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Gymnastics-related Injuries to Children Treated in Emergency Departments in the United States, 1990–2005

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What's Known on This Subject

Gymnastics has one of the highest injury rates of all girls' sports.

What This Study Adds

To our knowledge, this is the first study of gymnastics-related injuries to children in the United States using a nationally representative sample. The high injury rates found in this study suggest the need for increased prevention efforts to lower the risk of injury in gymnastics. This topic is highly relevant to the practicing pediatrician, who routinely receives questions from patients and families about sports-related safety, including gymnastics.

ABSTRACT

OBJECTIVE. The objective of this study was to describe the epidemiology of gymnastics-related injuries among children in the United States.

METHODS. A retrospective analysis was conducted of data for children 6 through 17 years of age from the National Electronic Injury Surveillance System of the US Consumer Product Safety Commission for 1990 through 2005. Sample weights provided by the National Electronic Injury Surveillance System were used to calculate national estimates of gymnastics-related injuries. Injury rates were calculated for the most frequently occurring types of injury using gymnastics participation data.

RESULTS. An estimated 425 900 children 6 through 17 years of age were treated in US hospital emergency departments for gymnastics-related injuries during the 16-year period of 1990–2005. The number of injuries averaged 26 600 annually. The number of injuries sustained per 1000 gymnastics participants per year for the pediatric population was 4.8. The number of injuries sustained per 1000 participants per year was greater for the ages 12 to 17 years (7.4) than for the ages 6 to 11 years (3.6). The place where an injury occurred include school (40.0%), a place of recreation or sports (39.7%), home (14.5%), or on other public property (5.8%). The body parts injured were upper extremity (42.3%), lower extremity (33.8%), head/neck (12.9%), trunk (10.4%), and other (0.6%). Injury diagnoses were strain/sprain (44.5%), fracture/dislocation (30.4%), abrasion/contusion (15.6%), laceration/avulsion (3.7%), concussion/closed head injury (1.7%), and other (4.2%). The majority (97.1%) of patients with gymnastics-related injuries were treated and released from the emergency department.

CONCLUSIONS. Gymnastics has one of the highest injury rates of all girls' sports. Establishment of a national database for gymnastics-related injuries, including exposure data for direct calculation of injury rates, would permit better identification and monitoring of risk factors for gymnastics-related injuries and aid in the development, implementation, and evaluation of injury prevention strategies based on epidemiologic evidence.

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Key Words

gymnastics, sports, injury prevention, emergency department, NEISS, children, adolescents

Abbreviations

ED—emergency department
NEISS—National Electronic Injury Surveillance System
CPSC—Consumer Product Safety Commission
RR—relative risk
CI—confidence interval

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MORE THAN 7000 YEARS ago, ancient Egyptian gymnasts vaulted over the backs of bulls.¹ Although the bull has been replaced by a more sturdy vaulting table,² gymnastics has remained a high-impact, acrobatic sport that demands a high level of strength, prowess, and grace. Although modern gymnastics has traditionally been a sport of adolescent athletes, US victories at the 1996 and 2004 Olympics have been correlated with an earlier age of entry and specialization in this sport.^{3,4} More than 600 000 US children take part in school-sponsored and club-level gymnastics competitions each year.⁵ Increased skill difficulty practiced at younger ages, coupled with maintaining the intensity and hours of training required to be competitive, has led to concern regarding the risk, severity, and long-term effects of injury to young gymnasts.³

Cross-sectional,⁶ retrospective,⁷⁻⁹ and prospective^{4,6,10-17} studies regarding gymnastics-related injuries have been completed; however, the majority of studies are restricted to case reports or sports-related injuries as a whole. In addition, in 2005, Caine and Nassar³ published a literature review of all gymnastics injury-related articles indexed in PubMed under “gymnastics” and “injury,” restricting their search to the pediatric population (0–17 years of age). Studies summarized in that review described the incidence, characteristics, and severity of gymnastics injuries. To our knowledge, there are no previously published reports of national numbers, rates, and trends of gymnastics-related injuries in the United States. This study describes the epidemiology of gymnastics-related injuries that required emergency department (ED) treatment from 1990 through 2005 for ages 6 through 17 years using data from the National Electronic Injury Surveillance System (NEISS) of the US Consumer Product Safety Commission (CPSC).¹⁸

