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An Epidemiologic Comparison of High School Sports Injuries Sustained in Practice and Competition

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Context: More than 7 million US high school students play sports.

Objective: To compare practice and competition injury rates and patterns in 5 boys' sports (football, soccer, basketball, wrestling, and baseball) and 4 girls' sports (soccer, volleyball, basketball, and softball) during the 2005–2006 school year.

Design: Prospective injury surveillance study.

Setting: Injury data were collected from 100 nationally representative United States high schools via High School RIO (Reporting Information Online).

Patients or Other Participants: Athletes from participating high schools injured while participating in a school-sanctioned practice or competition in one of the above sports.

Main Outcome Measure(s): Practice and competition injury rates, body site, diagnosis, and severity.

Results: High school athletes participating in these 9 sports at participating schools sustained 4350 injuries during the 2005–2006 school year, which corresponds to an estimated 1 442 533 injuries nationally. The rate of injury per 1000 athlete-exposures was higher in competition (4.63) than in practice (1.69) (rate ratio [RR] = 2.73, 95% confidence interval [CI] = 2.58, 2.90). Of all sports, football had the highest competition (12.09) and practice (2.54) injury rates per 1000 athlete-exposures. Compared with injuries sustained during practice, higher proportions of competition injuries were head/face/neck injuries (proportion ratio [PR] = 1.61, 95% CI = 1.34, 1.94), particularly in boys' soccer (PR = 7.74, 95% CI = 2.53, 23.65) and girls' basketball (PR = 6.03, 95% CI = 2.39, 15.22). Competition injuries were more likely to be concussions (PR = 2.02, 95% CI = 1.56, 2.62), especially in boys' soccer (PR = 6.94, 95% CI = 2.01, 23.95) and girls' basketball (PR = 5.83, 95% CI = 2.06, 16.49). Higher proportions of competition injuries caused the athlete to miss more than 3 weeks of play (PR = 1.28, 95% CI = 1.08, 1.52), particularly in baseball (PR = 3.47, 95% CI = 1.48, 8.11) and volleyball (PR = 2.88, 95% CI = 1.01, 8.24).

Conclusions: Rates and patterns of high school sport injuries differed between practice and competition. Providing athletic trainers with this information is a crucial step in developing the targeted, evidence-based interventions required to effectively reduce injury rates among the millions of high school student-athletes.

Key Words: injury surveillance, injury rates

Key Points

- Among a representative sample of United States high schools, competitions resulted in higher injury rates and greater proportions of head/face/neck injuries, concussions, and severe injuries than practices did.
- Sprains/strains and lower extremity injuries accounted for the majority of all injuries, regardless of sport or setting.
- Continued surveillance is warranted to monitor changes in practice and competition injury rates over time and to assess the effects of future interventions.

After a 16.1% participation increase during the past decade, more than 7 million United States high school athletes competed in interscholastic sports during the 2005–2006 school year, with highest participation in football and basketball.[1] Interscholastic sports play a key role in the successful development of students, being specifically linked to higher grade point averages, fewer school absences, and better behavior.[2] However, sport participation can lead to injury. Although the rate of high school sport injuries appears to have decreased in the past decade,[3,4] more than 1.4 million injuries were sustained by high school athletes during the 2005–2006 school year.[3] Comparing sport-, sex-, and exposure-specific patterns of injuries occurring in high school athletes can provide certified athletic trainers (ATs) with the scientifically based evidence needed to make effective, targeted recommendations for injury prevention.

Several research studies exist on the epidemiology of US high school athletic injuries, many focusing on only one sport[5–12] or one particular type of injury.[13–21] Although these studies are important for educating medical professionals, coaches, athletes, and parents in specific disciplines, they cannot describe injury patterns across a range of high school sports. No group has completed a longitudinal study comparing patterns of practice and competition injuries across a variety of boys' and girls' sports in a nationally representative sample of high schools. Authors of 2 comprehensive studies followed a large number of high school athletes participating in a variety of sports prospectively through 1 or more seasons, but neither group compared patterns of practice and competition injuries.[4,22] Additionally, these studies were either conducted a decade ago[4] or were limited in geographic location.[22]

Our objective was to compare the epidemiology of practice and competition injuries in high school athletes participating in 5 boys' sports (football, soccer, basketball, wrestling, and baseball) and 4 girls' sports (soccer, volleyball, basketball, and softball). For these 9 sports, the specific aims were to (1) calculate rates of high school

practice and competition injuries, (2) describe the body site, diagnosis, and severity of practice and competition injuries, and (3) compare body site, diagnosis, and severity of injury between practice and competition.

