

Epidemiology of Rare Injuries and Conditions Among United States High School Athletes During the 2005–2006 and 2006–2007 School Years

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Context: Although more than 7 million athletes participate in high school sports in the United States, to date no nationally representative studies of rare injuries and conditions (RICs) exist. Rare injuries and conditions include eye injuries, dental injuries, neck and cervical injuries, and dehydration and heat illnesses.

Objective: To describe the epidemiology of RICs sustained by high school athletes during the 2005–2006 and 2006–2007 school years.

Design: Prospective cohort study.

Setting: A nationally representative sample of 100 US high schools using an injury surveillance system, High School Reporting Information Online.

Patients or Other Participants: Athletes participating in football, boys' soccer, girls' soccer, volleyball, boys' basketball, girls' basketball, wrestling, baseball, or softball at one of the 100 participating high schools.

Main Outcome Measure(s): We reviewed all RICs to calculate injury rates and to identify potential risk factors and preventive measures.

Results: A total of 321 RICs were sustained during 3 550 141 athlete-exposures (AEs), for an injury rate of 9.04 RICs per 100 000 AEs. This represents an estimated 84 223 RICs sustained nationally. The RICs accounted for 3.5% of all high school athletes' injuries. The most common diagnoses were neck and cervical injuries (62.0%, $n = 199$) and dehydration and heat illnesses (18.7%, $n = 60$). Football had the highest RIC rate per 100 000 AEs (21.2), followed by wrestling (15.2) and baseball (7.60). The RICs occurred at a higher rate in boys (12.4) than in girls (2.51) (rate ratio = 4.93; 95% confidence interval = 3.39, 7.18). The majority of RICs (67.3%, $n = 216$) permitted athletes to return to play within 1 week of diagnosis.

Conclusions: The RIC injury rates varied by sport and sex and represented almost 100 000 potentially preventable injuries to high school athletes. Because of the potentially serious consequences, future researchers must develop and implement more effective preventive measures to aid certified athletic trainers in decreasing the RIC incidence among high school athletes.

Key Words: injury surveillance, eye injuries, dental injuries, neck injuries, heat illnesses

Key Points

- Rare injuries and conditions accounted for 3.5% of all high school athletes' injuries during the study time frame.
- The most common diagnoses were neck and cervical injuries and dehydration and heat illnesses.
- The highest rate of rare injuries and conditions was found in football, followed by wrestling and baseball.
- Rare injuries and conditions occurred more frequently in boys than girls.

In the United States, participants in high school athletics have grown from an estimated 4 000 000 in 1972 to more than 7 000 000 in 2006.¹ In a 1999 study,² high school athletes accounted for an estimated 2 000 000 injuries, 500 000 doctor visits, and 30 000 hospitalizations annually. With increasing numbers of adolescents participating in high school competitive sports and sustaining athletic-related injuries, the frequency of "rare" injuries and conditions becomes a concern.

A rare event in the medical field is a condition considered to be uncommon or unusual. With regard to athletes, this can include but is not limited to eye injuries, dental injuries, neck and cervical injuries, and dehydration and heat illnesses. Prior authors^{3–5} indicated that these rare injuries and conditions (RICs) accounted for 0.2% to 36.4% of all athletic injuries. Although rare, RICs are significant to the medical community, as they can result in high morbidity and a burden on health care, including costly surgeries and

treatments,^{4,6,7} medical disqualification from the sport,^{6,8} and other life-altering consequences.^{8–11}

Previous investigators of RICs have primarily focused on the general public¹⁰ or the prevention or management of these injuries and conditions.⁴ Few authors have researched the prevalence of individual RICs within the athletic community.^{5,8} The epidemiology of RICs across sports within a nationally representative population of high school athletes has not been examined. Most reports of high school injuries have concentrated on common injuries, such as strains, sprains, and fractures² and their associated risk factors¹²; none have focused exclusively on RICs. Because of the potentially serious consequences of these injuries, the need for further analysis of the incidence and risk factors of such RICs within the high school population is overwhelming.

In this study, we describe the epidemiology of RICs among high school athletes participating in 9 sports during

the 2005–2006 and 2006–2007 school years. By filling an important gap in the scientific literature, this epidemiologic data will be of use to athletic trainers and physicians treating these rare events as well as to public health professionals and those developing potential preventive measures.

