Lower Extremity Surfing Injuries Seen at United States Emergency Departments From 2002 to 2022

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Background: Surfing is an increasingly popular sport with a high propensity for both traumatic and atraumatic injuries.

Purpose: To analyze the trends, etiologies, and diagnoses of lower extremity orthopaedic-related surfing injuries presenting to United States (US) emergency departments (EDs) within a 21-year study period.

Study Design: Descriptive epidemiology study.

Methods: The National Electronic Injury Surveillance System database was queried for data on lower extremity surfing injuries presenting to US EDs from January 1 to December 31, 2022. Data collected included year, injury mechanism, injury location, diagnosis, and disposition. The raw data were used to calculate national estimates (NEs) based on each hospital's assigned statistical sample weight. Linear regressions were performed to analyze annual trends.

Results: A total of 776 lower extremity surfing injuries were included (NE = 49,218 injuries). The mean age of the patients was 29.4 $\pm$ 13.6 years. The most common injured areas were the foot (NE = 17,411; 35.4%), lower leg (NE = 8673, 17.6%), and knee (NE = 8139; 16.5%). The most common mechanism of injury was impact with board (NE = 17,144; 34.8%), and the most common fracture locations were the lower leg (NE = 1195; 29.5%), ankle (NE = 1594; 24.5%), and foot (NE = 1495; 23.0%). There were statistically significant decreases in weighted estimates for lower extremity surfing injuries by 108 per year ($P < .001$), for lacerations by 76 per year ($P < .001$), and for sprains by 18 per year ($P = .01$). Impact-with-board injuries decreased by 59 injuries per year ($P < .001$) and constituted 63.5% of lacerations and 12.1% of fractures. Only 3.9% of patients were admitted for hospitalization.

Conclusion: There was a decreasing trend in lower extremity surfing injuries presenting to US EDs during the 21-year study period.

Keywords: fractures; lacerations; mechanism of action; NEISS; ocean; sport; surfing

Surfing is an increasingly popular professional and recreational sport originating within the native Hawaiian and Polynesian communities.[2] It attracts participants from various ages, regions, and skill levels due to the minimal equipment requirements and ease of accessibility. Recent reports estimate approximately that there are 30 million surfers worldwide as it is primarily a recreational sport.[8,23] Surveyed data suggest that the number of surfers has increased by more than 35% in the past decade, including in landlocked areas, which can be attributed to the increasing affordability of surfboards, implementation of surf parks throughout the world, and greater exposure through social media.[29,30] With the recent approval of surfing as an official sport in the 2020, 2024, and 2028 Summer Olympic games, the number of surfers can be only expected to grow.[14]

Unlike nonaquatic sports (eg, American football, hockey, soccer, lacrosse), surfing entails a larger proportion of uncontrollable environmental factors, including wave size and power, wave frequency, underlying reef and coral, and ocean floor depth.[2,23,31] In addition, the

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surfboard poses risk for injury due to the size (up to 10 feet [3.04 m] long), material (e.g., soft top, wood, polyurethane, epoxy), and presence of sharp fins.[5,8,17,23,33] Expectedly, surfers experience both traumatic (eg, impact with the sand, surfboard, or water) and atraumatic (eg, overuse injuries from paddling) orthopaedic-related injuries.[18,24] Studies report one-third of surfers sustain an acute surfing-related injury each year necessitating medical care, missed work, or missed time surfing, while almost all surfers have experienced at least 1 injury during their career.[8] Previous studies have reported the upper extremity and spine are particularly susceptible to atraumatic injury from paddling, whereas the lower extremity is primarily affected by trauma.[4,8,18,25,31]

The National Electronic Injury Surveillance System (NEISS) is a publicly accessible database from the United States (US) Consumer Product Safety Commission that has been used to analyze trends in sports-related orthopaedic injuries presenting to emergency departments (EDs) in the US.[16,20,21,26,27,32] NEISS data are gathered from a representative sample of 100 hospitals selected from the over 5000 US EDs with a minimum of 6 beds and 24-hour services. Currently, only 3 studies exist in the literature that analyze surfing-related injuries utilizing the NEISS.[9,15,25] Klick et al[15] analyzed NEISS data from 2002 to 2013 and found that the most common surfing injuries were lacerations, sprains/strains, contusions, and fractures. However, those authors did not identify the body area involved and did not calculate national estimates (NEs) to provide representative national data. Hager et al[9] recently published an epidemiological study on surfing injuries but did not include mechanism of injury and did not investigate body region in further detail. Obana et al[25] identified a decreasing trend in upper extremity surfing injuries from 2012 to 2021.

