

Pediatric Sports- and Recreation-Related Eye Injuries Treated in US Emergency Departments

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abstract

OBJECTIVES: To investigate the epidemiologic characteristics of sports- and recreation-related eye injuries among children in the United States.

METHODS: Data from the National Electronic Injury Surveillance System were analyzed in a retrospective study of children ≤ 17 years of age treated in US emergency departments for sports- and recreation-related eye injuries from 1990 to 2012.

RESULTS: From 1990 through 2012, an estimated 441 800 (95% confidence interval: 378 868–504 733) children were treated in US emergency departments for sports- and recreation-related eye injuries, averaging 26.9 injuries per 100 000 children. Children 10 to 14 and 15 to 17 years old had the highest rate of eye injury. Three-fourths of injuries were sustained by boys. The most common types of injury were corneal abrasion (27.1%), conjunctivitis (10.0%), and foreign body in the eye (8.5%). Most eye injuries were treated and released (94.6%); however, 4.7% were hospitalized. The most common sports and recreation activities and equipment associated with eye injury were basketball (15.9%), baseball and softball (15.2%), and nonpowder guns (10.6%). The overall rate of eye injury decreased slightly during the study period; however, the rate of eye injury associated with nonpowder guns increased by 168.8%, and nonpowder gun-related eye injuries accounted for 48.5% of hospitalizations.

CONCLUSIONS: Pediatric sports- and recreation-related eye injuries remain common. Increased prevention efforts are needed, especially for eye injuries associated with nonpowder guns. Increased child, parent, and coach education, as well as adoption of rules that mandate the use of eye protective equipment should be undertaken.

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WHAT'S KNOWN ON THIS SUBJECT: Sports and recreation activities and equipment are associated with approximately one-fourth of all pediatric eye injuries. Basketball, baseball or softball, and football, in particular, are commonly associated with eye injury. Boys account for the majority of these injuries.

WHAT THIS STUDY ADDS: The overall rate of eye injury decreased slightly during the 23-year study period; however, the rate of eye injury associated with nonpowder guns increased by 168.8%, and nonpowder gun-related eye injuries were often serious, accounting for 48.5% of hospitalizations.

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Participation in sports and recreation provides numerous physical, social, emotional, psychological, and educational benefits.¹ However, these activities also place participants at risk for injury, including injuries to the eye. Sports and recreational activities account for a substantial proportion of all eye injuries in the United States.²⁻⁶ Authors of 1 study found that 24.4% of all pediatric eye injuries treated in US emergency departments (EDs) were related to sports and recreation.⁶ Basketball, baseball and softball, and football, in particular, are commonly associated with eye injury.^{7,8}

Although sports- and recreation-related eye injuries are not typically life-threatening, they can result in significant morbidity, including vision loss. Injury is one of the most common causes of monocular blindness, and ~7% of eye injury patients will have severe vision impairment.⁹ Although injuries may be common in sports, ~90% of sports-related eye injuries can be prevented by wearing appropriate eye and facial protection.^{10,11}

By using National Electronic Injury Surveillance System (NEISS) data from 1990 to 2012, the objective of this study was to investigate the epidemiologic characteristics of pediatric sports- and recreation-related eye injuries treated in US EDs. This study expands on previous eye injury research by focusing specifically on sports- and recreation-related eye injury characteristics and trends over a 23-year study period.

METHODS

Data Source

Data were obtained from the NEISS for children ≤ 17 years of age treated in US EDs from 1990 to 2012. The NEISS is a nationally representative stratified probability sample of

~100 EDs and is maintained by the US Consumer Product Safety Commission (CPSC).¹² Each patient record contains information regarding sex, age, body region injured, diagnosis, locale of the injury event, disposition from the ED, consumer product or activity associated with the injury, date of injury, and a brief narrative describing the circumstances of the incident.

Case Selection Criteria

NEISS cases in which the injured body region was coded 77 (“eyeball”) and the product code was included in the product grouping “Sports and Recreational Activities and Equipment,” as identified by the 2011 CPSC Annual Report,¹³ were evaluated for inclusion in the study ($n = 14\,866$). The brief narrative for each case was reviewed to ensure the injury occurred to the globe of the eye as a result of participating in a sport or recreational activity. Injuries to the eyelid, eyebrow, orbit, eye area, or other parts of the face without mention of an eye globe injury and cases in which the mechanism of injury involved repairing or maintaining sports or recreation equipment, such as welding on an all-terrain vehicle (ATV), inflating a tire, or using a screwdriver to repair a bicycle, were excluded from the study ($n = 1\,338$).

