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All-terrain vehicle use related fracture rates, patterns, and associations from 2002 to 2015 in the USA

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ABSTRACT

Background: Since their introduction to USA markets in the late 20th century, all-terrain vehicles (ATVs) have been a significant source of trauma. Many paediatric studies have demonstrated the disproportionate rate in which minors are affected by ATV-related trauma, but no studies have been performed on a large sample size spanning all age and geographic ranges. This study is the first to analyze ATV-related fracture rates, patterns, and associated risks across all ages nationwide.

Methods & statistical analysis: The National Electronic Injury Surveillance System (NEISS) was queried for ATV-related trauma for the years 2002–2015. The data were analyzed by age, sex, race, alcohol usage, helmet usage, type of injury, fracture location, and disposition from the emergency department (ED). Continuous data were analyzed using the *t*-test (2 groups) or ANOVA (≥3 groups). Discrete data were analyzed using χ^2 tests. SUDAAN 10™ software was used to account for the stratified and weighted nature of the data. Significance was set at $p < 0.05$.

Results: There were an estimated 1,862,342 ED visits for ATV-related injuries from 2002 to 2015; 482,501 (25.9%) sustained fractures with a mean age of 27.5 years. Among those with fractures, 75.7% were male, 28.5% resulted in hospital admission, 43.9% occurred at home, and 57.5% were unhelmeted. Anatomically, 51.8% involved the upper extremity, 23.6% involved the lower extremity, 6.4% involved the spine, 8.5% involved the skull/face, and 9.7% involved the ribs/sternum. Alcohol use was most frequently associated with skull (13.2%) and cervical spine (13.0%) fractures. Patients with skull or facial fractures were unhelmeted 88% of the time, and 87% of skull fractures were associated with brain injury. ATV-related fractures peaked in 2007 at 44,283 and trended downward through 2014.

Conclusion: This study is the first of its kind to analyze ATV-related trauma over all age groups throughout the entire USA. It can serve as a reference for clinical decision-making and future studies. It also reinforces the need for ATV regulation advocacy, specifically helmet use.

Background

All-terrain vehicles (ATVs) were introduced to USA markets in 1970 and quickly gained popularity for both recreational and agricultural use [1]. Low-pressure tires allowed for high maneuverability in a variety of terrains, and relatively small engines used considerably less fuel than tractors [1]. The U.S. Consumer Product Safety Commission (CPSC) estimated 400,000 ATVs were in use in 1985. This climbed to 1.8 million in 1990, 4.2 million in 2000, and 10.6 million by 2010 [2]. As ATV advertising, sales, and power increased over time, mortality followed [3–6]. The CPSC reported 29 ATV-related deaths in 1982, 235 in 1990, 445 in 2000, and 832 in 2007 before declining to 573 in 2012 [7].

In response to ever-increasing rates of morbidity and mortality in the 1970's and 1980's, the CPSC sued ATV manufactures to bring about the federally mandated "1988 Consent Decrees" [8]. Although their effectiveness was debatable, the "1988 Consent Decrees" did help decrease the epidemic's pace [5–7,9,10]. The legislation's 1998 expiration resulted in a nonbinding "All-Terrain Action Plan" made between ATV manufacturers and the CPSC [8] which ultimately led to a substantial increase in ATV-related injuries [9–13]. ATV regulations are now primarily enacted and enforced at the state level [14–18]. This has led to large variability in ATV usage laws across the country [14].

Many studies have been performed on the paediatric population because they are disproportionately affected by ATV-related trauma [12,19–31]. While children <16 years of age account for just

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17% of riders, they account for 31% of injuries, and often times, their injuries are more life-threatening [32]. Prior studies have reported fracture rates and locations, gender ratios, and alcohol/helmet use, but are limited by sample size, age range, and/or geographic breadth [3,12,19–31,33,34]. The main objective of this study is to describe fractures associated with ATV-related injuries using the National Electronic Injury Surveillance System (NEISS) database across the entire USA and all ages. Secondary objectives include describing associated internal injuries and the role of alcohol and helmet use in ATV-related injuries. This study can serve as a reference for clinical decision-making and future studies.

Methods

This study was considered exempt by our local IRB. The NEISS database collects data from a probability sample of approximately 100 hospitals reflecting the current distribution of USA hospitals [35]. Each hospital reports information for every consumer product-associated patient injury treated in the emergency department (ED) along with demographic patient information and contributing factors (alcohol use, helmet use, etc.) [35]. Sampled hospitals have at least six beds, an ED, and are located within the USA or its territories [35]. Psychiatric and penal institutions are excluded [35]. The probability sample is split into five strata (based on self-reported ED volume): small, medium, large, very large, and children's hospitals [35]. Hospitals' statistical weights, rather than raw case counts, are used to obtain national estimates of injuries and associated demographics [35]. The NEISS database, its coding manual, data acquisition information, and further details can be openly found at https://www.cpsc.gov/Research–Statistics/NEISS-Injury-Data.

We queried the NEISS database for ATV associated injuries for the years 2002 through 2015. We included three-wheeled ATVs (NEISS code 3285), four-wheeled ATVs (NEISS code 3286), >four-wheeled ATVs excluding dune buggies (NEISS code 3296), and ATVs with an unspecified number of wheels (NEISS code 3287). The data were downloaded into a Microsoft Excel® 2011 file for further analysis. Narrative accounts (a feature added to NEISS data in 2002) were searched to determine alcohol use, helmet use, and mechanism of injury (riding or struck by the ATV) by using the FIND command in Excel®. All data were analyzed by anatomic location/type of injury (fracture, internal organ injury, head injury), age, sex, race, alcohol use, helmet use, and disposition from the ED (home, admission, fatality). Geographic location was subdivided into home (personal residence, mobile home, personal land, farm, ranch), street/highway, public property, recreational sports/school, and industrial. Race was classified as white, black, Amerindian (Hispanic and Native American), Indo-Malay (Asian origins), and Indo-Mediterranean (Middle East and Indian subcontinent) [36].

Various levels of analysis were used to subdivide specific fracture locations. At the broadest level, the groups were the axial skeleton, upper extremities, and lower extremities. Axial fractures included the spine and non-spine (head and trunk). At more detailed levels of analysis, the spine was divided into the cervical (CS), thoracic (TS), lumbar (LS), and sacrococcygeal spine; the head into skull and face; the trunk into ribs and sternum; the upper extremity into clavicle, scapula, humerus, elbow, radius/ulna, wrist, hand, and finger; and the lower extremity into pelvis, hip, femur, knee, tibia/fibula, ankle, foot, and toe. These anatomical groupings were also used when comparing fracture rates within the literature to those in this study. Internal organ injury was subdivided into brain, thorax, abdomen, combined brain/thorax, and combined brain/abdomen. Head injuries included all diagnoses of closed head injuries, concussions, or traumatic brain injuries.

