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RESEARCH ARTICLE

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Injury risk factors to farm and ranch operators in the Central United States

Rohan Jadhav PhD,MPH[1] | Chandran Achutan PhD[2] | Gleb Haynatzki PhD[3] | Shireen Rajaram PhD[4] | Risto Rautiainen PhD,MS[2]

[1] Department of Public Health, California State University Fresno, Fresno, California

[2] Department of Environmental, Agricultural, and Occupational Health, University of Nebraska Medical Center, Omaha, Nebraska

[3] Department of Biostatistics, University of Nebraska Medical Center, Omaha, Nebraska

[4] Department of Health Promotion and Social and Behavioral Health, University of Nebraska Medical Center, Omaha, Nebraska

Correspondence
Rohan Jadhav, PhD, MPH, Department of Public Health, California State University Fresno, 2345, E San Ramon Ave, Fresno, CA 93740-8031, rjadhav@mail.fresnostate.edu

Background: This study focused on risk factors for serious injuries in farm and ranch operators in the central United States.

Methods: The Central States Center for Agricultural Safety and Health, in collaboration with the National Agricultural Statistics Service, sent mail surveys to 6953, 6912, and 6912 farms/ranches in 2011-2013, respectively, covering seven Midwestern states.

Results: The average survey response rate was 35%. The average annual incidence rate (injuries/100 workers) was 6.91 for all injuries and 2.40 for serious injuries. Univariate analyses determined several demographic and farm production-related risk factors for serious injury. Adjusted analysis showed a greater risk of serious injury for operators of age 45-54 years (vs. 65 and higher), those who worked 75-99% of their time (vs. less time), and those who operated larger land areas (vs. smaller).

Conclusion: The identified risk factors should be considered when targeting injury prevention programs.

KEYWORDS
agricultural injury, farm injury, injury risk factors, occupational injury on farm, serious farm injury

1 | INTRODUCTION

High rates of mortality and morbidity have been reported in agricultural workers in the past decades, particularly in the developed countries. According to the United States Bureau of Labor Statistics (BLS), agriculture had the highest rates of both fatal and non-fatal injuries in the United States in 2015. The incidence of fatal injuries was 22.8/100 000 full-time equivalent (FTE) workers, and the non-fatal injury rate was 5.7 injuries/100 FTE for hired farm workers.[1,2]

While agricultural injury surveys and studies commonly describe injury characteristics, the severity of injuries is often overlooked. Serious injuries require multi-faceted medical care, possibly care in intensive care units, and continued out-patient clinic sessions at physiotherapy, psychotherapy, or rehabilitation facilities.[3] The incidence rate, trends, and characteristics for serious injuries may differ from those for all injuries.[4] With better knowledge of the frequency and type of serious injuries, prevention, and care can be organized more efficiently, thereby reducing costs.[3]

Few studies have focused on serious injuries in agriculture. Two hospital-based studies described characteristics of injuries and injured operators using medical records.[5,6] One study evaluated the incidence and risk factors for serious injury in New York farmers using cross-sectional survey data.[7] A Finnish study investigated sources and risk factors for serious injury using insurance claims.[8] These studies contribute to the understanding of serious injury, but further studies are needed since the characteristics of injury and risk factors may differ by region and over time.

Government surveys have provided information on injuries in different agricultural population segments in the U.S. However, annual BLS surveys cover only hired workers on farms with 11 or more employees, and periodic National Institute for Occupational Safety and Health (NIOSH) surveys of self-employed farmers have been recently discontinued.[9–14] The Central States Center for Agricultural Safety and Health (CS-CASH), funded by NIOSH, initiated an annual injury surveillance system in collaboration with the U.S. Department of Agriculture's National Agricultural Statistics Service (NASS). This

surveillance covers seven states in the central United States. The objective of this study was to evaluate risk factors for serious injury in farm and ranch operators by conducting univariate and multivariate logistic regression analyses of a 3 year injury surveillance dataset (2011-2013) from the CS-CASH surveillance system.

