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All-terrain vehicle fatalities on paved roads, unpaved roads, and off-road: Evidence for informed roadway safety warnings and legislation

Gerene M. Denning and Charles A. Jennissen

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

ABSTRACT

Objective: All-terrain vehicles (ATVs) are designed for off-highway use only, and many of their features create increased risk with roadway travel. Over half of all ATV-related fatalities occur on roadways, and nonfatal roadway crashes result in more serious injuries than those off the road. A number of jurisdictions have passed or have considered legislation allowing ATVs on public roadways, sometimes limiting them to those unpaved, arguing that they are safe for ATVs. However, no studies have determined the epidemiology of ATV-related fatalities on different road surface types. The objective of the study was to compare ATV-related deaths on paved versus unpaved roads and to contrast them with off-road fatalities.

Methods: Retrospective descriptive and multivariable analyses were performed using U.S. Consumer Product Safety Commission fatality data from 1982 through 2012.

Results: After 1998, ATV-related deaths increased at twice the rate on paved versus unpaved roads. Still, 42% of all roadway deaths during the study period occurred on unpaved surfaces. States varied considerably, ranging from 18% to 79% of their ATV-related roadway deaths occurring on unpaved roads. Paved road crashes were more likely than those on unpaved surfaces to involve males, adolescents and younger adults, passengers, and collisions with other vehicles. Both the pattern of other vehicles involved in collisions and which vehicle hit the other were different for the 2 road types. Alcohol use was higher, helmet use was lower, and head injuries were more likely in paved versus unpaved roadway crashes. However, head injuries still occurred in 76% of fatalities on unpaved roads. Helmets were associated with lower proportions of head injuries among riders, regardless of road surface type. Relative to off-road crashes, both paved and unpaved roads were more likely to involve collisions with another vehicle. The vast majority of roadway crashes, however, did not involve a traffic collision on either paved or unpaved roads.

Conclusions: Although differences were observed between paved and unpaved roads, our results show that riding on either represented significantly greater dangers than riding off the road. Many vehicle warnings specifically mention the risks of paved but not unpaved roads, yet we found 23 states with half or more of their roadway deaths on unpaved surfaces. Safety warnings should explicitly state the dangers of roadway riding regardless of surface type. These data further support laws/ordinances greatly restricting ATV riding on all types of public roadways.

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Introduction

Studies have identified riding on roadways as an independent risk factor for all-terrain vehicle (ATV)-related deaths and injuries (Denning, Harland, et al. 2013; Denning, Jennissen, et al. 2013; Rodgers 2008; Williams et al. 2014). In fact, over 60% of all U.S. ATV-related fatalities have involved roadway crashes, and roadway deaths increased at twice the rate of those off-road from 1998 to 2006 (Denning, Harland, et al. 2013). In addition, statewide nonfatal roadway crashes were significantly more likely to involve a collision with another vehicle and to result in more serious injuries compared to those off-road (Denning, Jennissen, et al. 2013). These findings suggest that roadway riding is among the most dangerous practices by ATV riders and thus a significant public health concern.

Manufacturers explicitly state that ATVs are not designed for riding on the road, and the Consumer Product Safety Commission (CPSC) requires warning labels to this effect. However, survey studies show that roadway riding is a highly common practice, including among youth (Burgus et al. 2009; Campbell et al. 2010; Goldcamp et al. 2006; Hafner et al. 2010; Jennissen et al. 2014; Jones and Bleeker 2005; Levenson 2003).

Additionally, a recent report from the Consumer Federation of America shows a disturbing trend of cities, counties, and states moving to legalize recreational riding of ATVs on public roads (Weintraub and Best 2014). In some cases, governing bodies are passing legislation to allow ATVs on unpaved roads only, perhaps with the assumption that it is safe.

Although previous research demonstrates the dangers of roadway riding overall (Denning, Harland, et al. 2013; Denning, Jennissen, et al. 2013; Williams et al. 2014), no studies have examined ATV crash epidemiology in terms of road surface type. To address this question, we compared crashes on paved versus unpaved roads using a national ATV fatality database. We also compared key characteristics for fatalities from paved and unpaved roadways with those occurring off-road.

