Research Article

Lawnmower Injuries in Children: A National 13-Year Study of Urban Versus Rural Injuries

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Abstract

Introduction: Although the American Academy of Orthopaedic Surgery, American Academy of Pediatrics, and Pediatric Orthopedic Society of North America have established lawnmower safety guidelines, a notable number of injuries continue to occur. We sought to elaborate on the epidemiology of lawnmower injuries in the pediatric age group and compare urban versus rural injuries.

Methods: The Pediatric Health Information System database was queried for patients of 1 to 18 years of age from 2005 to 2017 who presented with a lawnmower injury. Results were computed using bivariate tests and multinomial regressions.

Results: A total of 1,302 lawnmower injuries were identified (mean age 7.7 ± 5.1 years, range 1 to 18 years; 78.9% males). Incidence rates by region, adjusted for regional case volume, were 2.16 injuries per 100,000 cases in the South, 2.70 injuries per 100,000 cases in the Midwest, 1.34 injuries per 100,000 cases in the Northeast, and 0.56 injuries per 100,000 cases in the Western United States. After stratifying and adjusting for total case volume by locale (urban/rural), it was found that urban areas had an incidence rate of 1.47 injuries per 100,000 cases, whereas rural areas had a rate of 7.26 injuries per 100,000 cases. Rural areas had higher rates of infection and higher percentages of patients requiring inpatient stay. The surgical complication rate in rural areas was 5.5% as compared to 2.6% in urban areas. Based on urban/rural status, a significant difference was observed with the age group, length of stay, income, surgical complication, and presence of infection at the bivariate level with $P < 0.05$. Rural areas had an overall amputation rate of 15.5% compared with 9.6% in urban areas, with rural patients being 1.7 times more likely to undergo an amputation ($P < 0.05$).

Conclusion: The findings of this study show that numerous geographic and locale disparities exist in pediatric lawnmower injuries and reveal the need for improved safety awareness, especially in at-risk rural populations.

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None of the following authors or any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Mr. Shah, Dr. Talwar, Dr. Schwend, Dr. Sponseller, Mr. Aoyama, and Dr. Ganley.

J Am Acad Orthop Surg 2020;28: e387-e394

DOI: 10.5435/JAAOS-D-19-00233

Lawnmower accidents often lead to devastating injuries in children, causing severe morbidity and sometimes mortality. Small children, in particular, face increased risk because of smaller stature, continued skeletal growth and development, and earlier developmental stages of motor control. Lengthy inpatient stays and multiple operations are often required because of the severity of these extensive injuries involving the bone and soft

tissues.[1–4] As a consequence, numerous detrimental effects on the physical and mental well-being of a child can result.[5] From a public health perspective, these injuries carry a very high economic burden, with the annual cost for management of pediatric lawnmower injuries around $90 million.[6] Unlike many public health crises, these injuries are often preventable and may be attributed to user error or limited parental oversight when children are playing.[7]

The national incidence of these injuries in the pediatric age group is estimated to be around 9,400 per year.[8] Lawnmower injuries follow a bimodal distribution, with injury rates peaking at 4 and 15 years of age.[9] The percentage of these injuries requiring hospitalization is also 2-fold higher compared with any other consumer product-related injury.[10] Of all traumatic amputations in children, 12% to 29% are attributed to lawnmowers.[11]

To reduce these injuries, the American Academy of Pediatrics (AAP) set lawnmower user guidelines in 1990 and 2001. The American Academy of Orthopaedic Surgery (AAOS) established updated guidelines in 2014, and the Pediatric Orthopedic Society of North America is currently collaborating with the AAP on awareness campaigns. Despite this, notable injuries from lawnmowers continue to occur in the pediatric cohort.[12] Numerous studies describing lawnmower injuries using the National Electronic Injury Surveillance System have been conducted in the past; however, no such type of study has been conducted using the Pediatric Health Information System (PHIS) database. The PHIS database is unique in that it is nationally representative and contains a varied selection of 49 participating children's hospitals located around the country in different geographic regions and locales.