Narratives were also reviewed for cases with the injured body region coded as 76 (“face, including eyelid, eye area, and nose”) and a product code included in the “Sports and Recreational Activities and Equipment” grouping. Of these 1030 cases, 278 were included, representing patients with injuries to multiple regions of the face, including an injury to the globe of the eye. For example, a patient could present with facial

lacerations and a subconjunctival hemorrhage from being hit with a baseball bat. In this instance, the facial lacerations would be coded as the primary injury, but the case would be included in this study because of the subconjunctival hemorrhage.

Case selection identified 13 806 cases in the database involving sports- and recreation-related eye injuries among children ≤ 17 years of age from 1990 to 2012.

Study Variables

Consistent with previous pediatric eye injury studies,⁶ patients were grouped into the following 4 age categories: (1) 0 to 4 years, (2) 5 to 9 years, (3) 10 to 14 years, and (4) 15 to 17 years.^{4,6} Locale of the injury event was grouped into the following categories: (1) place for sport or recreation, (2) home (including home, apartment, condo, and mobile home), (3) school, (4) other (including other public property, farm or ranch, and street or highway), and (5) not specified. Activity and product codes were grouped based on the categories in the 2011 CPSC Annual Report for “Sports and Recreational Activities and Equipment.”¹³ For the purposes of this study, snow skiing was combined with toboggans, sleds, snow discs, etc; trampolines were combined with playground equipment; archery was combined with darts; dancing was combined with gymnastics; boxing was combined with martial arts; and nonpowder guns include BB, pellet, and paintball guns. The 20 sports and recreation activities most frequently associated with eye injury were analyzed individually, with the remaining activities grouped into an “other sports and recreation activity” category. Disposition from the ED was categorized as: (1) treated and released (including examined and

released without treatment), (2) hospitalized (including patients who were treated and admitted, transferred for hospitalization or to another hospital, or held for observation), (3) left against medical advice, and (4) not specified.

Case narratives were manually reviewed individually to code a specific eye injury diagnosis, mechanism of injury, and the object responsible for the injury. NEISS diagnosis codes and narratives were both used to code a specific diagnosis as: (1) corneal abrasion; (2) conjunctivitis; (3) foreign body; (4) hyphema; (5) subconjunctival hemorrhage; (6) laceration or puncture; (7) iritis or keratitis; (8) visual blurring or vision loss; (9) other diagnosis (including burn, retinal detachment, corneal edema, abrasion or contusion not specified, and other eye injuries); and (10) not specified. Mechanism of injury was coded as: (1) hit, struck, or poked; (2) object or small particle in the eye; (3) shot; (4) contact with chemical; (5) fell; (6) struck eye against object; (7) scratched or scraped; (8) other mechanism; and (9) not specified. The object directly responsible for causing the eye injury was coded as: (1) ball, puck, or birdie; (2) bat, club, stick, pole, or racquet; (3) BB, pellet, or paintball; (4) small particle(s) (such as dirt, sand, glass, etc); (5) another person or body region; and (6) other or not specified.

Statistical Analysis

Data were analyzed by using SPSS 24.0 (IBM SPSS Statistics, IBM Corporation, Armonk, NY). Statistical analyses included relative risks (RRs) with 95% confidence intervals (CIs) and simple linear regression (to evaluate the statistical significance of secular trends). The

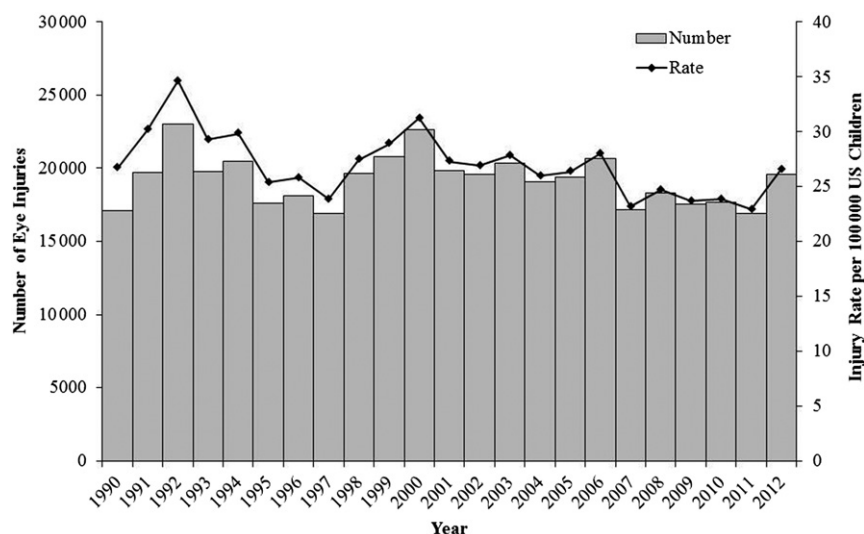


FIGURE 1

Estimated annual number and rate of pediatric sports- and recreation-related eye injuries treated in US EDs, NEISS 1990–2012.

