Characteristics of Crashes With Farm Equipment That Increase Potential for Injury

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ABSTRACT: ***Context:*** *Crash fatality and injury rates are higher on rural roadways than other roadway types. Although slow-moving farm vehicles and equipment are risk factors on rural roads, little is known about the characteristics of crashes with farm vehicles/equipment.* ***Purpose:*** *To describe crashes and injuries for the drivers of farm vehicles/equipment and non-farm vehicles involved in an injury crash. Passengers are not included in this analysis.* ***Methods:*** *Injury crashes were included that involved a farm vehicle/equipment and at least one non-farm vehicle reported in Iowa Department of Transportation crash data from 1995 to 2004. Odds ratios were calculated through logistic regression to identify increased odds for injury among drivers of non-farm vehicles and farm vehicles/equipment. We examined frequently occurring crash characteristics to identify crash scenarios leading to the highest odds for injury.* ***Findings:*** *Non-farm vehicle drivers were 5.23 times more likely to be injured than farm vehicle/equipment drivers (95% CI = 4.12–6.46). The absence of restraint use was a significant predictor of injury for both farm vehicle/equipment drivers (OR = 2.85; 95% CI = 1.14–7.13) and non-farm vehicle drivers (OR = 2.53; 95% CI = 1.54–4.15). Crash characteristics increasing the odds of injury for non-farm vehicle drivers included speeding, passing the farm vehicle/equipment, driving on a county road, having a frontal impact collision, and crashing in darkness. Ejection was the strongest predictor of injury for the farm vehicle/equipment driver.* ***Conclusion:*** *Non-farm vehicle drivers were much more likely to be injured than farm vehicle/equipment drivers, suggesting that farm vehicle/equipment crash prevention should be a priority for all rural road users. Prevention strategies that reduce motor vehicle speed, assist in safe passing, increase seat belt use, and increase conspicuousness of the farm vehicle/equipment are suggested.*

Rural fatality rates are more than twice as high as urban rates for a wide variety of injuries, including motor vehicle crashes.[1,2] In the United States, death rates in motor vehicle crashes are inversely associated with population density and per capita income, and crash fatality rates in the most rural counties are almost double the rate in urban counties.[3-5] Rural crashes are more frequent, more severe, and more likely to result in death than urban crashes.[6]

The environment of the rural road contributes to increased crashes and more severe injury outcomes. Paved rural roads typically have 2 narrow lanes without crash reduction features, such as divided traffic streams or controlled vehicle entrances and exits.[7-9] Most rural roads are not paved. Gravel roadways, which according to the Iowa Department of Transportation comprise 72% of rural roadways in Iowa, do not necessarily have two fully functional lanes under all weather conditions and have even fewer safety features than paved rural roads. Because these unpaved rural roads often have very low traffic counts, many intersections have no traffic control devices and poor speed enforcement.

Certain types of crashes, such as those involving motor vehicle collisions with farm vehicles and equipment, are unique to rural environments.[9,10] These crashes most frequently involve slow-moving tractors

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and are exacerbated by the speed differential with faster motor vehicles on rural roadways.

Iowa has the highest rate of farm equipment crashes reported on public roads in the United States, with a rate of 10.7 crashes per 100,000 population per year.[10] North Carolina has the second highest rate of 3.9 per 100,000 per year. Research on the fatality rates in crashes with farm vehicles/equipment indicates that 2 in every 100 crashes involving tractors and 1 in every 100 crashes involving other farm equipment leads to a fatality.[10] Using data from the US Fatal Accident Reporting System, Gerberich et al. found that in crashes with farm vehicles, the farm vehicle occupant was killed nearly twice as frequently as occupants of the other vehicle.[11] In contrast, a study from Sweden found that automobile occupants were about twice as likely to be injured compared with the slow-moving vehicle occupants.[12]

As we will show, during the past 10 years in Iowa, three out of four multiple vehicle crashes involving farm equipment resulted in injury. However, no studies have examined the likelihood for injury given a crash between a non-farm vehicle and farm equipment. This study explores correlates of motor vehicle crash injuries involving farm vehicles/equipment with non-farm vehicles in the state of Iowa.

