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The Epidemiology of Ankle Sprains in US High School Sports, 2011–2012 to 2018–2019 Academic Years

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Context: Continued monitoring of ankle sprain rates and distributions is needed to assess temporal patterns and gauge how changes in incidence may be associated with prevention efforts.

Objective: To describe the epidemiology of ankle sprains in 16 US high school sports during the 2011–2012 to 2018–2019 school years.

Design: Descriptive epidemiology study.

Setting: Online injury surveillance from high school sports.

Patients or Other Participants: High school athletes who participated in practices and competitions during the 2011–2012 to 2018–2019 school years.

Main Outcome Measure(s): A convenience sample of high school athletic trainers provided injury and athlete-exposure (AE) data to the National High School Sports-Related Injury Surveillance Study (data provided by High School Reporting Information Online [HS RIO]). Ankle sprain rates per 10 000 AEs with 95% CIs and distributions were calculated. Yearly rates were examined overall and by event type, injury mechanism, and recurrence.

Results: Overall, 9320 ankle sprains were reported (overall rate = 2.95/10 000 AEs; 95% CI = 2.89, 3.01). The highest sport-specific rates were reported in girls' basketball (5.32/10 000 AEs), boys' basketball (5.13/10 000 AEs), girls' soccer (4.96/10 000 AEs), and boys' football (4.55/10 000 AEs). Most ankle sprains occurred during competition (54.3%) and were due to contact with another person (39.5%) or noncontact (35.0%). Also, 14.5% of injuries were recurrent. Across the included academic years, ankle sprain rates generally increased. Compared with the 2011–2012 academic year, rates in the 2018–2019 academic year overall were 22% higher; noncontact-related and recurrent ankle sprain rates also generally increased by 91% and 29%, respectively.

Conclusions: Time trends suggested that ankle sprain rates have increased across the past decade, particularly among those with noncontact-related mechanisms, contrasting with previous research that indicated decreases in incidence. These findings may pinpoint specific etiologic factors that should direct prevention efforts, including considering both person-contact and noncontact mechanisms by mitigating illegal contact through rule changes and enforcement, as well as bracing and proprioceptive and balance-training programs.

Key Words: youth sports, noncontact injuries, lower extremity injuries

Key Points

- The sports with the highest reported ankle sprain rates were girls' basketball (5.32/10 000 athlete-exposures [AEs]), boys' basketball (5.13/10 000 AEs), girls' soccer (4.96/10 000 AEs), and boys' football (4.55/10 000 AEs).
- Ankle sprain rates may have increased over the past decade, particularly for noncontact and recurrent injuries (91% and 29% increases, respectively, between 2011–2012 and 2018–2019).

Ankle sprains are one of most common injuries reported across the general population and in athletic and emergency room settings.[1–4] Although often perceived as a minor or acute injury, the potential effects of ankle sprains can be serious. Ankle sprains were associated with high reinjury rates and adverse outcomes, including chronic ankle instability, ankle joint degeneration, and posttraumatic osteoarthritis.[4–8] Further, such outcomes were associated with high medical costs.[9] Consequently, ankle sprains are a public health concern that requires the development of preventive and treatment measures.

Although much is known about the epidemiology, identification, diagnosis, and management of ankle sprains, it is nonetheless an evolving area of medicine. New scientific findings, best-practices documents, and consensus statements are published regularly and have focused on topics including mechanisms of injury, injury recurrence, and differences between men's and women's sports.[4,10–12] In particular, high school athletics is an important setting for examining ankle sprains given its large population that continues to grow annually. In the 2018–2019 academic year, approximately 7.9 million US high school athletes engaged in organized sports.[13] In addition, adolescents were identified as a high-risk group for ankle sprains.[4] Previous

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injury-surveillance efforts explored ankle sprains resulting from high school athletics.[1,3] For example, Swenson et al[1] found that ankle sprain rates were higher for girls than boys in sex-comparable sports and higher in competition than in practice. However, these studies were limited to data captured through the 2013–2014 academic year.[3]

Given the lack of recent epidemiologic evidence, an update to the surveillance-based literature is needed. First, it is important to consider the incidence, etiology, and prevention of such injuries, as posited by the van Mechelen et al[14] sequence of prevention framework. Second, the sequence of prevention framework also emphasized that injury prevention was a cyclical process that included the ongoing monitoring of injury incidence for longitudinal assessments.[14] Last, injury surveillance substantiated etiologic hypotheses that small sample studies could target for in-depth examination.[15] Thus, an update can help (1) provide contextual information (setting, mechanisms, etc) on ankle sprain incidences in high school sports, (2) examine longitudinal trends, and (3) highlight areas of need for future research and prevention.

As such, our aim was to update the epidemiology of ankle sprains sustained in high school sports. Specifically, we examined the rates and characteristics of ankle sprains across 16 high school sports, whether ankle sprain rates differed between sex-comparable sports, and how the rates of ankle sprains changed across the study period (2011–2012 to 2018–2019 academic years).

METHODS

Data originated from the National High School Sports-Related Injury Surveillance Study (High School Reporting Information Online [HS RIO]) during the 2011–2012 to 2018–2019 academic years. The methods of HS RIO have been previously described[16] but are summarized here. This research was deemed exempt by the Colorado Multiple Institutional Review Board (Aurora, CO).

Sample and Sports Included

High School Reporting Information Online relied on a sample of high schools with at least 1 athletic trainer (AT) who had a valid email address. Two data-collection groups were used in HS RIO, both of which were included in this study. The first group involved a random sample of approximately 100 high schools recruited annually from 8 strata based on cross-sections of school population (enrollment $\leq$1000 or $>$1000) and US census geographic region (Midwest, Northeast, South, West). If a school dropped out of the system, a replacement from the same stratum was selected. These schools collected data for 9 sports (boys' baseball, basketball, football, soccer, and wrestling and girls' basketball, soccer, softball, and volleyball). The second group was an additional convenience sample of high schools recruited annually. These schools reported data for additional sports (eg, boys' ice hockey, lacrosse, and track and field; girls' field hockey, lacrosse, and track and field; and coed cheerleading) and any of the original 9 sports. The ATs working in high schools in the first group could also provide data for these additional sports. We selected the sports included in the research—boys' baseball, basketball, football, ice hockey, lacrosse, soccer, track and field, and wrestling; girls' basketball, field hockey, lacrosse, soccer, softball, track and field, and volleyball; and coed cheerleading—as data were available across all 8 years of the study period (ie, 2011–2012 to 2018–2019 academic years), although participation varied by sport and year.