estimated slope from the regression model was reported along with the associated *P* value. Statistical tests were considered significant at $\alpha \leq .05$. The overall injury rate per 100 000 US population was calculated by using the US Census Bureau July 1 population estimate from 1990 to 2012, and the annual injury rates were calculated using the corresponding July 1 annual population estimates for each year within the study period.¹⁴ NEISS weights provided by the CPSC were used to calculate national estimates, and all reported numbers in this article are stable national estimates unless stated otherwise. According to the CPSC, an estimate is potentially unstable if the sample size is <20 cases, the estimate is <1200 cases, or the coefficient of variation is >33%. The institutional review board at the authors' institution determined that this study was exempt.

RESULTS

General Characteristics

An estimated 441 800 (95% CI: 378 868–504 733) children ≤ 17 years of age were treated in US EDs

for a sports- or recreation-related eye injury from 1990 to 2012, averaging 19 209 children annually, with an overall injury rate of 26.9 injuries per 100 000 US children. The overall rate of eye injury decreased slightly (slope = -0.25 , $P = .003$) during the 23-year study period (Fig 1). Injury rate trends for the top 5 sports and recreation activities associated with eye injuries are given in Fig 2. Although the rate of eye injury remained relatively constant for football (slope = -0.004 , $P = .731$), the rate decreased for basketball (slope = -0.08 , $P = .001$) and baseball and softball (slope = -0.17 , $P < .001$). The injury rate increased by 169.6% (slope = 0.13 , $P < .001$) for nonpowder guns and 142.3% (slope = -0.06 , $P = .001$) for swimming during the study period. Children 10 to 14 and 15 to 17 years of age had the highest rate of overall eye injury (Fig 3). The rate of injury decreased among 0- to 4-year-olds (slope = -0.23 , $P < .001$), 5- to 9-year-olds (slope = -0.23 , $P = .028$), and 10- to 14-year-olds (slope = -0.37 , $P = .017$). Despite annual fluctuations, the rate of eye injury did not significantly change for 15- to 17-year-olds

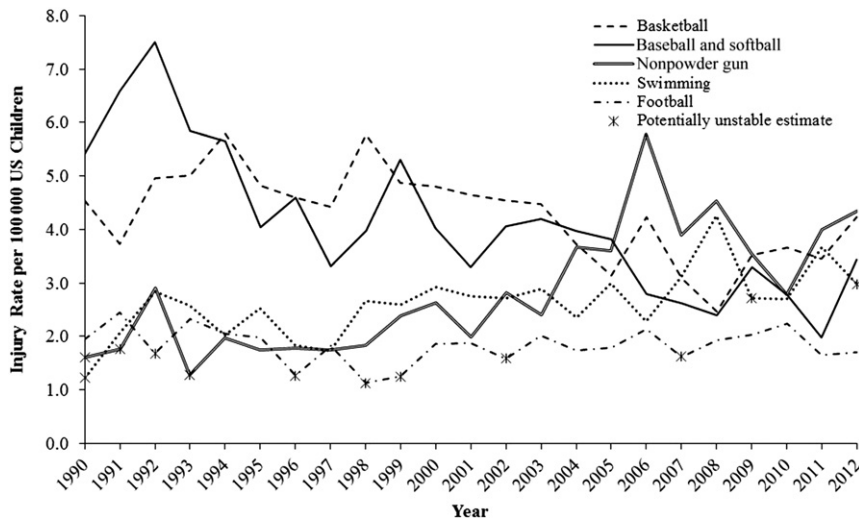


FIGURE 2
Estimated annual rates of the top 5 pediatric sports- and recreation-related eye injuries treated in US EDs, NEISS 1990–2012.

