

Trends in Concussion Incidence in High School Sports

A Prospective 11-Year Study

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Background: Understanding the risk and trends of sports-related concussion among 12 scholastic sports may contribute to concussion detection, treatment, and prevention.

Purpose: To examine the incidence and relative risk of concussion in 12 high school boys' and girls' sports between academic years 1997-1998 and 2007-2008.

Study Design: Descriptive epidemiology study.

Methods: Data were prospectively gathered for 25 schools in a large public high school system. All schools used an electronic medical record-keeping program. A certified athletic trainer was on-site for games and practices and electronically recorded all injuries daily.

Results: In sum, 2651 concussions were observed in 10 926 892 athlete-exposures, with an incidence rate of 0.24 per 1000. Boys' sports accounted for 53% of athlete-exposures and 75% of all concussions. Football accounted for more than half of all concussions, and it had the highest incidence rate (0.60). Girls' soccer had the most concussions among the girls' sports and the second-highest incidence rate of all 12 sports (0.35). Concussion rate increased 4.2-fold (95% confidence interval, 3.4-5.2) over the 11 years (15.5% annual increase). In similar boys' and girls' sports (baseball/softball, basketball, and soccer), girls had roughly twice the concussion risk of boys. Concussion rate increased over time in all 12 sports.

Conclusion: Although the collision sports of football and boys' lacrosse had the highest number of concussions and football the highest concussion rate, concussion occurred in all other sports and was observed in girls' sports at rates similar to or higher than those of boys' sports. The increase over time in all sports may reflect actual increased occurrence or greater coding sensitivity with widely disseminated guidance on concussion detection and treatment. The high-participation collision sports of football and boys' lacrosse warrant continued vigilance, but the findings suggest that focus on concussion detection, treatment, and prevention should not be limited to those sports traditionally associated with concussion risk.

Keywords: high school; injury; concussion; sports

Sports participants, their families, schools and organizations, and the medical community have an interest in

knowing the comparative incidence of concussion in scholastic sports and whether concussion rate is increasing. Concussion differs from many other sports injuries in that signs of injury may be difficult to detect and treat. According to one study, 1.6 to 3.8 million concussions in the United States were related to sports,¹⁰ including those with sports-related concussion who received no medical care. Increased attention to this potentially serious injury at the professional, collegiate, and youth level^{5,13} shows a growing focus on concussion at every level of sport. It appears likely that this substantially expanded awareness has been associated with increased coding sensitivity by those responsible for medical care of athletes at all levels, which may result in a more accurate depiction of concussion rate in given sports. Comparative data on concussion in common scholastic sports over time could help document which sports have the highest concussion risk and whether concussion rate has increased in individual high school sports and overall.

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Previous studies have identified areas of injury and concussion risk for high school athletes. An injury surveillance study sponsored by the Centers for Disease Control and Prevention found the highest overall injury rates in football, followed by wrestling, soccer (both boys' and girls'), and girls' basketball.¹⁸ Football, basketball, and soccer were among the activities associated with the greatest number of sports- and recreation-related traumatic brain injuries (which include but are not limited to concussion) for children aged 5 to 18 years in 2001-2005 based on emergency department visits.¹⁴ A comparative study of 9 scholastic sports in 100 US high schools⁸ found that concussions represented 9% (n, 396) of all high school athletic injuries. Of the 9 sports studied, concussion was found most commonly in football (41%) and girls' soccer (22%). No study has yet examined scholastic sports concussion incidence over time to determine whether incidence of concussion is increasing and, if so, whether scholastic boys' or girls' sports are associated with a more rapidly growing concussion risk.

Our purpose was to examine the incidence and relative risk of concussion in 12 high school boys' and girls' sports over an 11-year period (1997 to 2008). Our objectives were to determine (1) cumulative incidence rates of concussion in the sports studied, (2) the boys' and girls' sports with the highest relative risk of concussion, (3) the relative risk of concussion by sex among sports for which the game is nearly identical, (4) the rate of annual change in scholastic sports concussion overall, and (5) whether concussion rate is increasing across all sports, if at all.

