



Contents lists available at ScienceDirect

Journal of Hand Surgery Global Online

journal homepage: www.JHSGO.org

Original Research

Epidemiology of Fireworks-Related Injuries to the Upper Extremity in the United States From 2011 to 2017



Viviana M. Serra López, MD, MS,^{*} Adnan N. Cheema, MD,^{*} Benjamin L. Gray, MD, MSCE,^{*} Kevin Pirruccio, BA,[†] Nikolas H. Kazmers, MD, MSE[‡]

^{*} Department of Orthopaedic Surgery, University of Pennsylvania, Philadelphia, PA

[†] Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA

[‡] Department of Orthopaedic Surgery, University of Utah, Salt Lake City, UT

ARTICLE INFO

Article history:

Received for publication February 9, 2020

Accepted in revised form March 10, 2020

Available online April 18, 2020

Key words:

Epidemiology

Fireworks

Hand

Upper Extremity

Purpose: Fireworks may result in a wide spectrum of injury to the upper extremity ranging from mild burns to amputation. In this cross-sectional study, we describe the epidemiology of upper-extremity injuries in the United States associated with fireworks using the Consumer Product Safety Commission's National Electronic Injury Surveillance System (NEISS).

Methods: The NEISS database was queried between 2011 and 2017 for all injuries of the upper extremity (from shoulder to fingertip) associated with fireworks. There were 806 unique cases, yielding a total weighted estimate of 31,430 national cases presenting to emergency departments in the United States during this time frame. National estimates, standard errors, and 95% confidence intervals were calculated using parameters provided by the NEISS database. Significance of trends was determined using adjusted Wald tests, for which *P* values less than .05 were considered significant.

Results: The weighted estimate was 4,490 yearly cases from 2011 until 2017. Trend analysis did not show a significant change in the number of yearly cases during that time frame. Most injuries (62%) occurred around June 27 until July 11. Nearly 50% of those injured were aged 10 to 29 years and were male. Fireworks with low pyrotechnic content such as sparklers, snakes, and poppers resulted in 26% of injuries. Although 83% of patients were treated and released from the emergency department, other injuries were more severe, with a 4.5% rate of amputation, 7% rate of hospital admission, and 8% rate of transfer to another hospital.

Conclusions: Fireworks injuries to the hand and upper extremity continue to represent a serious burden of disease to the United States population and the health care system. Increased awareness, legislation, and targeted public education about the dangers of fireworks should be considered ways to reduce the incidence of these injuries.

Type of study/level of evidence: Prognostic III.

Copyright © 2020, THE AUTHORS. Published by Elsevier Inc. on behalf of The American Society for Surgery of the Hand. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Fireworks are commonly used for recreational purposes and in holiday celebrations around the world. They typically consist of a casing filled with combustible material and include devices that

can be handheld, such as sparklers, or those that can be detonated from a distance. They have the potential to result in serious injuries and can pose a substantial threat to the population. In some cases, these injuries may require extensive reconstructive or salvage procedures.^{1,2}

Epidemiologic studies of the US population documented injuries related to fireworks before 2011,³ with some focusing on pediatric injuries before 2015.⁴ Other studies described treatment for upper-extremity firework injuries to a subset of patients with severe injuries.^{1,2} However, studies focusing on the epidemiology of upper-extremity injuries for all age groups are lacking.

Declaration of interests: No benefits in any form have been received or will be received by the authors related directly or indirectly to the subject of this article.

Corresponding author: Viviana M. Serra López, MD, MS, Department of Orthopaedic Surgery, University of Pennsylvania, 3737 Market Street, 6th Floor, Philadelphia, PA 19104.

E-mail address: viviana.serralopez@pennmedicine.upenn.edu (V.M. Serra López).

<https://doi.org/10.1016/j.jhsg.2020.03.003>

2589-5141/Copyright © 2020, THE AUTHORS. Published by Elsevier Inc. on behalf of The American Society for Surgery of the Hand. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Table 1
Weighted National Estimates of Patients With Fireworks-Associated Upper-Extremity Injuries Presenting to US EDs, 2011 to 2017

Year	National Cases	Standard Error	95% Confidence Interval	Trend Test (P Value)*
2017	5,085	580	3,930–6,240	.25
2016	4,592	685	3,229–5,955	.70
2015	4,984	516	3,958–6,010	.34
2014	4,385	553	3,284–5,487	.86
2013	4,554	681	3,199–5,910	.71
2012	3,603	479	2,651–4,556	.39
2011	4,226	519	3,193–5,260	
Annual average (2011–2017)	4,490	573	3,349–5,631	

* All tests for significance of trends and hypothesis testing were determined using adjusted Wald tests, for which *P* values less than .05 (2-sided) were considered significant. The comparison value for these analyses was the 2011 national estimates shown above; for this reason, a *P* value is not reported in this row.