CONTACT Gerene M. Denning gerene-denning@uiowa.edu Department of Emergency Medicine, University of Iowa Carver College of Medicine, 1008 Roy Carver Pavilion, 200 Hawkins Drive, Iowa City, Iowa, 52242
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Methods

CPSC ATV fatality database

A retrospective study of ATV-related deaths from 1982 to 2012 was performed using CPSC fatality data obtained through a Freedom of Information Act request. Documentation and limitations of the data set have been previously described (Denning, Harland, et al. 2013; Denning et al. 2014). Only crashes involving ATVs were included in the analysis. Youth and adults were further grouped as follows: pediatric <6, 6–11, 12–15, and 16–17 years old and adults 18–30, 31–45, 46–60, and >60 years old. Other demographic and crash- and injury-related variables were coded as previously described (Denning, Harland, et al. 2013; Denning et al. 2014).

Road surface definitions

A paved road is defined as one with a hard smooth surface, most commonly concrete or asphalt. Unpaved roads generally have gravel or dirt surfaces. The CPSC variable "terrain" includes codes for paved and unpaved roads. To identify inconsistent data related to crash location (on vs. off the road), we compared the values of "ON" and "OFF" the road created from the CPSC "road" variable as previously described (Denning, Harland, et al. 2013), with values for the variable terrain. For "road" variable values of "OFF" the road, records with terrain codes for "paved" or "unpaved" roads were recoded as location unknown (62 records). Similarly, "ON" road location values with accompanying terrain codes for off-road locations—for example, "Off-Highway Vehicle (OHV) park/track"—were recoded as unknown (27 records). Remaining crashes identified as "ON" road were coded for road surface using terrain codes for paved, unpaved, or unknown (all other road-related terrain codes).

Data analysis

Only the years for which recorded deaths were indicated by the CPC to be complete (1982–2007) were used to calculate changes in the number of deaths over time. Data from all years were used for descriptive, comparative, and multivariable analyses. Data designated "unknown" or missing were not included in analysis. Descriptive analyses were performed using Microsoft ACCESS 2010. Bivariate analyses comparing proportions were done using the chi square test at the VassarStats Website for Statistical Computation (http://www.vassarstats.net). All other statistical analyses were performed using SPSS (IBM SPSS Statistics 22).

Multivariable logistic regression analysis was used to calculate adjusted odds ratios and 95% confidence intervals (CIs) for categorical outcomes, after controlling for significant covariates. We chose 31- to 45-year-olds as the age reference group because these riders are likely to have more experience and maturity than younger riders and are unlikely to have reduced cognitive or physical function relative to older riders. Persons with missing data for one or more of the variables in the model were not included in multivariable analysis. Alcohol involvement was not included in multivariable models, because more than half of all crashes were coded unknown for this variable. Data were also

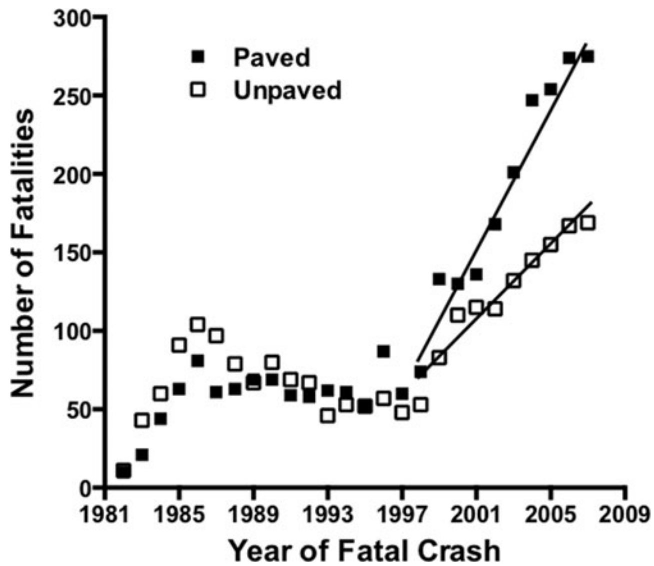

Figure 1. Graph of CPSC ATV fatalities over time for crashes on paved (solid square) and unpaved (open square) roads. Linear regression analysis of crashes from 1998 through 2007, the most recent year for which the CPSC reported data were complete, was performed. The lines demonstrate that the rate of increase in fatalities on paved roads (23 ± 1.8 deaths/year) was nearly twice that of unpaved roads (12 ± 1.1 deaths/year).

analyzed using hierarchical logistic regression analysis clustering by year of the crash or by the state where the crash occurred. Differences, when observed, were small and did not significantly change interpretation of any results (data not shown).

