
Rock Climbing Injuries Treated in Emergency Departments in the U.S., 1990–2007

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Background: Rock climbing is an increasingly popular sport in the U.S., with approximately nine million participants annually. The sport holds an inherent risk of falls and stress-related injuries. As indoor climbing facilities become more common, more people are participating in the sport.

Purpose: The objective of this study is to describe the prevalence, characteristics, and trends of rock climbing-related injuries treated in U.S. emergency departments from 1990 through 2007.

Methods: A retrospective analysis was conducted using data from the National Electronic Injury Surveillance System (NEISS) of the U.S. Consumer Product Safety Commission for all ages from 1990 through 2007. Sample weights provided by NEISS were used to calculate national estimates of rock climbing-related injuries. Trend significance of the number of rock climbing-related injuries over time was analyzed using linear regression. Analysis was conducted in 2008.

Results: An estimated 40,282 patients were treated in emergency departments for rock climbing-related injuries in the U.S. over the 18-year period. Patients aged 20–39 years accounted for more than half of all injuries. Fractures, sprains, and strains accounted for the largest portion of injuries (29.0% and 28.6%, respectively). The lower extremities were the most frequently injured body part, accounting for 46.3% of all injuries; ankle injuries accounted for 19.2%. Men were more likely to sustain lacerations (OR=1.65; 95% CI=1.03, 2.67) and fractures (OR=1.54; 95% CI=1.10, 2.17), whereas women were more likely to sustain a sprain or strain (OR=1.68; 95% CI=1.13, 2.51). Overexertion injuries were more likely to occur to the upper extremities (OR=5.32; 95% CI=1.99, 14.23). Falls were responsible for three quarters of all injuries (77.5%). Overall, 11.3% of patients were hospitalized.

Conclusions: Our results indicate that the most common rock climbing-related injuries are to the lower extremities and are fractures, sprains, and strains. More research is needed to determine how rock-climbers' characteristics, climbing setting, style of climbing, and use of safety equipment and training may affect their risk for certain injury patterns.

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Introduction

Rock climbing is an increasingly popular sport in the U.S.¹ Approximately nine million people participated in rock climbing in the U.S. in 2005, averaging six outings a year.² The number of indoor climbing facilities has increased in the U.S., and climbing walls have become a ubiquitous feature on college campuses and in other multi-use facilities (B. Zimmerman, Climbing Wall Association, Inc., personal communica-

tion, 2009). Improved safety standards and indoor climbing facilities have also made this extreme sport, once reserved for adrenaline junkies, more accepted and practiced by the general public, and many people have year-round access. As rock climbing has gained popularity over the past several decades, the participant pool has evolved from primarily elite, dedicated climbers to a large spectrum of ages and experience levels.

Improved technologic advancements in safety have made equipment more reliable and durable. However, 50%–80% of rock climbers report sustaining a climbing-related injury annually.^{3,4} The types of injuries sustained from rock climbing differ between elite and recreational climbers and by types of climbing (indoor versus outdoor; bouldering versus lead or top-roping; traditional versus sport).^{5–9} Whereas elite climbers are most susceptible to overuse injuries of the fingers,

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recreational climbers frequently have a wider range of injuries, including more lower-extremity injuries.^{4,10}

Research on rock climbing-related injuries has focused primarily on elite climbers,¹⁰⁻¹³ specific types or locations of injuries,¹⁴⁻¹⁷ and specific types of climbing.^{6,7,18} Studies have had limited sample sizes^{5,19} and often rely on self-report of injuries.^{3,4,8,18} This paper uses a nationally representative sample to examine nationwide rock climbing-related injury characteristics and trends at the national level. The objective of this study is to describe the prevalence, characteristics, and trends of rock climbing-related injuries treated in U.S. emergency departments from 1990 through 2007.