Statistical analysis

SUDAAN 10™ software (2008, RTI International, Research Triangle Park, NC) was used to account for the stratified and weighted nature of the NEISS data. The software calculates an estimated value for a particular parameter over a finite population [37]. The NEISS sampling frame serves as a finite population sampling of USA hospitals. from 2002 to 2015, the exact number of NEISS reporting hospitals ranged from 77 to 98 [38]. NEISS weights are adjusted monthly to account for non-reporting and hospitals that go out of business [38]. Each hospital's statistical weight is equal to the inverse of the probability of selection for the hospital in each stratum, or simply the total number of hospitals in the sampling frame divided by the total number of NEISS hospitals at the stratum level [35].

The mathematical details of such analyses are given below. From the weighted values, the estimated number of ED visits is calculated using the following formula [35]:

$$\text{Estimate} = \sum_{i=1} wgt_i x_i$$

where: wgt_i = weight of hospital i for the month; x_i = number of cases for a specified product or type of injury reported by hospital i for the given month

Except for unique weights of merged hospitals, the weights of the hospitals are the same within a stratum and thus the equation can be written as [35]:

$$\text{Estimate} = \sum_{h=1}^{m} \sum_{i=1}^{r_h} \left(\frac{N_h n'_h}{n_h r_h}\right) R_h * x_{hi}$$

where: m = Number of strata in the NEISS sample during the given time period; N_h = Number of hospitals in the NEISS sampling frame for stratum h; n_h = Number of hospitals selected for the NEISS sample for stratum h; n'_h = Number of in-scope hospitals in the NEISS sample for stratum h; r_h = Number of NEISS hospitals participating for stratum h for the given month; R_{h^*} = Ratio adjustment factor for stratum h for the given month; x_{hi} = Number of cases for a specified product or type of injury reported by hospital i in stratum h for the given month

The factor N_h/n_h is the basic weight associated with each hospital in stratum h [35]. Adjustments to the weights are made for nonresponse hospitals in the case of hospital mergers or closures [35]. The factor n'_h/r_h adjusts each hospital in each stratum for the lack of participation of one or more hospitals, when necessary [35]. This adjustment is typically very small (multiplicative factor ranging from 1.0 to 1.031) [35]. Monthly estimates are summed to derive annual estimates [35].

Continuous data were reported as the mean and categorical data as frequencies/percentages. Given the weighted nature of the data, the median with 20th and 80th percentiles (representing 60% of the data about the median) are reported in tables, which is relatively equivalent to ± one standard deviation about the mean (which represents ~68% of data). SUDAAN 10 does not readily describe/calculate a standard deviation, but readily calculates deciles around the median of the estimated values; for this reason we are using the above descriptors of variation around the median, and not the standard deviation of the mean. The t-test (2 groups) or ANOVA (≥3 groups) was used for analyses between groups of continuous data. The χ^2 test was used for analyses between groups of discrete data. A p value <0.05 was considered statistically significant.

Results

There were an estimated 1,862,342 ED visits for ATV-related injuries from 2002 to 2015; 482,501 (25.9%) sustained fractures. ED

visits due to ATV-related injuries of all types and fractures peaked in 2007 and declined through 2014 (Fig. 1). Fractures involved the extremities in 75.4% of patients; 78.5% were male, 45.4% presented to small hospitals, and 43.9% occurred at home (Table 1). There were 249,745 (51.8%) upper extremity fractures; 114,022 (23.6%) lower extremity fractures; 31,021 (6.4%) spine fractures; 40,876 (8.5%) skull/face fractures; and 46,837 (9.7%) rib/sternum fractures. Within the upper extremity fracture group (Table 2), the clavicle (25%), radius/ulna (21%), and wrist (20%) were the most frequent locations. Among lower extremity fractures (Table 3), tibia/fibula (34%) and ankle (21%) were the most frequent locations. Axial fractures were grouped by spine and non-spine (Table 4). Among spine fractures, lumbar fractures were the most frequent (39.7%) and sacrococcygeal the least (11.8%).

Age of patients

The mean age of those with fractures was 27.5 years. Patients <25 years accounted for >50% (250,626) of all fractures (e.g. age 0–14 years; 117,224 and 15–24 years; 133,402; Fig. 2). Patients with spine and rib/sternum fractures were older (34.7 and 41.9 years, respectively) compared to those with upper extremity (24.3 years),

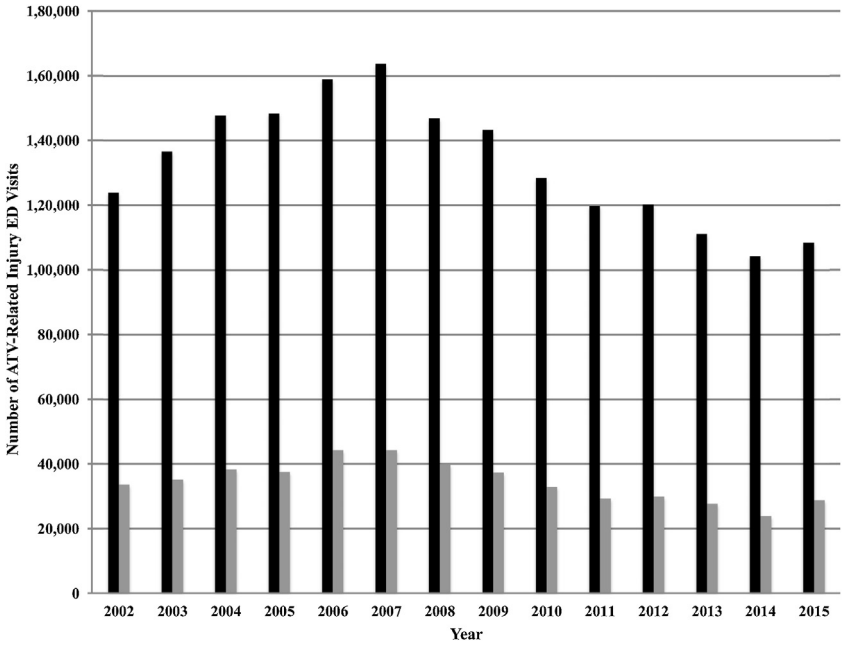

Fig. 1. Yearly number of patients with ATV-related injuries and fractures presenting to USA emergency departments from 2002 to 2015. The gray bars represent patients with fractures, and the black bars represent patients with all types of injuries.

