

Agricultural Injuries Among Operation Household Members: RRIS-II 1999

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ABSTRACT *The purpose of this study was to determine the magnitude and consequences of agricultural injuries, and to reveal potential risk factors among agricultural household members. The Regional Rural Injury Study (RRIS-II) collected injury and exposure data on agricultural households of 16,538 people in Minnesota, Wisconsin, North Dakota, South Dakota, and Nebraska for each six-month period of 1999. Adjusted injury rates, consequences, and potential risk factors were identified through analyses. Selection of variables for multivariate analyses was based on a causal model. Injuries reported here occurred while the individuals were involved in activities associated with their own farm or ranch, unless otherwise stated. Estimates of injury rates and the effects of various exposures were derived by Poisson and logistic regression. These models accounted for correlation within both subject and household, and were adjusted for non-response. The rate of agricultural injury to household members on their own operation was 74.5 injuries per 1,000 persons per year. Differences in rates due to age and gender diminished when rates were calculated according to hours worked. Although only 5% of injured persons required in-patient hospitalization, 28% required emergency department treatment, and 84% required some type of professional health care. Moreover, 47% of all injuries required time off from agricultural work, and 7% required time off from non-agricultural work. In multivariate analyses, decreased risks were associated with Minnesota, and increased risks were identified for those with prior injuries and for males. This study provides a basis for further research on agricultural injuries and their prevention.*

Keywords. *Agricultural operation household injuries, Agriculture, Injury consequences, Restricted activity.*

Agriculture is considered one of the most dangerous occupations due to its high occupational fatality rate. Based on national data for 2005, it accounted for 31.6 deaths per 100,000 workers, compared with 3.2 deaths for all occupations

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combined (NSC, 2007, p. 48). Rates for nonfatal agricultural injuries are more difficult to obtain due to the lack of population-based data. Existing data also suggest a nonfatal injury problem among agricultural residents (Aherin and Riessenberg, 1978; Gerberich et al., 1991; Gerberich et al., 1993; Gerberich et al., 2001; Gerberich et al., 2002; Rivara, 1997; Stallones, 1990). In 2005, an estimated 80,000 disabling injuries occurred in agricultural work, accounting for a rate of 3,700 injuries per 100,000 workers, a rate 44% higher than all occupations combined (NSC, 2007, p. 48). However, it should be noted that there have been discrepancies among the various data systems (Pollack and Keimig, 1987) and reporting limitations for agriculture, all of which present challenges for accurate estimation of injury rates.

Agricultural injury rates vary by gender. Across studies, males of all ages sustain more fatal and nonfatal agricultural injuries than females (Cogbill et al., 1991; Gerberich et al., 1991; Gerberich et al., 1993; Stallones, 1990; Gerberich et al., 2002; Pickett et al., 1999; Pratt et al., 1992; Stueland et al., 1991). This gender effect appears to result simply from differences in exposure; when calculated by hours worked, injury rates for males and females are comparable (Gerberich et al., 1991; Gerberich et al., 1993; Gerberich et al., 2001; Gerberich et al., 2002). However, the possibility of confounding of gender and specific types of exposure remains (Ryan et al., 2004). More recently, findings from the national Childhood Agricultural Injury Survey (CAIS) indicated that rates of injury among females <20 years of age increased between 1998 and 2001 (Hendricks et al., 2005). Although these findings suggested increased exposure to agricultural tasks among young females, exposure time data were not available for comparison.

Agricultural injury rates also vary with age. Children generally have a lower rate among persons at risk (Gerberich et al., 1991; Gerberich et al., 1993; Gerberich et al., 2001; Gerberich et al., 2002; Nordstrom et al., 1995; Pratt et al., 1992; Rasmussen et al., 2000). Conversely, per hour exposed, children have been found to have an injury rate at least as high as adults (Gerberich et al., 1991; Gerberich et al., 1993; Gerberich et al., 2001; Gerberich et al., 2002; Pratt et al., 1992; Rasmussen et al., 2000). However, as with gender, the same potential for confounding exists.

Agriculture differs from other occupations, with a plethora of possible injury sources due to the varied nature of the work according to equipment, structures, season, location, crop(s), or livestock. While animals have been identified as a major source of nonfatal injury (Boyle et al., 1997; Cogbill and Busch, 1985; Cogbill et al., 1991; Gerberich et al., 1991; Gerberich et al., 1993; Gerberich et al., 2001; Gerberich et al., 2002; Nordstrom et al., 1995; Rasmussen et al., 2000; Stueland et al., 1991), fatal events have been associated, primarily, with tractors and machinery (Myers and Hard, 1995; Rivara, 1997). From a 1991-1995 study of agricultural fatalities in Canada, it was reported that tractor rollovers were the leading cause of fatal injury in adults (Pickett et al., 1999).

To date, there have been disparate sources of data available to examine the fatal and nonfatal injury problem among agricultural operation household members. Definitions and methods have varied greatly, thus limiting pertinent comparisons. The purpose of this study was to examine systematically the magnitude, consequences, and potential risk factors for injuries among a representative sample of agricultural households with children in a five-state region of the U.S. While prior studies have examined some of the elements that we present in this article, the current effort represents a large-scale, population-based study that examined incidence, outcomes, and risk factors for agricultural injury among farm and ranch household members of all ages. We feel this comprehensive effort adds to the literature on agricultural injuries due to its size, complexity, and prospective design, its inclusion of both adults and children, and the effort to account for hours of work exposure in the estimation of injury rates and risk ratios.