Data Collection

The ATs at participating high schools reported injury incidence and athlete-exposure (AE) information on a weekly basis using a secure website. An *AE* was defined as 1 athlete participating in 1 school-sanctioned practice or competition. Although certain injuries were reported in HS RIO regardless of participation-restriction time, our injury of focus, ankle sprain, was reported only if it resulted in participation-restriction time of $\geq$24 hours. Thus, the inclusion criteria for ankle sprains in this study were (1) occurring because of participation in a school-sanctioned practice or competition (including performance in cheerleading), (2) requiring medical attention by an AT or physician, (3) being diagnosed as a sprain, (4) occurring to the ankle, and (5) resulting in participation restriction of $\geq$24 hours.

For each injury, the AT completed a detailed injury report. Characteristics pertinent to this investigation were event type (competition, practice), time in season (preseason, in-season, postseason), participation-restriction time (ie, the number of days that injured athletes were withheld from some form of participation in their sports), injury mechanism, and recurrence (to the currently injured body part: *yes* or *no*). Participation-restriction time was categorized into $<$7 days, 7 to 21 days, or $>$21 days; participation-restriction time of $>$21 days was associated with injuries resulting in the athletes being medically disqualified, choosing not to continue, or being released from the team. Injury mechanism was categorized as contact with another person, contact with surface, contact with apparatus, noncontact (including acute or no contact and overuse or chronic), or other (including other, unknown, or missing). Recurrent ankle sprains were further classified as recurrent from the present academic year or recurrent from a previous academic year.

When an AT noted that an ankle sprain had occurred, HS RIO was automated to request additional information regarding the ligament(s) affected. The AT could select from 6 ligaments, which were then recoded into 3 groups, similar to those used in previous injury-surveillance studies[17,18]: (1) lateral ligament complex (LLC), consisting of the anterior talofibular, posterior talofibular, and calcaneofibular ligaments; (2) deltoid ligament; and (3) high ankle, consisting of the anterior tibiofibular and posterior tibiofibular ligaments. No formal definitions were provided for terminology beyond *injury* and *AE*. Rather, HS RIO relied on the expertise and extensive training of the participating ATs for the detection and diagnosis of ankle sprains and their related characteristics and mechanisms. Internal validity checks conducted by HS RIO staff—which used a 5% random sample of schools to compare data reported in HS RIO with deidentified health logs[19]—have consistently identified sensitivity, specificity, positive predictive value, and negative predictive value above 90%.[20]

Statistical Analyses

Data were analyzed using SAS (version 9.4; SAS Institute). First, we examined ankle sprain frequencies

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Table 1. Ankle Sprain Counts and Rates Among High School Student-Athletes in 16 Sports, 2011–2012 to 2018–2019 Academic Years

Sport	No. of Ankle Sprains			No. of AEs[a]			Rate per 10 000 AEs			Competition vs Practice Rate Ratio (95% CI)
	Overall	Competition	Practice	Overall	Competition	Practice	Overall	Competition	Practice	
Overall total	9320	5058	4262	31 548 302	8 403 565	23 144 737	2.95	6.02	1.84	3.27 (3.14, 3.40)
Boys-only sports										
Baseball	163	94	69	2 053 767	722 437	1 331 330	0.79	1.30	0.52	2.51 (1.84, 3.43)
Basketball	1414	700	714	2 757 235	840 611	1 916 624	5.13	8.33	3.73	2.24 (2.01, 2.48)
Football	2777	1623	1154	6 108 314	1 058 781	5 049 533	4.55	15.33	2.29	6.71 (6.22, 7.23)
Ice hockey	29	23	6	413 498	144 112	269 386	0.70	1.60	0.22	7.17 (2.92, 17.6)
Lacrosse	180	105	75	978 307	294 173	684 134	1.84	3.57	1.10	3.26 (2.42, 4.38)
Soccer	593	390	203	2 288 668	693 547	1 595 121	2.59	5.62	1.27	4.42 (3.73, 5.24)
Track and field	122	41	81	2 217 461	420 783	1 796 678	0.55	0.97	0.45	2.16 (1.48, 3.15)
Wrestling	274	106	168	1 868 542	479 481	1 389 061	1.47	2.21	1.21	1.83 (1.43, 2.33)
Girls-only sports										
Basketball	1117	628	489	2 098 628	650 345	1 448 283	5.32	9.66	3.38	2.86 (2.54, 3.22)
Field hockey	106	48	58	601 841	192 312	409 529	1.76	2.50	1.42	1.76 (1.20, 2.58)
Lacrosse	209	102	107	738 550	228 593	509 957	2.83	4.46	2.10	2.13 (1.62, 2.79)
Soccer	971	647	324	1 957 460	599 496	1 357 964	4.96	10.79	2.39	4.52 (3.96, 5.17)
Softball	256	141	115	1 513 115	524 889	988 226	1.69	2.69	1.16	2.31 (1.80, 2.95)
Track and field	179	60	119	1 868 505	353 922	1 514 583	0.96	1.70	0.79	2.16 (1.58, 2.94)
Volleyball	783	338	445	2 120 887	706 210	1 414 677	3.69	4.79	3.15	1.52 (1.32, 1.75)
Coed sport										
Cheerleading[b]	147	30	107	1 963 524	493 873	1 469 651	0.75	0.61	0.73	0.83 (0.56, 1.25)

Abbreviation: AEs, athlete-exposures.