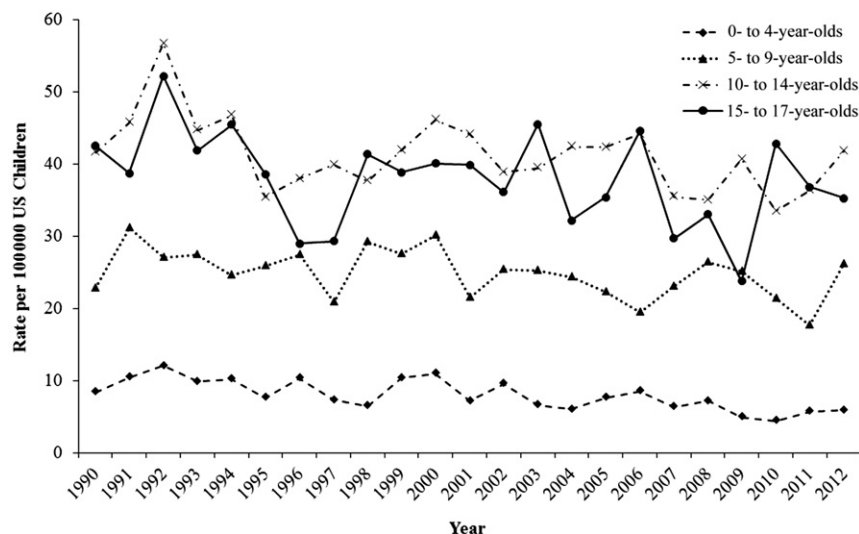


FIGURE 3
Annual rate of pediatric sports- and recreation-related eye injuries treated in US EDs by age group, NEISS 1990–2012.

(slope = -0.38 , $P = .063$) over the study period.

Three-fourths (75.2%) of sports- and recreation-related eye injuries were sustained by boys (Table 1), and 42.9% of injuries occurred among children 10 to 14 years old. The mean age was 11.0 years (SEM: 0.07; median: 11.0; interquartile range: 7.7–13.8). The most common types of injury were corneal abrasion (27.1%), conjunctivitis

(10.0%), and foreign body in the eye (8.5%). Eye injuries most frequently occurred at a place for sport or recreation (26.1%) and at home (20.3%). Most eye injuries were treated and released (94.6%); however, 4.7% were hospitalized. The most common eye injuries resulting in hospitalization were laceration or puncture (22.9%), hyphema (16.8%), and foreign body (15.1%). Among the cases of foreign body that resulted

in hospitalization, 70.4% were associated with BBs, pellets, or paintball guns. The most common sports and recreation activities and equipment associated with eye injury were basketball (15.9%), baseball and softball (15.2%), and nonpowder guns (10.6%) (Table 2). More than half (53.6%) of all eye injuries resulted from being hit, struck, or poked (Table 1). The most common object responsible for injury was a ball, puck, or birdie (24.6%), followed by a small particle(s) in the eye (12.4%). The majority (53.4%) of eye injuries occurred in the spring and summer months (April through August).

Sex and Age

Boys accounted for the majority of injuries in each of the 4 age groups (Table 1), with children 0 to 4 years old having the largest proportion of girls (34.0%) (Table 1). Corneal abrasion was the most common specific diagnosis among 0- to 4-year-olds (23.7%), 5- to 9-year-olds (28.0%), 10- to 14-year-olds (26.1%), and 15- to 17-year-olds (29.1%). However, conjunctivitis represented a greater proportion of cases among 0- to 4-year-old patients (16.1%) than among 10- to 14-year-old (8.9%; RR: 1.80; 95% CI: 1.40–2.31) and 15- to 17-year-old (6.7%; RR: 2.41; 95% CI: 1.75–3.34) patients. Likewise, the proportion of 0- to 4-year-old patients with a foreign body (13.9%) was greater than that of 5- to 9-year-old (8.6%; RR: 1.61; RR: 1.23–2.11), 10- to 14-year-old (8.1%; RR: 1.72; 95% CI: 1.32–2.23), and 15- to 17-year-old (7.3%; RR: 1.91; 95% CI: 1.43–2.55) patients. A similar proportion of children were hospitalized in each of the 4 age groups (Table 1).

Among children 0 to 4 years old, the most common sports and recreation activity and equipment associated with eye injury was playground equipment or trampolines (28.1%),

TABLE 1 Characteristics of Pediatric Sports- and Recreation-Related Eye Injuries Treated in US EDs by Age Group, NEISS 1990–2012