Methods

Data for this study were derived from the 1999 Regional Rural Injury Study II (RRIS-II) (Gerberich et al., 2002). The study was approved by the Institutional Review Board, Human Subjects Committee, for the University of Minnesota.

Study Population

A random, stratified sample of 3,200 farms/ranches was drawn from each state in the five-state region of Minnesota, Wisconsin, North Dakota, South Dakota, and Nebraska, from agricultural operations identified in the USDA National Agricultural Statistics Service's (NASS) Master List-frame (total = 16,000 operations). These five states represent several major types of agricultural production in the U.S. and include the lead producers of crops, beef and dairy cattle, and poultry. Each selected operation was mailed introductory letters from the respective state agricultural statistics offices and from the investigators; these letters described the study, included information pertinent to informed consent, and invited participation. Follow-up telephone interviews were then conducted by NASS-trained interviewers. These interviews established participant eligibility and obtained informed consent. To be considered eligible for the study, each operation must have adhered to the following criteria: (1) produced or had annual sales of agricultural goods of \$1,000 or more, or participation in a Conservation Reserve Program (CRP); (2) actively farming/ranching as of 1 January 1999 or had land in a CRP that they maintained; and (3) had a household including children 19 years of age or younger as of 1 January 1999. Finally, eligible and enrolled households were mailed comprehensive packets that contained a letter describing the study's forthcoming interview schedule, as well as informational cards used to facilitate data collection. A similar packet was mailed prior to the second study interview. To encourage participation, all operations were eligible to enter a drawing that provided at least a one in 32 possibility of receiving a \$100 U.S. savings bond.

Definitions and Classifications

Data were collected for all injury events that occurred within the study period, and met one or more of the following criteria: (1) resulted in restriction of normal activities for at least four hours; (2) resulted in a loss of consciousness, loss of awareness, or amnesia for any length of time; and (3) required professional health care, administered by a doctor, nurse, dentist, chiropractor, or other healthcare professional. In this study, injuries resulting from any source/vehicle or activity related to an agricultural operation, including transportation on roadways or raising animals for recreational or home use, as well as any injury that took place as a result of standing or playing in areas where farming or ranching activities occurred, were designated as "agricultural" injuries; these were further categorized as being either associated with the individual's own operation or with another operation. Injuries not related to agricultural operation activities were designated as "non-agriculture-related" injuries. This report focuses primarily on agricultural injuries associated with the individual's own operation. As used here, the terms "injuries," "agricultural injuries," or "agriculture-related injuries" refer to this type, unless stated otherwise.

Interviews, conducted for each six-month period of 1999, were completed by NASS interviewers, using a computer-assisted telephone interview instrument that was developed by the RRIS-II research team. These interviews obtained information on personal demographic characteristics, incidence and consequences of relevant injury events, and some exposure information for all ages. Injuries were independently coded by two study staff, and disagreements were adjudicated by the principal investigator.

Data Analyses

Analyses began with basic descriptive statistics on the sample, the incidence and consequences of reported events, and estimates of injured person and injury event rates per 1,000 persons and per 100,000 hours worked, with 95% confidence intervals (CI). It should be noted that “bystander” injuries were included for the purpose of estimating injury rates per 100,000 hours worked. “Bystander” injuries occurred when the participant was not actively taking part in agricultural work but incurred an agriculture-related injury. All injury rates were adjusted for within-household correlation using generalized estimating equations (Liang and Zeger, 1986). Potential selection bias was controlled by weighting observed responses by inverse probabilities of response (Horvitz and Thompson, 1952). The probability of response was estimated as a function of characteristics available in the NASS Master List–frame, which included state of operation, type of operation, and quintile of annual revenue. To account for unknown eligibility among non-respondents, probability of eligibility was estimated by these same characteristics (Mongin, 2001). These estimates were used to proportionately down-weight the complete non-respondents.

Odds ratios and confidence intervals were estimated for sociodemographic and exposure variables using logistic regression. A causal model (fig. 1) was developed to examine the relation between demographic factors and pertinent exposures and agricultural injuries. These factors and exposures included gender, age, race, marital status, education, state of residence, prior agricultural injury, and hours worked. Directed acyclic graphs, based on the causal model, were used to select potential confounders for logistic regression, following the methods described by Greenland and Robins (1999).