Results

Fatalities on paved and unpaved roads

Among the 6,625 roadway fatalities with identifiable surface types, 42% and 58% involved unpaved and paved roads, respectively. Unpaved roads were involved in the majority of roadway fatalities from 1982 to 1992, but over half of the deaths after that time were from crashes on paved road surfaces (Figure 1). Additionally, from 1998 through 2007, the rate of increase in fatalities on paved roads was almost twice that of unpaved roads, 23 ± 1.8 vs. 12 ± 1.1 deaths/year.

Road surface type by state

The proportion of crashes on unpaved roads varied considerably among states (Table 1). The highest proportion on unpaved roadways was 79% and the lowest was 18%. The majority of fatal crashes occurred on unpaved roads for 21 states and on paved roads for 27 states. Two states had equal proportions.

Person-related variables

No sex-dependent difference was seen by road surface type, but age-dependent differences were observed among both youth and adults (Table 2). Approximately 30% of all fatalities on both paved and unpaved roads involved persons less than 18 years of age. Older youth as compared to younger ($P < .0001$) and 18- to 30-year-olds compared to older adults ($P = .0005$) were a higher

Table 1. Percentage of ATV-related roadway fatalities on unpaved roads in each state from 1982 to 2012. N is the total number of fatalities documented as occurring on either paved or unpaved roads

State	n (% Unpaved)	State	n (% Unpaved)	State	n (% Unpaved)
WY	19 (79)	NV	29 (55)	NY	244 (37)
ID	86 (76)	MI	224 (54)	NC	234 (36)
MT	51 (75)	NM	61 (52)	PA	365 (36)
UT	96 (74)	AR	206 (51)	WI	147 (35)
AK	76 (72)	RI	4 (50)	NJ	53 (32)
WA	72 (71)	NH	34 (50)	LA	171 (28)
CO	63 (68)	IA	88 (49)	MD	47 (28)
AZ	125 (66)	ND	27 (48)	IL	135 (27)
OR	86 (65)	OK	99 (46)	TN	267 (27)
HI	11 (64)	MA	39 (44)	MS	199 (27)
NE	57 (63)	GA	236 (43)	SC	87 (26)
VT	37 (62)	MO	254 (43)	DE	8 (25)
KS	50 (60)	FL	351 (42)	CT	32 (25)
ME	90 (58)	VA	106 (42)	KY	315 (24)
MN	160 (57)	TX	326 (38)	OH	206 (23)
CA	297 (56)	AL	175 (38)	IN	112 (18)
SD	27 (56)	WV	389 (38)		

Because of missing, unknown, and inconsistent data for the "road" and "terrain" variables and because data are incomplete for 2009–2012, N does not represent all roadway fatalities for each state.

proportion of fatalities on paved than on unpaved roads. A difference was also observed in the proportion of crashes where ATVs had more than one rider when comparing each road surface type (28% each, Table 2) to off-road (23%, 780 of 3,448), $P < .0001$.

Helmet use was lower among riders on paved roads (12%) compared to those on unpaved roads (18%), $P < .0001$ (Table 2). However, rider helmet use on both road surface types was lower than use off the road (24%, 664 of 2,725), $P < .0001$. Alcohol involvement, where tested, was higher for paved roadway crashes (49%) than for unpaved ones (44%), $P = .002$ (Table 2). Involvement of alcohol in both paved and unpaved roadway crashes was higher than in off-road crashes (31%, 724 of 2,349), $P < .0001$.

Crash-related variables

The majority of fatalities on both paved (63%) and unpaved (85%) roads did not involve another motorized vehicle (Table 2). However, traffic collisions were more common on paved roads than on unpaved ones, $P < .0001$, but the proportion of fatalities from ATV–vehicle collisions was higher for both road surface types than for off-road crashes (5%, 223 of 4,252), $P < .0001$. Similarly, the proportion of crashes involving collisions with objects that were not motorized vehicles (ATV–Other) was higher for both paved and unpaved roads (34 and 40%, respectively) compared to off-road (20%, 866 of 4,252), $P < .0001$.

