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Characteristics of Pediatric Traumatic Amputations Treated in Hospital Emergency Departments: United States, 1990–2002

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ABSTRACT. *Objective.* **To examine the characteristics of children with traumatic amputations and the products associated with these injuries.**

Methods. **Data regarding amputation injuries to children younger than 18 years treated in US emergency departments from 1990 to 2002 were obtained from the National Electronic Injury Surveillance System. Data included demographics, product involved, and body region injured.**

Results. **An estimated 111 600 children younger than 18 years with amputation injuries were treated in US emergency departments from 1990 to 2002. The average age was 6.18 years (median: 4 years; mode: 1 year old). Males experienced 65.5% of these injuries. Finger amputations accounted for 91.6% of all amputations, ranging from 95.2% among 0- to 2-year-olds to 87.9% among 13- to 17-year-olds. Complete amputations accounted for 70.2% of all amputations among 13- to 17-year-olds compared with 52.6% of amputations among 0- to 2-year-olds. Adolescents also had the highest proportion of amputations resulting in hospital admission (26.6% for 13- to 17-year-olds compared with 11.9% for 0- to 2-year-olds). Adolescents had the highest proportion of amputation injuries involving lawn mowers (14.1% for 13- to 17-year-olds compared with 1.4% for 0- to 2-year-olds) and the highest proportion of amputations involving tools (29.3% for 13- to 17-year-olds compared with 2.5% for 0- to 2-year-olds). The percentage of amputations involving doors peaked in the youngest age group and decreased as age increased (65.8% of all amputations for 0- to 2-year-olds compared with 14.1% for 13- to 17-year-olds).**

Conclusions. **To our knowledge, this is the first study to use a nationally representative sample to broadly investigate amputation injuries among children. The majority of traumatic amputation injuries occur to young children, to males, and to fingers and the majority involve doors. Adolescents experience a higher proportion of more serious amputation injuries. Effective interventions exist but are inadequately used to prevent many of these injuries, including door stops and modifications, bicycle-chain and spoke guards, wearing closed-toe footwear while bicycling, a no–mow-in-reverse default feature on ride-on lawnmowers with the override switch located behind the mower operator, and a SawStop system on power saws. Use of these technical countermeasures and changes in relevant product standards to promote their implementation and use could lead to a decrease in pediatric traumatic amputations.** *Pediatrics* **2005;116:e667–e674. URL: www.pediatrics.org/cgi/doi/10.1542/peds.2004-2143;** ***trauma, amputation, injury, door, bicycle, lawn mower, power saw, children.***

ABBREVIATIONS. NEISS, National Electronic Injury Surveillance System; CPSC, US Consumer Product Safety Commission; ED, emergency department; CI, confidence interval; RR, relative risk; NMIR, no-mow-in-reverse.

Traumatic amputations are serious injuries that can result in permanent physical damage, disability, psychological sequelae, and altered occupational goals. Traumatic amputations are one of the most costly injuries, averaging a 4-day hospital stay and 4.3 surgical procedures and totaling approximately $23 465 per event.[1,2] Annually, almost one third of traumatic amputation injuries occur among children <18 years old.[3] Children are more susceptible to these injuries than adults because of their smaller extremities and lower skeletal mass.[4] In addition, skeletal immaturity predisposes them to more complications in the affected limb, including stunted growth, painful overgrowth, and limb shortening.[5–7] One case report documented 12 years of reconstructive surgery for a pediatric amputation patient.[8] In addition, children and their caretakers face decades of potential pain, psychological consequences, and difficulties with basic activities such as eating, playing, and doing schoolwork.[9,10] In 1 study, children reported moderate pain and phantom limb sensations at least once per week after a lawn mower–related amputation. Half of these children said that the injury influenced their future aspirations.[10]

However, relatively little research has been performed to investigate pediatric traumatic amputations. Previous studies have generally focused on a single type of product such as lawn mowers[4,8,10–21] and exercise equipment[22–31]; a single body part such as the finger[9,32–34]; or a specific treatment strategy for these injuries.[6,26,35–39] Only a small number of larger epidemiological studies included children, and those that did grouped them into categories as broad as 0 to 14 years, which prevents meaningful comparisons by age or developmental stage.[1,3,4,40,41] In addition, many of these studies used small, local data sets that date back as far as the early 1970s. It is unclear whether these studies accurately represent current

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national trends and characteristics of pediatric amputations because of the numerous product-safety measures implemented in recent years, the absence of nationally representative data in previous analyses, and the narrow focus of previous pediatric studies on specific body parts or products. Therefore, we analyzed 13 years of data (1990–2002) from the National Electronic Injury Surveillance System (NEISS) to examine the characteristics of children younger than 18 years old who received emergency treatment for traumatic amputations. To our knowledge, this is the first study to use a nationally representative sample to broadly investigate amputation injuries among children.