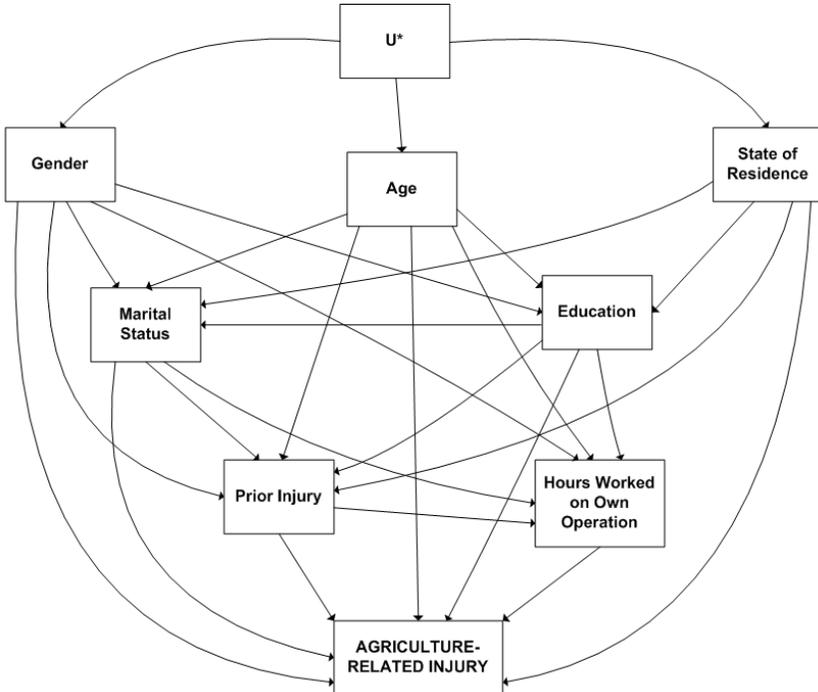


Figure 1. Causal model for agricultural injuries, RRIS-II 1999 (*U = unidentified association between variables).

Results

Of the 16,000 sampled agricultural operations, 4,389 were verified as eligible. Of these, 3,765 (85.8%) operations agreed to participate. Through the screening process, 8,288 (51.8%) were found to be ineligible, based on the participation screening criteria. Overall, there was a refusal/non-response rate of 24.7% of the original sample; this included 624 (3.9%) of the verified eligible operations and 3,268 (20.4%) operations that refused participation during the screening process, preventing verification of eligibility.

Injury Rates

We estimated injury rates, per 1,000 persons per year, for youths and adults combined, for each of three general classes (table 1). For persons at work on their own agricultural operations, the rate was 74.5; work on operations other than their own yielded 4.3. The rate for non-agricultural activities was 81.6. Combining these three classes, the overall injury rate estimate was 160.7. The degree of within-household correlation varies across such classes, as well as the level of non-response. To accommodate this variation, separate estimation procedures provided constituent rates that did not sum precisely to the overall. The estimates are shown with 95% confidence intervals in table 1. Subsequent results focus mainly on the general class of agricultural injuries associated with persons at work on their own operation.

Among the states (table 2), South Dakota had the highest rates of injury, whether counted per year (90.3) or per 100,000 hours (8.7), while Minnesota was lowest by both measures (53.3 and 5.9, respectively). Among the other three states, comparing annual and hourly rates, Wisconsin dropped from highest to lowest. Males had higher injury rates than females (from table 1, 110.9 vs. 36.2, respectively). This gap was smaller among youths (males and females, 36.8 and 18.7, respectively), and by hours worked (table 2), the difference changed direction, but with substantial overlap (males and females, 7.1 and 7.5 injury events per 100,000 hours worked, respectively).

Analysis according to age, with 1,000 persons as the denominator (table 2), indicated higher rates in adults than youths (123.2 and 28.0 injury events per 1,000 persons, respectively). By hours worked, there was again no apparent difference; the rounded point estimates were both 7.2. However, rates for children, compared with adults, were elevated for those aged 0-4, 5-9, and 10-14 years (49.5, 12.3, and 8.5, respectively).

Analysis by race showed that Caucasians (74.6) compared with non-Caucasians (51.9) experienced higher rates of injury for all injury categories; however, there were very few non-Caucasian participants (table 2). Based on a denominator of 100,000 hours worked, the rates were similar (7.2 and 7.3, respectively).

Analysis by educational status, with 1,000 persons as the denominator (table 2), found that high school graduates had the highest injury rate (140.4). Rate differences were smaller according to hours worked. By marital status, injury rates were highest in the "separated/divorced" group (table 2). By hours worked, the "widowed" group was highest (17.0), but the dearth of such individuals produces a wide confidence interval for this rate.

Table 1. Injury rates by general classification, per 1,000 persons per year, among 16,538 agricultural household members from the entire five-state region, RRIS-II 1999.

General Injury Classification	Number	Annual Rate (95% CI)
Agricultural, on their own operation	1214	74.5 (69.6, 79.8)
Agricultural, not on their own operation	69	4.3 (3.4, 5.6)
Non-agricultural	1300	81.6 (76.4, 87.1)
Total	2583	160.7 (153.1, 168.7)

Table 2. Agricultural injury counts and estimated rates, per year and per 100,000 reported hours worked, by demographic features and exposures, RRIS-II 1999.

