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Patterns of Recurrent Injuries Among US High School Athletes, 2005-2008

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Background: High school sports participants sustain millions of injuries annually; many are recurrent injuries that can be more severe than new injuries.

Hypothesis: Recurrent injury patterns differ from new injury patterns by sport and gender.

Study Design: Descriptive epidemiology study.

Methods: High school sports injury data for the 2005 through 2008 academic years were collected via High School Reporting Information Online (RIO) from a nationally representative sample of 100 US high schools.

Results: From 2005 through 2008, certified athletic trainers reported 13 755 injuries during 5 627 921 athlete exposures (24.4 injuries per 10 000 athlete exposures). Recurrent injuries accounted for 10.5% of all injuries. Football players had the highest rate of recurrent injury (4.36 per 10 000 athlete exposures). Girls had higher rates of recurrent injuries than boys in soccer (injury rate ratio = 1.39; 95% confidence interval, 1.07-1.82). Recurrent injuries most often involved the ankle (28.3%), knee (16.8%), head/face (12.1%), and shoulder (12.0%), and were most often ligament sprains (incomplete tears) (34.9%), muscle strains (incomplete tears) (13.3%), and concussions (11.6%). A greater proportion of recurrent injuries than new injuries resulted in the student choosing to end participation (recurrent = 2.4%, new = 0.7%). Recurrent shoulder injuries were more likely to require surgery than new shoulder injuries (injury proportion ratio = 4.51; 95% confidence interval, 2.82-7.20).

Conclusion: Recurrent injury rates and patterns differed by sport. Because recurrent injuries can have severe consequences on an athlete's health and future sports participation, injury prevention must be a priority. Knowledge of injury patterns can drive targeted preventive efforts.

Keywords: recurrent injury; reinjury; injury; high school; sports; epidemiology; surveillance

Concern in the United States over the increasing prevalence of obesity in high school-aged youth drives administrators, teachers, physicians, and parents to search for solutions.²⁹ One potential solution is to increase participation in physical activities such as school-sponsored sports.^{11,21} High school athletics participation has risen over the past decade from 6 million participants in the 1995-1996 academic year to 7.2

million participants in 2005-2006.²³ However, high school athletes sustain over 2 million injuries annually,²⁵ approximately 10% of which are recurrent injuries.^{25,26} Recurrent injuries can be more severe than the initial injury,²⁶ and previous injury correlates strongly with an increased risk of subsequent injury.^{19,28,30} As high school athletics participation continues to grow, there is an increased need for evidence-based, targeted measures to reduce the incidence of recurrent injuries.

Numerous studies have described the epidemiology of high school sports injuries in general, including studies that describe overall injury incidence^{7,9,19} or focus on specific body sites,^{12,18,24} injury diagnoses,^{14,17} or injury risk factors.⁸ However, few studies specifically address recurrent injuries. Existing studies often discussed recurrent injuries briefly, while providing a broader epidemiologic profile of all injuries in a particular sport,²⁵

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or were limited by sample size or geographic location.¹⁹ More comprehensive studies used older data that may not be representative of current trends in high school sports.²⁶ A nationally representative study of recurrent injuries among high school athletes is needed because such injuries can have a significant effect on an athlete's health.

One specific example of the potential seriousness of recurrent injuries is concussion. Not only are athletes who suffer 1 concussion more likely to suffer another concussion,^{2,4,13,17} but subsequent concussions can have more severe on-the-field presentations¹⁰; a second concussion sustained when the athlete is still symptomatic from the initial concussion can result in the life-threatening second-impact syndrome.^{3,4,6} Because of the potential severity of recurrent injuries, programs designed to reduce the frequency of injuries among high school athletes should specifically address recurrent injuries.

The objective of this study was to describe rates and patterns of recurrent injuries among US high school athletes participating in 9 sports: football, boys' and girls' soccer, girls' volleyball, boys' and girls' basketball, wrestling, baseball, and softball. Specifically, the aims were to (1) describe recurrent injury rates and patterns; (2) compare recurrent injury rates and patterns by type of exposure (practice and competition), sport, and gender; and (3) compare recurrent and new injury rates and patterns.

