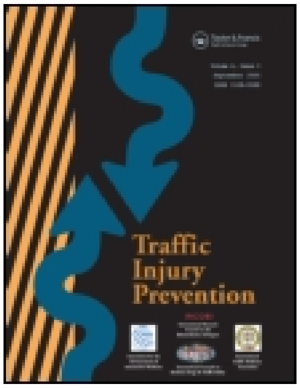

Traffic Injury Prevention
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gcpi20

All-Terrain Vehicles (ATVs) on the Road: A Serious Traffic Safety and Public Health Concern

Gerene Denning [a] , Charles Jennissen [a] , Karisa Harland [a] , David Ellis [a] & Christopher Buresh [a]

[a] Department of Emergency Medicine, Carver College of Medicine , University of Iowa , Iowa City , Iowa

Accepted author version posted online: 09 Apr 2012.Published online: 21 Dec 2013.

To cite this article: Gerene Denning , Charles Jennissen , Karisa Harland , David Ellis & Christopher Buresh (2013) All-Terrain Vehicles (ATVs) on the Road: A Serious Traffic Safety and Public Health Concern, Traffic Injury Prevention, 14:1, 78-85, DOI: 10.1080/15389588.2012.675110

To link to this article: http://dx.doi.org/10.1080/15389588.2012.675110

Traffic Injury Prevention (2013) **14**, 78–85

ISSN: 1538-9588 print / 1538-957X online
DOI: 10.1080/15389588.2012.675110

All-Terrain Vehicles (ATVs) on the Road: A Serious Traffic Safety and Public Health Concern

GERENE DENNING, CHARLES JENNISSEN, KARISA HARLAND, DAVID ELLIS, and CHRISTOPHER BURESH

Department of Emergency Medicine, Carver College of Medicine, University of Iowa, Iowa City, Iowa

Received 6 January 2012, Accepted 8 March 2012

Objectives: On-road all-terrain vehicle (ATV) crashes are frequent occurrences that disproportionately impact rural communities. These crashes occur despite most states having laws restricting on-road ATV use. A number of overall risk factors for ATV-related injuries have been identified (e.g., lack of helmet, carrying passengers). However, few studies have determined the relative contribution of these and other factors to on-road crashes and injuries. The objective of our study was to determine whether there were differences between on- and off-road ATV crashes in their demographics and/or mechanisms and outcomes of injuries.

Methods: Data were derived from our statewide ATV injury surveillance database (2002–2009). Crash location and crash and injury mechanisms were coded using a modification of the Department of Transportation (DOT) coding system. Descriptive analyses and statistical comparisons (chi-square test) of variables were performed. Multivariate logistic regression analysis was used to determine relative risk.

Results: 976 records were included in the final analysis, with 38 percent of the injured individuals from on-road crashes. Demographics were similar for crashes at each location, with approximately 80 percent males, 30 percent under the age of 16, and 15 percent passengers. However, females and youths under 16 were over 4 times more likely to be passengers ($P \leq 0.0001$), regardless of crash location. Compared to those off-road, on-road crash victims were approximately 10 times more likely to be involved in a vehicle–vehicle collision ($P < 0.001$), 3 times more likely to have a severe brain injury ($P < 0.001$), and twice as likely to have suffered major trauma ($P < 0.001$). Adult operators in on-road crashes were also twice as likely to test positive for alcohol as those off-road ($P < 0.05$). Helmet use significantly reduced the odds of sustaining a brain injury and on-road victims were only half as likely to be helmeted ($P < 0.01$).

Conclusions: More than 1 in 3 on-road crashes involved a collision with another vehicle, suggesting that ATVs on the road represent a potential traffic safety concern. Of note, helmets were associated with reduced risk for the number and severity of brain injuries, providing further support for the importance of helmet use. Finally, even controlling for helmet use, on-road crash victims suffered more major trauma and severe brain injuries than those off-road. Overall, our data reinforce the importance of laws restricting ATV road use and the need for effective enforcement, as well as the need to increase user education about ATV road-use laws and the dangers of riding on the roads.

Keywords: all-terrain vehicles, off-road motor vehicles, motor vehicle crash, traffic safety, injury prevention, rural health

Introduction

All-terrain vehicle (ATV)-related deaths and injuries have been an increasing public health problem over the past 4 decades, and the number of deaths, hospitalizations, and emergency department (ED) visits from ATV crashes in the United States is alarmingly high. ATV crashes currently result in over 700 deaths and 130,000 emergency department visits each year (Consumer Product Safety Commission 2010). The annual cost of lost lives and health care from these crashes is estimated at over $4.3 billion (Collins et al. 2007; Helmkamp, Furbee, et al. 2008, 2009).

ATV use is concentrated in a relatively small proportion of the overall population. In 2001, there were an estimated 23 million ATV riders out of a total U.S. population of 281 million. These riders lived mainly in rural areas and large suburban acreages (Bercher et al. 2001; Rodgers 2008). National and local data consistently demonstrate that ATVs represent a significant rural health concern (Gittelman et al. 2006; Killingsworth et al. 2005; Kirkpatrick et al. 2007; Kute et al. 2007).

There are approximately 10.2 million ATVs in the United States today, and vehicles are getting larger in size (>800 lbs) and faster (>80 mph; Helmkamp, Furbee, et al. 2008; Scutchfield 2003). Because ATVs can perform on diverse terrains, they are used in agriculture, industry, law enforcement, and

Address correspondence to: Gerene Denning, Department of Emergency Medicine, 1008 Roy Carver Pavilion, University of Iowa, 200 Hawkins Dr., Iowa City, IA, 52242. Phone: (319) 384-8123. FAX: (319) 353-7006. E-mail: gerene-denning@uiowa.edu

recreation. Although ATV-related injuries occur as a result of both work and play, most are from recreational use (Fisher et al. 2009; Hendricks et al. 2005; Kute et al. 2007; Rodgers 1993).

