

# Progress in Cheerleading Safety

## Update on the Epidemiology of Cheerleading Injuries Presenting to US Emergency Departments, 2010-2019

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**Background:** Although the athleticism required of cheerleaders has increased, the risks of cheerleading have been less studied as compared with other sports.

**Purpose:** To update our understanding of the epidemiology of cheerleading-related injuries.

**Study Design:** Descriptive epidemiology study.

**Methods:** We analyzed the National Electronic Injury Surveillance System (NEISS) for cheerleading-related injuries presenting to nationally representative emergency departments (EDs) in the United States from January 2010 through December 2019. Extracted data included patient age and sex, injury characteristics (diagnosis, body region injured, time of year, and location where injury occurred), and hospital disposition. Using patient narratives, we recorded the cheerleading skills, settings, and mechanisms that led to injury. NEISS sample weights were used to derive national estimates (NEs) from actual case numbers.

**Results:** From 2010 to 2019, a total of 9868 athletes (NE = 350,000; 95% CI, 250,000-450,000) aged 5-25 years presented to US EDs for cheerleading injuries. The annual number of injuries decreased by 15%, from 982 (NE = 35,000; 95% CI, 27,000-44,000) to 897 (NE = 30,000; 95% CI, 18,000-42,000) ( $P = .048$ ), corresponding to a 27% decline in the injury rate per 100,000 cheerleaders ( $P < .01$ ). The annual number of injuries caused by performing stunts decreased by 24%, from 240 (NE = 8700; 95% CI, 6700-11,000) to 216 (NE = 6600; 95% CI, 4000-9200) ( $P = .01$ ), with a 36% decline in the corresponding injury rate per 100,000 cheerleaders ( $P < .01$ ). Despite these decreases, annual incidence of concussions/closed head injuries increased by 44%, from 128 (NE = 3800; 95% CI, 2900-4700) to 171 (NE = 5500; 95% CI, 3400-7700) ( $P = .02$ ), and patients requiring hospital admission increased by 118%, from 18 (NE = 330; 95% CI, 250-410) to 24 (NE = 720; 95% CI, 440-1000) ( $P < .01$ ). The hospital admission rate increased by 9.0% ( $P = .02$ ).

**Conclusion:** The number of cheerleading-related injuries presenting to US EDs decreased from 2010 to 2019. However, the incidence of concussions/closed head injuries and hospital admissions increased, suggesting that further measures are needed to improve safety for cheerleaders.

**Keywords:** cheerleading; closed head injury; concussion; emergency department; hospital admission

Cheerleading is one of the most popular sports in the United States, with more than 3 million participants annually.<sup>26</sup> The technical skills involved in cheerleading routines have continued to grow in difficulty, and the public's awareness of the athleticism required has increased.<sup>10,32,38</sup> As the difficulty of the sport increases, cheerleaders have become more susceptible to injury. In 2012, approximately 37,344 pediatric cheerleading-related injuries presented to emergency departments (EDs) nationwide, corresponding to a rate of 64 injuries per 100,000 children and adolescents.<sup>23</sup>

In addition to the high overall rate of injury, cheerleading also presents a high risk of catastrophic injury.<sup>5,6,18,20</sup> In fact, cheerleading injuries account for more than half of the catastrophic injuries experienced by female athletes at the high school and college levels, surpassing the rate of catastrophic injuries caused by football among male athletes.<sup>22</sup>

Despite the indisputable risks of cheerleading, the sport receives less attention in the medical literature as compared with other sports of similar or lower risk level.<sup>3,13,15,27</sup> A lack of awareness of the physical demands of the sport may contribute to the limited cheerleading-related research, with multiple studies incorrectly characterizing cheerleading as a noncontact, individual (as opposed to team) sport.<sup>19,28,31,43,46,49</sup> Few epidemiologic

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studies have assessed cheerleading characteristics,<sup>12,16,19,23,33,35-37</sup> with the most recent study performed analyzing data through 2012.<sup>23</sup> All of these studies have reported an increase in injury rates, which was speculated to relate to the sport's increase in athleticism and a delayed implementation of safety measures. Recently, all levels of cheerleading, from elementary to collegiate and recreational to competitive, have undergone regulation changes. Many of these regulations were designed to increase safety without diminishing the athleticism of the sport and may result in changing injury patterns.<sup>16,21</sup>

The primary purpose of our study was to assess cheerleading-related injury patterns from 2010 to 2019 in terms of athlete demographic characteristics, injury incidence annually and per 100,000 cheerleaders, injury type, body region injured, mechanism of injury, injury setting/event type, and disposition from the ED.