This comprehensive investigation analyzes lawnmower injury data over a 13-year span using a unique pediatric-specific database to study the national and geographic epidemiological trends and the relevant characteristics, treatment, and complications of these injuries. Future strategies for lawnmower injury prevention are also discussed.

Methods

Injury data for this study were obtained from the PHIS, an administrative database that contains inpatient, emergency department, ambulatory surgery, and observation encounter-level data from over 49 not-for-profit, tertiary care pediatric hospitals in the United States. These hospitals are affiliated with the Children's Hospital Association (Lenexa, KS). Data quality and reliability are assured through a joint effort between the Children's Hospital Association and participating hospitals. Portions of the data submission and data quality processes for the PHIS database are managed by Truven Health Analytics (Ann Arbor, MI). Data are de-identified at the time of data submission and are subjected to a number of reliability and validity checks before being included in the database. This study was determined to have approval exemption by the primary host Institutional Review Board.

The PHIS database was queried for patients aged 0 to 18 years from 2005 to 2017 who presented to any of the participating hospitals for a lawnmower injury. The patient cohort was identified using a search for injury codes E920 and W28 indicating lawnmower injury. Data were subsequently grouped into relevant categories according to age, sex, race, geographic region, urban versus rural locale, discharge year, principal diagnosis type, principal treatment type, severity of injury, fixation type, primary source of payment, median household income, cost, length of stay, body region of injury, patient disposition, presence of infection, and surgical complication. The severity of injury is defined by PHIS using the 3M' All Patients Refined Diagnosis Related Group grouper: zero = not applicable, 1 = minor, 2 = moderate, 3 = major, and 4 = extreme. All Patients Refined Diagnosis Related Groups are a classification system that groups patients according to their reason of admission, severity of illness, and risk of mortality. Urban and rural locale were determined using established PHIS data that have been compiled using zip code information of where the injury occurred and were therefore determined by PHIS rather than by the study team. Some relevant data such as type of mower, injury severity score, blood transfusion, number of surgeries, and disability-adjusted life years were not available. Cost analysis was adjusted for inflation using the Consumer Price Index.

Descriptive statistics was performed to obtain frequencies and measures of central tendency (mean and median). All categorical data were initially analyzed using a Pearson chi-squared test for statistical significance. Subsequently, those categories that achieved significance at the bivariate level were then subjected to mixed-effects multinomial logistic regression modeling to account for hospital-level variation among PHIS hospitals. Results were displayed as odds ratios. Incidence at PHIS hospitals was calculated after adjusting for total overall case volume at those hospitals in the same specified time period. $P < 0.05$ was considered significant for all statistical tests. Analyses were performed using SPSS (IBM, Armonk, NY) and Stata 15 (StataCorp, College Station) statistical software.

Results

Demographics

There were a total of 1,302 lawnmower injuries identified in the PHIS database during the 2005 to 2017 time frame in patients 18 years and younger. The mean age at injury was 7.7 years (SD: 5.1 years, range 1 to 18 years). The age distribution of lawnmower injuries is shown in Figure 1. Rural areas (60.3%) had a higher percentage of injuries occurring in the youngest age group, consisting of 1- to 5-year-olds, compared with urban areas (43.7%). Most injuries occurred in males (78.9%), with the most prevalent racial group being Caucasians (Table 1). A combined 81.9% of all injuries occurred in the Midwest and South (Figure 2). Nearly half (46.5%) of all injuries required inpatient stay. In rural areas, 56.1% of patients required inpatient stay compared with 42.4% in urban areas.

Incidence

Incidence was calculated as a proportion of the number of lawnmower injuries that presented to PHIS hospitals in reference to the total number of all cases at those hospitals in the specified time period. The national incidence rate for lawnmower injuries at PHIS hospitals was found to be 1.83 injuries per 100,000 cases. Incidence rates by region, adjusted for regional case volume, were 2.16 injuries per 100,000 cases in the South, 2.70 injuries per 100,000 cases in the Midwest, 1.34 injuries per 100,000 cases in the Northeast, and 0.56 injuries per 100,000 cases in the Western United States. The annual frequency of injuries is shown in Figure 3. The summer months of May to August had the highest frequency of injuries (Figure 4).