Demographic Feature or Exposure	Annual Injury Rate, per 1000 Persons		Injury Rate per 100,000 Hours of Work	
	No. Injuries (No. Persons)	Estimate (95% CI)	No. Injuries (No. Persons)	Estimate (95% CI)
State of residence				
Minnesota	172 (3178)	53.3 (44.4, 63.9)	171 (3176)	5.9 (4.9, 7.0)
Nebraska	249 (3381)	73.5 (63.8, 84.7)	249 (3380)	7.1 (6.2, 8.2)
North Dakota	261 (3498)	76.7 (66.2, 89.0)	257 (3493)	7.4 (6.3, 8.5)
South Dakota	307 (3528)	90.3 (78.5, 103.8)	307 (3528)	8.7 (7.6, 10.0)
Wisconsin	225 (2953)	78.1 (66.3, 92.0)	223 (2950)	6.7 (5.7, 7.9)
Males				
Age 0-19	153 (4411)	36.8 (30.5, 44.5)	150 (4408)	6.8 (5.6, 8.3)
Age 20+	775 (4124)	188.9 (174.0, 205.1)	772 (4120)	7.2 (6.6, 7.8)
All ages	928 (8540)	110.9 (102.7, 119.7)	922 (8533)	7.1 (6.6, 7.7)
Females				
Age 0-19	74 (4077)	18.7 (14.6, 23.8)	74 (4077)	8.3 (6.5, 10.6)
Age 20+	212 (3917)	54.4 (46.7, 63.2)	211 (3913)	7.3 (6.3, 8.5)
All ages	286 (7998)	36.2 (31.7, 41.3)	285 (7994)	7.5 (6.6, 8.6)
Age groups (years)				
0-19	227 (8488)	28.0 (24.1, 32.6)	224 (8485)	7.2 (6.2, 8.4)
20+	987 (8041)	123.2 (114.4, 132.8)	983 (8033)	7.2 (6.7, 7.8)
0-4	14 (1108)	12.1 (7.0, 20.7)	14 (1108)	49.5 (28.3, 86.6)
5-9	36 (1917)	19.4 (13.6, 27.6)	36 (1917)	12.3 (8.7, 17.6)
10-14	102 (2644)	40.6 (32.5, 50.8)	101 (2644)	8.5 (6.8, 10.7)
15-19	75 (2819)	28.8 (22.8, 36.5)	73 (2816)	4.6 (3.6, 5.9)
20-24	20 (553)	39.0 (25.0, 60.8)	20 (553)	5.7 (3.7, 8.7)
25-34	120 (1059)	110.9 (90.8, 135.4)	120 (1059)	7.4 (6.1, 9.0)
35-44	507 (3721)	136.0 (122.5, 150.9)	504 (3717)	7.7 (6.9, 8.5)
45-54	276 (2277)	120.6 (104.7, 139.0)	276 (2274)	6.4 (5.6, 7.4)
55-64	53 (353)	157.7 (118.6, 209.6)	52 (353)	7.6 (5.6, 10.2)
65+	11 (78)	150.0 (75.8, 297.0)	11 (77)	9.2 (4.2, 20.3)
Race				
Caucasian	1201 (16347)	74.6 (69.6, 79.9)	1194 (16337)	7.2 (6.7, 7.7)
Non-Caucasian	9 (172)	51.9 (26.8, 100.6)	9 (171)	7.3 (3.7, 14.4)
Educational status (age 20+)				
Less than high school graduate	26 (266)	98.8 (63.0, 155.0)	26 (266)	5.0 (3.2, 7.7)
High school graduate or equivalency	451 (3222)	140.4 (125.8, 156.6)	451 (3218)	7.0 (6.3, 7.8)
Technical school or some college	333 (2897)	117.2 (103.3, 132.9)	329 (2896)	7.5 (6.6, 8.4)
College graduate or post-graduate	177 (1652)	104.6 (87.9, 124.5)	177 (1649)	7.8 (6.6, 9.2)

(continued)

Table 2 (cont'd). Agricultural injury counts and estimated rates, per year and per 100,000 reported hours worked, by demographic features and exposures, RRIS-II 1999.

Demographic Feature or Exposure	Annual Injury Rate, per 1000 Persons		Injury Rate per 100,000 Hours of Work	
	No. Injuries (No. Persons)	Estimate (95% CI)	No. Injuries (No. Persons)	Estimate (95% CI)
Marital status (age 16+ only)				
Married/living as married	926 (7255)	127.3 (118.0, 137.4)	922 (7248)	7.2 (6.6, 7.7)
Never married	91 (2770)	34.6 (27.7, 43.2)	89 (2767)	5.4 (4.3, 6.7)
Separate/divorced	26 (144)	183.0 (99.7, 335.7)	26 (144)	8.8 (4.9, 15.9)
Widowed	7 (43)	166.2 (58.8, 470.1)	7 (42)	17.0 (6.5, 44.1)
Weekly average hours worked				
<1	16 (2765)	6.0 (3.8, 9.6)	16 (2765)	574.2 (355.0, 928.8)
1-20	279 (7715)	36.5 (31.7, 42.0)	279 (7715)	10.4 (9.0, 11.9)
21-40	210 (2287)	91.3 (78.5, 106.0)	210 (2287)	6.6 (5.7, 7.7)
41-60	254 (1446)	175.8 (152.6, 202.5)	254 (1446)	6.9 (6.0, 7.9)
61-80	289 (1290)	223.2 (195.3, 255.1)	289 (1290)	6.2 (5.4, 7.1)
>80	131 (481)	282.9 (230.9, 346.5)	131 (481)	6.1 (5.0, 7.5)
Incidence of prior injury				
No prior injury	570 (13387)	43.3 (39.4, 47.4)	565 (13377)	5.3 (4.9, 5.9)
Prior injury	643 (3144)	205.5 (187.2, 225.5)	641 (3143)	10.4 (9.4, 11.4)

Annual injury rates increased with weekly average hours worked (table 2), but decreased on a per-hour basis. History of prior injury was associated with significantly higher rates by both measures, annual and hourly, with relative rates of 4.7 and 1.9, respectively, compared with no prior injury.