## METHODS

### Data Sources

The National Electronic Injury Surveillance System (NEISS), operated by the Consumer Product Safety Commission (CPSC), is a public database of injuries that present to EDs in the United States. Information in this database is supplied by 100 hospitals, each with at least 6 beds and an ED, selected as a representative probability sample of the more than 5300 US hospitals with EDs. Each hospital has staff trained to enter injury codes, demographic data, and treatment plans for each patient.<sup>30</sup> Patients are deidentified and assigned CPSC codes that indicate the activity or product involved in injury. National estimates (NEs) can then be calculated by summing the number of cases presenting to each ED and using a multiplier based on hospital size and number of similar-sized hospitals across the United States. All database entries are also accompanied by a free-text narrative summarizing the patient encounter, which provides more detail for the context of injury.

For injury rates, the annual number of US cheerleaders was gathered from available Cheerleading Participation Reports produced by the Sports and Fitness Industry Administration (SFIA).<sup>39</sup> Participation data are reported by year and obtained via online interviews with a representative, nationwide sample. Results are then weighted to reflect the US population according to the US Census Bureau. SFIA reports have been used reliably in previous epidemiological studies to provide participation numbers for injury rate calculation.<sup>8,17,41</sup>

### Patient Cohort

This study was deemed exempt from approval by our institutional review board. Using the code 3254 (cheerleading activity, apparel, or equipment), we identified 10,097 cheerleading-related injuries that presented to NEISS EDs from 2010 to 2019. A total of 9868 cases were included in our analysis after 229 cases were excluded. Cases were excluded if the narrative indicated that injuries were from noncheerleading activities, such as gymnastics, dance, or drill/flag team participation, or that cheerleading only secondarily exacerbated a previous injury. Narratives revealing the diagnosis to be a condition in which sports participation would not influence presentation, such as appendicitis and anaphylaxis, were also excluded. The following text is an example of a narrative we included in our analysis: "12 YOF [12-year-old female] at cheerleading practice did back handspring landed awkwardly on R [right] foot dx [diagnosis] ankle sprain." The following is an example of an excluded narrative: "11 YOF [11-year-old female] slipped and fell into a pool and injured foot then went to cheerleading and the foot pain got worse dx [diagnosis]: foot pain." For narratives without sufficient details describing cheerleading-specific injury mechanism, setting, skill, or stunt position, cases were included and noted as "unknown" for the incomplete variables. All narrative interpretations were reviewed for accuracy by the first author (A.L.X.), who has more than 12 years of cheerleading experience.

### Data Collection

*Patient Characteristics.* For each injury, we extracted data on patient sex and age. Age (with corresponding cheerleading level) was categorized as follows: 5-11 (elementary school level), 12-18 (middle/high school level), and 19-25 (collegiate level). The first 2 age groups also correspond to the most popular age range for all-star cheerleading (5-18 years).<sup>44</sup>

*Injury Setting.* The season of injury was categorized as winter (December-February), spring (March-May), summer (June-August), or autumn (September-November). Setting where the injury occurred was categorized as school, place of sports/recreation, home, other setting (farm/ranch, street/highway, other public property, or industrial place), and unknown. From the patient narrative, we categorized cheerleading-specific settings as team practice, cheerleading camp, cheerleading competition, noncheerleading sports event (eg, football game), tryouts, "other" (including nonregulated situations in which

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cheerleading skills are performed, such as home), or unknown setting.