METHODS

Data Source

The NEISS is operated by the CPSC to provide timely data on consumer product-related and sports activity-related injuries that are treated in EDs in the United States and its territories. The NEISS receives data from a network of ~100 hospitals, representing a stratified probability sample of 6100 hospitals with at least 6 beds and a 24-hour ED. The NEISS was established in 1972 and has had revisions in its sampling frame in the years 1978, 1990, and 1997, which included the addition of a separate stratum for children’s hospitals. Our data were adjusted by the CPSC to take the sampling frame changes into account. At all hospitals, ED medical charts are viewed by professional NEISS coders, and data regarding patients’ age, gender, race, injury diagnosis, body part injured, product(s) involved, disposition from the ED, and a brief narrative describing the incident are recorded. Each year, the NEISS provides data on a projected 500 000 injury-related ED visits and allows estimation of the number and epidemiology of these events for the entire nation. It has been shown to be highly sensitive and accurate in identifying consumer product and sports/recreation-related injury cases. Data analyzed in this study include gymnastics-related injuries (product codes 3231, 3237, and 3263 for 1990–1991 and product codes 1272, 3237, and 3263 for 1992–2005) that were treated in EDs from 1990 through 2005.

Data Analysis

The following variables were investigated during analysis: age, gender, diagnosis, body part injured, place where injury occurred, outcome of ED visit, and the gymnastics skill being performed at the time of injury. Data were divided into 2 age groups: 6 to 11 years and 12 to 17 years. These age groups were chosen to facilitate injury rate calculations, because the participation data from the 2006 Superstudy of Sports Participation¹⁹ combine 6- to 11-year-olds and 12- to 17-year-olds. Diagnoses were categorized as strain/sprain, fracture/dislocation, abrasion/contusion, laceration/avulsion, concussion/closed-head injury, or other

(eg, amputation, crushing, internal injury, nerve damage, puncture, hemorrhage). The body part injured was categorized as upper extremity, lower extremity, head/neck, trunk, or other (eg, pubic region, 25%–50% of body, or >50% of body). The place where an injury occurred was categorized as a recreational sports facility, school, home, or other public property (eg, street/highway, industrial). Outcomes of ED visits were categorized as treated and released, treated and admitted, other, and not recorded. A new variable for gymnastics skill, not previously coded by NEISS, was created for this analysis. The first author reviewed each NEISS narrative to assign a gymnastics skill code. Each gymnastics skill was categorized as handspring/flip, cartwheel/round-off, handstand, splits, headstand, dismount/landing, somersault, backbend/walkover, or not recorded. This categorization was further specified as “difficult” for handsprings and flips and as “easy” for all other skills.

Data were analyzed by using SPSS 14.0 (SPSS Inc, Chicago, IL).²⁰ Sample weights provided by the NEISS, based on the inverse probability of selection, were used in all analyses to make national projections regarding gymnastics-related injuries. The NEISS data set includes narrative descriptions of most of the reported injuries. Some of the narratives described injuries that took place in physical education class but not necessarily while performing gymnastics; therefore, the data set was edited to exclude cases that described an injury unrelated to gymnastics and injuries that did not mention “gymnastics” or any related gymnastics event or equipment (eg, balance beam, uneven bars, floor exercise, vault, pommel horse, parallel bars, high bar, still rings) or skill (eg, cartwheel, round-off, handstand, headstand, flip, handspring, dismount, landing, backbend, walkover, somersault, splits) that led to the injury. In total, 2666 (17.3%) cases were deleted from the original data set. Statistical analyses included χ^2 analysis with Yates correction, relative risk (RR) with 95% confidence intervals (CIs). The level of significance for all statistical tests was $\alpha = .05$. All data reported are national estimates unless specified as actual unweighted cases.