Given the propensity for both traumatic and atraumatic surfing injuries and paucity of epidemiologic studies on lower extremity surfing injuries, the purpose of this study was to analyze trends, mechanisms, and diagnoses of lower extremity orthopaedic surfing injuries presenting to EDs in the US. We hypothesized that the recent introduction of soft top boards in the early 2000s may have reduced the incidence of injuries, while the increase in the number of urgent care centers to manage lower severity injuries would reduce the number of ED visits/referrals. Subsequently, there would be an overall decreasing trend in lower extremity surfing injuries and injuries secondary to impact with the surfboard.

METHODS

Data Collection

Data were collected by querying the NEISS database for all surfing-related injuries (product code 1261: surfing [activity, apparel, or equipment]) involving the knee (product code 35), lower leg (product code 36), ankle (product code 37), upper leg (product code 81), foot (product code 83), and toe (product code 93). Treatment dates ranged from January 1 to December 31, 2022. All ages, diagnoses, and dispositions were included. The hospital for each datapoint was assigned a statistical sample weight that represented the corresponding volume for that hospital. The statistical sample weights were used to calculate NEs.

Variables collected included date of presentation, age, sex, race, injury location, injury diagnosis, disposition, and a narrative written by the healthcare provider. A single author (K.K.O.) individually reviewed each narrative to both confirm that the injury took place while surfing and identify the mechanism of injury. Included injury mechanisms were impact with board, impact with reef, impact with sand, impact with surfer, impact with water, overuse, twisting, other, or not specified. Twisting mechanisms were defined as injuries that mentioned twisting of the body or legs in the narrative, particularly when maneuvering or popping up onto the board. "Other" mechanisms were specified injuries within the narrative that were unable to be categorized into the aforementioned mechanisms, such as injury secondary to marine life (eg, sting, bite) or sunburn. The narrative was reviewed to differentiate between strain and sprain (product code 64). Narratives were also used to separate "lower leg" fractures into "fibula," "tibia," "tibia and fibula," or "unspecified lower leg." Overuse injuries were defined as nontraumatic lower extremity injuries associated with multiple instances of surfing.

Exclusion Criteria

The narratives were reviewed to identify injuries sustained during nonocean-related surfing activities, given

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Ethical approval was not sought for the present study.

TABLE 1
Distribution of Lower Extremity Injuries[a]

Injury Location	Raw Data (N = 776)	NE (N = 49,218)
Foot	263	17,411 (35.4)
Lower leg	143	8673 (17.6)
Knee	131	8139 (16.5)
Ankle	116	7109 (14.4)
Upper leg	76	5199 (10.6)
Toe	47	2687 (5.5)

[a]Data are reported as n or n (%). NE, National estimate.

these are incidentally coded as surfing-related by the NEISS. Examples included surfing injuries that did not take place in the ocean (eg, riding surfboard in the snow), surfboard-related injuries that did not occur while surfing (eg, tripped and fell while holding surfboard), non-surfing activities (eg, wake boarding, skim boarding, tubing, water skiing, etc), and injuries that did not specify activity.

Statistical Analysis

Statistical analyses were performed using STATA/MP Software Version 13.0 (StataCorp). Linear regression analyses were performed to analyze annual trends. Statistical significance was set at $P < .05$. NEs were calculated by multiplying each raw datapoint with the respective statistical weight of the corresponding hospital.

RESULTS

From January 1 to December 31, 2022, there were 1602 ED-diagnosed lower extremity surfing-related injuries (NE = 96,933). After reviewing the narratives and applying inclusion and exclusion criteria, 776 injuries were included for analysis (NE = 49,218). Of the included patients, 611 were male (NE = 39,539; 80.3%) and 165 were female (NE = 9679; 19.7%). The mean age at presentation was 29.4 ± 13.6 years (range, 3-84 years). The most common lower extremity areas affected included the foot with 263 injuries (NE = 17,411; 35.4%), lower legs with 143 injuries (NE = 8673; 17.6%), and knees with 131 injuries (NE = 8139; 16.5%) (Table 1).

The most common mechanisms of injury were impact with board in 263 cases (NE = 17,147; 34.8%), 247 unspecified mechanisms (NE = 15,820; 32.1%), 70 injuries with other mechanism (NE = 3945; 8.0%), and 53 cases of twisting (NE = 3698; 7.5%) (Table 2). The most common diagnoses were lacerations with 308 (NE = 20,879; 42.4%), fractures with 107 (NE = 6498; 13.2%), and sprains with 101 (NE = 6231; 12.7%) (Table 3).