On-road ATV and motorcycle crashes result in similar injury severities (Acosta and Rodriguez 2003; Fonseca et al. 2005), and ATVs kill more children each year than bicycle crashes (Helmkamp et al. 2009; Yanchar et al. 2006). Brain injuries are the major cause of death and disability from ATV use (Bhutta et al. 2004; Bowman et al. 2009; Brandenburg et al. 2007; Carr et al. 2004).

From 1997 to 2001, ATV-related emergency department visits increased 104 percent (54,700 vs. 111,700), which was significantly higher than the estimated increase in number of vehicles (40%), number of riders (26%), and number of riding hours (45%; Levenson 2003). These data suggest that increased exposure did not fully account for the observed increase in injuries during this time period. It has been suggested that factors such as increasing vehicle power and speed, children on adult-sized vehicles, and limited enforcement may contribute to this discrepancy (Axelband et al. 2007). Other risk factors for ATV-related deaths and injuries include being male, being under 16 years of age, lack of helmet use, carrying passengers, lack of experience, vehicle size, alcohol use, and operating on the road (Aitken et al. 2004; Gittelman et al. 2006; Hall et al. 2009; Rodgers 2008; Shulruf and Balemi 2010).

Most states restrict the use of ATVs on the road. Current Iowa law prohibits on-road use of ATVs except for agriculture-related purposes and to cross the road under specified conditions. However, the law allows counties and cities to pass ordinances designating roads and streets for ATV use. To our knowledge, no local ordinances have been passed to date, but state agencies report efforts in this direction. Despite current legislative limitations on roadway travel, the Iowa Department of Transportation (DOT) and the State Trauma Registry (STR) record numerous on-road crashes every year.

To our knowledge, West Virginia represents the only state to report statewide ATV fatalities by crash location (Helmkamp, Ramsey, et al. 2008). They found that 60 percent of fatalities from 2000 to 2004 resulted from on-road crashes. Nonfatal injury data were not reported by location type. Using Consumer Product Safety Commission (CPSC) data for our state (1982–2009), we found a similar percentage of on-road fatalities (57%, 71 out of 124). In this article, we are the first to provide statewide demographics, crash mechanisms, and injury outcomes for on-road ATV crashes and to compare them with crashes occurring off the road.

Methods

Iowa ATV Injury Surveillance Database

The Iowa Injury Prevention Research Center (IPRC) provided access to data from the DOT and the STR. The coordinator of the Department of Natural Resources (DNR) database provided approval for the use of DNR data. The University of Iowa Institutional Review Board provided overall approval for these studies. Access to all data was in compliance with federal, state, and local regulations.

We performed a retrospective study of Iowa ATV crashes and injuries for the time period from January 1, 2002, through December 31, 2009. Crash and injury data were part of our integrated ATV injury surveillance database from 3 sources (DOT, DNR, and STR). To create our database, we developed a standardized coding system. Research assistants compiled the original data and reconciled coding for all variables. The research scientist on the team independently checked all coding. Disagreements on coding were resolved by team discussions. Matching records from the data sources were identified using LinkPlus, available from the Centers for Disease Control and Prevention, and final data reflect counting each crash victim's record only once.

For these studies, all data sources had well-documented demographics and crash date information. Consistent with their function, DOT and DNR records provided more detailed crash and vehicle information but more limited injury information. On the other hand, the STR provided the most detailed injury data but was significantly more limited in documenting vehicle parameters and other variables such as helmet use. The STR provided validated injury severity data in the form of the Injury Severity Score (ISS). The ISS is calculated by summing scores for the 3 most severely injured body regions, and values range from 0 to 75. Analysis of covariance (ANCOVA) was used to determine the mean ISS scores by crash location after controlling for potentially confounding variables. The ISS was also dichotomized to >15 (major trauma) and ≤ 15 for multivariate analysis (Boyd et al. 1987). The Glasgow Coma Score (GCS) provided in the STR is a measure of the level of consciousness of a patient with a range of 3 to 15 and reflects the severity of brain injury. By accepted convention, GCS scores were categorized as no brain injury (GCS $= 15$) or as minor (GCS $= 13$–14), moderate (GCS $= 9$–12), and severe (GCS ≤ 8) brain injury. In addition, the GCS was dichotomized to the presence (GCS < 15) or absence (GCS $= 15$) of a brain injury for multivariate analysis.

Data were categorized as on-road or off-road and mechanisms were grouped as shown in Table 1. Although off-road use includes riding at racetracks and in public off-highway vehicle (OHV) parks, crashes at these locations were excluded. Preliminary data analysis indicated that crashes at tracks and parks were different from other off-road sites both demographically and with respect to mechanisms of injury. Moreover, racetracks and parks in our state have additional regulations (e.g., mandated helmet use) and better monitoring for enforcement purposes.

Data Calculation and Analyses

Descriptive analyses of demographics, helmet use, alcohol and drug involvement, crash and injury mechanisms, and injury outcomes were performed using Microsoft Excel. The indicated N values reflect the number of records that were documented for all of the relevant variables in the calculation. All other statistical analyses were performed using the Vassar Website for Statistical Calculations or SAS software (version

Table 1. Location and mechanism coding based on the Iowa DOT coding system

Crash location	Location descriptions
On-road	Roadway, including median
	Road shoulder
	Gore, outside traffic way
	Road right-of-way[a]: public/private
Off-road	Private land: outside city/in city/trail
	Public land: outside city/in city/trail
	Body of water: lake/stream/ice
	Roadside ditch
Crash mechanism	**Mechanism descriptions**
Vehicle–vehicle collision	Collision with vehicle in traffic, in/from roadway
	Collision with another ATV
Vehicle–other collision	Collision with fixed object (e.g., tree)
	Collision with nonfixed object (e.g., rock)
	Collision with pedestrian
	Collision with animal
Noncollision event	Noncollision events, including rollovers
Jump-related event	Crashes from missed jumps
Injury mechanism	
Motor vehicle collision	
Struck fixed object	
Struck nonfixed object	
Rollover, no self-ejection	
Rollover, self-ejection	
Struck/pinned by vehicle	

[a]A road right-of-way is a section of a public road that passes through a privately owned property.