Figure 1

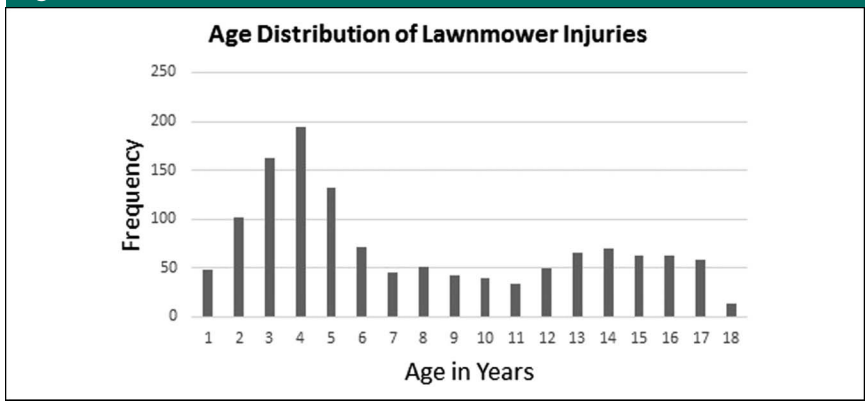


Chart showing the frequency of lawnmower injuries by age.

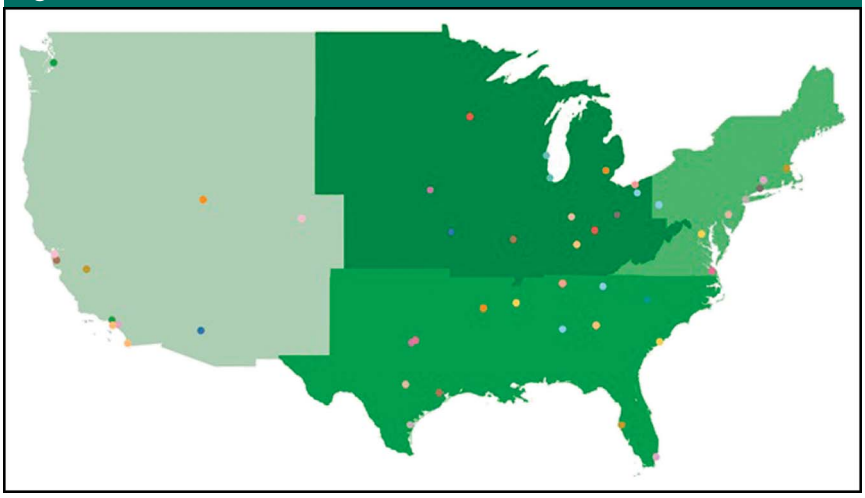
Table 1

Clinical Characteristics	
Total injuries	1,302
Mean age	7.7 ± 5.1 yr
Sex	
Males	78.9%/n = 1,027
Females	21.1%/n = 275
Race	
Caucasian	75.1%/n = 978
Black	15.7%/n = 204
Asian	1.7%/n = 22
Other	7.5%/n = 98
Locale	
Urban/Suburban	72.9%/n = 949
Rural	27.1%/n = 353
Type of injuries	
Amputations	30.9%/n = 402
Fractures/dislocations/ bony avulsions	24.2%/n = 315
Open wounds/ punctures/lacerations	28.8%/n = 375
Treatment type	
Conservative treatment	7.6%/n = 99
Débridement	19.8%/n = 258
Amputation	11.2%/n = 146
Open reduction	7.5%/n = 98
Closed reduction	1.6%/n = 208
Skin/tendon/muscle (graft/repair)	11.3%/n = 147
Other	6.1%/n = 79

Injury

The injuries grouped by body region were as follows: lower extremities (64.7%), upper extremities (22.0%), head/neck (2.2%), face (1.5%), and trunk (2.6%) (Figure 5). The most common types of injuries sustained after lawnmower accidents included amputations (30.9%),