For crashes with another motorized vehicle that was not an ATV, the proportions of cars and trucks involved on paved roads were similar, 48 and 44%, respectively (total $n = 1{,}124$ collisions), but trucks were over twice as common as cars in crashes with the ATV on unpaved roads, 53% versus 25% (total $n = 318$ collisions), $P < .0001$. In the majority of traffic collisions on paved roads, the ATV was hit by the other vehicle (578 of 1,108, 52%), whereas the opposite was true on unpaved roads; that is, the ATV hit the other vehicle in 60% of crashes (183 of 294), $P < .0001$.

Table 2. Person-, crash-, and injury-related variables for ATV-related fatalities from 1982 to 2012 on paved and unpaved roads

	Paved n (column%)[a]	Unpaved n (column%)[a]	P Value[b]
Sex			
Male	3301 (86%)	2391 (85%)	.06
Female	520 (14%)	431 (15%)	
Youth			
<6 years old	41 (4%)	51 (6%)	<.0001
6–11 years old	191 (17%)	216 (24%)	
12–15 years old	559 (50%)	443 (49%)	
16–17 years old	322 (29%)	195 (22%)	
Adult			
18–30 years old	1398 (52%)	909 (47%)	.0005
31–45 years old	765 (28%)	527 (27%)	
46–60 years old	350 (13%)	311 (16%)	
>60 years old	193 (7%)	172 (9%)	
Seating Position			
Operator alone	2289 (72%)	1712 (72%)	.82
Operator w Passenger	425 (13%)	313 (13%)	
Passenger	487 (15%)	347 (15%)	
Helmet Use			
Yes	337 (12%)	378 (18%)	<.0001
No	2472 (88%)	1669 (82%)	
Alcohol Involved			
Yes	1089 (49%)	756 (44%)	.002
No	1120 (51%)	949 (56%)	
Crash Mechanism			
ATV-ATV Collision	274 (7%)	119 (4%)	<0.0001
ATV-Vehicle Collision[c]	1129 (30%)	325 (12%)	
ATV-Other Collision[d]	1298 (34%)	1118 (40%)	
Non-Collision Event	1101 (29%)	1254 (45%)	
Head Injury			
Yes	2625 (87%)	1734 (76%)	<0.0001
No	394 (13%)	548 (24%)	
Crash Mechanism and Head Injury			
ATV-ATV Collision			
Head Injury Yes	221 (97%)	93 (91%)	.079
Head Injury No	8 (3%)	9 (9%)	
ATV-Vehicle Collision			
Head Injury Yes	698 (86%)	190 (81%)	.083
Head Injury No	116 (14%)	45 (19%)	
ATV-Other Collision			
Head Injury Yes	906 (88%)	682 (76%)	<.0001
Head Injury No	124 (12%)	210 (24%)	
Non-Collision Event			
Head Injury Yes	789 (84%)	768 (73%)	<.0001
Head Injury No	146 (16%)	282 (27%)	
Helmet Use and Head Injury			
Helmeted Victims			
Head Injury Yes	196 (75%)	190 (62%)	.008
Head Injury No	64 (25%)	117 (38%)	
Un-Helmeted Victims			
Head Injury Yes	1811 (89%)	1127 (79%)	<.0001
Head Injury No	220 (11%)	304 (21%)	

[a]Column totals may not equal overall totals due to missing or unknown values.
[b]P value from bivariate analysis using the chi-square test.
[c]Other motorized vehicle is not an ATV.
[d]Other object is not a motorized vehicle.

Helmets and head injuries

A significantly higher proportion of persons in fatal crashes sustained a head injury on paved as compared to unpaved roads, $P < .0001$ (Table 2). However, the proportion was still 76% for the latter. By crash mechanism, paved roadway crashes had higher proportions of head injuries than unpaved roadway crashes for "ATV–Other" designated collisions (88% vs. 76%) and for non-collision events (84% vs. 73%), $P < .001$ in each case. Fatal ATV–ATV collisions had the highest proportion of head injuries for both road surface types (>90%). Higher helmet use was consistently associated with a lower proportion of head injuries.