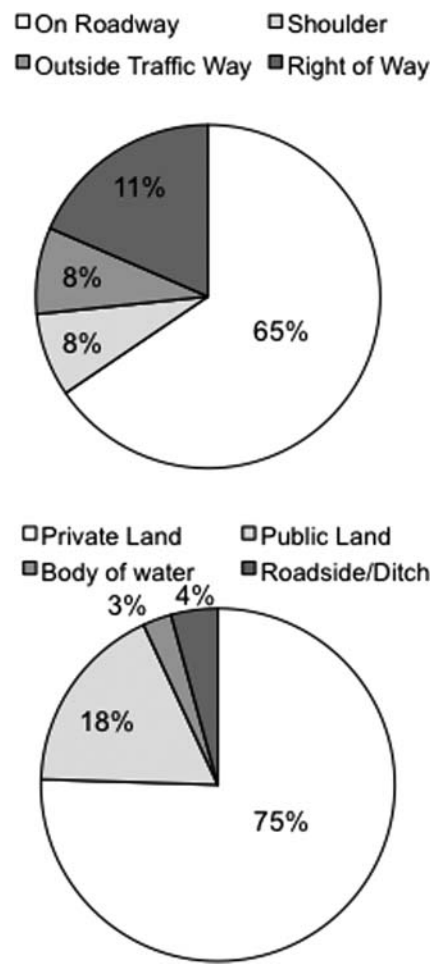

Fig. 1. Data from our statewide ATV injury surveillance database show the percentage of injuries at the indicated locations on (Top) and off (Bottom) the road. A road right-of-way is a section of a public road that passes through a privately owned property.

9.2) of the SAS System for Microsoft (SAS Institute Inc., Cary, NC). Comparisons of proportions were done using the chi-square test. To estimate the risks of dichotomous variables (e.g., being a passenger on an ATV, wearing a helmet), multivariate logistic regression was used to calculate unadjusted and adjusted odds ratios and 95 percent confidence intervals, after controlling for significant covariates. Subjects with missing data were excluded from regression analysis.

Results

ATV-Related Injuries by Crash Location

Accounting for matching records, there were 1619 crash victims in the combined statewide database for the years 2002–2009. Of these individuals, 1046 were documented for location. All records not documented for location were from the trauma registry. Of the 1046 documented records, 976 victims met study inclusion criteria as having been involved in an on-road crash or in an off-road crash that occurred outside of racetracks and OHV parks. More than 1 in 3 (38%) of these 976 victims were injured on the road. The primary sites for on-road and off-road injuries were on the roadway (Figure 1, top) and on private property (Figure 1, bottom), respectively.

Demographics and Helmet Use

Overall demographics, as well as demographics for operators and passengers, were similar when comparing on- and off-road crash victims (Table 2). Approximately 80 percent were males and one in 3 was under the age of 16. The percentage of victims who were passengers from on- and off-road crashes was also nearly equivalent at 15 percent. However, the demographics of operators and passengers were significantly different ($P \leq 0.0001$), for both crash locations (Table 2). Adjusted odds ratios indicated that passengers were 4.4 times more likely to be females (95% confidence interval [CI]: 3.25–8.89) and 4.5 times more likely to be under the age of 16 (95% CI: 2.74–7.32).

Helmet use overall was 18 percent and on-road use was significantly less than off-road (Table 3). Operators, but not passengers, were significantly less likely to be helmeted in on-road crashes ($P < 0.05$) compared to those off-road. In fact, on-road victims were approximately half as likely to be wearing a helmet compared to off-road victims (adjusted odds ratio [aOR]: 0.55; 95% CI: 0.34–0.88). There was also a trend toward less helmet use by passengers (10%) when compared to operators overall (19%; aOR: 0.41; 95% CI: 0.16–1.05). Helmet use was not different by gender or age.

Table 2. Overall demographics of on-road and off-road crashes and comparison of demographics by seating position

	On-road	Off-road
Gender		
Total N	364	600
Male	291 (80%)	485 (81%)
Female	73 (20%)	115 (19%)
Age		
Total N	341	595
Range (yrs old)	2–82	1–89
<16	103 (30%)	194 (33%)
≥16	238 (70%)	401 (67%)
Seating		
Total N	339	390
Operator	286 (84%)	332 (85%)
Passenger	53 (16%)	58 (15%)
Seating/Gender		
Total N	334	383
Operator		
Male	240 (85%)	282 (86%)
Female	42 (15%)	45 (14%)
Passenger		
Male	28 (54%)	25 (45%)
Female	24 (46%)	31 (55%)
Operator vs. Passenger		
P value	$P < 0.0001$	$P < 0.0001$
Seating/Age		
Total N	310	379
Operator		
<16	70 (25%)	78 (24%)
≥16	206 (75%)	247 (76%)
Passenger		
<16	20 (59%)	34 (63%)
≥16	14 (41%)	20 (37%)
Operator vs. Passenger		
P value	$P = 0.0001$	$P < 0.0001$
	OR[a] (95% CI)	aOR[b] (95% CI)
Odds of Being a Passenger		
Gender: Female	6.23 (4.01–9.67)	4.37 (3.25–8.89)
Age: <16	4.86 (3.05–7.76)	4.48 (2.74–7.32)
Location: On-road	1.07 (0.71–1.60)	0.72 (0.44–1.19)

[a]References (OR = 1.0) were male, ≥16 yrs of age, and off-road, respectively.
[b]Odds ratios were adjusted for all covariates in the table.