Table 1
Demographics of all fractures from ATVs*.

		n (%)						
		All Fractures	UE	LE	Axial			*p* value
					Spine	Skull/Face	Rib/Sternum	
	n (%)†	482,501 -	249,745 (51.8)	114,022 (23.6)	31,021 (6.4)	40,876 (8.5)	46,837 (9.7)	-
	Mean Age (years)	27.5	24.3	27.3	34.7	26.0	41.9	<0.0001
	Median (years) [20th,80th%]	23.0 [13.1,41.1]	19.6 [11.7,36.4]	22.7 [13.1,39.9]	31.2 [19.7,47.8]	22.0 [13.2,37.7]	41.3 [27.4,54.7]	-
Hospital Size	Small	219,070 (45.4)	120,711 (48.3)	49,326 (43.3)	11,543 (37.2)	15,292 (37.4)	22,198 (47.4)	<0.0001
	Medium	89,342 (18.5)	53,387 (21.4)	20,416 (17.9)	4,132 (13.3)	3,634 (8.9)	7,773 (16.6)	
	Large	100,717 (20.9)	43,459 (17.4)	24,942 (21.9)	9,105 (29.4)	12,744 (31.2)	10,467 (22.3)	
	Very Large	67,425 (14.0)	29,050 (11.6)	17,529 (15.4)	6,062 (19.5)	8,444 (20.7)	6,340 (13.5)	
	Children's	5,947 (1.2)	3,138 (1.3)	1,809 (1.6)	179 (0.6)	761 (1.9)	60 (0.1)	
Age	0 to 14	117,015 (24.3)	77,085 (30.9)	27,822 (24.4)	1,302 (4.2)	9,687 (23.7)	1,119 (2.4)	<0.0001
	15 to 24	133,157 (27.6)	74,071 (29.7)	32,668 (28.7)	8,733 (28.2)	12,709 (31.1)	4,976 (10.6)	
	25 to 34	87,039 (18.0)	41,109 (16.5)	20,900 (18.3)	7,237 (23.3)	7,525 (18.4)	10,268 (21.9)	
	35 to 44	65,751 (13.6)	29,852 (12.0)	14,921 (13.1)	5,127 (16.5)	5,560 (13.6)	10,291 (22.0)	
	45 to 54	45,022 (9.3)	16,663 (6.7)	9,990 (8.8)	4,950 (16.0)	3,144 (7.7)	10,275 (21.9)	
	55 to 64	21,391 (4.4)	7,002 (2.8)	4,552 (4.0)	2,162 (7.0)	1,860 (4.6)	5,815 (12.4)	
	65+	13,096 (2.7)	3,964 (1.6)	3,169 (2.8)	1,510 (4.9)	360 (0.9)	4,093 (8.7)	
Sex	Male	365,421 (75.7)	186,811 (74.8)	87,945 (77.1)	22,953 (74.0)	30,315 (74.2)	37,397 (79.8)	0.0021
	Female	117,009 (24.3)	62,863 (25.2)	26,077 (22.9)	8,068 (26.0)	10,561 (25.8)	9,440 (20.2)	
Disposition from the ED	Release	344,135 (71.4)	216,330 (86.7)	67,482 (59.2)	12,678 (41.0)	17,522 (43.0)	30,123 (64.3)	<0.0001
	Admit	137,260 (28.5)	33,109 (13.3)	46,381 (40.7)	18,175 (58.7)	22,898 (56.2)	16,697 (35.7)	
	Fatality	472 (0.1)		31 0.0	85 (0.3)	356 (0.9)		
Geographic Location	Home	117,820 (43.9)	68,528 (49.0)	26,996 (40.4)	5,409 (34.1)	7,505 (35.5)	9,382 (38.4)	0.0016
	Street	43,115 (16.1)	20,924 (15.0)	12,484 (18.7)	2,466 (15.6)	3,994 (18.9)	3,247 (13.3)	
	Public Property	31,222 (11.6)	14,437 (10.3)	8,059 (12.1)	2,174 (13.7)	3,255 (15.4)	3,297 (13.5)	
	School or Recreational Sports	68,970 (25.7)	33,022 (23.6)	17,542 (26.3)	5,359 (33.8)	5,468 (25.9)	7,579 (31.0)	
	Industrial	6,987 (2.6)	3,042 (2.2)	1,661 (2.5)	441 (2.8)	901 (4.3)	942 (3.9)	

UE indicates upper extremity; LE, lower extremity; CHI, closed head injury; TBI, traumatic brain injury.
*p value indicates the differences between upper extremity, lower extremity, spine, skull/face, and rib/sternum for each of the listed variables. The % represents the column percentage for each variable.
†The % represents the row percentage for all locations in total.

Table 2
Upper Extremity Fractures from ATVs*.

