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Causes of Mortality and Risk Factors for Injury Mortality among Children in the Agricultural Health Study

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Abstract

Farm children face unique health risks due to sharing their residential environment with hazardous machinery and materials. Causes of mortality among farm children have not been comprehensively described.

Objective—In the Agricultural Health Study (AHS) cohort, we examined causes of mortality among 21,360 children in Iowa and North Carolina between 1975 and 1998.

Methods—We matched identifying information for children provided by mothers on self-administered questionnaires to state death registries (1975–1998). Data on farm and family characteristics were provided by parents via enrollment questionnaires (1993–1997). Standardized mortality ratios (SMRs) were calculated, using state mortality data to generate expected deaths. We used logistic regression to examine parent, child and farm characteristics associated with injury mortality.

Results—There were 162 deaths in Iowa (SMR=0.69; 95% confidence interval (CI)=0.60, 0.81) and 26 deaths in North Carolina (SMR=0.42; 95%CI=0.28, 0.61) in children aged 0–19 years. This deficit was largely due to deaths in the first year of life. Although deaths from overall unintentional injury were not increased, excess agricultural machinery mortality was observed in Iowa (SMR=9.25; 95% CI=5.12, 16.70). In case-control comparisons, maternal age less than 25 years at child's birth (OR=2.17; 95%CI=1.05, 4.49) and having more than 2 children in the family (OR=2.79; 95% CI=1.47, 5.30) were associated with increased child injury mortality. For children under 14 years, participation in farm work was associated with increased risk of agricultural machine-related mortality (OR=3.92; 95% CI=1.04, 14.78).

Conclusions—Parent and child characteristics associated with child injury mortality could be used to target farm safety interventions.

Keywords

Children; farm; mortality; injury; agricultural machinery

INTRODUCTION

More than one million children live on farms¹ and are at risk for injury and death as they participate in farm work and share their residential and recreational environments with machinery, livestock, and hazardous materials. For farm children, injury-related morbidity and mortality are substantial: for every 100,000 farm children, 8 deaths and 1717 nonfatal injuries were reported between 1990 and 1993³.

Previous studies have examined specific causes of childhood farm deaths and attributed many to agricultural machinery, especially tractors^{2–4}. Other farm-related deaths were due to drowning^{3,5}, firearms³, falls from farm structures and buildings^{2,6,7}, toxic ingestions and exposures⁸, and animal-associated injuries^{4,6}. While these specific farm-related causes of injury mortality have been identified, other causes of mortality among farm children are possible but have not been as fully explored. Farm children face additional potential health problems, such as long-term exposures to animals, pesticides, solvents, and particulate airborne material, which some studies suggest may be associated with increased respiratory disease⁹ and cancer¹⁰. Further, farm children generally live in rural areas where there may be elevated rates of motor vehicle accidents^{11,12}. When injuries occur, farm children who reside in rural areas may have limited access to health services, which may increase the potential for severe injuries to result in fatality¹³.

Some characteristics of farm children have previously been associated with farm injury and mortality in the United States, including male sex^{2,14,15}, age, (with increased frequency of injury at ages 3–4 years¹⁶ and 15–19 years²), lack of supervision¹⁷, and performance of agricultural tasks by children¹⁸. Specific types of agricultural machinery, including tractors, combines, and wagons^{2,6,15} have also been described as causing farm-related injury mortality among children. In studies of children in the general population, younger maternal age, lower maternal educational level, and higher number of children in the household have been associated with increased childhood injury mortality^{19–21}. Family characteristics may also play a role in injury and mortality among farm children, but these characteristics have been little studied.

Describing causes of mortality among farm children and identifying child, family, and farm characteristics that are associated with child mortality are necessary to tailor interventions intended to promote safety and health among farm children. We draw upon the data provided by the Agricultural Health Study, a large, prospective cohort of farm families²² to: 1) compare cause-specific mortality rates in farm children to those expected in reference populations, and 2) conduct a preliminary examination of the relationship of child, family, and farm characteristics to injury mortality.