Methods

Data Source

The National Electronic Injury Surveillance System (NEISS) of the U.S. Consumer Product Safety Commission is a stratified probability sample of ~100 U.S. hospital emergency departments, including seven children's hospitals, representing 6100 hospitals with at least six beds and a 24-hour emergency department.²⁰ This data set provides high-quality data on consumer product-related and sports- and recreation-related injuries treated in emergency departments. At NEISS hospitals, emergency department medical charts are reviewed by professional coders, and data regarding patients' age, gender, race, injury diagnosis, injured body part(s), product(s) involved, and disposition, along with a brief narrative describing the incident, are recorded.^{20,21} All injuries identified by the NEISS product code for mountain climbing (1258), which includes rock climbing-related injuries, between 1990 and 2007 were reviewed (N=1845). A key-word search of these case narratives for *rock*, *wall*, and *gym* identified 1126 potential cases. After review of the narratives from potential cases, a total of 280 cases were excluded on the basis that they actually involved mountaineering, mountain climbing, or hiking, or otherwise did not involve rock climbing. The remaining 846 cases were used in the analysis. This study was approved by the IRB of the Research Institute at Nationwide Children's Hospital.

Variables

Data regarding patients' age, body part injured, injury diagnosis, and disposition were coded into categorical variables. Age was categorized into three groups: ≤ 19 years, 20-39 years, and ≥ 40 years. Body parts injured were categorized into the following body regions: head (included head, neck, face, mouth, ears, and eyes); upper extremities (included shoulder, upper arm, elbow, lower arm, wrist, hand, and finger); lower extremities (included upper leg, knee, lower leg, ankle, foot, and toe); trunk (included upper and lower trunk, hip, and pubic region); and other (included NEISS codes for other, 25%-50% of the body, all parts of the body, and internal injuries). Injury diagnosis was coded as laceration (included punctures and avulsions); soft tissue (included contusions, abrasions, hematomas, and crushing injuries); fractures; concussions; dislocations; sprains and/or strains; and other. Disposition was categorized as hospitalized (patients who were admitted to a hospital or transferred to

another hospital) and not hospitalized (patients who were treated and released, held for observation for <24 hours, or left without being seen).

Each case narrative was reviewed to categorize the mechanism of injury. Mechanism of injury was determined to be one of the following: fall, hit and/or strike; hit by and/or struck by an object; overexertion (e.g., felt a "pop" while performing a move); or other. For each case in which mechanism was coded as a fall, information about the height of the fall was coded as ≤ 20 ft. or > 20 ft.

Statistical Analysis

Data were analyzed using SPSS, version 15.0. Means were reported with SDs. Bivariate comparisons between variables were conducted using chi-square analysis with strength of association assessed using ORs with 95% CIs. Significance was assessed using $\alpha=0.05$. Trend significance of the number of rock climbing-related injuries over time was analyzed using linear regression. All statistical analyses accounted for the complex sampling frame of the NEISS.²⁰ All data reported in this article are national estimates unless specified as actual unweighted cases. Analysis was conducted in 2008.

Results

Demographics and Overall Trends

From 1990 through 2007, there were an estimated 40,282 (95% CI=23,477.60, 57,086.60) rock climbing-related injuries, averaging 2237 injuries annually. The annual number of cases increased 63.0% over the study period from 1617 in 1990 to 2637 in 2007 ($p<0.001$), with a high of 3314 injuries in 2003 and a decreasing trend from 2005 to 2007. The mean age of injured climbers was 26 years (range: 2-74 years; 95% CI=24.89, 27.11). Patients aged 20-39 years accounted for more than half of all injuries (56.0%), followed by climbers aged ≤ 19 years (29.6%) or ≥ 40 years (14.3%). Men accounted for 71.8% of all rock climbing-related injuries (Table 1).

Injury Diagnosis and Body Part Injured

Fractures, sprains, and strains accounted for the largest proportion of injuries (29.0% and 28.6%, respectively), followed by lacerations (17.1%); soft tissue injuries (16.9%); and dislocations (4.3%). There were not enough concussions in the dataset to yield stable estimates ($n=11$), and were therefore not included in the analysis. Lower extremities were the most frequently injured body part (46.3% of all injuries). Ankle injuries accounted for 19.2% of all injuries. Upper extremities were injured in 29.2% of cases, followed by injuries to the head (12.2%) and trunk (10.5%). Sprains and strains accounted for 63.6% of all ankle injuries, making the ankle (compared to all other body parts) nearly eight times more likely to sustain a sprain or strain (OR=7.91; 95% CI=5.52, 11.33) than other types of injury. Lower extremities were 2.71 times (95% CI=1.89, 3.87) more likely to have sprains or strains

