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Zipline-Related Injuries Treated in US EDs, 1997-2012

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ABSTRACT

Purpose: To investigate the epidemiology of zipline-related injuries in the United States.
Basic Procedures: The National Electronic Injury Surveillance System database was used to examine non-fatal zipline-related injuries treated in US emergency departments (EDs) from 1997 through 2012. Sample weights were applied to calculate national estimates.
Main Findings: From 1997 through 2012, an estimated 16850 (95% CI, 13188-20512) zipline-related injuries were treated in US EDs. The annual injury rate per 1 million population increased by 52.3% from 7.64 (95% CI, 4.86-10.42) injuries in 2009 (the first year with a stable annual estimate) to 11.64 (95% CI, 7.83-15.45) injuries in 2012. Patients aged 0-9 years accounted for 45.0% of injuries, females made up 53.1% of injuries, and 11.7% of patients required hospitalization. Fractures accounted for the largest proportion of injuries (46.7%), and the upper extremities were the most commonly injured body region (44.1%). Falls were the most common mechanism of injury, accounting for 77.3% of injuries. Among cases where the location of the injury event was known, 30.8% of injuries occurred in a residential setting and 69.2% occurred in a public place.
Principal Conclusions: This study is the first to characterize the epidemiology of zipline-related injuries using a nationally representative database. The rapid increase in zipline-related injuries in recent years suggests the need for additional safety guidelines and regulations. Commercial ziplines and publicly accessible non-commercial ziplines should be subject to uniform safety standards in all states and jurisdictions across the US, and homemade ziplines should not be used.

1. Introduction

First used over a century ago to transport supplies in the Indian Himalayas [1], the zipline has gained popularity as a form of outdoor recreation over the past decade [2]. A zipline, as defined by the United States Consumer Product Safety Commission (CPSC), is a horizontal rope or wire with a device for sliding along by hanging beneath it [3]. Several states have acknowledged the inherent risk of injury associated with ziplines and have established regulations governing commercial ziplines using safety standards developed by ASTM International, the Association for Challenge Course Technology, or the Professional Ropes Course Association [4]. However, the industry is largely self-regulating [5-8]. In recent years, media coverage of isolated serious injuries and deaths associated with ziplines has raised concerns regarding zipline safety [9-13].

Very little research has been conducted on the epidemiology of zipline-related injuries. The only peer-reviewed study related to the topic examined fatalities on challenge courses, finding that nearly one-fourth of all reported deaths were associated with the zipline component of the challenge course. That study did not examine non-fatal injuries and was limited to only 17 deaths. Further, it did not address injuries sustained on stand-alone ziplines or canopy tours, and most deaths were from only one challenge course provider. Therefore, that study was not representative of zipline-related injuries occurring nationally [14]. Several studies have addressed playground zipline-related injuries [15-17], which were excluded from the current study because of fundamental differences between the products involved. Playground ziplines, also termed track rides, are "a form of upper body equipment where the child holds on to a handle or other device that slides along a track above his or her head" [18]. These rides are subject to safety standards developed for playground equipment, unlike the ziplines associated with the injuries in the current study [3].

To our knowledge, this is the first study to examine non-fatal zipline-related injuries, including those occurring on homemade ziplines, commercial operations, challenge courses, and canopy tours, using a nationally representative database. An analysis of the epidemiology of these incidents will allow for a greater understanding of the injury risk associated with zipline use, which will help inform the development of additional safety guidelines and regulations.

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2. Methods

2.1. Data source

Data were obtained from the National Electronic Injury Surveillance System (NEISS), operated by the CPSC, for zipline-related injuries treated in US emergency departments (EDs) from 1997 through 2012. The NEISS is a stratified probability sample consisting of approximately 100 US hospital EDs, representing the more than 5000 24-hour hospital EDs in the United States and its territories with more than six beds [19]. The NEISS database provides information on age, gender, injury diagnosis, body region injured, disposition from the ED, product or activity involved, date of treatment, and locale, as well as a brief narrative describing the injury event. More specific information regarding NEISS data collection is described elsewhere [20].

2.2. Case selection criteria

Cases from the NEISS database were classified as zipline-related if the cases' narratives contained any of the following words: "zipline," "zip line," "zip-line," "zip cord," "zip swing," "zip wire," and "flying fox." The narratives of 830 zipline-related cases were further reviewed and 606 cases met the study criteria. All cases that explicitly stated or implied that they occurred on a playground zipline were excluded, as well as cases that occurred in the school locale and thus were assumed to be playground ziplines. When the type of zipline involved in the injury was not specified, it was presumed a traditional zipline and the case was included, because playground ziplines are customarily termed track rides [16]. Cases that were erroneously classified as zipline-related were excluded as well.

