Nine-year study of US high school soccer injuries: data from a national sports injury surveillance programme

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ABSTRACT

Background Research on high school soccer injury epidemiology is sparse.

Aim To describe high school soccer injury rates, trends and patterns by type of athlete exposure (AE), position and sex.

Methods This descriptive epidemiological study used data from a large national high school sports injury surveillance programme to describe rates and patterns of soccer-related injuries including concussion sustained from 2005/2006 to 2013/2014. Injury rates are calculated per 1000 AEs.

Results Overall, 6154 soccer injuries occurred during 2 985 991 AEs; injury rate=2.06 per 1000 AEs. Injury rates were higher during competition (4.42) than practice (1.05; rate ratio (RR)=4.19; 95% CI 3.98 to 4.41), and in girls (2.33) than boys (1.83; RR=1.27, 95% CI 1.21 to 1.34). Boys' non-concussion injury rates decreased significantly (p=0.001) during the study period while reported concussion rates increased significantly (p=0.002). Girls' non-concussion rates were relatively stable and reported concussion rates increased significantly (p=0.004). Player–player contact was the injury mechanism that led to the most competition injuries (injury proportion ratio (IPR)=2.87; 95% CI 2.57 to 3.21), while non-contact injuries were the most common mechanisms among practice injuries (IPR=2.10; 95% CI 1.86 to 2.38). Recovery from concussion was >7 days in a third of the cases. Injury patterns were similar between sexes with respect to position played and location on the field at the time of injury.

Conclusions High school soccer injury rates vary by sex and type of exposure, while injury patterns are more similar across sexes. Reported concussion rates increased significantly over the study period in male and female athletes.

INTRODUCTION

Soccer, the most popular worldwide sport, had an estimated 265 million players in 2006.[1] One of the fastest growing sports in the USA, high school soccer participation increased 4-fold among boys and 35-fold among girls from 1973 to 2014.[2] Soccer provides many health benefits, including improved cardiovascular and neuromuscular fitness.[3 4] However, like any sport, soccer poses an injury risk. After football and wrestling, soccer had the next highest injury rate among US high school sports in 2005/2006.[5] Sports injuries can be economically costly and can limit future sports participation.[6 7]

High school soccer injury studies are sparse.[8–12] Most paediatric soccer-related injury studies were conducted over 10 years ago.[13–16] Many focused on emergency department visits, were conducted during tournaments or were restricted to specific geographic areas and thus are not necessarily representative of a national sample.[14–22] Available papers indicate adolescent soccer players most commonly sustain lower extremity injuries, but recent concerns have focused on their risk of sports-related concussions.[12 23–26] There is continued debate regarding the concussion risk associated with heading the ball (eg, is contact with the ball an important concussion mechanism or is player–player contact during the act of heading the more common and more concerning mechanism of concussion) which has intensified concerns among some coaches and parents.[27] Increases in high school soccer participation and the potential long-term effects of injury emphasise the need to understand the epidemiology of high school soccer injuries to direct targeted intervention strategies.[28 29]

We analysed soccer injuries sustained by a nationally representative sample of US high school athletes from 2005/2006 through 2013/2014. The specific aims were to: (1) compare injury rates and patterns by type of athlete exposure (AE), (2) compare injury rates and patterns by sex, and (3) evaluate injury trends over time.

METHODS

Data collection

This descriptive epidemiological study used data collected from 2005/2006 through 2013/2014 by the National High School Sports-Related Injury Surveillance System, High School Reporting Information Online (RIO).[5 9] This multiyear prospective surveillance study recruited US high schools with National Athletic Trainers' Association (NATA)-affiliated, board certified athletic trainers (ATs) to report exposure and injury data for athletes participating in school-sanctioned high school sports. Since 2005/2006 High School RIO has captured data on nine original sports (including boys' and girls' soccer) from a randomly selected sample drawn from an eight-cell sampling strata (four geographic regions and two school sizes using a 1000 student cut point), resulting in a nationally representative sample of 100 schools.[9] ATs from participating schools log onto an internet-based data collection tool on a weekly basis to report AE and injury data. For each injury, ATs completed detailed reports describing the characteristics of the injured athlete, the injury and the injury event (note: no similar data were captured on non-injured teammates). A demo of the internet-based data collection tool is available at http://www.ucdenver.edu/

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academics/colleges/PublicHealth/research/ResearchProjects/piper/projects/RIO/Pages/Demo-Site.aspx. While High School RIO now has an expanded (convenience) sample including 22 sports, this study only used data from the 100 randomly selected high schools included in the original sample so that national estimates could be calculated. A more detailed description of the surveillance system is available elsewhere.[5 9]

Injury and exposure definitions

AEs are defined in High School RIO as a single athlete participating in a single practice or competition. Reportable injuries (1) occurred as the result of an organised high school practice or competition, (2) required medical attention by an AT or physician, and (3) resulted in restriction of athlete's participation for at least 1 day beyond the date of injury, or since 2007/2008 were fractures, concussions, heat illness/injuries or dental injuries (which were captured regardless of time loss).