Methods

Study Design and Population. The study population included injury crashes involving farm vehicles or equipment and at least 1 non-farm vehicle that were reported in the Iowa crash data for the 10-year period from 1995 through 2004. The Iowa crash database is maintained by the Iowa Department of Transportation, Office of Driver Services (ODS) and includes all investigating police officers' reports of motor vehicle crashes. The database includes separate hierarchically linked data files that describe the vehicles, the drivers, the injuries, the roadway, and the crash environment.

The Iowa Department of Transportation defines farm vehicles and equipment as a vehicle or special mobile equipment manufactured, designed, or reconstructed for agricultural purposes and, except for incidental uses, exclusively used in the conduct of agricultural operations. The farm equipment designation excludes trucks, trailers, and all-terrain vehicles involved in farm operations. However, the definition does not include more detailed information about the specific type of farm equipment. The classification of vehicle configuration in this study was based solely on the investigating police officer's decision at the scene, using no coding manual for exact definitions. For non-farm vehicles involved in the crash, we included all vehicles that were not classified by the investigating police officer as farm equipment. When referring to the drivers or operators of farm vehicles or equipment in this study, we will use the term farm equipment driver.

For the 10-year period from 1995 to 2004, we found 2,644 drivers involved in farm equipment crashes. Eliminating duplicate reports and crashes of single farm equipment only or multiple farm equipment only, we identified 2,169 crash reports involving farm equipment and at least 1 non-farm vehicle.

Driver injury severity categorizations on the crash report included fatal, incapacitating (major), not incapacitating (minor), possible injury, and no injury. For this study, we included fatal, major, and minor driver injuries. Crashes that involved injuries only to passengers were excluded, and passenger injuries were not included in this analysis. Passengers were excluded because farm equipment is much less likely to include passengers, and thus the non-farm vehicle is much more likely to report passenger injuries. Restricting the data to only crashes resulting in at least 1 driver injury resulted in 825 crashes with 1,700 drivers.

Variables. Crash and environmental information describe the overall crash and are similar for all vehicles and equipment involved in the crash. Crash characteristics included crash year, season, day, and time. Environmental variables included lighting (day, dusk/dawn, and dark), road surface (dry, wet, and other), and roadway classification (interstates, US/state highways, county roads, and other/unknown).

Driver and vehicle information variables were specific to each driver/vehicle in the crash. Driver information included driver age and gender, driver actions listed as a contributing circumstance to the crash, whether or not the driver was charged with a violation, severity of injury, use of restraints, and complete or partial ejection from the vehicle/equipment. Violations included running a stop sign, speeding, losing control of vehicle, failing to yield, having visual obstructions, or following too closely. Vehicle information included vehicle action and point of impact. Vehicle actions at the time of the crash were categorized as moving essentially straight, turning, passing, and slowing or stopping. Vehicle point of impact was categorized as front, rear, left side, right side, and other.

We did not include alcohol or speed variables because the data were missing too frequently or were not reliable. Fewer than 10% of drivers were tested for alcohol use. Speed was missing for the majority of drivers and, even when present, speed estimates are

often unreliable. Instead, we examined speed as a contributing cause of the crash and if the driver received a citation for speeding.

Analysis. First, we examined driver characteristics for the farm equipment driver and the non-farm vehicle driver, including age categories, gender, injury level, driver protection system used (seat belt, or airbag compared to none), and whether the driver was ejected (either completely or partially) from the vehicle. Driver contributing causes were also compared between the farm equipment and non-farm vehicle, including whether the driver was ticketed in the crash.