[a] One athlete participating in 1 practice or 1 competition.

[b] Competition category also includes performance events for cheerleading.

and rates per 10 000 AEs with 95% CIs. Injury rate ratios (IRRs) compared ankle sprain rates by event type. We also determined the frequencies of ankle sprains sustained to multiple ligament areas (eg, LLC and high ankle). Distributions were assessed by participation-restriction time, injury mechanism, and recurrence.

Next, rates were compared between sex-comparable sports (ie, basketball, baseball and softball, soccer, track and field). Lacrosse was not considered a sex-comparable sport as the rules regarding contact vary between the boys' and girls' sports. Also, injury proportion ratios (IPRs) compared proportions between sex-comparable sports that were selected a priori, including by participation-restriction time ($<$7 days, $>$21 days, etc), injury mechanism (contact with another person, noncontact, etc), and recurrence (recurrent, nonrecurrent ankle sprains). When we found overall sex-comparable sport differences, we repeated the analysis for each pairing of sex-comparable sports.

Finally, yearly rates were computed and graphed. Given that annual changes were expected to be nonlinear in nature, in order to statistically evaluate the change in ankle sprain rates across the study period, we used IRRs to compare the rates in 2011–2012 and 2018–2019. Comparisons of interest were selected a priori and consisted of comparisons overall and by event type (competition, practice), specific ligament complexes (LLC, deltoid, high ankle, etc), participation-restriction time ($<$7 days, $>$21 days, etc), injury mechanism (contact with another person, noncontact, etc), and recurrence (recurrent, nonrecurrent).

Upon completion of all a priori analyses, we conducted additional analyses to compare the 2011–2012 and 2018–2019 rates overall in the 9 original sports used in HS RIO (boys' baseball, basketball, football, soccer, and wrestling and girls' basketball, soccer, softball, and volleyball) and the proportions of ankle sprains resulting in $<$7 days and $>$21 days between recurrent versus nonrecurrent ankle sprains across all sports combined. The IRRs and IPRs with 95% CIs excluding 1.00 were considered statistically significant. An example of an IRR comparing ankle sprain rates in competition and practice is

$$\mathrm{IRR} = \frac{\left(\frac{\text{Total Number of Competition Ankle Sprains}}{\sum_{i=1}^{j} \text{Number of Participating Athletes}}\right)}{\left(\frac{\text{Total Number of Practice Ankle Sprains}}{\sum_{i=1}^{k} \text{Number of Participating Athletes}}\right)}$$

where j denotes all reported competition exposure events and k denotes all reported practice exposure events.

An example of an IPR comparing the proportion of recurrent ankle sprains in girls and boys is

$$\mathrm{IPR} = \frac{\left(\frac{\text{Number of Recurrent Ankle Sprains in Girls}}{\text{Number of Ankle Sprains in Girls}}\right)}{\left(\frac{\text{Number of Recurrent Ankle Sprains in Boys}}{\text{Number of Ankle Sprains in Boys}}\right)}$$

RESULTS

Ankle Sprain Counts and Rates

During the 2011–2012 through 2018–2019 academic years, 9320 ankle sprains occurred across 31 548 302 AEs, for an overall injury rate of 2.95/10 000 AEs (Table 1). The largest proportion of ankle sprains came from boys' football (n = 2777/9320), but the highest rate was in girls' basketball (5.32/10 000 AEs), followed by boys' basketball (5.13/10 000 AEs), girls' soccer (4.96/10 000 AEs), and boys' football (4.55/10 000 AEs). Most ankle sprains occurred in-season (75.1%), followed by the preseason (21.0%), and postseason (3.9%); an additional 65 had missing information.

The majority of sprains were reported in competition (54.3%). Sports with the highest ankle sprain rates in competition were boys' football (15.33/10 000 AEs) and

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Table 2. Counts and Rates of Ankle Sprains, by Specific Ligament Areas Affected, Among High School Student-Athletes in 16 Sports, 2011–2012 Through 2018–2019 Academic Years

	Ankle Sprains, No.[a]				Ankle Sprains, Rate per 10 000 Athlete-Exposures[b]			
Sport	Total	LLC	Deltoid	High	Total	LLC	Deltoid	High
Overall total	9320	7941	647	2067	2.95	2.52	0.21	0.66
Boys-only sports								
Basketball	1414	1252	63	321	5.13	4.54	0.23	1.16
Football	2777	2212	253	704	4.55	3.62	0.41	1.15
Soccer	593	490	54	115	2.59	2.14	0.24	0.50
Lacrosse	180	148	18	38	1.84	1.51	0.18	0.39
Wrestling	274	227	21	67	1.47	1.21	0.11	0.36
Baseball	163	146	9	39	0.79	0.71	0.04	0.19
Ice hockey	29	18	5	13	0.70	0.44	0.12	0.31
Track and field	122	110	5	19	0.55	0.50	0.02	0.09
Girls-only sports								
Basketball	1117	1006	62	232	5.32	4.79	0.30	1.11
Soccer	971	842	72	183	4.96	4.30	0.37	0.93
Volleyball	783	712	35	149	3.69	3.36	0.17	0.70
Lacrosse	209	188	13	50	2.83	2.55	0.18	0.68
Field hockey	106	90	5	27	1.76	1.50	0.08	0.45
Softball	256	222	15	46	1.69	1.47	0.10	0.30
Track and field	179	153	10	32	0.96	0.82	0.05	0.17
Coed sport								
Cheerleading	147	125	7	32	0.75	0.64	0.04	0.16

Abbreviation: LLC, lateral ligament complex.

[a] Counts of LLC, deltoid, and high ankle sprains do not sum to ankle sprain counts as certain injury events had multiple ankle sprain injuries (eg, 7941 of the 9320 ankle sprains affected the LLC).