Analyses

Statistical analyses were conducted using SAS Software, V.9.4 (SAS Institute, Cary, North Carolina, USA). Injury rates were calculated by dividing the number of injuries (numerator) by the number of AEs (denominator). National estimates of the numbers of soccer-related injuries were calculated by assigning a sample weight to each reported injury. Sample weights were calculated as the inverse probability of the school's selection into the surveillance study, based on the total number of US high schools in each of the eight sampling strata. Rate ratios (RRs) and injury proportion ratios (IPRs) were calculated with 95% CIs as follows:

$$\mathrm{RR} = \frac{(\text{Number of competition injuries} / \text{number of competition AEs})}{(\text{Number of practice injuries} / \text{number of practice AEs})}$$

$$\mathrm{IPR} = \frac{(\text{Number of boys concussions} / \text{number of all boys injuries})}{(\text{Number of girls concussions} / \text{number of all girls injuries})}$$

RRs and IPRs with 95% CIs not including 1.0 were considered statistically significant. Trends in injury rates over time were calculated using linear regression, with statistical significance set at $\alpha=0.05$. This surveillance project which captured the data analysed in this study was approved by the Nationwide Children's Hospital Human Subjects Review Board, Columbus, Ohio, USA.

Table 1 Soccer injury rates by type of exposure and sex, National High School Sports-Related Injury Surveillance Study, USA, 2005/2006 through 2013/2014

	Number of injuries	Number of AEs	Injury rate (per 1000 AEs)	Rate ratio (95% CI)
Total	6154	2 985 991	2.06	
Competition	3949	894 441	4.42	4.19 (3.98 to 4.41)
Practice	2205	2 091 550	1.05	Referent
Boys' soccer total	2912	1 592 238	1.83	
Competition	1755	476 261	3.68	3.55 (3.30 to 3.83)
Practice	1157	1 115 997	1.04	Referent
Girls' soccer total	3242	1 393 753	2.33	
Competition	2194	418 180	5.25	4.88 (4.54 to 5.26)
Practice	1048	975 573	1.07	Referent

AE, athlete exposure.

RESULTS

Injury rates

Overall, 6154 injuries were reported during 2 985 991 AEs (injury rate of 2.06 per 1000 AEs; table 1), corresponding to an estimated 3 381 189 soccer injuries nationally (1 874 022 (55.4%) among girls and 1 507 167 (44.6%) among boys). Compared with practice, injury rates were significantly higher in competition overall (RR=4.19, 95% CI 3.98 to 4.41), in boys (RR=3.55, 95% CI 3.30 to 3.83) and girls (RR=4.88, 95% CI 4.54 to 5.26). Comparing sexes, injury rates were significantly higher in girls overall (RR=1.27, 95% CI 1.21 to 1.34) and in competition (RR=1.42, 95% CI 1.34 to 1.52). Boys' non-concussion injury rates decreased significantly (p=0.001, β=−1.16, 95% CI −1.67 to −0.65) while concussion rates increased significantly (p=0.002, β=0.34, 95% CI 0.17 to 0.51; figure 1A). Girls' non-concussion rates were relatively stable (p=0.10, β=−0.47, 95% CI −1.06 to 0.12) while concussion rates increased significantly (p=0.004, β=0.67, 95% CI 0.29 to 1.05; figure 1B).

Injury characteristics

Overall: The majority of injuries were new (89.8%) rather than recurrent. The most common diagnoses were ligament sprains (grade I–III; 29.7%), concussions (17.9%) and muscle strains (16.1%). The most commonly injured body sites were the head/face (20.9%), ankle (20.6%) and knee (16.5%; table 2).

Soccer injuries most commonly resulted in <1 week time loss (45.0%), but 6.7% resulted in >3 weeks, 5.8% resulted in season-ending medical disqualification, and in 6.9% the season ended before the athlete could return. The most common injuries resulting in >3 weeks time loss were fractures (27.7%), ligament sprains (26.2%) and concussions (14.9%). Medical disqualifications occurred most frequently as a result of ligament sprains (43.6%), fractures (27.4%) and concussions (10.7%). Surgery was required for 6.1% of injuries; most commonly for ligament sprains (55.1%) and fractures (21.4%). This included grade III ligament sprains such as ACL rupture. Surgery most commonly occurred in knee injuries (66.4%). The rate of ACL sprain was 0.10 per 1000 AEs in girls and 0.03 per 1000 AEs in boys.

Concussions: The overall rate of concussion in this study was 0.36 per 1000 AEs. An estimated 604 371 concussions occurred nationally in high school soccer players during the study period. The most commonly endorsed concussion symptoms were headache (92.6%), dizziness/unsteadiness (68.8%) and concentration difficulty (52.2%). Loss of consciousness occurred in 3.6% of concussions and amnesia in 15.8%. Symptoms resolved within 1 day in 21.0% of concussions, but took >1 week to resolve in 29.4% of cases. Most concussions resulted in time loss between 1 and 3 weeks (54.8%). Athletes were medically disqualified for the season in 3.5% of concussion cases.

Sex comparison: Sex differences and comparisons are shown in figure 2A, B. Girls sustained a higher proportion of ligament sprains (34.4%) than boys (23.9%; (IPR 1.44, 95% CI 1.30 to 1.59), while boys sustained a higher proportion of fractures (8.9% vs 6.0%, IPR 1.49, 95% CI 1.19 to 1.86). Concussions represented a similar proportion of all injuries sustained by boys and girls (16.6% vs 19.0%, IPR 1.15, 95% CI 0.99 to 1.33). The most common body part and diagnosis combinations for boys were head/face concussions (16.6%), ankle sprains (14.5%) and thigh/upper leg strains (9.1%). For girls, the most common were ankle sprains (20.6%), head/face concussions (19.0%) and knee sprains (9.7%).