Table 1. Characteristics of rock climbing injuries treated in U.S. emergency departments, 1990–2007

Characteristic	Actual cases (n) ^a	National estimate ^b (%) ^c	95% CI
Total	846	40,282 (100)	23,477.6–57,086.6
Age (years)	846	40,282 (100)	23,477.6–57,086.6
≤19	243	11,927 (29.6)	6,450.4–17,402.8
20–39	473	22,607 (56.1)	12,185.2–33,029.5
≥40	130	5,748 (14.3)	3,653.6–7,842.6
Gender	846	40,282 (100)	23,477.6–57,086.6
Male	592	28,906 (71.8)	16,529.9–41,281.5
Female	254	11,376 (28.2)	6,792.2–15,960.7
Fall distance^d	175	7,976 (100)	3,519.5–12,432.5
≤20 ft.	112	5,283 (66.2)	2,566.2–7,999.1
>20 ft.	63	2,693 (33.8)	819.7–4,567.0
Case disposition	844	40,208 (100)	23,425.8–56,989.6
Not hospitalized	732	35,645 (88.5)	20,990.5–50,299.1
Hospitalized	112	4,563 (11.3)	1,823.5–7,302.3

^aSome *n* values may differ because of missing data.

^bThe estimates for some *n* values may differ because of missing data.

^cPercentages may not add up to 100 because of rounding.

^d33% of cases identified as a fall had information regarding the distance fallen

than other types of injury. Feet (compared to all other body parts) were twice as likely to sustain fractures (OR=1.97; 95% CI=1.18, 3.28) than other types of injury. Upper-extremity injuries (compared to all other body parts) were 16.23 times (95% CI=6.40, 41.20) more likely to be a dislocation than other types of injury. The head and leg (compared to other body parts) were more likely to sustain a laceration than other types of injuries (OR=5.10; 95% CI=2.85, 9.12 and OR=2.40; 95% CI=1.32, 4.35, respectively).

Men were 1.65 times (95% CI=1.03, 2.67) more likely to sustain lacerations than other types of injuries and 1.54 times (95% CI=1.10, 2.17) more likely to sustain fractures than other types of injuries. Women were 1.68 times (95% CI=1.13, 2.51) more likely to sustain a sprain or strain than other types of injury. The total proportion of lacerations decreased from 56.4% to 11.3% (*p*=0.001) over the study period.

Child and adolescent climbers aged ≤19 years (compared to those aged ≥20 years) were twice as likely to sustain lacerations (OR=1.99; 95% CI=1.14, 3.49) than other types of injuries. Climbers aged 20–39 years (compared to climbers aged ≤19 and ≥40 years) were 1.37 times (95% CI= 1.03, 1.82) more likely to sustain a sprain or strain than other types of injury and 1.62 times (95% CI=1.01, 2.59) more likely to sustain an ankle injury. Climbers aged ≥40 years (compared to those aged ≤39 years) were nearly twice as likely to sustain fractures (OR=1.88; 95% CI=1.35, 2.63) than other types of injuries. The distribution of body part injured and diagnosis by age is shown in Table 2.

Mechanism of Injury and Height of Fall

Falls were the mechanism of injury in more than three quarters of all rock climbing–related injuries (77.5%) for which mechanism of injury was able to be deter-

mined. Hitting or striking an object accounted for 7.1% of injuries, followed by being hit by or struck by an object (6.4%) and overexertion (3.1%). Men and climbers aged ≤19 years (compared to those aged 20–39 years or ≥40 years) were both more likely to be hit or struck by an object than to be injured by other mechanisms (OR=4.24; 95% CI=1.63, 11.05 and OR=2.28; 95% CI=1.27, 4.10, respectively).