**Injury Mechanism.** Using the narrative for each case, we recorded 3 additional details about the cheerleading context that led to injury. First, we categorized the mechanism of injury as a fall, a collision with another athlete, a collision with an object, performing a skill incorrectly (such as landing a tumbling pass on an inverted ankle), overexertion, multiple mechanisms (involving >1 mechanism), or unknown mechanism. Second, we categorized cheerleading skills as “stunts” (including partner stunts, pyramids, and basket tosses, all of which involve 1 or more athletes supported by  $\geq 1$  other athlete), tumbling, jumps/kicks, nonspecific training (including stretching, running, and conditioning), or unknown skill.<sup>45</sup> Third, if the injury involved a stunt, the narrative was assessed to determine the patient’s position as a base (one who holds, lifts, or tosses another cheerleader; we also included spotters in this category, who protect the upper body of a top person [herein, “flyer”] during stunts) or a flyer (one who is supported during a stunt).<sup>45</sup>

**Injury Characteristics.** Injury types were categorized as follows: concussion/closed head injury (CHI), dislocation, fracture, skin injury (laceration or avulsion), soft tissue injury (hematoma, abrasion, or contusion), sprain/strain, or other injury type. Injured body regions were categorized as head/neck (face, eye, ear, mouth, head, and neck); upper extremity (shoulder, upper and lower arm, elbow, wrist, hand, and finger); trunk (upper and lower trunk and pubic region); lower extremity (upper and lower leg, knee, ankle, foot, and toe); nonspecific region (multiple body regions involved); and unknown region. Joint involvement was also analyzed using the categories of ankle, elbow, knee, and wrist. (The NEISS coding manual does not have codes specific to shoulder and hip injuries of the joint itself.)

**ED Disposition.** Disposition from the ED was categorized as follows: released after evaluation with or without treatment, treated and admitted/transferred to another hospital/held for observation, left against medical advice, or dead on arrival to the ED.

## Statistical Analysis

Data were analyzed using SPSS Statistics, Version 27.0 (IBM). NEs were calculated from actual case numbers using sample weights provided by the CPSC, which are based on ED size and geographic location. An estimate may be unstable if the estimated frequency is <1200, the actual sample size is <20, or the coefficient of variation is >30%.<sup>24</sup> All estimates reported herein are stable unless otherwise noted.

Injury rates per 100,000 cheerleaders were calculated by dividing annual national injury estimates from NEISS by annual national participation estimates from SFIA. A linear regression was performed to assess injury trends over time. Chi-square tests and calculation of relative risks (RRs) with 95% CIs were used to compare trends among age groups, cheerleading skills leading to injury, and stunt positions.  $P < .05$  was considered significant.

## RESULTS

### Demographic Characteristics

A total of 9868 cases, corresponding to a NE of 350,000 (95% CI, 250,000-450,000) patients (98% female) aged 5-25, were treated for cheerleading-related injuries in US EDs from 2010 to 2019, equating to approximately 35,000 (95% CI, 25,000-45,000) injuries per year. Mean patient age was  $14 \pm 3.6$  years, with most patients (80%) aged 12-18 (Tables 1 and 2). When comparing data from 2010 and 2019, the proportion of patients aged 12-18 decreased significantly (from 81% to 76%;  $P < .01$ ), whereas the proportions of patients in the younger and older categories increased. During the same period, the proportion of male patients increased significantly (from 1.4% to 3.4%;  $P < .01$ ). Only 1598 patient narratives (16%) provided detail on all cheerleading-specific variables studied.

### Injury Incidence: Annually and per 100,000 Cheerleaders

From 2010 to 2019, the annual incidence of cheerleading-related injuries declined by 15%, from an estimated 35,000 (95% CI, 27,000-44,000) to 30,000 (95% CI, 18,000-42,000) ( $P = .048$ ), and the rate of injury per 100,000 cheerleaders declined by 27% ( $P < .01$ ). When analyzing the subset of injuries sustained when performing stunts, we found significant decreases in the annual number of injuries, from 8700 (95% CI, 6700-11,000) to 6600 (95% CI, 4000-9200) (24%;  $P = .01$ ) and the rate per 100,000 cheerleaders (36%;  $P < .01$ ) (Table 3).

### Injury Setting

Most injuries occurred at a place for sports/recreation (52%); 31% occurred at school, and 1.1% occurred in homes. Injuries were most commonly sustained during cheerleading practice (39%) (Table 2). When comparing data from 2010 and 2019, we found an increase in the annual percentage of injuries occurring during practice (from 32% to 49%;  $P < .01$ ). Injuries occurred most frequently during autumn (44%).

### Injury Mechanism

Falls accounted for 31% of injuries, followed by collisions between 2 athletes (19%) and landing a skill incorrectly (5.9%). Regarding cheerleading skills, injuries were caused most commonly by stunts (25%), followed by tumbling (11%). Of the stunt-related injuries, 44% occurred to bases and 39% to flyers.