Alcohol and Drugs

Alcohol use by ATV operators 16 years of age and older was evaluated (Table 4). The overall percentage of crashes documented to involve alcohol was 17 percent, 90 operators out of 528. This represented 42 percent of all operators tested. Interestingly, a higher percentage of operators in on-road crashes (48%) were tested for alcohol relative to those in off-road crashes (33%), $P < 0.0001$. In fact, on-road ATV crash operators had a 59 percent higher likelihood of being tested for alcohol (aOR: 1.59; 95% CI: 1.07–2.38), and females had a higher likelihood of being tested than males (aOR: 1.79; 95% CI: 1.02–3.14). A higher percentage of alcohol tests were positive for on- versus off-road operators (48% vs. 33%, $P < 0.05$), and adjusted odds ratios indicated that on-road crashes were about twice as likely to involve alcohol relative to off-road crashes (aOR: 2.04; 95% CI: 1.13–3.69). There was also a trend toward a difference between on- and off-road operators with respect to alcohol levels over the legal limit of 0.08 (aOR: 1.76; 95% CI: 0.92–3.34, $P = 0.1$).

Approximately 30 percent of operators 16 and older were tested for drugs (Table 4). Of those tested, 40 percent were positive. There were no differences in the percentage of operators tested for drugs and no difference in the percentage who tested positive when comparing operators on and off the roads. There were also no differences in operator drug use based on gender.

Table 3. Comparison of helmet use by victims in on- and off-road crashes overall and by seating position.

	On-road	Off-road	On vs. off
Overall helmet use			$P < 0.01$
N	278	306	
Yes	38 (14%)	70 (23%)	
No	240 (86%)	236 (77%)	
Helmet Use/Seating			
Operator			$P < 0.05$
N	247	207	
Yes	34 (14%)	50 (24%)	
No	213 (86%)	157 (76%)	
Passenger			$P = 1.0$
N	24	39	
Yes	2 (8%)	4 (10%)	
No	22 (92%)	35 (90%))	
	OR[a] (95% CI)	aOR[b] (95% CI)	
Odds of Wearing a Helmet			
Gender: Female	0.98 (0.57–1.69)	1.14 (0.60–2.16)	
Age: <16	1.32 (0.85–2.06)	1.24 (0.74–2.08)	
Seating: Passenger	0.27 (0.12–0.64)	0.41 (0.16–1.05)	
Location: On-road	0.48 (0.20–1.15)	0.55 (0.34–0.88)	

[a]References (OR = 1.0) for odds ratios were male, ≥16 yrs of age (adult), operator, and off-road, respectively.
[b]Odds ratios were adjusted for all covariates in the table.

Table 4. Alcohol and drugs in on-road and off-road crashes for operators 16 years of age or older.

	All	On-road	Off-road	On vs. off
Alcohol				
Total operators	528	262	266	
Operators tested	214 (41%)	126 (48%)	88 (33%)	$P < 0.001$
Tested Positive	90 (42%)	61 (48%)	29 (33%)	$P < 0.05$
Positive > 0.08	68 (32%)	43 (34%)	25 (28%)	$P = 0.1$
Drugs				
Total operators	388	219	169	
Operators tested	114 (29%)	59 (27%)	55 (33%)	$P = 0.26$
Tested Positive	46 (40%)	21 (36%)	25 (45%)	$P = 0.34$

	OR[a] (95% CI)	[a]OR[b] (95% CI)
Odds of Being Tested for Alcohol		
Gender: Female	1.74 (1.00–2.96)	1.79 (1.02–3.14)
Age: Continuous	0.99 (0.98–1.01)	1.00 (0.98–1.01)
Location: On-road	1.73 (1.21–2.49)	1.59 (1.07–2.38)
Odds of Documented Alcohol Use		
Gender: Female	0.97 (0.46–2.04)	0.92 (0.43–1.97)
Age: Continuous	1.00 (0.98–1.03)	1.01 (0.99–1.03)
Location: On-road	1.91 (1.09–3.36)	2.04 (1.13–3.69)
Odds of Operator Alcohol Levels > 0.08		
Gender: Female	0.71 (0.29–1.0)	0.68 (0.28–1.65)
Age: Continuous	1.01 (0.99–1.04)	1.02 (0.99–1.04)
Location: On-road	1.56 (0.85–2.86)	1.76 (0.92–3.34)

[a]References (OR = 1.0) for odds ratios were male, age, and off-road, respectively.
[b]Odds ratios were adjusted for all other covariates in the table.

Table 5. Comparison of crash and injury mechanisms for on- and off-road crashes

	On-road	Off-road	On vs. off
Crash mechanism			
N	347	504	
Vehicle–vehicle Collision	120 (35%)	25 (5%)	$P < 0.0001$
Vehicle–other collision	93 (27%)	102 (20%)	$P < 0.05$
Noncollision event	129 (37%)	355 (70%)	$P < 0.0001$
Jump-related event	5 (1%)	22 (4%)	$P < 0.05$
Injury mechanism			
N	350	519	$P < 0.001$
Motor vehicle collision	120 (34%)	23 (4%)	
Struck fixed object	76 (22%)	76 (15%)	
Struck nonfixed object	14 (4%)	15 (3%)	
Struck, unknown object	0 (0%)	2 (0.4%)	
Rollover, no self-ejection	107 (31%)	261 (50%)	
Rollover, self-ejection	3 (1%)	17 (3%)	
Struck/pinned by vehicle	30 (9%)	125 (24%)	

Variable	OR[a] (95% CI)	aOR[b] (95% CI)
Odds of vehicle–vehicle collision		
Gender: Female	0.96 (0.60–1.53)	1.04 (0.59–1.84)
Age: <16	1.45 (0.97–2.16)	1.49 (0.93–2.38)
Location: On-road	13.2 (8.21–21.3)	13.6 (8.28–22.4)
Odds of vehicle–other collision		
Gender: Female	1.07 (0.71–1.60)	0.90 (0.58–1.42)
Age: <16	1.14 (0.79–1.64)	1.20 (0.82–1.74)
Location: On-road	2.51 (1.78–3.55)	2.38 (1.66–3.41)
Odds of being struck or pinned by the vehicle		
Gender: Female	0.84 (0.48–1.44)	0.84 (0.43–1.66)
Age: <16	0.78 (0.48–1.26)	0.87 (0.46–1.66)
Location: On-road	0.54 (0.31–0.93)	0.49 (0.26–0.91)

[a]References (OR = 1.0) for odds ratios were male, ≥16 years of age (adult), operator, off-road, noncollision, not jump-related, and not pinned, respectively.
[b]Odds were adjusted for all covariates in the table.