Being hit or struck by an object (compared to being injured by other mechanisms) was 4.19 times (95% CI=2.37, 7.40) more likely to result in a laceration than were other types of injury; 3.87 times

(95% CI=1.23, 12.13) more likely to injure the head than another part of the body; and 2.88 times (95% CI=1.53, 5.43) more likely to result in hospitalization. The upper extremities accounted for two thirds (66.6%) of injuries caused by overexertion. Overexertion injuries (compared to other mechanisms) were more than five times as likely to occur to the upper extremities (OR=5.32; 95% CI=1.99, 14.23) than to other parts of the body. Injuries caused by a climber hitting or striking an object were 5.26 times (95% CI=2.86, 9.67) more likely to cause a laceration than other types of injury and twice as likely to be to the ankle (OR=2.17; 95% CI= 1.21, 3.89) than other parts of the body. Falls (compared to other mechanisms) were twice as likely to result in an injury to the trunk (OR=2.12; 95% CI=1.10, 4.12) than to another part of the body.

Two thirds of falls were from a height of ≤20 ft. (66.2%); 33.8% were from >20 ft. When injured in a fall, men were more than twice as likely as women to fall >20 ft. (OR= 2.65; 95% CI=1.28, 5.46). Over half (58.9%) of patients who fell from a height of >20 ft. were hospitalized, making them nearly 10 times more likely to be hospitalized (OR= 9.82; 95% CI=5.04, 19.15) than patients who had fallen ≤20 ft. Patients who fell >20 ft. were also 3.24 times (95% CI=1.48, 7.08) more likely to sustain fractures than other types of injuries.

Hospitalization

A total of 11.3% of rock climbing–related injuries resulted in hospitalization. Rock climbers who had fallen >20 ft. accounted for 70% of all hospitalized patients. Men were twice as likely as women to be hospitalized (OR=2.04; 95% CI=1.26, 3.31). Fractures

Table 2. Proportion of body parts injured and diagnosis of rock climbing injuries treated in U.S. emergency departments, 1990–2007, by age, gender, and hospitalization