Stunts were more likely than other skills to result in injury to the head/neck (RR, 1.8; 95% CI, 1.8-1.9) and to cause concussion/CHI (RR, 2.1; 95% CI, 2.1-2.2). Injury patterns were also significantly different between stunt positions (base vs flyer) for all body regions and injury types ( $P < .01$ ) except head/neck injuries ( $P = .21$ ). Bases were more likely to sustain wrist injuries (RR, 4.8; 95% CI, 4.4-5.2), injuries to the upper extremity (RR, 1.8, 95% CI,

TABLE 1

Patient and Injury Characteristics of Cheerleading-Related Injuries Among Athletes Aged 5-25 Years Treated in US EDs, NEISS (2010-2019)<sup>a</sup>

Characteristic	No. of Cases	NE	
		n (%) <sup>b</sup>	95% CI
Study sample	9868	350,000 (100)	250,000-450,000
Patient Characteristics			
Age group, years <sup>c</sup>			
5-11	1815	56,000 (16)	41,000-73,000
12-18	7704	280,000 (80)	200,000-360,000
19-25	349	14,000 (3.9)	10,000-17,000
Sex			
Female	9644	340,000 (98)	250,000-440,000
Male	224	7900 (2.2)	5700-10,000
Injury Characteristics			
Injury type			
Sprain/strain	3731	130,000 (38)	96,000-170,000
Concussion/CHI	1632	58,000 (16)	42,000-74,000
Fracture	1200	42,000 (12)	31,000-54,000
Soft tissue	1103	38,000 (11)	28,000-49,000
Skin	236	8700 (2.5)	6300-11,000
Dislocation	194	6700 (1.9)	4900-8600
Other	1772	65,000 (18)	47,000-83,000
Body region injured			
Head/neck	3065	110,000 (31)	79,000-140,000
Upper extremity	2773	100,000 (29)	74,000-130,000
Lower extremity	2773	95,000 (27)	69,000-120,000
Trunk	1111	39,000 (11)	28,000-50,000
Nonspecific	124	4800 (1.4)	3500-6100
Unknown	22	630 (0.18) <sup>d</sup>	460-810
Joint involvement			
Ankle	1176	40,000 (11)	29,000-51,000
Knee	956	33,000 (9.5)	24,000-42,000
Wrist	666	25,000 (7.2)	18,000-51,000
Elbow	439	15,000 (4.4)	11,000-20,000
Disposition			
Released from ED	9586	340,000 (97)	250,000-430,000
Admitted/transferred	228	8100 (2.3)	5900-10,000
Left against medical advice	53	2000 (0.56)	1400-2500
Dead on arrival to ED	1	4.8 (0.001) <sup>d</sup>	3.5-6.1

<sup>a</sup>CHI, closed head injury; ED, emergency department; NE, national estimate; NEISS, National Electronic Injury Surveillance System.

<sup>b</sup>Percentages may not sum to 100 and estimates may not sum to 350,000 because of rounding error.

<sup>c</sup>Mean  $\pm$  SD age was 14  $\pm$  3.6 years.

<sup>d</sup>Potentially unstable estimate.

1.8-1.9), and sprains/strains (RR, 1.5; 95% CI, 1.5-1.6). Meanwhile, flyers were more likely to sustain ankle injuries (RR, 7.9; 95% CI, 7.1-8.8), lower-extremity injuries (RR, 3.4; 95% CI, 3.2-3.6), and concussions/CHIs (RR, 1.5; 95% CI, 1.5-1.6). Compared with other cheerleading skills, tumbling was 1.8 (95% CI, 1.8-1.8) times as likely to result in upper-extremity injury. When tumbling, risks of injuries were higher to the elbow (RR, 2.8; 95% CI, 2.7-2.9) and wrist (RR, 1.3; 95% CI, 1.3-1.4). Tumbling was also 1.9

TABLE 2

Further Injury Characteristics of Cheerleading-Related Injuries Among Athletes Aged 5-25 Years Treated in US EDs, NEISS 2010-2019<sup>a</sup>