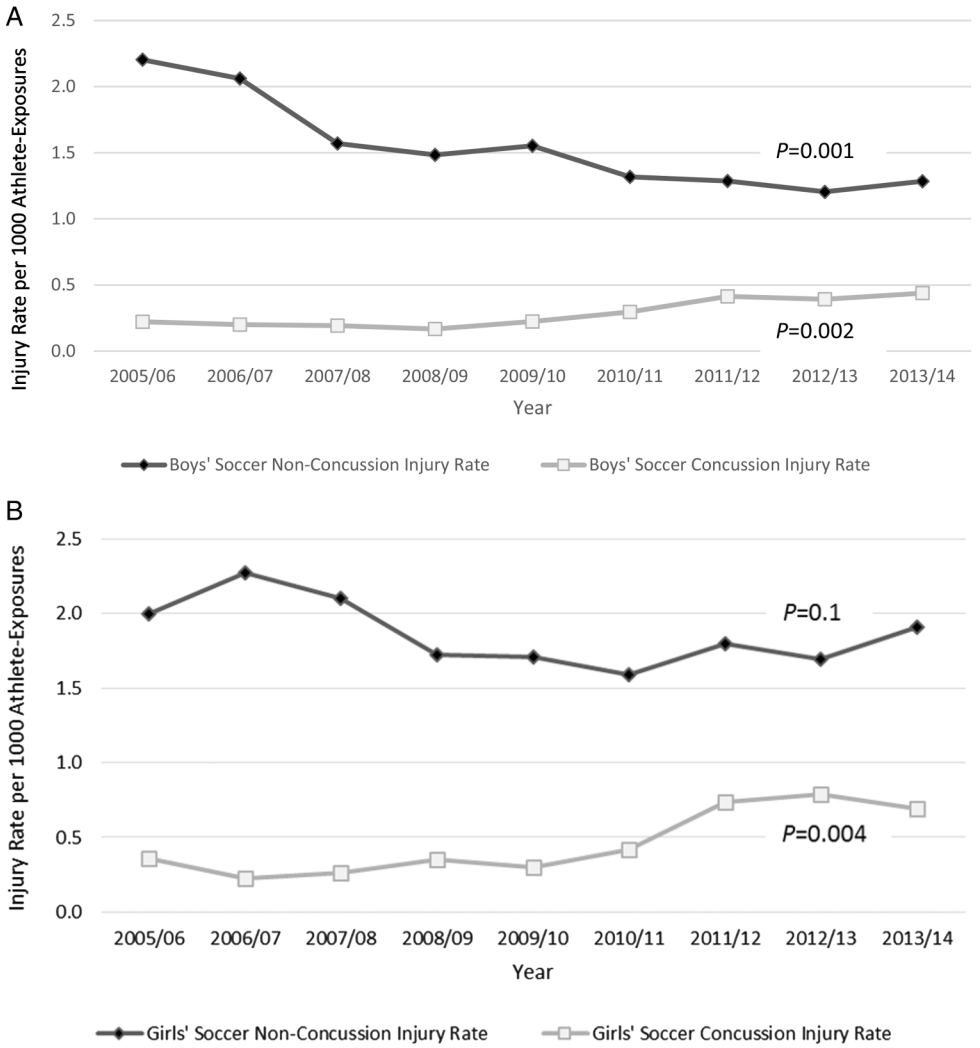

Figure 1 (A) Trends over time in rates of concussion injuries and non-concussion injuries in boys' soccer, High School Sports-Related Injury Surveillance Study, USA, 2005/2006 through 2013/2014. (B) Trends over time in rates of concussion injuries and non-concussion injuries in girls' soccer, High School Sports-Related Injury Surveillance Study, USA, 2005/2006 through 2013/2014 school years.

Table 2 Body sites injured among boys and girls soccer players, National High School Sports-Related Injury Surveillance Study, USA, 2005/2006 through 2013/2014*†

Body part injured	Boys′ number (%)	Boys′ national estimates (%)	Girls′ number (%)	Girls′ national estimates (%)	Overall number (%)	Overall national estimates (%)
Head/face‡	568 (19.5)	311 430 (20.7)	710 (21.9)	395 142 (21.1)	1278 (20.8)	706 572 (20.9)
Neck	17 (0.6)	9125 (0.6)	21 (0.6)	8458 (0.5)	38 (0.6)	17 583 (0.5)
Shoulder/clavicle	98 (3.4)	41 658 (2.8)	57 (1.8)	30 036 (1.6)	155 (2.5)	71 694 (2.1)
Arm/elbow	42 (1.4)	20 496 (1.4)	42 (1.3)	24 408 (1.3)	84 (1.4)	44 904 (1.3)
Hand/wrist	146 (5.0)	74 334 (4.9)	119 (3.7)	68 839 (3.7)	265 (4.3)	143 173 (4.2)
Trunk§	140 (4.8)	69 807 (4.6)	97 (3.0)	55 054 (2.9)	237 (3.9)	124 861 (3.7)
Hip	148 (5.1)	80 012 (5.3)	93 (2.9)	51 586 (2.8)	241 (3.9)	131 598 (3.9)
Thigh/upper leg	363 (12.5)	187 529 (12.5)	339 (10.5)	198 106 (10.6)	702 (11.4)	385 635 (11.4)
Knee	409 (14.1)	205 100 (13.6)	637 (19.7)	352 799 (18.9)	1046 (17.0)	557 899 (16.5)
Lower leg	229 (7.9)	118 043 (7.8)	222 (6.9)	130 895 (7.0)	451 (7.3)	248 938 (7.4)
Ankle	521 (17.9)	266 704 (17.7)	703 (21.7)	426 619 (22.8)	1224 (19.9)	693 323 (20.6)
Foot	202 (6.9)	106 206 (7.1)	177 (5.5)	110 348 (5.9)	379 (6.2)	216 554 (6.4)
Other	24 (0.8)	13 885 (0.9)	19 (0.6)	17 204 (0.9)	43 (0.7)	31 089 (0.9)
Total	2907 (100.0)	1 504 329 (100.0)	3236 (100.0)	1 869 494 (100.0)	6143 (100.0)	3 373 823 (100.0)