METHODS

Reporting Information Online (RIO; The Research Institute at Nationwide Children's Hospital, Columbus, OH), an Internet-based injury surveillance system, was used to collect injury and exposure data for athletes participating in 9 selected US high school sports: football, boys' soccer, girls' soccer, volleyball, boys' basketball, girls' basketball, wrestling, baseball, and softball. The surveillance method has been described in detail previously.¹³ In brief, high schools with a National Athletic Trainers' Association–affiliated certified athletic trainer (AT) with a valid e-mail address ($n = 4120$ in 2005–2006 and $n = 3378$ in 2006–2007) were invited to participate. A total of 425 and 316 (in 2005–2006 and 2006–2007, respectively) of the ATs agreed; their respective high schools were categorized into 8 sampling frames based on 4 US Census geographic regions¹⁴ and 2 school sizes (less than or equal to 1000 students or greater than 1000 students). A random selection of schools from each of the 8 sampling frames was chosen to create a nationally representative study sample of 100 schools. During the first 2 study years, 9 enrolled high schools dropped out of the study. Reasons for withdrawal included ATs leaving schools as a result of budget cuts, ATs with personal or family concerns, etc. If a school dropped out during the course of the study, another school from the same sampling frame was randomly selected for replacement.

Participating ATs reported injury incidence and athlete-exposures (AEs) weekly through the High School RIO Web site. A *reportable injury* was defined as an injury that occurred during an organized high school practice or competition, required medical attention by an AT or a physician, and resulted in restriction of the student-athlete's participation in practice or competition (or both) for 1 or more days. The RICs were defined as eye injuries, dental injuries, neck and cervical injuries, and dehydration and heat illnesses. An AE was defined as a single athlete's participation in 1 practice or competition. After each adverse event, the AT submitted a detailed report that described its characteristics, including age of the athlete, diagnosis, assessment method, and length of time until return to play. The ATs were able to view and update all previously submitted data throughout the study period.

Data were analyzed using SPSS (version 14.0; SPSS Inc, Chicago, IL) and Epi Info version 6.0 (Centers for Disease Control and Prevention, Atlanta, GA). A sample n is provided for each proportion. However, the denominator for the n does not always reflect the total number of injuries because of a small number of nonresponses. Analyses included calculation of rate ratios (RRs) and injury proportion ratios (PRs). Statistical significance was assessed using 95% confidence intervals (CIs) not containing 1.0 and P values less than .01. Injury rates (IRs) were calculated as the ratio of RICs per 100 000 total AEs. The following is a sample RR calculation comparing the overall rate of RICs between competitions and practices:

$$\text{RR} = \left[\frac{\text{total No. competition RICs}}{\text{total No. competition AEs}} \times 100\,000 \right] \div \left[\frac{\text{total No. practice RICs}}{\text{total No. practice AEs}} \times 100\,000 \right]$$

The following is a sample PR calculation comparing the proportion of RICs of the total number of boys' and girls' injuries:

$$\text{PR} = \frac{\text{total No. girls' RICs} / \text{total No. girls' injuries}}{\text{total No. boys' RICs} / \text{total No. boys' injuries}}$$

National estimates were calculated by assigning a sample weight to each reported injury. Sample weights were determined based on the inverse probability of a school's selection into the study. This study was approved by the Institutional Review Board at The Research Institute at Nationwide Children's Hospital.

RESULTS

All Rare Injuries and Conditions

During the study period, 321 RICs occurred during 3 550 141 AEs (Table 1), for an IR of 9.04 RICs per 100 000 AEs (Table 2). This represents an estimated 84 223 RICs sustained nationally during the 2005–2006 and 2006–2007 school years among high school athletes participating in the 9 sports studied. Combined, these RICs comprised 3.5% of the 9297 reported sport-related injuries. The RICs most commonly occurred in football, wrestling, and baseball (Table 1); however, they comprised the highest proportion of all reported injuries in baseball (6.0%, total $n = 431$), wrestling (5.9%, total $n = 835$), and football (4.7%, total $n = 4201$).