Multivariable data analysis

Paved versus unpaved roadway crashes

Multivariable analysis showed that paved roadway crashes were 23% more likely than crashes on unpaved surfaces to involve males than females (95% CI, 1.05–1.45) and 33% more likely to involve passengers than operators riding alone (95% CI, 1.11–1.59); see Table 3. Compared to fatal crashes among 31- to 45-year-olds, those involving youth under 16 years of age and adults 45–60 years of age were less likely to have occurred on paved than on unpaved roads.

Collisions and noncollision events

Collisions with motor vehicles and other objects were more likely than noncollision events (i.e., rollovers) to involve male operators than female operators, when controlling for important covariates (Table 3). Overall, compared to crashes among operators 31–45 years of age, collisions were more likely than noncollision events to occur among 12- to 30-year-olds and less likely when operators were over 45 years of age.

Collisions, compared to noncollision events, were also more likely when crashes were on paved or unpaved roads than if they were off-road, with ATV–Vehicle collisions on paved roads having the highest adjusted odds ratio (adjusted odds ratio [aOR] = 25.5, 95% CI, 20.2–32.2). The ATV colliding with something other than another vehicle (ATV–Other) was 21% more likely (95% CI, 1.06–1.37) if passengers were involved, whereas passengers had no effect on traffic collisions compared to noncollision events.

Helmet use

Males and females were equally likely to have been helmeted when controlling for other variables such as seating position (Table 4), whereas passengers were less likely to have been helmeted than operators riding alone (95% CI, 0.26–0.43). Riders in fatal paved and unpaved roadway crashes were 60% (95% CI, 0.35–0.47) and 33% (95% CI, 0.58–0.78) less likely to be helmeted, respectively, than those in fatal crashes off the road.

Head injury

When controlling for other factors, including helmet use, there were no sex-based differences in head injuries (Table 4). However, relative to 31- to 45-year-olds, 18- to 30-year-olds were more likely to have sustained a head injury (aOR = 1.26, 95% CI, 1.05–1.52), whereas head injuries among older age groups were less likely to have occurred. Head injuries among passengers were 65% more likely (95% CI, 1.29–2.11) than among operators riding alone.

Head injuries were over 3-fold more likely in fatal crashes on paved roads (aOR = 3.13, 95% CI, 2.64–3.71) compared to fatal off-road crashes. Similarly, riders killed on unpaved roads were 54% more likely (95% CI, 1.33–1.79) to sustain a head injury than those in off-road crashes. Head injuries were also more likely among riders killed in collisions than in noncollision events and were over 4 times more likely (95% CI, 2.73–7.12) in deaths resulting from a collision with another ATV. Overall, a head injury was approximately half as likely among helmeted riders (95% CI, 0.39–0.53).

Discussion

Risk of roadway riding

All-terrain vehicle is a misnomer, because ATVs are designed for off-road use only (Specialty Vehicle Institute of America 2014). Despite the vast majority of ATV riding being off-road, over 60% of all ATV-related deaths in the United States have resulted from roadway crashes (Denning, Harland, et al. 2013). Less than one third of these roadway deaths involved a crash with another vehicle. In a study of nonfatal ATV-related injuries, 38% occurred on roadways, with about one third of these involving a motor vehicle collision (Denning, Jennissen, et al. 2013). Moreover, nonfatal roadway crashes had a higher morbidity than off-road crashes.

The size and speed of ATVs have both increased dramatically since 1998. Traveling at higher speeds over typical off-road terrains is extremely difficult, so riders who want to experience top speeds may be more likely to ride on the road. In addition, there appears to be a growing movement pushing governing bodies at the municipal, county, or state levels to pass legislation allowing increased ATV use of public roads (Huber 2014; Weintraub and Best 2014).

The current study shows that over half of all fatal U.S. ATV roadway crashes occurred on paved roads and that, since 1998, paved roadway fatalities increased twice as fast as those on unpaved roads. Still, over 40% of roadway deaths were on unpaved road surfaces and 23 states had at least half of their deaths on roads that were unpaved.