METHODS

The AHS, described in detail elsewhere²², is a collaborative effort of the National Cancer Institute, the National Institute of Environmental Health Sciences, and the United States Environmental Protection Agency. Briefly, it is a large prospective study of pesticide applicators and their spouses in Iowa and North Carolina. Both private pesticide applicators (largely farmers; N=52,395) and commercial applicators (Iowa only, N=4,916) were asked to participate in the study when they applied for pesticide application licenses (1993–1997).

Approximately 75% of eligible female spouses of private applicators also enrolled (N=32,347); of these, 64% (N=20,625) completed questionnaires on family health, including information on their children. As described previously¹⁰ identifying information for 21,375 children born during or after 1975 was collected from mothers using these questionnaires. Identifying information for children, including names, sex, dates of birth, and social security numbers, was matched against Iowa and North Carolina state death certificate files to identify deaths of children aged 0–19 years between 1975 and 1998. Through this linkage, 177 deaths in Iowa and 26 deaths in North Carolina were initially identified. Fifteen of the Iowa deaths were subsequently matched to fetal death certificates and were excluded since these deaths did not occur to live-born children, resulting in 162 IA and 26 NC deaths among 21,360 children. The Agricultural Health Study and linking of AHS data with the Iowa and North Carolina death certificate files were approved by the Institutional Review Boards of the National Cancer Institute, the National Institute of Environmental Health Sciences, the University of Iowa, and Battelle Life Sciences, Inc.

Standardized Mortality Ratio Analysis

Standardized mortality ratios (SMRs) were calculated to compare the observed number of deaths identified among children of AHS participants to the expected number. For each state, the expected number of deaths was generated by applying sex, age, and time period-specific childhood mortality rates available from the National Center for Health Statistics to the person-years contributed by eligible children in the sample, according to the method of Breslow and Day²³. Each state's death rate was used to calculate the expected number of deaths for that state. For North Carolina only, reference rates used to generate SMRs were also race-specific (black/white); reference rates for whites were used for the Iowa sample as the sample is predominantly (96%) white. Age-specific and cause-specific standardized mortality ratios were also generated for each state. Causes of death were classified in accordance with the International Classification of Diseases (ICD-9) codes²⁴; injury mortality was classified according to the framework recommended by the National Center for Health Statistics and the National Center for Injury Prevention and Control²⁵.

Case-Control Analysis

Since unintentional injury was a leading cause of mortality within the cohort, we conducted an exploratory case-control analysis of unintentional injury mortality. We defined cases as children in NC or IA who died due to unintentional injury (N=54). All other age-eligible children born to cohort members served as controls for these analyses. We reviewed existing childhood farm injury literature to identify child, family, and farm characteristics which were potentially related to childhood farm injury mortality. *Child characteristics* were reported by mothers via questionnaires completed during their enrollment in 1993–1997 and included child's gender (female/male), and child's work on the farm, as defined by their response to whether the child "performed many of the activities associated with farming" (yes/no/never lived on farm). *Family characteristics* were also reported by either the mother or father via questionnaire. Mothers and fathers reported their age, educational level, and frequency of alcoholic drinks in the past year (times per week/month). Mothers also reported number of children in the family. Fathers also reported whether they ever had a head injury or agricultural machine injury (yes/no), and how often they participated in specific farming activities: driving combines, tilling soil, truck driving, tractor driving, engine repair, grain handling, hay handling, feed grinding, loading/unloading silage, and welding. *Farm characteristics* were reported by the father and included farm size and crops and animals produced. All questionnaires are available in electronic format²⁶.

Injury Mortality: Bivariate Analyses

Logistic regression analyses were used to compute odds ratios (OR) and 95% confidence intervals (CI), using SAS[®] version 8 software²⁷ to examine the associations between child, family and farm characteristics and injury mortality. After examining variable distributions, maternal and paternal education was collapsed to two categories (high school graduate or less, greater than high school graduate). Maternal and paternal alcohol consumption was also collapsed to three categories (none, ≤ 3 times/month, ≥ 1 time/week). Farm size was collapsed to two categories: < 200 acres, ≥ 200 acres. Number of children in the family was noted to be skewed to the right; original responses were collapsed to the following categories: ≤ 2 children, 3, 4, ≥ 5 children. Since odds ratios for 3, 4, and ≥ 5 children were similar, these categories were subsequently collapsed. The association between mother's age at child's birth and injury was initially examined through a comparison of means using Student's t-test. For logistic regression analyses, mother's age at child's birth was subsequently divided into quartiles. In initial bivariate analyses, ORs for each characteristic of the child, family, and farm were generated by logistic regression analysis, adjusting for state (North Carolina or Iowa).