Characteristics	0- to 4-year-olds	5- to 9-year-olds	10- to 14-year-olds	15- to 17-year-olds	Total	
	<i>n</i> (%) ^a	<i>n</i> (%) ^a	<i>n</i> (%) ^a	<i>n</i> (%) ^a	<i>n</i> (%) ^a	95% CI
Sex						
Boy	23 689 (66.0)	82 417 (73.4)	144 633 (76.3)	81 462 (78.3)	332 200 (75.2)	285 501–378 900
Girl	12 217 (34.0)	29 845 (26.6)	44 862 (23.7)	22 541 (21.7)	109 465 (24.8)	92 072–126 859
Not specified	6 (0.0) ^b	30 (0.0) ^b	99 (0.1) ^b	0 (0.0) ^b	134 (0.0) ^b	9–260
Specific diagnosis						
Corneal abrasion	8526 (23.7)	31 406 (28.0)	49 423 (26.1)	30 279 (29.1)	119 634 (27.1)	99 108–140 160
Conjunctivitis	5766 (16.1)	14 804 (13.2)	16 890 (8.9)	6920 (6.7)	44 380 (10.0)	34 184–54 576
Foreign body	5005 (13.9)	9674 (8.6)	15 371 (8.1)	7593 (7.3)	37 643 (8.5)	30 619–44 667
Laceration or puncture	2055 (5.7)	4725 (4.2)	6996 (3.7)	4407 (4.2)	18 184 (4.1)	15 227–21 140
Hyphema	873 (2.4) ^b	2867 (2.6)	8001 (4.2)	4763 (4.6)	16 504 (3.7)	12 508–20 501
Iritis or keratitis	44 (0.1) ^b	913 (0.8) ^b	3642 (1.9)	2784 (2.7)	7384 (1.7)	4977–9790
Subconjunctival hemorrhage	184 (0.5) ^b	1333 (1.2)	2385 (1.3)	1693 (1.6)	5594 (1.3)	4017–7171
Visual blurring or vision loss	6 (0.0) ^b	500 (0.4) ^b	1923 (1.0)	694 (0.7) ^b	3123 (0.7)	2072–4174
Other	12 213 (34.0)	41 898 (37.3)	78 134 (41.2)	41 335 (39.7)	173 579 (39.3)	150 968–196 191
Not specified	1241 (3.5)	4172 (3.7)	6828 (3.6)	3536 (3.4)	15 776 (3.6)	9531–22 020
Disposition from the ED						
Treated and released	34 079 (94.9)	106 605 (94.9)	178 224 (94.0)	98 840 (95.0)	417 749 (94.6)	357 183–478 314
Hospitalized	1373 (3.8)	4776 (4.3)	10 156 (5.4)	4659 (4.5)	20 965 (4.7)	17 234–24 695
Left against medical advice	348 (1.0) ^b	792 (0.7) ^b	1195 (0.6) ^b	451 (0.4) ^b	2785 (0.6)	1702–3868
Not specified	112 (0.3) ^b	118 (0.1) ^b	18 (0.0) ^b	53 (0.1) ^b	301 (0.1) ^b	67–536
Locale of injury						
Place for sport or recreation	5187 (14.4)	24 421 (21.7)	52 372 (27.6)	33 258 (32.0)	115 238 (26.1)	93 074–137 402
Home	13 807 (38.4)	29 639 (26.4)	34 456 (18.2)	11 920 (11.5)	89 823 (20.3)	74 567–105 078
School	1231 (3.4)	10 021 (8.9)	25 405 (13.4)	19 987 (19.2)	56 644 (12.8)	45 543–67 745
Other	1563 (4.4)	4687 (4.2)	8405 (4.4)	4816 (4.6)	19 471 (4.4)	14 071–24 871
Not specified	14 123 (39.3)	43 523 (38.8)	68 956 (36.4)	34 023 (32.7)	160 625 (36.4)	128 965–192 286
Mechanism of injury						
Hit, struck, or poked	13 956 (38.9)	57 159 (50.9)	103 689 (54.7)	62 148 (59.8)	236 952 (53.6)	204 099–269 805
Object or small particle in eye	8107 (22.6)	15 108 (13.5)	20 718 (10.9)	9490 (9.1)	53 422 (12.1)	43 902–62 943
Shot	1544 (4.3)	7650 (6.8)	25 881 (13.7)	10 959 (10.5)	46 034 (10.4)	37 354–54 713
Contact with chemicals	4402 (12.3)	12 715 (11.3)	13 112 (6.9)	4173 (4.0)	34 403 (7.8)	25 058–43 749
Fell	3802 (10.6)	5946 (5.3)	3644 (1.9)	1839 (1.8)	15 231 (3.4)	12 423–18 039
Struck eye against an object	1604 (4.5)	3175 (2.8)	3504 (1.8)	1387 (1.3)	9670 (2.2)	7386–11 954
Scratched or scraped	214 (0.6) ^b	1991 (1.8)	4007 (2.1)	2128 (2.0)	8341 (1.9)	6519–10 163
Other	114 (0.3) ^b	852 (0.8) ^b	613 (0.3) ^b	416 (0.4) ^b	1995 (0.5)	1099–2891
Not specified	2169 (6.0)	7695 (6.9)	14 426 (7.6)	11 463 (11.0)	35 752 (8.1)	26 238–45 266
Object responsible for injury						
Ball, puck, or birdie	3603 (10.0)	26 328 (23.4)	53 414 (28.2)	25 299 (24.3)	108 643 (24.6)	92 809–124 477
Small particle(s) in eye	8357 (23.3)	15 237 (13.6)	21 544 (11.4)	9842 (9.5)	54 980 (12.4)	44 818–65 143
Another person or body region	1033 (2.9) ^b	7035 (6.3)	19 760 (10.4)	17 956 (17.3)	45 784 (10.4)	37 958–53 611
BB, pellet, or paintball	1384 (3.9)	7221 (6.4)	25 511 (13.5)	10 896 (10.5)	45 012 (10.2)	36 479–53 545
Bat, club, stick, pole, or racquet	2692 (7.5)	7819 (7.0)	7133 (3.8)	2388 (2.3)	20 032 (4.5)	16 474–23 591
Other or not specified	18 842 (52.5)	48 652 (43.3)	62 232 (32.8)	37 623 (36.2)	167 348 (37.9)	142 811–191 886
Study total (row %) ^c	35 911 (8.1)	112 292 (25.4)	189 594 (42.9)	104 003 (23.5)	441 800 (100.0)	378 868–504 733