Next, we calculated odds ratios for injury compared to no injury through logistic regression models. Models for farm vehicles/equipment and non-farm vehicles were run separately so that effect estimates for increased injury odds could be compared between the 2 vehicle types. All models controlled for age and gender. For driver age, the age group of 26-65 was used as a reference because crash and crash fatality rates are lower for this age group than for younger and older drivers. Female drivers were compared to males, and drivers with some degree of ejection from the vehicle (partial or full) were compared to those who remained inside. For the injured drivers only, those with some degree of occupant protection (seat belts, airbags) were compared to those with none. Individual driver actions contributing to the crash were compared to no contributing action. For vehicle actions the reference category was vehicles that were moving straight; for road classifications the reference was US or state highways; for road conditions the reference was dry roads; and for light conditions the reference was daylight.

The logistic regression identified several factors that increased odds for injury. We were interested in finding combinations of factors that differentially contributed to increased odds for injury, but the sample size was not sufficient to examine interactions. Instead, we examined profiles for farm equipment and non-farm vehicle drivers that were both frequent and led to increased odds for injury. We first identified the most frequently found crash scenarios. High-frequency events or commonly occurring characteristics describing the crash environment, vehicle actions, driver characteristics and actions contributing to the crash were examined across variable types, and odds ratios were calculated for each in combination. We were able to simultaneously examine three variables at once. The resulting odds ratios indicate the increased odds for injury compared to drivers who had any 2, 1, or none of the same characteristics. We examined all possible combinations of variables and present the combinations that were statistically significant or very nearly so.

Results

Crash Characteristics. From 1995 through 2004, the Iowa crash database included 825 farm vehicle crashes that involved 827 farm equipment drivers and 873 non-farm vehicle drivers. Farm equipment crashes were most frequent in 1998 and 1999 (Table 1). Changes in the database structure in 2002 could have led to a decrease in reporting, or the number of farm equipment crashes could be decreasing over time. Nearly half of the crashes occurred in the fall, which is the harvesting season. Crashes were less common in the summer (23.0%) and spring (19.7%), and uncommon in the winter (7.6%). Other than Sunday, crashes are fairly evenly distributed among the days of the week. The highest frequency time for crashes was 2:01 pm to 6:00 pm. Crashes were least common between 10:01 pm and 6:00 am, and this is also likely to be a period when few farm equipment vehicles are on the road. Thus, the actual risk per mile traveled could be very high. Nearly one quarter of the crashes occurred when the lighting was dark, and over a third occurred on wet roadways.

Driver and Vehicle Characteristics. A significantly higher proportion of farm equipment drivers were under the age of 15, and a significantly higher proportion of non-farm vehicle drivers were between the ages of 16 and 25 (Table 2). Male drivers comprised a higher proportion of farm equipment drivers in collisions (96.2%) than non-farm vehicle drivers (67.1%).

A higher proportion of non-farm vehicle drivers sustained fatal, major, minor, and possible injury. Restraint use was much more common among non-farm vehicle drivers (72.4%) than farm equipment drivers (17.5%), and ejection was much more common among farm equipment drivers (6.3%) than non-farm vehicle drivers (1.7%).

Farm equipment drivers were ticketed in 27.6% of crashes, and non-farm vehicle drivers in 39.0%. For most crashes, law enforcement officers stated that there were no contributing actions taken by either driver or that any contributing actions were not known. However, contributing causes that were noted differed by vehicle type. The most commonly noted contributing cause for farm equipment drivers was failure to yield right-of-way, which was most common during left turns. Loss of control and speeding were the most frequent contributing causes among non-farm vehicles, and these were most frequent while passing. Driver distraction was noted as a contributing cause for

Table 1. Crash Characteristics in Collisions Involving Farm Equipment, Iowa, 1995-2004