[b] Athlete-exposure = 1 athlete participating in 1 practice or 1 competition.

girls' soccer (10.77/10 000 AEs; Table 1). Sports with the highest ankle sprain rates in practice were boys' basketball (3.73/10 000 AEs) and girls' basketball (3.38/10 000 AEs). Across the 16 sports, the competition rate was higher than the practice rate (6.02 [competition] versus 1.84 [practice] per 10 000 AEs; IRR = 3.27; 95% CI = 3.14, 3.40); this was observed in each sport except cheerleading (IRR = 0.83; 95% CI = 0.56, 1.25).

Of the 9320 ankle sprains, 85.2% involved the LLC, followed by 22.2% to the high ankle and 6.9% to the deltoid (Table 2). Also, 15.6% of all ankle sprains affected more than 1 group of ligaments. The most common combination was the LLC and high ankle (12.6% of all injury events), followed by the LLC and deltoid (1.8%). As with overall rates, the highest LLC rates were in girls' basketball (4.79/10 000 AEs), boys' basketball (4.54/10 000 AEs), and girls' soccer (4.30/10 000 AEs; Table 2). For deltoid ligament ankle sprains, boys' football had the highest rate (0.41/10 000 AEs). For high ankle sprains, the highest rates were in boys' basketball (1.16/10 000 AEs), boys' football (1.15/10 000 AEs), and girls' basketball (1.11/10 000 AEs).

Participation-Restriction Time. Overall, 44.4% of ankle sprains resulted in <7 days of participation-restriction time (Table 3). In addition, 5.8% resulted in >21 days of participation-restriction time; included in these 538 ankle sprains were 72 resulting in medical disqualification, 61 in the athlete choosing not to continue, and 12 in the athlete being released from the team. Distributions of participation-restriction time varied by sport and by ligament injured. For example, compared with other types of ankle sprains, high ankle sprains had a lower proportion resulting in <7 days of participation-restriction time (33.5%) and a higher proportion resulting in >21 days of participation restriction time (9.5%).

Injury Mechanism. Overall, 39.5% and 35.0% of all ankle sprains were due to contact with another person and noncontact, respectively (Table 4). Sports with larger proportions of ankle sprains due to noncontact mechanisms were boys' lacrosse (62.8%), girls' lacrosse (60.3%), and girls' field hockey (68.9%). Sport-specific mechanisms and activities highlighted a variety of manners in which ankle sprains occurred (Table 5). For example, foot inversion was a common mechanism overall in boys' and girls' soccer, girls' field hockey, boys' and girls' lacrosse, and boys' and girls' track and field.

Recurrence of Ankle Sprains. Overall, 1350 (14.5%) of injuries were noted as recurrent, of which 39.6% were recurrent from the present academic year and 60.4% from previous academic years. The proportion of ankle sprains resulting in participation-restriction time of <7 days was higher for recurrent ankle sprains versus nonrecurrent ankle sprains (48.0% versus 43.9%, respectively; IPR = 1.09; 95% CI = 1.03, 1.16). However, the proportion resulting in participation-restriction time of >21 days did not differ (5.3% versus 5.9%, respectively; IPR = 0.90; 95% CI = 0.70, 1.15).

Comparisons Between Sex-Comparable Sports

Ankle Sprain Rates. Among sex-comparable sports (ie, basketball, baseball and softball, soccer, track and field), a higher rate of ankle sprains occurred in girls versus boys (3.39 versus 2.46, respectively, per 10 000 AEs; IRR = 1.38; 95% CI = 1.30, 1.46). When stratified by sport, similar IRRs were noted in soccer (4.96 versus 2.59, respectively, per 10 000 AEs; IRR = 1.91; 95% CI = 1.73, 2.12), softball or baseball (1.69 versus 0.79, respectively, per 10 000 AEs; IRR = 2.13; 95% CI = 1.75, 2.59), and track and field (0.96 versus 0.55, respectively, per 10 000

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Table 3. Counts of Ankle Sprains, by Participation-Restriction Time, Among High School Student-Athletes in 16 Sports, 2011–2012 Through 2018–2019 Academic Years

Sport	All Injury Events, No. (%)			
	<7 Days	7–21 Days	>21 Days[a]	Other[b]
Overall total	4141 (44.4)	3568 (38.3)	538 (5.8)	1073 (11.5)
Boys-only sports				
Basketball	646 (45.7)	546 (38.6)	79 (5.6)	143 (10.1)
Football	1288 (46.4)	1039 (37.4)	140 (5.0)	310 (11.2)
Soccer	277 (46.7)	221 (37.3)	32 (5.4)	63 (10.6)
Lacrosse	83 (46.1)	68 (37.8)	6 (3.3)	23 (12.8)
Wrestling	132 (48.2)	93 (33.9)	26 (9.5)	23 (8.4)
Baseball	71 (43.6)	60 (36.8)	12 (7.4)	20 (12.3)
Ice hockey	10 (34.5)	12 (41.4)	3 (10.3)	4 (13.8)
Track and field	50 (41.0)	50 (41.0)	7 (5.7)	15 (12.3)
Girls-only sports				
Basketball	507 (45.4)	405 (36.3)	57 (5.1)	148 (13.2)
Soccer	394 (40.6)	387 (39.9)	71 (7.3)	119 (12.3)
Volleyball	333 (42.5)	312 (39.8)	47 (6)	91 (11.6)
Lacrosse	91 (43.5)	82 (39.2)	12 (5.7)	24 (11.5)
Field hockey	52 (49.1)	47 (44.3)	0	7 (6.6)
Softball	99 (38.7)	100 (39.1)	21 (8.2)	36 (14.1)
Track and field	59 (33.0)	79 (44.1)	13 (7.3)	28 (15.6)
Coed sport				
Cheerleading	49 (33.3)	67 (45.6)	12 (8.2)	19 (12.9)
Specific ligament complex affected				
Lateral	3603 (45.4)	3035 (38.2)	437 (5.5)	866 (10.9)
Deltoid	251 (38.8)	255 (39.4)	49 (7.6)	92 (14.2)
High ankle	693 (33.5)	861 (41.7)	197 (9.5)	316 (15.3)

[a] Includes those ankle sprains resulting in the athletes being medically disqualified, choosing not to continue, or being released from the team.