Overall, RIC IRs were higher among boys (12.4) than girls (2.51) (RR = 4.93, 95% CI = 3.39, 7.18) (Table 2) and higher in competition (15.9) than in practice (6.32) (Figure 1; RR = 2.52, 95% CI = 2.02, 3.14). Although most athletes (67.3%, $n = 208$) returned to play within 1 week (Figure 2), 15 injuries (4.9%) resulted in medical disqualification for the season, and 2 neck or cervical injuries (0.6%) resulted in career medical disqualification. Additionally, 16 injuries (5.1%) required surgery.

Eye Injuries

Rates and Proportions. High school athletes sustained 39 eye injuries (Table 1), for an IR of 1.10 per 100 000 AEs (Table 2). This represents an estimated 11 816 eye injuries sustained nationally during the study period. Although not significant, IRs were higher in boys (1.27) than girls (0.75) (RR = 1.69, 95% CI = 0.80, 3.57) and higher in competition (2.06) than in practice (0.70) (Figure 1; RR = 2.95, 95% CI = 1.56, 5.57).

Diagnoses and Outcomes. Common eye injuries included contusions (41.0%, $n = 16$), lacerations (25.6%, $n = 9$), and abrasions (12.8%, $n = 5$). One injury resulted in loss of peripheral vision. Only 2 of the 39 injured athletes (5.1%) were wearing applicable protective equipment. Although most athletes (74.4%, $n = 29$) returned to play within 1 week (Figure 2), 3 injuries (7.7%) required surgery. Two girls' basketball players required surgery

Table 1. Distribution of Rare Injuries and Conditions Among High School Athletes by Sex and Sport, High School Sports-Related Injury Surveillance Study, United States, 2005–2006 and 2006–2007 School Years

Sex or Sport	Eye Injuries, No. (%) (n = 39)	Dental Injuries, No. (%) (n = 23)	Neck and Cervical Injuries, No. (%) (n = 199)	Dehydration and Heat Illnesses, No. (%) (n = 60)	Total, No. (%) (n = 321)
By sex					
Boys' sports	30 (76.9)	18 (78.3)	188 (94.5)	55 (91.7)	291 (90.7)
Girls' sports	9 (23.1)	5 (21.7)	11 (5.5)	5 (8.3)	30 (9.3)
By sport					
Football	4 (10.3)	3 (13.0)	143 (71.9)	48 (80.0)	198 (61.7)
Boys' soccer	2 (5.1)	1 (4.3)	1 (0.5)	2 (3.3)	6 (1.9)
Girls' soccer	1 (2.6)	0	5 (2.5)	1 (1.7)	7 (2.2)
Volleyball	0	0	0	3 (5.0)	3 (0.9)
Boys' basketball	7 (17.9)	2 (8.7)	3 (1.5)	0	12 (3.7)
Girls' basketball	5 (12.8)	4 (17.4)	5 (2.5)	1 (1.7)	15 (4.7)
Wrestling	6 (15.4)	1 (4.3)	39 (19.6)	3 (5.0)	49 (15.3)
Baseball	11 (28.2)	11 (47.8)	2 (1.0)	2 (3.3)	26 (8.1)
Softball	3 (7.7)	1 (4.3)	1 (0.5)	0	5 (1.6)

for injuries that occurred in competition: 1 sustained a detached retina after being hit with the ball while rebounding, and 1 sustained a contusion after being elbowed while chasing a loose ball. One baseball player required surgery when he was hit by a line drive ball at

third base during a preseason practice, resulting in a laceration. Baseball, boys' basketball, and wrestling accounted for the majority of eye injuries (Table 1); these sports also resulted in the highest eye injury rates (Table 2).

Table 2. Rare Injury and Condition Rates per 100 000 Athlete-Exposures by Sex and Sport, High School Sports-Related Injury Surveillance Study, United States, 2005–2006 and 2006–2007 School Years