Injury Rate Calculations

Gymnastics participation data were obtained from the 2006 Superstudy of Sports Participation.¹⁹ These data are based on self-report for individuals in the United States who are ≥ 6 years of age and participated in gymnastics at least once during the 12-month period. Participation data for children 6 to 11 and 12 to 17 years of age were available for the year 2005 only. The number of gymnastics-related injuries per 1000 participants per year was calculated using these participation data and NEISS data for 2005. This study was approved by the institutional review board of the Research Institute at Nationwide Children’s Hospital.

RESULTS

From 1990 through 2005, 11 700 gymnastics-related injury cases were reported to the NEISS. These injuries represent an estimated 425 900 (95% CI: 371 500–529 200)

TABLE 1 Characteristics of Gymnastics-Related Injuries Treated in US Hospital EDs, 1990–2005

Selected Characteristics	Actual, <i>n</i>	Weighted	
		<i>N</i>	%
Gender	<i>n</i> = 11 683	<i>N</i> = 425 769	
Male	2326	76 001	17.9
Female	9387	349 768	82.1
Age, y	<i>n</i> = 11 717	<i>N</i> = 425 900	100.0
6–11	6270	213 837	50.2
12–17	5447	212 063	49.8
Place where injury occurred	<i>n</i> = 8506	<i>N</i> = 319 340	100.0
School	3155	127 662	40.0
Place of recreation or sports	3888	126 699	39.7
Home	1036	46 309	14.5
Other	427	18 671	5.8
Outcome of ED visit	<i>n</i> = 11 701	<i>N</i> = 424 946	100.0
Treated and released	11 330	413 737	97.4
Treated and admitted	284	7421	1.7
Other	87	3788	0.9

gymnastics-related injury cases nationally, averaging 26 600 injuries annually (95% CI: 23 200–33 100). A summary of the characteristics related to age, gender, place, and outcome are presented in Table 1. The average age of injured participants was 11.5 years (median: 11.0 years); 82.1% were female (Fig 1). The number of injuries decreased by 25.0% over 16 years, from 28 700 in 1990 to 21 500 in 2005 (Fig 2).

Gymnastics-related injuries occurred throughout the year, with most injuries occurring in October (9.6%) and March (12.2%; Fig 3). These peak months are associated with club gymnastics and high school gymnastics competition seasons, respectively.

Place Where Injury Occurred

The majority of gymnastics-related injuries occurred at school (40.0%) or at a place of recreation or sports (39.7%). The remainder of the injuries occurred at home (14.5%) or on other public property (5.8%). The place where an injury occurred was not recorded in 25.0% of the cases. Injuries at home were significantly more common in the 6- to 11-years age group compared with the 12- to 17-years age group (RR: 1.83; 95% CI:

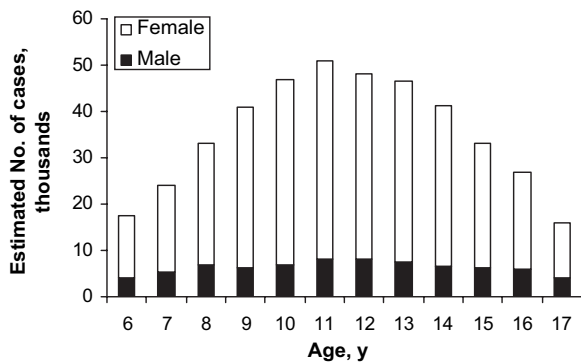


FIGURE 1 Estimated number of children aged 6 to 17 years with gymnastics-related injuries according to age and gender: US EDs, 1990–2005.