^a Column percentages may not sum to 100.0% because of a rounding error.

^b Estimate is potentially unstable because of sample size <20 cases, national estimate <1200 cases, or coefficient of variation >33.0%.

^c Row percentages may not sum to 100.0% because of a rounding error.

followed by swimming activity, pools and equipment (15.2%) and bicycles (10.0%) (Table 2). Baseball and softball was the most common activity and equipment category associated with eye injury among 5- to 9-year-olds (17.3%) and 10- to 14-year-olds (17.2%). Basketball (28.8%) and nonpowder guns (10.8%) were the most common activity and equipment categories

associated with eye injury among children 15 to 17 years old. Hit, struck, or poked was the most common mechanism of injury in all 4 age groups (Table 1). Patients 0 to 4 years old (22.6%) had a higher proportion of injuries because of objects or small particles in the eye compared with 5- to 9-year-olds (13.5%; RR: 1.68; 95% CI: 1.38–2.04), 10- to 14-year-olds (10.9%;

RR: 2.07; 95% CI: 1.71–2.49), and 15- to 17-year-olds (9.1%; RR: 2.47; 95% CI: 1.92–3.19). Patients 0 to 4 years old also had a higher proportion of eye injuries related to falls (10.6%) than 5- to 9-year-olds (5.3%; RR: 2.00; 95% CI: 1.47–2.73), 10- to 14-year-olds (1.9%; RR: 5.51; 95% CI: 3.96–7.66), and 15- to 17-year-olds (1.8%; RR: 5.99; 95% CI: 3.82–9.39). A ball, puck,

TABLE 2 Type of Sports and Recreation Activity and Equipment Associated With Pediatric Sports- and Recreation-Related Eye Injuries Treated in US EDs by Age Group, NEISS 1990–2012

Sports and Recreation Activity and Equipment	0- to 4-year-olds	5- to 9-year-olds	10- to 14-year-olds	15- to 17-year-olds	Total	
	<i>n</i> (%) ^a	<i>n</i> (%) ^a	<i>n</i> (%) ^a	<i>n</i> (%) ^a	<i>n</i> (%) ^a	95% CI
Basketball	772 (2.2) ^b	7506 (6.7)	31 819 (16.8)	29 969 (28.8)	70 066 (15.9)	59 468–80 664
Baseball or softball	3037 (8.5)	19 437 (17.3)	32 701 (17.2)	11 819 (11.4)	66 994 (15.2)	57 557–76 432
Nonpowder guns	1511 (4.2)	7385 (6.6)	26 753 (14.1)	11 281 (10.8)	46 930 (10.6)	37 931–55 929
Swimming activity, pools and equipment	5455 (15.2)	16 113 (14.3)	16 803 (8.9)	5014 (4.8)	43 385 (9.8)	31 963–54 808
Football	521 (1.5) ^b	5757 (5.1)	14 169 (7.5)	9522 (9.2)	29 969 (6.8)	24 979–34 959
Playground equipment or trampoline	10 086 (28.1)	11 505 (10.2)	4067 (2.1)	366 (0.4) ^b	26 024 (5.9)	20 974–31 074
Lacrosse, rugby, or other miscellaneous ball games	1927 (5.4)	6662 (5.9)	8693 (4.6)	3913 (3.8)	21 195 (4.8)	16 633–25 758
Bicycle	3609 (10.0)	7591 (6.8)	7647 (4.0)	2293 (2.2)	21 140 (4.8)	17 053–25 226
Soccer	165 (0.5) ^b	3061 (2.7)	9744 (5.1)	7059 (6.8)	20 028 (4.5)	15 396–24 660
Racquet sport	516 (1.4) ^b	3028 (2.7)	7532 (4.0)	3622 (3.5)	14 698 (3.3)	11 982–17 414
ATV, moped, minibike, etc	319 (0.9) ^b	2185 (1.9)	4616 (2.4)	3258 (3.1)	10 377 (2.3)	7734–13 021
Exercise equipment	664 (1.8) ^b	3422 (3.0)	3605 (1.9)	2119 (2.0)	9810 (2.2)	7523–12 097
Hockey, all kinds	444 (1.2) ^b	1928 (1.7)	4466 (2.4)	2505 (2.4)	9344 (2.1)	6896–11 792
Golf	534 (1.5) ^b	2420 (2.2)	1896 (1.0)	854 (0.8) ^b	5704 (1.3)	4431–6977
Snow skiing, toboggan, sled, snow disc, etc	393 (1.1) ^b	2243 (2.0)	2239 (1.2)	801 (0.8) ^b	5676 (1.3)	3679–7673
Darts or archery	828 (2.3) ^b	1899 (1.7)	1335 (0.7)	459 (0.4) ^b	4521 (1.0)	3533–5509
Volleyball	0 (0.0) ^b	702 (0.6) ^b	1855 (1.0)	1583 (1.5)	4140 (0.9)	3044–5235
Wrestling	5 (0.0) ^b	306 (0.3) ^b	655 (0.3) ^b	2140 (2.1)	3106 (0.7)	2132–4080
Dance, gymnastics, cheerleading, or baton	141 (0.4) ^b	871 (0.8) ^b	1032 (0.5)	685 (0.7) ^b	2729 (0.6)	1864–3594
Boxing or martial arts	248 (0.7) ^b	892 (0.8) ^b	332 (0.2) ^b	814 (0.8) ^b	2286 (0.5)	1437–3134
Other	4737 (13.2)	7380 (6.6)	7634 (4.0)	3928 (3.8)	23 678 (5.4)	19 935–27 421
Study total	35 911 (100.0)	112 292 (100.0)	189 594 (100.0)	104 003 (100.0)	441 800 (100.0)	378 868–504 733