MATERIALS AND METHODS

Data Collection

We used the National High School Sports-Related Injury Surveillance System, High School RIO (Reporting Information Online), an Internet-based sports injury surveillance system, to collect data. The methods of this surveillance study have been reported previously.^{5,27} In brief, we invited high schools with one or more National Athletic Trainers' Association-affiliated certified athletic trainers (ATCs) with a valid e-mail address to participate. We categorized willing participants into 8 strata based on school population (enrollment ≤ 1000 or >1000) and US Census geographic location.³¹ From these 8 strata, we randomly chose 100 high schools to participate. If a high school dropped out of the study, we selected a replacement school from the same stratum to maintain the 100-school study population. Certified athletic trainers from participating high schools logged onto the High School RIO Web site weekly throughout the academic year to report injury incidence and athlete exposure (AE) for 9 sports: football, boys' and girls' soccer, girls' volleyball, boys' and girls' basketball, wrestling, baseball, and softball.

Definition of Injury and Exposure

We defined an AE as 1 athlete participating in 1 athletic practice or competition. We defined a reportable injury as one that (1) occurred as a result of participation in an organized practice or competition, (2) required medical attention by an ATC or a physician, and (3) resulted in a

restriction of the athlete's participation for ≥ 1 day. Certified athletic trainers categorized all reportable injuries as (1) a new injury, (2) a recurrent injury that occurred in the current academic year, or (3) a recurrent injury that occurred in a previous academic year. Recurrent injuries were defined as injuries that occurred to a location on the body that sustained the same type of injury previously. Because ATCs are medically trained, it is expected that ATCs used their relationship with the athlete, the athlete's coach, and any other pertinent information to make appropriate decisions on recurrent status.

For each injury, the ATC completed a detailed injury report on the injured athlete (age, height, weight, etc), the injury (site, diagnosis, severity, etc), and the injury event (activity, mechanism, etc). Throughout the study, reporters were able to view previously submitted information and update reports as needed.

Statistical Analysis

We analyzed data using SPSS software, version 15.0 (SPSS, Chicago, Illinois). We calculated all rates and rate comparisons using unweighted case counts. Additional analyses used national estimates by applying weights calculated through the inverse of the probability of a school's selection into the study, with the standard errors for comparisons adjusted for the High School RIO sampling plan using the SPSS Complex Samples module.

We calculated recurrent injury rates as the number of recurrent injuries per 10 000 AEs. We calculated injury rate ratios (RRs) and injury proportion ratios (IPRs) with *P* values and 95% confidence intervals (CIs). We considered CIs not including 1.00 and *P* values $< .05$ statistically significant. An RR or IPR > 1.00 suggests a risk association, while an RR or IPR < 1.00 suggests a protective association. We calculated values of RR as follows:

$$RR = \frac{\# \text{ competition recurrent injuries} / \# \text{ competition AEs}}{\# \text{ practice recurrent injuries} / \# \text{ practice AEs}}$$

Additionally, we calculated values of IPR as follows:

$$IPR = \frac{\text{national estimated } \# \text{ competition recurrent injuries} / \text{national estimated } \# \text{ total competition injuries}}{\text{national estimated } \# \text{ practice recurrent injuries} / \text{national estimated } \# \text{ total practice injuries}}$$

This study was approved by the Institutional Review Board at the Research Institute at Nationwide Children's Hospital.

RESULTS

General

From 2005 through 2008, ATCs reported 13 755 injuries during 5 627 921 AEs (24.4 per 10 000 AEs). There were 12 310 (89.5%) new injuries and 1445 (10.5%) recurrent

TABLE 1
Rates of Recurrent and New Injuries per 10 000 Athlete Exposures,
High School Sports-Related Injury Surveillance Study, United States, 2005–2008^a

Sport	New Injuries/10 000 AEs				Total Recurrent Injuries/10 000 AEs ^b			
	Total	Competition	Practice	RR (95% CI) ^c	Total	Competition	Practice	RR (95% CI) ^d
Total	21.9	41.6	14.5	2.87 (2.77–2.97)	2.57	4.49	1.85	2.43 (2.19–2.69)
Boys	25.1	50.9	16.6	3.07 (2.95–3.20)	2.85	5.42	2.00	2.71 (2.41–3.06)
Girls	15.4	27.1	9.9	2.74 (2.54–2.94)	2.01	3.03	1.53	1.99 (1.62–2.43)
Football	38.5	114.4	22.7	5.05 (4.79–5.31)	4.36	12.51	2.67	4.69 (4.02–5.46)
Soccer								
Boys	19.2	36.9	11.5	3.20 (2.82–3.62)	1.83	3.29	1.20	2.74 (1.84–4.07)
Girls	21.5	47.3	10.5	4.51 (3.97–5.13)	2.55	5.33	1.37	3.89 (2.69–5.60)
Volleyball	12.0	14.1	11.0	1.28 (1.08–1.53)	1.73	1.44	1.88	0.77 (0.47–1.25)
Basketball								
Boys	14.4	23.3	10.8	2.16 (1.91–2.45)	2.07	3.20	1.60	2.01 (1.44–2.80)
Girls	16.1	30.1	10.3	2.93 (2.57–3.34)	2.57	4.15	1.91	2.17 (1.56–3.01)
Wrestling	21.7	34.4	17.3	1.99 (1.76–2.24)	2.39	3.35	2.06	1.62 (1.12–2.36)
Baseball	10.1	15.6	6.99	2.24 (1.88–2.65)	1.00	1.22	0.88	1.38 (0.80–2.37)
Softball	10.9	17.4	7.42	2.35 (1.94–2.83)	0.88	1.14	0.73	1.55 (0.80–3.01)

