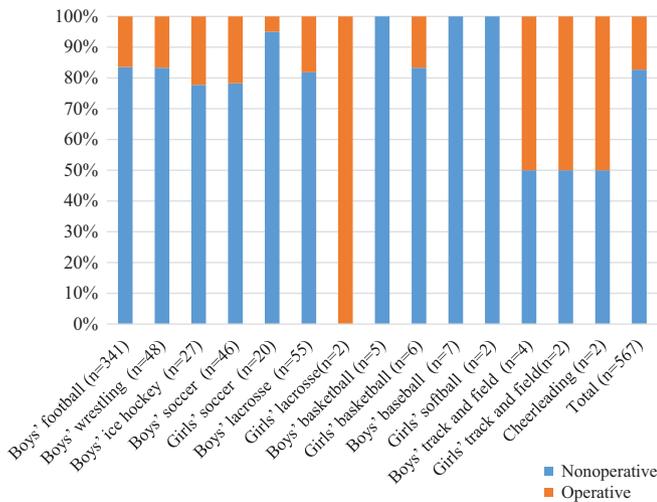


Figure 2. Treatment method for clavicle fractures by sport.

Treatment of Clavicle Fractures

The majority of clavicle fractures were treated nonoperatively (n = 469; 82.7%) rather than operatively (n = 98; 17.3%) (Figure 2). The proportion of injuries treated operatively varied across sports, but several sports with high proportions of injuries treated operatively had small numbers of injuries. In the 6 sports that each had at least 20 clavicle fractures, <25% of injuries were treated operatively.

Return to Play After Clavicle Fracture

Overall, 34.4% of athletes returned to play during the season in which they were injured, with most missing at least 21 days of sports participation (Table 2). Additionally, 25.6% of athletes were medically disqualified for the season, and another 36.2% had their sport season end before they were able to return, even though they did not receive a medical disqualification. Return to play after clavicle fracture varied by treatment modality. A significantly higher proportion of athletes treated nonoperatively (38.9%) than operatively (13.7%) were able to return to play (IPR, 2.85; 95% CI, 1.69-4.78). Conversely, a significantly higher proportion of athletes treated operatively (40.0%) than nonoperatively (22.6%) were medically disqualified for the season (IPR, 1.77; 95% CI, 1.31-2.39).

Mechanism of Injury

Overall, nearly all clavicle fractures resulted from either contact with another person (48.9%) or contact with the playing surface (46.6%) (Table 3). There were no significant differences in mechanism of injury among those athletes treated operatively versus nonoperatively (P = .38).

DISCUSSION

The principal findings of this study are that (1) clavicle fractures are relatively uncommon in the high school

TABLE 2
Return to Play Following Clavicle Fracture^a

	Nonoperative	Operative	Total
Time to return, d			
<1	9 (2)	1 (1.1) ^b	10 (1.8)
1-2	1 (0.2)	0 (0)	1 (0.2)
3-6	5 (1.1)	0 (0)	5 (0.9)
7-9	1 (0.2)	0 (0)	1 (0.2)
10-21	11 (2.5)	0 (0)	11 (2)
≥22	147 (32.9)	12 (12.6)	159 (29.3)
Medical disqualification for season	101 (22.6)	38 (40)	139 (25.6)
Athlete decided not to continue season	12 (2.7)	1 (1.1)	13 (2.4)
Season ended before medical clearance	153 (34.2)	43 (45.3)	196 (36.2)
Other ^c	7 (1.6)	0 (0)	7 (1.3)
Total ^d	447 (100)	95 (100)	542 (100)

^aValues are presented as n (%).

^bThis patient likely returned to the game in which the injury occurred and was subsequently treated surgically.

^cOther was selected by athletic trainers who were unsure of when the athlete was to return.

^dReturn-to-play data were not available for 22 clavicle fractures treated nonoperatively and 3 treated operatively.

