



Original Contribution

## Children treated for lawn mower-related injuries in US emergency departments, 1990–2014<sup>☆</sup>



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### ABSTRACT

**Objective:** Investigate the epidemiology of lawn mower-related injuries to children in the US.

**Methods:** A retrospective analysis was conducted of children younger than 18 years of age treated in US emergency departments for a lawn mower-related injury from 1990 through 2014 using data from the National Electronic Injury Surveillance System.

**Results:** An estimated 212,258 children <18 years of age received emergency treatment for lawn mower-related injuries from 1990 through 2014, equaling an average annual rate of 11.9 injuries per 100,000 US children. The annual injury rate decreased by 59.9% during the 25-year study period. The leading diagnosis was a laceration (38.5%) and the most common body region injured was the hand/finger (30.7%). Struck by (21.2%), cut by (19.9%), and contact with a hot surface (14.1%) were the leading mechanisms of injury. Patients <5 years old were more likely (RR 7.01; 95% CI: 5.69–8.64) to be injured from contact with a hot surface than older patients. A projectile was associated with 49.8% of all injuries among patients injured as bystanders. Patients injured as passengers or bystanders were more likely (RR 3.77; 95% CI: 2.74–5.19) to be admitted to the hospital than lawnmower operators.

**Conclusions:** Lawn mower-related injuries continue to be a cause of serious morbidity among children. Although the annual injury rate decreased significantly over the study period, the number of injuries is still substantial, indicating the need for additional prevention efforts. In addition to educational approaches, opportunities exist for improvements in mower design and lawn mower safety standards.

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## 1. Introduction

Despite stricter safety specifications and product design changes, lawn mowers continue to be an important source of serious pediatric morbidity in the United States (US) [1–18]. Between 1990 and 2004, an estimated 140,700 children under 20 years of age were treated in

US emergency departments (EDs) for lawn mower-related injuries [12]. Initial treatment of pediatric lawn mower-related injuries costs about \$90 million annually [19]. The long-term physical, psychological, and financial effects of these traumatic injuries can be devastating for those injured and for their families [8,17,19–22].

Lawn mower-related injuries have previously been described, but many studies were published years ago [1–3,6,9,19,23,24]. Previous studies using data from the National Electronic Injury Surveillance System (NEISS) examined fewer years and conducted less comprehensive analyses than the current study [8,10,13,14,17]. Most did not evaluate the case narratives included in the NEISS database to investigate mechanism of injury and other variables regarding the circumstances of the injury. Other studies were limited in focus, analyzing data from a single hospital system [3,4,9,11] or about a type of mower [14].

This study comprehensively analyzes data over a 25-year period using a nationally representative database to evaluate the

**Abbreviations:** ANSI, American National Standards Institute; CI, Confidence Interval; CPSC, United States Consumer Product Safety Commission; ED, Emergency Department; NEISS, National Electronic Injury Surveillance System; NMIR, No-mow-in-reverse; OPEI, Outdoor Power Equipment Institute; RR, Relative risk; US, United States.

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epidemiologic characteristics, including mechanism of injury, of lawn mower-related injuries to children in the US. It also provides a discussion of relevant injury prevention strategies.

## 2. Methods

### 2.1. Data sources and case selection criteria

This study analyzed data for lawn mower-related injuries among children younger than 18 years old treated in EDs from January 1, 1990 through December 31, 2014. Data were obtained from the National Electronic Injury Surveillance System (NEISS), which is operated by the US Consumer Product Safety Commission (CPSC) to monitor consumer product-related and sports and recreation-related injuries treated in US EDs. NEISS collects data daily from a sample of approximately 100 EDs, which represent a stratified probability sample of the >5300 hospitals with a 24-hour ED with 6 or more beds in the US and its territories [25]. The NEISS database contains information on patient age, gender, locale of injury, injury diagnosis, injured body region, disposition from the ED, product(s) involved, and a brief narrative of the circumstances of the injury incident.