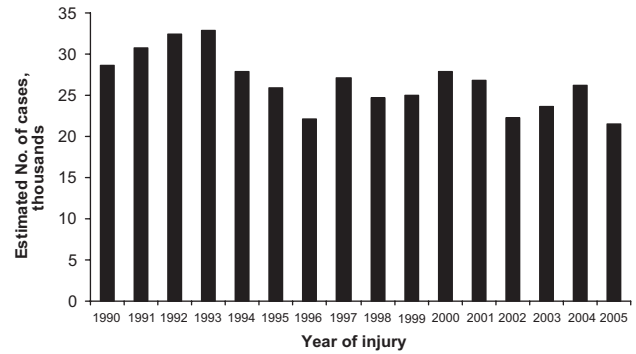


FIGURE 2 Estimated number of children aged 6 to 17 years with gymnastics-related injuries according to year of injury: US EDs, 1990–2005.

1.57–2.14; $P < .0001$), and injuries at school were more common in the 12- to 17-years age group than the 6- to 11-years age group (RR: 1.28; 95% CI: 1.17–1.40; $P < .0001$). Girls were more likely than boys to sustain injuries at a place of recreation or sports (RR: 1.71; 95% CI: 1.48–1.98; $P < .0001$). Boys were more likely than girls to sustain injuries at school (RR: 1.51; 95% CI: 1.34–1.70; $P < .01$).

Body Part Injured

The body parts injured were the upper extremity (42.3%), lower extremity (33.8%), head/neck (12.9%), trunk (10.4%), and other (0.6%; Fig 3). Upper extremity injuries were more common in the 6- to 11-years age group than in the 12- to 17-years age group (RR: 1.46; 95% CI: 1.37–1.56; $P < .0001$). Lower extremity injuries were more common in the 12- to 17-years age group compared with the 6- to 11-years age group (RR: 1.69; 95% CI: 1.56–1.83; $P < .0001$). Boys were more likely to sustain head/neck injuries than girls (RR: 2.04; 95% CI: 1.79–2.33; $P < .0001$), and girls were more likely to sustain upper extremity injuries than boys (RR: 1.31; 95% CI: 1.20–1.44; $P < .0001$).

Type of Injury

Injury diagnoses were strains/sprains (44.3%), fracture/dislocation (30.4%), abrasion/contusion (15.6%), lacer-

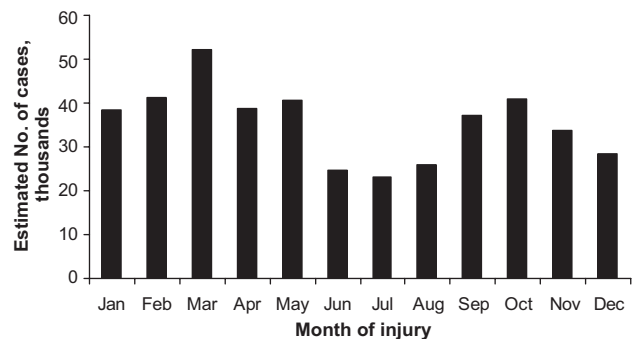


FIGURE 3 Estimated number of children aged 6 to 17 years with gymnastics-related injuries according to month of injury: US EDs, 1990–2005.

TABLE 2 Estimated Number, Average Number per Year, and Rate of Gymnastics-Related Injuries Treated in US Hospital EDs from 1990 to 2005 by Age Group

Parameter	Age Group, y		
	6-17	6-11	12-17
Total, n (%)	425 900 (100.0)	213 837 (50.2)	212 063 (49.8)
Average number per year	26 619	13 365	13 254
Injuries per 1000 participants per year	NA	3.6	7.4

NA indicates not applicable.

ation/avulsion (3.7%), concussion/closed head injury (1.7%), and other (4.2%). The type of injury was not recorded in 0.3% of the cases. Strains/sprains were more common in the 12- to 17-years age group than the 6- to 11-years age group (RR: 1.39; 95% CI: 1.31-1.48; $P < .0001$). Fractures/dislocations were more common in the 6- to 11-years age group than in the 12- to 17-years age group (RR: 1.36; 95% CI: 1.27-1.45; $P < .0001$). There was no observed association between gender and type of injury.