^aAE, athlete exposure; RR, injury rate ratio; CI, confidence interval.

^bTotal recurrent injuries is the sum of recurrence of injuries sustained in the same academic year and recurrence of injuries sustained in a previous academic year.

^cCompares new injury rate during competition to the new injury rate during practice.

^dCompares recurrent injury rate during competition to the recurrent injury rate during practice.

injuries, of which 595 (4.3%) were current year recurrent injuries and 850 (6.2%) were previous year recurrent injuries. As shown in Table 1, the overall recurrent injury rate was 2.57 per 10 000 AEs. New injuries occurred 8 times more frequently than recurrent injuries (RR = 8.52; 95% CI, 8.07–9.00). The recurrent injury rate was higher in competition than practice (RR = 2.43; 95% CI, 2.19–2.69). Compared with the other 7 sports, greater proportions of boys' (IPR = 1.24; 95% CI, 1.03–1.50) and girls' (IPR = 1.53; 95% CI, 1.27–1.86) basketball injuries were recurrent.

Football had the highest rate of recurrent injury (4.36 per 10 000 AEs) (Table 1). Compared with all other sports, football players were more likely to sustain a recurrent injury (RR = 2.28; 95% CI, 2.06–2.53), while baseball (1.00 per 10 000 AEs) and softball (0.88 per 10 000 AEs) players were least likely. Overall, boys were more likely to sustain a recurrent injury than girls (RR = 1.42; 95% CI, 1.26–1.60), but this was influenced heavily by football. In gender-comparable sports (ie, soccer, basketball, and baseball/softball), girls were more likely than boys to sustain recurrent injuries in soccer (RR = 1.39; 95% CI, 1.07–1.82), but there was no difference between girls' and boys' basketball (RR = 1.25; 95% CI, 0.99–1.57) or between softball and baseball (RR = 0.87; 95% CI, 0.57–1.34).

Exposure Type

In 6 of the 9 sports, recurrent injuries were significantly more likely to occur in competition than practice, especially in football (RR = 4.69; 95% CI, 4.02–5.46) and girls' soccer (RR = 3.89; 95% CI, 2.69–5.60) (Table 1). In baseball, softball, and volleyball, there were no statistically significant differences by type of exposure. In contrast, volleyball

had a lower recurrent injury rate in competition compared to practice (RR = 0.77; 95% CI, 0.47–1.25). Recurrent injuries were more likely to occur during competition than practice for both current year recurrent injuries (RR = 3.58; 95% CI, 3.05–4.22) and previous year recurrent injuries (RR = 1.84; 95% CI, 1.61–2.11).

Injury Type

The ankle was the most frequently diagnosed body site of recurrent injuries (28.3%), followed by the knee (16.8%), head/face (12.1%), shoulder (12.0%), lower back (6.4%), and upper leg (5.6%) (Figure 1). The most frequently diagnosed body sites of recurrent injuries varied by sport (Table 2). The ankle was the most frequently diagnosed site in boys' basketball (53.2%), girls' basketball (44.4%), volleyball (34.5%), boys' soccer (33.0%), girls' soccer (32.2%), softball (23.9%), and football (20.6%). The shoulder was the most frequently diagnosed site in wrestling (28.5%) and baseball (27.2%).