Injury Mortality: Multivariate Analyses

To examine whether associations identified in bivariate analysis were explained by confounding variables, we created a multivariate logistic regression model to examine the relationship of child, family, and farm characteristics to injury mortality. We examined correlations between potential covariates; maternal and paternal education were highly correlated ($r=0.81$); therefore only maternal education was entered into the model. Child's gender, child's work on the farm, mother's age at child's birth, mother's education, farm size, number of children in the family, father's history of head injury and agricultural machine injury, maternal and paternal alcohol consumption, farm product type, and state were entered into the initial regression model, as well as an interaction term between number of children in the family and the mother's age at child's birth, since preliminary analyses suggested a relationship between these variables. Terms were eliminated from the model if their removal did not change the odds ratios by more than 10% for any of the hypothesized risk factors.

RESULTS

Children in both states were predominantly white, with slightly more males than females (Table 1). Nearly half of children in both states were reported by their mothers to have worked on the farm. Over half of parents in both states had education beyond high school graduation. Family size was greater in Iowa, with 65% of children coming from families of more than 2 children, while only 35% of North Carolina children had families of this size. Many fathers had themselves sustained injuries; 15% of Iowa fathers and 11% of North Carolina reported histories of head injury, and agricultural machinery injuries were sustained by 30% (IA) and 18% (NC) of fathers. Farm sizes in Iowa were larger, with most farms greater than 200 acres, while fewer than half of North Carolina farms were greater than 200 acres.

The overall SMR for childhood mortality was 0.69 (95% CI=0.60, 0.81) in Iowa and 0.42 (95% CI=0.28, 0.61) in North Carolina (Table 2). Under age 1 year, mortality in both states was lower than expected (SMR=0.51; 95% CI=0.41, 0.64 in Iowa and SMR=0.26; 95% CI=0.15, 0.47 in North Carolina). Observed numbers of deaths among older children (5–19 years) in Iowa, however, were similar or slightly excessive compared to the general population. Overall unintentional injury mortality in the two states (Iowa SMR=1.23; 95% CI=0.93, 1.63; North Carolina SMR=0.55; 95% CI=0.25, 1.22) did not differ from expected, but was higher in Iowa than North Carolina. Eleven deaths were observed in Iowa due to agricultural machinery mortality (SMR=9.25; 95% CI=5.12, 16.70), with none in North Carolina. We also examined the SMR for the following specific causes of death and observed no differences in observed

compared with expected mortality: malignancy, chronic lower respiratory disease, heart disease, pneumonia and influenza, intentional injury, suicide, homicide, drowning, falls, fires/burns, firearms, pedal cyclist, pedestrian, poisoning, and suffocation. We did observe fewer deaths than expected due to congenital anomalies in North Carolina (SMR=0.19; 95% CI=0.05, 0.74); however, this was based on <3 deaths. We repeated all analyses using mortality data from the entire United States as the reference standard in calculation of SMRs. This resulted in no substantial change in SMRs and results are not shown.

In bivariate analyses of injury mortality, after adjusting for state (North Carolina vs. Iowa), male gender was not associated with increased risk of injury mortality (OR=1.09; 95% CI=0.64, 1.86) (Table 3). Child participation in farm work was associated with injury mortality but this relationship was not statistically significant (OR=1.58; 95% CI=0.95, 2.61). Being born to mothers under 25 years of age (OR=2.03; 95% CI=0.98–4.19) and being from families with more than two children (OR=2.71; 95% CI=1.43, 5.15) were associated with injury mortality. To examine whether the association between greater number of children and injury mortality may have occurred due to families deliberately planning a child following the death of another child, we conducted a supplemental analysis comparing birth years of siblings of injury mortality cases to those of controls, who were matched to cases on year of birth and number of children in the family. Among cases, only 12 of 63 families (19%) had additional children following the death of a child, while 25% of control families had a child subsequent to the death date of the case child. Mean follow-up time for this analysis was 6.2 years. No associations were found between the following variables and injury mortality risk: paternal history of head injury or agricultural machine injury, maternal or paternal alcohol consumption, crop or farm product type, or farm size, father's participation in specific activities including driving combines, tilling, driving trucks or tractors, repairing engines, handling grain or hay, grinding feed, handling silage, or welding.