Crash Characteristics	N (%) (n = 825)*	%
Year		
1995	89	10.8
1996	82	9.9
1997	94	11.4
1998	105	12.7
1999	115	13.9
2000	78	9.5
2001	86	10.4
2002	65	7.9
2003	47	5.7
2004	64	7.8
Season		
Winter (Dec., Jan., Feb.)	58	7.6
Spring (Mar., Apr., May)	151	19.7
Summer (Jun., Jul., Aug.)	176	23.0
Fall (Sept., Oct., Nov.)	382	49.8
Day		
Sunday	58	7.0
Monday	129	15.6
Tuesday	130	15.8
Wednesday	133	16.1
Thursday	126	15.3
Friday	137	16.6
Saturday	112	13.6
Time		
6AM-10AM	144	17.5
10:01-2PM	167	20.3
2:01-6PM	324	39.4
6:01-10PM	107	13.0
10:01-6AM	80	9.7
Light conditions		
Day	608	73.7
Dusk/Dawn	31	3.8
Dark	182	22.1
Unknown	4	0.5
Road surface		
Dry	468	57.4
Wet	303	38.2
Other	44	5.4
Road classification		
Interstate	2	0.2
US/State road	218	26.4
County highway or road	338	41.0
Other/Unknown	267	32.4

*Unknown responses excluded from table categories.

6.0% of non-farm and 2.2% of farm equipment drivers. Although proceeding straight was the most common vehicle action for both types of vehicles, passing was common for non-farm vehicle drivers and turning was common for farm equipment drivers. Non-farm vehicles were most frequently impacted in the front, while farm vehicles/equipment were most frequently impacted on the rear or side.

Of the 873 non-farm vehicles involved in crashes in this study, 476 (54.5%) were passenger cars, 200 (22.9%) light trucks including pick-up and panel trucks, 62 (7.1%) sports utility vehicles, on/off road vehicles, or multipurpose vehicles, and 51 (5.8%) semi-trailer trucks. The remaining categories of non-farm vehicles totaling 9.7% included other heavy trucks, motorcycles, trains, buses, and unknown non-farm vehicles.

Injury Characteristics. Non-farm vehicle drivers were 5.23 times more likely to be injured (95% CI = 4.12-6.46) than farm equipment drivers (not tabled). For both vehicle types, the youngest and oldest drivers had the highest risk for injury (Table 3). For farm vehicles/equipment the highest risk was for those under the age of 16.

The absence of restraint use was a significant predictor of injury for both farm equipment drivers (OR = 2.85; 95% CI = 1.14-7.13) and non-farm vehicle drivers (OR = 2.53; 95% CI = 1.54-4.15). Farm equipment drivers who were ejected were nearly 100 times more likely to be injured than those who were not ejected, which is a striking estimate despite the wide confidence intervals.

Losing control of the vehicle was the only driver contributing cause related to a statistically significant increased odds for injury for either type of vehicle. Farm equipment drivers were more likely to be injured when the point of impact was the rear or side of the vehicle. Non-farm vehicle drivers, however, were most likely to be injured when the front of the vehicle was the point of impact.

We examined the most frequent combinations of crash factors and the increased odds for injury in each (Table 4). Drivers of the non-farm vehicle who were driving straight, such as while passing the farm equipment or rear-ending it, who were not wearing their seatbelts, and who were charged in the collision were 9.7 times more likely to be injured than drivers who did not have this combination of crash factors. Speeding was the most frequent citation in this crash factor combination (95% CI = 3.8-24.6). Non-farm vehicle drivers who were in crashes during the day, did not wear a seat belt, and had a frontal impact were 9.6 times more likely to be injured (95% CI = 3.95-23.5). Frontal impact crashes also led to an increased potential for injury when on a county road (usually 2 lanes) either in the dark or when the non-farm vehicle driver was charged. The consistent crash factors leading to injury among non-farm vehicle drivers in these combinations were the following: not wearing a seat

Table 2. Driver Characteristics in Collisions Involving Farm Vehicles/Equipment, Iowa, 1995-2004