The proportions of recurrent injuries to the shoulder (IPR = 1.52; 95% CI, 1.28–1.80), lower back (IPR = 1.88; 95% CI, 1.43–2.47), and ankle (IPR = 1.47; 95% CI, 1.31–1.65) were higher than the proportions of new injuries at the same body sites. Conversely, the proportions of recurrent injuries to the hand (IPR = 0.27; 95% CI, 0.17–0.42) and wrist (IPR = 0.38; 95% CI, 0.18–0.80) were lower than the proportions of new injuries diagnosed at the same body sites.

The most common diagnosis for recurrent injuries was a ligament sprain (incomplete tear) (34.9%), followed by muscle strain (incomplete tear) (13.3%), concussion (11.6%), dislocation (7.0%), and contusion (4.5%) (Figure 2). A ligament sprain (incomplete tear) of the ankle was the

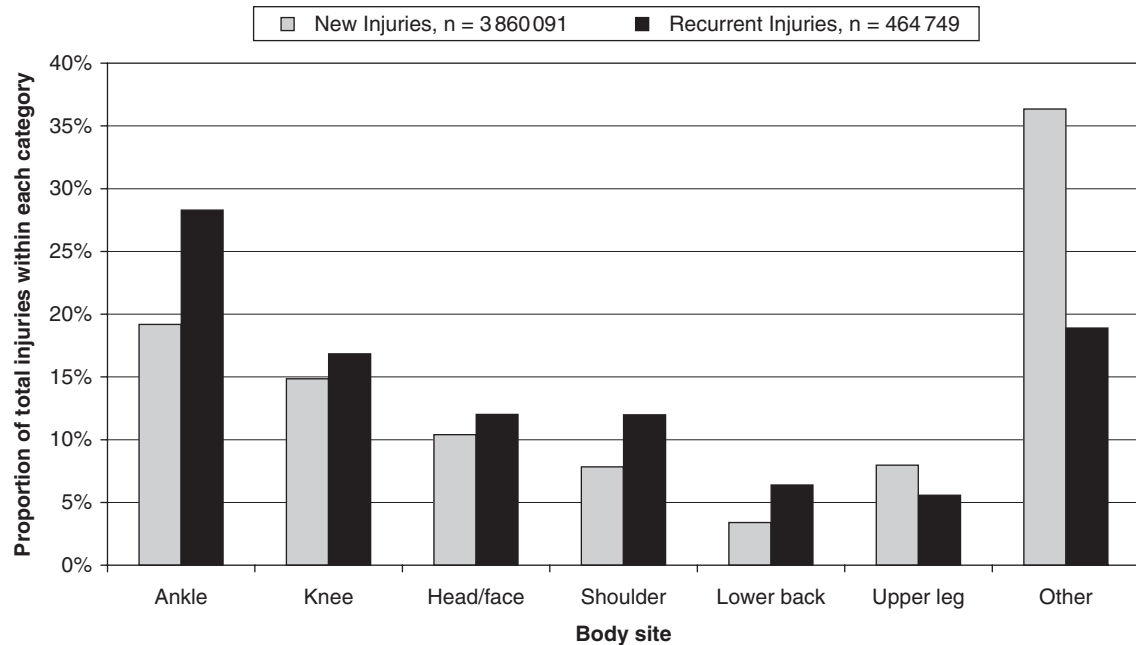


Figure 1. Most frequent body site of injury for new and recurrent injuries, High School Sports-Related Injury Surveillance Study, United States, 2005-2008. These frequencies reflect national estimates of new and recurrent injuries.

TABLE 2
Relative Proportions of New and Recurrent Injuries by Body Site,
High School Sports-Related Injury Surveillance Study, United States, 2005–2008^a