METHODS

High School RIO (Reporting Information Online, The Research Institute at Nationwide Children's Hospital, Columbus, OH), an Internet-based injury surveillance system collecting injury and exposure data for high school athletes participating in 5 boys' sports (football, soccer, basketball, wrestling, and baseball) and 4 girls' sports (soccer, volleyball, basketball, and softball) during the 2005–2006 school year, has been described in detail previously.[3] Briefly, all eligible schools (ie, all US high schools with an AT affiliated with the National Athletic Trainers' Association [NATA] willing to serve as a reporter) were categorized by US Census geographic location[23] (northeast, midwest, south, and west) and high school size (enrollment $\leq$1000 or $>$1000 students). Schools were then randomly selected from each substratum to obtain 100 study schools. A weighting algorithm based on the inverse probability of participant schools' selection into the study (based on US Census geographic location and high school size) was then applied to individual case counts in order to calculate national injury estimates. If a school dropped out of the study, another school was randomly selected from the same substratum for replacement. The ATs at participating schools reported injury and exposure data weekly through the High School RIO Web site.

An *athlete-exposure* (AE) was defined as 1 athlete participating in 1 practice or competition. An *injury* was defined as a condition meeting the following 3 criteria: (1) occurred as a result of participation in an organized high school practice or competition, (2) required medical attention by an AT or physician, and (3) resulted in restriction of the student-athlete's participation for 1 day or more beyond the day of injury. The ATs completed injury reports, which included athlete demographics (eg, age, weight, year in school), the circumstances surrounding the injury event (eg, mechanism, time in practice or competition, position played), and characteristics of the injury (eg, body site, diagnosis, severity). For each injury, ATs were able to view and update submitted injury reports as needed throughout the study period.

Data were analyzed using SPSS software (version 14.0; SPSS Inc, Chicago, IL) and Epi Info (version 6.0; Centers for Disease Control and Prevention, Atlanta, GA). The SPSS Complex Samples module rounds some numbers to the nearest even digit (rather than to the nearest digit) for statistical reasons. Injury rates were expressed as the ratio of unweighted injury counts per 1000 AEs. All other injury analyses utilized national estimates, with the standard errors for comparisons between high school practices and competitions adjusted for the High School RIO sampling plan using the SPSS Complex Samples module. Rate ratios (RRs) and proportion ratios (PRs) were calculated with 95% confidence intervals (CIs). An RR or PR $>$1.00 suggests a risk association, whereas an RR or PR $<$1.00 suggests a protective association. All CIs not including 1.00 were considered statistically significant. For example, the calculation comparing the overall rate of injury between competition and practice is as follows:

$$\begin{aligned}\text{RR} = &[(\text{No. of competition injuries}/\\ &\text{No. of competition AEs}) \times 1000]\\ &\div [(\text{No. of practice injuries}/\\ &\text{No. of practice AEs}) \times 1000]\end{aligned}$$

As an example of PR calculation, the following compares the proportion of concussions between competition and practice:

$$\begin{aligned}\text{PR} = &[(\text{National estimated No. of competition}\\ &\text{concussions/national estimated No. of}\\ &\text{total competition injuries})]\\ &\div [(\text{National estimated No. of practice}\\ &\text{concussions/national estimated No.}\\ &\text{of total practice injuries})]\end{aligned}$$

We were granted a waiver of the informed consent/assent requirement under the Institutional Review Board Latitude to Approve a Consent Procedure that Alters or Waives Some or All of the Elements of Consent, §46.116. This study was approved by the Institutional Review Board at The Research Institute at Nationwide Children's Hospital.

RESULTS

Injury Rates

During the 2005–2006 school year, athletes participating in 5 boys' sports (football, soccer, basketball, wrestling, and baseball) and 4 girls' sports (soccer, volleyball, basketball, and softball) at a nationally representative sample of 100 high schools sustained 4350 injuries (2110 in practice and 2240 in competition). As seen in Table 1, these injuries occurred during 1 730 764 AEs (1 246 499 practice AEs and 484 265 competition AEs), resulting in a total injury rate of 2.51 injuries per 1000 AEs. The rate of injury per 1000 AEs was higher in competition (4.63) than in practice (1.69) (RR = 2.73, 95% CI = 2.58, 2.90). In practice, the highest rate of injury per 1000 AEs occurred in football (2.54), followed by wrestling (2.04) and boys' soccer (1.58). In competition, the highest rate of injury per 1000 AEs occurred in football (12.09), followed by girls' (5.21) and boys' (4.22) soccer. The 4350 reported injuries represent an estimated 1 442 533 injuries (683 199 in practice and 759 334 in competition) sustained by high school athletes participating in these 9 sports nationally.