Characteristic	No. of Cases	NE	
		n (%) <sup>b</sup>	95% CI
Cause of Injury			
Mechanism			
Fall	3095	110,000 (31)	80,000-140,000
Collision with another athlete	1881	68,000 (19)	49,000-87,000
Performing a skill incorrectly	590	21,000 (5.9)	15,000-26,000
Overexertion	336	12,000 (3.4)	8600-15,000
Multiple mechanisms	301	10,000 (2.9)	7400-13,000
Collision with an object	68	1900 (0.54)	1400-2400
Unknown	3597	130,000 (37)	94,000-160,000
Skill			
Stunt	2498	89,000 (25)	65,000-110,000
Tumbling	1094	40,000 (11)	29,000-51,000
Nonspecific training	358	12,000 (3.5)	8800-16,000
Jump/kick	218	7400 (2.1)	5400-9400
Unknown	5700	200,000 (58)	150,000-260,000
Stunt position <sup>c</sup>			
Base	1084	39,000 (44)	29,000-50,000
Flyer	970	34,000 (39)	25,000-44,000
Unknown	442	15,000 (17)	11,000-19,000
Injury Setting			
Location			
Place of sports/recreation	5075	180,000 (52)	130,000-230,000
School	3096	110,000 (31)	80,000-140,000
Home	111	3700 (1.1)	2700-4800
Other	75	2800 (0.80)	2000-3600
Unknown	1511	52,000 (15)	38,000-67,000
Setting			
Practice	3834	140,000 (39)	98,000-170,000
Cheerleading competition	180	10,000 (2.9)	7300-13,000
Noncheerleading sports event	196	6900 (2.0)	5000-8800
Cheerleading camp	180	6500 (1.8)	4700-8300
Tryouts	42	1600 (0.45)	1100-2000
Other	56	1900 (0.54)	1400-2400
Unknown	5260	190,000 (54)	140,000-240,000
Season <sup>d</sup>			
Autumn	4183	150,000 (44)	110,000-200,000
Winter	2503	90,000 (25)	65,000-110,000
Spring	1335	44,000 (12)	32,000-55,000
Summer	1847	64,000 (18)	46,000-82,000

<sup>a</sup>ED, emergency department; NE, national estimate; NEISS, National Electronic Injury Surveillance System.

<sup>b</sup>Percentages may not sum to 100 and estimates may not sum to 350,000 because of rounding error.

<sup>c</sup>For known stunt-related injuries, n = 2498.

<sup>d</sup>Autumn, September-November; winter, December-February; spring, March-May; summer, June-August.

(95% CI, 1.9-2.0) times as likely to result in fractures compared with all other skills combined. The proportion of total injuries from collisions with another athlete decreased from

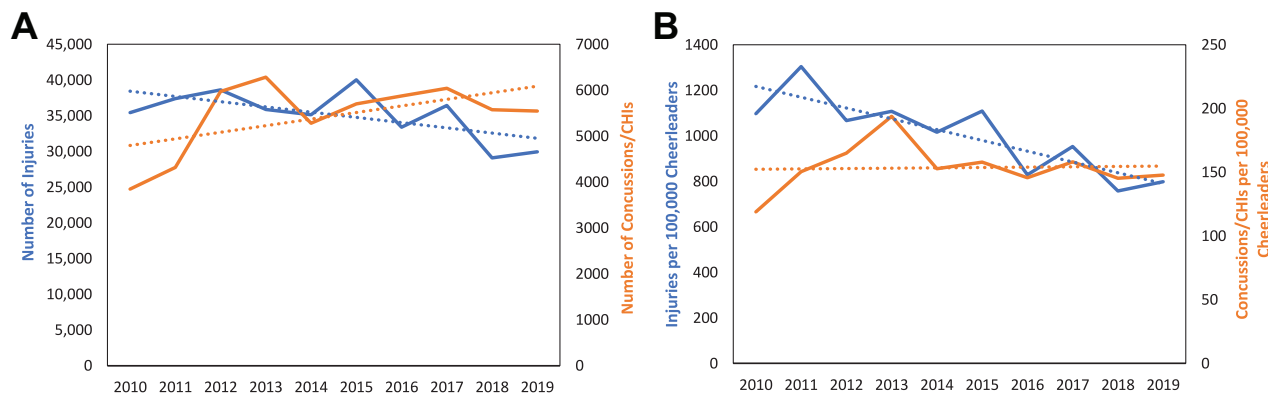
**TABLE 3**  
Trends in Cheerleading-Related Injuries That Presented to US EDs, NEISS 2010-2019<sup>a</sup>

