Accident Analysis and Prevention 41 (2009) 42–47

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Risk factors for a farm vehicle public road crash

Theresa M. Costello[a,1], Michael D. Schulman[b,*], Roger E. Mitchell[a]

[a] Department of Psychology, North Carolina State University, P.O. Box 7801, Raleigh, NC 27695, United States
[b] Department of Sociology and Anthropology, North Carolina State University, P.O. Box 8107, Raleigh, NC 27695, United States

ARTICLE INFO

Article history:
Received 17 September 2007
Received in revised form 8 July 2008
Accepted 29 August 2008

Keywords:
Agriculture
Crashes
Farmers
Farm vehicles
Haddon matrix
Injury
Public roads
Crash risk

ABSTRACT

Driver, vehicle, public road, and farm enterprise characteristics were examined for their combined association with farm vehicle public road crash group membership. North Carolina farms experiencing a public road crash from 1992 to 2003 ($n = 200$) were compared with a non-crash control group ($n = 185$) for a 1:1 case:control ratio. Five characteristics were associated with increased odds of crash group membership in the combined model (likelihood ratio = 175.95; d.f. = 15; $p < .001$): use of non-English speaking drivers (OR = 3.71); use of non-family hired help drivers (OR = 4.25); types of non-farm vehicle public road use (OR = 1.39); farm injury history (OR = 1.33); and, use of younger farm vehicle drivers (OR = 1.02). Farms reporting older farm vehicle drivers (OR = 0.97), and low farm income (OR = 0.29) were less likely crash group members. Recommendations are discussed for incorporating findings into farm vehicle crash prevention research and interventions.

1. Introduction

Farm vehicle public road crashes are a major safety concern for farmers (Costello et al., 2003; Luginbuhl et al., 2003; NCDOL, 1999) even though official statistics show that they are a relatively rare event (less than 1 percent of annual public road crashes in North Carolina see NCDOL, 1999). Indeed, farm vehicle drivers appear at a much higher risk for a public road crash than non-farm vehicle drivers when exposure, i.e., vehicle miles traveled (VMT), is considered (Costello et al., 2003; Glascock et al., 1995). When a farm vehicle public road crash does occur, it is five times more likely to result in a fatality than a non-farm vehicle-type crash (American Trucking Associations, 2000). Few empirical studies of farm vehicle public road crashes exist (Costello et al., 2003; Gerberich et al., 1996; McCurdy and Carroll, 2000) and such studies tend to concentrate on driver characteristics to the exclusion of broader environmental characteristics.

1.1. Background and previous studies

This research examines driver, vehicle, farm enterprise, and public road characteristics identified in the literature as increasing the risk for a public road crash involving a farm vehicle (Doss and Pfister, 1972; Ogden, 1997; Layde et al., 1993, 1995; Grieshop et al., 1996). Examining farm vehicle driver characteristics, younger drivers are often at a higher risk for injury than middle age individuals because of deficiencies in skill and experience (McCurdy and Carroll, 2000). Older drivers are often at higher risk for injury than middle age individuals because of sensory and muscular deficits and age-related medical conditions (Pickett et al., 1996).

With regard to farm and non-farm vehicle characteristics, farms that utilize large size vehicles are at increased risk for a farm vehicle public road crash because of the challenges involved in sharing a narrow, two-lane road with large, slow-moving farm vehicles (Mason, 2003). Passenger cars are most frequently involved in farm vehicle public road crashes, followed by trucks, and other non-farm vehicle types (Glascock et al., 1995; Hughes and Rodgman, 2000; Batten, 2000).

Characteristics of the farm enterprise are also important. Farms that use hired help, specifically hiring non-family or non-English speaking workers, have higher risk for injury due to workers' inexperience and communication challenges (Grieshop et al., 1996). Smaller farms are at increased risk for accidents or injuries compared with larger size farms because of the challenges of getting the farm work done under time pressure constraints, often with

* Corresponding author. Tel.: +1 919 515 9016; fax: +1 919 515 2610.
E-mail addresses: tmcostello@mindspring.com (T.M. Costello), michael_schulman@ncsu.edu (M.D. Schulman), roger_mitchell@ncsu.edu (R.E. Mitchell).
[1] 902 Woodbine Drive, P.O. Box 2522 Chapel Hill, NC 27515, United States. Tel.: +1 919 929 8903; fax: +1 919 929 8903.