Driver Characteristics	Farm Vehicle/ Equipment Driver N (%) (n = 827)*	Non-Farm Vehicle Driver N (%) (n = 873)*	P Value
Age			
1-15	17 (2.1)	11 (1.3)	<.0001
16-25	129 (15.9)	253 (29.6)	
26-45	290 (35.8)	288 (33.7)	
46-65	258 (31.8)	172 (20.1)	
65+	117 (14.4)	130 (15.2)	
Gender			
Male	777 (96.2)	573 (67.1)	<.0001
Female	31 (3.8)	281 (32.9)	
Injury level			
Fatal injury	13 (1.6)	18 (2.1)	<.0001
Major injury	48 (5.8)	109 (12.5)	
Minor injury	84 (10.2)	337 (38.6)	
Possible injury	103 (12.5)	274 (31.4)	
No injury	579 (70.0)	135 (15.5)	
Restraint use (seat belt or airbag)†			
Yes	26 (17.5)	339 (72.4)	<.0001
No	123 (82.5)	129 (27.6)	
Ejection from vehicle			
Yes	47 (6.3)	11 (1.7)	<.0001
No	701 (93.7)	641 (98.3)	
Driver was ticketed in crash			
Yes	194 (27.6)	296 (39.0)	<.0001
No	510 (72.1)	463 (61.0)	
Driver contributing causes‡			
Ran stop sign	10 (1.21)	10 (1.2)	.903
Speeding	1 (0.12)	59 (6.8)	<.0001
Lost control	16 (1.9)	117 (13.4)	<.0001
Failed to yield right-of-way	122 (14.8)	38 (4.4)	<.0001
Driver distracted	18 (2.2)	52 (6.0)	<.0001
Obstructed vision	30 (3.6)	30 (3.4)	.831
Following too close	2 (0.2)	44 (5.0)	<.0001
Other	170 (20.6)	212 (24.3)	.065
None/not mentioned	765 (92.5)	738 (84.5)	<.0001
Vehicle action			
Moving straight	448 (54.2)	601 (68.8)	<.0001
Turning	282 (34.1)	11 (1.3)	<.0001
Passing	0	190 (21.8)	<.0001
Slowing/stopping	40 (4.8)	22 (2.5)	.011
Other	43 (5.2)	26 (3.0)	.204
Missing	14 (1.7)	23 (2.6)	.183
Vehicle point of impact			
Front	94 (11.4)	537 (61.5)	<.001
Rear	263 (31.8)	26 (3.0)	<.001
Left Side	267 (32.3)	97 (11.1)	<.001
Right Side	81 (9.8)	142 (16.3)	<.001
Other	122 (14.8)	71 (8.1)	<.001

*Unknown responses excluded from table categories.
†Belt use was for injured occupants only. ‡ Categories are not mutually exclusive because one driver could have several contributing causes.

belt, having a frontal impact collision, driving on a county road, and having a crash in the dark.

Ejection from the farm equipment was the strongest predictor of injury for the farm equipment driver. Ejection most frequently occurred when the farm equipment was moving straight, in which the collision usually involved being rear-ended by the non-farm vehicle. In this scenario, especially when the farm

Table 3. Risk for Injury* in Farm Vehicle Crashes for Farm Equipment and Non-Farm Vehicle Drivers, Iowa, 1995-2004