TABLE 3
Mechanism of Clavicle Fracture^a

Mechanism of Injury ^b	Nonoperative	Operative	Total
Contact with another person	228 (48.8)	48 (49.5)	276 (48.9)
Contact with playing surface (eg, ground, field, court)	218 (46.7)	45 (46.4)	263 (46.6)
Contact with playing apparatus (eg, ball, equipment, goal post)	15 (3.2)	2 (2.1)	17 (3)
Acute no contact (eg, pulled muscle, rotation around a planted foot)	4 (0.9)	0 (0)	4 (0.7)
Other	2 (0.4)	2 (2.1)	4 (0.7)
Total ^c	467 (100)	97 (100)	564 (100)

^aValues are presented as n (%).

^bAthletic trainers were asked, "In your opinion, what mechanism initiated the injury? For example, if 2 players collided and then made contact with the ground, please choose *contact with another person*."

^cMechanism-of-injury data were not available for 2 clavicle fractures treated nonoperatively and 1 treated operatively.

patient population, with a rate of 1.80 per 100,000 AEs; (2) fractures are most likely to occur during ice hockey (boys) and during soccer (girls); (3) in sex-comparable sports, the IRs are significantly higher in males versus females; and (4) the majority of clavicle fractures in this patient population are treated nonoperatively versus surgically. Overall, while clavicle fracture rates are relatively

low, the rates vary by sport, sex, and type of activity, and understanding such differences should drive more effective, targeted injury prevention efforts.

As demonstrated in this study, clavicle fractures are particularly concerning because only one-third of high school athletes were able to return to play during the season in which they were injured. Of those who were able to return, a majority missed >21 days of sports participation. Time loss from sports can pose a social and emotional hardship on high school athletes, while surgical costs can pose an economic hardship on athletes and their families. The stability in clavicle fracture trends demonstrates the need for more effective, targeted injury prevention efforts to reduce the incidence of this serious sports-related injury.

Previous studies have identified clavicle fracture patterns, treatment trends, outcomes after clavicle fractures, and risks for fracture nonunions within the pediatric patient population.¹¹ In addition, several authors have investigated clavicle fractures in the adolescent population.^{2,9,20,21,26} As discussed by Bartley et al,¹ high school-aged adolescents are at greater risk for injury than children because of their larger size, strength, and velocity in sport. To our knowledge, the present study is the first to analyze these same factors in the high school patient population. Notably, player-to-player contact and player contact with the playing surface were the most common mechanisms of injury among high school athletes, as described in Table 3.^{1,8} Full-contact sports, such as ice hockey, had the highest incidence of clavicle fractures, while noncontact sports, such as girls' track and field and girls' cheerleading, had the lowest incidence of clavicle fractures. This low incidence of clavicle fractures among female athletes is unsurprising given the paucity of full-contact sports in women's athletics.

When the rules associated with a sport include significant contact (both player to player and player to contact surface), which is the case with ice hockey, football, and boys' lacrosse, the risk for contact injuries increases.⁸ Lacrosse is unique in that the male and female variants of the sport are quite different. In boys' lacrosse, body checking is legal, whereas the girls' version does not allow any body-to-body contact. This explains the large difference in IRs observed between boys' and girls' lacrosse, which did not exist in other sports with very similar male and female versions.

Of all sports, football continues to register the most high school athlete participants,¹⁷ which in turn drives the risk of contact injuries among boys. Following the introduction of Title IX in 1972, female participation in US athletics has increased over the past 5 decades and is currently at an all-time high.^{6,11,14} The most popular sports for girls include noncontact (or minimal contact) sports, such as track and field, volleyball, softball, cross-country, swimming and diving, tennis, and cheerleading.¹⁷ Thus, on the basis of choice of sport alone, females remain at a lower risk of sustaining a clavicle fracture, and accordingly, clavicle fracture

incidence based on sex is likely strongly influenced by the sports played by male and female high school athletes.