In a multivariate analysis of factors associated with injury mortality (Table 4), we found no interaction between maternal age at child's birth and number of children in the family and excluded this interaction term from subsequent analysis. Since number of children in the family and maternal age at child's birth were associated with injury mortality in bivariate analyses, we included these as key variables within the model and examined the effect of removal of covariates on these variables. After adjusting for state and number of children in the family, maternal age <25 years at child's birth was associated with increased risk of childhood injury mortality (OR=2.17; 95% CI=1.05, 4.49). After adjustment for the same covariates, more than 2 children in the family was associated with increased risk of childhood injury mortality (OR=2.79; 95% CI=1.47, 5.30).

Since we identified 11 deaths due to agricultural machinery injury, we explored characteristics associated with these deaths. All deaths in this category occurred to children ≤ 14 years (Table 5). Nearly all (91%) occurred in spring or summer. Seventy-three percent of children who died due to agricultural machinery participated in farm work; though not statistically significant, farm work was associated with agricultural machinery mortality (OR=2.48; 95% CI=0.66, 9.33). To examine whether young children working on the farm were at increased risk of agricultural machinery mortality, we analyzed separately the subset of 11,905 children who were ≤ 14 years at enrollment. In analysis of this subset, working on the farm under age 14 years was associated with agricultural injury mortality (OR=3.92; 95% CI=1.04, 14.78). A minority of children who died due to agricultural machinery injury were male (36%; $p>0.05$ by Fisher-exact test); a majority (54%) were from families with ≥ 4 children.

DISCUSSION

In the Agricultural Health Study, consistent with previous studies of mortality among farm children²⁻⁴, agricultural machinery injuries remain a major preventable cause of childhood death. In Iowa AHS children, agricultural machinery injuries accounted for 7% of all deaths between 1975 and 1998. While the elevated SMR for agricultural injury mortality certainly reflects the higher exposure opportunity of these farm children relative to children in the general population, it also indicates that agricultural machinery mortality is a substantial cause of excess preventable deaths among children. We did not expect a similar excess in North Carolina, since the reference data indicated that no agricultural machinery-related deaths would be expected in this smaller sample, and one was not detected.

Though we identified a specific excess in agricultural machinery-related mortality in Iowa, we did not detect a significant increase in overall unintentional injury mortality in this cohort of farm children. This may reflect exposure opportunities, since only farm children are likely to be exposed to the hazards of agricultural machinery, whereas children in non-farm settings may be exposed to different hazards that result in injury mortality.

We did not detect excess overall mortality in this sample; in fact, mortality from all causes and ages combined was lower than expected. Age-specific analyses revealed that this finding of lower than expected mortality was limited to children under age one year, who comprised approximately half of all deaths. Mortality rates among children over one year of age were similar to those in the general population. In this study, deaths were ascertained by linking the names of live-born children enumerated by the mother to state vital records. It is possible that some mothers failed to enumerate children who died in the first year of life, which would lead to under-ascertainment of deaths in the first year of life. The infant mortality rate could also be truly lower than the general population's rate, perhaps due to healthy perinatal lifestyles, and warrants further exploration as the cohort is followed in the future.

Children under 14 years who participated in farm work were at particularly increased risk for agricultural machinery-related fatality. These findings are consistent with a growing literature which has identified lack of developmental appropriateness of tasks performed by children on the farm as a risk factor for childhood farm injury⁴. Though our study does not provide insight into the specific nature of tasks performed by children, children's farm tasks have been characterized previously^{18,28}. Tractor operation has been reported among children under age 12²⁹, who are unlikely to have the necessary maturity and developmental skills to perform these tasks safely. The elevated risk of agricultural machinery-related mortality for younger children working on farms in the AHS underscores the continued need to assist farm families in determining appropriate child participation in farm work.