0001-4575/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.aap.2008.08.029

limited help (Gerberich et al., 1996; McCurdy and Carroll, 2000). Farm operators' perceptions and awareness of the risks involved in an activity vary (Bernstein, 1996; Grieshop et al., 1996; Laughery and Hammond, 1999). In addition, farmers' previous agricultural work injuries are associated with an increased risk for additional injuries (Norris et al., 2000; Browning et al., 1998). Variation in risk perceptions and injury experience may impact farm safety practices and farmer behavior.

Public road conditions also contribute to increased crash risk. Public road use results in "conflict" due to traffic density and sharing a public resource with a growing population of non-farm vehicle drivers (Satterthwaite, 1981; Kita, 2000). Farms are sharing once quiet rural roads with a growing population of non-farm vehicles (Costello and Wogalter, 2003).

In summary, farm vehicle public road crashes are complex social phenomena that occur within the context of the public road environment (Batten, 2000). Inherent in the use of limited public resources such as public roads is the act of "sharing." The complex nature of this public road "sharing" relationship suggests that a combination of driver, vehicle, farm enterprise, and public road environmental characteristics contribute to farm vehicle public road crash risk. This study investigates the extent to which these characteristics contribute to an increased risk of a farm vehicle public road crash using data collected from North Carolina farms.

2. Methods

2.1. Case–control study design

A case–control design was used to compare farms reporting a farm vehicle public road crash with farms that had not experienced a crash. A case was defined in this study as a North Carolina resident farm operator or owner/operator, who met the following criteria: drives farm vehicles on public roads; is 18 years of age or older; and either he/she or the farm help had experienced a farm vehicle public road crash between 1992 and 2003. Controls met the same screening criteria, except that neither the farmer respondent nor the farm help had experienced a farm vehicle crash between 1992 and 2003.

2.2. Crash case time frame

A long inclusion period (1992–April, 2003) was selected for cases in this study because of the small number of farm vehicle crashes reported each year on North Carolina public roads (approximately 300 crashes annually). Eighty-seven percent of all crash cases occurred within 8 years of the survey. Ten respondents, who reported a crash prior to 1992, were included in the non-crash group because the incident occurred outside of the designated time frame.

2.3. Farm as unit of sampling

This study used the farm as the unit of sampling and analysis rather than individual farm vehicle drivers. This decision was prompted by (a) the difficulty of deriving a complete sample of individual farm vehicle drivers in North Carolina and (b) the interest in capturing the effect of farm enterprise level characteristics, which calls for sampling at the level of the farm.

2.4. Participants

A USDA-sponsored agricultural program database provided a list of North Carolina resident farm land owners and farm operators (owners of farm land and renters) with unique phone numbers (n = 46,910) from which a SAS program for random selection without replacement and random ordering generated 20,000 telephone numbers for sequential calling. Calls were made at different times of the day and the week to reduce sampling bias, and at least 3 call backs were made before determining that a number could not be contacted. A total of 14,800 phone numbers were called. Of those 14,800 calls, 24 percent were unable to be screened for several reasons. Approximately 1.4 percent of calls were to individuals who refused to be screened. Approximately 22 percent of calls were placed to numbers that were either out of service (n = 1807), no longer where a farmer lives (n = 683), or could not be contacted (n = 807). Approximately 76 percent of the total 14,800 numbers called (i.e., 11,299 numbers) were to households that allowed successful screening. Approximately 34 percent (n = 3902) of households successfully screened met inclusion eligibility criteria. The eligibility criteria were: North Carolina resident farm operators or owner/operators; 18 years of age or older; actively farming; and, reporting driving farm vehicles on public roads at the time of the study. Reasons for not meeting eligibility criteria were no longer farming or driving a farm vehicle on public roads. Not all farm land owners in the database were actively operating farms (i.e., retired from farming and renting land to active farmer but participating in a USDA program because of ownership of land). Informed consent was obtained from all respondents following protocols approved by the NCSU IRB.

Eligible individuals were asked to participate in a 20 min telephone survey, which included a question as to whether he/she or his/her farm help had experienced a farm vehicle public road crash between 1992 and 2003. A total of 236 interviews (i.e., with 208 no-crash respondents and 28 crash case respondents) were completed in part one of the telephone interviews. The 208 became the no crash control cases. From that point on, eligible individuals were screened and asked to complete the interview only if they or their farm help had experienced a farm vehicle public road crash between 1992 and 2003. A total of 188 crash case surveys were completed in the second phase of sampling. Combined with the 28 crash cases identified in the first phase of interviewing, a total of 216 crash cases were available for data analysis. Altogether, a sample of 216 farm vehicle public road crash cases and 208 no-crash controls resulted in a 1:1 case–control ratio. No eligible individuals asked to complete the survey refused.