METHODS

Data Source

The NEISS is operated by the US Consumer Product Safety Commission (CPSC) to provide timely data on consumer product–related and sports activity–related injuries treated in emergency departments (EDs) in the United States and its territories. The NEISS receives data from a network of 98 hospitals, representing a stratified probability sample of 6100 hospitals with at least 6 beds and a 24-hour ED.[42] The hospital sample was last modified in 1997, including the addition of a separate stratum for children's hospitals. Our data were adjusted by the CPSC to take into account the sample changes. At all 98 hospitals, ED medical records are reviewed by professional NEISS coders, and data regarding patients treated for injuries are entered into the NEISS database. The database is updated daily and includes information regarding patients' age, gender, race, injury diagnosis, body part injured, product(s) involved, treatment received, and a brief narrative describing the incident. Each year, the NEISS provides data on a projected 500 000 injury-related ED visits and allows estimation of the number and epidemiology of such events for the entire nation. Data analyzed in this study were from children with amputation injuries treated in the ED of a hospital participating in the NEISS network from January 1, 1990, to December 31, 2002.

Variables

Traumatic Amputation

Traumatic amputation–related injury cases were identified by using the diagnosis code for amputation (NEISS code 50) and the narrative description of the incident by the NEISS. We defined a traumatic amputation as a traumatic loss of a limb, organ, or part, as stated in Stedman's medical dictionary.[43] We excluded 55 cases that were not true amputations based on the narrative description of the incident (eg, tooth loss, fingernail avulsion, toenail avulsion, or cases incorrectly coded). Cases were categorized further as a "complete" or "partial" amputation based on the narrative description. In 4.1% of cases, the degree of amputation (complete versus partial) was not specified.

Products Involved in Amputation Injury

Products associated with amputation injury were coded according to the product codes used by the NEISS. For the 107 cases with 2 products listed in the NEISS database, researchers read the narrative description of the event and determined which product was primarily involved. For example, for a narrative that reads "child pinched finger in door," we identified the product as "door" instead of "door" and "wall" as recorded by the NEISS. Any product representing a minimum of 5% of total injuries was assigned to its own category. All products representing <5% of total injuries were grouped into broader categories to allow meaningful comparisons. Within a broader category, any product with a minimum of 50 injury cases was identified as a subcategory.

Body Part Injured

The injured body parts reported in this study were identified directly from body-part codes used by the NEISS. Any body part representing a minimum of 30 injury cases was assigned its own category (ie, finger, toe, foot, and hand). Any body part representing <30 injury cases was included in the "other" category (ie, lower arm, upper arm, wrist, lower leg, upper leg, face, mouth, and ear).

Race

Race was not recorded by the NEISS until 2000. Therefore, race was not known for the majority (80.2%) of cases in this study. Because of this, and because interventions to prevent amputation injury are not affected by race, race was not included as a variable during data analyses.

Statistical Analysis

Data analyses were conducted by using SAS 8.02 (SAS Institute, Inc, Cary, NC)[22,44] and SUDAAN 8.0.2 (Research Triangle Institute, Research Triangle Park, NC)[45] software to account for the weighting structures of the NEISS. Experts at the CPSC provided statistical weights for NEISS data that adjust for the inverse probability of selection for each injury episode based on the volume of the specific ED involved and other factors built into the complex design of the surveillance system.[42] The NEISS was designed to project national estimates of injuries associated with specific types of products and activities.[42] The actual sample size reflects unweighted numbers and is clearly identified when presented in this article. All other numbers are national estimates calculated by using the statistical weights. National estimates of amputation injuries were calculated by age, gender, race, and year of injury. National estimates, percentages, and 95% confidence intervals (CIs) were calculated while stratifying by age group and product category. Relationships were examined further by using a χ^2 test and calculating relative risk (RR) with 95% CIs. Linear regression was also used to examine the secular trend in the number of amputation injuries. Findings were considered statistically significant at $P < .05$.

Ethical Considerations

This study was approved by the Columbus Children's Research Institute Institutional Review Board.