We found that younger maternal age at the time of the child's birth and having more than 2 children in the family were independently associated with greater childhood injury mortality. These findings are consistent with previous analyses of risk factors for injury in general, non-farm populations, in which child injury mortality has similarly been associated with young maternal age and higher number of children^{20,21}. Young parents, especially adolescents, may have less knowledge about child development³⁰, which is associated with the assignment of age-appropriate tasks to children³¹, and may affect children's risk for injury. Both younger maternal age and higher number of children could also hamper parents' supervisory capability. Lack of close parent supervision has been previously associated with farm injury among children¹⁷ and has been associated with increased childhood injury mortality in a sample of non-farm children³². Factors related to supervision could play a role in agricultural machinery deaths: most occurred in spring or summer, which have been noted by others to be times of increased frequency of injury and mortality due to the intensity of farming activity^{14,33}, and

are times when children may not be in school and parents may have limited ability to supervise them. Over half of the children who died due to agricultural injury mortality were between 5 and 9 years old, suggesting that injury prevention efforts may need to be targeted at this age group. The lack of agricultural injury mortality between ages 15 and 19 and the predominance of females among agricultural machinery deaths were unexpected but the number of deaths was small and these findings may have occurred by chance. Given our small sample size, we are unable to evaluate this further.

Though others have described fatalities among farm children due to drowning^{3,5}, falls^{2,6,7}, animals⁴, and electricity⁴, we did not identify excess mortality due to these or other causes. Small numbers of observed and expected deaths due to some of these causes may have limited our ability to detect differences, and especially limited evaluation of mortality in North Carolina. It is also possible that we under-ascertained some of these causes of death since they were obtained from death certificate data. In a previous study examining the accuracy of death certificates in determining cause of death among children, 13% of death certificates were inaccurate when compared with a comprehensive examination of circumstances of death by a child fatality task force³⁴. It is also possible that the composition of the AHS cohort affected the causes of childhood death that we observed. While we enrolled 82% of the licensed private pesticide applicators in NC and IA, farmers in the AHS are generally younger and have larger farms compared with the general farm population in NC and IA³⁵. Consequently, our findings may not be readily generalizable to farms not included in the AHS, including small and organic farms.

We did not observe relationships between children's risk for injury-related mortality and parent characteristics, such as father's own history of injury, parental alcohol consumption, and frequency of specific farming tasks performed by the father or farm characteristics, such as farm product type and farm size. Since we used parental self-report via questionnaires to assess parents' behavior and farming practices, there could be recall inaccuracies. Additionally, parents were asked to report on their behaviors and practices based on the year prior to questionnaire completion. We do not have information about how their practices or behaviors may have differed in previous years, when many of their children were younger. Further, the deaths that we identified spanned a wide range of time, from 1975 to 1998. Farming practices do change; consequently, mortality risk factors identified among children during this time period may be less pertinent to children currently residing on farms. The findings of excess mortality related to agricultural machinery, and young maternal age and greater family size as injury-related mortality risk factors, provide useful information for targeting interventions to protect the health and promote the survival of today's farm children.

To protect children from farm-related fatal injuries, many resources are available to farm families. The North American Guidelines for Children's Agricultural Tasks provides guidance to families in determining appropriate farming tasks for children³⁶, and the American Academy of Pediatrics has recognized the value of these guidelines in educating parents about child development and assignment of farm work³⁷. Though rigorous evidence supporting the effectiveness of other programs is lacking at this time, farm safety camps and school programs have shown some promise in educating children and their families about injury prevention³⁸. Our results underscore the continued need to pursue childhood injury prevention on farms through further dissemination of the North American Guidelines for Children's Agricultural Tasks and through educational resources and programs such as those available through Farm Safety 4 Just Kids³⁹. Though decreasing in numbers and constantly changing, American farms remain a source of residence and livelihood for many families, and play a critical role in food production. Farm parents value involving children in farm work and frequently want their children to gain farming experience⁴⁰. Farm families continue to need support to effectively balance the demands of raising and supervising children, completing

farming tasks, and exposing children to the benefits of participating in farming, while protecting children from fatal injuries.