	Farm Equipment Drivers			Non-Farm Vehicle Drivers		
Risk Factor	N	% Injured	Odds Ratio (95% CI)	N	% Injured	Odds Ratio (95% CI)
Driver age						
1-15	17	35.3	2.64 (0.95-7.33)	11	45.5	0.88 (0.27-2.94)
16-25	129	13.2	0.73 (0.42-1.27)	253	58.9	1.53 (1.12-2.08)
26-45	290	14.8	Ref	288	51.0	1.00
46-65	258	20.5	Ref	172	47.7	1.00
65+	117	21.4	1.30 (0.79-2.13)	130	60.0	1.60 (1.08-2.38)
Gender						
Male	777	17.6	Ref	573	53.2	1.00
Female	31	25.8	0.87 (0.40-1.90)	281	56.6	1.02 (0.77-1.35)
Restraint use						
Yes	26	42.3	Ref	339	63.1	Ref
No	123	69.9	2.85 (1.14-7.13)	129	80.6	2.53 (1.54-4.15)
Ejected from vehicle						
Yes	47	91.5	98.7 (34.3-284.2)	11	81.8	4.31 (0.92-20.2)
No	701	9.7	Ref.	641	52.4	Ref
Ticket was issued						
Yes	194	13.9	0.68 (0.43-1.08)	296	57.8	1.30 (0.98-1.74)
No	510	19.2	Ref	463	51.0	Ref
Driver contributing causes						
Ran stop sign	10	10.0	n/a†	10	60.0	1.33 (0.37-4.83)
Speeding	1	0.0	n/a	59	62.7	1.42 (0.81-2.48)
Lost control of vehicle	16	50.0	4.13 (1.41-12.13)	117	63.2	1.55 (1.03-2.35)
Failure to yield	122	12.3	0.57 (0.31-1.05)	38	52.6	1.01 (0.52-1.95)
Driver was distracted	18	33.3	2.57 (0.87-7.58)	52	61.5	1.35 (0.75-2.43)
Vision obscured	30	10.0	n/a	30	63.3	1.44 (0.67-3.11)
Following too closely	2	0.0	n/a	44	56.8	1.10 (0.59-2.06)
Other	170	18.8	1.0 (0.64-1.57)	212	50.5	0.93 (0.67-1.28)
None	765	17.2	Ref	738	52.0	Ref
Vehicle action						
Going straight	448	19.2	Ref	601	56.9	Ref
Left turn	282	17.5	0.91 (0.62-1.34)	11	36.4	n/a
Passing	0	0.0	n/a	190	52.1	0.84 (0.61-1.17)
Slowing/stopping	40	7.5	0.31 (0.09-1.06)	22	18.2	n/a
Unknown	14	7.1	n/a	23	21.7	0.22 (0.08-0.60)
Other	43	18.0	0.42 (0.15-1.22)	26	38.5	0.52 (0.23-1.17)
Vehicle point of contact						
Front	94	11.7	1.37 (0.56-3.32)	537	58.9	1.87 (1.13-3.09)
Rear	263	22.4	3.04 (1.52-6.07)	26	15.4	0.24 (0.07-0.76)
Left side	267	18.0	2.27 (1.12-4.58)	97	48.5	1.29 (0.69-2.40)
Right side	81	19.8	2.40 (1.04-5.53)	142	46.5	1.15 (0.65-2.06)
Other	122	9.0	Ref	71	43.7	Ref.
Lighting conditions						
Daylight	610	18.5	Ref	640	51.1	Ref
Dark	182	14.3	0.76 (0.48-1.21)	118	61.5	1.54 (1.10-2.16)
Dusk or dawn	31	16.1	0.85 (0.32-2.28)	36	50.0	0.96 (0.49-1.90)
Road conditions						
Dry	469	16.2	Ref	498	57.0	Ref
Wet	304	19.7	1.32 (0.90-1.92)	318	46.9	0.67 (0.51-0.89)
Other	44	18.2	1.18 (0.53-2.66)	45	55.6	0.95 (0.51-1.77)
Road classification						
Interstate	2	0	n/a	3	0	n/a
US/state highway	218	15.1	Ref	242	54.1	Ref

(Continued).