Data regarding lawn mower-related injuries (product codes 1401, 1402, 1422, 1439, and 1448) reported to the NEISS were obtained for the 25-year study period. The narrative for each case was reviewed to identify miscoding and to create new variables describing injury circumstances. Cases were excluded from analysis if the outcome was fatal (2 cases) or if the injury was unrelated to a lawn mower. The US Census Bureau's July 1 intercensal and postcensal residential population estimates were used to calculate injury rates in this study [26].

### 2.2. Study variables

NEISS case narratives were used to code for mechanism of injury, user type (operator, passenger, bystander, other), and mower part or object associated with the injury (projectile, mower blade, or other). Case coding definitions were refined through an iterative process comparing coding agreement among authors to achieve consistent assignment of categories.

The NEISS codes for locale of incident were regrouped into: home (included the NEISS categories of home, farm, and manufactured/mobile home), and non-home (included school, sports/recreation place, street/highway, industrial place, and other public place).

Mechanism of injury categories consisted of: 1) fell and struck/struck on (included tripped and fell), 2) struck by, 3) fell off, 4) run over, 5) backed over, 6) cut by, 7) caught/entrapped, 8) contacted a hot surface, 9) tip-over/roll-over, and 10) other (included mower malfunction, overextension, and other specified mechanisms). The “backed over” category included cases in which the patient was backed over by a ride-on mower. A case was coded as “cut by” if the narrative specified that the patient was struck or hit by the blade, if a body part went under the mower deck with the blades, if the patient stepped on something while mowing, or if the narrative indicated an unspecified laceration or amputation. For cases with more than one mechanism mentioned, such as “patient fell off mower and then was run over,” rules for assigning a mechanism were established as followed: 1) being backed over took precedence over falling off the mower; 2) falling off took precedence over striking on/falling and striking/tripping and falling, being run over, and being caught/trapped in the mower; 3) being run over took precedence over being caught/entrapped; and 4) striking on/falling and striking/tripping and falling took precedence over contact with a hot surface.

The NEISS injury diagnoses were grouped into: 1) laceration (included the NEISS categories of laceration, puncture, and avulsion), 2) burn (included thermal, chemical, scald, radiation, and electrical burn, and burns not specified), and 3) soft tissue injury (included contusion/abrasion, crushing, and hematoma). Fracture, amputation, foreign body, and

sprain/strain were each kept as separate categories without regrouping. All remaining NEISS codes for injury diagnosis were grouped into “other.”

For body part injured, NEISS categories were grouped into: 1) head/neck (included head, ear, face, mouth, and neck), 2) trunk (included upper trunk, lower trunk, and pubic region), 3) upper extremity (included shoulder, upper arm, elbow, lower arm, and wrist), 4) lower extremity (included upper leg, knee, lower leg, and ankle), 5) hand/finger, 6) foot/toe, 7) globe of eye, and 8) other (included all remaining NEISS codes).

Disposition from ED categories were grouped into three categories: 1) admitted (including NEISS categories: treated and transferred to another hospital, treated and admitted for hospitalization, and held for observation), 2) treated and released, and 3) left against medical advice.

### 2.3. Data analysis

Data were analyzed using IBM SPSS Statistics for Windows, Version 19.0 (IBM Corp., Armonk, NY) and SAS Enterprise Guide 7.11 HF3 (SAS Institute Inc., Cary, NC) statistical software. Complex survey procedures, which accounted for the NEISS sampling design, were used to calculate national estimates and the Taylor series linearization method was used to calculate the variance of the estimates. All estimates reported in this study are stable estimates unless stated otherwise. An estimate is deemed potentially unstable if the estimate is <1200 cases, the sample size is <20 cases, or the coefficient of variation is >33% [27]. Trend analyses were performed using weighted linear regression with weights equal to the inverse of the variance of the estimated statistics. The estimated annual rate of change from the regression model, denoted by “m,” was reported along with the *p*-value associated with the *t*-test used to test for its statistical significance. Other statistical analyses included Rao–Scott  $\chi^2$  test for association and calculation of relative risks (RRs) with 95% confidence intervals (CIs). Statistical significance was determined at the level  $\alpha = 0.05$ . This study was approved by the Institutional Review Board of the authors' institution.

