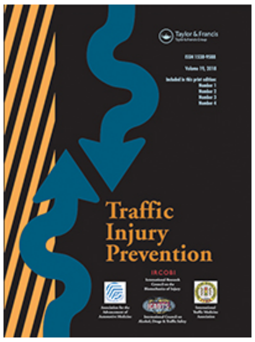

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Prevalence of alcohol impairment and odds of a driver injury or fatality in on-road farm equipment crashes

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ABSTRACT

Objective: The objective of this article was to estimate the prevalence of alcohol impairment in crashes involving farm equipment on public roadways and the effect of alcohol impairment on the odds of crash injury or fatality.

Methods: On-road farm equipment crashes were collected from 4 Great Plains state departments of transportation during 2005–2010. Alcohol impairment was defined as an involved driver having blood alcohol content of ≥0.08 g/100 ml or a finding of alcohol impairment as a driver contributing circumstance recorded on the police crash report. Injury or fatality was categorized as (a) no injury (no and possible injury combined), (b) injury (nonincapacitating or incapacitating injury), and (c) fatality. Hierarchical multivariable logistic regression modeling, clustered on crash, was used to estimate the odds of an injury/fatality in crashes involving an alcohol-impaired driver.

Results: During the 5 years under study, 3.1% (61 of 1971) of on-road farm equipment crashes involved an alcohol-impaired driver. One in 20 (5.6%) injury crashes and 1 in 6 (17.8%) fatality crashes involved an alcohol-impaired driver. The non-farm equipment driver was significantly more likely to be alcohol impaired than the farm equipment driver (2.4% versus 1.1% respectively, $P = .0012$). After controlling for covariates, crashes involving an alcohol-impaired driver had 4.10 (95% confidence interval [CI], 2.30–7.28) times the odds of an injury or fatality. In addition, the non-farm vehicle driver was at 2.28 (95% CI, 1.92–2.71) times higher odds of an injury or fatality than the farm vehicle driver. No differences in rurality of the crash site were found in the multivariable model.

Conclusion: On-road farm equipment crashes involving alcohol result in greater odds of an injury or fatality. The risk of injury or fatality is higher among the non-farm equipment vehicle drivers who are also more likely to be alcohol impaired. Further studies are needed to measure the impact of alcohol impairment in on-road farm equipment crashes.

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Introduction

Motor vehicle crashes, a leading cause of injury and death in the United States (Heron 2016), occur at 2.4 times higher rates in rural communities compared to urban communities (National Center for Statistics and Analysis 2016). Rural settings pose a number of unique risk factors for crashing. First, rural roadways, in and of themselves, are hazardous for drivers due to poor roadway infrastructure and high travel speeds. Second, rural roadways are a common thoroughfare for farm equipment, which are slow-moving vehicles that pose unique challenges to rural roadway drivers because of vehicle size and speed differentials. Third, risky drinking (defined as exceeding daily or weekly limits or presence of an alcohol use disorder; Borders and Booth 2007) and risky driving behaviors (e.g., reduced seat belt use, speeding; Federal Highway Administration 2014) are more prevalent in rural than urban/suburban areas. Each of these factors may contribute to increased rural roadway hazards. Notably, however, the NHTSA (National Center for Statistics and Analysis 2014) data revealed equal (~31%) proportions of alcohol-impaired driving among rural versus urban traffic fatalities.

Little is known about the role of alcohol-impaired driving among an often overlooked and understudied rural roadway use group: farm equipment operators. Previous research has suggested that 12% of farm equipment operators and 6% of those in crashes with farm equipment have a previous conviction for driving while intoxicated (Gerberich et al. 1996). Alcohol-impaired crashes involve poor driver decision making and slow response to hazards (Ogden and Moskowitz 2004). This may be exacerbated when approaching farm equipment, due to a lack of experience interacting with such equipment, leading to misjudging the differences in the speed and size of farm equipment compared to passenger vehicles. Given that collisions with farm equipment are more likely to result in injury or fatality to the occupants of the other vehicle (Gerberich et al.

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Supplemental data for this article can be accessed on the publisher's website.

1996; Gkritza et al. 2010; Peek-Asa et al. 2007), this is not just a farm safety issue but rather a public health concern affecting all public roadway users. Because occupants of both farm and non-farm vehicles are at increased risk of injury or death when alcohol is involved in a crash, it is important to understand how alcohol impairment may affect injury and fatality risk among those involved in farm equipment crashes.

Though we know about the configurations of these crashes, no study to date has examined the impact of an alcohol-impaired driver on the risk of an injury or fatality in on-road farm equipment crashes. Therefore, the objectives of this analysis were to examine the prevalence of alcohol-impaired driving in on-road farm equipment crashes and to examine how alcohol impairment affects risk of a driver injury or fatality.