Most Common Injuries (Body Part and Injury Type)

Upper extremity fractures/dislocations were most common for children 6 to 11 years of age (50.2%). Lower

extremity sprains/strains were most common for children 12 to 17 years of age (51.8%).

Gymnastics Skill Performed

The gymnastic skills being performed at the time of injury were handsprings/flips (42.3%), cartwheels/round-offs (30.7%), handstands (8.9%), dismounts/landings (5.8%), somersaults (4.9%), backbends/walkovers (3.5%), splits (2.1%), and headstands (1.7%). The skill being performed at the time of injury was not recorded in 66.1% of the cases. Head/neck injuries were more likely to occur among individuals doing headstands (RR: 7.14; 95% CI: 3.15-16.19; $P < .002$) than among individuals performing other skills. The 12- to 17-years age group was more likely to be injured while performing a difficult skill (a handspring or flip) than the 6- to 11-years age group (RR: 1.41; 95% CI: 1.28-1.56; $P < .0001$).

Hospital Admissions

The majority (97.4%) of patients with gymnastics-related injuries was treated and released from the ED. Of the patients admitted, 91.5% had a fracture/dislocation, 74.2% had injuries to an upper extremity, 43.2% were injured at a place of recreation or sports, 63.0% were 6 to 11 years of age, and 79.6% were female. The 6- to 11-year-olds were more likely to be admitted than the

TABLE 3 Estimated Number and Rate of Gymnastics-Related Injuries Treated in US Hospital EDs from 1990 to 2005 by Body Part Injured, Type of Injury, and Age Group

Parameter	Age Group, y		
	6-17	6-11	12-17
Body part injured			
Upper extremity			
Total, n (%)	180 263 (42.3)	107 416 (50.2)	72 847 (34.4)
Average number per year	11 266	6714	4553
No. per 1000 participants per year	NA	35.2	50.9
Lower extremity			
Total, n (%)	144 083 (33.8)	53 937 (25.2)	90 146 (42.5)
Average number per year	9005	3371	5634
No. per 1000 participants per year	NA	17.7	62.9
Head/neck			
Total, n (%)	54 896 (12.9)	29 895 (14.0)	25 001 (11.8)
Average number per year	3431	1868	1563
No. per 1000 participants per year	NA	9.8	17.5
Type of injury ^a			
Strain/sprain			
Total, n (%)	188 856 (44.5)	79 236 (37.2)	109 620 (51.8)
Average number per year	11 804	4952	6851
No. per 1000 participants per year	NA	26.1	76.6
Fracture/dislocation			
Total, n (%)	128 875 (30.4)	74 467 (35.0)	54 408 (25.7)
Average number per year	8055	4654	3401
No. per 1000 participants per year	NA	24.6	38.0
Abrasion/contusion			
Total, n (%)	66 240 (15.6)	36 806 (17.3)	29 434 (13.9)
Average number per year	4140	2300	1840
No. per 1000 participants per year	NA	12.1	20.6

The percentages represent that of children in each age group who sustained each category of injury.

^aType of injury was not documented for 1429 cases.

12- to 17-year-olds (RR: 1.69; 95% CI: 1.23–2.32; $P < .001$).

Injury Rates

The 6- to 11- and 12- to 17-year age groups sustained similar percentages of the total number of injuries (43.4% and 43.1%, respectively); however, the number of injuries sustained per 1000 participants per year was greater for the 12- to 17-year age group (7.4) than for the 6- to 11-year age group (3.6; RR: 2.07; 95% CI: 2.01–2.13; $P < .01$). The estimated number and rate of gymnastics-related injuries for all injuries combined and for the 3 most commonly injured body parts and types of injury, according to age, are shown in Tables 2 and 3. These tables show the average number of injuries per year and the rate of injury for all injuries combined while stratifying by age group and body part injured or type of injury.