MATERIALS AND METHODS

Institutional review board approval for the study was obtained. Data were prospectively gathered for each of the 25 high schools in a large public school system over a consecutive 11-year period (1997-2008). The population included 158 430 student athletes over the study period, with each athlete considered unique in each sport and season played.

Through 2005, each high school in the study employed 2 part-time certified athletic trainers. After 2005, each school had 1 full-time certified athletic trainer and 1 part-time. All schools used a district-mandated electronic medical record-keeping program for injury surveillance: Sports Injury Management Systems software (Flantech, Iowa City, Iowa). As an official part of their daily job responsibilities, the certified athletic trainers recorded all injuries and illnesses in the record-keeping system. A systemwide program supervisor monitored the record-keeping program to maximize compliance and data quality. A certified athletic trainer was available daily and was on-site for all games.

The study included student athletes in 6 boys' sports (football, lacrosse, wrestling, soccer, basketball, and baseball) and 6 girls' sports (field hockey, lacrosse, soccer, basketball, cheerleading, and softball). Concussion was defined as an event that occurred during official scholastic games or practices, was brought to the attention of the

certified athletic trainer, and was determined to be concussion through examination by the athletic trainer. Athletic trainers are trained in concussion management through annual in-service sessions led by neuropsychologists who specialize in concussion diagnosis and treatment. They frequently see athletes and may be able to observe possible concussion-related changes in athletic behavior. These certified individuals refer to a physician for more complicated situations. The athletic trainers used the Standardized Assessment of Concussion (CSMi Medical Solutions, Stoughton, California)¹² for on-field assessment and provided continuum of care, including subsequent reevaluations in the athletic training facility and neurologic testing (ImPACT [Immediate Post-Concussion Assessment and Cognitive Testing], ImPACT Applications, Inc, Pittsburgh, Pennsylvania).¹¹

Incidence rates and rate ratios were based on 1000 athlete-exposures (AEs), with AE defined as 1 athlete's participation in a practice or competition. Cumulative incidence rates were calculated from 1997-1998 through 2007-2008 for each of the 12 sports studied. Ratios comparing the boys' and girls' incidence rates were calculated for the 6 sports in which the boys' and girls' games were the same or very similar (girls' and boys' basketball, girls' and boys' soccer, softball and baseball). No injury was reported more than once. Overall incidence of repeat concussion was evaluated, but each concussion was coded as a separate injury.

Incidence rates were plotted over the study period for the sports, separately and combined. Tests for trend were calculated to assess a change in incidence over time for each sport. All analyses were performed using R: A Language and Environment for Statistical Computing, version 2.9.1 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Among the 12 high school sports studied between 1997-1998 and 2007-2008, there were 2651 concussion injuries in 10 926 892 AEs, for an overall incidence rate of 0.24 cases per 1000 AEs (Table 1). Boys' sports had 53% of total AEs but 75% of all concussions. Boys' and girls' sports were ranked in order of overall incidence of concussion. Football accounted for more than half of all concussions; boys' lacrosse had the next highest percentage. The concussion rate for football was nearly 11 times that of baseball, the boys' sport with the lowest incidence of concussion. Among the girls' sports, soccer represented the highest proportion of events overall (7.4%), with an incidence rate (0.35) second only to football. The next highest number of concussions in girls' sports occurred in cheerleading, basketball, and lacrosse, although the lacrosse incidence rate (0.20) was higher than that for cheerleading (0.06). The rate of girls' soccer was 6 times that of cheerleading, the girls' sport with the lowest incidence of concussion. The overall concussion rate for boys was more than twice that for girls.