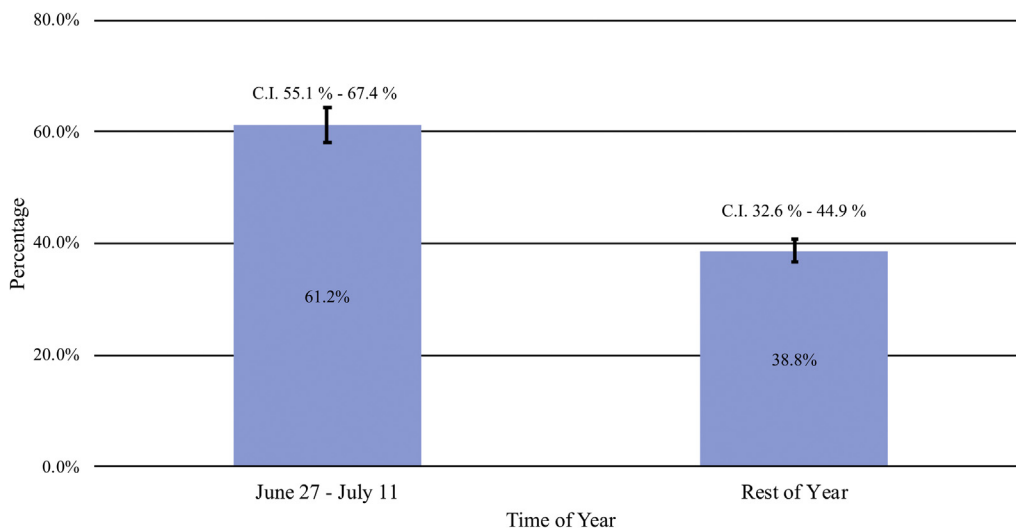


Figure 1. Percentage of injuries treated in US EDs from June 27 until July 11 in the study period compared with those seen during the rest of the year. CI, confidence interval.

The purpose of this study was to describe the epidemiology of upper-extremity injuries associated with fireworks using the US Consumer Product Safety Commission's (CPSC's) National Electronic Injury Surveillance System (NEISS). Furthermore, we aimed to characterize anatomic injury patterns in the upper extremity related to these injuries and detail the most commonly associated mechanisms and associated rates of hospital admission. We further delineated these injuries based on demographic data, including age, sex, and race. We hypothesized that the incidence of firework-related injuries has not changed significantly and continues to represent a serious burden of disease.

Materials and Methods

This cross-sectional descriptive epidemiological study identified cases of upper-extremity injuries associated with fireworks in the CPSC NEISS. The NEISS database is a nationally representative, statistically validated probability sample of hospital emergency departments (EDs) in the United States, stratified by both hospital size and geographic location.^{5,6} The data are publicly available, and the collection methodologies have been previously reported.^{6,7} Based on hospital size and location, weighted estimates are assigned to presenting cases such that national estimates and sampling errors for queried injuries may be derived. Although there are several databases that could be used to monitor injury data, such as MarketScan or the Center for Disease Control and Prevention's National Hospital Ambulatory Care Survey, their primary purpose is not to monitor injuries.^{8,9} Identification of cases using

these alternate systems would depend on use of the International Classification of Diseases diagnostic codes as opposed to a specific product code.^{9,10} In addition, these databases are not designed to estimate the overall incidence of certain injuries. For these reasons, the NEISS was best suited for our analysis.

In this study, each yearly sample in the NEISS database was queried between 2011 and 2017 for all injuries classified as upper-extremity injuries and associated with fireworks. The NEISS coding manual assigns a 2-digit code to the affected body part and a 4-digit product code to the consumer product involved, which were used to build the query.⁷ In this study, the codes for affected body part used were those for "shoulder" (30), "elbow" (32), "arm, lower (not including elbow or wrist)" (33), "wrist" (34), "arm, upper" (80), "hand" (82), and "finger" (92). Fireworks are assigned a product code of "1313." This product code also applies to the following items, which are listed individually: cherry bombs, gopher bombs, firecrackers, rockets, bottle rockets, and smoke bombs. In addition, a narrative regarding the injury is provided, which was used to verify the body part and firework type involved. Each case in the queried data is assigned a unique identifier, thus preventing cases from being counted more than once.