DISCUSSION

To our knowledge, this is the first study of gymnastics-related injuries to children in the United States using a nationally representative sample. Gymnastics has 1 of the highest injury rates of all girls' sports.²¹ In its 23rd Annual Report, the National Center for Catastrophic Sports Injury Research reported that from 1982 to 2005, gymnastics and ice hockey were associated with the highest clinical incidence of catastrophic injuries in both male and female participants.^{21,22} Our study's annual injury rate per 1000 participants 6 to 17 years of age for gymnastics (4.8) is on par with the high injury rates reported for other popular sports, such as cheerleading, soccer, and basketball.²¹ The high reported incidence of catastrophic injuries and injury rates found in our study suggest the need for increased prevention efforts to lower the risk for injury in gymnastics.

Age-related injury patterns identified in this study are also consistent with those reported in other studies regarding pediatric fall-related injuries.^{23–26} In our study, as age increased, the frequency of lower extremity injuries and strains/sprains increased, and the frequency of upper extremity injuries, fractures/dislocations, and concussions/closed head injuries decreased. The 6- to 11-year age group was more likely to be injured at home than the 12- to 17-year age group, which may reflect where the younger age group spends a great deal of active time. It is unlikely that children use competition or training mats to practice gymnastics at home; as a result, they are more likely to practice on hard, unsafe surfaces. These surfaces may increase the risk for injuries in this population. The high frequency of upper extremity injuries in the 6- to 11-year age group could be attributable to improper training in correct falling procedures. Gymnasts, unlike football or rugby players, are not taught to fall in a manner that diffuses the impact of the fall across as much of the body surface as possible; consequently, individuals have a tendency to stiffen up and brace themselves with their arms during a fall.²⁷ Our data also showed that girls are more likely to sustain upper extremity injuries than boys.

Several previous studies reported injury rates among male and female gymnasts,^{3,4,7–17,28} which defined an injury as "any damaged body part that would interfere with training." These studies found that the number of injuries ranged from 1.4 to 3.7 injuries per 1000 hours of gymnastics activity.^{3,6,10,12–14} The injury rates in our study were higher: 3.6 injuries per 1000 hours for the 6- to 11-years age group, 7.42 injuries per 1000 hours for the 12- to 17-year age group, and 4.8 injuries per 1000 hours for the combined 6- to 17-year age group. This discrepancy may be attributable in part to different study populations and ascertainment of injury and participation data. Most previous studies were restricted to club or high school gymnastics, whereas our study did not have those limitations and included gymnastics performed at home, in physical education classes, and at other locations. The broad range of places where an injury occurred in our study may reflect the dangers of practicing gymnastics at home or even during physical education classes without appropriate supervision, training mats, or other safety measures.

The severity of injury in previous studies was determined by the type of injury, the amount of time lost after injury, the overall clinical outcomes, and whether surgery was required. Injury severity ranged from minor abrasions to injuries resulting in functional disability and even death.³ The most common types of injuries were sprains, strains, contusions, fractures, and overuse injuries,^{3,8,10–14} and our study corroborated these findings. Previous studies also demonstrated that the lower extremities were more frequently injured (54.1%–70.2%) than the upper extremities (17.1%–25.0%).³ It is unclear why this does not agree with our findings that the upper extremities (40.9%) sustained more injuries than the lower extremities (33.4%). Previous studies also reported that most injuries (52.0%–83.4%) are related to competition and are sudden onset in nature.³ Our study showed that the 6- to 11-years age group was more likely to get hurt performing a difficult skill, compared with an easy skill, than the other age group.

Gymnastics is a demanding sport, and highly publicized injury incidents have occurred. A widely known case occurred on May 5, 1988, when 15-year-old gymnast Julissa Gomez was paralyzed after hyperextending her neck while attempting a Yurchenko vault during warm-ups at the World Sports Fair in Tokyo, Japan. She later died of complications.²⁹ Julissa's injury helped prompt change in the sport. In 1989, the International Gymnastics Federation increased vaulting safety by allowing U-shaped springboard mats to be used during competitions. These mats are now mandatory. Under the 2006 Code of Points, performing a Yurchenko-style vault without the safety mat results in an automatic score of 0. Also, in 2001, the traditional horse was completely phased out and replaced by a larger, more stable vaulting table to provide gymnasts with additional safety. Such alterations indicate that the gymnastics world has been willing to make implement changes to make the sport safer.