Mechanisms resulting in lacerations included 193 impacts with the board (NE = 13,262; 63.5%), 79 instances not specified (NE = 5439; 26.1%), and 20 impacts with the reef (NE = 1236; 5.9%). Mechanisms resulting in fractures included 45 instances not specified (NE = 2935; 45.2%), 12 twisting (NE = 863; 13.3%), 18 impacts with the sand (NE = 844; 13.0%), and 14 impacts with the board (NE = 786; 12.1%).

TABLE 2
Distribution of Mechanisms of Injury[a]

Injury Mechanism	Raw Data (N = 776)	NE (N = 49,218)
Impact with board	263	17,147 (34.8)
Not specified	247	15,820 (32.1)
Other	70	3945 (8.0)
Twist	53	3698 (7.5)
Impact with reef	45	2805 (5.7)
Impact with water	39	2401 (4.9)
Impact with sand	38	1964 (4.0)
Overuse	15	978 (2.0)
Impact with surfer	6	460 (0.9)

[a]Data are reported as n or n (%). NE, National estimate.

TABLE 3
Distribution of Diagnoses[a]

Diagnosis	Raw Data (N = 776)	NE (N = 49,218)
Laceration	308	20,879 (42.4)
Fracture	107	6498 (13.2)
Sprain	101	6231 (12.7)
Contusion/abrasion	86	5119 (10.4)
Strain	53	3915 (8.0)
Other	66	3790 (7.7)
Dislocation	21	1173 (2.4)
Puncture	13	559 (1.1)
Hematoma	9	506 (1.0)
Foreign body	2	153 (0.3)
Burn	3	109 (0.2)
Allergic reaction	2	104 (0.2)
Crushing injury	1	79 (0.2)
Nerve damage	1	55 (0.1)
Avulsion	3	48 (0.1)

[a]Data are reported as n or n (%). NE, National estimate.

The most common locations of fractures were the lower legs in 34 injuries (NE = 1915; 29.5%), the ankles in 28 injuries (NE = 1594; 24.5%), and the feet in 23 injuries (NE = 1495; 23.0%) (Table 4).

Lower leg fractures were subdivided into 11 that affected the fibula only (NE = 590; 30.8%), 9 affecting the tibia only (NE = 523; 27.3%), 8 unspecified lower leg fractures (NE = 484; 25.3%), and 6 tibia and fibula fractures (NE = 318; 16.6%). Disposition consisted of 736 treated and released or examined and left without treatment (NE = 46,939; 95.4%), 32 treated and admitted for hospitalization (NE = 1720; 3.5%), 5 left without being seen (NE = 342; 0.7%), and 3 treated and transferred (NE = 217; 0.4%).

Linear regression demonstrated a statistically significant decrease in weighted estimate lower extremity surfing injuries by 108 per year (95% CI, −150.8 to −64.7; $P < .001$; coefficient = −107.8) from 2002 to 2022. There were also statistically significant decreases in weighted

TABLE 4
Distribution of Fractures[a]

Fracture Location	Raw Data (n = 107)	NE (n = 6498)
Ankle	28	1594 (24.5)
Foot	23	1495 (23.0)
Toe	19	1244 (19.1)
Lower leg	34	1915 (29.5)
Fibula only	11	590 (30.8)
Tibia only	9	523 (27.3)
Unspecified lower leg	8	484 (25.3)
Tibia and fibula	6	318 (16.6)
Knee	2	175 (2.7)
Femur	1	75 (1.2)

[a]Data are reported as n or n (%). NE, National estimate.

estimate lacerations by 76 per year (95% CI, –98.3 to −54.3; $P < .001$; coefficient = −76.3), and weighted estimate sprains by 18 per year (95% CI, –30.8 to −4.7; $P = .01$; coefficient = –17.8), but not contusions/abrasions ($P = .44$) or fractures ($P = .10$) (Figure 1). There was a statistically significant decrease in weighted estimate impact-with-board injuries by 59 injuries per year (95% CI, –81.7 to −35.4; $P < .001$; coefficient = −58.6) (Figure 2).

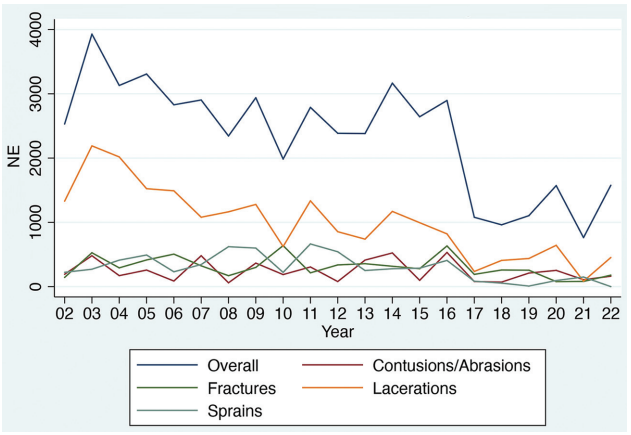

Figure 1. NEs of annual overall injuries and most common diagnoses, 2002-2022. NE, National estimate.