		n (%)																p value
		Clavicle		Scapula		Humerus		Elbow		RU		Wrist		Hand		Finger		
	n (%)†	61,532	(24.6)	22,756	(9.1)	17,532	(7.0)	11,724	(4.7)	52,731	(21.1)	51,149	(20.5)	15,809	(6.3)	16,572	(6.6)	-
	Mean Age (years)	28.0		30.5		22.0		21.5		20.1		22.0		25.9		24.8		<0.0001
	Median (years) [20th,80th%]	25.0 [14.7,39.5]		27.9 [15.9,42.7]		14.4 [7.8,35.0]		16.7 [8.7,33.2]		14.3 [9.2,29.3]		17.5 [11.6,31.0]		21.9 [15.2,36.7]		19.7 [12.3,36.1]		
Age	0 to 14	10,280	(16.7)	3,592	(15.8)	8,484	(48.4)	4,933	(42.1)	25,569	(48.5)	17,679	(34.6)	2,277	(14.4)	4,325	(26.1)	<0.0001
	15 to 24	19,107	(31.1)	5,677	(24.9)	3,586	(20.5)	2,796	(23.9)	12,925	(24.5)	18,150	(35.5)	6,417	(40.6)	5,482	(33.1)	
	25 to 34	13,995	(22.7)	4,947	(21.7)	1,621	(9.2)	1,719	(14.7)	5,336	(10.1)	7,005	(13.7)	3,362	(21.3)	3,123	(18.8)	
	35 to 44	9,555	(15.5)	4,246	(18.7)	1,380	(7.9)	1,211	(10.3)	4,624	(8.8)	4,349	(8.5)	2,363	(14.9)	2,123	(12.8)	
	45 to 54	5,919	(9.6)	2,283	(10.0)	1,397	(8.0)	665	(5.7)	2,373	(4.5)	2,317	(4.5)	917	(5.8)	807	(4.9)	
	55 to 64	1,361	(2.2)	1,392	(6.1)	526	(3.0)	298	(2.5)	1,243	(2.4)	1,357	(2.7)	369	(2.3)	377	(2.3)	
	65+	1,314	(2.1)	619	(2.7)	538	(3.1)	100	(0.9)	660	(1.3)	293	(0.6)	105	(0.7)	335	(2.0)	
Sex	Male	52,226	(85.0)	18,684	(82.1)	9,985	(57.0)	7,497	(63.9)	37,890	(71.9)	36,172	(70.7)	12,695	(80.3)	11,720	(70.7)	<0.0001
	Female	9,234	(15.0)	4,072	(17.9)	7,547	(43.0)	4,227	(36.1)	14,840	(28.1)	14,977	(29.3)	3,114	(19.7)	4,852	(29.3)	
Disposition from the ED	Release	55,744	(90.8)	18,439	(81.1)	12,732	(72.6)	9,771	(83.3)	43,873	(83.2)	45,211	(88.6)	15,018	(95.0)	15,449	(93.3)	<0.0001
	Admit	5,667	(9.2)	4,287	(18.9)	4,800	(27.4)	1,953	(16.7)	8,858	(16.8)	5,799	(11.4)	792	(5.0)	1,108	(6.7)	
	Fatality																	
Alcohol Use	Yes	2,290	(3.7)	772	(3.4)	279	(1.6)	197	(1.7)	459	(0.9)	881	(1.7)	389	(2.5)	209	(1.3)	0.0003
	No	59,242	(96.3)	21,985	(96.6)	17,253	(98.4)	11,527	(98.3)	52,272	(99.1)	50,268	(98.3)	15,420	(97.5)	16,363	(98.7)	
Unhelmeted	Yes	4,631	(54.0)	985	(34.4)	830	(39.1)	724	(68.7)	2,492	(43.0)	1,051	(27.9)	307	(32.8)	708	(49.9)	0.0009
	No	3,942	(46.0)	1,877	(65.6)	1,295	(60.9)	330	(31.3)	3,310	(57.0)	2,711	(72.1)	630	(67.2)	710	(50.1)	
Head Injury	Yes	2,968	(4.8)	847	(3.7)	852	(4.9)	314	(2.7)	2,017	(3.8)	1,073	(2.1)	238	(1.5)	424	(2.6)	<0.0001
	No	58,548	(95.2)	21,910	(96.3)	16,680	(95.1)	11,410	(97.3)	50,713	(96.2)	50,076	(97.9)	15,571	(98.5)	16,147	(97.4)	

CHI indicates closed head injury; TBI, traumatic brain injury.
†The % represents the row percentage for all locations in total.
*p value indicates the differences between types of upper extremity fractures (i.e. clavicle, scapula, humerus, etc.) for each of the listed variables. The % represents the column percentage for each variable.

lower extremity (27.3 years), and skull/face (26.0 years) fractures ($p < 0.0001$). Of those with upper extremity fractures, patients with radius/ulna fractures were the youngest (20.1 years) and scapula fractures the oldest (30.5 years, $p < 0.0001$). Of those with lower extremity fractures, femur fractures were the youngest (20.9 years) and hip fractures the oldest (38.5 years, $p < 0.0001$). Of those with axial fractures, patients with rib fractures were the oldest (42.0 years) and skull fractures the youngest (13.9 years, $p < 0.0001$).

Admission rates and associated injuries

The overall admission rate for those with fractures was 28.5% (Table 1). Patients with upper extremity fractures were most likely to be released (86.7%). Those with femur, hip, and pelvis fractures all demonstrated >70% hospital admission rates (85.8%, 83.7%, and 73.4%, respectively; $p < 0.0001$). Patients struck by an ATV accounted for 1.5% of lower extremity fractures compared to 0.9% of upper extremity fractures ($p < 0.0001$). Of those with fractures and internal organ injuries, brain injuries were the most frequent (72.9%; $p = 0.0013$) (Table 5). Brain injury occurred in 87.2% of those with skull fractures.

Alcohol and helmet use

Positive alcohol consumption was reported on 2.7% of all narrative accounts, 3.8% with fractures, and 2.3% without fractures ($p = 0.032$) (Table 5). Alcohol use was most frequently associated with skull (13.2%) and cervical spine (13.0%) fractures ($p = 0.0003$); these fracture populations both demonstrated >80% admission rates ($p < 0.0001$). Those with reported alcohol use were younger than those with no reported alcohol use (25.5 vs 34.3 years, $p < 0.0001$). Of those with fractures, 57.5% were not helmeted. Those with skull or facial fractures were unhelmeted 88% of the time ($p = 0.0009$). Only 11.1% (205,886) of patients had documented helmet status in their NEISS narrative comments.

Discussion

Aside from skin injuries, fractures are often the most common ATV-related injury [21,25–28,31,33,39], particularly in males [19,40]. In this USA-wide analysis, ~1.8 million ATV-related injuries presented to EDs from 2002 to 2015; ~480,000 (25.9%) had at least one fracture. The majority (81.8%) of the fractures

Table 3
Lower Extremity Fractures from ATVs*.