*Data represent weighted national estimates.
†Owing to a small number of cases with unknown body part, totals do not sum to the total number of injuries.
‡Head/face includes head, eyes, ears, nose, mouth and teeth.
§Trunk includes chest, thoracic spine, ribs, abdomen, lower back, lumbar spine and pelvis.

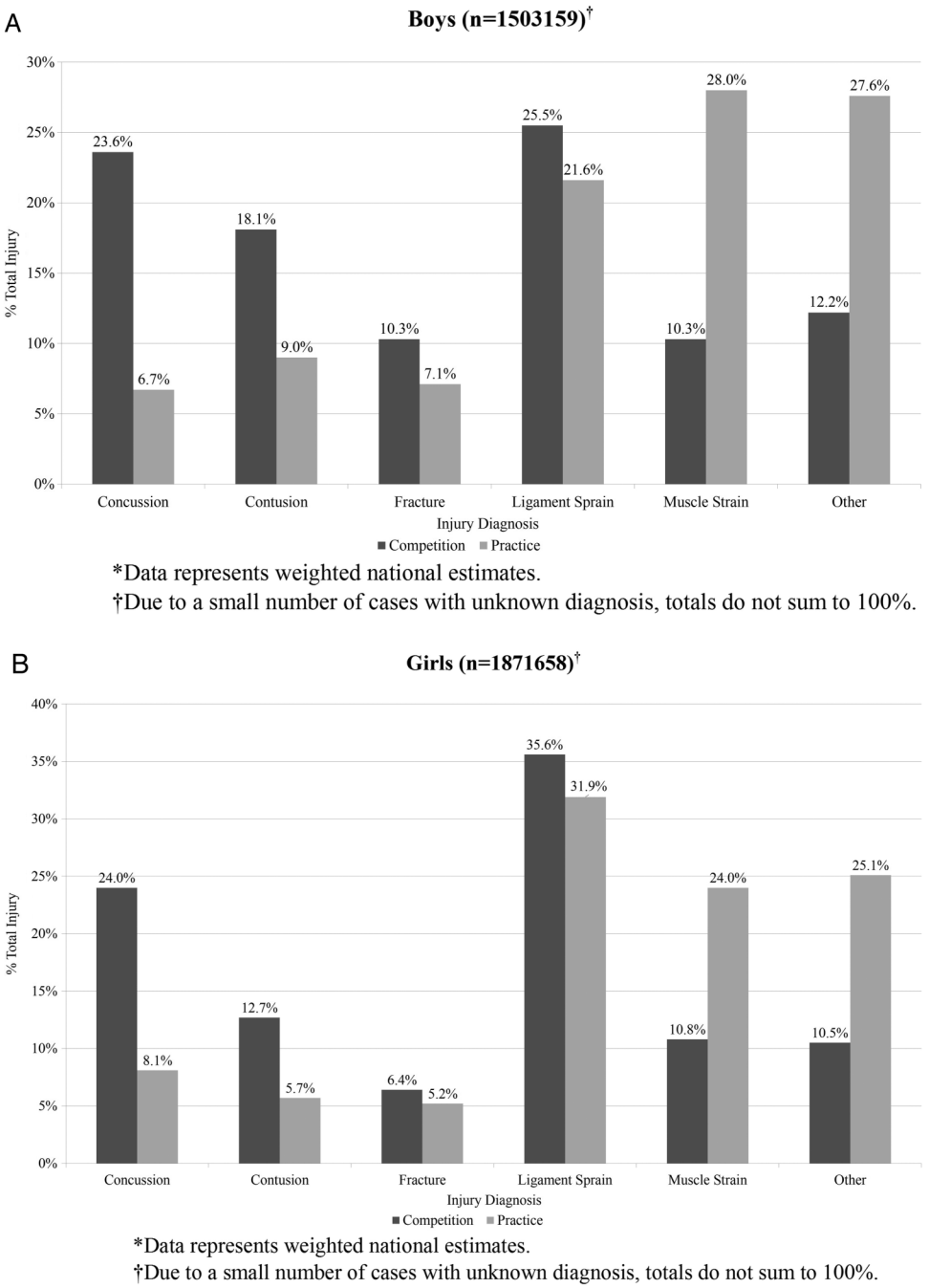

Figure 2 (A) Boys' soccer injury diagnosis by type of exposure, National High School Sports-Related Injury Surveillance Study, USA, 2005/2006 through 2013/2014*. (B) Girls' soccer injury diagnosis by type of exposure, National High School Sports-Related Injury Surveillance Study, USA, 2005/2006 through 2013/2014*.

A larger proportion of athletes returned to activity within 1 week (boys=48.5% and girls=42.8%). The most common injuries resulting in >3 weeks time loss among boys were concussions (17.8%), knee sprains (15.5%) and ankle sprains (8.9%), and among girls were knee sprains (26.0%), concussions (22.0%) and ankle sprains (13.2%).