Sport	Injury Type	Ankle	Knee	Shoulder	Head/Face	Upper Leg	Lower Back	Other	Total	
Football	New	13.6%	14.6%	11.3%	11.0%	6.6%	4.3%	38.7%	100%	
	Reinjury	20.6%	15.1%	17.9%	12.9%	6.0%	5.4%	22.2%	100%	
Soccer	Boys	New	20.4%	14.4%	2.9%	11.9%	14.2%	2.9%	33.3%	100%
		Reinjury	33.0%	17.4%	2.3%	14.0%	10.3%	4.7%	18.2%	100%
	Girls	New	23.3%	21.3%	1.5%	11.3%	11.9%	1.7%	29.1%	100%
		Reinjury	32.2%	23.5%	0.0%	19.7%	10.8%	2.7%	11.1%	100%
Volleyball	New	42.6%	9.9%	6.7%	5.0%	2.4%	6.7%	26.7%	100%	
	Reinjury	34.5%	13.4%	11.7%	2.6%	0.0%	16.0%	21.8%	100%	
Basketball	Boys	New	34.3%	11.3%	2.3%	7.8%	4.8%	3.5%	35.9%	100%
		Reinjury	53.2%	15.3%	8.2%	2.2%	0.5%	8.2%	12.4%	100%
	Girls	New	29.5%	17.5%	3.2%	11.0%	7.5%	1.9%	29.3%	100%
		Reinjury	44.4%	20.4%	2.7%	14.1%	1.8%	4.3%	12.2%	100%
Wrestling	New	6.8%	16.1%	16.9%	8.4%	2.6%	3.2%	45.9%	100%	
	Reinjury	5.0%	12.5%	28.5%	12.0%	0.9%	13.0%	28.1%	100%	
Baseball	New	13.7%	7.2%	15.9%	7.4%	9.1%	3.4%	43.4%	100%	
	Reinjury	14.3%	15.9%	27.2%	4.4%	8.6%	9.2%	20.5%	100%	
Softball	New	15.9%	10.9%	7.6%	10.0%	9.6%	1.1%	44.9%	100%	
	Reinjury	23.9%	12.9%	20.8%	8.3%	1.3%	8.3%	24.5%	100%	

^aThese proportions reflect national estimates of new and recurrent injuries.

most frequent specific diagnosis, accounting for 25.4% of all recurrent injuries. As shown in Table 3, a ligament sprain (incomplete tear) was the most common diagnosis for recurrent injuries in boys' basketball (58.4%), girls' basketball (43.6%), volleyball (42.7%), girls' soccer (37.2%),

boys' soccer (34.8%), football (29.8%), softball (26.3%), and wrestling (20.1%). The most common diagnosis for recurrent injuries in baseball was a muscle strain (incomplete tear) (31.9%). Additionally, common recurrent injuries in volleyball included tendinitis (6.8%) and tendon strain

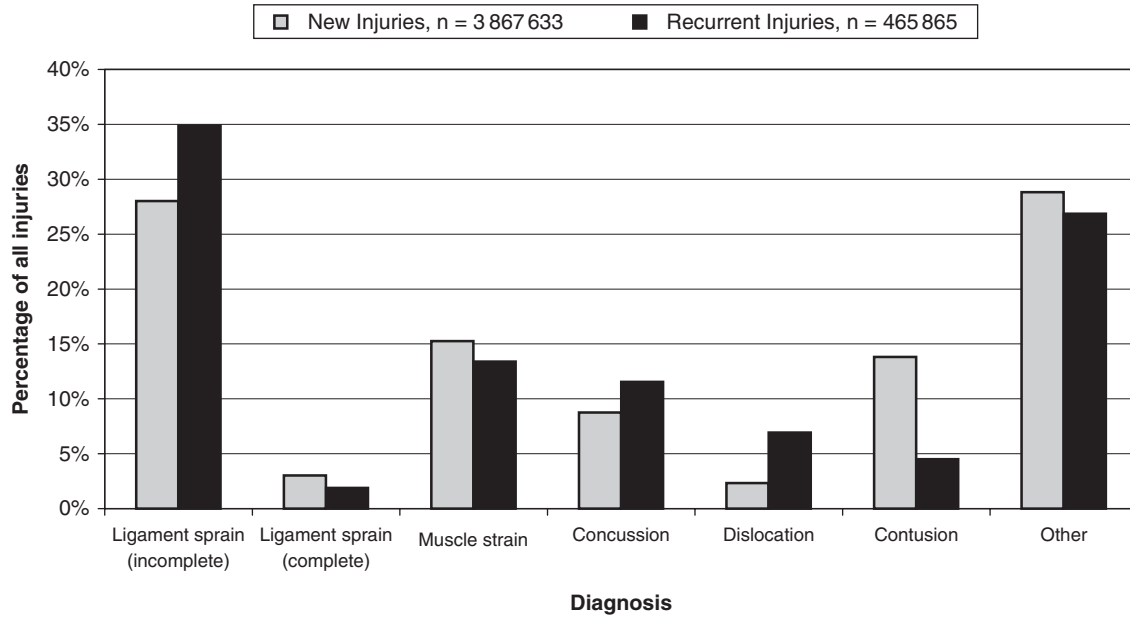


Figure 2. Most frequent diagnoses of injury for new and recurrent injuries, High School Sports-Related Injury Surveillance Study, United States, 2005-2008. These frequencies reflect national estimates of new and recurrent injuries. “Muscle strain” includes complete and incomplete tears, but complete tears made up less than 1% of injuries.