2.3. Variables

NEISS variables for diagnosis, body region injured, patient age, disposition from the ED, and locale were recategorized for analysis. Diagnoses were categorized into (1) lacerations (including lacerations and punctures), (2) concussions/closed head injuries (including internal injuries to the head region), (3) soft tissue injuries (including contusions and abrasions), (4) fractures, (5) strains and sprains, and (6) other (including dislocations, burns, dental injuries, and internal injuries not to the head). Body region injured was classified as (1) head and neck (including the categories of head, face, mouth, eyeball, and neck), (2) trunk (including upper and lower trunk and pubic region), (3) upper extremity (including finger, hand, wrist, lower arm, elbow, upper arm, and shoulder), (4) lower extremity (including upper and lower leg, knee, foot, ankle, and toe), and (5) other. Patient age was grouped into <10, 10-19, and ≥20 in order to compare injuries incurred by young children with those among older children and adults. Disposition from the ED was grouped into (1) treated and released and (2) hospitalized (including treated and transferred to another hospital, treated and admitted, and kept for <24 hours for observation). One fatality was excluded from this study, in which an eight-year-old girl suffered a skull fracture and epidural hemorrhage after falling ten feet from a homemade zipline.

The primary mechanism of injury was determined from the case narratives and categorized as (1) fell from the zipline or zipline platform, (2) collision with a static object or another person, or (3) other (hand caught in zipline, zipline broke or malfunctioned, hit by zipline handle, anxiety or stress, and difficulty landing). The height of the fall also was determined from case narratives and categorized as (1) ≤10 feet or (2) >10 feet. Locale was classified as (1) residential (including homes and farms), or (2) public place (including sport/recreation areas and other public places).

2.4. Data analyses

Statistical analyses were conducted using IBM SPSS version 20.0 (IBM Corp, Armonk, NY), and SAS 9.3 (SAS Institute Inc, Cary, NC) statistical software. Sample weights provided by the CPSC were used to calculate the national injury estimates. The Taylor series linearization method, which accounted for the NEISS sampling design, was used to calculate the variance of the estimates. All reported results are stable national estimates unless stated otherwise. An estimate is potentially unstable if it is based on <20 actual cases, the estimate is <1200, or the coefficient of variation is >30%. National injury rates were calculated using US Census Bureau July 1 intercensal and postcensal residential population estimates for 1997 through 2012 [21-23] as denominators. Due to potentially unstable annual estimates from 1997 to 2008, trend analysis was not conducted for the entire study period and was restricted to years with stable annual estimates (2009-2012). The Rao-Scott χ^2 test was used to test for association, and relative risks (RRs) with 95% confidence intervals (CIs) were also calculated. Statistical tests were considered significant at $\alpha = .05$. The institutional review board at the authors' institution approved this study.

3. Results

3.1. General characteristics

From 1997 through 2012, an estimated 16850 (95% CI, 13188-20512) zipline-related injuries were treated in US EDs, resulting in an injury rate of 3.58 (95% CI, 2.80-4.36) per 1 million US residents. The majority (67.7%) of the injuries occurred from 2009 through 2012. The annual injury rate per 1 million US residents increased by 52.3% from 7.64 (95% CI, 4.86-10.42) injuries in 2009 (the first year with a stable annual estimate) to 11.64 (95% CI, 7.83-15.45) injuries in 2012 (Fig. 1). This corresponded to a 55.8% increase in the annual number of injuries, from 2345 (95% CI, 1492-3198) injuries in 2009 to 3653 (95% CI, 2457-4849) injuries in 2012. The mean patient age was 16.0 years (SD, 1.5) and the median patient age was 9.6 years (range, 2-82; interquartile range, 6.4-17.1). Patients aged <10 years accounted for 45.0% of injuries, followed by patients aged 10-19 years (33.0%) (Table). Among the 79.5% of cases where locale was known, 30.8% occurred in a residential area, either at the patient's home or at the home of a relative, friend, or neighbor. Females accounted for 53.1% of all zipline-related injuries, and 11.7% of patients were admitted to the hospital. Most (91.2%) of the injuries occurred from early spring (April) through late fall (October) with the number of injuries peaking in July (Fig. 2).