[b] Includes other, missing, or those ankle sprains that ended the athletes' seasons before they could return to activity.

AEs; IRR = 1.74; 95% CI = 1.38, 2.19) but not in basketball (5.32 versus 5.13, respectively, per 10 000 AEs; IRR = 1.04; 95% CI = 0.96, 1.12). Findings in specific sex-comparable sport pairs were similar when stratified by event type (ie, competitions and practices).

Participation-Restriction Time. Among sex-comparable sports, the proportion of ankle sprains resulting in participation-restriction time of <7 days was higher in boys than in girls (45.5% versus 42.0%, respectively; IPR = 1.09; 95% CI = 1.02, 1.16). When stratified by sport, similar IRRs were seen in soccer (46.7% versus 40.6%, respectively; IPR = 1.15; 95% CI = 1.03, 1.29) but not in basketball (45.7% versus 45.4%, respectively; IPR = 1.01; 95% CI = 0.92, 1.10), softball or baseball (43.6% versus 38.7%, respectively; IPR = 1.13; 95% CI = 0.89, 1.42), or track and field (41.0% versus 33.0%, respectively; IPR = 1.24; 95% CI = 0.92, 1.68). The proportion of ankle sprains resulting in participation-restriction time of >21 days did not differ (5.7% versus 6.4%, respectively; IPR = 0.88; 95% CI = 0.71, 1.10).

Injury Mechanism. Among sex-comparable sports, the proportion of ankle sprains due to contact with another person was higher in boys than girls (39.7% versus 32.1%, respectively; IPR = 1.24; 95% CI = 1.15, 1.33). When stratified by sport, similar IRRs were found in basketball (46.0% versus 37.8%, respectively; IPR = 1.22; 95% CI = 1.11, 1.34) but not in soccer (40.1% versus 37.9%, respectively; IPR = 1.06; 95% CI = 0.93, 1.20), softball or baseball (8.6% versus 5.9%, respectively; IPR = 1.47; 95% CI = 0.73, 2.96), or track and field (4.9% versus 2.2%, respectively; IPR = 2.20; 95% CI = 0.63, 7.64).

Among sex-comparable sports, the proportion of ankle sprains due to noncontact mechanisms was higher in girls than in boys (38.1% versus 32.8%, respectively; IPR =

Table 4. Ankle Sprain Injuries, by Injury Mechanism, Among High School Student-Athletes in 16 Sports, 2011–2012 Through 2018–2019 Academic Years

Sport	Injury Mechanism, No. (%)[a]				
	Contact With Person	Contact With Surface	Contact With Apparatus	Noncontact	Other
Overall total	3677 (39.5)	1768 (19.0)	360 (3.9)	3265 (35.0)	250 (2.7)
Boys-only sports					
Basketball	651 (46.0)	280 (19.8)	5 (0.4)	447 (31.6)	31 (2.2)
Football	1392 (50.1)	380 (13.7)	22 (0.8)	898 (32.3)	85 (3.1)
Soccer	238 (40.1)	92 (15.5)	42 (7.1)	205 (34.6)	16 (2.7)
Lacrosse	25 (13.9)	27 (15.0)	7 (3.9)	113 (62.8)	8 (4.4)
Wrestling	116 (42.3)	63 (23.0)	2 (0.7)	82 (29.9)	11 (4.0)
Baseball	14 (8.6)	51 (31.3)	47 (28.8)	50 (30.7)	1 (0.6)
Ice hockey	11 (37.9)	8 (27.6)	4 (13.8)	5 (17.2)	1 (3.4)
Track and field	6 (4.9)	46 (37.7)	14 (11.5)	50 (41.0)	6 (4.9)
Girls-only sports					
Basketball	422 (37.8)	213 (19.1)	5 (0.4)	441 (39.5)	36 (3.2)
Soccer	368 (37.9)	162 (16.7)	68 (7.0)	346 (35.6)	27 (2.8)
Volleyball	357 (45.6)	189 (24.1)	32 (4.1)	200 (25.5)	5 (0.6)
Lacrosse	33 (15.8)	42 (20.1)	6 (2.9)	126 (60.3)	2 (1.0)
Field hockey	8 (7.5)	14 (13.2)	9 (8.5)	73 (68.9)	2 (1.9)
Softball	15 (5.9)	81 (31.6)	73 (28.5)	81 (31.6)	6 (2.3)
Track and field	4 (2.2)	54 (30.2)	21 (11.7)	94 (52.5)	6 (3.4)
Coed sport					
Cheerleading	17 (11.6)	66 (44.9)	3 (2.0)	54 (36.7)	7 (4.8)
Specific ligament complex affected					
Lateral	3045 (38.3)	1529 (19.3)	287 (3.6)	2882 (36.3)	198 (2.5)
Deltoid	319 (49.3)	103 (15.9)	43 (6.6)	164 (25.3)	18 (2.8)
High ankle	917 (44.4)	381 (18.4)	82 (4.0)	645 (31.2)	42 (2.0)

[a] *Noncontact* includes acute/no contact and overuse/chronic; *other* includes other, unknown, or missing.