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Abbreviations

AHS	Agricultural Health Study
CI	Confidence interval
SMR	Standardized mortality ratio
OR	Odds ratio

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Table 1

Characteristics of Children of Agricultural Health Study Participants At Enrollment in 1993–1997 (N=21,360)

	North Carolina (N=4,018)	Iowa (N=17,342)
<i>Child characteristics</i>	%*	%*
Child's age at paternal enrollment (years)		
0–4	15	16
5–9	21	23
10–14	27	28
15–19	37	33
Male	52	52
White	90	96
Child worked on farm [†]		
Yes	41	50
No	47	44
Did not live on farm	10	5
<i>Parent/family characteristics</i>		
Maternal age at child's birth		
<25	22	21
≥25, <28	28	28
≥28, <32	22	24
≥32	29	28
Maternal education		
≤High school grad	39	34
>High school	61	66
Paternal education		
≤High school grad	48	47
>High school	53	53
Maternal alcohol consumption		
None	64	25
≤3 times/month	28	61
≥1 time/week	8	14
Paternal alcohol consumption		
None	48	17
≤3 times/month	30	43
≥1 time/week	22	41
Paternal history of agricultural machine injury [‡]	18	30
Paternal history of head injury [‡]	11	15
Number of children in family		
≤2	65	35
>2	35	65
<i>Farm characteristics</i>		

	North Carolina (N=4,018)	Iowa (N=17,342)
<i>Child characteristics</i>	% [*]	% [*]
Major farm products ^δ		
Beef	26	45
Hogs	10	55
Alfalfa	3	35
Corn	40	91
Hay	24	39
Oats	8	31
Soybeans	43	83
Farm size (acres)		
<200	46	15
≥200	41	81

* Percent totals may be <100 due to missing data

[†] Mothers reported whether or not child worked on farm (yes/no); specific tasks performed by children were not reported

[‡] Total N=14408 for these responses as a subset of farmers answered questionnaires inquiring about these injuries

^δ Percent totals exceed 100 since farms reported multiple products

Table 2

Total, Age-Specific, and Selected Cause-Specific Standardized Mortality Ratios (SMR) for 21,360 Children of Participants in the Agricultural Health Study (1975–1998)

	North Carolina [*] (N=4018)		Iowa [*] (N=17,342)	
	No.	SMR [†] (95% CI)	No.	SMR [†] (95% CI)
Total deaths	26	0.42 (0.28, 0.61)	162	0.69 (0.60, 0.81)
Age at death				
<1 year	11	0.26 (0.15, 0.47)	81	0.51 (0.41, 0.64)
1–4 years	5	0.69 (0.29, 1.65)	25	0.84 (0.57, 1.25)
5–9 years	<3 ^δ	0.26 (0.04, 1.88)	18	1.25 (0.79, 1.99)
10–14 years	<3	0.60 (0.15, 2.41)	13	1.12 (0.65, 1.93)
15–19 years	7	1.12 (0.53, 2.35)	25	1.25 (0.85, 1.85)
Cause of death				
<i>Congenital anomalies</i>	<3	0.19 (0.05, 0.74)	35	0.76 (0.55, 1.06)
<i>Malignancy</i>	<3	0.57 (0.08, 4.02)	13	1.21 (0.65, 2.25)
<i>Heart disease</i>	3	2.08 (0.67, 6.43)	3	0.59 (0.19, 1.83)
<i>All intentional injury</i>	<3	0.86 (0.21, 3.42)	3	0.42 (0.14, 1.30)
Suicide	<3	0.89 (0.13, 6.32)	3	0.72 (0.23, 2.22)
<i>All unintentional injury</i> [‡]	6	0.55 (0.25, 1.22)	48	1.23 (0.93, 1.63)
Motor vehicle	4	0.64 (0.24, 1.69)	25	1.23 (0.83, 1.82)
Drowning	0	0	3	0.69 (0.22, 2.14)
Agricultural machinery	0	0	11	9.25 (5.12, 16.70)
Pedal cyclist	0	0	3	1.78 (0.58, 5.53)
Pedestrian, other	0	0	3	1.78 (0.58, 5.53)
Suffocation	<3	1.88 (0.26, 13.35)	<3	0.66 (0.16, 2.63)

^{*} SMRs adjusted for sex and calendar year. SMRs for North Carolina are also adjusted for race (black/white); SMRs for Iowa are presented for whites only due to small numbers of nonwhites in AHS and reference populations.