TABLE 3
Proportions of New and Recurrent Injuries by Diagnosis,
High School Sports-Related Injury Surveillance Study, United States, 2005–2008^a

Sport	Injury Type	Ligament Sprain ^b	Muscle Strain ^b	Concussion	Contusion	Dislocation	Other ^c	Total	
Football	New	25.6%	13.7%	10.4%	16.3%	3.0%	31.0%	100%	
	Reinjury	29.8%	12.3%	12.4%	6.6%	9.4%	29.5%	100%	
Soccer	Boys	New	23.8%	18.5%	9.2%	17.3%	1.5%	29.8%	100%
		Reinjury	34.8%	15.7%	13.8%	4.2%	5.9%	25.6%	100%
	Girls	New	29.8%	16.3%	10.6%	11.9%	1.0%	30.3%	100%
		Reinjury	37.2%	14.0%	19.1%	2.8%	1.9%	25.0%	100%
Volleyball	New	48.5%	13.8%	4.4%	4.8%	1.5%	27.0%	100%	
	Reinjury	42.7%	14.8%	2.6%	0.0%	5.5%	34.4%	100%	
Basketball	Boys	New	39.4%	9.5%	4.7%	11.1%	2.4%	32.8%	100%
		Reinjury	58.4%	8.0%	2.2%	1.0%	5.8%	24.4%	100%
	Girls	New	35.6%	11.8%	9.1%	7.1%	1.7%	34.6%	100%
		Reinjury	43.6%	6.3%	13.7%	5.5%	3.5%	27.4%	100%
Wrestling	New	23.4%	17.5%	5.1%	8.1%	4.3%	41.5%	100%	
	Reinjury	20.1%	18.4%	9.6%	5.9%	14.8%	31.2%	100%	
Baseball	New	20.7%	19.4%	2.5%	16.3%	1.1%	40.0%	100%	
	Reinjury	24.9%	31.9%	4.4%	4.8%	5.2%	28.8%	100%	
Softball	New	20.7%	15.4%	5.3%	18.7%	2.3%	37.6%	100%	
	Reinjury	26.3%	11.8%	8.3%	1.0%	9.3%	43.3%	100%	

^aThese proportions reflect national estimates of new and recurrent injuries.

^bIncomplete tears; complete tears represent a small minority of ligament sprains and muscle strains.

^cThese diagnoses include, but are not limited to, tendon strains, fractures, tendinitis, infections, inflammation, and torn cartilage.

(incomplete tear) (6.5%). In wrestling, infections accounted for 6.5% and torn cartilage for 6.3% of all recurrent injuries. Tendon strains (incomplete tears) made up 9.2% of baseball recurrent injuries. Softball recurrent injuries

included tendon strain (incomplete tear) (9.3%), tendinitis (5.2%), and torn cartilage (5.2%).

Dislocations (IPR = 3.01; 95% CI, 2.34-3.87), subluxations (IPR = 2.54; 95% CI, 1.61-4.02), inflammations (IPR = 2.25;

TABLE 4

Severity of Recurrent and New Injuries, High School Sports-Related Injury Surveillance Study, United States, 2005–2008

Outcome	Recurrent Injuries			New Injuries	
	Current Academic Year No. Cases (%)	Previous Academic Year No. Cases (%)	Total No. Cases (%)	No. Cases (%)	Overall Recurrent Injury Proportion Ratio (95% CI) ^a
Time loss					
< 1 week	90 597 (48.7)	130 682 (48.6)	221 279 (48.6)	1 983 957 (52.3)	0.92 (0.86–0.99)
1–3 weeks	61 629 (33.1)	82 219 (30.6)	143 848 (31.6)	1 120 761 (29.5)	1.06 (0.96–1.18)
> 3 weeks	8941 (4.8)	17 655 (6.6)	26 596 (5.8)	288 285 (7.6)	0.76 (0.58–1.01)
Medical disqualification	16 295 (8.8)	23 372 (8.7)	39 667 (8.7)	290 531 (7.7)	1.14 (0.92–1.41)
Other ^b	8472 (4.6)	14 989 (5.6)	23 461 (5.2)	109 705 (2.9)	1.77 (1.30–2.41)
Need for surgery					
Yes	9606 (5.2)	17 207 (6.4)	26 813 (5.9)	223 404 (5.9)	1.00 (0.78–1.27)
No	175 720 (94.8)	252 247 (93.6)	427 967 (94.1)	3 550 064 (94.1)	

^aReferent group was all new injuries. CI, confidence interval.