## 3. Theory

This study provides a comprehensive epidemiological analysis of nationally representative emergency department data covering a 25-year period regarding an important source of ongoing pediatric injury morbidity. In addition, within the context of study findings, it describes relevant injury prevention strategies.

## 4. Results

An estimated 212,258 (95% CI: 176,130–248,386) children <18 years of age were treated for lawn mower-related injuries in US EDs from 1990 through 2014 (Table 1). This equaled an average of 8490 (95% CI: 7045–9935) injuries annually or 11.9 (95% CI: 9.8–13.9) injuries per 100,000 US children. The number of injuries per year decreased significantly by 53.9% ( $m = -191.8$ ;  $p < 0.001$ ) from 10,420 (95% CI: 6960–13,880) in 1990 to 4808 (95% CI: 2985–6631) in 2014 (Fig. 1). The annual injury rate per 100,000 children <18 years of age decreased significantly by 59.9% ( $m = -0.32$ ;  $p < 0.001$ ) from 16.2 (95% CI: 10.8–21.6) in 1990 to 6.5 (95% CI: 4.1–9.0) in 2014. The mean and median age of injured patients was 9.9 years (standard deviation: 0.12) and 10.6 years (interquartile range: 4.2 to 14.2), respectively. The age distributions of the injured patients were bimodal with peaks at 2 and 15 years of age (Fig. 2).

The majority of children injured by a lawn mower were boys (77.2%) and 42.1% were 13–17 years of age (Table 1). Of the 73.2% of cases with a known locale of injury, 97.1% occurred at home. Mechanism of injury was specified in 96.3% of cases, and among these, “struck by” (21.2%) was the most common mechanism of injury, followed by “cut by” (19.9%) and “contact with hot surface” (14.1%). “Back-over” incidents

**Table 1**  
 Characteristics of children treated in United States emergency departments for lawn mower-related injuries by age group, NEISS 1990–2014.