^a Column percentages may not sum to 100.0% because of a rounding error.

^b Estimate is potentially unstable because of sample size <20 cases, national estimate <1200 cases, or coefficient of variation >33.0%.

or birdie was the most common object responsible for injury among 5- to 9-year-olds (23.4%), 10- to 14-year-olds (28.2%), and 15- to 17-year-olds (24.3%), whereas a small particle(s) in the eye was the most common object among 0- to 4-year-olds (23.3%) (Table 1).

Type of Sports and Recreation Activity and Equipment

Boys sustained 96.4% of eye injuries associated with wrestling, 92.6% associated with football, and 90.7% associated with nonpowder guns. The activity and equipment categories with the highest proportion of injured girls were the dance, gymnastics, cheerleading, or baton category (77.6%); volleyball (52.3%); and the swimming activity, pools and equipment category (41.7%). Basketball accounted for the largest proportion of subconjunctival hemorrhage (26.9%) and corneal

abrasion (23.4%). Hyphema (33.2%) and laceration or puncture (22.6%) were most commonly related to nonpowder guns. More than half (52.5%) of conjunctivitis cases were associated with swimming activity, pools and equipment. Corneal abrasion was the most common injury associated with baseball and softball (16.8%) and football (30.7%). Together, baseball and softball (20.5%) and nonpowder guns (20.5%) accounted for 41.0% of iritis or keratitis cases. The most common injury associated with playground equipment or trampolines was corneal abrasion (30.6%), followed by foreign body (29.3%).

Nearly half (48.5%) of eye injuries that required hospitalization were associated with nonpowder guns. Of these, 79.2% were associated with BB or pellet guns and 19.3% were associated with paintball

guns. Nonpowder gun-related eye injuries were nearly 8 times more likely to be hospitalized than injuries associated with other sports and recreation activities and equipment (21.7% versus 2.7%; RR: 7.93; 95% CI: 6.61–9.53). Hit, struck, or poked in the eye was the most common mechanism of injury for all sports and recreation activities and equipment, except for nonpowder guns (shot: 96.0%); swimming activity, pools and equipment (contact with chemicals: 67.0%); playground equipment or trampoline (object in eye: 50.1%); ATV, moped, minibike, etc (object in eye: 49.8%); and bicycle (fell: 33.9%, and object in eye: 33.4%). Basketball (53.8%) and football (14.5%) accounted for more than two-thirds of eye injuries for which another player or body region was responsible. Hit, struck, or poked in the eye with a ball, puck, or birdie

accounted for 71.6% of baseball- and softball-related eye injuries.