Methods

Study population

This analysis is part of a larger study to examine on-road farm equipment crashes among the 9 states in the Great Plains region (Iowa, Illinois, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin). Data used for this analysis are from the Department of Transportation (DOT) crash records from 4 of the 9 Great Plains states—Iowa, Missouri, North Dakota, and South Dakota—for the years of 2005 through 2010. Only crashes where the alcohol-impaired status of all drivers involved in the crash was known were included in the analysis. The driver was identified from all occupants in a vehicle based on the DOT data element called seating position as a value of "1" or "driver." Other states were excluded because >75% of data on alcohol use were missing.

Data definitions

Farm equipment was defined as tractors or other self-propelled equipment of husbandry, and a crash was considered to involve farm equipment if "farm equipment" was selected as the vehicle type on the DOT crash report by law enforcement (Harland et al. 2014; Ramirez et al. 2016; Ranapurwala et al. 2016; Toussaint et al. 2017). A crash was considered on-road if it was included in the DOT data. Data on crash characteristics (manner of collision, time of day, lighting, day of the week, weather conditions, agricultural season, multiple vehicles involved), both the farm equipment and the other vehicle driver (age, gender, driver contributing circumstances, injury severity), and vehicle characteristics (farm equipment or not, vehicle action) were included in this analysis. Driver age is presented as continuous and categorical (<34, 35–44, 45–54, 55+), manner of collision was defined in 7 categories (noncollision, head-on, rear-end, angle–oncoming left turn, sideswipe same direction, sideswipe opposite direction, and other). The vast majority of crashes occurred on clear weather days; therefore, weather was dichotomized to clear or not clear. Time of day was categorized into 6-h blocks (12 a.m.–5:59 a.m., 6 a.m.–11:59 a.m., 12 p.m.–5:59 p.m., 6 p.m.–11:59 p.m.), and the season of the crash was grouped based on agricultural seasons in the 4 states analyzed (January–March for winter, April–May for planting, June–August for growing, and September–December for harvest). Between the 4 states, there were 22 potential driver contributing circumstances that were combined into 6 categories: no contributing action, disregarded traffic regulation, failed vehicle maneuver, operating in a reckless/careless/negligent/aggressive manner, operating inattentive/distracted, and other contributing action. Rurality of the crash was determined by linking the crash ZIP code with the rural–urban commuting area codes 2.0 from the University of Washington (WWAMI Rural Health Research Center n.d., http://depts.washington.edu/uwruca/ruca-approx.php). Ten rural–urban commuting area codes were condensed to 4 categories as recommended by the University of Washington: urban, large rural, small rural, and isolated rural. Alcohol impairment was defined as the driver having a blood alcohol concentration of ≥0.08 g/100 mL or a driver contributing circumstance of alcohol-impaired being recorded by law enforcement. Consistent with prior research (Peek-Asa et al. 2007), a driver injury or fatality was categorized as no injury (no and possible injury combined), injury (nonincapacitating or incapacitating injury), or fatality.

Analysis

To examine differences in crash, driver, and vehicle characteristics by the presence or absence of alcohol impairment, Pearson's chi-square test was used for proportions and Student's *t* test for differences in means. To delineate differences within categorical variables with greater than 2 levels with a P value $< .05$, standardized residuals (se_i) greater than 2 are presented in the text to show which level of the variable contributes the most to the chi-square statistical significance. Hierarchical multivariable logistic regression was used to estimate the odds of an injury or fatality to a driver in a crash involving alcohol impairment. To control for the correlation among drivers involved in the same crash but in different vehicles, vehicles from the same crash were clustered in the model, using generalized estimating equation modeling with a binomial distribution, logit link function, and exchangeable correlation matrix. Due to the small number of fatalities and the unadjusted odds estimates of injuries and fatalities both showing an increased odds among alcohol-impaired drivers, injuries and fatalities were combined in the multivariable model to provide more stable odds estimates. Covariates included in the multivariable model were selected based on a priori knowledge (Gerberich et al. 1996; Gkritza et al. 2010; Peek-Asa et al. 2007). Age of the driver was included as a continuous variable to reduce the number of degrees of freedom for a parsimonious model. The odds of an injury or fatality are presented by adjusted odds ratios with 95% confidence intervals.