RESULTS

Number and Characteristics of Children

An estimated 111 600 children younger than 18 years with amputation injuries were treated in US hospital EDs from 1990 to 2002. The distribution of these patients according to age group, gender, race, and year of injury is shown in Table 1 and according to age and gender in Fig 1. The number of amputation injuries peaked at 1 year of age (~20 300 injuries during the 13-year study period) and steadily declined to 7 years old (~3900 injuries during the 13-year study period), after which the numbers reached a plateau. The average age was 6.2 years (median: 4.0 years). Males experienced 65.6% of injuries. However, females accounted for a higher percentage of injuries among young children and a much lower percentage among adolescents. Among individuals with recorded race, white children experienced 64.2% of the injuries, and black children sustained 18.3% of the injuries. A linear model of the total number of amputations regressed on year resulted in slope B = −268.95 ($P = .006$), thus demonstrating a trend of decreasing numbers of amputations from 1990 to 2002 (Fig 2).

Characteristics According to Age Group

Partial amputations accounted for proportionally more amputation injuries among 0- to 2-year-olds (43.8%), with a steady decline in this proportion throughout childhood (38.6% for 3- to 5-year-olds, 37.4% for 6- to 12-year-olds, and 25.5% for 13- to

TABLE 1. Characteristics of Children With Amputation Injuries for the Actual Sample and National Estimates: United States, 1990–2002

	Actual Sample		National Estimates	
	N	%	*N*	%
Total	3393	100.0	111 621	100.0
Age, y				
0–2	1296	38.2	39 193	35.1
3–5	752	22.2	23 612	21.2
6–12	850	25.0	28 433	25.5
13–17	495	14.6	20 384	18.3
Gender				
Male	2161	63.7	73 145	65.5
Female	1231	36.3	38 410	34.4
Not specified	1	0.0	67	0.1
Year				
1990	137	4.0	7322	6.6
1991	198	5.8	8872	8.0
1992	209	6.2	6168	5.5
1993	248	7.3	10 236	9.2
1994	258	7.6	8978	8.0
1995	207	6.1	8829	7.9
1996	231	6.8	11 417	10.2
1997	304	9.0	9699	8.7
1998	299	8.8	8204	7.4
1999	284	8.4	9627	8.6
2000	340	10.0	7393	6.6
2001	369	10.9	8151	7.3
2002	309	9.1	6725	6.0

Source: NEISS, 1990–2002.

17-year-olds) (Table 2). Accordingly, complete amputations followed the opposite trend, with adolescents having the highest proportion (70.2%) of complete amputations and 0- to 2-year-olds having the lowest proportion (52.6%) ($P < .001$). Disposition from the ED was consistent with this pattern. The youngest age group had the highest percentage of children treated and released (86.9% for 0- to 2-year-olds compared with 70.7% for 13- to 17-year-olds; $P < .001$). The oldest age group had the highest percentage of children admitted to the hospital (26.6% for 13- to 17-year-olds compared with 11.9% for 0- to 2-year-olds; RR: 2.25; 95% CI: 1.63–3.09).

For all ages, the vast majority (91.6%) of amputation injuries were to a finger, although 0- to 2-year-olds had a significantly ($P < .01$) higher percentage of finger amputations (95.2% of all injuries compared with 87.9% for 13- to 17-year-olds; RR: 1.08; 95% CI: 1.03–1.14). The percentage of amputations involving doors peaked in the youngest age group and decreased as age increased (65.8% of all injuries for 0- to 2-year-olds, 54.4% for 3- to 5-year-olds, 47.7% for 6- to 12-year-olds, and 14.1% for 13- to 17-year-olds). Children 0 to 2 years old were 4.68 (95% CI: 3.71–5.90; $P < .001$) times more likely to sustain a door-related amputation compared with the 13- to 17-year-old age group. Lawn mowers were associated with proportionally more amputations among adolescents and proportionally fewer with decreasing age (14.1% for 13- to 17-year-olds compared with 6.8% for 6- to 12-year-olds, 5.0% for 3- to 5-year-olds, and 1.4% for 0- to 2-year-olds). In fact, adolescents were 10.30 (95% CI: 3.55–29.88; $P < .001$) times more likely to be treated for a lawn mower–related amputation than children 0 to 2 years old. Although adolescents represented 44.2% of lawn mower–related amputations, the average age of children with lawn mower injuries was 9.3 years. Adolescents were also 11.72 (95% CI: 6.33–21.72; $P < .001$) times more likely to be treated for a tool-related injury than children 0 to 2 years old. Bicycle-related amputations accounted for proportionally more injuries among the intermediate age groups (8.1% for 3- to 5-year-olds and 9.8% for 6- to 12-year-olds compared with 5.1% for 0- to 2-year-olds and 6.7% for 13- to 17-year-olds). Amputations involving household items remained relatively stable across the age groups (accounting for 16.5% of all amputations among 0- to 2-year-olds, 13.7% among 3- to 5-year-olds, 16.4% among 6- to 12-year-olds, and 15.3% among 13- to 17-year-olds).