The overall (12-sport) concussion rate increased from 0.12 per 1000 AEs in 1998 to 0.49 per 1000 in 2008,

TABLE 1
Concussion Data for School Years 1997-1998 to 2007-2008

Sport	Concussions ^a n (%)	Athletic Exposures ^a n (%)	Rate per 1000 Athletic Exposures	Rate Ratio (95% Confidence Interval) ^b	Mean Annual Increase, %
Boys					
Football	1407 (53.1)	2 335 666 (21.4)	0.60	10.9 (10.3, 11.5)	8
Lacrosse	244 (9.2)	800 085 (7.3)	0.30	5.5 (4.9, 6.3)	17
Soccer	103 (3.9)	606 100 (5.5)	0.17	3.1 (2.5, 3.7)	13
Wrestling	123 (4.6)	724 430 (6.6)	0.17	3.1 (2.6, 3.7)	27
Basketball	77 (2.9)	788 022 (7.2)	0.10	1.8 (1.4, 2.2)	17
Baseball	32 (1.2)	579 420 (5.3)	0.06	1 ^c	14 ^d
Girls					
Soccer	195 (7.4)	554 400 (5.1)	0.35	6.0 (5.2, 6.9)	14
Lacrosse	114 (4.3)	559 295 (5.1)	0.20	3.5 (2.9, 4.2)	14
Basketball	120 (4.5)	730 876 (6.7)	0.16	2.8 (2.3, 3.3)	24
Softball	47 (1.8)	439 175 (4.0)	0.11	1.8 (1.3, 2.4)	23
Field hockey	58 (2.2)	588 456 (5.4)	0.10	1.7 (1.3, 2.2)	20
Cheerleading	131 (4.9)	2 220 967 (20.3)	0.06	1 ^c	26
All boys	1986 (74.9)	5 833 723 (53.4)	0.34	2.6 (2.5, 2.7)	14
All girls	665 (25.1)	5 093 169 (46.6)	0.13	1 ^c	21
All athletes	2651	10 926 892	0.24		16

^aCount (proportion of total in last row).

^bCompares boys' sports to baseball as reference, girls' sports to cheerleading as reference, and all boys' sports to all girls' sports as reference.

^cReference.

^dBecause no concussions were reported for baseball in school year 1997-1998, the mean annual increase for baseball uses school year 1998-1999 as a baseline.

a 4.2-fold increase (95% confidence interval, 3.4-5.2) corresponding to an average yearly increase of 15.5% (Table 1, Figure 1). Football showed the greatest increase in concussion rate over time (Table 1). Although football was responsible for much of the overall increase in concussion rate, other boys' sports (eg, lacrosse and wrestling) and girls' sports (eg, soccer, lacrosse, basketball, and softball) showed substantial increases. Concussion rate increased over the study period in all 12 sports.

Girls had a higher rate of concussion than that of boys in those sports where the boys' and girls' games are essentially the same. The rate ratio (95% confidence interval) for girls compared with boys was 1.7 (1.3-2.2) in basketball, 2.1 (1.6-2.6) in soccer, and 1.9 (1.2-3.0) in softball/baseball. In lacrosse—where the girls' game has fundamentally different rules, protective equipment, and nature of play as compared with the boys' game—girls had a lower concussion rate than that of boys (0.2 vs 0.3).

Change in concussion rate for various sports groupings over time is shown in Figure 2 and Table 1. Concussion rates increased across all 12 sports, ranging from an average annual increase of 8% for football to 27% for wrestling. Although the degree of change varied, it was evident among sports classified as collision, contact, or incidental contact. All 6 boys' sports, whether helmeted or not, increased over time, although rates for the helmeted sports (football, boys lacrosse, baseball) were nearly twice those of nonhelmeted sports. In sports where the boys' and girls' game are similar, concussion rates for girls were consistently higher over time. In lacrosse, concussion rates were higher for boys.