Parameter	2010		2019		Change From 2010 to 2019, %	Slope (m), n/year	P
	No. of Cases	Estimate (95% CI)	No. of Cases	Estimate (95% CI)			
<b>Incidence</b>							
Total injury	982	35,000 (27,000-44,000)	897	30,000 (18,000-42,000)	-15	-730	.048
Stunt injury	240	8700 (6700-11,000)	216	6600 (4000-9200)	-24	-290	.01
Concussion/CHI	128	3800 (2900-4700)	171	5500 (3400-7700)	44	250	.02
Admission	18	330 <sup>b</sup> (250-410)	24	720 <sup>b</sup> (440 -1000)	120	70	<.01
<b>Rate<sup>c</sup></b>							
Total injury		1100 (840 -1300)		800 (490-1100)	-27	-470	<.01
Stunt injury		270 (210-330)		180 (110-250)	-36	-12	<.01
Concussion/CHI		120 (91-150)		150 (90-210)	24	Nonlinear	.21
Admission		10 (7.8-13)		19 (12-27)	9.0	1.6	.02

<sup>a</sup>CHI, closed head injury; ED, emergency department; NEISS, National Electronic Injury Surveillance System.

<sup>b</sup>Potentially unstable estimate.

<sup>c</sup>Rate per 100,000 cheerleaders.



**Figure 1.** Comparison of total cheerleading-related injuries versus concussions/CHI that presented to US EDs from 2010 to 2019. (A) Annual concussion/CHI numbers continued to increase despite decreasing total injury incidence from 2010 to 2019. (B) Total injury rate per 100,000 cheerleaders decreased, whereas the concussion/CHI rate remained stable during the study period. Blue line, total injury; CHI, closed head injuries; yellow line, concussion/CHI.

19% in 2010 to 17% in 2019 ( $P < .01$ ), whereas the proportion caused by performing a skill incorrectly increased from 2.4% to 8.4% ( $P < .01$ ). Injuries from tumbling increased as well (7.3% to 11%;  $P < .01$ ). Notably, the proportion of injuries occurring among bases versus flyers was not significantly different ( $P = .29$ ).

**Injury Characteristics**

*Injury Types.* Sprains/strains accounted for 38% of all injuries, followed by concussions/CHIs (16%), fractures (12%), and soft tissue injuries (11%) (Table 1). The incidence of concussions/CHIs increased by 44% ( $P = .02$ ) (Figure 1). We found no significant change in the concussion/CHI rate per 100,000 cheerleaders ( $P = .21$ ). The proportion of annual injuries comprising fractures decreased from 12% in 2010 to 9.3% in 2019 ( $P < .01$ ). Similarly, sprains/strains decreased from 44% to 33% ( $P < .01$ ). The

proportion of annual injuries occurring at places of sports/recreation, such as gymnasiums, increased from 37% in 2010 to 54% in 2019 ( $P < .01$ ).

Distribution according to age group differed significantly for all injury types ( $P < .01$ ), except skin injuries ( $P = .19$ ). Patients aged 5-11 were 1.15 (95% CI, 1.1-1.2) times as likely as patients aged 12-18 and 1.3 (95% CI, 1.2-1.3) times as likely as patients aged 19-25 to be diagnosed with a concussion/CHI. Patients aged 12-18 were 1.2 (95% CI, 1.2-1.2) times as likely to sustain fractures than the other 2 age groups combined, and patients aged 19-25 were 1.1 (95% CI, 1.1-1.2) times as likely to sustain sprains/strains than the other 2 age groups combined.

*Injured Body Regions.* Injuries to the head/neck were the most common (31%), followed by the upper extremities (29%), lower extremities (27%), and trunk (11%). Joint injuries accounted for 32% of all injuries, with ankle injuries being the most common (11%) (Table 1). Distribution by age

TABLE 4  
Cheerleading-Related Injuries That Presented to US EDs  
and Required Hospital Admission/Transfer, NEISS 2010-  
2019<sup>a</sup>

Type of Injury	No. of Cases
Head, neck, or spine	96
Concussion/CHI	50
Skull/facial fracture	10
Vertebral fracture	9
Sprain/strain	6
Contusion	4
Unspecified pain or injury	17
Upper extremity	87
Fracture	
Forearm	32
Elbow	24
Humerus	20
Hand/wrist	5
Dislocation	2
Sprain/strain	1
Unspecified pain or injury	3
Lower extremity	18
Tibial/fibular fracture	7
Ankle/foot fracture	3
Femoral fracture	2
Slipped capital femoral epiphysis	2
Sprain/strain	1
Unspecified pain or injury	3
Other <sup>b</sup>	29

<sup>a</sup>CHI, closed head injury; ED, emergency department; NEISS, National Electronic Injury Surveillance System.