Products Associated With Amputation Injury

Table 3 presents details regarding the body part amputated, type of amputation, and disposition from the ED for each product category. Doors accounted for the majority (49.3%) of amputations, and 99.0% of door-related injuries were to the finger. Among children with door-related amputations with a recorded location of injury, 79.7% occurred in the home and 11.8% occurred at school. Doors were associated with the highest proportion of partial amputations (43.3%), and almost all children with door-related amputations were treated and released (90.7%). In contrast, 51.9% of children with lawn mower–related amputations required admission to the hospital, which was significantly more than other products combined ($P < .001$). The RR for hospitalization for lawn mower–related injuries was 3.41 (95% CI: 2.64–4.41) when compared with all other sources of injuries. Lawn mowers had the highest proportion of toe and foot amputations of all products (37.8% to the toe and 14.2% to the foot; $P < .001$; RR: 12.33; 95% CI: 9.28–16.40). Of all lawn mower–related amputations for which the type of lawn mower was known, 70.4% involved a ride-on lawn mower. Bicycles had the highest proportion of complete amputations (73.4%) when compared with other products. The majority of these injuries occurred to fingers while the injured person was trying to fix a chain, playing with the gear-changing mechanism, or reaching down for something while riding. Power saws accounted for 17.8% (1545 of 8695) of tool-related amputation injuries during the 13-year study period. Children with amputations related to power saws were 2.93 (95% CI: 1.91–4.48; $P < .01$) times more likely to be hospitalized than those with amputations associated with other products; 50.3% (95% CI: 29.4–71.1%) of children with power saw–related injuries were hospitalized compared with 17.2% (95% CI: 14.3–20.6%) of children with amputations related to other sources. A higher proportion of power saw–related amputations were complete (77.3% [95% CI: 56.6–89.9%]) compared with amputations associated with all other products combined (60.4% [95% CI: 56.6–64.0%]); however, this difference was not statistically significant.

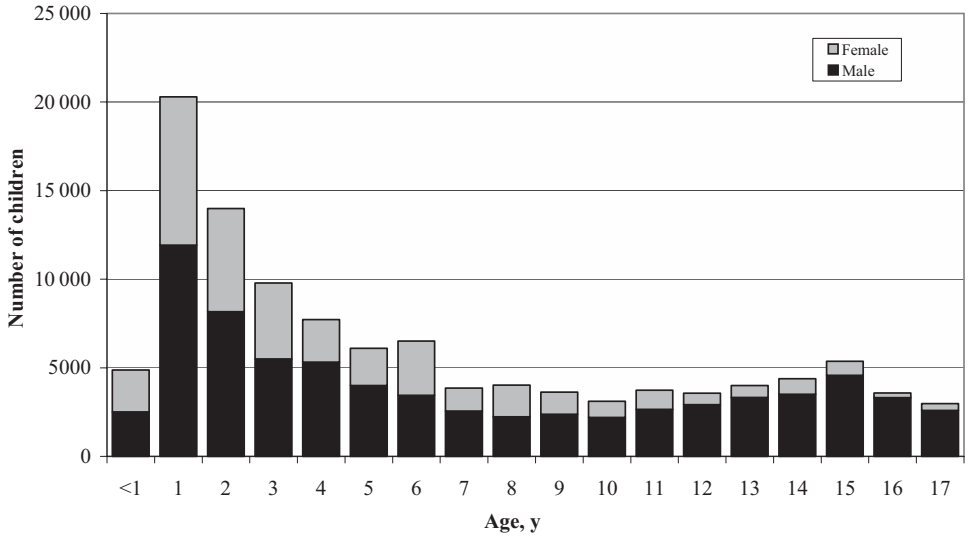

Fig 1. Number of children with amputation injuries according to age and gender: United States, 1990–2002.