Surgery was required for a similar proportion of boys' (5.4%) and girls' (6.6%) injuries. This was most often required for boys' knee sprains (38.2% of all boys' injuries requiring surgery), head/face fractures (9.2%) and torn knee cartilage (8.3%), and girls' knee sprains (63.6%) and torn knee cartilage (8.4%).

Type of athlete exposure: (1) Type of injury: overall, muscle strains represented a greater proportion of practice than competition injuries (IPR 2.48, 95% CI 2.13 to 2.88), while concussions (IPR 3.21, 95% CI 2.62 to 3.94), fractures (IPR 1.30, 95% CI 1.02 to 1.66) and ligament sprains (IPR 1.18, 95% CI 1.06 to 1.32) represented a higher proportion of competition injuries. (2) Affected body part: head/face injuries represented a higher proportion of competition injuries (IPR 3.01, 95% CI 2.52 to 3.61), while hip (IPR 2.69, 95% CI 1.94 to 3.72), thigh/upper leg (IPR 1.86, 95% CI 1.55 to 2.23), foot (IPR 1.82, 95% CI 1.42 to 2.34) and lower leg (IPR 1.74, 95% CI 1.38 to 2.19) represented a higher proportion of practice injuries.

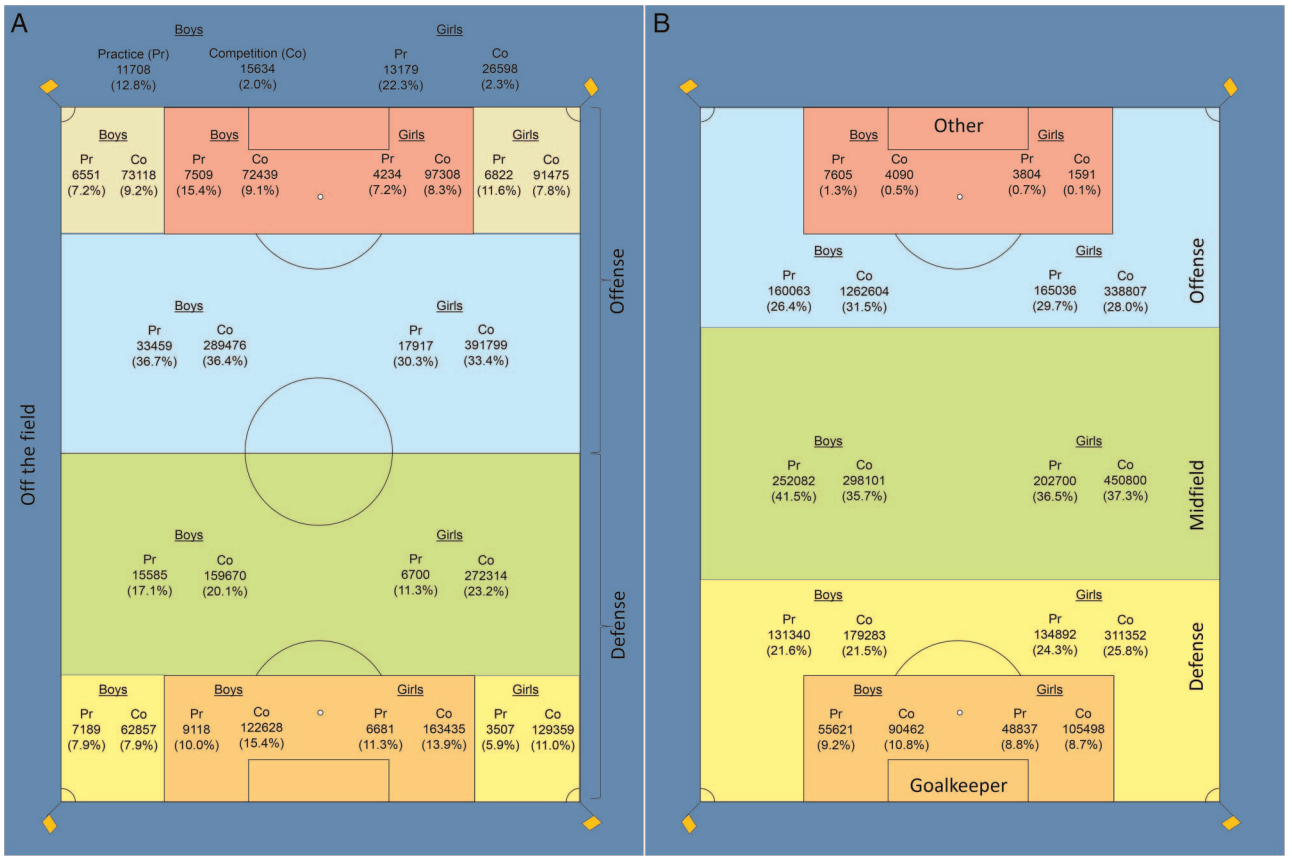

Figure 3 Soccer field location (A), and playing position (B) at time of injury among boys' and girls' soccer players, National High School Sports-Related Injury Surveillance Study, USA, 2005/2006 through 2013/2014.

Compared with practice (15.3%), a greater proportion of competition injuries (23.4%) resulted in over 3 weeks' time loss (IPR 1.53, 95% CI 1.32 to 1.78) in surgery (7.5% vs 3.3%; IPR 2.27, 95% CI 1.63 to 3.15). The rate of knee ligament sprains (including ruptures) sustained in competition requiring surgery among girls (0.28 per 1000 AEs) was much higher than the boys' competition rate (0.095; RR 2.94, 95% CI 2.08 to 4.14) as well as the girls' practice rate (0.02; RR=14.99, 95% CI 9.15 to 24.70).