		n (%)								p value
		Pelvis	Hip	Femur	Knee	Tibia/Fibula	Ankle	Foot	Toe	
	n (%)†	9,638 (8.5)	3,355 (2.9)	12,036 (10.6)	5,300 (4.7)	38,250 (33.6)	23,878 (21.0)	14,351 (12.6)	7,108 (6.2)	-
	Mean Age (years)	32.6	38.5	20.9	29.6	26.9	29.2	23.8	27.8	<0.0001
	Median (years) [20th,80th%]	28.2 [16.1,48.3]	34.4 [17.5,57.2]	15.3 [10.7,28.8]	27.9 [16.7,38.2]	21.4 [12.7,40.3]	24.8 [14.3,41.5]	20.7 [12.7,33.4]	26.1 [13.0,41.7]	-
Age	0 to 14	1,269 (13.2)	401 (11.9)	5,039 (41.9)	761 (14.4)	9,976 (26.1)	4,464 (18.7)	4,077 (28.4)	1,721 (24.2)	<0.0001
	15 to 24	3,066 (31.8)	601 (17.9)	3,654 (30.4)	1,004 (18.9)	10,916 (28.5)	6,945 (29.1)	4,851 (33.8)	1,560 (22.0)	
	25 to 34	1,125 (11.7)	645 (19.2)	1,545 (12.8)	1,985 (37.4)	6,580 (17.2)	4,608 (19.3)	2,790 (19.4)	1,622 (22.8)	
	35 to 44	1,745 (18.1)	644 (19.2)	815 (6.8)	833 (15.7)	4,736 (12.4)	3,599 (15.1)	1,424 (9.9)	1,126 (15.8)	
	45 to 54	1,225 (12.7)	349 (10.4)	592 (4.9)	474 (8.9)	3,558 (9.3)	2,176 (9.1)	862 (6.0)	755 (10.6)	
	55 to 64	774 (8.0)	234 (7.0)	211 (1.8)	155 (2.9)	1,576 (4.1)	1,274 (5.3)	234 (1.6)	172 (2.4)	
	65+	435 (4.5)	482 (14.4)	180 (1.5)	89 (1.7)	908 (2.4)	812 (3.4)	113 (0.8)	151 (2.1)	
Sex	Male	6,566 (68.1)	2,792 (83.2)	9,395 (78.1)	4,356 (82.2)	30,763 (80.4)	18,263 (76.5)	10,362 (72.2)	5,344 (75.2)	<0.0001
	Female	3,071 (31.9)	563 (16.8)	2,642 (21.9)	945 (17.8)	7,487 (19.6)	5,615 (23.5)	3,990 (27.8)	1,764 (24.8)	
Disposition from the ED	Release	2,567 (26.6)	546 (16.3)	1,695 (14.1)	4,054 (76.5)	22,056 (57.7)	17,080 (71.9)	12,914 (90.0)	6,604 (92.9)	<0.0001
	Admit	7,071 (73.4)	2,809 (83.7)	10,326 (85.8)	1,246 (23.5)	16,163 (42.3)	6,686 (28.1)	1,438 (10.0)	504 (7.1)	
	Fatality			15 (0.1)		17 (0.0)				
Alcohol Use	Yes	431 (4.5)	208 (6.2)	523 (4.3)	227 (4.3)	1,228 (3.2)	520 (2.2)	85 (0.6)		0.0003
	No	9,207 (95.5)	3,148 (93.8)	11,514 (95.7)	5,074 (95.7)	37,022 (96.8)	23,358 (97.8)	14,266 (99.4)	7,108 (100.0)	
Unhelmeted	Yes	711 (51.6)	184 (32.0)	1,547 (57.7)	285 (60.1)	1,687 (44.1)	815 (56.1)	301 (59.6)	267 (60.7)	0.0009
	No	668 (48.4)	391 (68.0)	1,136 (42.3)	189 (39.9)	2,142 (55.9)	639 (43.9)	204 (40.4)	173 (39.3)	
Head Injury	Yes	753 (7.8)	151 (4.5)	1,038 (8.6)	295 (5.6)	1,020 (2.7)	367 (1.5)	165 (1.1)	77 (1.1)	<0.0001
	No	8,885 (92.2)	3,204 (95.5)	10,999 (91.4)	5,005 (94.4)	37,230 (97.3)	23,511 (98.5)	14,187 (98.9)	7,031 (98.9)	

CHI indicates closed head injury; TBI, traumatic brain injury.
*p value indicates the differences between types of lower extremity fractures (i.e. pelvis, hip, femur, etc.) for each of the listed variables. The % represents the column percentage for each variable.
†The % represents the row percentage for all locations in total.

Table 4
Axial Fractures from ATVs*.

		n (%)								p value
		Spine				Non-spine				
		CS	TS	LS	SC	Skull	Face	Rib	Sternum	
	n (%)†	5,847 (18.8)	9,210 (29.6)	12,347 (39.7)	3,677 (11.8)	12,197 (13.9)	28,679 (32.7)	45,587 (52.0)	1,250 (1.4)	-
	Mean Age (years)	36.0	34.4	35.1	31.8	22.9	27.3	42.0	37.4	<0.0001
	Median (years) [20th,80th%]	34.0 [21.0,48.8]	31.0 [18.9,48.7]	30.5 [20.0,48.6]	28.8 [18.9,43.3]	17.3 [10.4,34.8]	24.0 [14.0,38.7]	41.4 [27.7,54.6]	32.9 [18.9,54.5]	-
Age	0 to 14	476 (8.1)	385 (4.2)	293 (2.4)	207 (5.6)	3,994 (32.8)	5,693 (19.9)	1,113 (2.4)	6 (0.5)	<0.0001
	15 to 24	945 (16.2)	2,773 (30.1)	3,844 (31.1)	1,171 (31.8)	4,075 (33.4)	8,634 (30.1)	4,618 (10.1)	358 (28.7)	
	25 to 34	1,499 (25.6)	2,119 (23.0)	2,796 (22.6)	823 (22.4)	1,399 (11.5)	6,126 (21.4)	9,971 (21.9)	297 (23.8)	
	35 to 44	970 (16.6)	1,433 (15.6)	1,878 (15.2)	845 (23.0)	1,394 (11.4)	4,165 (14.5)	10,211 (22.4)	79 (6.3)	
	45 to 54	1,295 (22.2)	1,292 (14.0)	1,935 (15.7)	428 (11.6)	590 (4.8)	2,553 (8.9)	10,070 (22.1)	205 (16.4)	
	55 to 64	403 (6.9)	742 (8.1)	887 (7.2)	131 (3.6)	534 (4.4)	1,326 (4.6)	5,579 (12.2)	236 (18.9)	
	65+	258 (4.4)	466 (5.1)	714 (5.8)	72 (2.0)	209 (1.7)	151 (0.5)	4,025 (8.8)	68 (5.4)	
Sex	Male	4,593 (78.6)	7,378 (80.1)	9,409 (76.2)	1,633 (44.4)	9,060 (74.3)	21,255 (74.1)	36,291 (79.6)	1,106 (88.5)	<0.0001
	Female	1,253 (21.4)	1,832 (19.9)	2,939 (23.8)	2,044 (55.6)	3,137 (25.7)	7,424 (25.9)	9,296 (20.4)	144 (11.5)	
Race	White	3,804 (90.1)	6,107 (93.4)	8,373 (91.3)	2,229 (85.9)	7,043 (78.7)	18,555 (86.7)	31,860 (92.1)	1,023 (97.0)	0.0001
	Black	147 (3.5)	61 (0.9)	287 (3.1)	16 (0.6)	452 (5.1)	911 (4.3)	848 (2.5)	16 (1.5)	
	Amerindian	270 (6.4)	373 (5.7)	515 (5.6)	349 (13.5)	1,454 (16.2)	1,938 (9.1)	1,903 (5.5)	16 (1.5)	
Disposition from the ED	Release	963 (16.7)	2,985 (32.4)	6,229 (50.5)	2,561 (69.6)	730 (6.0)	16,792 (58.8)	29,466 (64.7)	657 (52.6)	<0.0001
	Admit	4,730 (81.9)	6,225 (67.6)	6,104 (49.5)	1,116 (30.4)	11,128 (91.2)	11,770 (41.2)	16,104 (35.3)	593 (47.4)	
	Fatality	85 (1.5)				339 (2.8)	17 (0.1)			
Alcohol Use	Yes	760 (13.0)	543 (5.9)	614 (5.0)	98 (2.7)	1,610 (13.2)	2,576 (9.0)	3,319 (7.3)	39 (3.1)	0.0003
	No	5,086 (87.0)	8,667 (94.1)	11,734 (95.0)	3,579 (97.3)	10,587 (86.8)	26,103 (91.0)	42,268 (92.7)	1,211 (96.9)	
Unhelmeted	Yes	1,367 (79.6)	1,549 (64.0)	1,082 (58.5)	544 (70.6)	4,182 (88.2)	5,340 (88.1)	4,291 (62.5)	16 (18.4)	0.0009
	No	351 (20.4)	870 (36.0)	769 (41.5)	227 (29.4)	562 (11.8)	724 (11.9)	2,576 (37.5)	71 (81.6)	
Head Injury	Yes	1,068 (18.3)	1,088 (11.8)	646 (5.2)	661 (18.0)	11,424 (93.7)	5,224 (18.2)	3,402 (7.5)	30 (2.4)	<0.0001
	No	4,779 (81.7)	8,101 (88.2)	11,701 (94.8)	3,016 (82.0)	773 (6.3)	23,454 (81.8)	42,035 (92.5)	1,219 (97.6)	
Head Injury Type	CHI, TBI, Concussion	766 (71.7)	964 (88.5)	630 (97.4)	646 (97.7)	872 (7.6)	4,535 (86.8)	2,914 (85.7)	15 (48.4)	<0.0001
	Skull Fracture	114 (10.7)	16 (1.5)			7,252 (63.5)	6 (0.1)			
	Intracranial Hemorrhage	188 (17.6)	109 (10.0)	17 (2.6)	15 (2.3)	3,305 (28.9)	684 (13.1)	488 (14.3)	16 (51.6)	
Internal Organ Injury	Brain	961 (76.7)	795 (50.2)	608 (74.5)	572 (88.5)	10,638 (95.2)	5,091 (94.5)	2,083 (27.0)	30 (14.3)	<0.0001
	Thorax	123 (9.8)	310 (19.6)	75 (9.2)		15 (0.1)	115 (2.1)	3,659 (47.4)	164 (78.1)	
	Abdomen	77 (6.1)	184 (11.6)	94 (11.5)			152 (2.8)	774 (10.0)	16 (7.6)	
	Brain/Thorax	16 (1.3)	262 (16.6)	17 (2.1)	67 (10.4)	519 (4.6)	32 (0.6)	1,062 (13.8)		
	Brain/Abdomen	76 (6.1)	32 (2.0)	22 (2.7)	7 (1.1)			139 (1.8)		