DISCUSSION

Nationally, on average, more than 19 000 children were treated in EDs for sports- and recreation-related eye injuries each year during the study period. There was an overall slight decrease in the annual number of these injuries during these years, which coincided with a decrease in participation in many youth sports during this period.¹⁵ Although the number and rate of eye injuries decreased during the study period, these injuries remain common among children. Consistent with previous studies, this study found basketball, baseball and softball, and nonpowder guns to be the most common sports and recreation activities and equipment associated with pediatric eye injury.^{7,8} According to the National Eye Institute, the sports with the highest rate of eye injuries are baseball and softball, ice hockey, racquet sports, and basketball.¹⁰ In this study, basketball accounted for the largest proportion of patients with subconjunctival hemorrhage and corneal abrasion. The American Academy of Pediatrics (AAP) and American Academy of Ophthalmology (AAO) classify basketball as a sport with high risk for eye injury and recommend all participants wear eye protection with polycarbonate lenses.¹⁶ Despite these recommendations, protective eyewear for basketball players is not required by the National Federation of State High School Associations (NFHS)¹⁷ and does not seem to be popular among athletes at all levels of play. The culture and tradition of the sport may prevent parents and coaches from encouraging protective eyewear use. Although the rate of basketball-related eye injuries decreased during the study period, more than 3000 basketball-related

eye injuries were treated in US EDs annually. Increased education of parents, coaches, athletic directors, and athletes about the benefits of using protective eyewear is needed. In addition, NFHS should consider revising its policies to require protective eyewear for basketball players.

Baseball and softball was the second most common activity associated with eye injuries in this study. Despite the decrease in the rate of baseball- and softball-related eye injuries during the study period, on average, there were 2900 ED visits annually for baseball- and softball-related eye injuries, and 71.6% of these injuries were associated with being hit or struck by the ball. This underscores the importance of adhering to AAP and AAO recommendations for protective eyewear use, which include facemasks attached to batter and base runner helmets and polycarbonate faceguards for fielders.¹⁶ The NFHS mandates the use of facemasks on batting helmets in softball but these are optional in high school baseball and Little League.^{18,19} Although faceguards for defensive players are allowed in high school baseball and Little League, they are not required.^{20,21} Similar to basketball, education regarding the importance of wearing appropriate protective eyewear and consistent protective equipment rules across all ages may help prevent eye injuries associated with baseball and softball.

Findings from this study indicate that prevention of nonpowder gun-related eye injuries deserves special attention. The rate of eye injury associated with nonpowder guns increased 169% during the study period, and these injuries accounted for almost half of all hospitalizations.

Indeed, eye injuries associated with nonpowder guns were nearly 8 times more likely to result in hospitalization than eye injuries associated with other sports and recreation activities and equipment. The AAP and AAO do not have specific recommendations for eye protection when using BB and pellet guns; however, they do recommend wearing eye protection meeting the ASTM standard F1776 when using paintball guns.²² It is important for children to be taught to shoot BB and pellet guns at paper or gel targets with a backstop that will trap BBs or pellets and prevent ricochet, as well as wear eye protection that meets the American National Standards Institute and International Safety Equipment Association standard Z87.1-2015 or the ASTM standard F2879-16.^{23,24} Both parents and children should be educated on proper safety precautions when handling and using guns, and appropriate adult supervision should be provided.

This study has several limitations. Injury estimates were based on patients who visited an ED for care; patients who were seen at an urgent care or other medical setting are not captured in the NEISS data set. Therefore, this study underestimates the actual number of injuries. In addition, this ED-based study may not be representative of the entire spectrum of sports- and recreation-related eye injuries. The NEISS provides a separate code for the eye and the face (which includes eyelid, eye area, and nose). Although there are coding inconsistencies among NEISS coders, we individually reviewed case narratives for both eye and face injuries to ensure, to the best of our ability, that only injuries to the eye were included in the study. There were also

inconsistencies in the content of case narratives, especially related to the object causing injury. Finally, data were not available regarding the number of children who actively participated in all the sports and recreational activities included in this study; therefore, census data were used to calculate population-based injury rates. Despite these limitations, this study provides a comprehensive epidemiologic description of sports- and recreation-related eye injuries among children over a 23-year study period by using a large, nationally representative sample.

CONCLUSIONS

Pediatric sports- and recreation-related eye injuries remain common. Increased prevention efforts are needed, including child, parent, and coach education, along with adoption of rules that mandate the use of eye protective equipment to decrease sports- and recreation-related eye injuries among children. The severity and increasing rate of eye injuries associated with nonpowder guns underscore the need for special preventive efforts directed toward this source of pediatric eye injury. Future research to assess the success of these efforts will be needed.

ABBREVIATIONS

AAO: American Academy of Ophthalmology
 AAP: American Academy of Pediatrics
 ATV: all-terrain vehicle
 CI: confidence interval
 CPSC: Consumer Product Safety Commission
 ED: emergency department
 NEISS: National Electronic Injury Surveillance System
 NFHS: National Federation of State High School Associations
 RR: relative risk

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