Sex or Sport (Athlete-Exposures)	Eye Injuries	Dental Injuries	Neck and Cervical Injuries	Dehydration and Heat Illnesses	All Rare Injuries and Conditions	Rate Ratios ^a	95% Confidence Interval
By sex							
Boys' sports (2 353 754)	1.27	0.76	7.99	2.34	12.4	4.93	3.39, 7.18
Girls' sports (1 196 387)	0.75	0.42	0.92	0.42	2.51	1.00	Not applicable
By sport							
Football (933 340)	0.43	0.32	15.32	5.14	21.2	19.8	6.33, 61.9
Boys' soccer (332 919)	0.60	0.30	0.30	0.60	1.80	1.68	0.42, 6.72
Girls' soccer (304 527)	0.33	0	1.64	0.33	2.30	2.14	0.55, 8.29
Volleyball (279 880)	0	0	0	1.07	1.07	1.00	Not applicable
Boys' basketball (423 239)	1.65	0.47	0.71	0	2.84	2.65	0.75, 9.37
Girls' basketball (357 412)	1.40	1.12	1.40	0.28	4.20	3.92	1.13, 13.5
Wrestling (322 373)	1.86	0.31	12.10	0.93	15.2	14.2	4.42, 45.5
Baseball (341 883)	3.22	3.22	0.58	0.58	7.60	7.09	2.15, 23.4
Softball (254 568)	1.18	0.39	0.39	0	1.96	1.83	0.44, 7.67
Overall (3 550 141)	1.10	0.65	5.61	1.69	9.04		

^a In all rate ratios, the sex or sport with the lowest rate of rare injuries and conditions served as the comparison group.

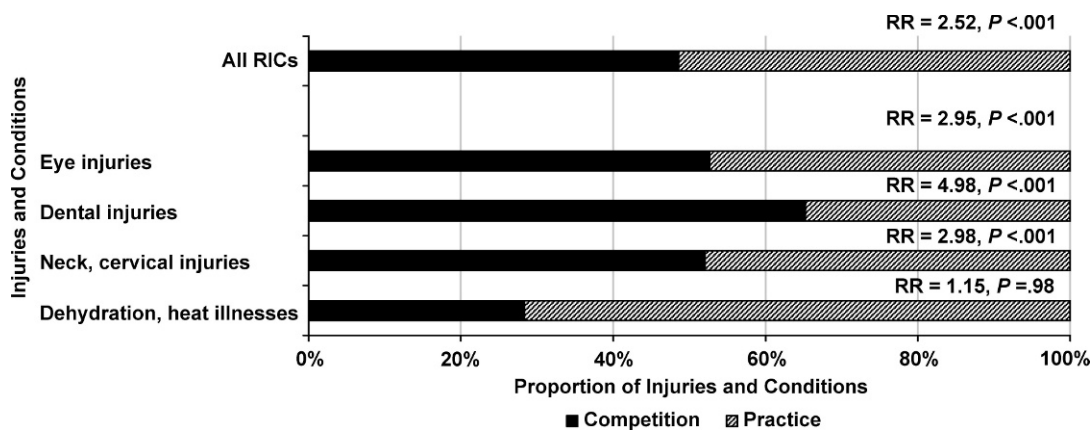


Figure 1. Proportions and rate ratios^a of rare injuries and conditions (RICs) among high school athletes by competition or practice, High School Sports-Related Injury Surveillance Study, United States, 2005–2006 and 2006–2007. ^a Rate ratio (RR) = competition injury rate/practice injury rate. ^b Does not include 3 injuries for which exposure information was unknown.