Body Site of Injury by Type of Exposure

Most injuries affected the lower extremities (n = 817 944, 57.2%) or upper extremities (n = 307 837, 21.5%), followed by the head/face/neck (n = 208 348, 14.6%) and trunk (n = 95 294, 6.7%). Specifically, the most frequently injured body sites were the ankle (n = 324 969, 22.7%), the head/face (n = 176 673, 12.3%) and the thigh/upper leg (n = 114 721, 8.0%). Injuries to the lower extremities were most

Table 1. Practice and Competition Injury Rates, High School Sport-Related Injury Surveillance Study, United States, 2005–2006 School Year

Sport	Injuries		Exposures		Rate of Injury (per 1000 Athlete-Exposures)	Rate Ratio[a] (95% Confidence Interval)
	No.	Percentage	No.	Percentage		
Overall	4350		1 730 764		2.51	
Practice	2110	48.5	1 246 499	72.0	1.69	
Competition	2240	51.5	484 265	28.0	4.63	2.73 (2.58, 2.90)
Boys' sports	3293		1148 698		2.87	
Practice	1638	49.7	851 591	74.1	1.92	
Competition	1655	50.3	297 107	25.9	5.57	2.90 (2.71, 3.10)
Football	1880		431 242		4.36	
Practice	888	47.2	349 183	81.0	2.54	
Competition	992	52.8	82 059	19.0	12.09	4.75 (4.34, 5.20)
Soccer	372		153 400		2.43	
Practice	164	44.1	104 106	67.9	1.58	
Competition	208	55.9	49 294	32.1	4.22	2.68 (2.18, 3.29)
Basketball	412		218 342		1.89	
Practice	228	55.3	156 679	71.8	1.46	
Competition	184	44.7	61 663	28.2	2.98	2.05 (1.69, 2.49)
Wrestling	415		166 279		2.50	
Practice	257	61.9	126 059	75.8	2.04	
Competition	158	38.1	40 220	24.2	3.93	1.93 (1.58, 2.35)
Baseball	214		179 435		1.19	
Practice	101	47.2	115 564	64.4	0.87	
Competition	113	52.8	63 871	35.6	1.77	2.02 (1.55, 2.65)
Girls' sports	1057		582 066		1.82	
Practice	472	44.7	394 908	67.8	1.20	
Competition	585	55.3	187 158	32.2	3.13	2.62 (2.32, 2.95)
Soccer	334		141 581		2.36	
Practice	108	32.3	98 166	69.3	1.10	
Competition	226	67.7	43 415	30.7	5.21	4.73 (3.76, 5.95)
Volleyball	196		119 235		1.64	
Practice	112	57.1	75 544	63.4	1.48	
Competition	84	42.9	43 691	36.6	1.92	1.30 (0.98, 1.72)
Basketball	374		186 161		2.01	
Practice	182	48.7	132 836	71.4	1.37	
Competition	192	51.3	53 325	28.6	3.60	2.63 (2.15, 3.22)
Softball	153		135 089		1.13	
Practice	70	45.8	88 362	65.4	0.79	
Competition	83	54.2	46 727	34.6	1.78	2.24 (1.63, 3.08)

[a] Practice is used as referent group.

common in boys' (n = 164 694, 75.7%) and girls' (n = 133 908, 73.2%) soccer, injuries to upper extremities were most common in baseball (n = 28 758, 43.3%) and wrestling (n = 39 995, 38.2%), injuries to the head/face/neck were most common in softball (n = 12 266, 19.5%) and wrestling (n = 19 791, 18.9%), and injuries to the trunk were most common in volleyball (n = 10 108, 12.5%) and wrestling (n = 12 623, 12.0%).

Body site injured by sport and type of exposure is displayed in Table 2. Lower extremity injuries occurred in similar proportions among practice (n = 400 236, 59.3%) and competition (n = 417 708, 55.4%) injuries (PR = 1.07, 95% CI = 1.00, 1.14). The largest difference was seen in boys' soccer, in which lower extremity injuries accounted for a larger proportion of injuries in practice (n = 86 851, 88.6%) compared with competition (n = 77 843, 65.1%) (PR = 1.36, 95% CI = 1.19, 1.56). Conversely, although statistically insignificant, lower extremity injuries made up a greater proportion of competition injuries in baseball (n = 13 835, 41.2%, and n = 9503, 29.0%, respectively) (PR = 1.42, 95% CI = 0.92, 2.21) and softball (n = 16 995, 49.1%, and n = 9928, 35.0%, respectively) (PR = 1.40, 95% CI = 0.85, 2.32).

Similar proportions of upper extremity injuries were sustained in practice (n = 151 763, 22.5%) and competition (n = 156 074, 20.7%) (PR = 1.09, 95% CI = 0.95, 1.24). The largest difference was seen in girls' basketball, where upper extremity injuries made up a greater proportion of practice injuries (n = 7223, 14.6%) compared with competition (n = 3514, 6.6%) (PR = 2.21, 95% CI = 1.13, 4.31). This trend was not seen in boys' basketball, in which similar proportions of practice (n = 7919, 14.5%) and competition (n = 6633, 14.8%) injuries were to the upper extremities. Conversely, although statistically insignificant, larger proportions of upper extremity injuries constituted competition injuries in boys' (n = 10 081, 8.4%, and n = 4948, 5.1%, respectively) (PR = 1.67, 95% CI = 0.64, 4.35) and girls' (n = 7536, 6.3%, and n = 3069, 4.9%, respectively) (PR = 1.28, 95% CI = 0.41, 4.06) soccer.