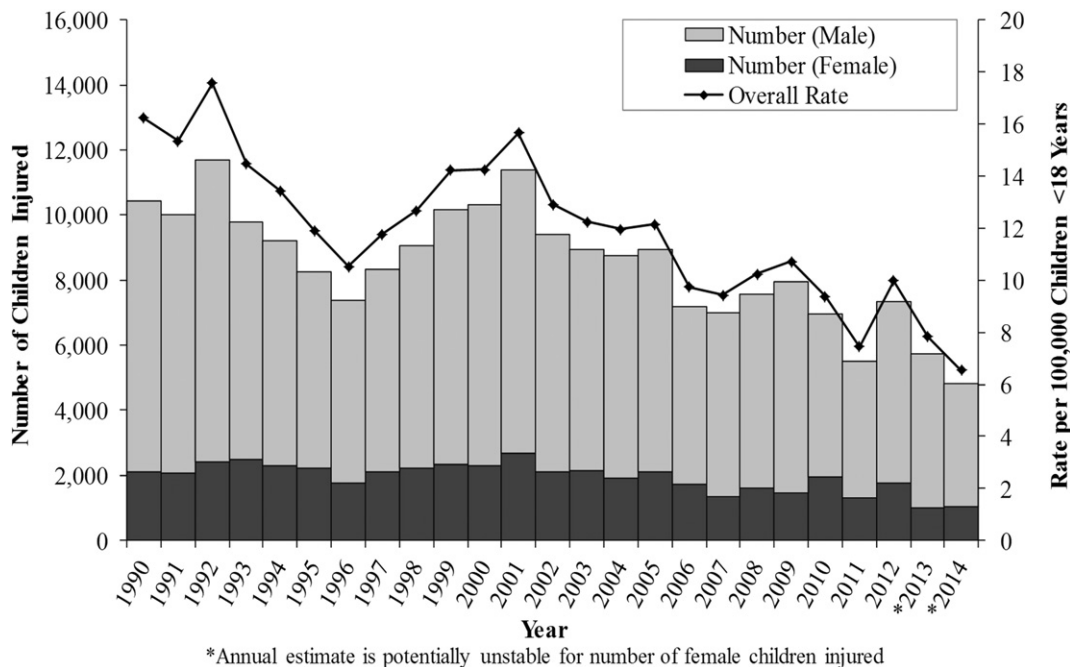
Characteristics	Age group			Total	
	0–4 yrs N (% <sup>a</sup> )	5–12 yrs N (% <sup>a</sup> )	13–17 yrs N (% <sup>a</sup> )	N (% <sup>a</sup> )	95% CI
<i>Study total (row %)</i>	51,005 (24.0)	71,896 (33.9)	89,357 (42.1)	212,258 (100.0)	176,130–248,386
<b>Gender</b>					
Male	36,356 (71.3)	53,482 (74.4)	73,909 (82.8)	163,747 (77.2)	136,513–190,982
Female	14,648 (28.7)	18,414 (25.6)	15,375 (17.2)	48,437 (22.8)	39,247–57,628
<i>Subtotal</i>	51,005 (100.0)	71,896 (100.0)	89,284 (100.0)	212,185 (100.0)	176,130–248,386
<b>Incident location</b>					
Home	38,450 (98.7)	53,001 (97.7)	62,344 (95.6)	153,795 (97.1)	125,749–181,841
Other	516 (1.3) <sup>b</sup>	1234 (2.3)	2838 (4.4)	4588 (2.9)	3155–6022
<i>Subtotal</i>	38,966 (100.0)	54,235 (100.0)	65,182 (100.0)	158,383 (100.0)	129,519–187,247
<b>Mechanism of injury</b>					
Struck by	5870 (11.7)	16,881 (24.2)	20,760 (24.5)	43,511 (21.2)	35,079–51,943
Cut by	4463 (8.9)	11,436 (16.4)	24,790 (29.2)	40,689 (19.9)	33,659–47,718
Contacted hot surface	20,014 (39.8)	4638 (6.6)	4159 (4.9)	28,811 (14.1)	23,153–34,469
Struck on/fell and struck/tripped and fell	5492 (10.9)	10,767 (15.4)	6484 (7.6)	22,743 (11.1)	17,914–27,571
Fell off	6641 (13.2)	8596 (12.3)	3223 (3.8)	18,460 (9.0)	14,718–22,201
Caught/entrapped	2,170 (4.3)	5,610 (8.0)	6,580 (7.8)	14,360 (7.0)	11,395–17,324
Run over	2773 (5.5)	4351 (6.2)	3416 (4.0)	10,540 (5.1)	8488–12,593
Tip-over/roll-over	421 (0.8) <sup>b</sup>	861 (1.2) <sup>b</sup>	2259 (2.7)	3541 (1.7)	1960–5121
Backed over	1147 (2.3) <sup>b</sup>	480 (0.7) <sup>b</sup>	15 (0.0) <sup>b</sup>	1641 (0.8)	1019–2263
Other	1234 (2.5)	6253 (8.9)	13,145 (15.5)	20,632 (10.1)	15,457–25,807
<i>Subtotal</i>	50,223 (100.0)	69,873 (100.0)	84,832 (100.0)	204,927 (100.0)	170,564–239,291
<b>User type</b>					
Operator	1015 (7.5) <sup>b</sup>	16,644 (56.1)	48,253 (93.5)	65,912 (69.5)	53,117–78,707
Bystander	5015 (37.1)	4875 (16.4)	1240 (2.4)	11,130 (11.7)	8458–13,803
Passenger	2785 (20.6)	2980 (10.0)	1058 (2.1) <sup>b</sup>	6823 (7.2)	4499–9147
Other	4718 (34.9)	5152 (17.4)	1066 (2.1) <sup>b</sup>	10,936 (11.5)	8379–13,494
<i>Subtotal</i>	13,533 (100.0)	29,650 (100.0)	51,618 (100.0)	94,801 (100.0)	76,557–113,046
<b>Object associated with injury</b>					
Projectile	4161 (8.3)	11,418 (16.7)	11,358 (13.9)	26,937 (13.5)	21,340–32,534
Mower blade	1663 (3.3)	4868 (7.1)	11,308 (13.8)	17,839 (8.9)	14,260–21,418
Other	44,079 (88.3)	52,081 (76.2)	59,158 (72.3)	155,318 (77.6)	128,579–182,058
<i>Subtotal</i>	49,903 (100.0)	68,367 (100.0)	81,825 (100.0)	200,095 (100.0)	166,407–233,782

<sup>a</sup> Column percentages may not sum to 100.0% due to round error.