Prevention of gymnastics-related injuries depends on the establishment and universal enforcement of uniform rules and regulations for gymnasts, coaches, and spotters.

Unfortunately, at this time, a set of uniform rules and regulations has not been developed or implemented. Whereas some high school gymnastics programs and private gyms require safety training for their gymnasts and coaches, many fail to implement such training programs. A standardized program, including how to fall correctly, how to land safely, how to advance gymnasts to harder skills, and how to spot correctly, should be required for all coaches and gymnasts to ensure proper safety education. Special attention should be placed on advancing gymnasts to more difficult skills in a more prudent and safe manner via spotting and using soft pits and mats when necessary. To prevent the risk for reinjury, gymnasts should refrain from working out for the appropriate amount of time when advised to do so by a certified athletic trainer or physician. It will be difficult to achieve lower injury rates without a national database to track and analyze gymnastics-related injuries. The current lack of such a database makes it more difficult to develop and evaluate evidence-based safety recommendations.

This study has several limitations. In the past, concerns have been raised regarding NEISS estimates for children's injuries.^{27,30–32} The NEISS has been criticized for underestimating children's injuries, because NEISS strata were based initially on geographic location and hospital size, not by hospital type.^{27,32} In actuality, NEISS may have overestimated children's injuries before 1997.^{33,34} In response to concerns, the NEISS sampling frame was changed in 1997 to include a separate children's hospitals stratum. Data reported in this study were adjusted to account for the sample change and to provide a valid estimation of gymnastics-related injuries. The NEISS includes only injuries that were treated in EDs and thus underrepresents the actual number of gymnastics-related injuries; these data do not account for gymnastics-related injuries that were treated in settings outside of the ED. Also, the data set reports only the most severe injury for each individual, which also underrepresents the number of minor injuries. The NEISS does not include injuries that were treated by a physician in a private office, physical therapist, school trainer, coach, or the gymnast himself or herself; therefore, gymnastics-related injuries that are reported by the NEISS may not be representative of injuries that are treated in non-ED health care settings or those that are not treated at all. Furthermore, information provided in the narrative descriptions in the NEISS database is limited. The narratives often fail to provide information regarding the presence and qualifications of a spotter or coach at the time of injury, the skill being attempted at the time of injury (66.1% of these data were not recorded in this study), the apparatus being used at the time of injury, the gymnast's level of experience, and whether the gymnast was injured during competition or practice. Because it is an ED-based database, the NEISS also does not report the final outcome of injury, the frequency of reinjury, and the number of days of activity lost after injury.

Gymnastics participation data are difficult to obtain, and those provided by American Sports Data, Inc¹⁹ are the most comprehensive that we were able to find.

These data were collected from self-report surveys, and information provided by survey participants was not independently verified.

CONCLUSIONS

An estimated 26 600 (95% CI: 23 200–33 100) gymnastics-related injuries occurred annually during the study period, and the number of injuries decreased by 25% over 16 years, from 28 700 in 1990 to 21 500 in 2005. Our study's annual injury rate per 1000 participants 6 to 17 years of age for gymnastics (4.8) is similar to high injury rates reported for other popular sports. The high incidence of catastrophic injuries previously reported and the high injury rates found in this study suggest the need for increased prevention efforts to lower the risk for injury in gymnastics. Prevention strategies should also focus on children and adolescents 6 to 17 years of age. Increased attention should also be directed toward the 6- to 11-year age group, which may be more likely to practice unsupervised gymnastics at home than older children. Unsupervised gymnastics is not recommended, because trained spotters and coaches are essential to ensure the safe practice of gymnastics. Establishment of a national database for gymnastics-related injuries, including exposure data for direct calculation of injury rates, would permit better identification and monitoring of risk factors for gymnastics-related injuries and aid in the development, implementation, and evaluation of injury prevention strategies that are based on epidemiologic evidence.

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