2 | METHODS

The CS-CASH surveillance of non-fatal agricultural injuries among farm and ranch operators covers seven states, namely Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. NASS administered annual surveys in 2011, 2012, and 2013, and the CS-CASH research team (co-authors) analyzed the data, which have no personal identifiers. The surveys were sent out in March/April each year and gathered data on injuries that occurred in the previous calendar year.

The survey was pilot-tested in two states (IA, MO) in 2010 prior to its implementation in the seven-state region.[15] Pilot response rate was 41% (n = 857 responses). Farms that responded included 1287 principal operators, 500 workers, and 360 children (aged less than 20 years). The 1 year incidence of injury was 7.8%, 4.8%, and 5.3% among principal operators, hired workers, and children and youth, respectively. This pilot study demonstrated the feasibility of the method, and the survey was then expanded to the CS-CASH service region (seven states) with minor modifications.

2.1 | Ethics review and approval

For this study, we analyzed secondary data collected and de-identified by USDA NASS. Therefore, this study was exempted by University of Nebraska Medical Center's biomedical institutional review board.

2.2 | Data collection

The base population for the injury surveys was those farm and ranch operators in the seven-state region that responded to the Census of Agriculture in 2007 (used in 2011 and 2012 injury surveys) and 2012 (used in 2013 injury survey). The Census defines a farm as "any place from which $1000 or more of agricultural products were produced or sold, or normally would have been sold, during the year." The Census does not provide a separate definition for a ranch but refers to both farms and ranches as "operations."[16] In our injury survey, we asked respondents to self-identify if they consider their operation a farm or a ranch, without giving definitions. Many definitions can be found for a ranch, typically describing it as an operation raising livestock on large areas of land, primarily in western parts of North-America. In 2007, the Census of Agriculture reported 458 055 farm and ranch operations and 680 169 operators in this region, which represented 20.8% of the total U.S. agricultural operations (N = 2 204 792), and 20.4% of operators (N = 3 337 450).

NASS administered the annual injury surveys by mail to random samples of 6953 (2011), 6912 (2012), and 6912 (2013) farms/ranches (approximately 1000 farms/ranches in each state, each year). A second mailing of the injury survey was sent out to all potential respondents three weeks after the first mailing. The survey included questions about injuries to the principal operator and up to two other operators on each farm or ranch. The survey also had questions about injuries to children on the farm (reported elsewhere).

Following the data collection, NASS linked injury survey data with selected variables on farm characteristics from their existing Census database. NASS then created a de-identified dataset for secondary analyses by the CS-CASH research team. This measure enabled the evaluation of both individual and farm-level attributes of injury. Here, we report on characteristics and risk factors for serious injury, which is a subset of all reported injuries.

2.2.1 | Dependent variables

The research dataset included variables on farm production, demographic characteristics, and injuries for up to three operators. The following question was used to report injuries: "How many farm-related injuries occurred to each operator during [calendar year]?" The response options were 0 (None), 1 (One), 2 (Two), and 3 (Three or more) injuries. We defined agricultural injury as follows: "Injury" is the result of a sudden, unexpected, forceful event, which has an external cause, and which results in bodily damage or loss of consciousness. This definition was used earlier in the Iowa Certified Safe Farm study[17] and is similar to definitions used in workers' compensation systems.[8,18] "Farm-related" was defined as work and leisure activities on this operation, plus commuting, transporting, and business trips for this operation. We asked if the injury happened during work or leisure without providing definitions for these activities.

The consequences of the most serious injury to each operator were evaluated by asking questions about: (a) the type of medical care received (no care, out-patient care or hospitalization); (b) lost work-time due to injury (no lost time, less than half-day, half to one day, 2-6 days, 7-29 days, or 30 days or more); and c) estimated costs from the injury, both out-of-pocket costs and those paid by insurance.