<sup>b</sup> Estimate is potentially unstable due to sample size <20 cases, estimate <1200, or coefficient of variation >33.0%.

accounted for 0.8% (1641 estimated cases) of injuries, and of these, 69.9% (1147, estimate is potentially unstable) were to patients <5 years of age. Patients <5 years of age were more likely to be injured by contact with a hot surface than older patients (RR: 7.01; 95% CI: 5.69–8.64;

39.8% vs 5.7%), while patients 5–17 years of age were more likely to be injured as a result of being “struck by” (RR: 2.08; 95% CI: 1.64–2.64; 24.3% vs 11.7%) or “cut by” (RR: 2.64; 95% CI: 2.16–3.21; 23.4% vs 8.9%) than younger patients. Information for “user type” was



**Fig. 1.** Estimated number and rate of children treated in United States emergency departments for lawn mower-related injuries by year and gender, NEISS 1990–2014.

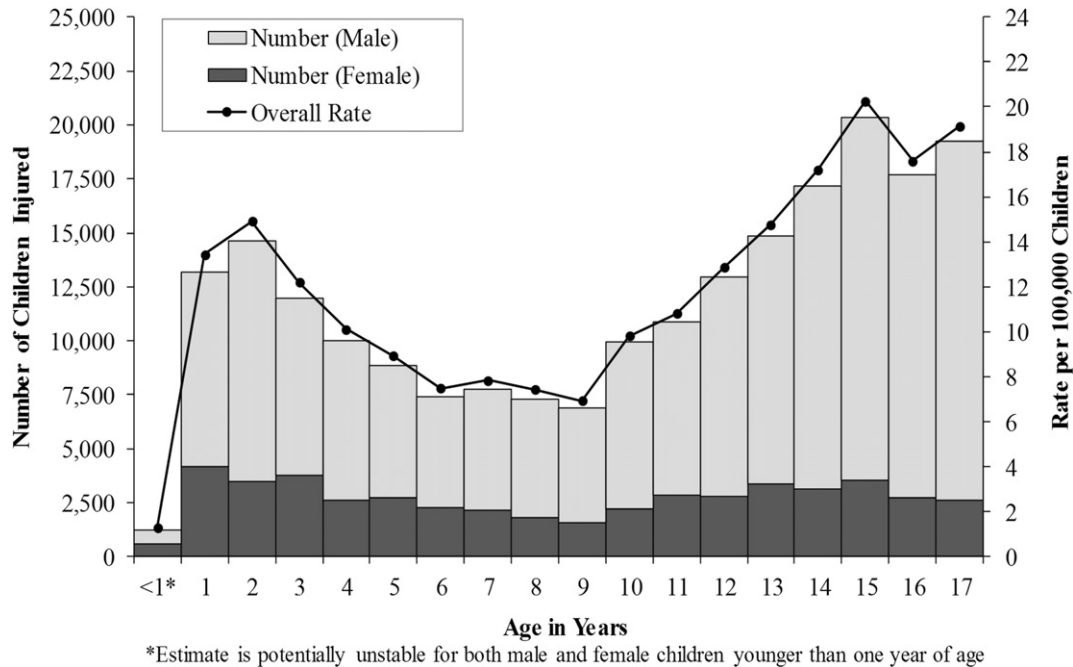


Fig. 2. Estimated number and rate of children treated in United States emergency departments for lawn mower-related injuries by child age and gender, NEISS 1990–2014.