^bOutcomes of “other” include nonmedical release from team, student-elected nonmedical discontinuation, or other outcomes where the athlete’s ability to play in the future was undetermined.

95% CI, 1.49–3.39), stress fractures (IPR = 2.09; 95% CI, 1.11–3.91), and ligament strains (incomplete tears) (IPR = 1.24; 95% CI, 1.13–1.37) made up higher proportions of recurrent injuries than new injuries. Conversely, contusions (IPR = 0.33; 95% CI, 0.25–0.43), fractures (IPR = 0.28; 95% CI, 0.20–0.40), and lacerations (IPR = 0.05; 95% CI, 0.01–0.33) made up lower proportions of recurrent injuries than new injuries.

Severity

As shown in Table 4, injuries that caused <1 week of time loss were slightly less common among recurrent injuries than among new injuries (IPR = 0.92; 95% CI, 0.86–0.99). The overall proportion of recurrent injuries requiring surgery was similar to the proportion of new injuries requiring surgery (IPR = 1.00; 95% CI, 0.78–1.27) (Table 4). However, in wrestling, recurrent injuries were more likely than new injuries to require surgery (IPR = 2.24; 95% CI, 1.25–4.02). Recurrent wrestling injuries requiring surgery were often torn knee cartilage (19.5%) and shoulder dislocations (9.6%).

New injuries that frequently required surgery were knee ligament sprains (complete tears) (30.8%), torn knee cartilage (8.2%), and fractures of the hand (6.7%) and nose (5.3%). Recurrent injuries that frequently required surgery were shoulder dislocations (23.1%), torn knee cartilage (17.2%), knee ligament sprains (complete tears) (8.2%), and shoulder ligament sprains (incomplete tears) (5.4%). Recurrent injuries accounted for 45.5% of all shoulder injuries requiring surgery, of which 58.4% occurred in football, 16.3% in wrestling, and 11.1% in boys’ basketball. A greater proportion of recurrent shoulder injuries required surgery compared with new shoulder injuries (IPR = 4.51; 95% CI, 2.82–7.20).

Athletes were 3 times more likely to chose to discontinue sport participation after a recurrent injury than after a new injury (2.4% and 0.7%, respectively) (IPR = 3.49; 95% CI, 2.16–5.62). Of the recurrent injuries that resulted in a student choosing to discontinue participation, ligament

sprain (incomplete tears) was the most common diagnosis (28.0%), followed by dislocation (18.6%), concussion (13.0%), muscle strain (incomplete tear) (12.3%), and tendinitis (9.1%).

DISCUSSION

We used data from 2005 through 2008 to describe the epidemiology of sports-related recurrent injuries among US high school students. We found that 10.5% of all injuries were recurrent injuries, that recurrent shoulder injuries were significantly more likely to require surgery than new injuries, and that students were more likely to discontinue sports participation after recurrent injuries. We anticipate that high school sports participation will continue to increase, which will likely result in an increase in the number of recurrent injuries. Because previous injury correlates strongly with an increased risk of subsequent injury^{18,28,30} and recurrent injuries can severely affect an athlete’s health, injury prevention programs must focus on reducing injury rates, injury recovery efforts, return-to-play decisions, and other attempts to reduce recurrent injury rates.

Our finding that recurrent injuries accounted for 10.5% of all high school sports-related injuries was consistent with previous studies,^{25,26} indicating that the relative proportion of these injuries has not changed over the past decade. Our findings also confirmed that the most commonly diagnosed body sites for recurrent injuries are joints (eg, ankle or knee), as reported by Rauh et al.²⁶ We found, however, higher proportions of recurrent head injuries in girls’ soccer and girls’ basketball and higher proportions of recurrent ankle injuries in girls’ basketball, volleyball, and softball. We found lower proportions of recurrent lower leg injuries in girls’ basketball and softball and recurrent knee injuries in softball and volleyball. Although many of our findings, such as a high recurrence of sprains and strains, were consistent with those reported by Rauh et al,²⁶ we found that concussions made up a

larger proportion of recurrent injuries in girls' basketball, girls' soccer, and softball. Although this difference may be due in part to statistical variation, it may also suggest increased awareness of appropriately diagnosing concussions.