<sup>b</sup>Other injuries were asthma, heat exhaustion, cardiac arrhythmia, rhabdomyolysis, seizures, chest pain, and syncope.

group differed significantly for all joint injuries and body regions ( $P < .01$ ), except for trunk injuries ( $P = .13$ ). Lower-extremity injuries were most common among patients aged 19-25 (31%), whereas head/neck injuries were most common among patients aged 5-11 (32%). Patients aged 19-25 were 1.2 (95% CI, 1.1-1.2) times as likely to sustain lower-extremity injuries as younger patients. Patients aged 5-11 were 1.1 (95% CI, 1.1-1.1) times as likely as patients aged 19-25 to sustain head/neck injuries. When comparing data from 2010 and 2019, we found significant increases in the percentages of head/neck injuries (28%-33%) and lower-extremity injuries (27%-31%) and a significant decrease in upper-extremity injuries (32%-25%) ( $P < .01$  for all).

### ED Disposition

Most injured cheerleaders (97%) were released from the ED after evaluation. Overall, 2.3% were admitted, kept for observation, or transferred to another medical facility, and 0.56% left against medical advice. One patient was dead on arrival to the ED in 2019 after falling from a stunt during competition. Table 4 lists cases that led to hospital admission. The annual number of patients admitted/transferred to a hospital increased significantly by 118% ( $P < .01$ ), and

the admission rate per 100,000 cheerleaders increased by 9.0% ( $P = .02$ ) (Table 3).

### DISCUSSION

Understanding the profile of sport injuries demanding acute care is critical for implementing safety protocols and aiding physicians in advising on sport participation. From 2010 to 2019, an estimated 350,000 athletes aged 5-25 years presented to EDs in the United States for cheerleading-related injuries. The annual number of injured athletes declined significantly by 15%, but the numbers of concussions/CHIs and hospital admissions increased significantly. The distribution of injuries also shifted to favor male patients, occur at places of sports/recreation, and result from tumbling. To our knowledge, our study is the first report a national decrease in cheerleading injuries over time.

The most recent and comprehensive analysis of NEISS data included data from 1990 to 2012. Naiyer et al<sup>23</sup> reported a 243% increase in cheerleading injury incidence during the 23-year period, citing a rise in the number of cheerleaders and increase in sport athleticism as primary explanations. From 2010 to 2019, cheerleading has continued to increase in the difficulty of stunts and tumbling skills being performed. The sport has also expanded, with participation rising from 3.2 million in 2010 to nearly 3.8 million in 2019.<sup>26</sup> Despite these trends, we found a significant 27% reduction in injury rate when accounting for the number of cheerleaders participating annually in the sport.

As the risks associated with cheerleading have become more apparent, the number of rule changes designed to increase safety for recreational, scholastic, and all-star cheerleaders of all experience levels has increased. For example, 2 recent safety regulations instituted by USA Cheer (the national governing body of cheerleading)<sup>25</sup> increase the number of athletes involved in tossing and catching flyers when performing inverted skills (when flyers' feet are held above their heads) during a pyramid and require a spotter for stunts involving only 1 base. These changes were enacted in 2018, which is the year for which we found the largest decrease in injury incidence and rate. Regulations typically target stunts, likely because of evidence suggesting that basket tosses and pyramids are the skills most likely to cause injury.<sup>4,6,9</sup> This focus of recent regulations on stunts is consistent with our finding that the number of injuries caused by stunts declined significantly during the past decade. This explanation also aligns with the findings of Yau et al,<sup>47</sup> who reported a 4-fold reduction in catastrophic cheerleading injuries after the implementation of a rule prohibiting the performance of basket tosses on hard surfaces during the 2006-2007 cheerleading season. Together, these results suggest the effectiveness of national organizations' efforts to enhance safety.