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Table 5. Most Reported Specific Injury Mechanism and Activity Combinations for Ankle Sprain Injuries Among High School Student-Athletes in 16 Sports, 2011–2012 Through 2018–2019 Academic Years

Sport and Activity	No. (%)
Boys' football	
Being tackled during running play	454 (16.3)
Blocking during running play	250 (9.0)
Tackling during running play	213 (7.7)
Boys' soccer	
Foot inversion during general play	69 (11.6)
Foot inversion while defending	34 (5.7)
Foot inversion while handling ball	30 (5.1)
Girls' soccer	
Foot inversion during general play	91 (9.4)
Foot inversion while defending	59 (6.1)
Foot inversion while handling ball	50 (5.2)
Girls' volleyball	
Jumping and landing while blocking	129 (16.5)
Contact with teammate while blocking	116 (14.8)
Contact with opponent while blocking	62 (7.9)
Boys' basketball	
Jumping and landing while rebounding	330 (23.3)
Jumping and landing while shooting	104 (7.4)
Foot inversion during general play	83 (5.9)
Girls' basketball	
Jumping and landing while rebounding	170 (15.2)
Foot inversion during general play	116 (10.4)
Foot inversion while defending	71 (6.4)
Boys' wrestling	
Takedown	91 (33.2)
Sparring	49 (17.9)
Conditioning	21 (7.7)
Boys' ice hockey	
Foot inversion while chasing loose puck	5 (17.4)
Contacts with boards or glass while skating	3 (10.3)
Boys' baseball	
Contact with bases while running bases	41 (25.2)
Foot inversion while running bases	14 (8.6)
Foot inversion while fielding batted ball	13 (8.0)
Girls' softball	
Contact with bases while running bases	62 (24.2)
Contact with bases while sliding	38 (14.8)
Foot inversion while running bases	28 (10.9)
Girls' field hockey	
Foot inversion during general play	23 (21.7)
Foot inversion while defending	11 (10.4)
Foot inversion while chasing loose ball	8 (7.6)
Boys' lacrosse	
Foot inversion while defending	22 (12.2)
Foot inversion during general play	22 (12.2)
Foot inversion while chasing loose ball	16 (8.9)
Girls' lacrosse	
Foot inversion during general play	40 (19.1)
Foot inversion while defending	20 (9.6)
Foot inversion while handling or cradling ball	17 (8.1)
Boys' track and field	
Foot inversion while running	18 (14.8)
Foot inversion while jumping and landing	13 (10.7)
Fall or trip while running	12 (9.8)
Girls' track and field	
Foot inversion while running	27 (15.1)
Foot inversion while jumping and landing	19 (10.6)
Ground contact while jumping and landing	15 (8.4)
Cheerleading	
Ground contact during partner stunt	17 (11.6)
Ground contact during moving tumble[a]	15 (10.2)
Ground contact during standing tumble[b]	14 (9.5)

[a] Round-off back handspring, series of flips or twists or both.
[b] Stationary flips, back handsprings.

1.16; 95% CI = 1.08, 1.25). When stratified by sport, IRRs were similar in basketball (39.5% versus 31.6%, respectively; IPR = 1.25; 95% CI = 1.12, 1.39) but not in soccer (35.6% versus 34.6%, respectively; IPR = 1.03; 95% CI = 0.90, 1.18), softball or baseball (31.6% versus 30.7%, respectively; IPR = 1.03; 95% CI = 0.77, 1.38), or track and field (52.5% versus 41.0%, respectively; IPR = 1.28; 95% CI = 0.99, 1.65).

Recurrence of Ankle Sprains. Among sex-comparable sports, the proportion of recurrent ankle sprains did not differ between girls and boys (16.8% versus 15.6%, respectively; IPR = 1.08; 95% CI = 0.95, 1.22).

Annual Changes Across Study Period

Overall and by Event Type. Across the academic years included in the study period, ankle sprain rates generally increased overall, although this appeared to be mostly attributable to competition injuries (Figure, part A). Rates in the 2018–2019 academic year were higher overall compared with rates in the 2011–2012 academic year (3.21 versus 2.64, respectively, per 10 000 AEs; IRR = 1.22; 95% CI = 1.11, 1.33) and in competitions (6.74 versus 5.05, respectively, per 10 000 AEs; IRR = 1.34; 95% CI = 1.18, 1.51) but not in practices (1.90 versus 1.77, respectively, per 10 000 AEs; IRR = 1.07; 95% CI = 0.94, 1.22). Also, when considering only the 9 original sports from which data were collected in HS RIO (boys' baseball, basketball, football, soccer, and wrestling and girls' basketball, soccer, softball, and volleyball), overall ankle sprain rates increased 24% across the study period (3.95 [2018–2019 academic year] versus 3.18 [2011–2012 academic year] per 10 000 AEs; IRR = 1.24; 95% CI = 1.13, 1.36).

When examined by specific ligament complexes injured, ankle sprain rates generally increased (Figure, part B). Compared with rates in the 2011–2012 academic year, rates in the 2018–2019 academic year were higher for LLC injuries (2.77 versus 2.26, respectively, per 10 000 AEs; IRR = 1.23; 95% CI = 1.12, 1.35) and high ankle sprains (0.63 versus 0.50, respectively, per 10 000 AEs; IRR = 1.25; 95% CI = 1.02, 1.53) but not for deltoid ligament complex injuries (0.21 versus 0.18, respectively, per 10 000 AEs; IRR = 1.16; 95% CI = 0.83, 1.63).

Injury Mechanism. Across the studied academic years, rates of ankle sprains from contact with another person were rather consistent from 2011–2012 to 2016–2017, followed by an increase in 2017–2018 and decrease in 2018–2019 (Figure, part C). Rates in the 2011–2012 and 2018–2019 academic years did not differ (1.24 versus 1.10, respectively, per 10 000 AEs; IRR = 1.13; 95% CI = 0.98, 1.30). In contrast, noncontact-related ankle sprains generally increased. Compared with the rate in the 2011–2012 academic year, the rate in 2018–2019 was higher (IRR = 1.91; 95% CI = 1.63, 2.24).