As described throughout the literature, surgical treatment of clavicle fractures in adolescents is heavily influenced by fracture pattern and severity.^{3,7,10,18,27} In a survey of Pediatric Orthopaedic Society of North America members in 2011, more than 90% of members were in favor of nonoperative treatment for nondisplaced and angulated-type midshaft clavicle fractures, while segmental fracture treatment was more variable, with almost half the respondents favoring operative management.³ A recent meta-analysis of randomized controlled trials found that, when compared with nonoperative treatment, plate fixation significantly reduces the risk of nonunion in the setting of displaced midshaft clavicular fractures.³⁰ While several studies have also observed improved functional outcomes with operative versus nonoperative treatment, it appears that the improvement may be due to the prevention of nonunion with surgical fixation.^{15,23} Estimates regarding the "number needed to treat" to avoid a negative outcome following displaced midshaft clavicular fracture are relatively high. To prevent 1 nonunion or symptomatic malunion, it would be necessary to treat an estimated 4.6 to 6.2 patients with primary plate fixation.^{15,23} Thus, when surgical management of a clavicle fracture is being considered, proper patient selection is imperative, and the risk of nonunion should be assessed.²⁹ Risk factors for nonunion following clavicular fracture include advanced age, female sex, and the presence of comminution or displacement of the fracture.²⁹

In the present study, the majority of clavicle fractures in the high school patient population were treated nonoperatively (83%) versus surgically (17%). Athletes treated surgically were found to have a slower return-to-play duration when compared with athletes treated nonoperatively. However, these results should be interpreted with caution, as the severity of injury is likely a confounding variable in the comparison of surgical and nonsurgical management of clavicle fractures. That is, the more severe, comminuted, and displaced fractures were likely treated surgically, and the severity of injury influenced return-to-sport parameters independently of treatment approach. As such, fracture complexity likely contributed to the higher rate of medical disqualification for the remainder of the season in athletes with operative (40%) versus nonoperative (22.6%) management. Furthermore, the criteria for return to sports or medical disqualification was not accounted for, nor was the timing of injury relative to the season's progress. It is possible that a higher proportion of patients treated surgically had injuries occurring at or near the end of the season. This factor may have even influenced the decision of surgical versus nonsurgical treatment when a fracture pattern was considered "borderline" for surgery.

Limitations

The limitations of this study arise from the limitations of the surveillance system from which the data set was accessed. First, only high schools with National Athletic Trainers' Association-affiliated ATs were eligible for

¹¹References 2, 3, 5, 7, 10, 12, 16, 18, 19, 21, 24-28, 31.

inclusion in High School RIO. Thus, the findings of this study may not be generalizable to schools without ATs. Second, only those injuries brought to the attention of the reporting AT were included in High School RIO, which means that some injuries may go unreported. Given the relative severity of clavicle fractures, this concern is limited in the current study, as it is unlikely that large numbers go unrecognized by ATs. While it may be difficult to rely on data provided by someone other than the treating medical provider, the majority of cases in High School RIO received care from an orthopaedic surgeon as well as an AT. As such, data provided by the ATs in these cases were reported per the treating surgeon's clinical response to the injury, not just their own. Moreover, it has been shown that ATs are highly accurate in evaluating acutely injured athletes and have a high rate of diagnostic concordance with treating physicians.¹³ Finally, High School RIO has limited information on injury specifics and treatment modalities. For example, the type of clavicle fracture is not available (eg, nondisplaced and angulated type midshaft clavicle fractures versus segmental fractures), nor are the criteria for return to play or medical disqualification, timing of the injury/surgery relative to the season's progress, or the technique performed in surgical treatments. More detailed classification of the clavicle fractures and surgical repairs could be informative to clinicians. Despite these limitations, this study provides the most extensive evaluation of the epidemiology of clavicle fractures among high school athletes to date and is the first to analyze data from a multiyear national surveillance study.

CONCLUSION

To our knowledge, this is the first study to describe the epidemiology of clavicle fractures among US high school athletes. Although clavicle fracture rates are relatively low, rates vary by sport, sex, and type of activity. Understanding such differences should drive more effective, targeted injury prevention efforts. This is particularly important given the time loss from sport associated with this injury. Increased time loss from sports with surgical versus conservative treatment should be discussed with the patients and their parents prior to intervention.

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