The overall percentage of crashes with positive drug screens was 12 percent, 46 operators out of 388. However, some drug tests were done after treatment and it was not always possible to know whether opioids and/or benzodiazopines were given as part of treatment or were due to illicit drug use. With these caveats in mind, drugs detected in ATV operators who tested positive included marijuana (46%), other (30%), opiates (11%), amphetamines (5%), benzodiazopines (5%), and cocaine (3%). Marijuana was the most common drug detected at both locations. No positive results were seen for barbiturates or for PCP.

Crash and Injury Mechanisms

On the road, 62 percent of all injuries were from collision-related events (vehicle and other). On-road victims were greater than 10 times more likely to be involved in a vehicle–vehicle collision ($P < 0.0001$), and motor vehicle collisions were the most common on-road injury mechanism. Collisions with motor vehicles other than ATVs accounted for 93 percent (111/120) of on-road crashes, whereas 80 percent (20/25) of off-road vehicle–vehicle crashes involved another ATV.

On-road victims were also more than twice as likely to be involved in other types of collisions compared to off-road victims ($P < 0.05$; Table 5). Collisions with fixed objects were more common than with non-fixed objects for both locations, but the objects involved reflected the differences between the two. For on-road crashes, fixed objects were primarily hit after the ATV left the road. These included the ditch/embankment (35%), a tree (29%), or a fence (6%). Other fixed objects in on-road collisions were part of traffic infrastructure such as bridges, poles, signposts, and guardrails (<4% each). For off-road crashes, trees and roots comprised nearly half of all fixed objects struck (47%). Fences (25%) and hills/embankments (8%) were the next most common.

Noncollision events (e.g., rollovers) were the most common mechanism for off-road crashes and injuries (74%), and off-road victims were more likely than on-road victims to be injured in a jump-related event ($P < 0.05$). Consistent with the predominance of rollovers, off-road crash victims were significantly more likely to be struck or pinned by the vehicle compared to on-road victims, $P < 0.001$.

Table 6. Injury outcomes for on-road and off-road crashes. State trauma registry records provided injury severity scores (ISS) and Glasgow Coma Scores (GCS)

Injury Severity Score	On-road	Off-road	On vs. Off
ISS			
N	123	430	
Mean ISS (95% CI)	12.5 (10.6–14.6)[a]	9.5 (7.9–11.0)	$P < 0.01$
ISS			
≤15	81 (66%)	363 (84%)	$P < 0.001$
>15 (major trauma)	42 (34%)[a]	67 (16%)	
Glasgow Coma Scores			
GCS			
N	125	405	Head injury
Normal (15)	93 (74%)	364 (90%)	$P < 0.0001$
Mild/moderate (9–14)	11 (9%)	22 (5%)	Severe
Severe (≤8)	21 (17%)	19 (5%)	$P < 0.0001$

Variable	OR[b] (95% CI)	aOR[c] (95% CI)
Odds of major trauma (ISS > 15)		
Gender: Female	1.02 (0.61–1.73)	1.00 (0.58–1.73)
Age: <16	0.64 (0.40–1.04)	0.68 (0.41–1.12)
Location: On-road	2.81 (1.78–4.43)	2.23 (1.37–3.64)
Mechanism: Collision	1.35 (0.83–2.19)	1.09 (0.65–1.83)
Helmet use: Yes	0.56 (0.23–1.35)	0.70 (0.28–1.72)
Odds of a brain injury (GCS < 15)		
Gender: Female	0.62 (0.31–1.22)	0.54 (0.27–1.10)
Age: <16	1.04 (0.61–1.77)	1.31 (0.75–2.28)
Location: On-road	3.06 (1.83–5.12)	2.76 (1.58–4.84)
Mechanism: Collision	1.38 (0.78–2.44)	1.07 (0.57–1.98)
Helmet use: Yes	0.19 (0.04–0.82)	0.18 (0.04–0.81)
Odds of a severe brain injury (GCS ≤ 8)		
Gender: Female	1.01 (0.47–2.19)	0.84 (0.37–1.91)
Age: <16	1.09 (0.55–2.18)	1.40 (0.67–2.91)
Location: On-road	4.33 (2.33–8.38)	3.44 (1.66–7.12)
Mechanism: Collision	1.88 (0.91–3.86)	1.27 (0.58–2.78)
Helmet use: Yes	0.14 (0.02–1.09)	0.14 (0.02–1.07)

[a]$P < 0.001$ relative to off-road.
[b]References (OR = 1.0) for odds ratios were male, ≥16 years of age, off-road, noncollision, and no helmet use.
[c]Odds ratios were adjusted for all other covariates in the table.

Injury Outcomes

Trauma registry data were used to determine the overall injury severity and the presence and severity of brain injuries

(Table 6). For on-road victims, both the mean ISS (12.5 vs. 9.5, $P < 0.01$) and the proportion of on-road victims who suffered major trauma, indicated by an ISS > 15 (34% vs. 15%, $P < 0.001$), were significantly higher than for off-road victims.

Similarly, there were significantly higher percentages of brain injuries (GCS < 15) and severe brain injuries (GCS $\leq$ 8) among on-road versus off-road victims ($P < 0.0001$). Helmet use significantly decreased the odds of a brain injury overall (aOR: 0.18; 95% CI: 0.04–0.81), and a strong trend toward reducing severe brain injuries was observed (aOR: 0.14; 95% CI: 0.02–1.07).