Figure 2



Heat map of lawnmower injuries by region. Darker shades indicate higher incidence. Major locations of PHIS hospitals are shown as dots. PHIS = Pediatric Health Information System

Figure 3

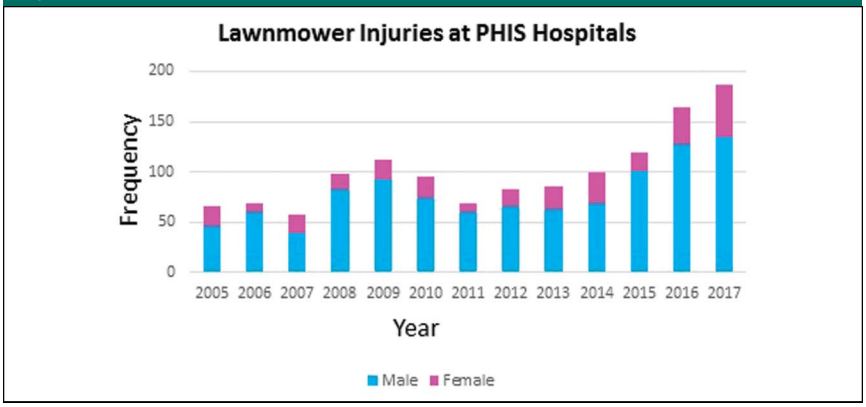


Chart showing the annual frequency of lawnmower injuries at PHIS hospitals by sex. PHIS = Pediatric Health Information System

open wounds/punctures/lacerations (28.8%), and fractures/dislocations/bony avulsions (24.2%). Management of these injuries involved debridement (19.8%), amputation (11.2%), skin/tendon/muscle (graft/repair) (11.3%), conservative treatment (7.6%), open reduction (7.5%), and closed reduction (1.6%). The initial severity of injury was also categorized. It was found that children younger than 10 years of age had a significantly higher proportion of PHIS-defined moderate, major, and extreme injuries (21.4%/12.3%/3.2%) compared with children aged 10 years and older (16.0%/2.4%/0.9%) ($P < 0.05$). After further subgroup analysis, the median cost of lawnmower injuries for children younger than 10 years of age (8,843 dollars) was significantly greater than that for children older than 10 years of age (2,608 dollars), as was the median length of stay, 1.5 days versus 1.0 day ($P < 0.05$). Overall, regardless of locale, 19.8% of patients required an inpatient stay of greater than 5 days. All dollar amounts were adjusted for inflation.

Rural Versus Urban

After stratifying by locale (urban/rural), injury incidence was calculated and adjusted for using total case volume by locale. Urban areas had an incidence rate of 1.47 injuries per 100,000 cases, whereas rural areas had a rate of 7.26 injuries per 100,000 cases. The median income in urban areas was 11,442 dollars greater than that in rural areas. Despite this disparity, rural and urban areas had nearly equal ratios of commercial insurance and Medicaid payments. The overall infection rate was 6.0%, and the overall complication rate was 3.3%. A significant difference at the bivariate level ($P < 0.05$) was observed in infection rates between urban (4.8%) and rural (9.4%) locales. Moreover, rural communities had significantly higher complication rates, 5.5% versus 2.6% ($P < 0.05$). Compared with urban areas, rural communities also had a higher proportion of patients requiring inpatient stay greater than 5 days ($P < 0.05$) (Table 2). Rural areas had an overall amputation rate of 15.5% compared with 9.6% in urban areas, with rural patients being 1.7 times more likely to undergo an amputation ($P < 0.05$). Rural areas had a significantly higher proportion of moderate/major injuries (25.2%/9.4%) compared with urban areas (18.8/8.2) ($P < 0.05$). Urban areas had a higher proportion of minor injuries (70.9%) compared with rural areas (62.6%) ($P < 0.05$). The average cost of presenting injuries was 18,693 dollars (range: 0 to 216,416 dollars). A difference was observed in the median cost of injuries between urban (5,184 dollars) and rural (9,473 dollars) areas, with rural areas having significantly greater associated costs ($P < 0.05$).