2.5. Measures

The dependent variable in this study was dichotomous, with crashes defined as either the farm operator or owner/operator or his/her farm help having experienced a farm vehicle public road crash between 1992 and 2003. Crashes were coded as 1, and no-crashes as zero (0).

All measures in this study were self-report with the farm operator or owner/operator respondent reporting characteristics of farm vehicle public road use for his/her respective farm, rather than for a specific driver. In addition, farm operators or owner/operators were asked questions about the status of driver, vehicle and environmental characteristics at the time of the interview, rather than at the time of the crash. Driver, vehicle, farm enterprise and public road environmental independent variables were measured as described below.

Age of youngest farm vehicle driver is a continuous variable measured by asking farm operator or owner/operator respondents the age of the *youngest* individual driving farm vehicles on public roads for their farm.

Age of oldest farm vehicle drivers is a continuous variable measured by asking farm operator or owner/operator respondents the

age of the *oldest* individual driving farm vehicles on public roads for their farm.

Public road driving exposure was measured by asking farm operators or owner/operators the number of hours per week they or their farm help drive farm vehicles on public roads during busy months.

Farm help status was measured by asking farm operators or owner/operators whether they have non-family hired help driving farm vehicles on public roads. *Yes* responses were coded as 1 and *no* responses were coded as zero (0).

Non-English speaking help status was measured by asking farm operators or owner/operators whether any of their farm help driving farm vehicles on public roads were non-English speaking. This variable, initially measured continuously (i.e., "how many. . ."), was dichotomized so that *Yes* responses were coded as 1 and *no* responses were coded zero (0).

Farm injury history was measured by asking farm operators or owner/operators how many times while working in agriculture they had been injured badly enough on the job to miss a day of work or receive medical treatment. This was used us a dummy variable with any yes responses coded as one (1).

Farm vehicle age was measured by asking farm operators or owner/operators the age of the farm vehicles they drive on public roads. The age of the oldest farm vehicle mentioned was used for data analysis and model testing.

Farm truck—usage was measured by asking farm operators or owner/operators what types of farm vehicles they or their farm help drive, tow or load and transport on public roads, besides farm tractors. Farm truck types (i.e., pick up trucks and dump trucks) mentioned were summed as zero (0) for no mention or one (1) for one or more mentions for use in data analysis and model testing.

Large size farm vehicle—usage was measured by asking farm operators or owner/operators what types of farm vehicles they or their farm help drive, tow or load and transport on public roads, besides farm tractors. Large size farm vehicle types mentioned (i.e., combines, harvesters, specialty equipment and hay balers) were summed as zero (0) for no mention or one (1) for one or more mentions for use in data analysis and model testing.

Total non-farm vehicle public road use characteristics were measured by asking farm operators or owner/operators the following open-ended question: "what are the roads you use to transport farm equipment used for besides farming?" Responses were summed for use in data analysis and model testing. Examples of non-farm vehicle public road use included: local traffic; commuter route; construction site access; livestock trucking route; construction route. Summary scores ranged from one (1) to seven (7) non-farm vehicle public road uses. Higher scores indicated a greater number and variety of non-farm vehicle public road uses.

Traffic density was measured by asking farm operators and owner/operators whether their farm was located in an area with: (1) little traffic, (2) moderate traffic, or (3) heavy traffic. Response frequencies were used for data analysis and model testing.

Number of farm operations was measured by asking farm operators or owner/operators "how many farm operations they own or manage."

Farm income was measured by asking farmers to report their gross annual farm sales. Gross annual farm sales responses were categorized into one of three groups based on US agricultural census data categories for gross annual farm sales, namely: *low income* (<$25,000 annual gross farm sales); medium income ($25,000 to $99,999 annual gross farm sales); and *high income* ($100,000 or greater annual gross farm sales) (USDA, 1999). Medium income was the referent group. Farm size is often measured in agricultural studies using farm income as a proxy variable (Murphy, 2003; USDA, 1999).

Several variables included in the study to assess farm driver perceptions (e.g., actions taken to prevent crashes, perceived road use conflict, perceived danger in driving farm vehicles on public roads) were eliminated from the analyses because they could be endogenous to the crash process itself.