Of note, even after controlling for all variables, including helmet use, victims on the road were still 2.8 times more likely to suffer a brain injury ($P < 0.0001$) compared to off-road victims. Similarly, on-road crash victims were 3.4 times more likely to suffer a severe brain injury ($P < 0.0001$) than were off-road victims. The relative likelihood of a brain injury was not different by gender or age. There were no significant differences in injury severity or brain injury of victims by crash mechanism (collision vs. noncollision).

Discussion

Only a few studies have addressed the issue of riding ATVs on the road and even fewer have examined mechanisms and outcomes of on-road crashes. Riding on the road is an independent risk factor for injury. ATV design, including a high center of gravity and knobby, low pressure tires, increases the risk of operators losing control of the vehicle on roadway surfaces, particularly at high speed or when turning (General Accounting Office [GAO] 2010). This study was designed to take a closer look at on-road crashes in our state in order to determine whether there were significant differences in their characteristics and risk of injury when compared to off-road crashes.

Previous exposure studies show that riders of all ages are operating ATVs on the road (Burgus et al. 2009; Hafner et al. 2010), and in a recent survey of over 3000 students (primarily 11 to 15 years of age), we found that 81 percent of those who had ridden an ATV reported riding on the road (C. Jennissen, manuscript in preparation). Iowa allows on-road ATV use for agricultural purposes if the operator has a valid driver's license. However, more than two thirds of all riding has been reported to be for recreational, not work-related purposes (GAO 2010). Thus, it seems highly unlikely that all on-road operation of these vehicles, particularly by children and teens, was for agricultural work. This suggests that many ATV users either do not know Iowa laws restricting road use or choose to ignore them.

On-road crash victims in Iowa were not significantly different from off-road victims in terms of gender and age. The proportion of injured victims who were passengers in on- and off-road crashes was also similar (16% vs. 15%) and mirrored those of previous reports (Helmkamp, Ramsey, et al. 2008).

However, as previously reported (CPSC 2003), females and children in our study were significantly more likely to be passengers, and this was true both on and off the road. Carrying passengers appears to be a common practice, with 77 percent of ATV operators from a national sample reporting that they carry passengers, averaging 2.5 h per 10 h of riding time (Rodgers 1999). Passengers can act as a distraction, increasing the likelihood of a collision, and can alter the center of gravity, increasing the likelihood of a rollover. Thus, reducing multiple riders on ATVs through education and law enforcement could have an appreciable impact on these demographic groups.

Regression analysis indicated that operators in on-road crashes were more than twice as likely to test positive for alcohol. Drug use, on the other hand, was not significantly different for on- and off-road operators in our study population. Interestingly, the proportion of on-road operators tested for alcohol was higher than for off-road operators. We speculate that this may reflect the fact that the majority of on-road crashes were recorded by the DOT, whose primary function is law enforcement. Though the DNR also serves an enforcement purpose, since 2005, the Iowa DNR only monitors ATV use in public recreational areas. Thus, the majority of off-road crashes outside the parks came from the state trauma registry, whose primary function is recording emergency care. Alcohol testing in emergency departments is highly variable. The basis for the higher likelihood of females being tested for alcohol is currently unknown. It should also be noted that not all operators in crashes were tested for alcohol and that tests may have been administered when alcohol levels had significantly decreased from those at the crash scene. Therefore, the actual percentage of crashes involving intoxicated operators may be higher than indicated.

Previous studies found that alcohol was involved in 10 to 20 percent of nonfatal ATV crashes, values similar to ours of 17 percent, and in 40 to 50 percent of fatal crashes (Carr et al. 2004; Lord et al. 2010). The National Highway Traffic Safety Administration (NHTSA) has reported similar percentages of alcohol involvement in nonfatal and fatal motor vehicle crashes (10% and 41%, respectively; Hanson 2002) and in fatal motorcycle crashes (36%; Shankar 2003). Iowa law prohibits operating an ATV while under the influence of drugs and alcohol. Better education and enforcement of state laws are clearly needed to reduce deaths and injuries due to alcohol and drug use.

The most common crash and injury mechanisms varied by crash location. Similar to previous studies (Helmkamp, Furbee, et al. 2008), we found that a collision with another motor vehicle was the most common crash mechanism on the road, whereas a noncollision rollover, often accompanied with being struck or pinned by the vehicle, was the most common off-road mechanism of injury. Both collisions and being pinned by the vehicle are risk factors for a fatal outcome (Hall et al. 2009; Shulruf and Balemi 2010). It is very important to note that on-road ATV crash victims in our study were 10 times more likely to be involved in a motor vehicle collision than those off-road and that 93 percent of these crashes involved a motor vehicle other than another ATV. This indicates that on-road ATV operators may represent a traffic safety hazard not only to themselves but also to drivers and passengers of other vehicles. Whereas the proportion of collisions with objects other than vehicles was higher on the road than off, this may simply reflect the much higher likelihood that off-road crashes involved noncollision events (i.e., rollovers).

Brain injuries are the leading cause of death and serious disability from ATV crashes (Bowman and Aitken 2010; Hall et al. 2009). Overall, a higher percentage of brain injuries were observed in trauma patients from on-road crashes compared to those off-road. A higher percentage of severe brain injuries was also observed for on- versus off-road victims. Importantly, we found that helmet use was protective, significantly decreasing the risk of suffering a brain injury among our study population. This finding builds on previous results (Murphy and Yanchar 2004; Myers et al. 2009). Moreover, the increased proportion of brain injuries and lower rates of helmet use among on-road victims further support the particular importance of helmet use among riders engaging in high-risk behaviors.

ATV helmet laws vary by state, with 21 states having none, 12 states mandating helmet use by all riders, 11 states mandating use by minors, and 6 states with other restrictions. Iowa and the state of Mississippi only require helmets be worn in state OHV parks and on public trails. Future studies will be needed to determine the effectiveness of these helmet laws and to identify factors that contribute toward or are barriers to their success. Strong advocacy will also be needed to expand effective laws and enforcement strategies to other states.