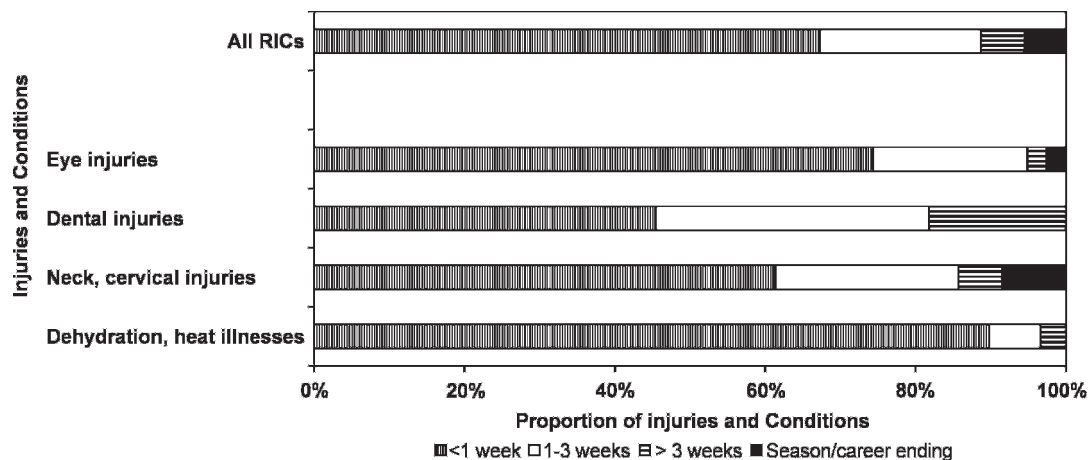


Figure 2. Days of play lost as a result of rare injuries and conditions (RICs) among high school athletes, High School Sports-Related Injury Surveillance Study, United States, 2005–2006 and 2006–2007 school years. Does not include 9 injuries for which time-loss information was unknown.

Sport-Specific Information. All 11 baseball eye injuries were caused by contact with the ball (Table 3), and all occurred among players in the infield. The most common activities at the time of injury were fielding (63.6%, n = 7) and batting (18.2%, n = 2). All 7 eye injuries reported in boys’ basketball were caused by collisions with other players (Table 3), 3 (42.9%) of which occurred during rebounding. The most common mechanism was contact with an opponent’s finger or hand (71.4%, n = 5). Of the wrestling eye injuries with a reportable mechanism, 4 (100%) resulted from contact with another player (Table 3). The most common mechanism of injury was riding (33.3%, n = 2).

Dental Injuries

Rates and Proportions. Athletes sustained 23 dental injuries (Table 1), resulting in an IR of 0.65 per 100 000 AEs (Table 2). This represents an estimated 7155 dental injuries sustained nationally during the study period.

Although not significant, IRs were higher among boys (0.76) than girls (0.42) (RR = 1.83, 95% CI = 0.68, 4.93). The IRs were higher in competition (1.54) than in practice (0.31) (Figure 1; RR = 4.98, 95% CI = 2.11, 11.74).

Diagnoses and Outcomes. The most common dental injuries were tooth avulsions (43.5%, n = 10), fractures (39.1%, n = 9), and luxations (13.0%, n = 3). Only 3 of the injured athletes (13.0%) were wearing applicable protective equipment. Many athletes (45.5%, n = 10) returned to play within 1 week (Figure 2). Thirteen injuries (56.5%) required surgery. Baseball, girls’ basketball, and football accounted for the majority of dental injuries (Table 1). The rate of dental injuries in baseball (3.22) was more than 3 times higher than the rates in all other sports combined (IR = 0.87) (RR = 3.68, 95% CI = 1.83, 7.40) (Table 2).

Sport-Specific Information. Contact with the ball caused the majority (90.9%, n = 10) of baseball dental injuries (Table 3). All injuries occurred in the infield, primarily during fielding (36.4%, n = 4) and catching (27.3%, n = 3). Although more than half (60.0%, n = 6) of those injured

Table 3. Mechanism of Rare Injuries by Sex and Sport, High School Sports-Related Injury Surveillance Study, United States, 2005–2006 and 2006–2007 School Years [All Values Are No. (%)]

Sex or Sport	Eye Injuries (n = 39) ^a			Dental Injuries (n = 23)			Neck or Cervical Injuries (n = 199) ^b		
	Player-Player Contact	Player-Apparatus Contact	Player-Surface Contact	Player-Player Contact	Player-Apparatus Contact	Player-Surface Contact	Player-Player Contact	Player-Apparatus Contact	Player-Surface Contact
By sex									
Boys’ sports	14 (51.9)	13 (48.1)	0	7 (38.9)	11 (61.1)	0	142 (83.6)	3 (1.8)	25 (14.7)
Girls’ sports	2 (25.0)	6 (75.0)	0	4 (80.0)	0	1 (20.0)	7 (70.0)	1 (10.0)	2 (20.0)
By sport									
Football	2 (66.7)	1 (33.3)	0	3 (100.0)	0	0	127 (93.4)	1 (0.7)	8 (5.9)
Boys’ soccer	1 (50.0)	1 (50.0)	0	1 (100.0)	0	0	0	1 (100.0)	0
Girls’ soccer	0	1 (100.0)	0	0	0	0	2 (40.0)	1 (20.0)	2 (40.0)
Volleyball	0	0	0	0	0	0	0	0	0
Boys’ basketball	7 (100.0)	0	0	1 (50.0)	1 (50.0)	0	1 (50.0)	0	1 (50.0)
Girls’ basketball	2 (50.0)	2 (50.0)	0	3 (75.0)	0	1 (25.0)	4 (100.0)	0	0
Wrestling	4 (100.0)	0	0	1 (100.0)	0	0	14 (48.3)	0	15 (51.7)
Baseball	0	11 (100.0)	0	1 (9.1)	10 (90.9)	0	0	1 (50.0)	1 (50.0)
Softball	0	3 (100.0)	0	1 (100.0)	0	0	1 (100.0)	0	0
Overall	16 (43.7)	19 (54.3)	0	11 (47.8)	11 (47.8)	1 (4.3)	149 (82.8)	4 (2.2)	27 (15.0)