A total of 806 unique cases of upper-extremity injuries associated with fireworks were observed in the NEISS database from 2011 to 2017, yielding a total weighted estimate of 31,430 national cases presenting to US EDs during the study period.

National estimates, standard errors, and 95% confidence intervals were derived using the provided survey parameters (strata, weights, and primary sampling units) in the NEISS database.

Table 2
Overall Demographics of Patients Presenting to US EDs With Fireworks-Associated Upper-Extremity Injuries, 2011 to 2017

Demographic Variable	%	% Standard Error	95% Confidence Interval (%)
Age, y			
0–9	16.8	2.0	12.9–20.7
10–19	25.0	1.6	21.9–28.2
20–29	25.8	2.1	21.7–30.3
30–39	17.3	1.7	13.9–20.7
40–49	9.0	1.4	6.3–11.8
50–59	5.0	1.0	2.9–7.0
≥ 60 [†]	1.1		
Sex			
Male	75.7	2.4	70.9–80.6
Female	24.3	2.4	19.4–29.1
Race			
White	56.8	4.2	48.5–65.1
Black	8.8	2.0	4.9–12.8
Hispanic [*]	6.1		
Not specified	25.9	4.9	16.1–35.6
Disposition			
Treated and released	83.9	3.0	78.0–89.9
Treated and transferred	7.8	2.0	3.9–11.8
Treated and admitted	6.8	2.2	2.4–11.2
Location			
Unknown	51.3	4.4	42.5–60.1
Home	41.6	4.4	32.8–50.4

^{*} The estimate is considered to be potentially unstable owing to the number of unweighted cases from the sample frame totaling less than 20, the weighted national estimate totaling less than 1,200, or coefficient of variation greater than 33%. Therefore, no standard errors or confidence intervals are provided; the unstable percentage estimate is provided for reference purposes only. Variable results with sample frame totals less than 20 cases or percentages less than 0.1% were omitted from this table, resulting in percentage totals not necessarily summing to 100%.

Significance of trends and hypothesis testing were determined using adjusted Wald tests, for which $P < .05$ (2-sided) was considered significant.

Results

From 2011 to 2017, there was an estimated average of 4,490 annual cases of patients who presented to US EDs with upper-extremity injuries associated with fireworks. No significant trend was observed when comparing number of injuries throughout the study period, with no difference seen in the number of cases per year. These data are further stratified by year in Table 1. Most of these cases (61%) presented from June 27 through July 11 each year, as noted in Figure 1.

Table 2 lists demographic data. Notably, most injuries involved males and patients aged 10 to 29 years. After initial ED evaluation, 8% of patients required transfer to another hospital, and 7% required admission.

Many of the cases reviewed (41%) did not specify the type of firework involved in the injury. Of those that were reported, approximately 27% involved firecrackers or aerial devices. The hand and fingers constituted 87% of all injuries to the upper extremity. Amputations or fractures were diagnosed in 11% of cases. Table 3 provides further details.

Discussion

The main study findings pertain to identifying cohorts most commonly affected by upper-extremity injuries caused by fireworks. Specifically, we observed that males aged 10 to 29 years were most commonly affected. Burns were the most common injury type, and the hand was the most often affected

Table 3
Overall Diagnostic Characteristics of Patients Presenting to US EDs With Fireworks-Associated Upper-Extremity Injuries, 2011 to 2017

Variable	%	Standard Error (%)	95% Confidence Interval (%)
Type of firework			
Firecrackers	17.3	2.0	13.4–21.3
Aerial devices	10.0	1.9	6.2–13.7
Roman candles/fountains	4.0	1.0	2.1–5.9
Sparklers and novelty devices	26.4	2.4	21.6–31.3
Illegal	2.7	0.7	1.3–4.0
Unspecified	40.7	2.4	36.0–45.4
Part of body injured			
Finger	34.5	1.7	31.0–37.9
Hand	51.8	2.0	47.8–55.8
Wrist [*]	1.7		
Lower arm	6.4	1.0	4.4–8.4
Upper arm	3.0	0.7	1.5–4.4
Elbow [*]	0.6		
Shoulder [*]	2.0		
Diagnosis			
Burn (thermal)	70.2	2.7	64.8–75.7
Laceration	8.7	1.2	6.3–11.1
Amputation	4.5	1.3	1.9–7.1
Fracture	6.4	1.2	4.1–8.7
Other [†]	10.2	1.2	7.7–12.6

^{*} The estimate is considered to be potentially unstable owing to the number of unweighted cases from the sample frame totaling less than 20, the weighted national estimate totaling less than 1,200, or coefficient of variation greater than 33%. Therefore, no standard errors or confidence intervals are provided; the unstable percentage estimate is provided for reference purposes only. Variable results with sample frame totals less than 20 cases or percentages less than 0.1% were omitted from this table, resulting in percentage totals not necessarily summing to 100%.