Results

Crash characteristics

From 2005 through 2010, there were 1,971 farm equipment crashes involving 3,601 vehicles (1,984 farm vehicles, 1,617 non-farm vehicles) in 4 Great Plains states (Iowa, Missouri, North Dakota, and South Dakota). Overall, 3.1% (61 of 1971) of on-road farm equipment crashes involved an alcohol-impaired driver. The proportion of alcohol-impaired driver crashes differed significantly by state (North Dakota [6.1%], South Dakota

Table 1. Crashes by whether any driver was alcohol impaired, 4 Great Plains states, 2005–2010 ($n = 1{,}971$).

	Driver alcohol impaired				
	No		Yes		
Crash characteristics	*N*	(row %)	*N*	(row %)	*P* value
All crashes	1,910	(96.9)	61	(3.1)	
State					.0096
Iowa	998	(97.6)	25	(2.4)	
Missouri	577	(97.5)	15	(2.5)	
North Dakota	155	(93.4)	10	(6.1)	
South Dakota	180	(94.2)	11	(5.8)	
Crash severity					<.0001
Property damage	1,235	(98.8)	15	(1.2)	
Injury	638	(94.4)	38	(5.6)	
Fatality	37	(82.2)	8	(17.8)	

[5.8%], Missouri [2.5%], Iowa [2.4%], $P = .0096$). About 1 in 6 (17.8%) fatal crashes involved an alcohol-impaired driver and 1 in 20 (5.6%) crashes that resulted in an injury had an alcohol-impaired driver involved (Table 1). Among alcohol-impaired crashes, 10% were head-on and 33.3% were rear-end crashes ($se_i = 2.78$) compared to 4.8 and 18.9% among non-alcohol-impaired crashes, respectively ($P = .3$; Table 2). Over 42% of alcohol-impaired crashes occurred between 6:00 p.m. and 11:59 p.m., whereas only 5.6% of non-alcohol-impaired crashes occurred during these times ($se_i = 11.3$, $P < .0001$). In addition, over half (52.4%) of alcohol-impaired crashes occurred in the dark (9.8% dark with street lights [$se_i = 6.36$] and 42.6% dark without street lights [$se_i = 7.25$]) compared to 12.4% of non-alcohol-impaired crashes occurring under the same conditions. Alcohol-impaired crashes occurred more frequently on Friday (29.5%, $se_i = 3.07$) than non-alcohol-impaired crashes (15.0%, $P = .03$). When comparing urban to rural (large, small, and isolated combined), 87.9% of alcohol-involved crashes occurred in rural ZIP codes, whereas only 75.0% of non-alcohol-involved crashes occurred in rural ZIP codes ($P = .02$, data not shown).

Driver and vehicle characteristics

The presence of alcohol impairment differed significantly by farm equipment versus non-farm equipment. Non-farm equipment drivers were significantly more likely to be alcohol impaired than farm equipment drivers (2.4 versus 1.1%, respectively, $P = .0012$). The alcohol-impaired crashes ($n = 61$) involved 62 impaired drivers: 21 farm equipment drivers, 39 non-farm equipment drivers, and a crash involving both an impaired farm equipment and non-farm equipment driver. The impaired non-farm equipment drivers' vehicle action (e.g., heading straight, turning) did not differ significantly from the impaired farm equipment drivers' vehicle action (data not shown, $P = .20$). Alcohol-impaired non-farm equipment drivers most frequently rear-ended the farm equipment, whereas alcohol-impaired farm equipment drivers were more often involved in a noncollision (e.g., ran off road; Figure 1, $P < .0001$).

Table 2. Crash, vehicle, and person characteristics significantly associated with whether any driver was alcohol impaired, 4 Great Plains states, 2005–2010.

Crash characteristics	*P* value
Manner of collision	.03
Lighting	<.0001
Time of day	<.0001
Day of week	.03
Driver and vehicle characteristics	
Driver age	.03
Farm equipment	.0017

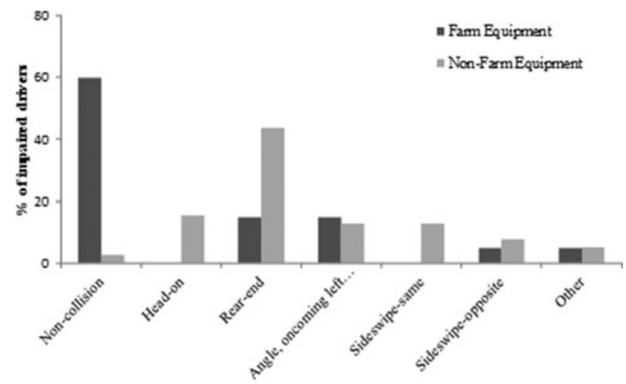

Figure 1. On-road farm equipment crash mechanism by vehicle driver impaired.