Injury events

Overall: Common general injury mechanisms were player–player contact (42.5%), non-contact (22.4%), contact with playing surface (15.8%) and contact with playing apparatus (10.2%). In total, 27.5% of concussions were sustained during heading, which often occurred from player–player contact (68.1%), followed by contact with the ball (17.4%).

Most injuries occurred in midfielders (37.6%), followed by forwards (28.9%), defenders (23.6%) and goalkeepers (9.4%). The most common field locations where injuries occurred included the area from the top of the goal box to the centre line on the offensive side of the field (34.6%) and top of the goal box extended to the centre line on the defensive side of the field (21.5%; figure 3).

Sex comparisons: Among boys and girls, the most common general mechanism of injury was player–player contact (44.1% and 41.3%, respectively; tables 3 and 4). The most common sport-specific direct mechanism for boys and girls included player–player contact (27.0% and 27.7%, respectively), contact with the ball (11.4% and 14.0%, respectively), and indirect mechanism (overuse, heat illness, conditioning, etc; 15.4% and 14.0%, respectively). Knee sprains occurred most commonly from player–player contact in boys (62.2%) and girls (50.8%). Similarly, concussions occurred most commonly from player–player contact in boys (68.8%) and girls (51.3%).

The most common activities leading to boys' and girls' injuries were general play (23.7% and 23.6%, respectively), defending (9.9% and 15.9%, respectively) and chasing a loose ball (10.7% and 12.1%, respectively). Among boys, injuries requiring surgery were sustained most often during general play (14.3%), chasing a loose ball (13.9%) and defending (13.3%). Among girls, injuries requiring surgery were sustained most often during general play (21.4%) and defending (17.5%).

Boys and girls had similar patterns of positions played when injuries occurred (figure 3), with midfielders most commonly injured (38.2% and 37.1%, respectively). Field location patterns among boys and girls were also similar, with most injuries occurring between top of the goal box and the centre line on the offensive side of the field (36.4% and 33.3%, respectively).

Type of athlete exposure: Player–player contact resulted in more injuries in competition (55.6%) than practice (19.4%; IPR 2.87, 95% CI 2.57 to 3.21). Non-contact injuries accounted for more injuries in practice (33.7%) than competition (16.0%; IPR 2.10, 95% CI 1.86 to 2.38). Contact with the ball resulted in a higher proportion of injuries in practice (14.8%) than competition (11.7%; IPR 1.26, 95% CI 1.06 to 1.50) as did non-contact mechanisms (ie, overuse, heat illness, conditioning, etc; 30.3% and 5.8%, respectively; IPR 5.14, 95% CI 4.26 to 6.21; tables 3 and 4). Being stepped on, fell on or kicked (12.3% and 6.5%, respectively; IPR 1.87, 95% CI 1.48 to 2.37), slide tackles (6.2% and 2.3%, respectively; IPR 2.66, 95% CI 1.83 to 3.87) and player–player contact (36.1% and 11.9%,

Table 3 Soccer injury mechanism, activity and time of injury among boys' soccer players, National High School Sports-Related Injury Surveillance Study, USA, 2005/2006 through 2013/2014*

	Boys					
	Practice		Competition		Overall	
	N	Per cent	N	Per cent	N	Per cent
General mechanism						
Player–player contact	137 807	22.0	517 513	60.2	655 320	44.1
No contact	222 798	35.5	124 161	14.4	346 959	23.3
Playing surface contact	93 943	15.0	133 308	15.5	227 251	15.3
Playing apparatus contact	64 868	10.3	58 766	6.8	123 634	8.3
Overuse/chronic	94 473	15.1	12 047	1.4	106 520	7.2
Other	13 782	2.2	13 586	1.6	27 368	1.8
Specific mechanism						
Player-to-player contact (not slide tackle)	86 337	14.1	309 248	36.3	395 585	27.0
NA (ie, overuse, heat illness, conditioning, etc)	182 591	29.7	43 458	5.1	226 049	15.4
Contact with ball	92 427	15.1	74 742	8.8	167 169	11.4
Stepped on, fell on or kicked	40 815	6.6	107 683	12.6	148 498	10.1
Rotation around a planted foot/inversion	52 817	8.6	77 837	9.1	130 654	8.9
Slide tackle	17 850	2.9	64 161	7.5	82 011	5.6
Uneven playing surface	25 435	4.1	12 069	1.4	37 504	2.6
Contact with goal	2912	0.5	4250	0.5	7162	0.5
Other	112 833	18.4	159 008	18.7	271 841	18.5
Activity						
General play	197 457	32.1	148 679	17.6	346 136	23.7
Chasing a loose ball	54 956	8.9	100 602	11.9	155 558	10.7
Dribbling	53 150	8.6	102 125	12.1	155 275	10.6
Defending	37 845	6.1	106 230	12.6	144 075	9.9
Heading ball	27 785	4.5	105 865	12.5	133 650	9.2
Goaltending	41 034	6.7	72 879	8.6	113 913	7.8
Passing (foot)	34 414	5.6	45 875	5.4	80 289	5.5
Receiving a pass	26 507	4.3	48 342	5.7	74 849	5.1
Shooting (foot)	34 789	5.7	37 711	4.5	72 500	5.0
Conditioning	66 940	10.9	1301	0.2	68 241	4.7
Receiving a slide tackle	6438	1.0	27 793	3.3	34 231	2.3
Blocking a shot	11 272	1.8	18 474	2.2	29 746	2.0
Attempting a slide tackle	9491	1.5	15 133	1.8	24 624	1.7
Other	13 578	2.2	12 543	1.5	26 121	1.8
Time of injury during practice						
First ½ hour	78 053	13.1	–	–	78 053	13.1
Second ½ hour	156 336	26.2	–	–	156 336	26.2
1–2 hours into practice	298 656	50.1	–	–	298 656	50.1
>2 hours into practice	63 345	10.6	–	–	63 345	10.6
Time of injury during competition†						
Precompetition/warm-ups	–	–	17 418	3.3	17 418	3.3
First half	–	–	175 016	33.5	175 016	33.5
Second half	–	–	327 062	62.7	327 062	62.7
Overtime	–	–	2562	0.5	2562	0.5