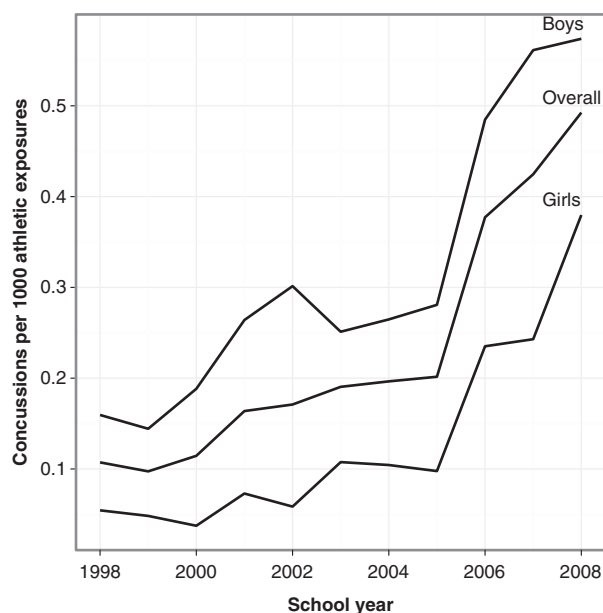


Figure 1. Concussion rates from 1997-1998 to 2007-2008: overall and for boys' and girls' sports.

As noted, each concussion was coded as a separate injury. However, repeat concussions represented 11% of all concussions (291 of 2651). There were 231 athletes with 2 concussions; 26 had 3 or more. Among athletes with repeat concussions, the median interval was 316