Table 2 summarizes variables significantly associated with alcohol impairment. A detailed table is provided in Appendix Table 1 (see online supplement). Alcohol-impaired crashes occurred more frequently among 35- to 44-year-olds than non-alcohol-impaired crashes (27.9 vs. 14.8%, respectively, $se_i = 2.84$, $P = .03$; Appendix Table 1). Among driver contributing circumstance, 23.2% of alcohol-impaired crashes were due to operating in an inattentive or distracted manner compared to 5.6% of non-alcohol-impaired crashes ($se_i = 5.63$, $P < .0001$). A higher proportion of alcohol-impaired crashes resulted in nonincapacitating (17.0%, $se_i = 2.34$), incapacitating (15.3%, $se_i = 4.83$), and fatal (11.9%, $se_i = 7.72$) injuries compared to non-alcohol-impaired crashes (8.4, 3.4, 1.0%, respectively; $P < .0001$). Among the 3,601 drivers included in the data, 21.9% ($n = 789$) were missing data on occupant protection (data not shown). Of those with missing occupant protection, 62% were farm equipment drivers and 38% were non-farm equipment drivers. Among those with data on occupant protection, over 86% of farm equipment drivers used no protection, whereas only 13% of non-farm equipment drivers were unrestrained ($P < .0001$). The driver was unrestrained in 66% of crashes involving alcohol impairment compared to only 47% of those with no alcohol impairment ($P = .04$) and 53% of injury/fatality crashes had an unrestrained driver compared to 46% of crashes with no injury/fatality ($P = .0016$).

Adjusted odds of injury or fatality

Alcohol impairment is strongly associated with crash injury severity. In unadjusted analyses, alcohol-impaired crashes had odds of an injury 4.85 (95% confidence interval [CI], 2.66–8.83) times that for non-alcohol-impaired crashes and odds of a fatality 19.2 (95% CI, 7.84–46.8) times that for non-alcohol-impaired crashes. To increase stability of odds estimates, injuries and fatalities were combined for the multivariable modeling. After controlling for driver age, manner of collision, rurality of the crash, and state, the odds of an injury or fatality among alcohol-impaired drivers were 3.94 (95% CI, 2.14–7.25) times

Table 3. Adjusted odds of an injury/fatality among farm equipment–related on-road crashes, 4 Great Plains states, 2005–2010.

	aOR	(95% CI)
Age	1.01	(0.999–1.01)
Farm equipment driver		
No	2.49	(2.06–3.01)
Yes	1.00	(ref)
Driver alcohol impaired		
Yes	3.94	(2.14–7.25)
No	1.00	(ref)
Manner of collision		
Noncollision	1.00	(ref)
Head-on	0.78	(0.49–1.23)
Rear-end	0.50	(0.35–0.71)
Angle, oncoming left turn	0.38	(0.26–0.56)
Sideswipe, same direction	0.13	(0.08–0.19)
Sideswipe, opposite direction	0.26	(0.16–0.41)
Other	0.29	(0.17–0.47)
Rurality of crash		
Urban	1.00	(ref)
Large rural	1.07	(0.74–1.55)
Small rural	1.09	(0.78–1.52)
Isolated rural	1.14	(0.85–1.54)
State		
Iowa	1.00	(ref)
Missouri	1.96	(1.27–3.00)
North Dakota	0.95	(0.60–1.48)
South Dakota	0.72	(0.38–1.36)

as high as that for non-alcohol-impaired drivers and the odds of being injured or fatally injured among non-farm equipment drivers were 2.49 (95% CI, 2.06–3.01) times as high as that for farm equipment drivers (Table 3).

In a subanalysis of only drivers with available occupant restraint data, the adjusted odds of injury/fatality were calculated for alcohol impairment and non-farm equipment drivers, controlling for all covariates in Table 3 and for restraint use type, including none. The adjusted odds for alcohol impairment, aOR = 3.82 (2.06–7.08), and non-farm equipment driver, aOR = 2.51 (1.20–3.15), did not differ significantly in this model compared to that presented in Table 3.

Discussion

Overall, about 3% of farm crashes in Iowa, Missouri, North Dakota, and South Dakota involve alcohol-impaired driving. As expected, fatalities and injuries were more likely when alcohol was present. Notably, however, alcohol-involved fatalities (17.8%) are much less frequent among on-road farm equipment crashes compared to national reports for all roadway fatalities (22%), bicycle-involved crashes (24%), and motorcycle-involved crashes (29%; NHTSA 2015). In this study, a number of other factors, such as age, time of day, and day of week, were shown to be associated with larger proportions of alcohol-involved crashes among roadway crashes and fatalities.