2.6. Data analysis

Logistic regression was used to test the proposed research model regarding farm vehicle public road crash group membership differences. SAS for Windows was used for all data analyses. Outliers were identified using the following criteria: A Cook CI-interval displacement statistic of .13 or greater; and a positive change in all three of the following statistics, namely, the logistic regression X^2, and the linear regression R^2, and R^2 adjusted when variable was deleted from the model. After cleaning data for outliers ($n = 9$) and missing data ($n = 30$), a sample of $n = 200$ crash cases and $n = 185$ no-crash controls were available for data analysis. The final data set for analysis without the outliers and missing data cases was very close to the goal of having a one to one ratio of crash cases and no-crash controls. We elected not to use the outliers and missing data cases so as to not to create possible biases in the measured variables.

A combined model of driver, vehicle, farm enterprise, and public road environmental variables posited to be associated with farm vehicle public road crash group membership was compared with the constant-only model by means of a likelihood ratio test at a $p < .05$ significance level. The unique contribution of each individual variables was tested using the Wald statistic and the odds ratio point estimate, along with the 95% Wald confidence limits. Only statistically significant independent variables are presented in the Tables for reasons of parsimony.

3. Results

3.1. Sample description

The mean age of North Carolina resident farm operators or owner/operators in this study ($n = 385$) was 55 years, which is comparable to USDA agricultural census data (1999) for North Carolina (mean = 55 years). Mean acreage for the study sample was 539 acres, which was higher than the North Carolina census mean of 185 acres. A mean annual gross farm sales of $133,000 for this sample was lower than the North Carolina census mean of $155,000 (NCOSPL, 1997, 2000). This study's sample represents a smaller percentage of low income farms (28%) than the North Carolina (67%) USDA agricultural census data, and a higher percentage of medium and large income farms. Descriptive statistics (means) showed that farms with crashes had more workers, farmed more acres, and had higher gross farm sales than non-crash farms.

These findings suggest that, although the study sample is similar in age and race to the North Carolina agricultural census population, North Carolina resident farm operators or owner/operators included in the USDA agricultural program database may differ somewhat from the average US Census data profile for North Carolina farmers.

The means and percentages of the independent variables significant in the combined model are displayed in Table 1. Intercorrelations between independent variables, significant and non-significant, ranged from $r = 0.1$ to $r = 0.64$, with no evidence of multicollinearity.

3.2. Model testing

The study's model tested the combined association of fifteen driver, vehicle, public road, farm enterprise, and farm operator char-

Table 1
Independent variable means and frequency percentages for total sample and by farm vehicle public road crash status, and chi square or *t*-test results for crash versus no crash group comparisons (statistically significant independent variables)

Variable	Total sample ($n = 385$)	Crash ($n = 200$)	No crash ($n = 185$)
Age of youngest farm vehicle driver on public roads (mean)	33.6	31.1**	36.4
Age of oldest farm vehicle driver on public roads (mean)	60.5	59.6	61.5
Non-family hired farm help drive farm vehicles on public roads (*D*, %)	46.7	76.5**	24.0
Non-English speaking (*D*, %)	28.0	41.0**	14.0
Farm injury history (mean number of events)	1.0	1.5**	0.5
Total number and variety of non-farm vehicle public road uses (mean)	1.9	2.2**	1.5
Farm vehicle age (i.e., years of age of oldest farm vehicle driven)	34.3	34.4	34.0
Use of farm truck (*D*)	77.0	83.5**	70.2
Use of large-size farm vehicles (*D*)	67.0	77.0**	56.2
Driving exposure (i.e., number of hours driven farm equipment on public roads	13.6	16.0**	11.0
Number of farm operations managed	3.1	3.8**	2.3
Gross farm income			
Low income (<$25K) (*D*, %)	28.3	11.0**	47.0
High income ($100K or more) (*D*, %)	46.7	65.0**	27.0
Traffic density			
Low density	19.7	13.0**	27.0
High density income	24.9	30.5**	18.9

Note: X^2 (d.f. = 1) or *t*-test (d.f. = 383) significant differences between crash and no-crash groups $^{*}p < .05$, $^{**}p < .001$; *D*, %: dichotomous variable response percentage.

acteristics with farm vehicle public road crash group membership. The model was significant with a likelihood ratio of 175.95 (d.f. = 15; $p < .001$; −2 log likelihood intercept only = 533.1; −2 log likelihood full model = 357.2).