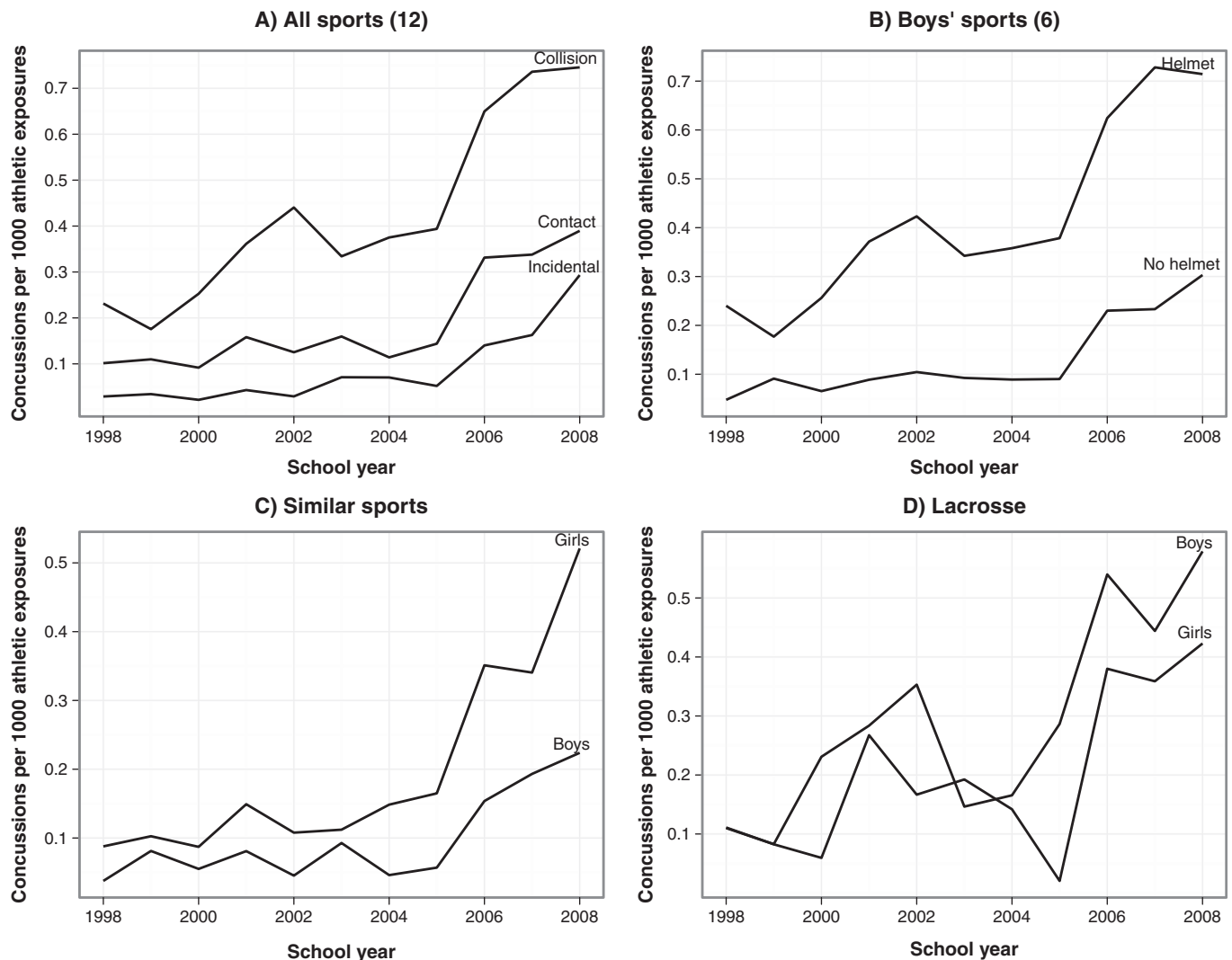


Figure 2. Concussion rates from 1997-1998 to 2007-2008: A, collision sports (football, men's lacrosse, wrestling), contact sports (boys' and girls' soccer, girls' lacrosse, field hockey), and incidental-contact sports (softball, boys' and girls' basketball, baseball, and cheerleading); B, boys' helmeted sports (football, lacrosse, baseball) and nonhelmeted sports (wrestling, basketball, soccer); C, sports with similar rules and protective equipment (baseball/softball, basketball, and soccer); D, boys' and girls' lacrosse.

days, with 19% (n, 54) of repeat concussions occurring within 1 month (<31 days) of each other.

DISCUSSION

These data suggest that the concussion rate in boys' and girls' scholastic sports in a large school district increased substantially during the study period. As expected, collision sports such as football and lacrosse (total concussions, 1407 and 244; incidence rates, 0.60 and 0.30, respectively) contributed to the 3-fold higher cumulative incidence of concussion in boys' sports as compared with girls' sports. However, the concussion incidence rate in girls' soccer (number of concussions, 195; incidence rate, 0.35) ranked second among all 12 sports, slightly higher than that of boys' lacrosse. When similar boys' and girls' sports were

compared, girls' sports had approximately twice the concussion risk. Concussion rate increased for the combined groups, for boys' sports and girls' sports overall, and for all individual sports over the 11-year study period. An increase in concussion rate across all sports in 2005 may be associated with the increase in athletic trainer coverage in the program.

Our findings are similar to those of previous studies that reported incidence of concussion across boys' and girls' high school sports. For 9 sports in US high school and college programs, Gessel et al⁸ found that football had the largest percentage of concussions (40.5%, 0.47 rate per 1000 AEs; compared with our study period, 53.2%, 0.56 rate), with girls' soccer (21.5%, 0.36 rate), boys' soccer (15.4%, 0.22 rate), and girls' basketball (9.5%, 0.21 rate) next in rank. Similarly, Rechel et al¹⁵ found the highest rates of overall injury in the game setting in football

(12.09 per 1000 AEs), girls' soccer (5.21), and boys' soccer (4.22).

In the current study, girls had significantly higher (approximately 2-fold) risk of concussion compared with boys in all similar sports evaluated. Gessel et al⁸ reported a similar significantly higher risk for girls compared with boys in soccer and basketball but not baseball/softball. The current findings in all similar sports suggest that the difference in concussion risk in similar sports for girls versus boys is not a result of a data anomaly in a given sport. In contrast to these findings in similar sports, girls' lacrosse had a lower concussion rate than that of boys' lacrosse. This finding appears to reflect the fundamental difference between the games in terms of rules, protective equipment, and level of contact permitted.