Source/Vehicle, Activities, and Body Parts Associated with Injury

The leading sources associated with injuries were animals (34%), followed by falls/surfaces (24%), and large machinery/equipment (18%) (table 3). Animals (41%) were also the leading source/vehicle for agriculture-related injuries on other operations. Primary activities associated with these injuries included: herding/moving animals (8%), mounting/dismounting (mostly machinery or vehicles, rarely animals, 7%), and general repairs (7%). Riding animals (9%) was the leading activity associated with agriculture-related injury on other operations. Primary activities associated with non-agricultural injuries included basketball (13%), football (11%), and general play (6%).

The primary anatomical sites and types of injuries were the back (21%) and sprains/strains (34%). Those injuries incurred on other operations included the back (17%) and bruises/contusions (39%) and, for non-agriculture-related injuries, the arm/elbow/wrist (14%) and sprains/strains (39%) were the primary sites.

Injury Consequences

In table 4, various measures of severity are presented. There were two injury-related deaths identified in this population, accounting for 0.1% of the combined total reported injuries. Both of these fatalities were classified as falls, and one was associated with the individual's agricultural operation activity. Although hospitalization was required in only 4.3% of the combined total injuries, 81.9% required some kind of professional medical care. In-patient hospitalization was reported as the primary location for treatment in only 1.8% of injuries. However, when including secondary or later treatment, over 5.0% of the injured individuals reported in-patient hospitalization.

Table 3. Associated vehicle or source of injury, RRIS-II 1999.

Associated Vehicle or Source	Agricultural Injury on Own Operation	
	Number ^[a]	% ^[b]
Tractor	146	12.2
Motor vehicle	72	6.0
Large machinery/equipment	211	17.6
Small power equipment/hand tools	140	11.7
Livestock/animals	404	33.7
Storage structures	67	5.6
Chemicals/drugs/medications	23	1.9
Body of water	0	0
Falls/surfaces	286	23.9
Sports/recreation	1	0.1
Housework/household	0	0
Yardwork/gardening	13	1.1
Other	131	10.9
General activity	132	11.0

[a] Out of 1,198 injuries, up to two vehicles or sources may be associated with each injury.

[b] Proportion of the 1,198 injuries associated with the given vehicle or source. Due to the allowance for up to two sources for each injury, the total of the percents exceeds 100.

Table 4. Injury severity measures for 1,214 agricultural injuries, RRIS-II 1999.^[a]

Severity Measure	Response Categories	Agricultural Injury on Own Operation	
		Number	%
Hospitalization required for injury?	No	1161	95.7
	Yes	52	4.3
Primary location for injury treatment	None	220	18.1
	Physician office	390	32.2
	Hospital emergency department	246	20.3
	In-patient hospital	22	1.8
	Dentist office	16	1.3
	Chiropractor	274	22.6
	At injury scene	22	1.8
	Other health care facility	23	1.9
Time of restricted activity	None	201	16.6
	>0 to <4 hours	120	9.9
	4 hours to < 1 day	169	14.0
	1 day to <7 days	380	31.4
	7 days to <14 days	108	8.9
	14 days to <1 month	105	8.7
	1 month to <3 months	84	6.9
3 months or more	43	3.6	
Deceased		1	0.1
Lost agricultural work time	No	647	53.4
	Yes	564	46.6
Lost other work time	No	1128	93.1
	Yes	83	6.9
Amount of other work time lost due to injury	None	1128	93.2

(continued)

Table 4 (cont'd). Injury severity measures for 1,214 agricultural injuries, RRIS-II 1999.^[a]

Severity Measure	Response Categories	Agricultural Injury on Own Operation	
	>0 to <4 hours	2	0.2
	4 hours to < 1 day	14	1.2
	1 day to <7 days	27	2.2
	7 days to <14 days	14	1.2
	14 days to <1 month	12	1.0
	1 month to <3 months	9	0.7
	3 months or more	4	0.3

[a] Total contributing counts may be slightly under 1,214 due to non-response for specific items.

In terms of proportions of injuries, physician offices (32%) and emergency departments (20%) were the primary locations utilized for treatment. Restricted activity was associated with 83% of the injuries, and 28% resulted in at least seven days of restricted activity. Moreover, 47% resulted in some amount of time lost from agricultural work, and 7% resulted in time lost from work outside of their own operation.