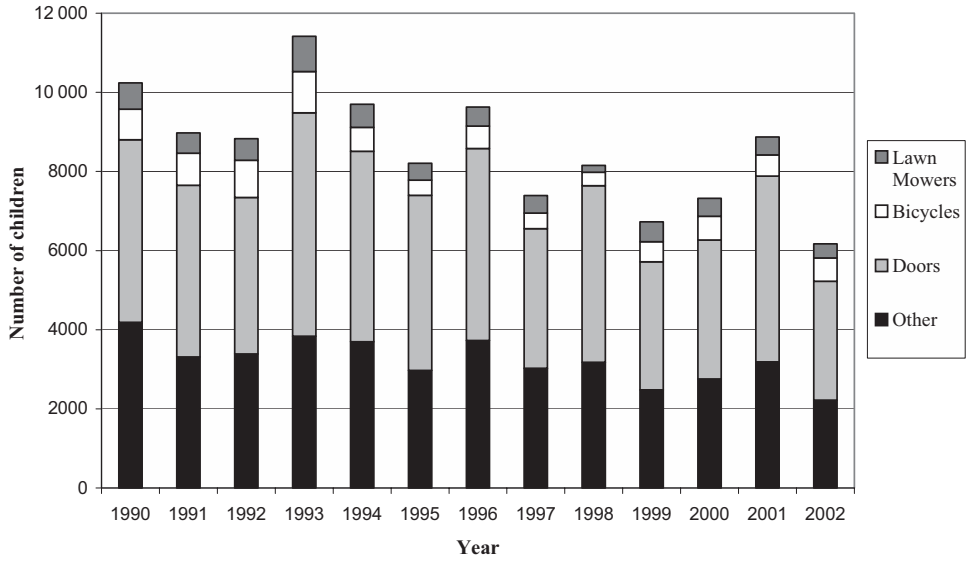

Fig 2. Number of children with amputation injuries according to year of injury and product involved: United States, 1990–2002.

DISCUSSION

This study identified several age- and product-specific patterns among children with traumatic amputation injuries. There was a decrease in the annual number of children with amputation injuries during the study period, which is consistent with previous findings.[40] The majority of these injuries occurred to young children, to males, and to fingers and involved doors. The youngest age group (0–2 years) had the highest proportion of finger amputations and amputations related to doors. The vast majority of these injuries were partial amputations and did not require hospitalization. In contrast, adolescents had the highest proportion of complete amputations and hospital admissions. They also had the highest proportion of injuries involving lawn mowers and tools, including saws, compared with other age groups.

The preponderance of door-related finger injuries among young children in our study and others[9,32,46] is likely related to the easy accessibility of doors, the developmental stage of exploring toddlers, and the role of other children. More than three quarters of all door-related amputations in our study occurred in the home. Doors are in every room of a home, where toddlers and young children spend the majority of their time. These children are eager to explore their world and often move with fingers first yet lack perception of their limitations and risks. In addition, siblings and other children often contribute to these injuries. One study reported that another child shut the door in 47% of pediatric door-related finger injuries, and the majority of the involved doors were in the living room or bathroom.[9] Children may be playing in these common rooms and not realize the proximity of another child's digits to the door that they are closing.

There are several methods for prevention of door-related finger amputations. A doorstop can be placed above children's reach on doors to prevent the door from completely closing. Hanging a towel over the top of the door at the hinge side while children are

TABLE 2. The Number and Percentage of the Type of Amputation, Body Part Injured, Product Involved, and ED Disposition According to Age Group for Children With Amputation Injuries: United States, 1990–2002