Recurrent ankle ligament sprains (incomplete tears) were the most frequently diagnosed recurrent injuries. Previous studies demonstrated that ankle injuries are common in sports in which high levels of jumping and pivoting put excess strain on the ankle,^{1,22,24,33} but that ankle injuries can be reduced with appropriate protection.^{15,20} Because previous injury correlates strongly with the risk of reinjury,^{19,28,30} additional focus must be placed on preventing primary ankle sprains, perhaps through preventive interventions such as balance training and strength training. Further research to determine the effectiveness of different types of protective equipment in adolescent athletes could be useful. In addition, primary ankle sprains must be appropriately treated and fully rehabilitated. Future research should evaluate the rate of rehabilitation and return to play decisions as risk factors for recurrent injury because young athletes may be particularly anxious to return to their sport.

Interestingly, while recurrent injuries accounted for only 10.5% of all injuries, recurrent shoulder injuries represented 45.5% of all shoulder injuries that required surgery. Although some studies have shown knee, ankle, and wrist braces to be effective at reducing injuries while still allowing for sports participation,^{15,32} protective shoulder devices that allow for full sports participation are less developed because of the complexity of the shoulder joint and the range of motion required during sporting activities. As new shoulder braces are developed and used, further research will be needed to confirm their effectiveness in adolescent as well as adult athletes so that high school sports participants can be best protected. Nevertheless, the high number of recurrent shoulder injuries that required surgery underscores the need for better protective measures to prevent initial shoulder injuries (primary prevention) and to protect injured shoulders to prevent reinjury or increased injury severity (secondary and tertiary prevention). Particular attention should be focused on fully rehabilitating shoulder injuries before allowing young athletes to return to play. In addition, our results may be an indication that primary shoulder injuries are being treated conservatively, whereas surgical treatment is reserved for recurrent cases, suggesting that surgical treatment of primary shoulder injuries should be considered under certain circumstances.

The proportion of recurrent injuries resulting in the student choosing not to continue to participate in the sport was higher than the proportion of new injuries resulting in such a decision. This may have several explanations, such as the student wanting to avoid subsequent injury or the parents deciding to keep their child away from what they believe are risky activities. For example, concussions were one of the most common recurrent injuries after which students chose not to participate. This may reflect an increased awareness among athletes and their parents of

the potential for cumulative neurologic impairment following multiple concussions.¹⁶ Although concussion and other recurrent injuries can pose severe risk to students, the benefits of athletic participation can be great, and a student who elects not to participate further in a sport may not enjoy the benefits of a physically active lifestyle. Future research is needed to determine the reasons for voluntary withdrawal from a sport after recurrent injury, with an objective of encouraging the injured student to remain physically active.

Why some recurrent injuries are more severe than initial injuries is not always clear. In some instances, athletes may not allow enough time for initial injuries to heal fully before returning to play. Future research should evaluate the potential correlation between recovery time and severity of reinjury for various sites and diagnoses of injury. Information from such research should be used to drive evidence-based decisions regarding when an adolescent athlete can safely return to play following various types of injuries.

Like all studies, ours has limitations. We limited our sample to high schools with ATCs, which restricted our population, but this ensured that a medically trained professional documented injuries, which increased data quality and consistency. Additionally, because AEs were unit-based rather than time-based, we were unable to report participation/exposure rates by minutes or hours of practice and competition. We were also unable to calculate the amount of AE time accrued between the incident and recurrent injury. If the amount of time between the incident and recurrent injury varied greatly by sport, this could have biased our injury rate ratios. However, these limitations were necessary to reduce reporter burden. Finally, because this was an explorative study, we did not adjust *P* values for multiple comparisons. Despite the limitations, this study was the largest and most recent epidemiologic analysis of recurrent injuries among US high school athletes.

CONCLUSION

High school sports participation continues to rise in the United States. To curb the incidence of new and recurrent injuries, additional attention must be paid to effective methods for injury prevention. This study described the epidemiology of recurrent injuries among US high school athletes participating in football, boys' and girls' soccer, volleyball, boys' and girls' basketball, wrestling, baseball, and softball, showing that recurrent injuries are most often ligament sprains (incomplete tears), muscle strains (incomplete tears), and concussions, and most frequently involve the ankle, knee, head/face, and shoulder. The potential for increased severity of recurrent injuries compared with new injuries makes it imperative that effective evidence-based targeted interventions are developed. Establishing measures to protect students from recurrent injuries should be an important part of any injury prevention program in high school sports.

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