The primary outcome of interest for this study was serious injury. We defined serious injury as an injury that resulted in at least half-day of lost work-time, professional medical care (out-patient or hospitalization), and expenses of $1000 USD or greater with out-of-pocket and insurance costs combined. Using these three criteria, we created a dichotomous outcome variable for each operator to signify if they had "serious injury" (yes, no). Those with only minor injuries or no injuries were coded as "no" serious injury.

2.2.2 | Independent variables

Individual-level independent variables included operator sex (male, female), operator status (principal, 2nd, 3rd), age, primary occupation (farm/ranch, other), percent of time worked on farm/ranch (0-24%, 25-49%, 50-74%, 75-99%, and 100%), internet access (yes, no), principal operator's total household income (less than $20 000, $20 000-$29 999, $30 000-$39 999, $40 000-$49 999, and $50 000

USD or more), percent of the total household income that came from agricultural operation, off-farm work days (none, 1-49 days, 50-99 days, 100-199 days, and 200 days or more), and retirement status (yes, no).

Farm-level independent variables included the type of operation (farm, ranch), total acres, field crops (yes, no), hay/forage (yes, no), woodland crops (yes, no), total cattle, hogs, poultry, sheep/lambs, horses/ponies, presence of other animals (yes, no), number of tractors by horsepower (less than 40, 40-99, and 100 or more), number of households sharing income from the operation, and type of organization (family or individual, partnership, incorporated under state law etc.).

2.3 | Data analysis

We calculated the injury rate for each year as the number of injuries divided by the number of operators multiplied by 100. Some operators reported up to three injuries in 1 year, and all reported injuries were included in the total count of injuries. The average annual incidence (injury rate) was calculated by dividing the total number of injuries by the total number of operators listed in responses multiplied by 100. We also calculated injury rates at the sub-population level; incidence rate for each level of all categorical variables was calculated by dividing the number of injuries within the variable level by the total number of operators reported for that level.

We calculated the incidence of serious injuries in the same manner. Using "if-then" statements in SAS,[19] we created the serious injury outcome variable from four injury variables: number of injuries reported, type of medical care received, lost work days, and costs (out-of-pocket and paid by insurance). Descriptive statistics were calculated, and the difference between serious injury and minor injury for the sources and characteristics of injury were evaluated by conducting cross-tabulations between the characteristics and the serious injury variable. We used the Fisher's Exact test for statistical significance ($P < 0.05$).

Risk factors for serious injury were evaluated using logistic regression. We conducted unadjusted analyses on all explanatory variables, individually, using $P < 0.05$ to indicate statistical significance. To control for potential confounding, an adjusted model was constructed with the backward stepwise selection procedure, starting with all statistically significant explanatory variables found in unadjusted analyses.

We converted continuous variables into categorical variables. The predictors of serious injury were measured by odds ratios (OR) and their 95% confidence intervals (CI). The model-fit was evaluated by the Hosmer-Lameshow test where Chi Square *P*-value of <0.05 would indicate lack of fit in the model.

We conducted unadjusted and adjusted logistic regression analyses for the evaluation of risk factors for all injuries as well as the serious injuries subset. We then compared the risk factor associations found for all injuries and serious injuries only.

The effect of missing values was taken into consideration. Missing values for self-reported responses for injury source and body part involved may have resulted in different totals for serious and minor injury combined (285 and 241 injuries, respectively). In addition, the proportion of missing values was 12.8% and 44.6% for the operator and farm-level independent variables, among the ones selected for the final multivariate model. However, the power of study was high (>0.95), irrespective of the presence of missing data, indicating the sample size was adequate, and missing responses may not have much effect on our findings.

3 | RESULTS

3.1 | Response rate

The average response rate (all years, all states combined) was 35% ($n = 7264$ responses). The response rate was highest in 2013 (37.3%) and lowest in 2011 (33%). Most operations were identified as farms (82%), the remainder (18%) being ranches. Among the seven states, Minnesota had the highest average response rate of 39.1%, and North Dakota had the lowest rate of 24.3%.