^a Does not include 4 injuries for which mechanism was unknown.

^b Does not include 19 injuries for which mechanism was unknown.

returned to play in less than 1 week, more than half (54.5%, $n = 6$) required surgery. Surgeries resulted primarily after sustaining a hit from a line drive (50.0%, $n = 5$) or a ground ball (33.3%, $n = 8$). In girls' basketball, most athletes sustaining a dental injury (75.0%, $n = 3$) did not return to play for more than 1 week. Three injuries (75.0%) were due to collision with another player (Table 3), 2 of which occurred while rebounding. Surgery was required for 2 of the girls' basketball dental injuries; one athlete was hit with the ball while rebounding, and one hit the court while chasing a loose ball.

Neck and Cervical Spine Injuries

Rates and Proportions. Athletes sustained 199 neck and cervical spine injuries (Table 1), resulting in an IR of 5.61 per 100 000 AEs (Table 2). This represents an estimated 49 432 neck and cervical injuries sustained nationally during the study period. Neck and cervical IRs were higher in boys (7.99) than girls (0.92) (RR = 8.69, 95% CI = 4.73, 15.96) and higher in competition (10.50) than in practice (3.53) (Figure 1; RR = 2.98, 95% CI = 2.24, 3.95).

Diagnoses and Outcomes. Common diagnoses of neck and cervical injuries included muscle strains (61.8%, $n = 123$), nerve injuries (21.1%, $n = 42$), and ligament sprains (8.5%, $n = 17$). Most athletes (61.4%, $n = 116$) returned to play within 1 week (Figure 2). Two injuries (1.0%), a cervical vertebrae fracture sustained by a wrestler while riding and a recurrent nerve injury sustained by a football player while tackling, resulted in medical disqualification for career. No injuries required surgery. Neck and cervical injuries were most common in football and wrestling (Table 1); the rate of neck and cervical injuries per 100 000 AEs in these 2 sports (14.5) was more than 19 times higher than in all other sports combined (IR = 0.74) (RR = 19.6, 95% CI = 11.9, 32.2) (Table 2).

Sport-Specific Information. Most football neck and cervical injuries (93.4%, $n = 134$) were caused by contact with another player (Table 3), specifically tackling (53.6%, $n = 75$) and being tackled (20.7%, $n = 29$), followed by blocking (10.7%, $n = 15$) or being blocked (10.7%, $n = 15$). Most occurred during a running play (60.7%, $n = 85$). More than half of these athletes (59.4%, $n = 82$) returned to play in less than 1 week, 25.4% ($n = 35$) returned in 1 to 3 weeks, and 11.6% ($n = 16$) returned in more than 3 weeks. Of those players sustaining a neck or cervical injury that caused them to miss more than 3 weeks of play, most injuries resulted from tackling (66.7%, $n = 10$), and almost half occurred among linebackers (40.0%, $n = 6$).

The most common mechanisms for wrestling neck and cervical injuries were contact with the playing surface (51.7%, $n = 15$) and contact with another player (48.3%, $n = 14$) (Table 3). The most common activity at the time of injury was takedown (36.4%, $n = 12$), and 42.4% ($n = 14$) of wrestlers sustaining a neck or cervical injury weighed 135 lbs (61.23 kg) or less. Half of these wrestlers returned to play in less than 1 week (51.3%, $n = 20$), 25.6% ($n = 10$) returned in 1 to 3 weeks, and 23.1% ($n = 9$) returned in more than 3 weeks. Patterns varied little by severity. Of those wrestlers sustaining a neck or cervical injury that caused them to miss more than 3 weeks of play, 50.0% ($n = 4$) occurred during takedown and 50.0% ($n = 4$) occurred among wrestlers weighing 135 lbs (61.23 kg) or less.