Other reports have noted higher risk to girls in similar sports. Recent studies have found that women are at higher risk for sports-related concussion than men.^{7,8,15} Previous studies suggest that the mechanism of boys' and girls' concussion may vary, with girls' concussion associated more with surface or ball contact than with player contact.⁷ Concussion outcome may be worse in females than males.⁷ Females have been reported to have different baseline and postconcussion outcomes. Covassin et al⁶ found a statistically significant difference in baseline neuropsychological function between male versus female collegiate athletes. Evidence suggests that females are more willing than males to report general injuries,^{7,17} which represents a potential bias toward increased detection in females. Biomechanical factors such as head size and neck strength and girth have been associated with higher concussion rates among females.^{1,7,19,20} These reports suggest the potential for detection bias in comparing women's and men's sports and the need for differentiating between boys and girls when investigating concussion.

Our data on trends showed an overall increase of 16.5% in concussion rate annually over the past decade in both boys' and girls' sports, with a substantial increase in rate beginning in 2005. An increase in athletic trainer coverage from 2 part-time positions to 1 full-time and 1 part-time occurred in 2005 for all locations. This expanded access to a trained professional may have substantially increased the likelihood that concussion was recognized and treated.²¹ We are not aware of any other change in the surveillance system at that point in the study. Other possible influences, such as substantially increased intensity of play, seem unlikely because it is doubtful that larger increases would have consistently occurred across all sports at one point in time.

An increased concussion rate was observed over the study period in each sport, with greater increases in football, boys' lacrosse, and girls' soccer. This trend may reflect the extensive media coverage of concussion risk in professional and amateur sports. New state laws^{3,4} and rule changes and treatment recommendations by the National Collegiate Athletic Association, the National Athletic Trainers' Association,⁹ the National Federation of State High School Associations, the Centers for Disease Control and Prevention,⁵ and sports-governing bodies have likely

contributed to greater awareness of concussion among players, coaches, parents, and clinicians.

The increases in concussion rate observed in this study do not appear to be related to level of contact in a given sport. The collision sports of football and boys' lacrosse contributed the expected high percentage of the total number of concussions, but we observed increasing concussion rates in every sport. Our findings suggest that although the highest percentages of concussions occur in high-impact sports, efforts to detect, treat, and prevent concussion should not be limited to those sports.

Despite the use of a helmet, the percentages of concussions were highest in the helmeted sports of football and boys' lacrosse. Previous studies have noted that the use of protective equipment does not have a conclusive effect on concussion risk in high-impact helmeted sports.^{2,8,15} These data suggest that protection from concussion may involve a multifaceted approach to injury prevention.

Unlike previous authors,^{8,16-18} we did not include loss of playing time in our definition of injury. This decision was based on the assumption that clinical management of concussion may have changed over the study period. Including lost time as part of the injury definition could have disproportionately affected concussion incidence observed in the earlier years of the study in that players might not have been removed from the game after receiving a possible concussion at that time. Athletes suspected of sustaining a concussion or head injury were more likely to be removed from play later in the study period.

This study is limited in that the data reflect findings in one school district. Although this school district is one of the largest in the country and may reflect common practice, the findings may not be generalizable to other scholastic sports programs. Generalizing these data to other programs assumes a similar number of AEs in a given sport and expertise in concussion management among the athletic training staff. The analysis was based on the assumption that an AE in one sport is equal to an AE in another sport in terms of time, activity, and intensity.

Our data represent each unique clinical event for athletes who may have played more than 1 sport and more than 1 season. The scholastic program in this study may have included more coverage by athletic trainers than what is common in other programs. We speculate that added athletic trainer coverage beginning in 2005 was associated with observation of higher concussion rates after implementation, but we are not able to fully establish the reason for the increase. A bias toward increased reporting of concussion in females might have influenced the findings.

In conclusion, although the collision sports of football and boys' lacrosse had the highest number of concussions and football the highest concussion rate, concussion occurred in all other sports and was observed in girls' sports at rates similar to or higher than those in boys'. The increase over time in all sports may reflect actual increased occurrence or greater coding sensitivity with widely disseminated guidance on concussion detection and treatment. The high-participation collision sports of

football and boys' lacrosse warrant continued vigilance, but the findings suggest that focus on concussion detection, treatment, and prevention should not be limited to those sports traditionally associated with concussion risk.

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