ATV design

Several ATV design features contribute to the higher risk of losing control on the roads (Carman et al. 2010; Huhlein 1998; Thorbole et al. 2012). The relatively narrow track, high center of gravity, and lack of a rear differential on most models—that is, no differences in the rate of rear tire rotation when turning—increase the risk of a rollover under many driving conditions. Most roadway intersections are at right angles, making it harder to take the wider turns required by ATVs. Operators may misjudge their ability to turn or negotiate a curve at roadway speeds, leading to a rollover and/or collision event.

The low-pressure ATV tires and their tread are specifically designed for off-road terrains. Roadway tires grip and release the road, whereas ATV tires are made to grab surfaces for traction and can unexpectedly and unevenly do so on roadway surfaces, leading to loss of control. In addition, bumps or ruts on unpaved roadways, when hit at higher speeds, could result in loss of control with a resulting crash. Rider–vehicle–roadway surface dynamics are extremely complex and appear to significantly increase the risk of ATV crashes and resulting injuries on both paved and unpaved roads.

Table 3. Multivariable regression analysis to determine the odds of the crash being on a paved versus an unpaved road or of being the indicated collision type versus a noncollision event, as a function of each variable in the model[a]

	Odds of the crash being on a paved vs. an unpaved roads (model $n =$ 5,571)			Odds of the crash being a collision vs. a noncollision event					
				ATV–ATV (model $n =$ 4,947)		ATV–vehicle[b] (model n = 4,570)		ATV–other[c] (model n = 7,071)	
	aOR	95% CI		aOR	95% CI	aOR	95% CI	aOR	95% CI
Fatally injured person's sex			Operator's sex						
Male	1.23	1.05–1.45	Male	1.38	0.95–2.00	1.54	1.21–1.97	1.22	1.03–1.44
Female	1.0 (ref)		Female	1.0 (ref)		1.0 (ref)		1.0 (ref)	
Fatally injured person's age (years old)			Operator's age (years old)						
<6	0.39	0.24–0.61	<6	0.77	0.10–5.73	1.81	0.57–5.78	0.73	0.35–1.56
6–11	0.52	0.52–0.66	6–11	0.61	0.31–1.20	3.49	2.52–4.82	0.60	0.46–0.79
12–15	0.75	0.63–0.91	12–15	1.30	0.87–1.96	4.88	3.75–6.32	1.32	1.10–1.57
16–17	0.98	0.78–1.24	16–17	2.20	1.38–3.51	4.60	3.32–6.36	1.55	1.23–1.97
18–30	0.97	0.83–1.13	18–30	2.14	1.60–2.87	2.10	1.66–2.65	1.5	1.30–1.74
31–45	1.0 (ref)		31–45	1.0 (ref)		1.0 (ref)		1.0 (ref)	
46–60	0.72	0.59–0.88	46–60	0.46	0.28–0.74	0.67	0.51–0.96	0.62	0.51–0.75
>60	0.76	0.59–0.98	>60	0.21	0.10–0.47	1.21	0.86–1.69	0.50	0.39–0.63
Fatally injured person's seating			Crash location						
Operator alone	1.0 (ref)		Paved road	6.50	4.88–8.66	25.5	20.2–32.2	4.07	3.57–4.63
Operator with passenger	1.06	0.90–1.25	Unpaved road	2.53	1.84–3.50	5.94	4.61–7.64	3.06	2.69–3.49
Passenger	1.33	1.11–1.59	Off-road	1.0 (ref)		1.0 (ref)		1.0 (ref)	
			Carrying passengers						
			No	1.0 (ref)		1.0 (ref)		1.0 (ref)	
			Yes	1.82	0.91–3.65	1.10	0.92–1.32	1.21	1.06–1.37

[a]Persons with missing data for one or more of the variables in the model were not included in the analysis.
[b]Other motorized vehicle is not an ATV.
[c]Other object is not a motorized vehicle.

Risky behaviors

Adolescents and younger adults are those most prone to risk-taking behaviors, particularly young males (Aitken et al. 2004; Chen et al. 2007; Grummon et al. 2014). Males often comprise 80% or more of ATV-related deaths and injuries (Denning, Harland, et al. 2013; Denning, Jennissen, et al. 2013; Denning et al. 2014; Goldcamp et al. 2006; Shults et al. 2005). In the current study, fatal crashes on paved roads were more likely to involve males than females, and traffic collisions were more likely than noncollision events to involve male versus female operators. Similarly, collisions were more likely than noncollision events to involve younger operators (16–30 years of age) than older adults.