3.2. Injury diagnosis and body region injured

Fractures accounted for 46.2% of all zipline-related injuries, followed by soft tissue injuries (15.2%) and strains/sprains (15.1%) (Table). Concussions and closed head injuries constituted 7.7% of all injuries. Patients aged <10 years were more likely to suffer a fracture compared with older patients (RR, 1.68; 95% CI, 1.32-2.14). The most commonly injured body region was the upper extremities (44.1%), followed by the lower extremities (24.3%), head and neck (18.6%), and trunk (13.0%) (Table). Injuries to the upper extremities were more likely to result in a fracture than injuries to other body regions (RR, 3.38; 95% CI, 2.37-4.82). Patients <10 years of age were more likely to incur an injury to the upper extremities (RR, 1.84; 95% CI, 1.41-2.41) than older patients. Patients aged ≥20 years were more likely to sustain an injury to the lower extremities than younger patients (RR, 2.81; 95% CI, 1.86-4.25).

3.3. Mechanism of injury

Among all zipline-related injuries where mechanism of injury was stated, falls accounted for 77.3% and collisions accounted for 13.4% (Table). Fall-related injuries were commonly diagnosed as fractures (56.3%) and frequently occurred to the upper extremities (51.8%) or the head and neck region (17.6%). Among those hospitalized, 77.9% were admitted for a fall-related fracture. Falls accounted for 90.4% of the injuries among children aged <10 years and 77.7% of all injuries

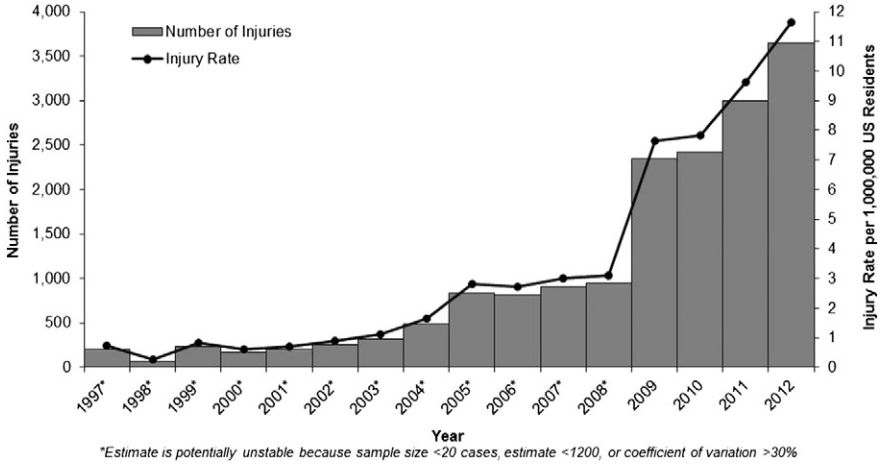

Fig. 1. Annual number and rate of patients treated for a zipline-related injury in US EDs, 1997-2012.

among children aged 10-19 years. Patients aged <20 years were more likely than patients aged ≥20 years to sustain an injury from a fall (RR, 1.95; 95% CI, 1.36-2.82). Injuries that did not arise from a fall were more likely to affect the lower extremities than fall-related injuries (RR, 3.11; 95% CI, 2.10-4.61). The height of the fall was ≤10 f. in 68.5% of cases where fall height was documented in the NEISS case narrative.

Table
Characteristics of zipline-related injuries treated in US EDs, 1997-2012

Characteristics	National Estimate (%[a])	95% CI
Age (y)		
0-9	7575 (45.0)	5911-9240
10-19	5562 (33.0)	4315-6809
≥20	3707 (22.0)	2143-5270
Gender		
Male	7910 (46.9)	6396-9424
Female	8940 (53.1)	7089-10791
Disposition from ED		
Treated and released	14871 (88.3)	12112-17631
Admitted	1979 (11.7)	1337-2621
Body region injured		
Upper extremity	7421 (44.1)	5685-9158
Lower extremity	4085 (24.3)	2868-5302
Head/neck	3137 (18.6)	2341-3932
Trunk	2184 (13.0)	1304-3064
Other	17 (0.1) [b]	
Injury diagnosis		
Fracture	7793 (46.2)	6139-9446
Soft tissue injury	2560 (15.2)	1711-3410
Sprain/strain	2541 (15.1)	1606-3476
Laceration	1786 (10.6)	927-2645
Concussion/CHI	1296 (7.7)	840-1752
Other	874 (5.2) [b]	
Mechanism of injury		
Fall	12058 (77.3)	9761-14356
Collision	2099 (13.4)	1373-2825
Other	1451 (9.3)	813-2089
Fall height		
≤10 feet	2162 (68.5)	1672-2652
>10 feet	995 (31.5) [b]	
Locale		
Residential	4119 (30.8)	2618-5621
Public place	9270 (69.2)	7345-11196
Total	16850	13188-20512

CHI, closed head injury.
[a] Percentages may not sum to 100.0% due to rounding error.
[b] Estimate is potentially unstable because sample size <20 cases, estimate <1200, or coefficient of variation >30%.