Compared with injuries sustained during practice (n = 74 552, 11.0%), a higher proportion of competition injuries were to the head/face/neck (n = 133 796, 17.7%) (PR = 1.61,

Table 2. Body Sites of Practice and Competition Injuries by Sport, High School Sport-Related Injury Surveillance Study, United States, 2005–2006 School Year

	Boys' Sports					Girls' Sports			
	Football	Soccer	Basketball	Wrestling	Baseball	Soccer	Volleyball	Basketball	Softball
National estimate[a]									
Practice, n	231 782	98 015	54 765	68 772	32 814	62 745	48 637	49 606	28 358
Competition, n	279 560	119 601	44 826	36 006	33 542	120 168	32 289	53 343	34 591
Lower extremities									
Practice, %	48.3	88.6	69.6	31.6	29.0	80.9	66.8	78.4	35.0
Competition, %	46.8	65.1	66.2	29.4	41.2	69.2	61.8	65.5	49.1
Injury PR[b]	0.97	0.74	0.95	0.93	1.42	0.85	0.93	0.84	1.40
95% CI	0.87, 1.08	0.64, 0.84	0.81, 1.12	0.64, 1.35	0.92, 2.21	0.73, 1.00	0.71, 1.22	0.72, 0.98	0.85, 2.32
Upper extremities									
Practice, %	29.0	5.1	14.5	37.0	47.6	4.9	18.1	14.6	40.7
Competition, %	29.7	8.4	14.8	40.5	39.2	6.3	19.9	6.6	32.3
Injury PR	1.02	1.67	1.02	1.10	0.82	1.28	1.10	0.45	0.79
95% CI	0.87, 1.21	0.64, 4.35	0.59, 1.79	0.80, 1.49	0.57, 1.20	0.41, 4.06	0.53, 2.28	0.23, 0.88	0.46, 1.38
Head/face/neck									
Practice, %	14.0	2.5	9.9	19.4	12.6	10.2	4.3	3.9	22.4
Competition, %	17.1	19.7	13.0	17.9	15.6	21.1	3.4	23.4	17.1
Injury PR	1.23	7.74	1.31	0.92	1.24	2.07	0.81	6.03	0.77
95% CI	0.96, 1.57	2.53, 23.65	0.68, 2.53	0.55, 1.53	0.55, 2.77	0.94, 4.57	0.19, 3.48	2.39, 15.22	0.33, 1.76
Trunk									
Practice, %	8.7	3.8	6.0	12.0	10.9	4.0	10.9	3.1	1.9
Competition, %	6.4	6.8	6.0	12.2	3.9	3.4	14.9	4.5	1.5
Injury PR	0.74	1.79	0.99	1.02	0.36	.86	1.36	1.44	0.79
95% CI	0.52, 1.06	0.58, 5.51	0.41, 2.44	0.54, 1.94	0.07, 1.76	0.20, 3.64	0.52, 3.56	0.48, 4.28	0.07, 8.91

Abbreviations: PR, proportion ratio; CI, confidence interval.
[a] These frequencies do not sum to the total national injury estimate because a few injury reports did not specify body site of injury.
[b] Practice is used as referent group.

95% CI = 1.34, 1.94). Specifically, competition injuries were more likely to be head/face/neck injuries than practice injuries in boys' soccer (n = 23 574, 19.7%, and n = 2498, 2.5%, respectively) (PR = 7.74, 95% CI = 2.53, 23.65), girls' basketball (n = 12 472, 23.4%, and n = 1924, 3.9%, respectively) (PR = 6.03, 95% CI = 2.39, 15.22), and girls' soccer (n = 25 342, 21.1%, and n = 6382, 10.2%, respectively) (PR = 2.07, 95% CI = 0.94, 4.57), although the latter was statistically insignificant. Similar proportions of practice (n = 48 944, 7.2%) and competition (n = 46 350, 6.1%) injuries were to the trunk (PR = 1.18, 95% CI = 0.90, 1.55). Although statistically insignificant, the largest difference was in baseball, with a greater proportion of practice injuries (n = 3564, 10.9%) to the trunk than competition injuries (n = 1316, 3.9%) (PR = 2.77, 95% CI = 0.57, 13.47).

Injury Diagnosis by Type of Exposure

Most injuries incurred by athletes were sprains/strains (52.1%), with fewer contusions (12.3%), fractures (9.8%), and concussions (9.1%). Sprains/strains were most common in volleyball (77.3%) and girls' basketball (62.5%), contusions were most common in baseball (18.0%) and boys' soccer (16.1%), fractures were most common in softball (17.5%) and wrestling (15.3%), and concussions were most common in girls' soccer (15.7%) and girls' basketball (11.4%).