Dehydration and Heat Illnesses

Rates and Proportions. Athletes sustained 60 instances of dehydration or heat illness during the study period (Table 1), resulting in an IR of 1.69 per 100 000 AEs (Table 2). This represents an estimated 15 819 episodes of dehydration or heat illness sustained nationally during the study period. The IRs were higher in boys (2.34) than girls (0.42) (RR = 5.59, 95% CI = 2.24, 13.97). Competition (1.75) and practice (1.67) had similar IRs (Figure 1).

Diagnoses and Outcomes. All dehydration and heat illness conditions occurring in competition (28.3%, $n = 17$) happened in the second half of the contest. Most episodes occurring during practice (83.7%, $n = 36$) happened after the first hour of practice; 30.2% ($n = 13$) occurred after more than 2 hours of practice. More than half of the incidents occurred during preseason training (60.0%, $n = 36$). Most athletes (88.3%, $n = 53$) returned to play within 1 week (Figure 2); the majority (65.0%, $n = 39$) returned to play within 1 to 2 days. However, 2 football athletes (1 offensive guard and 1 wide receiver) sustained heat illnesses while conditioning and chose to discontinue their season. Most instances of dehydration and heat illness occurred in football (Table 1): the rate per 100 000 AEs (5.14) was more than 11 times higher than rates for all other sports combined (IR = 0.46) (RR = 11.2, 95% CI = 5.96, 21.1) (Table 2).

DISCUSSION

All Rare Injuries and Conditions

Injuries and conditions such as eye injuries, dental injuries, neck and cervical injuries, and dehydration and heat illnesses are considered uncommon among high school athletes; however, as participation in high school athletics continues to increase, so will the number of athletes who sustain RICs. We are the first to present the epidemiology of RICs across high school sports using nationally representative data. We found that RICs accounted for 3.5% of all injuries during the 2005 through 2007 school years, with an IR of 9.04 per 100 000 AEs. This represents 82 986 RICs sustained nationally by US student-athletes participating in football, boys' soccer, girls' soccer, volleyball, boys' basketball, girls' basketball, wrestling, baseball, and softball. The incidence and patterns of RICs varied by sport, sex, and type of exposure. Identifying such patterns is the essential first step to assist ATs, physicians, and public health professionals in developing targeted preventive measures.

Eye Injuries

With the potential for serious damage, eye injuries represent an important source of preventable morbidity among athletes.⁶ Treating eye injuries also imposes a financial burden, with costs between \$200 and \$1570 per case.⁶ Consistent with previous studies,^{6,15-17} eye injuries comprised 0.4% of all injuries sustained by high school athletes in this study, with baseball and boys' basketball accounting for the highest proportions.

Previous authors¹⁶ have found that properly fitted, sport-specific eye protection can reduce the risk of eye injury by at least 90%; however, most high school athletes

are not currently required to wear such equipment. In this study, all baseball eye injuries occurred through contact with the ball, and none of the injured athletes were wearing eye protection. Based on previous research and the beneficial outcomes with eye protection, baseball players should be strongly encouraged, if not required, to wear proper face and eye protection during both offensive and defensive play. Given the high prevalence of preventable eye injuries in basketball, basketball players should also consider wearing eye protection.

Dental Injuries

Consistent with prior research,⁵ dental injuries accounted for 0.2% of all high school sport injuries in our study. Yet we found that dental injury rates were highest in baseball, whereas a previous author⁵ found that boys' soccer players had the highest number of dental injuries, followed by baseball players. These inconsistent results may be due to the broader definition of injury (including teeth, jaw, and soft tissue injuries) in the previous study; we included only teeth injuries.