The most unexpected finding was that injury severity and brain injury were independent of the crash mechanism (collision vs. noncollision). We speculate that higher forces, perhaps due to higher speeds, were the major determinant of injury severity rather than the type of crash involved.

In contrast to many other motorized vehicles, there is no significant safety culture around ATVs, and this poses a daunting challenge for ATV-related injury prevention. Our study emphasizes the potential risk of on-road ATV use and supports the prohibition of ATVs on public roadways. Armed with these data, we have initiated efforts to raise public awareness, educate stakeholders about state ATV laws and the dangers of riding on the road, and advocate against increasing ATV road use.

Whereas knowledge of the laws is an important component of traffic safety, effective enforcement of laws is also essential. Enforcing ATV laws is particularly challenging, especially in rural areas. In future studies, we will investigate aspects of Iowa ATV law enforcement, including how it can more effectively be performed and the impact of improved enforcement. Certainly, initiatives that educate law enforcement personnel and support them at every level in their efforts to decrease on-road ATV-related deaths and injuries are vital.

Our studies have the limitations inherent in retrospective research and experienced by other ATV injury prevention researchers. Limitations include incomplete capture of crash and injury records, missing parameters, and/or incomplete parameter documentation from data source to data source. Additionally, crash narratives from the trauma registry may be less accurate than those from the DOT and DNR, because health care providers are not trained in crash reporting. These limitations stem in part from the lack of a centralized state-supported database for ATV crashes and injuries and the lack of standardized data collection tools. In addition, we found a potential sampling bias in alcohol testing, with operators on the road being more likely to be tested. The basis for this potential bias is discussed above and readers should use caution in interpreting our results. Similarly, the protocol and decision-making processes used to determine whether an individual is tested for drugs may be different from source to source (e.g., DOT and STR) and from person to person, and the accuracy of drug test results is not known. The involvement of alcohol and drugs in ATV crashes may be underestimated due to these and other limitations. Finally, our study is limited to ATV victims in the state of Iowa and does not necessarily reflect the ATV-related crashes and injuries experienced in other states. Together, the stated limitations may reduce the generalizability of our results.

This study is one of only 2 state-based studies focused on the impact of on-road ATV crashes, and it expands upon a previous West Virginia study to provide compelling evidence of the particular threats from ATVs on the roads. One of the major strengths of our study lies in its multidisciplinary approach. Use of our data has led to wide-ranging interactions with agencies and community-based groups and has greatly assisted us in developing targeted ATV injury prevention programming. To our knowledge, we are the only state to create an integrated database of ATV crashes and injuries that includes linking records from multiple data sources. This database allows us to address questions that are not possible using single data sources, contributes to state-specific educational materials and surveillance data, and has resulted in multiple joint efforts with state agencies.

Conclusions

We found that a relatively high proportion of on-road ATV crashes involved a collision with another motor vehicle, indicating that ATVs represent a potential traffic safety hazard when on the road. Importantly, our studies provide additional proof for the protective effects of helmets and support the need to advocate for ATV helmet laws in states that do not currently have them. Of note, even controlling for helmet use, on-road ATV crash victims suffered more major trauma and severe brain injuries than those off the road. Taken together, our findings support the enforcement of laws that restrict on-road ATV use and for more education regarding the dangers of driving ATVs on the road. We also strongly advocate against any ordinances that would increase ATV road use.

Acknowledgments

Funding for these studies was provided by the University of Iowa Department of Emergency Medicine and by a grant to Dr. Christopher Buresh awarded through the Iowa Injury Prevention Research Center (IPRC, grant # 1R49CE001167-05). The IPRC funding was provided by the National Center for Injury Prevention and Control. We would also like to thank our partners and collaborators in the College of Public Health and at numerous state agencies. Student research assistants were supported in part by the University of Iowa Carver College of Medicine Medical Student Summer Research Program and the Iowa Center for Undergraduate Research.

References

Acosta JA, Rodriguez P. Morbidity associated with four-wheel all-terrain vehicles and comparison with that of motorcycles. *J Trauma.* 2003;55:282–284.

Aitken ME, Graham CJ, Killingsworth JB, Mullins SH, Parnell DN, Dick RM. All-terrain vehicle injury in children: strategies for prevention. *Inj Prev.* 2004;10:303–307.

Axelband J, Stromski C, McQuay Jr N, Heller M. Are all-terrain vehicle injuries becoming more severe? *Accid Anal Prev.* 2007;39:213–215.

Bercher DL, Staley K, Turner LW, Aitken M. Pediatric injuries resulting from use of all-terrain vehicles. *J Ark Med Soc.* 2001;97:351–353.

Bhutta ST, Greenberg SB, Fitch SJ, Parnell D. All-terrain vehicle injuries in children: injury patterns and prognostic implications. *Pediatr Radiol.* 2004;34:130–133.

Bowman SM, Aitken ME. Still unsafe, still in use: ongoing epidemic of all-terrain vehicle injury hospitalizations among children. *J Trauma.* 2010;69:1344–1349.

Bowman SM, Aitken ME, Helmkamp JC, Maham SA, Graham CJ. Impact of helmets on injuries to riders of all-terrain vehicles. *Inj Prev.* 2009;15:3–7.

Boyd CR, Tolson MA, Copes WS. Evaluating trauma care: the TRISS method. Trauma Score and the Injury Severity Score. *J Trauma.* 1987;27:370–378.

Brandenburg MA, Brown SJ, Archer P, Brandt EN Jr. All-terrain vehicle crash factors and associated injuries in patients presenting to a regional trauma center. *J Trauma.* 2007;63:994–999.

Burgus SK, Madsen MD, Sanderson WT, Rautiainen RH. Youths operating all-terrain vehicles—implications for safety education. *J Agromedicine.* 2009;14:97–104.