[†] Includes both of the other type of injuries and those with unspecified injuries.

part of the upper extremity. These findings are similar to those based on data from over a decade ago.^{3,11} Furthermore, the data did not show a significant change in the number of yearly national cases from 2011 to 2017. We observed that most injuries occurred within the 4-week period surrounding Independence Day, similar to recent trends reported by the CPSC.¹² In other countries, fireworks-related injuries are also more common around the dates of national celebrations.^{13–17} In addition, implementation of public education programs in other countries has been correlated with a decrease in injuries related to fireworks.^{13,18} This supports the idea that a focus on education and prevention for the general public should be increased around certain holidays and might target young males, to help increase awareness about injuries.

Throughout the United States, state laws vary regarding the regulation of fireworks, and limited data are available about the effects of legislation across the country. Grant et al¹⁹ evaluated survey data collected after legalization of certain fireworks in North Carolina, and suggested stronger legislation was needed to restrict the access to pyrotechnics based on the costs involved in property losses, injury, and fire suppression. In 2002, the state of Minnesota changed its legislation to allow for use of nonaerial and nonexplosive fireworks and noted that firework-related injuries had doubled from that time until 2005.²⁰ In West Virginia, there was an increase in fireworks-related injuries after the passage of a law in 2016 that allowed the sale of consumer fireworks.²¹ Data from fireworks-related injuries in pediatric patients from 2006 until 2012 noted an increase in the number of patients requiring admission and longer length of stays, which suggests that as state laws have allowed for access to fireworks, the severity of injuries has increased.²² In addition, the American Academy of Pediatrics²³ recommends prohibiting the private use of fireworks. Given these findings, consistent legislation across states that further limits

access to fireworks may help decrease the frequency and severity of fireworks-related injuries.

Secondary study findings suggest that firework injuries to the upper extremity burden the ED, given the large percentage of patients who are treated and discharged in that setting. In addition, some of these patients likely require the evaluation of hand surgery consultants, which increases the burden to specialists as well. In 8% of cases, patients required transfer to another hospital for treatment. This affects 2 health care systems and the respective teams involved in the patient's care. Furthermore, injuries that involve amputations or fractures can lead to morbidity and disability in these patients, increasing costs to the health care system and affecting the patient's quality of life.

Strengths of this study are that data were collected over 7 years from a large nationwide database. Limitations include that the data include only patients who presented to EDs for treatment, which may have led to an underestimation of the actual number of cases. Another limitation is that 41% of fireworks associated with injuries were classified as unspecified in the data set, which limited our ability to understand how different classes of fireworks may have affected patients. In addition, this study does not describe the extent of the injuries sustained; instead we noted that 84% of patients were treated and released from an ED, which led to the assumption that most of these injuries were not severe. For those who required transfer or admission, no data were available regarding those who required evaluation by a hand specialist or surgical management, including multistage reconstructive surgery. These data could give further insight into both the direct and indirect costs associated with severe injuries. Furthermore, the NEISS presents data as a weighted average; therefore, it has some inherent limitations because the data are an estimate. Moreover, the NEISS database does not include state-level data. This limited our ability to look at data at the level of the different US states and examine whether interventions in specific states were correlated with trends observed.

This epidemiologic study suggests that young males are most commonly affected by firework injuries to the upper extremity, and that most injuries occur in the 1-month period surrounding Independence Day. This information may be pertinent to primary prevention strategies, which will be important because some of the observed injuries were severe (including amputations, fractures, and burns) and some required hospital admission or transfer to a higher level of care. Similar preventative efforts were successful in the past, whereas liberalization of fireworks legislation has been associated with an increase in injuries.^{13,18,21} In addition, the overall rate of injuries did not decrease over the years in the period studied, which may suggest that increased prevention measures would be beneficial. Overall, increased public awareness and education are needed regarding the dangers of fireworks, as well as further legislation to protect the population.