[†] Individual state data (North Carolina and Iowa) were used as reference standards for calculation of each SMR

[‡] Motor vehicle, drowning, agricultural machinery, pedal cyclist, pedestrian, and suffocation mortality are subsets of “All unintentional injury”. Other specific causes of unintentional injury are not shown due to small numbers (<2 deaths)

^δ Exact number not displayed to limit individual identifiability

Table 3

Relationship of Child, Family, and Farm Characteristics to Injury Mortality In 21,360 Children of Agricultural Health Study Participants

	No. exposed	Exposed cases	OR* (95% CI)
<i>Child characteristics</i>			
Male	11107	29	1.09 (0.64, 1.86)
Child worked on farm	10225	38	1.58 (0.95, 2.61)
<i>Parent/family characteristics</i>			
Mother's age at child's birth (years)			
<25	4473	27	2.03 (0.98, 4.19)
≥25, <28	5015	12	1.24 (0.55, 2.79)
≥28, <32	5892	14	0.91 (0.39, 2.11)
≥32	4473	10	Referent
Maternal education			
≤High school grad	6323	23	1.36 (0.82, 2.28)
>High school	14974	40	Referent
Paternal education			
≤High school grad	9643	28	0.97 (0.59, 1.60)
>High school	11717	35	Referent
Maternal alcohol consumption			
None	6584	18	Referent
≤3 times/month	11198	36	1.18 (0.67, 2.07)
≥1 time/week	2547	5	0.72 (0.27, 1.93)
Paternal alcohol consumption			
None	4655	15	Referent
≤3 times/month	8355	28	1.04 (0.56, 1.95)
≥1 time/week	7664	20	0.81 (0.41, 1.58)
Paternal history of agricultural machine injury [‡]	3914	12	1.00(0.52, 1.95)
Paternal history of head injury [‡]	1973	8	1.40 (0.65, 3.02)
Number of children in family			
≤2	8597	12	Referent
>2	12700	51	2.71 (1.43, 5.15)
<i>Farm characteristics</i>			
Farm products [§]			
Beef	8856	32	1.38 (0.84, 2.27)
Hogs	9973	32	1.03 (0.61, 1.72)
Alfalfa	6125	21	1.11 (0.65, 1.91)
Corn	17504	56	1.41 (0.59, 3.40)
Hay	7664	16	0.58 (0.33, 1.03)
Oats	5719	14	0.71 (0.39, 1.29)
Soybeans	16182	55	1.96 (0.90, 4.27)

	No. exposed	Exposed cases	OR* (95% CI)
Farm size (acres)			
<200	4580	9	Referent
≥200	15464	53	1.57 (0.74, 3.32)

* OR adjusted for state

δ Referent group for each product consists of farms where that product is not produced

$\neq$ Total N=14408 for these responses as a subset of farmers answered questionnaires inquiring about these injuries

Table 4

Multivariate Model of Factors Associated With Injury Mortality Among 19,781* Children of Participants in the Agricultural Health Study (1975–1998)

Factor	OR [†]	95% CI
Mother's age at child's birth (years)		
<25	2.17	1.05, 4.49
≥28	1.34	0.59, 3.02
≥28, <32	0.96	0.41, 2.21
≥32	Referent	
Number of children in family		
≤2	Referent	
>2	2.79	1.47, 5.30

* Estimates are based on model which does not include all 21,360 children due to missing values for some responses

[†] OR adjusted for above factors and for state (North Carolina or Iowa)

Table 5

Characteristics of 11 Iowa Agricultural Machinery-Related Deaths Among Children of Participants in the Agricultural Health Study, 1975–1998

Age at death (years)	No.	Percent (%)
1–4	3	27
5–9	6	55
10–14	2	18
Child worked on farm	8	73
Season of death		
Summer (Jun–Aug)	4	36
Autumn (Sep–Nov)	0	
Winter (Dec–Feb)	1	9
Spring (Mar–May)	6	55
Male	4	36
Farm size (acres)		
<199	1	9
≥200	10	91
Farm products*		
Beef cattle	7	64
Hogs	8	73
Corn	10	91
Soybeans	10	91
Number of children in family		
1–2	3	27
>2	8	73
Year of death		
1980–1984	3	27
1985–1989	3	27
1990–1996	5	45

* Percent totals exceed 100 since farms reported multiple products