	National estimate (%) ^a	Hospitalized % ^a (OR; 95% CI)		Age % ^a (OR; 95% CI)		Gender % ^a (OR; 95% CI)	
		≤19 years	20–39 years	≥40 years	Male	Female	
Body part injured							
Lower extremity ^b	40198 (100)	33.3 (0.55; 0.28, 1.07)	49.7 (1.38; 1.02, 1.85)	44.0 (0.90; 0.60, 1.35)	46.0 (0.97; 0.68, 1.36)	46.8 (1.04; 0.73, 1.46)	
Upper extremity ^c	18607 (46.3)	16.9 (0.46; 0.17, 1.25)	32.5 (0.81; 0.56, 1.18)	29.7 (1.03; 0.62, 1.73)	28.6 (0.91; 0.60, 1.40)	30.5 (1.09; 0.72, 1.67)	
Head ^d	11733 (29.2)	24.1 (2.68; 1.64, 4.38)	10.3 (0.68; 0.46, 0.99)	12.3 (1.02; 0.52, 1.99)	12.3 (1.03; 0.65, 1.65)	11.9 (0.97; 0.61, 1.54)	
Trunk ^e	4910 (12.2)	22.2 (2.86; 1.56, 5.43)	10.5 (1.00; 0.66, 1.54)	12.8 (1.36; 0.70, 2.42)	10.4 (0.96; 0.53, 1.76)	10.8 (1.04; 0.57, 1.90)	
Diagnosis							
Fracture	37872 (100)	69.6 (8.19; 5.17, 12.98)	26.0 (0.87; 0.67, 1.15)	38.9 (1.88; 1.35, 2.63)	29.5 (1.54; 1.09, 2.17)	21.4 (0.65; 0.46, 0.92)	
Sprains/strains	10966 (29.0)	0.0	29.6 (1.37; 1.03, 1.82)	19.4 (0.62; 0.42, 0.90)	23.8 (0.59; 0.40, 0.88)	34.5 (1.68; 1.13, 2.51)	
Laceration ^f	10822 (28.6)	4.1 (0.20; 0.06, 0.68)	23.1 (1.99; 1.14, 3.49)	14.0 (0.83; 0.34, 1.01)	17.8 (1.65; 1.03, 2.67)	11.6 (0.60; 0.38, 0.98)	
Soft tissue ^g	6473 (17.1)	2.6 (0.13; 0.03, 0.62)	12.8 (0.71; 0.38, 1.32)	17.3 (1.26; 0.80, 2.00)	17.1 (1.10; 0.64, 1.89)	17.2 (1.14; 0.85, 1.52)	
Dislocation	1622 (4.3)	0.0	5.6 (1.70; 0.85, 3.40)	3.6 (0.79; 0.41, 1.53)	3.9 (0.91; 0.26, 3.22)	4.3 (1.10; 0.31, 3.85)	
Other	1187 (3.1)	15.3 (11.45; 6.18, 21.21)	4.2 (1.57; 0.69, 3.58)	3.2 (1.06; 0.48, 2.32)	3.2 (1.12; 0.56, 2.23)	2.9 (0.90; 0.45, 1.79)	
Mechanism							
Fall	31116 (100)	81.5 (1.32; 0.75, 2.33)	79.0 (1.20; 0.83, 1.74)	76.4 (0.93; 0.56, 1.55)	76.8 (0.85; 0.49, 1.48)	79.6 (1.18; 0.68, 2.04)	
Hit/strike	24124 (77.5)	0.7 (0.08; 0.01, 0.73)	7.5 (1.10; 0.55, 2.21)	4.3 (0.35; 0.21, 1.43)	7.3 (1.12; 0.60, 2.08)	6.6 (0.90; 0.48, 1.67)	
Hit/struck by	2207 (7.1)	13.6 (2.88; 1.53, 5.43)	10.1 (2.28; 1.27, 4.10)	7.7 (1.27; 0.39, 4.18)	8.0 (4.24; 1.63, 11.05)	2.0 (0.24; 0.09, 0.61)	
Overexertion	1,981 (6.4)	1.4 (0.40; 0.10, 1.79)	3.9 (1.78; 0.63, 5.09)	5.5 (2.10; 0.80, 5.36)	2.4 (0.43; 0.16, 1.19)	5.3 (2.33; 0.84, 6.45)	
Other	978 (3.1)	2.8 (0.42; 0.10, 1.78)	6.1 (1.08; 0.51, 2.98)	6.1 (0.92; 0.52, 1.62)	5.6 (0.85; 0.30, 2.40)	6.6 (1.18; 0.42, 3.34)	

^aPercentages may not add up to 100 because of rounding.
^bLower extremities include upper leg, knee, lower leg, ankle, foot, and toe.
^cUpper extremities include shoulder, upper arm, elbow, lower arm, wrist, hand, and finger.
^dHead includes neck, face, eyes, ears, and mouth.
^eTrunk includes hip, groin, lower trunk, and upper trunk.
^fLaceration includes lacerations, punctures, and avulsions.
^gSoft tissue includes contusions, abrasions, hematomas, and crushing injuries.

were 8.19 times more likely to result in hospitalization (95% CI=5.17, 12.98) than were other types of injuries, accounting for 69.6% of all hospitalizations. Injuries to the trunk were 2.86 times (95% CI=1.51, 5.43) as likely to result in hospitalization as were injuries to other body parts.

Discussion

Rock climbing is a sport of growing popularity in the U.S. To our knowledge, this is the first study using nationally representative data to examine rock climbing-related injuries. Rock climbing-related injuries rose by two thirds during the 18-year study period. This rise is in concordance with the 67% rise in participation in the sport since 1998,¹ which indicates that the increase may be a result of increased participation rather than an increased risk of injury. The majority of rock climbing-related injuries occurred among those aged 20–39 years. Research indicates that those aged 16–24 years make up the majority of climbing participants (56%), with 20% aged >35 years.² The average age of patients in the current study (26 years) is consistent with the average age in previous reports.^{4,9,19} The proportion of male injuries is consistent with estimates of male participation (73% in 2005); women, however, sustained a larger proportion of rock climbing-related injuries than that found in previous studies.^{2–5,8} Women may have been under-represented in previous studies as a result of small sample sizes or limited inclusion criteria. Because this is a nationally representative sample, it may be a better representation of injury data among the general recreational climbing population.