More than half of the dental injuries in this study required surgical repair. Such repair costs can range from \$900⁷ to \$15000.⁴ Most of the baseball dental injuries occurred when a player was hit in the mouth by a ball; this was different than the situation in basketball, in which the majority of injuries were due to contact with another player. No injured baseball or basketball players were wearing mouthguards, despite their proven protective value.^{3,18} In a previous study, the introduction of mouthguards to all high school and college football players decreased injury rates to the face and mouth from 50% of all injuries to less than 0.5%.¹⁹ Based on the effectiveness of mouthguards and our findings, we believe high school baseball and basketball players should be required to wear mouthguards to protect against dental injury.

Neck and Cervical Injuries

Neck and cervical injuries have the potential to cause severe negative outcomes, such as season-ending injuries, quadriplegia, and death.⁸ Consistent with previous studies,²⁰ the most common injuries seen in this study were muscle strains, nerve injuries, and ligament sprains. Football accounted for the majority of neck and cervical injuries, usually from player-to-player contact during tackling or blocking. Despite the relatively high rate of neck and cervical injuries among football players, our rate of high school football neck and cervical injuries is lower than that found among collegiate football players,²¹ likely because high school football players are somewhat smaller than collegiate football players and, thus, their collisions are usually not as forceful.⁸ Additionally, catastrophic cervical spine injury rates in high school football have decreased dramatically since spear tackling was made illegal in 1976.²² Renewed emphasis on proper tackling and blocking techniques should continue to decrease the prevalence and severity of neck and cervical injuries in high school football players. Wrestling also accounted for a high incidence of neck and cervical injuries in this study. Consistent with previous findings,²³ these injuries were most common during takedown and highlight the need for continued efforts to train wrestlers in the safest, most

effective techniques for executing and defending against the takedown.

Dehydration and Heat Illnesses

Although a slight level of dehydration may not seem severe, it can lead to negative consequences, including heat illness. Increases in body temperature and reduction in work capacity can become evident when dehydration levels exceed 3% of body weight²⁴⁻²⁶; however, an athlete may not become thirsty until he or she is 5% dehydrated, when he or she is already prone to heat illness.²⁷ Failure to properly hydrate can lead to impairment of physical activity²⁸ and increase the risk of heat stroke, currently the third leading cause of death in athletes.^{10,29}

In this study, most episodes of dehydration and heat illness occurred in football players. More than half of these conditions (60.0%) occurred during preseason practice, after the athlete had already been participating for over an hour. This finding is consistent with prior studies, which have shown that dehydration is generally not a problem if the athletic session lasts less than 60 minutes²⁷ and that heat illness is most common early in the season, when athletes are not properly acclimatized to the environmental conditions.^{9,11} Coaches and athletes should be educated on the risk of dehydration and heat illness during the football season. Athletes should be permitted an acclimatization period¹¹ and encouraged to consume fluids, even before they are thirsty.²⁷

Limitations

Like all investigations, this study has limitations. Data collection was limited to 9 sports, and only high schools whose athletes had access to a National Athletic Trainers' Association-affiliated AT were eligible to participate. Not all schools have access to an AT, which may limit the generalizability of our results. This potential limitation was balanced by the improved data quality and consistency that resulted from using only trained medical professionals. Additionally, only those injuries that resulted in at least 1-time loss from play and that came to the attention of an AT were included in the study; therefore, it is likely that our data underestimate the actual RIC rate. This potential limitation was necessary to decrease the time burden on the ATs. Finally, AE was defined as an athlete's participation in a single practice or competition. Although a more precise approach is based on minutes during which the athlete was exposed to potential injury, it was not feasible for the AT to be at all sport practices and competitions to monitor the playing time of each individual athlete. Despite these limitations, this is the most comprehensive study of RICs among a nationally representative population of high school athletes to date.

CONCLUSIONS

Injuries and conditions such as eye injuries, dental injuries, neck and cervical injuries, and dehydration and heat illnesses are relatively rare among high school athletes; however, they have the potential for high morbidity and a significant burden on health care.^{6,7,9} The RICs present serious, yet potentially preventable, outcomes for high school athletes. Our findings indicate both sport-specific

and sex-specific risk factors for RICs. Physicians, public health professionals, ATs, coaches, and athletes should be educated about these risk factors and patterns. Further investigation into these risk factors and patterns will allow for the development of suitable preventive measures. Through proper education and the implementation of appropriate prevention strategies, these RICs could become even rarer.

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