Despite the overall decrease in national injury incidence, we found a continued increase in the incidence of cheerleading-related concussions/CHIs. This finding aligns with those of previous studies, which report a high and increasing risk of concussions/CHIs as cheerleading has

developed.<sup>42,47</sup> Our findings are consistent with previous findings of stunts as the primary skills placing athletes at risk of concussions/CHIs,<sup>33</sup> with flyers having a significantly higher risk than bases. The high rates of concussion/CHI may reflect increased reporting, or they may indicate that the increased regulation cannot eliminate the inherent risk associated with the sport. It is essential to note that concussion rates in other sports during the same period also increased, but increased mostly to a lesser extent than we found for cheerleading.<sup>2,7,14,29,50</sup> Thus, although universal factors, such as increased diagnosis and sensitivity, may partially explain our temporal trends, cheerleading-specific elements likely play a role. Moreover, the continued increase in concussions/CHIs may explain the significantly higher number of patients who were admitted or transferred after ED evaluation in 2019. Except for fractures, which decreased significantly during the study period, concussions/CHIs were the most common diagnosis requiring inpatient care. Concussions/CHIs accounted for 22% of hospital admissions between 2010 and 2019. This represents an increase since 2002-2007, when Jacobson et al<sup>12</sup> reported only 7 cases of CHI and no concussions requiring hospital admission (13% of total admissions) during that period. The increase we found may also reflect greater vigilance and caution of health care providers in risk stratifying head injuries, particularly in children, because the consequences of such injuries have been a featured point of sports medicine in recent years.<sup>11</sup>

Furthermore, our findings reflect changes in the sport. A larger proportion of injuries occurred in male cheerleaders in 2019 compared with 2010, aligning with an increase in participation by boys and men.<sup>48</sup> From 1990 to 2012, most injuries occurred at schools.<sup>23</sup> From 2010 to 2019, most injuries occurred at places of sports/recreation, such as private gymnasiums, with an increase from 37% to 54%. This shift may reflect increased participation in competitive cheerleading, such as all-star programs, that require non-scholastic practice settings. This transition may be associated with a rise in attention to this type of cheerleading in the media. In contrast to common beliefs,<sup>9,33,34</sup> bases have a similar or higher risk of injury than flyers. This is consistent with our results, with 44% of stunting injuries occurring to bases versus 39% to flyers. The number of tumbling injuries also increased during the study period. These findings may reflect that many regulations target the safety of flyers.<sup>1</sup> Increasing focus on bases and tumbling skills during safety training may help further reduce injury rates.

The results of our study are limited by the information contained in the NEISS database, which may not be generalizable to a larger population given its small hospital sample size. A small proportion of entries provided data on all variables studied because narratives were often vague and did not describe the full extent of the circumstances surrounding the injury. Narratives and our interpretation of them are also prone to error, so the accuracy of cheerleading-specific variables derived from narratives may be especially limited. The lack of specificity of the narratives precluded more detailed analysis, such as distinguishing among basket tosses, pyramids, and partner stunts, or determining the type of cheerleading

(recreational, scholastic, or all-star) involved. Another inherent weakness is that the NEISS database does not account for individuals who sustain multiple injuries and does not provide information that would enable control of confounding factors, such as coach certification and athlete experience. Furthermore, the NEISS data set does not include minor or chronic injuries or fatal, onsite injuries. More experienced cheerleaders have a high incidence of overuse injuries, but these injuries are typically treated in a clinic rather than an ED.<sup>40</sup> Thus, the numbers provided by NEISS are likely an underestimation of the true incidence of injury in cheerleaders. Finally, the SFIA participation reports cover participants aged 6 years or older, which may include athletes older than 25, and would omit those who are 5 years old. As a result, the annual injury rates presented may be under- or overestimations, but this would be true for data of all years, and the important trends reported would remain.

Our study provides an update on recent injury patterns in cheerleading and shows the progress made during the past decade regarding safety in a sport known to cause injury. Although overall annual injury numbers have decreased, the incidence of severe acute injuries continues to rise. Increased education on injury prevention is needed for coaches and athletes alike, particularly regarding concussions/CHIs. Health care providers should also be aware of the sport's prevalent injuries and the circumstances surrounding them to better counsel these athletes. Our study suggests that cheerleading demands more attention in sports medicine, and our findings can serve as a foundation for future studies of cheerleading injury risk.

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