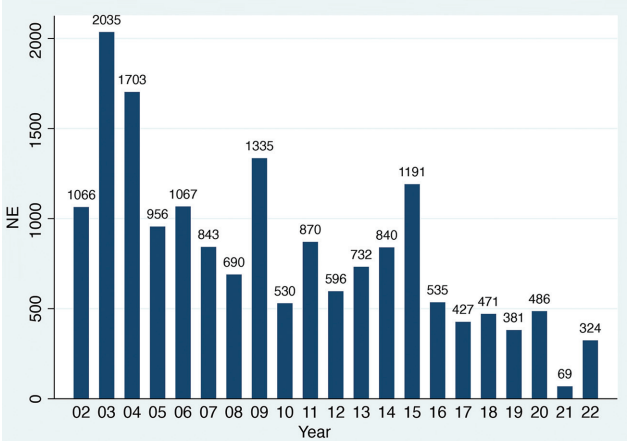

Figure 2. NEs of annual incidence of surfing injury due to impact with the board, 2002-2022. NE, National estimate.

DISCUSSION

In the current study, we identified a statistically significant decline by 108 injuries per year in lower extremity orthopaedic-related surfing injuries presenting to US EDs per year from 2002 to 2022 (95% CI, –150.8 to −64.7; $P < .001$). This finding was unexpected, as estimated national and international surfing participation has grown with the increasing publicity. Although previous studies have highlighted the risk of injury associated with large wave breaks, sharp reefs, and impacts with the sand, the greatest risk factor has remained the surfboard itself.[6,8,28,33] Thus, the decreasing trend in overall lower extremity injuries in the current study may be attributed to the concomitant decreases in lacerations (76 lacerations per year; 95% CI, –98.3 to −54.3; $P < .001$) and impact-with-board injuries (59 injuries per year; 95% CI, –81.7 to −35.4; $P < .001$). These findings are supported by the large proportion of lacerations in this study (42%) and the proportion of lacerations secondary to impact with the surfboard (63.5%), which are similar to the results from previous studies.[11,13,15,18,22,31]

An underlying contributor to the decreasing trend in lower extremity injuries may be the introduction of soft-top surfboards in the early 2000s. Soft-top surfboards are approximately one-third the cost of boards made from other materials, allowing a broader demographic to access surfing.[29] The composition consists of an expanded polystyrene foam core wrapped with a soft ethylene-vinyl acetate sheet that reduces the force of impact and makes them more buoyant, lightweight, and stable than fiberglass or epoxy boards of equivalent sizes.[29] Likewise, they are most commonly sold as long boards, with wide dimensions increasing the volume of the board and ease of rideability. The greater stability may also be reducing the incidence of "wipeouts" in novice surfers and, thus, injuries to themselves and other surfers, resulting in fewer lacerations from the fins.[19] In addition, use of wetsuits, which are more prevalent in colder climates, may also guard against laceration and surfing impact.[18] Interestingly, the reef, which can be an environmental concern for surfers, was responsible for only 5.9% of lacerations in this study, highlighting what we feel is the larger risk associated with surfboards. A proposed technique to reduce the risk of surfboard fin-associated laceration is by dulling the fin using sandpaper.[7,12] In addition, the improved maneuverability of soft-top boards may have resulted in the small but statistically significant decline in sprains ($P = .01$).

Greater on-site management and access to urgent care clinics may also be contributing factors to the decreasing trend in lower extremity injuries. In general, by far the

majority of surfing injuries are of low severity, reflected by only 3.9% of injuries in this study requiring hospitalization.[11,25] Urgent care centers and on-site bystander and lifeguard intervention can manage these lower acuity injuries without necessitating an ED visit. Importantly, surfers who have completed surf rescue training and education programs have performed a greater number of water rescues.[1,33] More than 20% of surfers have assisted with more than 5 surf rescues, and more than 80% have assisted with at least 1.[1] Recently, media highlighted how bystander surfers fashioned a tourniquet using surfboard leashes around a surfer's leg and used a longboard to carry him to shore after a shark bite.[3] As surfing continues to grow in popularity, so will the number of bystanders available to provide intervention.