Discussion

Lawnmower injuries are a notable cause of pediatric morbidity and mortality. These traumatic injuries consequently impart an enormous physical and psychosocial burden on pediatric patients and their families. Because of their prevalence, lawnmower injuries also place a substantial burden on healthcare and economic systems.

An overwhelming majority of children injured by lawnmowers in our study were male (78.9%). Similar injury rates for males have been found in other studies. This higher rate of injury compared with that of females may be explained by boys having a higher proclivity for physical activities and exploring outdoor enviornments[13,14] or by adolescent boys being assigned lawn mowing tasks more frequently than girls. Our study also found that nearly half of the 1,302 patients in our study were between the ages of 1 to 5 years. This suggests that these accidents occurred because of a lack of oversight or parental error involving children/babies who had not yet developed the judgment and ability to avoid and recognize the dangers of lawnmowers. The summer months of May through August continued to have the highest frequency of injuries, consistent with the greatest use of lawnmowers during the summer time and confirming what other studies have found.[3,9]

The overwhelming majority of injuries were sustained to the extremities. In total, 30.9% of injury cases were classified as amputations, a similar percentage to other studies.[15–19] This can be attributed to the short height and small stature of children, especially in the 1 to 5 years age group, which we found sustained the largest number of injuries. Other studies have also found that bystander injuries usually affect younger children, whereas older children usually sustain operator error type injuries.[20,21] Previous studies have found that 91% of all nonfatal injuries in children younger than 5 years occur at home.[22–24] Twenty six percent of injuries involving riding mowers involve children younger than 15 years of age, whereas 14% of children <14 years of age are injured by walking behind mowers.[25] Extremely young infants and children can easily be missed behind a riding mower, placing them at risk even being in the yard during mowing. Despite some manufacturers including a safety feature that does not spin the blades while in reverse, most models have a user-controlled override feature which negates additional

Figure 4

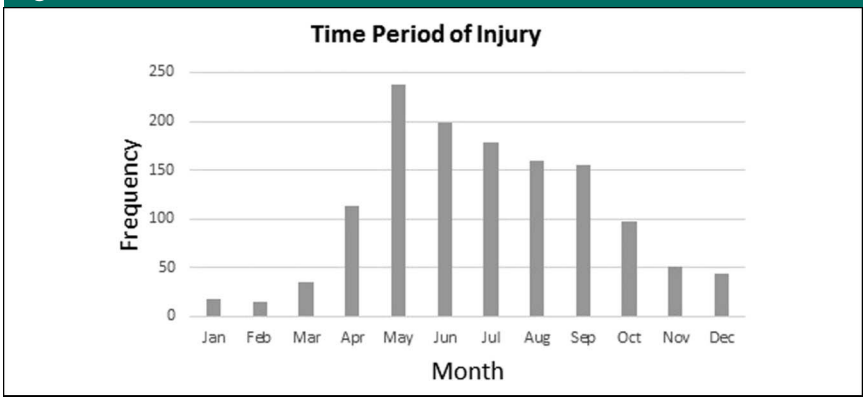


Chart showing the frequency of lawnmower injuries by month.