3.2 | Operator characteristics

A total of 9707 operators were identified on 6945 responding farms and ranches; 71.5% were principal operators, 23.5% second operators, and 5% third operators. The majority of principal operators were male (93.6%), second operators were more frequently female (56.5%), and third operators were predominantly male (80.5%). The average age was 59.7 years for principal operators, 52.4 years for second operators and 42.2 years for third operators.

3.3 | Injury incidence

Out of the 9707 total operators, 560 operators had one or more injuries for a total of 671 injuries during 2011-2013, resulting in an average annual incidence of 6.91 injuries/100 workers. Because some operators ($n = 111$) had more than one injury, the average annual incidence by injured persons was lower (5.76 injured workers/100 workers). Of all injuries, 34.7% were serious according to our definition, and the average annual incidence of serious injuries was 2.40/100 workers. The vast majority of operators either did not have injuries or their injuries were minor (97.5%).

3.4 | Injury outcomes

For the most serious injuries, injury outcomes were characterized in terms of the type of medical care received for injury, days of work lost due to injury, and the expenses paid out-of-pocket and/or by insurance. Missing observations were found in these variables. Thirty percent of injured operators did not respond to the question about the type of care. This significant missingness could have occurred because they may have perceived their injury to not be "serious." A similar situation may have occurred for other injury descriptor variables where data were missing for the out-of-pocket amount paid (21.3%),

TABLE 1 Serious and minor injury frequencies attributed to individual source: Central states injury surveillance 2011-2013

Injury source	Serious injury	Percentage (%)	Minor injury	Percentage (%)
Tractor	18	9.6	7	13.2
ATV	9	4.8	3	5.7
Machinery	19	10.1	2	3.8
Livestock	72	38.3	20	37.7
Hand tool	13	6.9	9	17.0
Power tool	8	4.3	7	13.2
Chemical/pesticide	1	0.5	0	0
Working surface	30	15.9	2	3.8
Truck/automobile	12	6.4	2	3.8
Other vehicle	4	2.1	0	0
Water	2	1.1	1	1.8
Total	188	100	53	100

amount paid by insurance (40.8%), and lost work-time (6.3%). Most injured operators received out-patient level care (57.7%), and very few were hospitalized (3.2%). Many operators did not lose worktime (29%). Among operators who did lose worktime, the length of disability was distributed fairly evenly across all levels, with frequencies ranging from 8.4-16.8%. Most operators spent less than $100 for treatment of injury; some used their insurance (21.4%) and some used their own financial resources (31.6%). The proportion of operators who paid a high amount ($10 000 or more) was small; in those cases 8.2% reported coverage by insurance and 3% had out-of-pocket expenses.

The characteristics of serious and minor injuries were compared using the Fisher's exact test. No significant differences were found among categories for both outcomes. The frequencies of operators with any injury and serious injury are presented by injury source (Table 1) and body part injured (Table 2). Machinery, automobile, and working surface-related injuries constituted a high percentage of serious injuries. A large proportion of minor injuries were caused by tractors, hand tools, and power tools. Most serious injuries involved lower extremity (leg/knee/hip, foot), back, and head. Minor injuries commonly occurred to finger or hand/wrist.

3.5 | Risk factors for serious injury

Several individual and farm-level determinants of injury were found in unadjusted logistic regression analyses. As illustrated in Table 3, statistically significant individual-level determinants included: operator status, age, gender, primary occupation, work-time on agricultural operation, operator's percentage of income from farming/ranching, operator's retirement status, and internet access status. The farm-level determinants included the type of agricultural operation, growing field crops, 100 hp and larger tractors in use, amount of farm sales, and total acres in operation.

Operators 65 years of age or higher had the lowest incidence of serious injury (1.69 serious injuries/100 workers), compared to all other age categories. Operators in the middle age group (45-54 years) had the highest risk of serious injury (OR: 2.19; confidence intervals in Table 3), compared to operators 65 years or older.