Odds ratio point estimates and Wald 95% confidence limits presented in Table 2 for the driver, vehicle, farm enterprise, farm operator, and public road environmental variables significant for increased crash group membership likelihood controlling for all other independent variables are: non-English speaking help (OR = 3.71; CI = 1.95–7.03); non-family hired help (OR = 4.25; CI = 2.37–7.63); farm injury history (OR = 1.33; CI = 1.11–1.60); non-farm vehicle public road use (OR = 1.39; CI = 1.10–1.76); and, younger farm vehicle drivers (OR = 1.02; CI = 1.00–1.04).

Odds ratio point estimates and Wald 95% confidence limits for the one driver and one environmental variables that significantly decrease crash group membership likelihood controlling for all other independent variables are: older farm vehicle drivers (OR = 0.97; CI = 0.95–0.99); and low farm income (OR = 0.29; CI = 0.14–0.59) compared with farms reporting medium farm income. These results are net of the effects of the non-statistically significant independent variables (hours driven on public roads; oldest farm vehicle; farm trucks; large size farm vehicles; traffic density; total non-farm public road use; number of farming operations) that function as controls for exposure, farm size and scale, and traffic density.

Table 2
Logistic regression odds ratio point estimates and 95% Wald confidence limits (for statistically significant independent variables) ($n = 385$)

Variable	Odds ratio point estimate	95% Wald confidence limits
Age of youngest driver	1.02	1.00–1.04*
Age of oldest driver	*0.97*	*0.95–0.99***
Non-family hired help (*D*)	4.25	2.37–7.63**
Non-english speaking help (*D*)	3.71	1.95–7.03**
Farm injury history	1.33	1.11–1.60**
Total non-farm public road use	1.39	1.10–1.76**
Farm vehicle age	1.01	0.99–1.03
Use of farm truck (*D*)	1.78	0.93–3.41+
Use of large-size farm vehicles (*D*)	1.74	0.98–3.09+
Driving exposure	1.012	0.99–1.03
Number of farm operations managed	1.02	0.95–1.10
Low farm income (D)	*0.29*	*0.14–0.59***
High farm income (*D*)	1.37	0.72–2.58
Low traffic density	0.65	0.33–1.29
High traffic density	1.51	0.78–2.92

Note: $^{+}p < .10$; $^{*}p < .05$; $^{**}p < .001$. *D* = dichotomous variable.
Variables significant in the expected direction are underlined.
Variables significant in a direction opposite to that expected are italicized.

4. Discussion

The posited combination of driver, vehicle, farm enterprise, and public road environmental characteristics significantly predicted farm vehicle public road crash group membership. Several of the expected relationships were supported. Farms reporting non-family and non-English speaking farm vehicle drivers and younger farm vehicle drivers were at increased farm vehicle public road crash group membership risk. Farms reporting a history of farm injury of any sort were also at increased risk for farm vehicle crash group membership. This could reflect an overall behavioral adaptation towards farm safety that shapes the way that farm vehicles are used on public roads. Not surprisingly, increased non-farm vehicle public road use (i.e., a greater variety of non-farm vehicle driving purposes) was associated with an increased risk for crash group membership.

Some variables were significantly associated with crash group membership in ways that were not expected. Farms reporting older drivers were less likely crash group members. Perhaps our measure of age did not capture the point at which the benefits of greater experience are outweighed by decreasing physical stamina, coordination, and so on. Finally, low farm income, a proxy for farm size, was associated with lower likelihood of crash group membership. The relationship could not be due to smaller farms having less driving exposure, since there was a very modest negative correlation between low farm income and driving exposure ($r = .14$, $p < .05$).

Past farm vehicle public road crash preventive actions have focused primarily on the driver and the farm vehicle (Costello et al., 2003) rather than taking a combined driver, vehicle, and environmental approach. Future farm vehicle public road crash reduction interventions should consider a combined approach that addresses driver, vehicle, road conditions, and characteristics of the farm and the farmer/farm help.

4.1. Study limitations

Case–control studies of farm vehicle public road crashes are labor-intensive and present a number of challenges. Therefore, this

study had a number of limitations, in particular, ones pertaining to: recall accuracy and measurement time periods; survey question design and measurement; the level of analysis; and, sampling bias. Each limitation is addressed below.