CS indicates cervical spine; TS, thoracic spine; LS, lumbar spine; SC, sacrococcygeal; CHI, closed head injury; TBI, traumatic brain injury.
*p value indicates the differences between the cervical spine, thoracic spine, lumbar spine, and sacrococcygeal spine for each of the listed variables. The % represents the column percentage for types of axial fractures (i.e. spine, non-spine).
†The % represents the row percentage for all locations in total.

involved the extremities or spine; thus, it is likely that orthopaedists are often consulted. Otolaryngologic, oral maxillofacial, and neurosurgeons also provide care to such patients and should be keenly aware of fracture patterns and associated risks.

This study is the first to analyze ATV-associated fracture rates, patterns, and associations of all ages nationwide. Shults et al. [19] reported a similar fracture rate (28%) in a nationwide study using analogous methodology, but their patient population was limited to <16 years of age. A variety of adult and paediatric studies have documented ATV-related fracture rates from 25% to 60% (Table 6) [19,21–24,26–28,33,34,41,42]. The variability in these rates is due to many factors. Certain studies collectively report dislocations with fractures, or "orthopaedic patients." Others report the fracture rate as a percentage of all inflicted injuries, rather than per patient. Some report only those taken to the operating room. Lastly, sample size, geography, or both have limited prior studies.

The top three most common fractures involved the upper extremity: clavicle (61,532; 12.7%), radius/ulna (52,731; 10.9%), and wrist (51,149; 10.6%). Although upper extremity fractures are common ATV-related injuries, other studies (Table 6) demonstrated higher percentage of lower extremity or axial fractures) [3,21–25,27,28,33,41,42]. This study found the percentage of upper extremity fractures (51.8%) to be approximately double that of the lower extremity (23.6%). This discrepancy from prior literature is likely due to the scope of both age and geography presented in this study. The percentage of spine fractures in this study is similar to those in the literature [12,20–23,25,27,28,30,31,33,34,42]. The 28.5% hospital admission rate among those with fractures in this study is similar to that in the literature (13%–64%) for all patients presenting to EDs for ATV-related injuries [19,26,27]. Hip, femur, CS, and skull fractures all had >80% admission rates but collectively only accounted for 6.5% of all fractures. Patients with fractures were most likely to report to small hospitals (45.4%), which likely served more rural, less densely populated regions.

The rate of alcohol use among all patients (2.7%) was lower than that found in the literature (22–33%) [3,22,34,42]. This could be attributed to age range, sample size, and incomplete NEISS narrative reporting. Our study included children of all ages and adults. Sanfilippo et al. [34] and Rios-Reboyras et al. [3] both reported a 33% alcohol usage rate with sample sizes of 36 and 33, respectively, and a collective age range of 10–69 years. Dietz et al. [22] reported a lower rate of 22%, had a much larger sample size at 1234 patients, and an age range of 1–87 years. Larger, more nationally representative sample sizes of all ages as found in this study likely have higher accuracy. The presence or absence of concomitant alcohol use should be reported for all patients in the NEISS database to ensure no alcohol users are missed among the nonresponse group in the narrative comments section.