References

- Sandvall BK, Keys KA, Friedrich JB. Severe hand injuries from fireworks: injury patterns, outcomes, and fireworks types. *J Hand Surg Am.* 2017;42(5):385.e1–385.e8.
- Ortiz R, Ozkan S, Chen NC, Eberlin KR. Firework injuries of the hand: an analysis of treatment and health care utilization [published online ahead of print March 17, 2019]. *Hand (N Y).* <https://doi.org/10.1177/1558944719829905>.
- Moore JX, McGwin G, Griffin RL. The epidemiology of firework-related injuries in the United States: 2000–2010. *Injury.* 2014;45(11):1704–1709.
- Billock RM, Chounthirath T, Smith GA. Pediatric firework-related injuries presenting to United States emergency departments, 1990–2014. *Clin Pediatr (Phila).* 2017;56(6):535–544.
- NEISS Highlights, Data and Query Builder. Available at: <https://www.cpsc.gov/cgibin/NEISSQuery/home.aspx>. Accessed February 2, 2020.
- Schroeder T, A K. The NEISS Sample (Design and Implementation) from 1979 to 1996. Available at: <https://www.cpsc.gov/s3fs-public/2001d010-6b6.pdf>. Accessed February 2, 2020.
- US Consumer Products Safety Commission. National Electronic Injury Surveillance System Coding Manual. Available at: https://www.cpsc.gov/s3fs-public/2018-NEISS-CPSC-only-CodingManual.pdf?FYUWXTUPXns1FCZe6d3.1x.d1RHLeP_. Accessed February 2, 2020.
- Horan JM, Mallonee S. Injury surveillance. *Epidemiol Rev.* 2003;25:24–42.
- Alluri RK, Leland H, Heckmann N. Surgical research using national databases. *Ann Transl Med.* 2016;4(20).
- International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). Available at: <https://www.cdc.gov/nchs/icd/icd9cm.htm>. Accessed February 16, 2020.
- Canner JK, Haider AH, Selvarajah S, et al. US emergency department visits for fireworks injuries, 2006–2010. *J Surg Res.* 2014;190(1):305–311.
- Tu Y, Ng J. 2018 Fireworks annual report: fireworks-related deaths, emergency department-treated injuries, and enforcement activities during 2018. Available at: https://www.cpsc.gov/s3fs-public/Fireworks_Report_2018.pdf. Accessed February 2, 2020.
- Puri V, Mahendru S, Rana R, Deshpande M. Firework injuries: a ten-year study. *J Plast Reconstr Aesthetic Surg.* 2009;62(9):1103–1111.
- Saadat S, Mafi M, Smith GA. Higher education does not protect against firework-related injuries: a review of the economic burden and the risk factors of firework-related injuries in the capital of Iran. *Public Health.* 2012;126(1):40–46.
- Vaghardoost R, Ghavami Y, Sobouti B, Mobayen MR. Mortality and morbidity of fireworks-related burns on the annual last Wednesday of the year festival (Charshanbeh Soori) in Iran: an 11-year study. *Trauma Mon.* 2013;18(2):81–85.
- Read DJ, Bradbury R, Yeboah E. Firework-related injury in the Top End: a 16-year review. *ANZ J Surg.* 2017;87(12):1030–1034.
- Nizamoglu M, Frew Q, Tan A, et al. The ten-year experience of firework injuries treated at a UK regional burns and plastic surgery unit. *Ann Burn Fire Disasters.* 2018;31(1):13–16.
- D'Argenio P, Cafaro L, Santonastasi F, Taggi F, Binkin N. Capodanno Senza Danno: The effects of an intervention program on fireworks injuries in Naples. *Am J Public Health.* 1996;86(1):84–86.
- Grant E, Fuller C, Birckmayer J, Marshall S, Peterson H. State study of pyrotechnics-related injuries and property damage. *J Burn Care Rehabil.* 1998;19(3):265–267.
- Roesler J, Day H. Sparklers, smoke bombs, and snakes, oh my! Effect of legislation on fireworks-related injuries in Minnesota. *Minn Med.* 2007;90(7):46–47.
- Rudisill TM, Preamble K, Pilkerton C. The liberalization of fireworks legislation and its effects on firework-related injuries in West Virginia. *BMC Public Health.* 2020;20(1):137.
- Myers J, Lehna C. Effect of fireworks laws on pediatric fireworks-related burn injuries. *J Burn Care Res.* 2017;38(1):e79–e82.
- American Academy of Pediatrics: Committee on Injury and Poison Prevention. Fireworks-related injuries to children. *Pediatrics.* 2001;108(1):190–191.