Carr AM, Bailes JE, Helmkamp JC, Rosen CL, Miele VJ. Neurological injury and death in all-terrain vehicle crashes in West Virginia: a 10-year retrospective review. *Neurosurgery.* 2004;54:861–866; discussion 866–867.

Collins CL, Smith GA, Comstock RD. Children plus all nonautomobile motorized vehicles (not just all-terrain vehicles) equals injuries. *Pediatrics.* 2007;120:134–141.

Consumer Product Safety Commission. All-terrain vehicle 2001 injury and exposure studies. 2003. Available at: http://www.cpsc.gov/library/atv2003.pdf. Accessed February 15, 2012.

Consumer Product Safety Commission. 2009 Annual report of ATV-related deaths and injuries. 2010. Available at: http://www.cpsc.gov/library/foia/foia11/os/atv2009.pdf. Accessed February 15, 2012.

Fisher RM, Berg RL, Marlenga B. Children's exposures to farm worksite hazards on management-intensive grazing operations. *J Agromedicine.* 2009;14:192–197.

Fonseca AH, Ochsner MG, Bromberg WJ, Gantt D. All-terrain vehicle injuries: are they dangerous? A 6-year experience at a level I trauma center after legislative regulations expired. *Am Surg.* 2005;71:937–940; discussion 940–931.

General Accounting Office. All-terrain vehicles: how they are used, crashes, and sales of adult-sized vehicles for children's use. Report to Congressional Committees (GAO-10-418). 2010. Available at: http://www.gao.gov/new.items/d10418.pdf. Accessed January 20, 2012.

Gittelman MA, Pomerantz WJ, Groner JI, Smith GA. Pediatric all-terrain vehicle-related injuries in Ohio from 1995 to 2001: using the injury severity score to determine whether helmets are a solution. *Pediatrics.* 2006;117:2190–2195.

Hafner JW, Hough SM, Getz MA, Whitehurst Y, Pearl RH. All-terrain vehicle safety and use patterns in central Illinois youth. *J Rural Health.* 2010;26:67–72.

Hall AJ, Bixler D, Helmkamp JC, Kraner JC, Kaplan JA. Fatal all-terrain vehicle crashes injury types and alcohol use. *Am J Prev Med.* 2009;36:311–316.

Hanson D. Alcohol consumption and traffic crashes. 2002. Available from http://www2.potsdam.edu/hansondj/DrivingIssues/1101913925.html Accessed February 1, 2012.

Helmkamp JC, Aitken ME, Lawrence BA. ATV and bicycle deaths and associated costs in the United States, 2000–2005. *Public Health Rep.* 2009;124:409–418.

Helmkamp JC, Furbee PM, Coben JH, Tadros A. All-terrain vehicle-related hospitalizations in the United States, 2000–2004. *Am J Prev Med.* 2008;34:39–45.

Helmkamp JC, Ramsey WD, Haas SM, Holmes M. *All-Terrain Vehicle (ATV) Deaths and Injuries in West Virginia: A Summary of Surveillance and Data Sources*. Charleston, WV: Criminal Justice Statistical Analysis Center, Division of Criminal Justices Services, Department of Military Affairs and Public Safety; 2008. Available at: http://www.wvdcjs.com/statanalysis. Accessed November 21, 2011.

Hendricks KJ, Myers JR, Layne LA, Goldcamp EM. Household youth on minority operated farms in the United States, 2000: exposures to and injuries from work, horses, ATVs and tractors. *J Safety Res.* 2005;36:149–157.

Killingsworth JB, Tilford JM, Parker JG, Graham JJ, Dick RM, Aitken ME. National hospitalization impact of pediatric all-terrain vehicle injuries. *Pediatrics.* 2005;115:e316–e321.

Kirkpatrick R, Puffinbarger W, Sullivan JA. All-terrain vehicle injuries in children. *J Pediatr Orthop.* 2007;27:725–728.

Kute B, Nyland JA, Roberts CS, Hartwick-Barnes V. Recreational all-terrain vehicle injuries among children: an 11-year review of a central Kentucky level I pediatric trauma center database. *J Pediatr Orthop.* 2007;27:851–855.

Levenson M. All-terrain vehicle 2001 injury and exposure studies. Consumer Product Safety Commission Report. 2003. Available at: http://www.cpsc.gov/library/foia/foia03/os/atvex2001.pdf. Accessed November 21, 2011.

Lord S, Tator CH, Wells S. Examining Ontario deaths due to all-terrain vehicles, and targets for prevention. *Can J Neurol Sci.* 2010;37:343–349.

Murphy N, Yanchar NL. Yet more pediatric injuries associated with all-terrain vehicles: should kids be using them? *J Trauma.* 2004;56:1185–1190.

Myers ML, Cole HP, Mazur JM. Cost effectiveness of wearing head protection on all-terrain vehicles. *J Agromedicine.* 2009;14:312–323.

Rodgers GB. All-terrain vehicle injury risks and the effects of regulation. *Accid Anal Prev.* 1993;25:335–346.

Rodgers GB. The characteristics and use patterns of all-terrain vehicle drivers in the United States. *Accid Anal Prev.* 1999;31:409–419.

Rodgers GB. Factors associated with the all-terrain vehicle mortality rate in the United States: an analysis of state-level data. *Accid Anal Prev.* 2008;40:725–732.

Scutchfield SB. All-terrain vehicles: injuries and prevention. *Clin Orthop Relat Res.* 2003:61–72.

Shankar U. *Alcohol Involvement in Fatal Motorcycle Crashes*. Washington, DC: National Center for Statistics and Analysis; 2003. DOT HS 809 576.

Shulruf B, Balemi A. Risk and preventive factors for fatalities in all-terrain vehicle accidents in New Zealand. *Accid Anal Prev.* 2010;42:612–618.

Yanchar NL, Kennedy R, Russell C. ATVs: motorized toys or vehicles for children? *Inj Prev.* 2006;12:30–34.