Injury diagnosis by sport and type of exposure is displayed in Table 3. Sprains/strains were more common in practice (57.8%) than competition (47.1%) (PR = 1.23, 95% CI = 1.14, 1.32). Specifically, practice injuries were more likely to be sprains/strains than competition injuries in boys' (67.3% and 40.8%, respectively) (PR = 1.65, 95% CI = 1.31, 2.08) and girls' (70.1% and 50.3%, respectively) (PR = 1.39, 95% CI = 1.12, 1.73) soccer. Contusions made up a greater proportion of competition injuries (15.5%) than practice injuries (8.7%) (PR = 1.78, 95% CI = 1.45, 2.19). Specifically, competition injuries were more likely to be contusions than practice injuries in boys' (23.1% and 7.7%, respectively) (PR = 3.01, 95% CI = 1.47, 6.14) and girls' (11.4% and 2.9%, respectively) (PR = 3.95, 95% CI = 1.50, 10.40) soccer.

Fractures made up a greater proportion of competition injuries (11.1%) compared to practice injuries (8.5%) (PR = 1.30, 95% CI = 1.04, 1.63). Although statistically insignificant, this difference was especially apparent in boys' soccer (9.0% and 3.4%, respectively) (PR = 2.62, 95% CI = 0.93, 7.40) and volleyball (6.0% and 3.1%, respectively) (PR = 1.94, 95% CI = 0.29, 12.99). This difference was statistically significant in football (13.2% and 9.2%, respectively) (PR = 1.43, 95% CI = 1.06, 1.92).

Concussions made up a greater proportion of competition injuries (12.0%) compared to practice injuries (5.9%) (PR = 2.02, 95% CI = 1.56, 2.62). Specifically, competition injuries were more likely to be concussions in boys' soccer (15.6% and 2.3%, respectively) (PR = 6.94, 95% CI = 2.01, 23.95), girls' basketball (19.0% and 3.3%, respectively) (PR = 5.83, 95% CI = 2.06, 16.49), and girls' soccer (18.8% and 9.7%, respectively) (PR = 1.93, 95% CI = 0.85, 4.41), although the latter was statistically insignificant. An exception to this trend was seen in softball, where injuries were more likely to be concussions in practice (8.9%) compared to competition (0.4%) (PR = 20.26, 95% CI = 2.27, 180.80). Although statistically insignificant, volleyball players also sustained a greater proportion of concussions during practice (4.2% and 1.5%, respectively) (PR = 2.75, 95% CI = 0.45, 16.97).

Table 3. Diagnoses of Practice and Competition Injuries by Sport, High School Sport-Related Injury Surveillance Study, United States, 2005–2006 School Year[a]

	Boys' Sports					Girls' Sports			
	Football	Soccer	Basketball	Wrestling	Baseball	Soccer	Volleyball	Basketball	Softball
National estimate[b]									
Practice, n	234 342	98 014	54 764	69 183	33 922	62 967	49 136	49 753	28 617
Competition, n	280 059	119 601	44 826	36 260	33 542	122 803	32 677	53 343	34 696
Sprains/strains									
Practice, %	51.5	67.3	59.0	43.7	50.6	70.1	76.3	65.9	43.7
Competition, %	43.0	40.8	52.6	45.7	40.5	50.3	78.7	59.3	42.0
Injury PR	0.83	0.61	0.89	1.05	0.80	0.72	1.03	0.90	0.96
95% CI	0.75, 0.93	0.48, 0.77	0.73, 1.09	0.80, 1.37	0.56, 1.15	0.58, 0.89	0.86, 1.24	0.74, 1.09	0.60, 1.54
Contusions									
Practice, %	12.7	7.7	7.6	6.5	10.6	2.9	3.8	5.3	11.3
Competition, %	15.9	23.1	18.1	5.3	25.6	11.4	7.7	6.7	19.1
Injury PR	1.25	3.01	2.39	0.80	2.42	3.95	2.03	1.26	1.69
95% CI	0.97, 1.62	1.47, 6.14	1.28, 4.48	0.34, 1.90	1.20, 4.89	1.50, 10.40	0.40, 10.39	0.43, 3.71	0.61, 4.66
Fractures									
Practice, %	9.2	3.4	11.6	15.3	9.6	5.0	3.1	6.5	16.6
Competition, %	13.2	9.0	11.0	15.2	14.9	8.4	6.0	4.1	18.3
Injury PR	1.43	2.62	0.94	1.00	1.56	1.68	1.94	0.63	1.10
95% CI	1.06, 1.92	0.93, 7.40	0.48, 1.84	0.56, 1.77	0.62, 3.89	0.56, 5.05	0.29, 12.99	0.25, 1.56	0.44, 2.76
Concussions									
Practice, %	8.7	2.3	3.4	4.6	1.8	9.7	4.2	3.3	8.9
Competition, %	12.0	15.6	3.7	6.3	2.5	18.8	1.5	19.0	0.4
Injury PR	1.39	6.94	1.07	1.37	1.42	1.93	0.36	5.83	0.05
95% CI	1.01, 1.91	2.01, 23.95	0.31, 3.64	0.57, 3.32	0.27, 7.40	0.85, 4.41	0.06, 2.24	2.06, 16.49	0.01, 0.44

Abbreviations: PR, proportion ratio; CI, confidence interval.
[a] Practice is used as referent group.
[b] These frequencies do not sum to the total national injury estimate because a few injury reports did not specify diagnosis of injury.