available for 43.8% of cases, and of these, 69.5% were operators, 11.7% were bystanders, and 7.2% were passengers. The majority of patients age 5–12 years (56.1%) and 13–17 years (93.5%) were injured as an operator, while the majority of patients <5 years of age were injured as a bystander (37.1%) or passenger (20.6%). Of the 94.0% of cases with a mower part or object associated with the injury, projectiles and mower blades were associated with 13.5% and 8.9% of the injuries, respectively. Almost half (49.8%) of the bystanders were injured by

projectiles. Patients who were bystanders were 3.30 times (95% CI: 2.78–3.92; 49.8% vs 15.1%) more likely to be injured by a projectile than operators and passengers combined.

The most common types of lawn mower-related injuries were lacerations (38.5%) and burns (15.0%; Table 2). Though less common, amputations accounted for 4.4% of the injuries. Patients <5 years of age were more likely to sustain a burn than older patients (RR: 6.01; 95% CI: 4.93–7.33; 41.0% vs 6.8%), while patients 5–17 years of age were more likely

**Table 2**  
Characteristics of lawn mower-related injuries treated in United States emergency department among children by age group, NEISS 1990–2014.

Characteristics	Age group			Total	95% CI
	0–4 yrs	5–12 yrs	13–17 yrs		
	N (%) <sup>a</sup>	N (%) <sup>a</sup>	N (%) <sup>a</sup>	N (%) <sup>a</sup>	
<b>Study total (row %)</b>	51,005 (24.0)	71,896 (33.9)	89,357 (42.1)	212,258 (100.0)	176,130–248,386
<b>Body region injured</b>					
Hand/finger	21,693 (42.5)	15,626 (21.8)	27,588 (31.1)	64,907 (30.7)	53,659–76,155
Lower extremity (excl. foot/toe)	6294 (12.3)	15,653 (21.9)	16,474 (18.5)	38,422 (18.2)	31,385–45,459
Foot/toe	5377 (10.5)	11,070 (15.5)	15,855 (17.8)	32,301 (15.3)	26,578–38,024
Head/neck (excl. globe of eye)	11,409 (22.4)	11,452 (16.0)	7435 (8.4)	30,296 (14.3)	23,915–36,678
Upper extremity (excl. hand/finger)	2765 (5.4)	7871 (11.0)	7526 (8.5)	18,161 (8.6)	14,732–21,590
Trunk	1892 (3.7)	4352 (6.1)	5566 (6.3)	11,810 (5.6)	8586–15,034
Globe of eye	1069 (2.1) <sup>b</sup>	4127 (5.8)	5457 (6.1)	10,653 (5.0)	8247–13,059
Other	505 (1.0) <sup>b</sup>	1425 (2.0) <sup>b</sup>	2941 (3.3)	4871 (2.3)	3011–6732
<b>Subtotal</b>	51,005 (100.0)	71,575 (100.0)	88,842 (100.0)	211,422 (100.0)	175,824–247,021
<b>Diagnosis</b>					
Laceration	14,914 (29.2)	31,631 (44.1)	35,033 (39.3)	81,578 (38.5)	67,467–95,690
Burn	20,882 (41.0)	5628 (7.8)	5,344 (6.0)	31,855 (15.0)	25,718–37,991
Soft tissue injury	6046 (11.9)	11,580 (16.1)	13,423 (15.0)	31,048 (14.6)	24,791–37,306
Fracture	2830 (5.5)	7943 (11.1)	9248 (10.4)	20,021 (9.4)	16,249–23,794
Sprain/strain	632 (1.2) <sup>b</sup>	4086 (5.7)	7521 (8.4)	12,239 (5.8)	9228–15,251
Amputation	2344 (4.6)	3019 (4.2)	3908 (4.4)	9271 (4.4)	7328–11,214
Foreign body	291 (0.6) <sup>b</sup>	2503 (3.5)	4172 (4.7)	6966 (3.3)	5285–8647
Other	3054 (6.0)	5404 (7.5)	10,573 (11.8)	19,031 (9.0)	13,793–24,268
<b>Subtotal</b>	50,993 (100.0)	71,793 (100.0)	89,223 (100.0)	212,009 (100.0)	176,289–247,728
<b>ED disposition</b>					
Treated and released	45,543 (89.3)	65,162 (90.7)	83,892 (93.9)	194,597 (91.7)	161,223–227,972
Admitted	5425 (10.6)	6691 (9.3)	5265 (5.9)	17,381 (8.2)	13,542–21,220
Left against medical advice	7 (0.0) <sup>b</sup>	27 (0.0) <sup>b</sup>	199 (0.2) <sup>b</sup>	233 (0.1) <sup>b</sup>	25–442
<b>Subtotal</b>	50,975 (100.0)	71,880 (100.0)	89,357 (100.0)	212,212 (100.0)	176,499–247,925