Not surprisingly, greater proportions of alcohol-impaired crashes occur at night. Using data from 2006, the last year with data on alcohol-impaired nonfatal crashes, the NHTSA (2006) reported that alcohol was involved in greater than 50% of fatal crashes and 25% of injury crashes occurring between 9 p.m. and 6 a.m. In unadjusted analyses, this study found Fridays, but not Saturdays or Sundays, to have a higher proportion of alcohol-impaired crashes than other days of the week. For 2014, NHTSA reported greater proportions of alcohol involvement in fatal crashes on weekends among drivers of all age (NHTSA 2015). In addition, previous studies have found that weekday daytime crashes were significantly less likely to involve alcohol compared to weekend nighttime crashes (0.4 vs. 1.5%; Berning et al. 2015; NHTSA 2015).

When examining age of the drivers involved in on-road farm equipment crashes, we found age to be evenly distributed among alcohol-impaired crashes. The distribution of alcohol impairment by age in our analysis is higher than that found among all fatal crashes reported by NHTSA in 2014 (NHTSA 2015) (26.6% < 34, 24% 35–44, 20.3% 45–54, and 12% 55+ years) with a higher proportion of those 55 or older found to be alcohol impaired in farm equipment crashes. The differences in the proportions could be due to our analysis including injuries and fatalities, whereas national data only examine alcohol impairment in fatal crashes. In addition, the older average age among drivers involved in alcohol-impaired farm equipment crashes in our analysis may be due to the average age of U.S. farmers being older than the average age of U.S. licensed drivers (58.3 years for farmers, 44 years for the U.S. licensed population; Federal Highway Administration 2000; U.S. Department of Agriculture 2014).

We found no statistically significant difference in alcohol impairment by number of vehicles in the crash (3.8% single vehicle, 2.9% multiple vehicles). This differs from Shyhalla's (2014) study of passenger vehicles, which found a higher proportion of alcohol impairment among single-vehicle versus 2-vehicle crashes (10.7% single-vehicle, 1.4% 2-vehicle). A single-vehicle crash in this analysis involved only a single piece of farm equipment (versus Shyhalla's [2014] study reporting passenger vehicles), and our results suggest that the non-farm equipment driver is most often alcohol impaired. This may lead to multiple-vehicle crashes having a similar proportion of alcohol impairment as single-vehicle crashes. Of note, intoxicated driving can result in more aggressive driving, as found in our study (Table 2; Paleti et al. 2010). Given the higher proportion of impairment among non-farm equipment drivers, impaired drivers may have been more aggressive when passing and approaching farm equipment.

As found in previous studies, those in the non-farm equipment vehicle were more likely to be injured or fatally injured (Gerberich et al. 1996; Gkritza et al. 2010; Peek-Asa et al. 2007). In our study, those in non-farm vehicles were over twice as likely to be injured or fatally injured after controlling for alcohol use, manner of collision, rurality of crash, state, and age. Non-farm vehicles are at a distinct disadvantage in crashes with farm equipment due to the overwhelming energy transfer from the larger, heavier farm equipment to the smaller, lighter passenger vehicle. This stresses the importance of education for all road users on interacting with farm equipment on the roadway because when a crash occurs drivers are more likely to receive an injury.

This study has several limitations. This is a secondary analysis of DOT farm equipment–related crashes obtained through police reports. Less severe crashes resulting in minor property damage or no injuries are less likely to be reported to police, particularly if it is a single-vehicle crash (Janstrup et al. 2016; Loo and Tsui 2007). This analysis is limited in its generalizability because only 4 states were examined. Nationwide, approximately

70% of all fatally injured drivers and 27% of surviving drivers are tested for alcohol impairment (NHTSA 2012). For the states included in this analysis, the prevalence of known blood alcohol level among fatally injured drivers ranges from 28 to 87% (IA = 28.5, MO = 80.5, ND = 86.8, SD = 80.9) and surviving drivers from 26 to 85% (IA = 26.2, MO = 57.9, ND = 26.0, SD = 85.2; NHTSA 2012). Among these states, all but Iowa have mandatory blood alcohol content testing for fatally injured drivers (NHTSA 2012). Increased testing of fatally injured drivers could result in a detection bias of alcohol impairment explaining some of the results of this analysis, although an increased odds of alcohol impairment was also found among nonfatally injured drivers.

Overall, the prevalence of alcohol impairment in crashes involving farm equipment is less than 3%. In farm equipment crashes, the odds of an injury or fatality increases with alcohol impairment and among drivers of non-farm equipment. Increased education of all road users regarding interacting with farm equipment on the roadway and continued interventions to decrease alcohol-impaired driving are needed.

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