4. Discussion

From 1997 through 2012, there were an estimated 16850 individuals treated in US EDs for zipline-related injuries. Almost 70% of these injuries occurred during the last four years of the study period (2009-2012), indicating a growing problem. There were more than 3600 individuals treated for injuries in 2012, equaling an average of 10 persons per day. The annual number and rate of zipline-related injuries increased by 55.8% and 52.3%, respectively, from 2009 to 2012. These increases are likely due to an increase in exposure to ziplining as the activity continues to gain popularity. This trend is made evident by the rapid growth of the zipline industry. In 2001, there were only ten commercial ziplines operating in the US; this number increased to more than 200 by 2012 [2].

Although zipline injuries occurred at a relative low rate of 3.58 per one million US residents, these injuries are often medically serious. In this study, 11.7% of patients with zipline-related injuries required hospitalization. In comparison, only 2.3% of patients who were treated in US EDs for sports- and recreation-related injuries in 2000 to 2001 were hospitalized [24]. This high rate of hospitalization is more consistent with rates occurring with adventure sports [25] and reflects the inherent danger associated with ziplining. Fractures were the most common injury diagnosis, and almost half of all injuries were to the upper extremities. Injuries to the lower extremities were more likely to occur during a non-fall or collision event; narratives suggest that many of these injuries were sustained as riders attempted to slow or stop themselves at the end of the zipline by bracing their feet against the zipline anchor, such as a tree or pole. The frequent occurrence of such collision injuries, and their responsibility for 13.4% of all zipline-related injuries, suggests a need for automatic, reliable braking systems on all ziplines, especially those that achieve high speeds.

Young children <10 years of age accounted for almost half of the zipline-related injuries and among these, 90% were due to falls. The high proportion of fall-related injuries among young children may likely be attributed to a lack of upper body strength required to hold onto the zipline handles for the duration of the ride and a lack of safety harness use. Some zipline braking systems may also cause riders to suddenly stop at the end of the ride, causing the rider to lose their grip and fall. In addition, young children may be allowed to ride on ziplines not built specifically for their age group, which may increase their risk of fall-related injuries. The body region injured and diagnosis varied by age group in a similar manner to other activities involving falls from heights [26-29]. Patients <10 years were more likely to experience an injury to the upper extremities and head and neck than other age

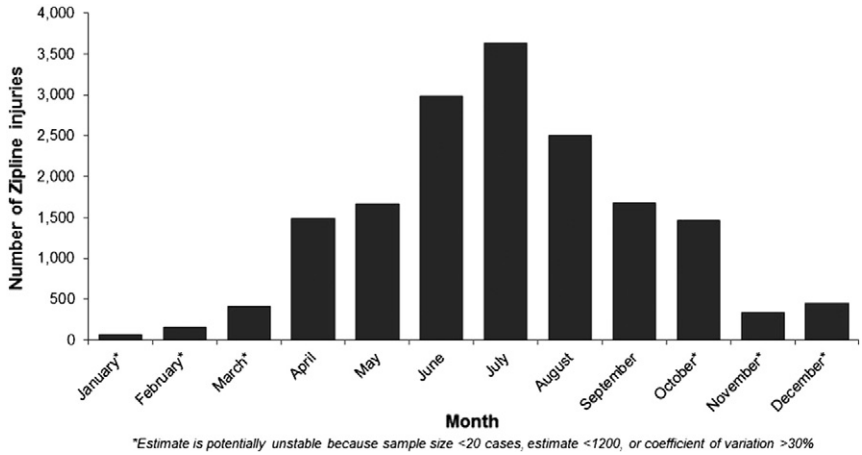

Fig. 2. Estimated number of zipline-related injuries treated in US EDs by month, 1997-2012.

groups, while adult patients more commonly experienced injuries to the lower extremities. Fractures were the most commonly observed injury among patients <10 years, often to the upper extremities. These injury patterns may be due, in part, to small children's higher center of gravity and a lack of the arm strength needed to break their fall, predisposing them to more injuries to the upper extremities and head and neck [26].