Multivariate Analyses

Results for the multivariate analyses are presented in table 5. Increased risks were identified for state of residence, gender, and prevalence of prior agricultural injury. Residence in Minnesota was associated with lower risk. Risk for males was three times that of females. By age group, those aged 0-4, 5-9, 10-14, 15-19, 20-24, and 45-54 were at decreased risk, compared to the referent group (35-44 years). Race and educational status were not found to be important factors. By marital status, a decreased personal risk was found for the never married group, compared with the married/living as married referent group. Analyzed by hours worked, those who worked 0, 1-20, 21-40, 41-60, or 61-80 hours per week, on their own operation, were at a lower risk, compared to the referent group (>80 hours). Those who had incurred a prior agricultural injury, compared with those who had no prior injury, had a personal risk 2.6 times greater.

Table 5. Multivariate analyses for agriculture-related injury incurred on their own operation, adjusted for variables according to causal model, RRIS-II 1999.

Demographic Characteristic or Variable	No. of Respondents	No. of Events	OR ^[a]	95% CI
State of residence (adjusted by age and gender)				
Minnesota	3118	149	1 (referent)	--
Nebraska	3332	219	1.43	(1.13, 1.82)
North Dakota	3378	221	1.44	(1.14, 1.83)
South Dakota	3483	252	1.65	(1.31, 2.08)
Wisconsin	2853	191	1.47	(1.15, 1.88)
Gender (adjusted for age and state of residence)				
Female	7808	257	1 (referent)	--
Male	8356	775	3.08	(2.66, 3.57)
Age group (in years, adjusted for gender and state of residence)				
0-4	1092	14	0.09	(0.05, 0.16)
5-9	1891	36	0.15	(0.10, 0.22)
10-14	2577	93	0.29	(0.23, 0.36)
15-19	2740	71	0.21	(0.16, 0.27)
20-24	543	19	0.27	(0.17, 0.43)

(continued)

Table 5 (cont'd). Multivariate analyses for agriculture-related injury incurred on their own operation, adjusted for variables according to causal model, RRIS-II 1999.

Demographic Characteristic or Variable	No. of Respondents	No. of Events	OR ^[a]	95% CI
Age group (cont'd) (in years, adjusted for gender and state of residence)				
25-34	1040	103	0.94	(0.74, 1.20)
35-44	3642	410	1 (referent)	--
45-54	2222	229	0.81	(0.67, 0.96)
55-64	345	49	1.12	(0.79, 1.60)
65+	72	8	0.86	(0.41, 1.80)
Race				
Caucasian	15998	1020	1.22	(0.61, 2.45)
Non-Caucasian	159	9	1 (referent)	--
Educational status (ages 20+ only) (adjusted for age, gender, and state)				
Less than high school graduate	253	22	0.79	(0.47, 1.33)
High school graduate or equivalency	3156	371	1.20	(0.98, 1.49)
Technical school or some college	2843	279	1.16	(0.93, 1.45)
College graduate or post-graduate	1608	146	1 (referent)	--
Marital status (includes those ages 16+ only) (adjusted for age, gender, educational status, and state of residence)				
Married/living as married	7098	771	1 (referent)	--
Never married	2701	84	0.44	(0.26, 0.72)
Separated/divorced	141	17	0.79	(0.46, 1.36)
Widowed	37	5	2.23	(0.80, 6.22)
Hours worked on operation (weekly average) (adjusted for age, gender, educational status, marital status, and prior injury status)				
0	2759	16	0.05	(0.03, 0.10)
1-20	7700	254	0.27	(0.20, 0.38)
21-40	2285	186	0.49	(0.37, 0.66)
41-60	1444	208	0.66	(0.50, 0.87)
61-80	1288	233	0.76	(0.58, 0.99)
>80	478	103	1 (referent)	--
Incidence of prior agriculture-related injury (adjusted for age, gender, educational status, marital status, and state)				
No prior injury	13052	523	1 (referent)	--
Prior injury	3094	507	2.55	(2.19, 2.97)

[a] Multivariate odds ratio of agricultural activity-related injury.

In table 6, the multivariate rate ratios are shown for agriculture-related injury incurred on their own operation per 100,000 hours worked. Compared with the respective referent groups, increased injury rates were identified for South Dakota residence; the 0-4 and 5-9 age groups; working a weekly average of 0, 1-20, and 21-40 hours; and for those who had experienced a prior agricultural injury. Decreased rates were found for the 15-19 year age group, those with less than a high school graduate education status, and those who had never been married. In contrast to the multivariate analysis with 1,000 persons as a denominator, this analysis did not find a gender effect. Consistent with the per 1,000 person multivariate analysis, no differences were found according to race.

Table 6. Multivariate analyses for agriculture-related injury incurred on their own operation per 100,000 hours worked, adjusted for variables as indicated to influence variable of interest per causal model, RRIS-II 1999.