Injury Severity by Type of Exposure

The majority of all injuries (52.5%) resulted in less than 1 week of time loss, 30.3% resulted in 1 to 3 weeks of time loss, 6.8% resulted in more than 3 weeks of time loss without resulting in the end of the athlete's season or career, and 10.4% resulted in the end of the athlete's season or career. Injury severity by sport and type of exposure, expressed as time loss, is displayed in the Figure. Overall, compared with practice injuries (15.0%), a greater proportion of competition injuries resulted in more than 3 weeks of time loss or in the end of the athlete's season or career (19.2%) (PR = 1.28, 95% CI = 1.08, 1.52). Specifically, competition injuries were more likely to result in more than 3 weeks of time loss or in the end of the athlete's season or career in baseball (23.9% and 6.9%, respectively) (PR = 3.47, 95% CI = 1.48, 8.11), volleyball (21.3% and 7.4%, respectively) (PR = 2.88, 95% CI = 1.01, 8.24), and boys' soccer (16.6% and 8.4%, respectively) (PR = 1.98, 95% CI = 0.96, 4.11), although the latter was statistically insignificant.

Although only 5.3% of all injuries required surgery, competition injuries (6.4%) were more likely to require surgery than practice injuries (4.0%) (PR = 1.62; 95% CI = 1.18, 2.24). Specifically, although not always statistically significant, competition injuries in volleyball (10.0% and 0.9%, respectively) (PR = 11.01, 95% CI = 1.99, 61.02), boys' soccer (4.7% and 1.5%, respectively) (PR = 3.18, 95% CI = 0.61, 16.70), girls' soccer (7.7% and 2.7%, respectively) (PR = 2.89, 95% CI = 0.62, 13.51), girls' basketball (8.9% and 3.5%, respectively) (PR = 2.55, 95% CI = 0.89, 7.33), and baseball (13.1% and 6.3%, respectively) (PR = 2.08, 95% CI = 0.72, 5.97) required surgery more frequently than practice injuries. Conversely, although statistically insignificant, surgery was required more frequently among practice injuries (6.5%) than competition injuries in softball (2.9%) (PR = 2.26, 95% CI = 0.35, 14.73).

DISCUSSION

We are the first to describe overall practice and competition injury rates and patterns in 9 sports using data collected among a representative sample of US high schools and found that competition results in higher injury rates and greater proportions of head/face/neck injuries, concussions, and severe injuries. With growing participation in high school sports,[1] our results provide ATs with a timely comparison of practice and competition injuries, a crucial step toward identifying targeted, evidence-based recommendations for better injury prevention at the high school level.

Overall, injury rates among US high school athletes in our 2005–2006 study were lower than injury rates during the 1995–1997 NATA Injury Surveillance Project,[4] a study of US high school athletes that used similar methods. These rate differences may be due to the more inclusive injury definition used in the 1995–1997 study, which defined an *injury* as the athlete being unable to return the day of injury and which included all fractures, dental injuries, and mild brain injuries, regardless of time loss. Conversely, because our injury definition required that the athlete receive medical attention and have restricted participation the day after injury, fewer minor injuries were likely reported in our 2005–2006 study. Additionally, the 1995–1997 study included only varsity athletes, whereas our study included freshmen, junior varsity, and varsity