ATV crashes have been shown to be more likely when multiple risk factors are involved (Rodgers 2008). A survey of adolescents found that among the 3,344 who had been on an ATV, 89% reported having engaged in more than one of 3 unsafe riding behaviors and 57% had been in a crash (Jennissen et al. 2014). Additionally, those students reporting having ridden on the road and having ridden with passengers were over 3 times more likely to indicate having been in a crash than were students reporting neither unsafe behavior. Other studies have also shown that those injured in roadway crashes were more likely to have engaged in multiple unsafe riding practices compared to those in off-road crashes (Denning, Harland, et al. 2013; Denning, Jennissen, et al. 2013; Denning et al. 2014).

Compared to fatal unpaved roadway crashes, those on paved roads were more likely to involve passengers, riding unhelmeted, and using alcohol. However, it is important to note that all of these behaviors were more common among riders killed on paved and unpaved roads than among deaths occurring off the road.

Collision vs. noncollision events

ATVs on the road pose a risk to other motorists (Denning, Harland, et al. 2013; Denning, Jennissen, et al. 2013). Although the current study shows that collisions with another vehicle were more likely to occur on paved than on unpaved roads, vehicle collisions on both road surface types were more likely than off the road. This probably reflects relative traffic densities for these 3 locations. Similarly, differences between paved and unpaved roadway collisions with respect to the other vehicle involved may reflect the nature of traffic on different road types; for example, trucks are relatively more common on unpaved rural roads.

Collisions with objects other than motor vehicles were equally likely for the 2 road surface types but were more likely in both cases than for off-road terrains. These results suggest that with loss of ATV control on roadways, there may be an inability to stop before hitting something on or near the road due to higher traveling speeds and other factors, regardless of surface type. Almost all ATVs are designed for an operator only and carrying passengers is a known risk factor for crashes (Rodgers 2008). In our study, collisions with other objects were more likely to occur than noncollision events when passengers were present.

Despite the danger of a collision with a motorized vehicle when ATVs are on the road, the vast majority of fatal ATV crashes on both paved and unpaved roads did not involve another vehicle. Nearly two thirds of paved road crashes and an even higher proportion of unpaved road crashes were not traffic-related. Obviously, other factors, such as higher speeds on roads and off-road design features, are major contributors to ATV crash-related deaths on roadways.

Table 4. Multivariable regression analysis to determine the odds of being helmeted or of sustaining a head injury, as a function of each variable in the model[a]

	Odds of being helmeted[b] (model $n = 7375$)		Odds of a head injury[c] (model $n = 6161$)	
	aOR	95% CI	aOR	95% CI
Sex				
Male	1.08	0.89–1.31	1.09	0.90–1.31
Female	1.0 (ref)		1.0 (ref)	
Age (years old)				
<6	1.58	0.99–2.51	1.40	0.87–2.24
6–11	2.51	1.98–3.19	1.05	0.82–1.34
12–15	2.25	1.83–2.77	1.24	0.99–1.55
16–17	2.06	1.58–2.68	1.25	0.93–1.69
18–30	1.21	1.00–1.45	1.26	1.05–1.52
31–45	1.0 (ref)		1.0 (ref)	
46–60	0.72	0.56–0.92	0.68	0.55–0.85
>60	0.29	0.21–0.42	0.47	0.37–0.60
Seating				
Operator alone	1.0 (ref)		1.0 (ref)	
Operator with passenger	0.42	0.34–0.53	1.08	0.89–1.32
Passenger	0.34	0.26–0.43	1.65	1.29–2.11
Crash location				
Paved road	0.40	0.35–0.47	3.13	2.64–3.71
Unpaved road	0.67	0.58–0.78	1.54	1.33–1.79
Off-road	1.0 (ref)		1.0 (ref)	
Crash mechanism				
ATV–ATV collision	Not included in model		4.42	2.73–7.19
ATV–vehicle collision[d]			1.38	1.09–1.74
ATV–other collision[e]			1.28	1.10–1.48
Noncollision event			1.0 (ref)	
Helmet use				
Yes	Not included in model		0.46	0.39–0.53
No			1.0 (ref)	

[a]Victims with missing data for one or more of the variables in the model were not included in the analysis.
[b]Referent is not wearing a helmet.
[c]Referent is no head injury.
[d]Other motorized vehicle in the collision was not an ATV.
[e]Other object in the collision was not a motorized vehicle.