Other serious injuries can be attributed to a lack of helmet use. While 56% of those with fractures and documented helmet use status were unhelmeted, the unhelmeted rate rose to 88% in patients with skull or facial fractures. It is important to note that 87% of skull fracture patients had associated brain injury. Our helmet use rate is similar to that of the literature (32% to >90% unhelmeted, median 84%) [3,21–24,27,28,31,33,34,41,42]. Of the 1.86 million patients in this study, only 205,886 (11.1%) had documented helmet status in the NEISS narrative comments. We suspect that patients with head injuries are more likely to have a documented helmet use status in the NEISS narrative comments. The true numbers of those helmeted/unhelmeted in the NEISS narrative comments are likely different for other fracture locations. Helmet use while riding ATVs decreases intracranial hemorrhage rates from 22% to 3% [43]. At the time of writing, only 16 of 50 states require helmet use while riding an ATV regardless of geographic location (public vs. private land) [17,18]. Seven of the 16 states require this for riders of all ages, seven require this of riders <18 years old, and two require this of riders <16 years old [18]. Ten other states have laws requiring

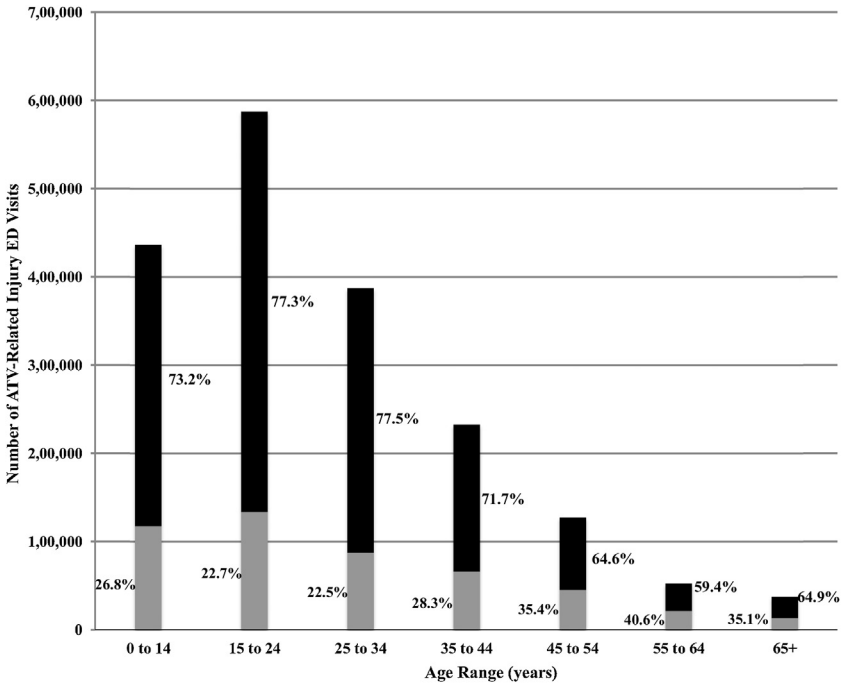

Fig. 2. Presence of fractures in ATV-related injury patients presenting to USA emergency departments from 2002 to 2015. The gray bars represent patients with fractures, and the black bars represent patients without fractures. Percentages are relative to the presence of fractures within each specific age range.

Table 5
Alcohol use, helmet use, and head/ internal organ injuries associated with all fractures from ATVs*.

		n (%)						
		All Fractures	UE	LE	Axial			*p* value
					Spine	Skull/Face	Rib/Sternum	
	n (%)†	482,501 -	249,745 (51.8)	114,022 (23.6)	31,021 (6.4)	40,876 (8.5)	46,837 (9.7)	-
	Mean Age (years)	27.5	24.3	27.3	34.7	26.0	41.9	<0.0001
	Median (years) [20th,80th%]	23.0 [13.1,41.1]	19.6 [11.7,36.4]	22.7 [13.1,39.9]	31.2 [19.7,47.8]	22.0 [13.2,37.7]	41.3 [27.4,54.7]	-
Alcohol Use	Yes	18,256 (3.8)	5,475 (2.2)	3,222 (2.8)	2,015 (6.5)	4,186 (10.2)	3,358 (7.2)	0.015
	No	464,245 (96.2)	244,270 (97.8)	110,800 (97.2)	29,006 (93.5)	36,690 (89.8)	43,479 (92.8)	
Unhelmeted	Yes	35,894 (57.5)	11,727 (44.4)	5,796 (50.2)	4,542 (67.8)	9,522 (88.1)	4,307 (61.9)	0.0001
	No	26,498 (42.5)	14,667 (55.6)	5,739 (49.8)	2,158 (32.2)	1,286 (11.9)	2,648 (38.1)	
Head Injury	Yes	36,126 (7.5)	8,579 (3.4)	4,064 (3.6)	3,403 (11.0)	16,648 (40.7)	3,432 (7.4)	0.0012
	No	446,187 (92.5)	241,150 (96.6)	109,958 (96.4)	27,597 (89.0)	24,228 (59.3)	43,254 (92.6)	
Head Injury Type	CHI, TBI, Concussion	22,829 (63.2)	7,978 (93.0)	3,571 (87.9)	2,945 (86.5)	5,407 (32.5)	2,928 (85.3)	<0.0001
	Skull Fracture	7,388 (20.4)			130 (3.8)	7,258 (43.6)		
	Intracranial Hemorrhage	5,915 (16.4)	601 (7.0)	493 (12.1)	328 (9.6)	3,989 (24.0)	504 (14.7)	
Internal Organ Injury	Brain	32,117 (72.9)	7,733 (73.3)	3,667 (76.9)	2,874 (67.8)	15,730 (95.0)	2,113 (26.7)	0.0013
	Thorax	6,491 (14.7)	1,739 (16.5)	291 (6.1)	509 (12.0)	130 (0.8)	3,822 (48.2)	
	Abdomen	2,283 (5.2)	537 (5.1)	449 (9.4)	356 (8.4)	152 (0.9)	789 (10.0)	
	Brain/Thorax	2,561 (5.8)	334 (3.2)	252 (5.3)	362 (8.5)	551 (3.3)	1,062 (13.4)	
	Brain/Abdomen	594 (1.3)	206 (2.0)	112 (2.3)	137 (3.2)		139 (1.8)	

UE indicates upper extremity; LE, lower extremity; CHI, closed head injury; TBI, traumatic brain injury.
*p value indicates the differences between upper extremity, lower extremity, spine, skull/face, and rib/sternum for each of the listed variables. The % represents the column percentage for each variable.
†The % represents the row percentage for all locations in total.

helmets limited to public property, three-wheeled ATVs, or both [18]. Legislative work is needed to increase helmet use across the entire US.

A decrease in ATV-related injuries since ~2007 has been noted and correlated to a decline in ATV sales secondary to the 2008 economic recession [10,13,19,21]. Our study demonstrated the same findings (Fig. 1). ATV-related fractures peaked in 2007 at 44,283 and trended downward through 2014. However, we hypothesize this trend is changing. ATV-related injuries and fractures increased from 2014-2015. We suspect that as discretionary spending rises, so will the rate of ATV use and subsequent injury. Thus, it is important for ATV safety regulations to continue to be enacted and enforced. Data shows there is public support for legislation [44], but outcomes stemming from state statutes have been mixed. Some studies have shown legislation has no effect on morbidity, mortality, or helmet use [15,29,45] while others demonstrate at least partial effectiveness [16,46–48]. In addition to being a reference for clinical decision-making regarding ATV trauma, this study may also support the growing body of evidence surrounding ATV legislation.