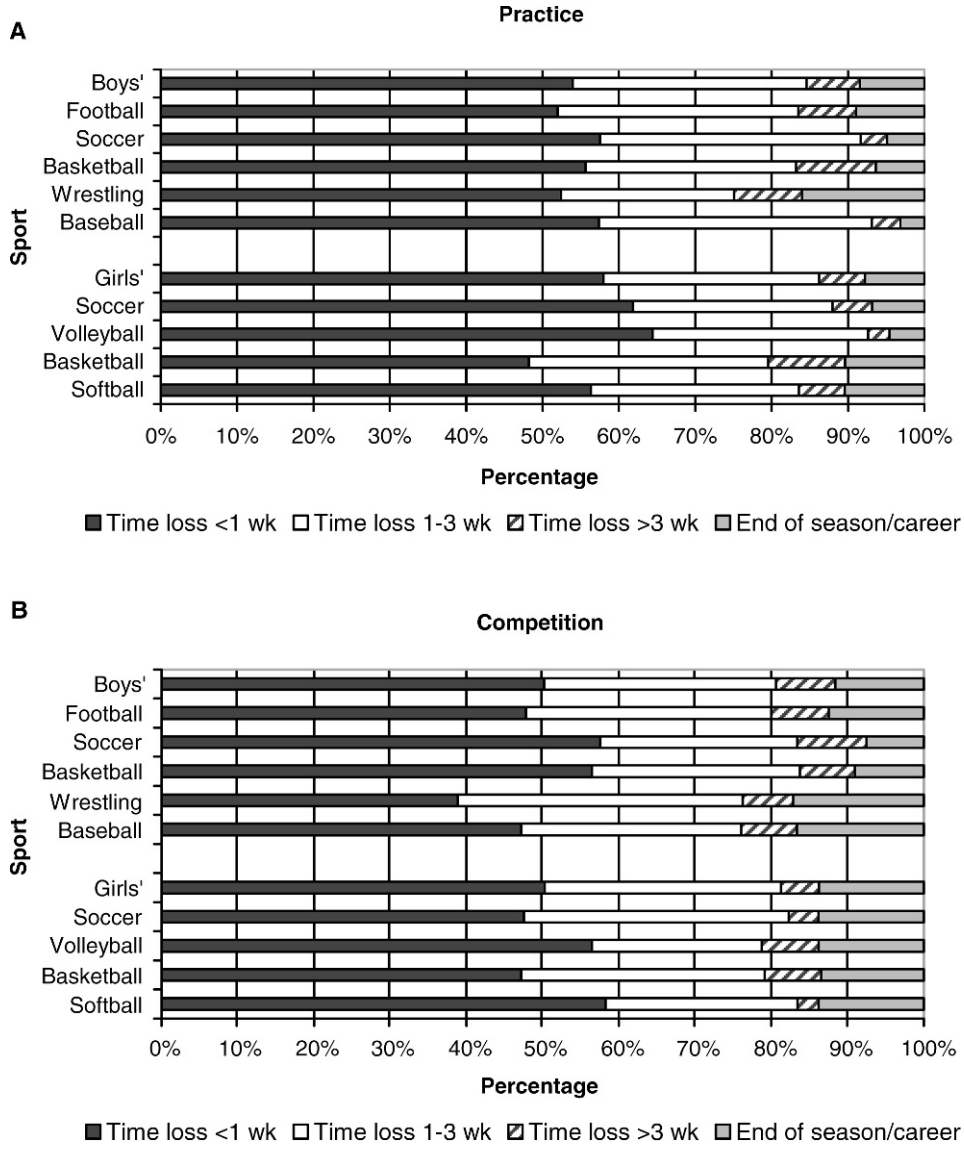

Figure. Time Loss of Practice (A) and competition (B) injuries by sport, High School Sport-Related Injury Surveillance Study, United States, 2005–2006 school year.

players, and previous researchers have found higher injury rates as level of competition increases.[23,24]

During the 2005–2006 school year, we found that the overall rate of competition injury for athletes participating in 5 boys' sports (football, soccer, basketball, wrestling, and baseball) and 4 girls' sports (soccer, volleyball, basketball, and softball) was 2.73 times higher than the rate of practice injury (range = 1.30 to 4.75 among the 9 sports). Previous investigators have consistently found higher injury rates during competition. In the 1995–1997 NATA Injury Surveillance Project, injury rates ranged from 1.5 to 5.0 times higher in competition compared with practice in the 10 sports studied.[4] In a separate study of North Carolina high school athletes in 12 sports from 1996–1999, injury rates were 4.0 times higher in competition.[22] Several other authors have found that injury rates in specific sports, such as football,[10,12,24] soccer,[5,25] basketball,[8] and wrestling,[9,20] were higher in competition. Higher rates of injury during competition may be due to increased play intensity,[5] increased legal and illegal physical contact,[11,25] and increased exposure to high-risk activities (eg, tackling in football). Despite the higher injury rate during competition, we found that similar proportions of injuries were sustained in competition (51.5%) and practice (48.5%). Similar to results published previously,[4,22] this finding is due to the greater amount of time spent in practice compared with competition.

Compared with practice injuries, we noted a higher proportion of head/face/neck injuries and concussions during competition, particularly evident in boys' and girls' soccer and girls' basketball. Similarly, compared with practice, higher competition concussion rates have been found in boys' soccer,[19,21] girls' soccer,[21] and girls' basketball[19,21] at the high school level. This is likely due to the increased amount of physical contact that takes place during competition in these sports.[26] Specifically, authors[26] of a study among high school athletes found that most boys' and girls' soccer concussions resulted from player collisions, whereas most girls' basketball concussions resulted from rebounding and player collisions. These activities likely occur either more often or at increased intensity during competition. Additionally, boys' and girls'

soccer and girls' basketball players likely do not wear protective headgear. Interestingly, we found the opposite trend in softball, in which concussions constituted a greater proportion of practice injuries than competition injuries. One potential explanation for this may be that girls participate in more repetitions of potentially high-risk activities, such as pitching, batting, sliding, and fielding, during practice compared with competition. Due to the small number of softball concussions reported, additional research is needed to determine if this trend persists.