	0–2 y		3–5 y		6–12 y		13–17 y		Total (0–17 y)	
	N	% (95% CI)	*N*	% (95% CI)	*N*	% (95% CI)	*N*	% (95% CI)	*N*	% (95% CI)
Total injuries	39 193	35.1 (32.5–37.8)	23 612	21.1 (19.1–23.3)	28 433	25.5 (23.0–28.1)	20 384	18.3 (15.8–21.0)	111 622	100.0 (—)
Type of amputation										
Complete	20 615	52.6 (47.6–57.5)	13 476	57.1 (51.3–62.6)	16 457	57.9 (53.3–62.3)	14 317	70.2 (64.9–75.1)	64 865	58.1 (54.6–61.5)
Partial	17 167	43.8 (39.0–48.7)	9131	38.6 (33.1–44.6)	10 641	37.4 (32.5–42.6)	5195	25.5 (21.0–30.5)	42 134	37.8 (34.1–41.5)
Not specified	1411	3.6 (2.0–6.4)	1005	4.3 (2.3–7.7)	1336	4.7 (2.9–7.6)	872	4.3 (2.3–7.9)	4623	4.1 (2.6–6.4)
Body part injured										
Finger	37 312	95.2 (93.0–96.7)	21 114	89.4 (85.7–92.3)	25 924	91.2 (87.9–93.6)	17 907	87.9 (82.9–91.5)	102 257	91.6 (90.0–93.0)
Toe	1449	3.7 (2.3–5.8)	1675	7.1 (5.0–10.0)	1814	6.4 (4.5–9.1)	1904	9.3 (6.1–14.1)	6842	6.1 (5.00–7.6)
Foot	87	0.2 (0.1–0.7)	593	2.5 (1.3–4.7)	206	0.7 (0.2–2.3)	83	0.4 (0.1–1.5)	969	0.9 (0.5–1.4)
Hand	35	0.1 (0–0.3)	40	0.2 (0–1.0)	177	0.6 (0.2–1.8)	180	0.9 (0.4–2.2)	432	0.4 (0.2–0.7)
Other*	310	0.8 (0.3–1.9)	189	0.8 (0.2–2.8)	311	1.1 (0.5–2.3)	310	1.5 (0.6–3.9)	1120	1.0 (0.6–1.6)
Product involved										
Doors	25 772	65.8 (61.6–69.7)	12 872	54.4 (48.6–60.4)	13 572	47.7 (42.7–52.8)	2864	14.1 (11.1–17.7)	55 079	49.3 (45.7–53.0)
Lawn mowers	535	1.4 (0.5–3.6)	1170	5.0 (2.9–8.4)	1920	6.8 (4.7–9.7)	2866	14.1 (10.3–19.0)	6491	5.8 (4.5–7.5)
Bicycles	1995	5.1 (3.7–7.0)	1907	8.1 (5.8–11.2)	2800	9.8 (7.3–13.2)	1375	6.7 (4.4–10.2)	8077	7.2 (6.0–8.7)
Tools	979	2.5 (1.4–4.4)	858	3.6 (2.1–6.2)	1886	6.6 (4.4–9.9)	5972	29.3 (23.2–36.2)	8695	8.7 (6.9–10.9)
Household	6504	16.5 (14.1–19.4)	3228	13.7 (10.1–18.3)	4655	16.4 (13.5–19.7)	3096	15.3 (11.9–19.2)	17 483	15.6 (14.1–17.3)
Sports equipment and toys	2599	6.6 (4.8–9.1)	2704	11.5 (8.5–15.3)	2643	9.3 (6.9–12.5)	2347	11.5 (8.2–15.9)	10 293	9.2 (7.8–10.9)
Miscellaneous	808	2.1 (1.3–3.2)	872	3.7 (2.2–6.2)	957	3.4 (2.0–5.6)	1864	9.2 (6.2–13.4)	4501	4.0 (3.2–5.1)
ED disposition										
Treated and released	34 066	86.9 (82.8–90.2)	19 093	80.9 (76.2–84.8)	22 833	80.3 (75.2–84.6)	14 401	70.7 (63.3–77.0)	90 393	81.0 (77.4–84.2)
Admitted to hospital	4646	11.9 (8.7–15.9)	4274	18.1 (14.3–22.7)	5023	17.7 (13.8–22.3)	5426	26.6 (20.9–33.2)	19 369	17.3 (14.4–20.7)
Other†	480	1.2 (0.6–2.6)	245	1.0 (0.4–2.6)	577	2.0 (1.0–3.9)	557	2.7 (1.4–5.3)	1858	1.7 (1.1–2.6)

* The "other" category (body part) includes body parts with <30 actual cases, specifically the lower arm, upper arm, wrist, lower leg, upper leg, face, mouth, and ear.
† The "other" category (ED disposition) includes children held for observation with no record of whether they were released or admitted and children with missing data regarding disposition.
Source: NEISS, 1990–2002.