Figure 5

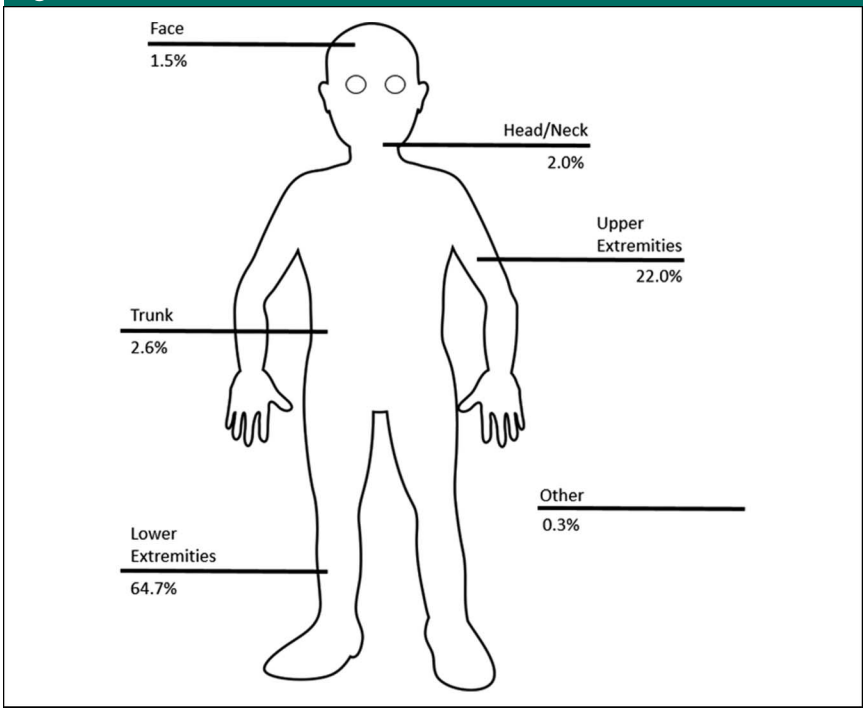


Illustration showing the percentage distribution of lawnmower injuries by body region.

Table 2

Urban Versus Rural Lawnmower Injuries

Urban (N = 946)	
Median age	6.5 ± 5.2 yr
Median income	$40,758 ± 17,357
Infection rate	4.8%/n = 45
Complication rate	2.6%/n = 34
Length of stay categories	
Less than 1 d	60.7%/n = 790
1-5 d	21.3%/n = 277
Greater than 5 d	18.0%/n = 234
Rural (N = 356)	
Median age	5.0 ± 4.3 yr
Median income	$32,354 ± 5,359
Infection rate	9.4%/n = 122
Complication rate	5.5%/n = 72
Length of stay categories	
Less than 1 d	49.0%/n = 638
1-5 d	26.5%/n = 345
Greater than 5 d	24.5%/n = 319

safety benefits.[26] Finally, reports have indicated that children have a greater severity of injury from lawnmower injuries than do adults.[27]

Geographic and locale differences have seldom been investigated in relation to lawnmower injuries.[9] We specifically sought to expand on the literature in this area by looking at regional variation and differences between urban versus rural locales. The South and the Midwest had the highest incidence of pediatric lawnmower injuries even after adjusting for total case volume in these regions. This could be explained by the warmer weather in the South yielding a higher amount of time spent for households mowing lawns. The high frequency of injuries in the Midwest could possibly be explained by an increased prevalence of riding lawnmowers because they allow larger land areas to be covered. Larger lawns also allow an increased opportunity to mow, which may increase risk of injury.

Our results show that great variation also exists between urban and rural communities. Rural communities were found to have markedly higher surgical complication and infection rates. Patients in rural areas also had 1.7 times higher risk of having an amputation, which places an increased burden on socioeconomic resources. In 1997, Loder et al[28] found that the average prosthetic from the time of injury to 18 years of age costs approximately $73,140 to $116,040 per single lower extremity in children with traumatic lawnmower amputations. Moreover, the percentage of patients requiring inpatient stay was also higher in rural areas. With these findings, it can be said that lawnmower injuries in rural areas often result in worse outcomes. This may be because of several reasons including more severe injuries at the time of initial presentation because of the higher chances of encountering larger, riding lawnmowers and longer transport times to reach a hospital from the location of the injury. Perhaps, rural cultural attitudes and behaviors toward lawn mowing may also explain these differences. Careful attention must be given to lawnmower injuries occurring in rural locales because of the discrepancies detailed above. To correct these discrepancies, national awareness surrounding regional and geographic differences must be raised. Rural medical personnel should also become aware of the possibility of increased initial injury severity and the higher risk of adverse outcomes in the short- and long-term. The importance of the Pediatric Advanced Life Support protocol, fluid resuscitation, antibiotic usage, and tetanus administration should be highlighted.