*Data represent weighted national estimates.
†Soccer time of injury during competition was added to High School RIO beginning in 2008/2009.
NA, not available; RIO, Reporting Information Online.

respectively; IPR 3.00, 95% CI 2.58 to 3.49) represented a higher proportion of competition injuries. Defending (IPR 2.10, 95% CI 1.69 to 2.61), chasing a loose ball (IPR 1.68, 95% CI 1.36 to 2.08), heading (IPR 2.94, 95% CI 2.18 to 3.96) and receiving a slide tackle (IPR 3.27, 95% CI 1.81 to 5.92) resulted in greater proportions of competition injuries.

DISCUSSION

This study is the most detailed and largest epidemiological description of US high school soccer injuries to date. It demonstrates that injury rates have changed over time and injury rates and patterns vary by the type of AE and by sex. A better understanding of the epidemiology of high school soccer injuries will drive more effective targeted injury prevention efforts.

Injury rates

This study found an overall injury rate of 2.06 per 1000 AEs. Injury rates reported in other investigations vary widely (2–7 injuries per 1000 AEs), likely due to different methodological

Table 4 Soccer injury mechanism, activity and time of injury among girls' soccer players, National High School Sports-Related Injury Surveillance Study, USA, 2005/2006 through 2013/2014*

	Girls					
	Practice		Competition		Overall	
	N	Per cent	N	Per cent	N	Per cent
General mechanism						
Player–player contact	96 059	16.6	670 108	52.5	766 167	41.3
No contact	183 698	31.7	217 637	17.0	401 335	21.6
Playing surface contact	110 181	19.0	191 766	15.0	301 947	16.3
Playing apparatus contact	70 163	12.1	148 129	11.6	218 292	11.8
Overuse/chronic	100 471	17.3	29 398	2.3	129 869	7.0
Other	19 565	3.4	19 490	1.6	39 055	2.1
Specific mechanism						
Player-to-player contact (not slide tackle)	56 003	9.7	453 976	35.9	509 979	27.7
NA (ie, overuse, heat illness, conditioning, etc)	178 382	30.9	79 753	6.3	258 135	14.0
Contact with ball	83 946	14.5	173 620	13.7	257 566	14.0
Stepped on, fell on or kicked	36 439	6.3	151 930	12.0	188 369	10.2
Rotation around a planted foot/inversion	79 597	13.8	140 434	11.1	220 031	11.9
Slide tackle	9962	1.7	66 100	5.2	76 062	4.1
Uneven playing surface	31 310	5.4	20 558	1.6	51 868	2.8
Contact with goal	2059	0.4	4572	0.4	6631	0.4
Other	100 471	17.4	172 687	13.7	273 158	14.8
Activity						
General play	184 982	32.1	247 288	19.7	432 270	23.6
Chasing a loose ball	40 358	7.0	181 355	14.5	221 713	12.1
Dribbling	53 902	9.4	137 594	11.0	191 496	10.5
Defending	54 892	9.5	236 939	18.9	291 831	15.9
Heading ball	11 587	2.0	97 569	7.8	109 156	6.0
Goaltending	31 800	5.5	82 545	6.6	114 345	6.2
Passing (foot)	37 064	6.4	69 060	5.5	106 124	5.8
Receiving a pass	11 697	2.0	63 844	5.1	75 541	4.1
Shooting (foot)	30 238	5.3	52 830	4.2	83 068	4.5
Conditioning	81 530	14.2	3320	0.3	84 850	4.6
Receiving a slide tackle	3963	0.7	32 075	2.6	36 038	2.0
Blocking a shot	8172	1.4	24 506	2.0	32 678	1.8
Attempting a slide tackle	3881	0.7	8056	0.6	11 937	0.7
Other	21 891	3.8	16 730	1.3	38 621	2.1
Time of injury during practice						
First ½ hour	81 059	14.6	–	–	81 059	14.6
Second ½ hour	132 929	23.9	–	–	132 929	23.9
1–2 hours into practice	310 583	55.9	–	–	310 583	55.9
>2 hours into practice	30 942	5.6	–	–	30 942	5.6
Time of injury during competition†						
Precompetition/warm-ups	–	–	13 245	1.6	13 245	1.6
First half	–	–	287 571	34.6	287 571	34.6
Second half	–	–	524 709	63.2	524 709	63.2
Overtime	–	–	5237	0.6	5237	0.6

*Data represent weighted national estimates.
†Soccer time of injury during competition was added to High School RIO beginning in 2008/2009.
NA, not available; RIO, Reporting Information Online.

approaches.[30] One prior study reported non-concussion injury rates in boys decreased over a 3-year period, whereas non-concussion rates in girls held relatively steady.[12] Our findings were similar. More research is needed to understand these trends and sex differences in non-concussion injury rates. A re-evaluation of injury prevention programmes, especially in girls, should be performed with the goal of more effectively reducing non-concussion soccer injury rates.