TABLE 2 Serious and minor injury frequencies by individual body part: Central states injury surveillance 2011-2013

Body part involved in injury	Serious injury	Percentage (%)	Minor injury	Percentage (%)
Head/neck	19	8.6	4	6.2
Eye	7	3.2	1	1.7
Chest/trunk	5	2.3	3	4.7
Back	39	17.7	10	15.6
Arm/shoulder	34	15.4	8	12.5
Finger	25	11.3	16	25.0
Hand/wrist	12	5.4	8	12.5
Leg/knee/hip	55	24.9	10	15.6
Toe	1	0.4	2	3.1
Foot	24	10.8	2	3.1
Total	221	100	64	100

TABLE 3 Risk factors for all and serious injuries-unadjusted risk estimates for all injuries and serious injury, and descriptive data, and injury rates for serious injury: Central states injury surveillance 2011-2013

Risk factors	All Injuries		Serious injury				
	OR	95%CI	Yes	No	Rate	OR	95%CI
Operator status							
Principal	1.34	1.10-1.65	186	6466	2.79	1.54	1.11-2.13
Operator 2 and 3	1	-	47	2527	1.85	1	-
Operator age (years)							
20-44	1.63	1.25-2.13	44	1541	2.77	1.65	1.09-2.51
45-54	1.73	1.35-2.23	67	1772	3.64	2.19	1.50-3.20
55-64	1.51	1.19-1.91	75	2752	2.65	1.58	1.09-2.28
65 or higher	1	-	47	2730	1.69	1	-
Gender							
Male	1.46	1.14-1.87	202	7206	2.72	1.55	1.05-2.28
Female	1	-	30	1659	1.77	1	-
Primary occupation							
Farming/ranching	2.03	1.68-2.46	174	4839	3.47	2.44	1.81-3.28
Other	1	-	59	4003	1.45	1	-
Work-time on operation (%)							
0-24	1	-	23	2426	0.93	1	-
25-49	1.76	1.29-2.38	41	1742	2.29	2.48	1.48-4.15
50-74	1.88	1.34-2.63	28	1121	2.43	2.63	1.51-4.59
75-99	3.19	2.38-4.28	56	1243	4.31	4.75	2.91-7.75
100	2.56	1.95-3.36	84	2276	3.55	3.89	2.44-6.19
Principal operator by percent income (%)							
Up to 49	0.64	0.53-0.78	85	4048	2.05	0.50	0.37-0.67
50 and up	1	-	101	2418	4.00	1	-
Principal operator by retirement status							
Retired	0.55	0.41-0.73	17	1365	1.23	0.37	0.22-0.62
Active	1	-	169	5101	3.20	1	-
Internet access							
Yes	1.27	1.04-1.54	145	4417	3.17	1.64	1.15-2.33
No	1	-	41	2049	1.98	1	-
Agricultural operation							
Farm-level							
Ranch	1.40	1.14-1.75	35	1030	3.28	1.27	0.87-1.86[a]
Farm	1	-	141	5308	2.58	1	-
Field crops harvested							
Yes	1.38	1.14-1.67	106	2813	3.63	1.88	1.35-2.61
No	1	-	55	2748	1.96	1	-
Tractor of 100hp in use							
Yes	1.79	1.47-2.17	121	3174	3.71	2.26	1.59-3.20
No	1	-	44	2608	1.65	1	-
Land in use (acres)							
1-100	0.24	0.12-0.47	38	1950	1.91	0.17	0.05-0.60
101-1000	0.28	0.14-0.55	89	3372	2.57	0.23	0.07-0.79

(Continues)

TABLE 3 (Continued)