Participation-Restriction Time. Across the academic years in the study period, ankle sprain rates generally increased. Compared with rates in the 2011–2012 academic year, rates in the 2018–2019 academic year were higher for ankle sprains resulting in participation-restriction time of <7 days (1.44 [2018–2019 academic year] versus 1.18 [2011–2012 academic year] per 10 000 AEs; IRR = 1.21; 95% CI = 1.06, 1.38) but not for those resulting in >21

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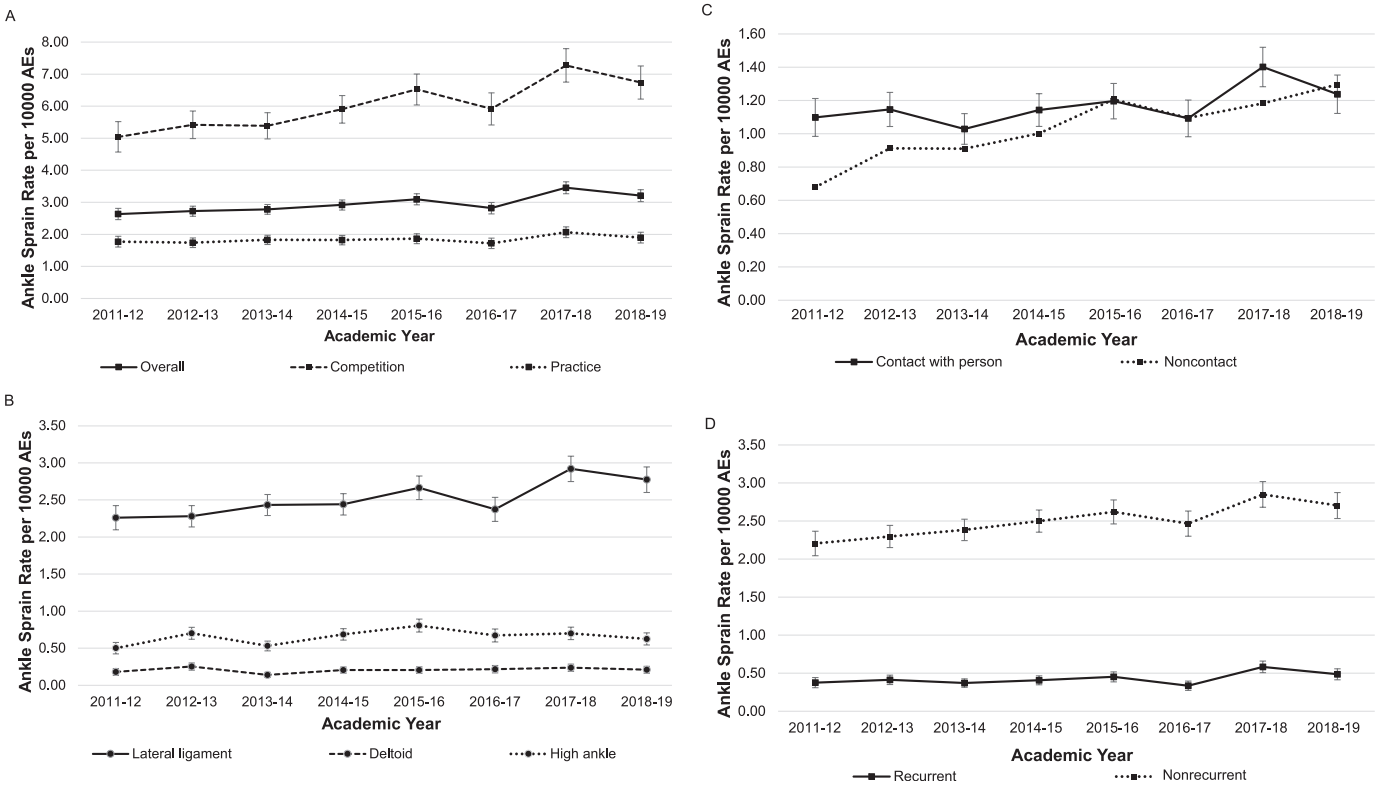

Figure. Yearly ankle sprain rates among high school student-athletes in 16 sports, by A, event type; B, ankle sprain type; C, injury mechanism; and D, injury recurrence, 2011–2012 through 2018–2019 academic years. Error bars represent 95% CIs. Abbreviation: AE, athlete-exposure.

days (0.18 versus 0.14, respectively, per 10 000 AEs; IRR = 1.28; 95% CI = 0.87, 1.87).

Recurrence of Ankle Sprains. Across the study period, recurrent and nonrecurrent ankle sprain rates increased (Figure, part D). Compared with rates in the 2011–2012 academic year, rates in the 2018–2019 academic year were higher for recurrent (0.49 [2018–2019 academic year] versus 0.38 [2011–2012 academic year] per 10 000 AEs; IRR = 1.29; 95% CI = 1.03, 1.63) and nonrecurrent ankle sprains (2.70 versus 2.21, respectively, per 10 000 AEs; IRR = 1.23; 95% CI = 1.11, 1.35).

DISCUSSION

In this investigation, we updated the epidemiologic information on ankle sprains sustained during participation in high school athletics; the most recently published epidemiologic data from a large dataset were nearly a decade old.[1,3] Distribution patterns of injuries were similar to those in the previous literature, with the highest rates occurring in basketball, football, and soccer.[1,3] However, time trends suggested that the rate of ankle sprains across the past decade increased. These findings, coupled with the studies describing the adverse outcomes (eg, chronic ankle instability, ankle joint degeneration, posttraumatic osteoarthritis) and medical costs associated with ankle sprains,[4–9] highlight the need for research and clinical care to aid the development, implementation, and evaluation of preventive and treatment measures that can reduce the incidence and severity of such injuries.[15]

We examined 16 sports, whereas previous authors[1] provided complete data for only the 9 original sports in HS RIO (boys' baseball, basketball, football, soccer, and wrestling and girls' basketball, soccer, softball, and volleyball). The increase in the rate of ankle sprains contrasts with prior surveillance research that demonstrated decreases across the 2005–2006 to 2010–2011 academic years.[1] However, the injury rates we found did not exceed the higher injury rates reported previously.[1] Such trends may be due to variations in sampling across data-collection efforts in each academic year. Nevertheless, it is imperative to ensure that the rates do not return to peaks noted earlier. With nearly 8 million high school athletes in the United States[13] and a previous investigation[4] having identified adolescents as a high-risk group for ankle sprains, the implementation of preventive and treatment measures is essential.