The concussion rate increased among both boys and girls during the study period. This may be partially due to better recognition of concussion symptoms and signs by medical and coaching staff, or the implementation of state concussion laws in the later years of our study. The precise reason for increasing concussion rates requires further investigation.

Type of athlete exposure

Similar to previous research, we found higher injury rates in competition compared with practice.[3 12 15 21 31] This is likely due to more intense, full contact and potentially riskier play that occurs in competition. Future research should evaluate the

potential for reducing injuries through enhanced enforcement of soccer's existing rules with a focus on reducing player–player contact. A novel finding presented here is that injuries most commonly occurred between the goal boxes. Walden *et al*[32] reported a similar pattern in their video analysis of non-contact ACL injuries of 39 male professional football players. Future research is needed to determine if this is due to more time being spent in these quadrants of the field during games, player characteristics or something else.

Injury characteristics

A higher proportion of more serious injuries, including fractures, ligament sprains and concussions occurred in competition compared with practice in both sexes. Although a similar proportion of boys' and girls' injuries resulted in surgical repair (5.4% vs 6.6%), knee sprains represented a much higher proportion of those injuries requiring surgery in girls (63.6%) than boys (38.2%). This indicates a need for targeted preventive programmes for girls' knee ligament sprains to reduce the need for surgical intervention, as well as further research into potential reasons for this observed difference between sexes.[33 34]

Injury events

Similar to previous studies, the majority of competition injuries resulted from player–player contact while the majority of practice injuries resulted from non-contact mechanisms.[14 30 31 35] Although injury rates were significantly higher in competition than practice, over a third of all injuries occurred in practice. Research is needed to identify potential changes to coaching philosophies, warm-up or training to reduce practice injury rates. The majority of injuries during competitions occurred during the second half indicating a potential accumulated effect of fatigue. We found midfielders and offensive players had more injuries compared with defenders and goal keepers, yet previous studies reported mixed results regarding player position.[21 29 30 36 37] Further prospective studies are required to determine if there are correlations between soccer players' position and injury risk. Less than 5% of all injures were associated with slide tackles, perhaps a reflection of referee focus on improving safety by enforcing rules regarding unsafe tackling.

Limitations

Participants were limited to high schools with NATA-affiliated ATs which may limit generalisability because not all US schools have ATs. However, using trained sports medicine professionals as data reporters improves data quality. Only injuries that came to the attention of an AT could be reported. Medical coverage of high school soccer is inconsistent with physician coverage rare at most schools and AT coverage shared across multiple sports (eg, an AT covering an away football game is not available to cover a home soccer game).

Additionally, High School RIO captures only time loss injuries or any concussion, fracture, dental injury or exertional heat event. Minor injuries (eg, contusions), not resulting in time loss, are not captured. Therefore, the High School RIO surveillance system undercaptures the true number of soccer injuries which means we undoubtedly underestimated the true injury rate in this study. This limitation restricting reporting primarily to time-loss injuries is a necessary aspect of the High School RIO surveillance methodology to decrease reporter time burden and was considered acceptable given the decreased clinical importance of non-time-loss injuries.

Finally, exposure time is calculated in the High School RIO surveillance methodology as AEs rather than athlete minutes because it was not feasible for ATs to attend all practices and competitions for all sports under surveillance to record the exact number of minutes each player participated. We acknowledge there have been multiple publications providing guidance regarding methodologies for capturing exposure data in sports injury surveillance studies,[28 38–41] but note the guidance varies across publications and thus concludes the 'best' exposure data are dependent on the specific parameters of the study population and research resources. We believe that the athlete's unit-based exposure (ie, number of athlete practices and number of athlete competitions) is an acceptable methodology given the limitations of the US high school sports setting.

This study also did not examine the impact of acute or chronic training load on injury risk, or the presence or compliance of any injury prevention programmes in each school. We also did not record specific ligament sprain categories (grade I, II or III). A final limitation of the High School RIO methodology is the failure to capture any data on uninjured athletes (eg, demographic data) in the cohort beyond the basic athletic participation data used as the exposure variable in the calculation of injury rates.

CONCLUSIONS

This is the most comprehensive study of soccer injuries among a large national sample of US high school athletes. This study found most injuries occur in competitions as a result of player–player contact, and that concussion rates or reporting are increasing for male and female soccer players. Given the morbidity associated with injuries, these findings should drive additional research into the development, implementation and evaluation of targeted prevention strategies.

What are the findings?

- During the study period, non-concussion injury rates decreased significantly for boys but were relatively stable for girls. Concussion rates increased significantly for boys and girls.
- Symptoms resolved within 1 day in 21.0% of concussions but took >1 week to resolve in 29.4%. Most concussions resulted in time loss between 1 and 3 weeks (54.8%); 3.5% of athletes were medically disqualified for the season.
- Player–player contact was the most common mechanism of injury during competition, while non-contact mechanisms were most common during practice.

How might it impact on clinical practice in the future?

This study describes common soccer injuries sustained during practice and competition. Epidemiological data can be used to guide medical event planning and to develop targeted interventions to achieve the highest effectiveness in soccer injury prevention.

Correction notice This paper has been amended since it was published Online First. The affiliations have been corrected.

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