Demographic Characteristic or Variable	No. of Respondents	No. of Events	OR ^[a]	95% CI
State of residence (adjusted by age and gender)				
Minnesota	3173	171	1 (referent)	--
Nebraska	3375	249	1.23	(0.98, 1.54)
North Dakota	3492	257	1.27	(1.00, 1.60)
South Dakota	3528	307	1.49	(1.19, 1.87)
Wisconsin	2950	223	1.14	(0.90, 1.46)
Gender (adjusted for age and state of residence)				
Female	7990	285	1 (referent)	--
Male	8528	922	0.94	(0.81, 1.09)
Age group (in years, adjusted for gender and state of residence)				
0-4	1108	14	6.40	(3.62, 11.30)
5-9	1917	36	1.60	(1.10, 2.32)
10-14	2644	101	1.11	(0.86, 1.42)
15-19	2816	73	0.60	(0.46, 0.78)
20-24	553	20	0.74	(0.48, 1.15)
25-34	1059	120	0.95	(0.77, 1.18)
35-44	3717	504	1 (referent)	--
45-54	2274	276	0.84	(0.70, 1.00)
55-64	353	52	1.0	(0.73, 1.37)
65+	77	11	1.23	(0.55, 2.74)
Race				
Caucasian	16337	1194	0.98	(0.50, 1.93)
Non-Caucasian	171	9	1 (referent)	--
Educational status (ages 20+ only) (adjusted for age, gender, and state of residence)				
Less than high school graduate	266	26	0.56	(0.34, 0.93)
High school graduate or equivalency	3218	451	0.90	(0.74, 1.11)
Technical school or some college	2896	329	0.95	(0.77, 1.18)
College graduate or post-graduate	1649	177	1 (referent)	--
Marital status (includes those ages 16+ only) (adjusted for age, gender, educational status, and state of residence)				
Married/living as married	7248	922	1 (referent)	--
Never married	2764	89	0.48	(0.29, 0.79)
Separated/divorced	144	26	1.25	(0.70, 2.25)
Widowed	42	7	1.81	(0.60, 5.49)
Hours worked on operation (weekly average) (adjusted for age, gender, educational status, marital status, and prior injury status)				
0	2760	16	142.40	(76.22, 266.01)
1-20	7702	278	2.77	(2.06, 3.72)
21-40	2287	210	1.48	(1.13, 1.94)
41-60	1444	253	1.21	(0.94, 1.54)
61-80	1289	289	1.01	(0.79, 1.28)
>80	478	131	1 (referent)	--
Incidence of prior agriculture-related injury (adjusted for age, gender, educational status, marital status, and state)				
No prior injury	13359	564	1 (referent)	--
Prior injury	3141	641	2.12	(1.84, 2.43)

[a] Multivariate odds ratio of agricultural activity-related injury per 100,000 hours worked.

Discussion

This study identified the magnitude and initial consequences of agricultural injuries, and potential risk factors for all members of agricultural households in a sample of Midwest operations. Prior to this time, limited population-based data pertinent to this problem have been available, particularly for children.

The results of this study should be interpreted with reference to certain limitations. There was a potential for information bias in the calculation of rates according to 100,000 hours worked due to the inclusion of “bystander” injuries in the numerator. While there was a potential upward bias in this injury rate calculation, it was important to include these rates in order to provide some understanding of differences in rates according to differences in the denominator, i.e., “persons at risk” versus “hours worked” (Ruser, 1998; Windau et al., 1999). Through future efforts, it will be important to address the amount of bystander exposure time that is associated with agricultural operation activities in order to more fully understand the risk of associated injuries.

Other potential information bias may result if there is a tendency of parents to understate the extent of injuries sustained by their children at work. Future studies may partially address this problem through validation sub-studies of injury endpoints involving hospitalization. Interviewer bias was minimized through use of a specially designed computer-assisted telephone interview instrument, which, in concert with rigorous training, limited interviewer improvisation. While there was a potential opportunity for recall bias, prior efforts and validation studies have found that a six-month recall period, as used in this study, maximizes the quality of reporting while also minimizing study cost (Gerberich et al., 1990; Gerberich et al., 1993; Gerberich et al., 2002; Braun et al., 1994).

Selection bias was diminished by randomly selecting farms from the USDA-NASS Master List-Frame; this was the most appropriate source for agricultural operation selection because it is updated and maintained on a regular basis and all states manage the list frame similarly. In addition, non-response posed a potential bias in this study, in that the characteristics of non-respondent operations may have been different from respondent operations. This potential bias was minimized, however, by adjusting all injury rates by the probabilities of response and eligibility, which were calculated using operation characteristics from the NASS Master List-Frame. Finally, to minimize confounding in the multiple logistic regression analyses, minimal sets of confounders were identified from directed acyclic graphs, based on the causal model (Greenland et al., 1999).

Despite differences in study definitions and design compared to prior studies, it should be noted that some results from the current study reflect those from previous efforts. For instance, males had a substantially higher rate of agriculture-related injury than females, which is consistent with reports from previous efforts (Gerberich et al., 1991; Gerberich et al., 1993; Gerberich et al., 2002; Myers and Hard, 1995; Nordstrom et al., 1995; Pickett et al., 2001). However, this gender difference disappeared when hours worked was used as the denominator. Thus, while males had a greater incidence of injuries, their risk for injury per hour worked is similar to that for females. In concert with recent findings showing increased rates of agricultural injury among females (Hendricks et al., 2005), the current results further emphasize the importance of exposure hours in estimating rates and rate ratios.