The American Academy of Orthopaedic Surgeons, American College of Surgeons, American Pediatric Surgical Association Trauma Committee, American Academy of Pediatrics, and Canadian Association of Pediatric Surgeons have all released position statements citing the dangers of ATV use [8]. Each endorses legislation that would limit the use of ATVs to drivers age 16 years and older and many suggest licensure be required before individuals are allowed to operate an ATV [8]. Our study supports prior research indicating children are disproportionately affected by ATV trauma [8,17]. ATV drivers and/or riders ≤14 years old had the second highest fracture rate at ~24%. The paediatric population's safety should be taken into special consideration as future ATV legislation is enacted.

Table 6
Literature Comparisons of ATV Injuries.

References	Time Span	Location	All-comers/ Admitted	Admitted (%)	Type of Injuries Studied	n	Age Studied	Mean Age	F/M (%)	Alcohol Use (%)	Unhelmeted (%)	Fracture (%)	UE (%)	LE (%)	Axial (%)	Spine (%)	CS (%)	TS (%)	LS (%)	SC (%)
Present Study	2002-2015	Entire USA	All Patients	29*	All Injuries	1,862,342	All Ages	27.5	24/76	3	56	26†	52	24	25	6	19	30	40	12
Shults et al	2001-2010	Entire USA	All Patients	13	All Injuries	361,161	<16	-	33/67	-	-	28†	-	-	-	-	-	-	-	-
Sawyer, Bernard et al	2006	Entire USA	Admissions	-	Spine	4,483	≤18	12.9	24/76	-	-	-	-	-	-	7	16	39	29	16
Garay et al	2004-2014	PA	Admissions	-	Fractures	1912	<18	14.0	25/75	-	51	55†	32	44	23	14	22	78		-
Dietz et al	2000-2007	Morgantown, WV	Admissions	-	All Injuries	1,234	1-87	30.0	21/79	22	71	52†	34	39	27	27	-	-	-	-
Shah et al	1998-2007	Little Rock, AR	All Patients	-	All Injuries	512	<1-20	11.6	32/68	-	>90	34†	32	59	9	9	27	41	32	-
Hogue et al	2005-2011	Dallas, TX	All Patients	-	All Injuries	334	<18	8.7	33/67	-	86	43†	32	39	28	2	0	40	60	0
Kute et al	1995-2005	Louisville, KY	Admissions	-	All Injuries	238	Pediatric	11.4	30/70	-	84	63†	25	32	43	4	-	-	-	-
Balthrop et al	1998-2003	Louisville, KY	Admissions	-	All Injuries	188	14-88	32.0	15/85	25	86	45^	18	27	55	26	42	15	35	8
Mangano et al	1993-2003	St. Louis, MO	Admissions	-	All Injuries	185	<18	12.3	30/70	-	68	53^	42	59	-	-	-	-	-	-
Bhutta et al	1998-2001	Little Rock, AR	Admissions	-	All Injuries	141	<1-19	11.6	26/74	-	-	-	24	33	43	6	-	-	-	-
Yanchar et al	1993-2002	Halifax, Nova Scotia	All Patients	31	All Injuries	130	<16	-	-	-	-	48^	-	-	-	-	-	-	-	-
Kellum et al	2004-2006	Memphis, TN	All Patients	64	All Injuries	96	≤16	11.0	33/67	-	91	60†	23	44	33	7	-	-	-	20
Murphy et al	1990-2002	Halifax, Nova Scotia	Admissions	-	All Injuries	92	<16	12.1	21/79	-	32	51^	34	40	27	7	-	-	-	-
Su et al	2001-2004	Montreal, Quebec	Admissions	-	All Injuries	50	3-17	13.0	50/50	-	84	50^	25	31	44	-	-	-	-	-
Kirkpatrick et al	2001-2007	Oklahoma City, OK	All Patients	-	All Injuries	73	<16	9.9	-	-	-	-	45	45	9	9				
Sanfilippo et al	1993-2007	Philadelphia, PA	Admissions	-	Spine	36	14-59	29.4	8/92	33	53	-	-	-	-	-	36	64		-
Rios-Reboyras et al	1998-2000	San Juan, Puerto Rico	Admissions	-	Fractures	33	10-69	23.0	21/79	33	88	-	30	61	9	-	-	-	-	-
Sawyer, Beebe et al	4 Year period	Memphis, TN	Admissions	-	Spine	29	<18	15.7	48/52	-	86	-	-	-	-	-	13	42	32	13

F indicates female; M, male; UE, upper extremity; LE, lower extremity; CS, cervical spine; TS, thoracic spine; LS, lumbar spine; SC, sacrococcygeal.
*The % admitted among those with fractures.
†The % of fracture among all patients.
^The % of fracture among all injuries.

Accuracy and completeness of the NEISS data are certain limitations to this study. Large datasets that succumb to the complexities coding always have the potential for inaccuracy. The NEISS database is limited not only in its ability to track patients over the course of time, but also in its ability to document treatments rendered (i.e. a patient being admitted for surgery versus observation). This being said, prior studies have indicated NEISS database reports consumer product related injuries with 89%–98% accuracy [49,50]. We believe these data to be limited in scope but highly accurate. Additionally, the NEISS database only captures patients who were cared for in the ED; thus, it is skewed to those with more serious injuries. The true rate of ATV-related injuries is likely higher than reported, as the NEISS database does not include patients presenting to non-ED medical venues (e.g. primary care offices, urgent care clinics). Lastly, the narrative comments section was used to determine the frequency of alcohol and helmet usage. Incomplete narrative reporting has the potential to give lower values than what might be actually true.

Conclusion

This study is the first of its kind to analyze nationwide ATV-related fracture rates, patterns, associations, and cost over a 14-year period. It outlays expected fracture patterns, confirms the need for helmet use, warns against a potential rise in ATV-related injuries, and can serve as a reference for clinical decision making and future studies. It is imperative the medical community continue to advocate for ATV safety in public and legislative forums. Electronic databases such as the NEISS serve as an important source of extensive data. Judicious reporting of variables such as helmet and alcohol use for all patients will allow researchers to more powerfully examine risks associated with ATV use. Future areas of ATV-related trauma study include learning more about vulnerable populations, how society can intervene before injuries occur, and performing a thorough cost analysis of ATV-related trauma.

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Appendix A. Supplementary data

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