We found that concussions made up 9.8% of practice injuries in girls' soccer but accounted for only 2.3% of practice injuries in boys' soccer. This increased prevalence of practice concussions in females may have several explanations. A previous group[17] found that only half of all high school football players who sustained a concussion during the season reported it, usually due to the player's belief that the injury was not serious enough to be reported and/or motivation to continue playing in the competition. Female athletes and their ATs, coaches, and parents may be more cautious when dealing with a potential concussion. Additionally, females may be more likely to report their concussions, or ATs may be more likely to assess them for a concussion at the observation of less severe symptoms.

Compared with practice injuries, we found that larger proportions of competition injuries were season ending or required surgery. Although authors of few published studies have compared injury severity between competition and practice, one investigator[18] found that catastrophic head injuries among football players occurred most often during competition. The higher proportion of severe injury we noted is likely due to the increased aggressiveness[5] and physical contact[11,25] in competition. This heightened intensity may foster a greater number of high-speed, high-impact collisions, situations that result in severe injury more frequently than the lower-impact, controlled contact found more often in practice.

With few exceptions, we found that sprains/strains and lower extremity injuries accounted for the majority of all injuries, regardless of the type of sport or whether the injury occurred during practice or competition. These trends remain consistent with those shown by previous researchers, who cited high frequencies of sprains/strains[4,5] and lower extremity injuries[4,5,11,22] among high school athletes. These findings suggest that despite the unique characteristics possessed by each sport and the differences that exist between practice and competition, all sports involving common activities such as running, jumping, and quick changes of direction place the lower extremities at risk of injury, particularly sprains/strains.

As do all studies, this study had limitations. Only high schools with NATA-affiliated ATs were eligible for participation, but using only medically trained reporters increased the overall quality and consistency of reported data. Because this study was based on the first year of High School RIO data collection, a small number of injuries in certain stratifications prevented some findings from being statistically significant. As this national high school sport injury surveillance study continues in future years, additional research will be needed to confirm the findings from this first year of the study and to evaluate trends over time. However, the overall number of injuries collected was still quite high compared with reports from many previous sport injury studies. The limitation of the definition of injury to that resulting in time loss of 1 day beyond the day of injury restricted the number of reported injuries. Thus, results based on data from this surveillance system are an underestimate of the true injury burden among high school athletes. However, this limitation was necessary, as this definition made this national study feasible by reducing the reporting burden on participating ATs and reducing individual AT subjectivity in reporting minor injuries. Furthermore, as high school ATs cannot attend all sports' practices and competitions, injuries with less than 1 day of lost play would not have been captured reliably. Finally, our definition of AE as participation in a single competition or practice was less precise than a definition based on minutes of exposure. Yet a more precise definition was not logistically practical, as it was not possible for ATs to attend all sports' practices and competitions to record the exact number of minutes that each player participated.

Despite these limitations, this study was geographically representative, and the known probability of selection allowed us to apply weights to calculate national estimates. By replicating previous work (such as the 1995–1997 NATA Injury Surveillance Project as well as other smaller studies) using a different sample design and an advanced, Internet-based data collection method, this study expands upon the previous knowledge base. Due to the geographic representativeness and the technologically advanced methods, this study speaks to the fact that identifying ways to prevent competition injuries should be a priority.

The injury patterns we found point to several potential preventive interventions that could be employed by ATs and coaches. The increased rate and severity of competition injuries suggest a need to incorporate drills of potentially high-risk situations into practice under controlled conditions in an effort to decrease competition injury rates. For example, in football the tackle is the activity responsible for the highest proportion of competition injuries.[24] We suggest that the incidence and severity of tackle-related injuries may be reduced if coaches emphasize the development of tackling skills in practice through a progression of closely supervised drills (ie, from tackling stationary dummies, to partial speed drills, to tackling teammates at full speed). Schools and sporting leagues need to ensure that coaches are qualified and up to date on the appropriate techniques for teaching athletes the skills that yield the best performance while maintaining the highest possible level of safety.[26] With the high proportion of concussions seen in competition and the potential long-term negative sequelae that can result from head injuries, all players should be made aware of concussion symptoms and encouraged to report them,[17,21] and coaches and ATs should follow appropriate return-to-play guidelines.[26] Sprains/strains and lower extremity injuries were most common across all sports in practice and competition, indicating that attention paid to these areas may have the biggest effect in reducing injury. Both sprains/strains and lower extremity injuries may be reduced by preseason neuromuscular training,[16] increased vigilance during preseason conditioning,[27] and better field conditions. Finally, coaches should always stress the diligent use of appropriate protective equipment in both practice and competition.

We found that rates and patterns of high school sport injuries differed between practice and competition. Continued surveillance is warranted to monitor changes in these patterns over time and to assess the effects of future interventions (eg, rule and equipment changes). Sport-specific studies identifying activities with high injury risk can help ATs and coaches develop targeted training techniques to lower injury rates. Additionally, continued research into the biomechanics of particular injuries, such as sprains/strains, concussions, and lower extremity injuries, may give researchers insights into further training or protective equipment interventions. When considering the growing population of high school athletes along with the important physical and social benefits of sport participation, reducing sport injury rates should be a priority.

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