In addition, with persons at risk as the denominator, children, compared with adults, were found to have a lower rate of agriculture-related injury. However, when rates of agriculture-related injury were calculated according to 100,000 hours worked, these differences were greatly diminished, and the highest rates of injury were found in children aged nine years and under. Again, these findings are in accord with previous reports (Gerberich et al., 1993; Gerberich et al., 2002; Nordstrom et al., 1995). Thus, it is suggested

that children, especially young children, may be at greater risk for agriculture-related injury per unit time of exposure than adults. However, there is a potential for bias in these estimators due to the inability to collect accurate data, for either children or adults, on bystander activity during agricultural activities (Brison et al., 2006; Pickett et al., 2005). In the other direction, injuries to children may also be under-reported. Given these potential biases, these estimates must be viewed cautiously.

When calculated per 1,000 persons, those who worked a lower number of average weekly hours had the lowest risks of agriculture-related injury, and a dose-response relationship was evident across categories of increasing average weekly work hours. However, when the odds ratios were calculated according to 100,000 hours worked, those who worked less than an average of 40 hours per week had higher risks. One reason for this finding may be that farmer/ranchers who worked on their operation "part-time" (≤ 40 hours per week) had outside work and experienced a greater degree of stress and fatigue. Another explanation could be that the greater work experience and expertise associated with working more than an average of 40 hours per week acts as a protective factor against incurring an agriculture-related injury. From a previous study, it was also reported that increased work experience corresponded to a lower rate of nonfatal occupational injury (Oh and Shin, 2003). Experience, expertise, and fatigue as risk or protective factors for agriculture-related injury are areas for further investigation.

The current study also found that those who had experienced a prior agriculture-related injury were at much higher risk for incurring another agriculture-related injury, a finding similar to those from previous studies (Bancej and Arbuckle, 2000; McGwin et al., 2000; Zhou and Roseman, 1994; Elkington, 1990). This increased risk for subsequent injury may result from working and living in more hazardous environments and/or having less safety-consciousness. However, recall also may play a role, because individuals reporting a history of prior injury may be more likely to recall past injury experiences compared to those reporting no prior agriculture-related injury.

While there were no differences according to educational status when rates were calculated per person, rates calculated according to hours worked indicated that those with less than a high school education were found to have a significantly lower rate of injury compared to the college-educated referent group. This finding is in contrast to known trends of occupational injuries in general, where more highly educated workers sustain a lower nonfatal injury rate for a variety of reasons (McGwin et al., 2000).

Although little research has reported on the association between marital status and agricultural injury, the results from this study differ from prior reports on marital status and injury, in general. Prior studies have found that "never married" marital status is associated with a higher risk for fatal and nonfatal injury (Garvey-Wilson et al., 2003; Leff et al., 2003; Whitlock et al., 2004), whereas this study found the "never married" risk to be lower. This may be due to the design of RRIS-II, which restricted the sample to households with children, yielding more married adult operators than usual. Unmarried adults in this sample therefore tend to be older children, with possibly different exposures than the general population. Further analysis of marital status and agricultural injury may help identify some of the behavioral and/or environmental protective factors associated with never-married status.

Differences were also identified according to state of residence. With 1,000 persons as the denominator, all states were found to have a greater risk of agricultural injury compared to the Minnesota referent group. However, these differences were greatly diminished when hours worked was used as the denominator, with the exception of South Dakota, which retained a higher rate. Wisconsin had the highest annual rates, but the lowest hourly rate. This may be a result of more work hours on dairy operations. Further in-

vestigation may be warranted to reveal the possible risk and/or protective factors associated with agricultural operations among these states.

Animals and falls were the most frequently associated sources of agricultural injury. These findings are consistent with numerous studies (Boyle et al., 1997; Cogbill et al., 1991; Gerberich et al., 2001; Lee et al., 1996; Nordstrom et al., 1995; Paulson et al., 2006; Xiang et al., 2000) and further emphasize the importance of etiologic research and subsequent translation into interventions in order to address these relatively common events. Also of particular relevance was the frequency of back injuries in this population, which was not unexpected given that back pain is the most common type of claim identified in worker compensation data (Guo et al., 1999). The notable proportion of injuries treated by chiropractors in the current study was likely related to this, and bears interesting implications about possible ergonomic interventions as well as access to and use of health care in rural settings.

Especially important to consider are the consequences of the injuries identified. In terms of treatment, among the injured members of these households, 5% required inpatient hospitalization, 28% required emergency department treatment, and 84% required some type of professional health care intervention. These results indicate that hospital-based surveillance systems would be much less effective than population-based methods in measuring the magnitude and consequences of injury in this community because only a small percentage of important injuries are detected. Of further importance is that 47% of the agricultural injuries required time off from agricultural work and 7% required time off work outside of the operation. These results indicate that agricultural injuries lead to a substantial burden relevant to the use of healthcare resources as well as a major economic burden pertinent to lost work time. Despite indications that agricultural injuries have subsided in recent years (Hendricks et al., 2005), continuing research programs are warranted to design and evaluate appropriate intervention efforts for this burden.

Overall, this study of agricultural injuries incurred among agricultural operation household members serves as a basis for further, in-depth research of particular injuries incurred by this population group, including agricultural machinery-, animal-, and sports-related injuries (Kurszewski et al., 2006). Such research will be important to the development of appropriate intervention efforts.

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