There are two overall means to decrease pediatric lawnmower injuries. The first is through United States Consumer Product Safety Commission-based safety rules that guide the development and manufacturing of the lawnmowers themselves. The second is through the direct awareness programs targeted specifically at consumers. The safety measures built into the lawnmower design can most effectively be improved by further scientific research, exploring risk stratification and design guidelines. Once implemented, strict adherence to manufacturer requirements and guidelines is required. Pediatricians and orthopaedic specialists can actively encourage and support increased safety features for lawnmowers through legislative means. Further research into the efficacy of awareness programs and organizational advocacy statements should be conducted and validated. Finally, a multifaceted consumer awareness approach is needed to markedly decrease the incidence of these injuries. This may be accomplished using patient educational materials, community events, and national awareness campaigns. This study was particularly focused on pediatric lawnmower events, but these results may be applicable to a wider population.

Despite guidelines set forth by the AAP in the 1990s and 2000s to improve lawnmower safety, which included not allowing children younger than 12 years of age to use a push lawnmower and prohibiting children younger than 15 years of age from using riding lawnmowers, this analysis has shown that lawnmower injuries in the pediatric cohort are still prevalent.[12,29] The AAOS released a position statement in 2008 and in 2014 detailing 13 recommendations to prevent power lawnmower injuries, and the Pediatric Orthopedic Society of North America has also been working on establishing updated guidelines. One recently published study analyzing the effectiveness of professional society advocacy campaigns on pediatric orthopaedic injuries found that lawnmower injury rates did not fall following AAOS and AAP statements in 1998 and 2001; however, a 2012 AAOS statement did coincide with a 21% drop in injuries from 2012 to 2013.[30] This drop may also be attributable to improvements in lawnmower safety design and mechanisms. Overall, taking into consideration the results of this study, the effectiveness of such statements remains unclear. Further research into validating the value of professional guidelines, recommendations, and position statements needs to be conducted and could provide novel insights for such organizations.

There are several limitations to this study that require recognition. By its very nature, the study was limited by the fact that only the 49 PHIS-participating pediatric hospitals were studied. As a result, only an incidence rate for PHIS hospitals was provided; a national incidence could not be calculated. These hospitals are often large, level 1 trauma centers and thus may have a skewed patient cohort. Moreover, the PHIS database collects pediatric hospital and emergency department information. As a consequence, patients who were treated in primary care settings or seen at adult/secondary hospitals for relatively minor injuries were not included. Thus, the information collected may be skewed toward greater injury severity and under representative of more minor injuries. Moreover, the conditions and practices used by pediatric-only hospitals may not best represent other types of hospitals nationwide. Finally, the composition of rural versus urban hospitals may have varied over time in the database. This could not be accounted for and may have had a confounding effect on some of the bivariate conclusions that could be drawn from the model. However, other pitfalls were potentially avoided because of the large sample size and the extended time frame studied.

Other limitations include the reliability of analyzing an administrative database. The results of this study are highly dependent on the reliability of medical record data collection and coding which often subject to physician/other medical professional error and bias. Although evidence points to the contrary, with one study finding a 98% accuracy of ICD (International Classification of Diseases) coding in the PHIS database, the possibility for such errors always exists.[31] Because of the de-identified nature of the database, detailed information on mechanism/situation of injury and operative management was not available for comparison. Finally, information about the level of exposure to lawnmowers or time spent near lawnmowers is not available and thus is a limitation of all studies of this nature, making it difficult to draw conclusions about risk.

Conclusion

Despite established safety guidelines, organizational position statements, and general consumer awareness, lawnmower injuries continue to be prevalent, especially in young children. They often pose a large burden on the well-being of the patient and socioeconomic systems. Although devastating, these accidents are largely preventable. This analysis of lawnmower injuries in the PHIS database, previously never before conducted, has provided further data about the national epidemiology of these injuries and novel insights into the notable differences pertaining to geographic and urban/rural variation. The results of this study have identified that young children in rural areas are particularly at risk for adverse outcomes. While injury prevention and safety efforts should be a major point of emphasis for all children, recent evidence suggests that educational efforts should be further targeted for rural communities, especially in the Southern and Midwestern United States.

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