4.1.1. Measurement time periods

Crash cases were considered eligible for the study if they occurred from 1992 to 2003. Since the occurrence of farm vehicle public road crashes is such a rare event, a longer time period was chosen in order to capture a sufficient number of cases. We chose not to ask respondents to describe the characteristics of a specific crash (e.g., driver characteristics, traffic patterns) because of concern about the accuracy of recall of details of a crash in the distant past. For this reason, questions were asked about current conditions, with the assumption that these would, for the most part, be indicative of prior conditions. If these conditions changed since the crash, the actual relationships between predictor variables and case–control status would be obscured. To the extent that conditions changed as a result of a crash (e.g., increased safety practices from pre-crash to post-crash), this could very well reduce differences between the control and crash conditions. There is no indication that such differences occurred. However, future case–control studies of this type might ask respondents what they had done differently (if anything) in response to the occurrence of a crash.

4.1.2. Survey design and measurement

There are several potential weaknesses with regard to choices made in the design of this study. First, the respondent was asked to describe characteristics of the farm and/or farm environment (e.g., traffic density, farm income, and so on). There was no independent verification of the respondent's responses. Second, given the difficulty of doing a comprehensive assessment of the experiences of all drivers on a farm in a brief phone interview, we chose to select an "index" person or item for particular questions. To assess the degree to which there was a history of farm injury (i.e., a proxy for farm safety), we asked about the experiences of the interview respondent himself/herself. To assess the age (and presumed safety) of farm equipment, we asked the age of the oldest farm vehicle being used. This obviously creates measurement problems if the experiences of the index respondent are not generally representative of others working on the farm.

There are some other potential weaknesses with regard to the validity of the instruments used in this study. A number of variables used in this study were measured using single item closed and open-ended questions. In addition, retrospective recall of events (such as number of hours driving a farm vehicle) may be susceptible to error. There are certainly methodologies from other areas that might increase the validity of retrospective recall (e.g., the time-line follow-back technique that has been used to increase the validity of recall of frequency of alcohol use) (Sobell and Sobell, 1992). However, such approaches are time intensive and difficult to use in brief telephone surveys where soliciting participation is a challenge. Further research in the validation of measures in the farm vehicle crash area would be helpful.

4.1.3. Level of analysis

The thrust of this study was to examine how driver, vehicle, farm enterprise, and public road environmental characteristics at the farm level related to crash group status. The assumption was that respondents' responses serve as an approximate measure of characteristics of the farm enterprise. (For example, the owner/operator's report of his/her injury history was taken as a proxy for attention to safety issues by the farm enterprise). To the extent that the operator or owner/operator's responses were atypical of the farm overall, use of these measures would obscure actual relationships. Independent measurement of farm-level characteristics (e.g., rates of farm injury) are difficult to obtain, but would increase confidence in the validity of results.

4.1.4. Sampling bias

Two possible limitations of the study involve potential bias in construction of the sample and in the self-election of respondents.

First, a USDA agricultural program database for North Carolina resident farm land owners and farm operators (owners and renters of farm land) was used to generate the sampling frame for this study. Eligibility criteria ruled out farm land owners who were not actively farming, resulting in a large number of ineligible numbers. Farm operators not participating in a USDA program (i.e., very small scale "hobby" farms) are not necessarily listed in this data base. Comparison of the study sample demographic profile with the North Carolina agricultural census profile in Table 1 indicated that the study sample had fewer small size farms, higher mean farm acreage, and reported lower mean gross farm income. These findings suggest a potential sampling bias, and thus, raise questions about the generalizability of the study to the total population of North Carolina farmers. A comparison of farm vehicle driver age and percentage of crashes by month for this study with those of North Carolina crash report data (Hughes and Rodgman, 2000), however, suggests that the study sample is comparable to North Carolina farmers reporting a vehicle public road crash. Therefore, these findings suggest that although the USDA agricultural program database may have provided a biased sampling frame, crash case data comparisons suggest the study sample is reasonably representative of North Carolina farmers who drive farm vehicles on public roads and are involved in a crash. In other words, very small-scale farms that may not be participating in a USDA program, and therefore not part of the USDA database, are also the farms that tend not to drive farm vehicles on public roads.