Table 3. Continued

Risk Factor	Farm Equipment Drivers			Non-Farm Vehicle Drivers		
	N	% Injured	Odds Ratio (95% CI)	N	% Injured	Odds Ratio (95% CI)
County road	303	15.5	1.03 (0.64-1.68)	310	59.4	1.24 (0.88-1.75)
City street	37	10.8	0.67 (0.22-2.04)	18	47.4	0.75 (0.38-1.50)
Other	267	22.8	1.70 (1.06-2.73)	131	46.8	0.75 (0.53-1.06)

*Injury included crash reports that listed driver injury as fatal, major, or minor, which were compared to no or "possible" injury. "Possible" injury indicates that no visible injury was present and medical response was sought.
†n/a = Odds ratio not available because of small cell sizes.

equipment driver was not charged in contributing to the crash, the farm equipment driver was more than 60 times more likely to be injured than when this combination of factors was not present. Although the confidence intervals for these estimates are wide due to the small samples in some variable categories for 3-way risk estimates, even the lower boundary of the 95% confidence interval indicates more than a 10-fold increased injury risk.

Discussion

We found that in injury collisions with farm equipment, drivers of the non-farm vehicle were more than 5 times more likely to be injured than the driver of the farm equipment. These results are similar in direction to those of Pinzke and Lundqvist[12] who reported that automobile occupants were about twice as likely as slow-moving vehicle occupants to be injured in collisions involving slow-moving vehicles on roads in Sweden. Conversely, Gerberich et al.[11] found that farm vehicle occupants were 1.9 times more likely to be killed than non-farm vehicle occupants or non-motorists. However, Gerberich et al.[11] examined only fatal outcomes, which could include fatalities of drivers, passengers, and non-motorists, and included single farm vehicle crashes, so the crash criteria differ from those in the present study.

We found that a higher proportion of non-farm vehicle drivers (39%) than farm equipment drivers (27.6%) received a citation in their crash. These findings are very consistent with Luginbuhl et al.[13] who found in a survey of North Carolina farmers that 34% of non-farm vehicle drivers and 23% of farm vehicle drivers were cited in self-reported crashes.

We found that 31.8% of farm equipment crashes resulted in rear end point of impact for the farm equipment. These findings differ from those of Glascock et al.[14] who reported that 15% of collisions were caused by rear end impact to the farm vehicle. Inclusion criteria for crashes differed between these studies in that Glascock et al.[14] reported on all roadway crash reports involving farm vehicles and farm

Table 4. Frequent Crash Characteristics and Odds for Injury in Farm Equipment Collisions, Farm Equipment and Non-Farm Vehicle Drivers, Iowa, 1995-2004

Crash Scenario	Number With			OR (95% CI)
	Risk 1	Risk 2	Risk 3	
Non-farm Vehicle				
Driving straight, no seat belt, driver charged	467	212	45	9.72 (3.83-24.63)
Day, no seat belt, frontal impact	386	367	62	9.64 (3.95-23.54)
County road, dark, frontal impact	396	251	47	4.49 (2.13-9.44)
County road, driver charged, frontal impact	374	290	63	4.26 (2.20-8.25)
Dark, Frontal impact, driver charged	373	272	36	2.58 (1.22-5.43)
Dark, no driver fault specified, frontal impact	351	375	122	2.31 (0.95-5.16)
Farm vehicle				
Driver ejected, driver not charged, moving straight	374	401	28	67.68 (11.82-387.52)
Driver ejected, moving straight, rear impact	302	198	20	60.31 (13.41-271.21)
Driver ejected, frontal impact, moving straight	375	114	18	49.43 (10.93-223.48)

equipment over a 4-year period in Ohio, regardless of whether or not an injury occurred. We found that 74% of the collisions occurred in daylight conditions, which is similar to the 78% reported by Glascock et al.[14] Neither study had data showing miles or time traveled during daylight hours to assess exposure time.