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TABLE 3. Number and Percentage of Body Part Injured, Type of Amputation, and ED Disposition According to Product Category for Children With Amputation Injuries: United States, 1990–2002

	Doors		Lawn Mowers		Bicycles		Tools		Household		Sports Equipment/Toys		Miscellaneous	
	N	% (95% CI)	*N*	% (95% CI)	*N*	% (95% CI)	*N*	% (95% CI)	*N*	% (95% CI)	*N*	% (95% CI)	*N*	% (95% CI)
Total injuries	55 079	49.3 (45.7–53.0)	6492	5.8 (4.4–7.3)	8077	7.2 (5.9–8.6)	9695	8.7 (6.7–10.6)	17 483	15.7 (14.1–17.2)	10 294	9.2 (7.7–10.8)	4501	4.0 (3.1–5.0)
Body part injured														
Finger	54 531	99.0 (98.2–99.5)	2743	42.3 (33.6–51.4)	7038	87.1 (80.2–91.9)	9150	94.4 (88.6–97.3)	16 396	93.8 (91.3–95.6)	8448	82.1 (75.2–87.4)	3951	87.8 (78.9–93.2)
Toe	407	0.7 (0.4–1.5)	2458	37.9 (28.7–48.0)	994	12.3 (7.6–19.4)	139	1.4 (0.3–7.0)	976	5.6 (3.8–8.1)	1531	14.9 (10.1–21.4)	337	7.5 (3.3–16.3)
Foot	0	—	918	14.2 (9.0–21.5)	0	—	0	—	0	—	34	0.3 (0.1–2.4)	17	0.4 (0.1–2.7)
Hand	36	0.1 (0.0–0.2)	138	2.1 (0.6–7.7)	0	—	118	1.2 (0.3–4.7)	34	0.2 (0.0–1.4)	42	0.4 (0.1–1.4)	64	1.4 (0.5–3.6)
Other*	105	0.2 (0.1–0.7)	234	3.6 (1.2–10.0)	45	0.6 (0.1–3.8)	289	3.0 (1.0–8.3)	77	0.4 (0.1–1.5)	239	2.3 (0.8–6.9)	132	3.0 (0.8–9.7)
Type of amputation														
Complete	28 788	52.3 (47.6–57.0)	4196	64.6 (55.3–73.0)	5930	73.4 (65.9–80.0)	6663	68.7 (60.1–76.2)	10 295	58.9 (52.0–65.4)	6458	62.7 (55.2–69.7)	2535	56.3 (43.0–68.8)
Partial	23 885	43.4 (38.2–48.6)	2142	33.0 (24.7–42.5)	1847	22.9 (17.0–30.0)	2651	27.4 (20.4–35.7)	6599	37.8 (31.7–44.2)	3248	31.6 (25.1–38.8)	1762	39.1 (27.0–52.8)
Not specified	2407	4.4 (2.6–7.0)	154	2.4 (0.0–6.8)	299	3.7 (1.3–10.1)	381	3.9 (1.6–9.3)	589	3.4 (1.6–6.9)	588	5.7 (2.2–13.9)	205	4.6 (1.3–15.1)
ED disposition														
Treated and released	49 959	90.7 (87.8–93.0)	2611	40.2 (31.1–50.1)	6583	81.5 (73.6–87.4)	6243	64.4 (54.1–73.5)	15 080	86.3 (81.2–90.1)	6963	67.6 (59.2–75.1)	2955	65.6 (54.3–75.5)
Admitted to hospital	4807	8.7 (6.5–11.6)	3367	51.9 (41.5–62.1)	1460	18.1 (12.2–26.0)	3181	32.8 (24.1–42.9)	2156	12.3 (8.6–17.4)	2890	28.1 (21.2–36.2)	1509	33.5 (23.8–44.9)
Other†	314	0.6 (0.2–1.4)	514	7.9 (3.5–17.1)	34	0.4 (0.1–3.1)	271	2.8 (1.3–6.1)	247	1.4 (0.6–3.2)	441	4.3 (2.0–9.2)	38	0.8 (0.2–2.9)

* The "other" category (body part) includes body parts with <30 actual cases, specifically the lower arm, upper arm, wrist, lower leg, upper leg, face, mouth, and ear.
† The "other" category (ED disposition) includes children held for observation with no record of whether they were released or admitted and children with missing data regarding disposition.
Source: NEISS, 1990–2002.

playing will also prevent unintentional door closing and injury. In Australia, a plastic covering device is available that fits vertically along the hinge side of the door and door frame and prevents access to the closing surfaces. In Denmark, a "pinch-free" door design is on the market that has a rubber seal along the hinge side of the door that is displaced when fingers are caught between closing surfaces and prevents injury.[32]

Our findings regarding bicycle-related amputations are consistent with multiple studies indicating that school-aged children are at the highest risk for such injuries.[47–50] Our data also showed that bicycle-related amputations are more often complete than amputations associated with any other product. The majority of these injuries were to fingers, with some toe injuries. Studies from other countries have shown that right big toe amputations are the most common amputation injury among bicycle passengers.[51–53] The toe amputations in our study were likely caused by the same mechanism described previously (ie, the passenger's toe is caught by the chain and led into the sharp teeth of the gears).[51] The NEISS narrative description of bicycle-related finger amputations revealed that these injuries most commonly occurred when a finger was caught in the chain or spokes of the bicycle. Frequently, the injured person was trying to fix a chain, playing with the gear-changing mechanism, or reaching down for something while riding. Prevention strategies include the use of chain and spoke guards to shield against inadvertent access by fingers and toes, as well as not wearing open-toed footwear while riding.