Our findings also indicated increases for specific types of ankle sprains (such as competition-related or noncontact ankle sprains) that exceeded the increase among all ankle sprains (22% increase in 2018–2019 versus 2011–2012). More specifically, the rate of competition-related ankle sprains was 34% higher and the rate of noncontact ankle sprains was 91% higher in 2018–2019 compared with 2011–2012. It is important to note that while these relative changes are striking, the absolute changes in ankle sprain rates may be less clinically meaningful (eg, increases of 1.69 competition and 0.62 noncontact-related ankle sprains per 10 000 AEs across 8 academic years). Still, these results may indicate that individuals who sustain an ankle sprain with such characteristics (eg, due to noncontact-related mechanisms) may require attention in terms of the continued development, implementation, and evaluation of injury-prevention interventions to ensure that such increases in incidence can be mitigated.

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In addition to these time trends, sport-specific variations also existed. Overall, basketball, soccer, and football had the highest ankle sprain rates, although ankle sprains were documented in all 16 sports. Differences between sex-comparable sports were also present, with higher rates in girls than in boys, which contrasts with earlier research[1,21] noting a lack of sex-based differences. Further, most ankle sprains were due to mechanisms related to player contact as well as noncontact, including foot inversion, which have been identified as a specific mechanism of interest.[21] In particular, among sex-comparable sports, the proportion of ankle sprains due to noncontact mechanisms was higher in girls than in boys. As reflected in best practice and consensus statements,[4,10–12] general preventive strategies are available, including bracing and taping. Proprioceptive, neuromuscular, and balance-training programs have also been effective in reducing the incidence of ankle sprains.[22–24] At the same time, our findings highlighted that although ankle sprain prevention strategies were essential for all participants regardless of sex,[21] tailoring such programming to be sport specific and sex specific may be beneficial. For example, the authors[24] of a recent systematic review observed that neuromuscular training was particularly effective in reducing noncontact ankle sprains in women. Prevention programming is also needed to mitigate contact-related injuries,[18] with a specific focus on rule changes or enforcement that addresses illegal contact.[25] This is of utmost concern in a setting such as high school athletics, where participants engage in skill development.[1]

Nearly half of all ankle sprains (44.4%) resulted in participation-restriction time of <7 days. About 5.8% of all ankle sprains restricted participation for >21 days, with nearly 1 in 10 high ankle sprains requiring >21 days (9.5%). This aligns with previous research in high school and collegiate athletics.[1,18] It is important to note that HS RIO only included ankle sprains resulting in participation-restriction time of ≥ 24 hours (ie, *time-loss injuries*). In high school and collegiate athletics, substantial proportions of ankle sprains were *non–time loss* (ie, participation-restriction time of <24 hours).[5,17,18] Thus, our findings may underrepresent the actual burden of ankle sprain injuries.

In addition, our estimate that 15% of ankle sprains were recurrent was on the low end compared with previous estimates (12%–47%)[26–28] and likely reflected the HS RIO methods.[16] It is possible that many recurrent injuries were non–time loss and therefore missed in this analysis, as HS RIO does not collect data on non–time-loss ankle sprains. This may be substantiated by our finding that compared with nonrecurrent ankle sprains, a higher proportion of recurrent ankle sprains required participation-restriction time of <7 days. Earlier data[5] supported this concern about rapid return-to-play times for recurrent ankle sprains. As a result, although we urge caution in interpreting our estimate of recurrent ankle sprains, further investigation of strategies is needed to ensure that sufficient participation-restriction time is granted for recurrent ankle sprains in order to mitigate the risk of long-term adverse outcomes.

Limitations

First, only data from high schools with ATs were included. Hence, the study findings may not be generalizable to all high schools, particularly those without AT access.[29] Second, we could not account for underreporting, misdiagnosis, or misclassification of ankle sprains and their characteristics. However, the injuries were assessed and documented by ATs, who are trained to accurately detect and diagnose injuries. Further, previous researchers[30] found that ATs displayed high agreement with physicians in diagnosing injuries. Nonetheless, although injury-surveillance programs such as HS RIO strive for standardization through their definitions and codebook descriptions, such data were vulnerable to variability among ATs in reporting. Third, HS RIO did not collect data on non–time-loss ankle sprains and thus may have underestimated the true incidence of ankle sprains occurring in high school athletics. Fourth, we did not consider additional injuries that may have occurred concurrently with the reported ankle sprains (eg, 5th metatarsal fracture), which may have affected injury-related outcomes such as participation-restriction time. Fifth, this study could not account for additional factors that may be associated with the incidence and distribution of ankle sprains, such as variations in the implementation of injury-prevention programs at each high school and in the characteristics of participating athletes, such as maturation status and biomechanics. Sixth, it is also important to recognize that some comparisons were conducted with smaller sample sizes, which may have hindered our ability to detect statistically significant differences. Finally, we calculated at-risk exposure using AEs, as opposed to potentially more precise metrics such as minutes and hours. Nonetheless, time-based exposure data may be too laborious and burdensome for ATs in high school athletics, particularly when the number of medical staff available to cover all school-sanctioned sports is limited.

CONCLUSIONS

As previous investigators[4] had identified adolescents as a high-risk group for ankle sprains, the examination of ankle sprains in high school athletics is important for identifying injury-prevention needs. Although patterns in the distribution of ankle sprains were similar to earlier findings,[1,3] the rate of ankle sprains across the past decade increased, particularly for those due to non-contact-related mechanisms. Efforts are needed to reduce the incidence of ankle sprains, including a focus on rule changes or enforcement to ensure the proper skill development occurs in high school athletes. Our results from large-scale surveillance data can inform future studies that may allow for more in-depth examinations[15] and, therefore, allow for the development, implementation, and evaluation of preventive and treatment measures.

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efforts are greatly appreciated and have had a tremendously positive effect on the safety of high school student-athletes.

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