Helmet use and head injuries

In previous studies, helmet use was less likely and head injury more likely when deaths occurred on the road than off (Denning, Harland, et al. 2013; Denning, Jennissen, et al. 2013). In this study, helmet use by those involved in fatal crashes was lower on paved than on unpaved roads, and both were lower than among persons killed in off-road crashes. Similar to previous studies, lower helmet use was consistently associated with a higher proportion of head injuries (Bowman et al. 2009; Denning, Harland, et al. 2013; Rodgers 1990). However, even after controlling for other variables including helmet use, crashes on paved roadways were more likely than those on unpaved roadways and crashes on both road surface types were more likely than those off-road to involve riders who sustained a head injury. We hypothesize that this reflects higher speeds and greater impact forces generated on paved versus unpaved roads and on roadways versus off the road.

When controlling for other variables, those who died in a collision were more likely to have sustained a head injury than those who died in noncollision events. Particularly striking was the finding that head injuries were over 4 times more likely among those dying in ATV–ATV crashes than those killed in noncollision events. This suggests that ATV–ATV collisions are less likely to lead to a fatality unless a head injury occurs, and deaths from this type of crash may be particularly preventable with helmet use. Although head injuries are still common in noncollision events, trauma to vital internal organs of the torso or asphyxiation due to the vehicle pinning the rider are often seen with ATV rollover-related deaths.

Public policy implications

The CPSC mandates warning labels on all ATVs about the dangers of riding on the road. However, many manufacturer warnings and safety training materials only mention paved roads. This could lead people to conclude that unpaved roads are safe for ATVs. Our findings do not support this conclusion. In nearly half of the states, 50% or more of the roadway deaths occurred on unpaved surfaces. Additionally, several negative characteristics/outcomes were higher for both road surface types compared to off-road. Because roadway crashes represent the majority of ATV-related fatalities in every state, including those with higher proportions on unpaved roads, and assuming that riding on roads is less frequent than off-road riding, the evidence suggests that both paved and unpaved roads are significantly more dangerous riding environments than off-road locations.

A second problem with many safety warnings is language that emphasizes collisions with other vehicles. This may again lead to assumptions that traffic density is the only concern. Though ATV–vehicle collisions were much more likely on the road than off, they only accounted for 37 and 16% of paved and unpaved roadway deaths, respectively.

Reducing roadway riding through legislation

An article by the Consumer Federation of America documents recent passage of laws and ordinances across the United States that legalize ATV use on public roads (Weintraub and Best 2014). Much of this is occurring under circumstances where public policy makers have limited knowledge about ATV safety, where they are hearing mixed safety messages (Huber 2014), and where false assumptions are being made. ATV injury prevention experts fear that these laws and ordinances will inevitably increase ATV roadway-associated deaths and injuries (Weintraub and Best 2014).

Although differences were observed between paved and unpaved roads, our results show that riding ATVs on either represented significantly greater risks than riding off the road. Keeping ATVs off public roads is a critical strategy to reduce deaths and injuries. Manufacturers and safety agencies should develop warning language that more strongly and accurately conveys the message that riding ATVs on any road is an unnecessary high-risk activity and that most roadway crashes do not involve other vehicles. Stakeholders should understand the dangers of ATVs on all roads and strongly advocate for evidence-based ATV safety laws.

Study limitations

Retrospective studies are often limited by incomplete documentation of some variables and the inability to collect missing data. Data were collected using a standardized form for all states and every variable used in analysis was available for all years of the study period. Documentation of the variables ranged from 100% (age) to 50% (alcohol) and is reflected in the *n* values found in the tables. Whereas documentation issues could impact our results, the fact that fatalities are more readily captured than injuries, that all states are represented, and that the sample size is large makes it more likely the results are representative for the United States. Because study data are for the United States, however, they may not be generalizable to other countries. The unavailability of ATV exposure data, including that on paved and unpaved roads and off-road terrains, prevents death rate calculations and other analyses.

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