The American Academy of Pediatrics has highlighted the incidence and severity of lawn mower–related injuries to children and recommends that children not operate walk-behind mowers until they are 12 years old or riding mowers until they are 16 years old. The American Academy of Pediatrics also recommends that children younger than 6 years be kept inside while mowers are in operation.[12] Despite these recommendations, more than half of the lawn mower–related amputations in our study occurred to children younger than 12 years. It is interesting to note that the average age of children with lawn mower–related amputations in our study was 9.3 years, which is older than the average age of 4.5 to 6.8 years reported in earlier studies.[2,8,14,15,20] Lawn mowers were associated with more severe injuries than any other product in our study. They caused the largest number of toe and foot amputations and had the highest proportion (51.9%) of injuries requiring hospitalization. This result is consistent with previous research that has shown that the majority of lawn mower–related injuries are to the toes, feet, or ankles[2,8,18] and that the hospital admission rate is higher than that for injuries associated with other consumer products overall.[19]

Automatic, or "passive," protection provided by safe product design is the most effective strategy for prevention of lawn mower–related injuries. Design modifications to better prevent toes and feet from penetrating under the mower and into the path of the rotating blades should be considered. Mower blades with less mass and altered cutting characteristics would also minimize tissue damage when inadvertent human contact occurs. To help prevent severe injuries when a child is backed-over by a ride-on lawn mower, all of these mowers should have a no-mow-in-reverse (NMIR) default feature with a manual override option. The NMIR feature disengages the blades when the mower is shifted into reverse gear, and an override switch allows the operator to reengage the blades if desired. The manual override switch is located in front of the mower operator (eg, on the front control panel of the mower) on those models that have this feature. However, manufacturers should locate the override switch on either the posterior wheel well or behind the operator's seat, which would force the operator to look behind the mower and facilitate recognition of potential bystanders before disengaging the NMIR safety feature. Equipping all ride-on lawn mowers with an NMIR default feature and locating the NMIR override switch behind the operator should be incorporated as requirements in the voluntary lawn mower safety standard ANSI/OPEI B71.1.[54]

Power saw–related amputations were also often severe and were associated with the second highest hospital admission rate (50.3%) among products in this study, second only to lawn mower–related amputations. An innovative amputation-prevention system is currently available for power saws called the SawStop system.[55] The SawStop system works by recognizing a change in an electrical signal on the saw blade when it contacts a user's body, bringing the blade to a stop within 5 milliseconds. This system is a model for passive prevention through product design modification. SawStop was awarded the CPSC Chairman's Commendation in 2001 for developing this innovative safety technology.[56]

Several methodologic limitations exist in our study. First, the NEISS only captures injuries serious enough to require treatment in an ED. Therefore, our findings may not be representative of injuries treated in other health care settings or injuries that do not receive medical attention. The NEISS database also does not contain a direct indicator of severity. However, we were able to use data regarding hospital admission and complete versus partial amputation to estimate severity. In addition, injury rates were not possible to calculate because of the lack of data regarding exposure to risk.

CONCLUSIONS

To our knowledge, this is the first study to use a nationally representative sample to broadly investigate amputation injuries among children. The majority of traumatic amputation injuries occur to young children, to males, and to fingers and involve doors. Adolescents experience a higher proportion of more serious amputation injuries. Effective interventions exist but are inadequately used to prevent many of these injuries, including door stops and modifications, bicycle-chain and spoke guards, wearing closed-toe footwear while bicycling, an NMIR default feature on ride-on lawnmowers with the override switch located behind the mower operator, and

a SawStop system on power saws. Use of these technical countermeasures and changes in relevant product standards to promote their implementation and use could lead to a decrease in pediatric traumatic amputations.

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Characteristics of Pediatric Traumatic Amputations Treated in Hospital Emergency Departments: United States, 1990–2002

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