Several findings that did not reach statistical significance may have important implications for prevention. In the 10-year period of the present study, 17 farm equipment drivers were under the age of 16, and these young farm equipment drivers were more likely to be injured than older farm equipment drivers. Although they comprise a small proportion of injured drivers, these young farm equipment drivers are also likely to represent only a small proportion of farm vehicle miles traveled. One potential prevention strategy would be to restrict driving of farm vehicles by unlicensed young drivers on public roads. A high proportion of non-farm vehicle drivers were between the ages of 16 and 25, which are the youngest of licensed drivers. These young drivers also had the highest risk for injury among non-farm vehicle drivers. This suggests that inexperienced drivers may be more likely to be involved in farm equipment collisions, and that driver training and education programs should focus on driving specific to rural roadways.

Injury crashes were also common in the dark, although farm vehicle miles traveled are probably lowest during the nighttime hours. The actual risk per vehicle mile traveled could be quite high. These crashes are likely related to poor visibility or poor conspicuity of the farm vehicle and/or inadequate recognition and action of the non-farm vehicle driver. Possible preventive strategies could include better conspicuity, including lighting and markings, of the farm equipment. Modern farm tractors and self-propelled agricultural machines with cabs are typically equipped with one or more rearview mirrors, lighting visible from the front and rear, and turning signals. However, many older machines do not have these features. Additional studies to evaluate the optimal lighting and signage standards and that identify the proportion of farm vehicles on the road that are compliant with theses standards are needed.

Our analysis indicates several types of crashes that increase the potential for injury. Injury to non-farm vehicle drivers was most frequent when the driver was not wearing a seat belt, had a frontal impact collision, was on a county road, and had a crash in the dark. Frontal impact collisions of the non-farm vehicle may occur when the driver is passing the farm equipment and hits another vehicle, or when the driver rear-ends the farm equipment (which can occur when the driver does not see the farm equipment or does not adequately assess and act). These injury crashes often occurred on county roads, which are typically 2-lane roads that allow speeds of up to 55 miles per hour. Signage to control passing and to alert drivers of the potential presence of farm vehicles on the road may be important to prevent these crashes. Efforts to control speed on county roads is also important, especially during times of increased farm equipment traffic, including planting and harvest seasons.

In this study, ejection is the single strongest predictor of injury among farm equipment drivers. We did not assess the effect of crash energy on ejection, but greater energy likely increases ejection. Studies that compare injury outcomes by seat belt status among farm equipment operators who are in crashes of similar energy are needed. Although seat belt use is the most effective method of preventing ejection from motor vehicles, there are remaining research questions about whether farm equipment drivers on roadways would fare better in crashes of similar energy if restrained. Only 17.5% of the injured farm equipment drivers in our study were wearing seat belts. This proportion was far lower than the 72.4% of drivers injured in the non-farm vehicle who were wearing seat belts. In a survey of 623 North Carolina farmers, 73% reported that they wore a seat belt, although the authors stated that they believed this to be over-reported.[13] Seat belt use surveys have further indicated that seat belt use is lower among drivers on rural than urban roads.[15-17] Studies to assess the protective effects of seat belts for drivers and operators of farm vehicles and equipment on public roadways would help inform future specific prevention strategies, while seat belt campaigns and enforcement of seat belt laws should be emphasized for motor vehicle drivers on rural roads.

Our findings indicate a higher proportion of being ticketed and injured among the non-farm vehicle drivers compared with the farm equipment drivers, and these results should encourage all rural motorists to share rural roadways safely with farm vehicles/equipment in avoiding collisions. Research and prevention have focused primarily on the farm vehicle driver. Surveys in North Carolina have found that farmers perceive travel on rural roads as becoming increasingly dangerous, and they identify farm vehicle crashes as their primary occupational safety and health priority.[10,13] Among 656 North Carolina farmers who responded to a survey about farm safety, 40% disagreed or strongly disagreed with the statement: "Most rural residents know or understand highway safety rules."[13] Future prevention efforts need to focus on the behavior of the non-farm vehicle driver, on preventing the most

common types of crashes, and on protecting farm equipment drivers from ejection in crashes that occur while driving on roadways.

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