Second, as discussed earlier, approximately 22 percent of calls were placed to numbers that were either out of service ($n = 1807$), no longer where a farmer lived ($n = 683$), or could not be contacted ($n = 807$). It is undetermined how many of these "unscreened" phone numbers actually represent non-identified eligible participants. It is also unclear to what extent non-identified eligible participants might be different from those farm owners or owner/operators who were successfully screened. Thus, there may be bias in the individuals successfully screened in this study. Future studies might devote increased resources to following more intensively a small subsample of non-responders to check for sampling bias. Investigators might also examine whether degree of difficulty of recruitment in their own sample is related to important predictor or dependent variables.

In spite of these limitations, significant relationships were found in expected directions, suggesting the robustness of these findings.

4.2. Implications for future interventions

Driver age, farm help status, non-family hired help, and history of farm injury were associated with farm vehicle public road crash group membership. Intervention research should determine whether farm vehicle driver licensing, training, testing and monitoring programs would be effective methods for reducing farm vehicle public road crash risk. Readers should note that farms who used non-family hired help and non-English speaking help were more likely to be in the crash group, but the study did not determine the identify of the driver of the crash (i.e., whether the actual crash-involved driver was non-family hired help and/or non-English speaking help).

The public road environment is changing in North Carolina. Once quiet roads used by farm vehicles are now being shared with an increasing number and variety of non-farm vehicles. Peak morning and afternoon times are key time periods for public road use and thus ripe for public road competition and conflict. When asked, farmers suggested such things as slow moving vehicle lanes, improved signage, driver training, and better speed limit enforcement as possible interventions. Traffic pattern and time usage information would be helpful.

4.3. Conclusion

Public road crashes are complex social phenomena (Batten, 2000). A combination of driver, vehicle, farm enterprise, and public road environmental characteristics were associated with farm vehicle public road crash group membership, providing important clues about risk factors that warrant attention and possible intervention.

The increase in urban growth in North Carolina is expected to continue. Urban and agricultural traffic often compete for the same public road resources at the same key time periods during the day. In addition, farm vehicles are often large and slow moving. Commuters and faster moving vehicles may become frustrated driving behind farm vehicles and attempt unsafe passing maneuvers

In summary, the data from this study suggest a combination of driver, vehicle, public road, and farm enterprise characteristics contribute to increased farm vehicle public road crash risk. Thus, a multifaceted approach to farm vehicle public road safety that goes beyond the farmer and farm vehicle is warranted. Agriculture remains an important industry in North Carolina, so further research and intervention examining how farmers and non-farmers can safely share public roads is warranted.

Acknowledgments

Support for this research came from NIOSH grant 5U500H07551-04 to the Southern Coastal Agromedicine Center and North Carolina State University. Additional support was received from the North Carolina Agricultural Research Service. The opinions expressed are those of the authors who would like to thank the following individuals for their guidance and input: Dr.'s Daniel Bauer, Hank Cole, Ronald Czaja, David Dickey, Ron Huges, Bill Hunter, Paul Leigh, and Michael Wogalter; Regina Luginbuhl; Joy Smith; and, the North Carolina agricultural community.

References

American Trucking Associations, 2000. Sharing the road with farm equipment. SafetyNet (Online). Available at: www.truckline.com/safetynet/highway/sharing_farm_equipment.htm.

Batten, D.F., 2000. Safety and collective behavior on congested traffic networks. In: von Holst, H., Nygren, A., Andersson, A.E. (Eds.), Transportation, Traffic Safety and Health: Man and Machine. Springer-Verlag, Berlin, Germany.

Bernstein, P.L, 1996. Against the Gods: The Remarkable Story of Risk. John Wiley & Sons, Inc., Hoboken, NJ.

Browning, S.R., Truszczynaska, H., Reed, D., McKnight, R.H., 1998. Agricultural injuries among older Kentucky farmers: the farm family health and hazard surveillance study. American Journal of Industrial Medicine 33, 341–353.

Costello, T., Schulman, M., Luginbuhl, R., 2003. Understanding the public health impacts of farm vehicle public road crashes in North Carolina. Journal of Agricultural Safety and Health 9 (1), 19–32.

Costello, T., Wogalter, M., 2003. Driver attitudes, beliefs and reported behavior associated with sharing public roads with farm vehicles. In: Proceedings of the HFES 47th Annual Meeting.

Doss, H.J., Pfister, R.G., 1972. Nature and Extent of Farm Machinery Use in Relation to Frequency of Accidents in Michigan and Ohio. Michigan State University, Agricultural Engineering Department, East Lansing, Mich.