Although the lower leg accounted for 17.6% and ankle for 14.4% of overall injuries in the current study, they constituted the largest proportion of fractures (29.5% and 24.5% of overall fractures, respectively). Fractures were attributed to both the atraumatic and traumatic mechanisms including twisting during maneuvering or a fall, impact with the reef, sand, or surfboard. Previous literature has highlighted the prevalence of traumatic surfing-related fractures.[18,25] However, this is the first study to identify atraumatic twisting of the lower extremity as the most common identifiable mechanism of fracture. This can be secondary to aggressive turning, aerial maneuvers, or loss of balance on the surfboard.[13] In addition, surfing introduces unique strain on the lower extremities, as they are planted on the board but are subjected to immense torsional and rotational forces as the board moves on top of the water. The rider can control board acceleration and maneuvering but may be subjected to environmental factors such as wind and wave dynamics and morphology, which can be unanticipated, leading to an unsuccessful ride.

This study is also the first to subcategorize lower leg surfing fractures into fibula only, tibia only, tibia and fibula, and unspecified lower leg. Isolated fibula and tibia fractures comprise similar proportions of lower leg fractures (30.8% and 27.3%, respectively), while fractures consisting of both the tibia and fibula are of a smaller proportion (16.6%).

Impact with the surfboard was the most common mechanism of injury in the current study, constituting over one-third of overall injuries. This occurs when the surfer falls on his or her surfboard or a surfboard (either the surfer's own or another's surfboard) becomes a projectile during a wipeout.[18] This result is similar to previous reports of surfboard impact constituting 24.7% to 35.8% of all mechanisms of injury.[17,19,33] The proportion in the current study was larger than that in a recent study on upper extremity surfing injuries presenting to US EDs (34.8% vs 22.4%), highlighting the greater risk of injury to the lower extremity secondary to impact with the surfboard.[25] While the popularity and number of surfers in each location continue to rise, so will the likelihood of injury from surfboards of adjacent surfers during wipeouts. Despite this increased risk, we found a decreasing annual incidence of impact-with-board injuries, which we feel likely corresponds to the introduction of soft-top surfboards in the early 2000s.

Limitations

This study has multiple limitations, largely attributed to the limited detail provided in the narratives. First, the ability to discern the mechanism of injury from the narratives is predicated on the information inputted by the trained coder, which is a limitation of any database relying on the accuracy of input. Almost one-third of mechanisms in this study were not specified in the narratives. Adding further detail may have influenced the overall findings, particularly for mechanism of fractures in which 45.2% were not specified. However, the outcomes are similar to previous surfing studies, and the proportion of mechanisms not specified are similar to that of NEISS studies across various sports.[10,11,15,19,22,26,27,31] Thus, further detail in the narratives may result in a proportional distribution to the mechanisms and not influence the overall findings. Second, we were unable to delineate the type of surfboard used and the true impact of soft-top surfboards contributing to the decreasing trends. This may provide greater insight into the injury profiles associated with varying mechanical and physical properties of surfboards such as board type (eg, shortboard, longboard) and board material (eg, wood, polyurethane, epoxy, carbon, soft top).

A third limitation was that we could not determine whether there was a corresponding increase in lower extremity surfing injuries at urgent care centers or on-site intervention during the study period by utilizing the NEISS database. Future studies analyzing annual trends in surfing injuries presenting to urgent care centers are warranted. Fourth, the narratives did not provide information on fracture characteristics warranting surgical intervention (eg, proximal location, oblique pattern, shortening, angulation, rotational malalignment, cortical apposition). Thus, we were unable to determine the true severity of lower leg fractures in the study. Fifth, the NEISS does not provide geographic information, so we were unable to assess the distribution of injuries across different regions of the US. Sixth, it is possible that the COVID-19 pandemic played a role in decreasing injuries during the study period due to stay-at-home mandates. However, the decline persisted in this study through 2022, after stay-at-home orders were lifted, which suggests that the COVID-19 pandemic had less of an impact on surfing, as it is a recreational sport that facilitates social distancing. Subsequently, other factors may be larger contributors to the decline in surfing injuries presenting to US EDs. Lastly, NEs are representative data based on information stratified across 100 US hospitals and may not reflect the true incidence of lower extremity surfing injuries. However, they are a reliable sample as surfing is predominantly a recreational sport and participant data are limited.

CONCLUSION

In this study, we found a statistically significant decreasing trend in lower extremity surfing injuries presenting

to US EDs from 2002 to 2022. This trend may be due to advancements in surfboard technology and material, contributing to the decline in impact with board injuries, lacerations, and sprains. Urgent care centers and on-site intervention may be playing larger roles in managing these less severe injuries, obviating subsequent ED visits.

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