The ankle was the most commonly injured body part, and the lower extremities were the most commonly injured body region. Fractures, sprains, and strains were the most common types of injuries. Previous studies, which analyzed data from medical centers, found similar patterns of injury.^{7,9,19} However, several studies utilizing convenience samples of climbers or Internet-based surveys that relied on self-reporting, found overuse injuries or those caused by excessive strain to the upper extremities to be the most common.^{3–5,8} The discrepancy may be partially explained by the minor nature of many rock climbing related injuries recalled by participants in these surveys. Although several studies reported that approximately one third of rock climbers sought medical treatment for their injuries,^{3,4} the current study focuses on rock climbing-related injuries that received medical treatment in emergency departments. It was found that injuries to the upper extremities were much more likely to be dislocations than other types of injury, which may reflect the stress regularly placed on upper limbs during climbing.

The foot was the most commonly fractured body part. This finding is consistent with previous reports and the mechanics of falling while using safety equip-

ment.⁴ Rock climbers typically wear a harness around their waist, attached to a rope, causing them to fall feet-first with the force of an impact absorbed by their lower extremities.^{9,22,23} This likely scenario may also explain the rarity of concussions and severe head injuries.⁹ Although there are helmets made for rock climbing, data on their use were not available. Injuries to the head were most often lacerations and resulted from being hit by an object. This type of injury is consistent with risks in outdoor settings and may be minimized in indoor climbing facilities.

Three quarters of rock climbing-related injuries were a result of falls. Falls were twice as likely to involve injury to the trunk. This finding may be due to the fact that many falls result in suspension of climbers on the end of a rope rather than impact with the ground or a rock ledge. During the fall and subsequent suspension, the climber's trunk may make contact with the rock face. Back strain may also occur from the force of the fall being stopped by the rope.²³ Falls of >20 ft. were ten times more likely to result in hospitalization than were falls of ≤20 ft. There have been no previous studies of rock climbing-related injuries that have found a correlation between height of fall and severity of injury.^{9,22,23}

Overall, 11.0% of all patients injured while rock climbing were hospitalized. The proportion of patients hospitalized due to rock climbing-related injuries is relatively high compared to hospitalizations for other sports and recreational injuries investigated using the NEISS database.²⁴ This high proportion of hospitalizations may reflect the inherent dangers of the sport and the risks climbers must take to participate. Men were more likely to sustain fractures and to be hospitalized for their injuries than women, who were more likely to receive sprains and/or strains while climbing. This difference in injury type and severity may be related to climbing style, risk-taking, and experience level, as well as the fact that more men than women climb at higher difficulty levels.¹⁸

Limitations

This study has several limitations. The total number of rock climbing-related injuries was underestimated, because the NEISS captures only those injuries treated in emergency departments. Many rock climbing-related injuries may be treated at home or by a community-based healthcare facility. The current study does not address rock climbing-related injury fatalities because NEISS is generally not regarded as useful for identifying fatal injuries. The NEISS database does not include unique identifiers and does not allow for estimation of numbers of patients with multiple encounters. Mechanism of injury, number of falls, and fall height were gleaned from case narratives and are thus subject to reporting or interpretation error. Information specific

to type of rock climbing, experience level, climbing surface, and level of route difficulty could not be determined from the data. Additionally, measures of participation and frequency of exposure to rock climbing were not available.

Conclusion

This report confirms much of the existing research on medically-attended rock climbing-related injuries, which indicates that lower-extremity injuries and fractures, sprains, and strains are most common. However, this is the first study to examine rock climbing-related injuries using a nationally representative sample. More research is needed on the role of personal safety equipment and environmental protection (e.g., padded floors in climbing gyms) and their impact on injury prevention among rock climbers. As the demographic characteristics of recreational climbers shift to include those who are younger and more inexperienced, with the increasing availability and popularity of climbing, the injury patterns of the sport may change as well. Given the disproportionate focus on elite climbers in the literature, the epidemiology of rock climbing-related injuries among recreational climbers should be studied specifically so that injury prevention strategies and awareness can be appropriately targeted.

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