Gerberich, S., Robertson, L., Gibson, R., Reiner, C., 1996. An epidemiological study of roadway fatalities related to farm vehicles: United States. Journal of Occupational and Environmental Medicine 38 (11), 1135–1140.

Glascock, L.A., Bean, T.L., Woo, R.K., Carpenter, T.G., Holmes, R.G., 1995. A summary of roadway accidents involving agricultural machinery. Journal of Agricultural Safety and Health 1 (2), 93–104.

Grieshop, J., Stiles, M., Villanueva, N., 1996. Prevention and resiliency: a cross cultural view of farmworkers' and farmers' beliefs about work safety. Human Organization 55 (1), 25–32.

Hughes, R., Rodgman, E., 2000. Crashes involving farm tractors and other farm vehicles/equipment in North Carolina, 1995–1999. Prepared for North Carolina Division of Motor Vehicles (NCDMV), Commercial Motor Vehicle Enforcement Section. University of North Carolina, Highway Safety Research Center, Chapel Hill, NC.

Kita, H., 2000. Design of driving environment, driving behavior, and traffic safety. In: von Holst, H., Nygren, A., Andersson, A.E. (Eds.), Transportation, Traffic Safety and Health: Human Behavior. Springer-Verlag, Berlin, Germany.

Laughery, K.R., Hammond, A., 1999. Overview. In: Wogalter, M.S., DeJoy, D.M., Laughery, K.R. (Eds.), Warnings and Risk Communication. Taylor & Francis, Inc., Philadelphia, PA.

Layde, P.M., Nordstrom, D.L., Stueland, D., Brand, L., Olson, K.A., 1995. Machine-related occupational injuries in farm residents. Annual of Epidemiology 5, 419–426.

Layde, P.M., Stueland, D., Nordstrom, D.L., Olson, K.A., Follen, M.A., Brand, L., Konitzer, K., Herr, J., Leick, I., Lezotte, C., 1993. Identifying Preventable Risk Factors for Farm Injuries. Centers for Disease Control and Prevention, Atlanta, GA.

Luginbuhl, R.C., Jones, V.C., Langley, R.L., 2003. Farmer's perceptions and concerns: the risks of driving farm vehicles on rural roadways in North Carolina. Journal of Agricultural Safety and Health 9 (4), 327–348.

Mason, G., 2003. Telephone Conversation Regarding Farm Vehicle Speed and Public Road Use. The Tractor Place, Inc., Knightdale, NC.

McCurdy, S.A., Carroll, D.J., 2000. Agricultural injury. American Journal of Industrial Medicine 38, 463–480.

Murphy, D.J., 2003. Chapter 1: Reasons and motivations for conducting this review. In: Looking Beneath the Surface of Agricultural Safety and Health. American Society of Agricultural Engineers, St. Joseph, MI.

NCDOL, 1999. Fifth annual gold star luncheons: fixing grower's sights on rural highway safety. The Cultivator 15 (May), 1–2.

NCOSPL, 1997. Population Growth 1980–1990. Office of State Planning, Raleigh, NC. Available at: www.ospl.state.nc.us/demog/estgr0.htm.

NCOSPL, 2000. Population growth 1990–1999. Office of State Planning, Raleigh, NC. Available at: www.ospl.state.nc.us/demog/c99estp.htm.

Norris, F., Matthews, B.A., Riad, J.K., 2000. Characterological, situational, and behavior risk factors for motor vehicle accidents: a prospective examination. Accident Analysis and Prevention 32, 505–515.

Ogden, K.W., 1997. The effects of paved shoulders on accidents on rural highways. Accident Analysis and Prevention 29 (3), 353–362.

Pickett, W., Chipman, M.L., Brison, R.J., Holness, D.L., 1996. Medications as risk factors for farm injury. Accident Analysis and Prevention 28 (4), 453–462.

Satterthwaite, S.P., 1981. A survey of research into relationships between traffic accidents and traffic volumes. Supplementary Report SR 692, p. 43. Transport and Road Research Laboratory, Crowthorne, UK.

Sobell, L.C., Sobell, M.B., 1992. Timeline followback: a technique for assessing self-reported ethanol consumption. In: Allen, J., Litten, R.Z. (Eds.), Measuring Alcohol Consumption: Psychosocial and Biological Methods. Humana Press, Totowa, NJ, pp. 41–72.

USDA, 1999. Historical highlights: 1997 and earlier census years. In: 1997 Census of Agriculture, North Carolina. USDA National Agricultural Statistics Service, Washington, DC.