<sup>a</sup> Column percentages may not sum to 100.0% due to round error.

<sup>b</sup> Estimate is potentially unstable due to sample size <20 cases, estimate <1200, or coefficient of variation >33.0%.

to be diagnosed with a fracture than younger patients (RR: 1.92; 95% CI: 1.45–2.55; 10.7% vs 5.5%). The hand/finger (30.7%) was the most commonly injured body region, followed by the lower extremity (18.2%) and foot/toe (15.3%; Table 1). Of the injuries to the globe of the eye, 48.2% were a result of being struck by a projectile. Most (91.7%) patient were treated and released. Overall, 8.2% of injured children were admitted to the hospital, while 21.0% of bystanders, 18.8% of passengers, and 5.1% of operators were admitted. Patients who were bystanders or passengers were 3.77 times (95% CI: 2.74–5.19; 20.1 vs 5.3%) more likely to be admitted than operators.

## 5. Discussion

Approximately 8500 children <18 years of age were injured annually during the study period, equaling about one child every hour. However, the injury rate decreased by more than half from 1990 to 2014. The cause of this decline is unknown, but is likely attributable to multiple factors. Voluntary safety specifications for both walk-behind and ride-on lawn mowers were first published in 1987 by the American National Standards Institute (ANSI) and the Outdoor Power Equipment Institute (OPEI) and have been revised periodically since then [18]. Improvements in lawn mower design based on these safety specifications are likely to be an important contributing factor to the observed decline in lawn mower-related injuries. Increased awareness of lawn mower-related hazards resulting from widespread education on mower safety also may have influenced the observed declining trend [6,7,28,29].

Children <5 years old in our study were more likely to be injured from contact with a hot mower surface and sustain a burn compared with older children. This is consistent with previous research [12]. Young children are curious and tend to explore their environments without awareness of hazards, such as hot surfaces. The most recent revision of the ANSI/OPEI voluntary safety specifications, released in 2012, includes a new testing protocol for shielding hot mower surfaces [30]. However, the protocol uses a 95th percentile adult male maneuvering a finger probe while seated in the mower operating position, and does not consider the circumstances of injury to young children who may approach the mower from positions other than the operator's seat. In this study, most children 5–12 years of age were injured as the mower operator. The developmental immaturity of this age group to properly operate mowing equipment is likely a contributing factor to the occurrence of these injuries. Because of the coordination, strength, and judgment required to operate mowing equipment, the AAP recommends that children not operate a walk-behind lawn mower until at least 12 years of age and a ride-on mower until at least 16 years of age [6].

Children injured as passengers or bystanders were more likely to be admitted to the hospital. This demonstrates the risk of serious injury to children who are not directly using a lawn mower, and the need to protect non-operators of mowers, especially young children. Children should never be carried as a passenger on a ride-on mower, because they can easily be injured in a fall or tip-over [6]. An important cause of injury among bystanders is being struck by a thrown object. In this study, bystanders were more than three times more likely to be injured by projectiles than lawn mower passengers or operators. A rotary mower blade can launch an object at a speed of >200 miles an hour [31]. Because of their short stature, young children may be more likely to be struck in the head or trunk by a projectile, resulting in an injury that is more severe than a strike to the lower extremity of an adult. In addition, almost half of the injuries to the globe of the eye in this study resulted from a projectile. This supports the use of protective eyewear by lawn mower operators.