Approximately 30% of injuries occurred in the residential setting and 70% occurred in public areas. Although our data could not distinguish commercial ziplines from amateur and backyard ziplines, according to a zipline industry consultant, "among the approximately 13 000 ziplines in the country, the majority are amateur or backyard ziplines located at camps, schools, or outdoor education programs" [4]. Many of the injuries that occurred in residential areas may have been associated with backyard/homemade ziplines built for private use. Do-it-yourself zipline kits and specific zipline components (wires, harnesses, etc.) are available for purchase online. However, due to the inherent risks of injuries associated with ziplines, parents, caregivers, and children should be strongly discouraged from installing and using ziplines at home. Improper installation, maintenance, or operation of ziplines can result in serious injuries and even death [9-13].

Coded injury locales and case narrative sampling for injuries that occurred at public areas suggest that many of these injuries were associated with ziplines located at sport and recreation facilities, such as summer camps and parks. Although these ziplines are often open for use by the public, they are not regulated under state law in many states and may not meet industry standards. These self-regulated zipline operations represent an unaddressed potential hazard to the public. Publicly accessible ziplines operated by a non-commercial entity, such as a summer camp or outdoor education program, that are comparable to commercial ziplines, should adhere to safety standards and regulations for commercial ziplines [30-33]. Smaller publicly accessible ziplines that are intended for younger children should follow the standards and guidelines developed by ASTM International and the CPSC, respectively, governing playgrounds [34,35], which address site selection, height, and surfacing.

Several states have recently recognized the hazards associated with ziplines and have implemented regulations [36]. Entities that are not regulated by the state are often required by their insurance providers to adhere to similar standards before coverage is provided. States and insurance companies generally require ziplines to meet standards developed by the Association for Challenge Course Technology [32], ASTM International [31], International Professional Zipline Association [30],or Professional Ropes Course Association [33], which cover design, manufacturing, installation, operation, and maintenance of ziplines. These standards include engineering criteria for new ziplines; safety features such as dual cable systems, harnesses, and automatic braking systems; and training programs for staff. In March 2014, the American National Standards Institute approved the Professional Ropes Course Association's *1.0-.3-2014 Ropes Challenge Course Installation, Operation and Training Standards* as an American National Standard. The Association for Challenge Course Technology attempted unsuccessfully to appeal this decision [37]. The standards applied to ziplines vary among states and even among jurisdictions within a state [36]. This variability complicates the certification process; acceptance and use of one universal zipline standard would allow for more effective and efficient regulation and inspection.

Consumers can minimize risks associated with ziplining by taking precautions. They should seek out operations that meet one of the aforementioned sets of standards. Further, riders should adhere to posted safety instructions and follow recommendations provided by zipline operators.

5. Study limitations

The NEISS collects data on patients who are treated in hospital EDs and does not capture injured individuals who are treated in urgent care or primary care settings, or who did not seek medical treatment. Therefore, this study underestimates the number of zipline-related injuries and may not be representative of the entire spectrum of zipline-related injuries. Due to small sample sizes, relatively broad age ranges were required to ensure stable estimates in cross-variable analyses. This may have obscured differences in injury characteristics across the age spectrum. United States census data were used as denominators to calculate injury rates because data are not available on the number of ziplining participants. This method produces a very conservative national injury rate, but is a necessary and acceptable approach in the absence of true exposure data. Fatalities were not included in this study because the NEISS does not capture fatalities well. Case narratives did not provide sufficient details to discriminate between commercial zipline operations and homemade ziplines. Although attempts were made to eliminate playground ziplines (track rides) from the study, it is possible that some of the injuries that occurred in public areas may have been associated with these ziplines.

6. Conclusions

Ziplines are rapidly gaining popularity as a form of outdoor recreation, and they pose a risk for serious injury because of the potential for falls from heights. This study is the first to characterize the epidemiology of zipline-related injuries using a nationally representative database. The rapid increase in zipline-related injuries in recent years suggests the need for additional safety guidelines and regulations. Commercial ziplines and publicly accessible non-commercial ziplines should be subject to uniform safety standards in all states and jurisdictions across the US, and homemade ziplines should not be used. Additional research on injury characteristics of commercial and non-commercial

ziplines should be conducted to develop refined injury prevention strategies.

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