Though relatively uncommon, lawn mower-related back-overs can cause devastating injuries. These injuries often result in major amputations and other permanent disabilities with associated financial burden. These injuries also may lead to post-traumatic stress disorder, anxiety, and depression [21]. An estimated 1641 back-over injuries occurred nationwide during the 25-year study period. Children <5 years of age

accounted for 69.9% of the back-over injuries; however, this estimate is potentially unstable because the estimate is <1200 cases. Typical circumstances associated with back-over injuries involve a child <5 years of age running out to join a family member mowing the lawn on a ride-on mower, who does not see or hear the child approaching from behind. The operator shifts into reverse without looking behind the mower and backs over the child, which results in amputation or other serious injury.

Automatic safety measures that are designed into the lawn mower are the best way to prevent injuries from mowers [30]. Rollers and shields can help keep hands and feet from penetrating under the mower, while also protecting the blades from large objects. Prevention of amputations from mowers is especially important because they are often severe, can require multiple surgical interventions, and result in permanent disability [2,19,23,32]. To help prevent back-over injuries, every ride-on mower should be equipped with a tamper-resistant no-mow-in-reverse (NMIR) mechanism. ANSI/OPEI B71.1–2003 required all ride-on mowers (except zero-turn radius and front-mount mowers) manufactured after September 1, 2004 to be equipped with a NMIR feature, which disengages the blades when the mower is shifted into reverse. However, most of these mowers also are equipped with an override switch that allows the operator to reengage the blades while in reverse. Currently, this switch is located in front of the operator on almost all mower models with NMIR override. Operators are able to reengage the mower blades while traveling in reverse without ever looking behind them, which negates the safety purpose of the NMIR mechanism. Manufacturers should place the override switch on the back of the mower behind the operator's seat to force the operator to turn around and look behind him/her before reengaging the blades. Currently, only a handful of models have the override switch on the back. In addition, some ride-on mowers automatically reset the override switch to “off” when the operator shifts into a forward gear (the safest design), while others only reset when the operator manually turns off the override or when the engine is shut off (less safe designs). A rearward proximity warning device, rearward camera, and even a simple rearview mirror are additional potential strategies for reducing the risk of back-over injuries.

In addition to safer mower design, there are other strategies to prevent lawn mower-related injuries to children, including those promoted by the CPSC and AAP [33,34]. Young children should be kept indoors under adult supervision while a mower is in use, and children should never ride as passengers or be towed behind mowers in wagons or trailers. Children should not be allowed to operate a mower until they are developmentally ready, and they should always be taught and supervised by an adult before operating mowers independently. The blades should never be disimpacted while the mower is on. To reduce the risk of eye injury from projectiles, operators should wear protective eyewear when mowing. Operators should be aware of their surroundings at all times, and should always look behind the mower before reversing.

### 5.1. Limitations

This study has several limitations. The number of lawn mower-related injuries is underestimated because the NEISS does not capture injuries treated in medical settings other than EDs or for which medical attention is not sought. An inherent selection bias also exists in the population that receives emergency care for injuries. Therefore, the injuries reported in this study may not be representative of the entire spectrum of lawn mower-related injuries. The inconsistency in the level of detail available in NEISS narratives limited evaluation of mechanism of injury and some of the other variables considered in this study. The type of mower was not specified in many cases, and the NEISS does not yet have a separate code for zero-turn-radius mowers. The small number of back-over cases limited detailed statistical analyses of these injuries. Another study limitation was the lack of data quantifying exposure of

children to lawn mowers; however, the use of US Census data to calculate population-based injury rates is an acceptable alternative.

## 6. Conclusions

Lawn mower-related injuries continue to be a cause of serious morbidity among children. Although the annual injury rate decreased significantly over the study period, the number of injuries is still substantial, indicating the need for additional prevention efforts. In addition to educational approaches, opportunities exist for improvements in mower design and strengthening the voluntary safety specifications for lawn mowers in ANSI/OPEI B71.1.

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