Risk factors	All Injuries		Serious injury				
	OR	95%CI	Yes	No	Rate	OR	95%CI
1001-3000	0.46	0.23-0.90	44	830	5.03	0.47	0.13-1.63[a]
3001-10000	0.28	0.13-0.60	12	287	4.01	0.37	0.10-1.41[a]
10 000 and up	1	-	3	27	10.00	1	-
Total sales (USD)							
1-100	0.48	0.36-0.65	15	1159	1.27	0.37	0.21-0.63
101-1000	1.17	0.75-1.81[a]	5	188	2.59	0.76	0.31-1.89[a]
1001-3000	0.60	0.40-0.89	10	434	2.22	0.66	0.34-1.26[a]
3001-10 000	0.54	0.39-0.76	17	685	2.42	0.71	0.42-1.18[a]
10 000 and up	1	-	139	4000	3.35	1	-

[a]Statistically not significant ($P \geq 0.05$).

Male operators had 1.55 higher odds of serious injury compared to female operators. Operators who spent the majority of their time on farming/ranching had 2.44 times higher odds compared to part-time operators. Operators who spent 75-99% of their time on agricultural operations had 4.75 times greater odds, in comparison to operators who worked 0-24% of their time in farming/ranching. Access to the internet increased the odds of serious injury (OR: 1.64).

Principal operators who earned 50% or more of their income from agriculture had twice the odds of serious injury compared to those who earned a lesser proportion of their income from agriculture. Principal

TABLE 4 Adjusted risk estimates for predictors of serious and all injuries: Central states injury surveillance 2011-2013

	All injuries		Serious injury	
Risk Factors	OR	95%CI	OR	95%CI
Operator age (years)				
20-44	2.20	1.48-3.28	1.98	1.08-3.62
45-54	2.55	1.82-3.57	3.05	1.88-4.97
55-64	2.12	1.56-2.88	1.82	1.13-2.93
65 or higher	1	-	1	-
Primary occupation				
Farming/ranching	2.26	1.74-2.93	-	-
Other	1	-	-	-
Agricultural operation				
Ranch	1.42	1.07-1.88	-	-
Farm	1	-	-	-
Work-time on operation (%)				
100	-	-	4.22	1.97-9.05
75-99	-	-	5.62	2.59-12.19
50-74	-	-	4.38	1.94-9.88
25-49	-	-	2.74	1.24-6.07
0-24			1	-
Land in use (acres)				
1-100	-	-	0.22	0.06-0.84
101-1000	-	-	0.22	0.06-0.78
1001-3000	-	-	0.40	0.11-1.43[a]
3001-10 000	-	-	0.25	0.06-1.03[a]
10 000 and up	-	-	1	-

[a]Statistically not significant ($P \geq 0.05$).

operators who were retired had 0.37 times lower odds of serious injury than those who were not retired.

The odds of serious injury were 1.27 times higher in operators who operated ranches, compared to those operating farms. Growing field crops increased the odds as well (OR: 1.88). Having large tractors (100 hp or more) increased the odds of serious injury (OR: 2.26). The odds of serious injury also increased with the size of the operation (in acres and sales).

The determinants of all injuries were similar to those of serious injuries except use of 40-99 hp tractors (Table 3). Unadjusted analysis showed use of these type of tractors increased the risk of (any) injury by 1.28 times in comparison to those who did not (95%CI: 1.05-1.56).

Three determinants of serious injury were found significant in adjusted logistic regression analysis. As shown in Table 4, these were operator age, worktime, and size of land area in operation. In adjusted analyses for any injury, three factors were also found significant. As illustrated in Table 4, these were operator age, primary occupation, and type of agricultural operation.

4 | DISCUSSION

4.1 | Injury incidence

The average annual injury incidence was 6.91 injuries/100 self-employed farmers/ranchers in the current study. The BLS reported a similar incidence rate of 5.70 injuries/100 hired workers in agriculture (includes forestry and fishing) in 2013[2]). Our incidence rate was within the range of 4.10-16.60 injuries/100 workers reported by other studies.[8,13,14,20–22] Our incidence rate of 2.40 serious injuries/100 workers was also between two reported incidence rates of 1.25 and 9.00 serious injuries/100 workers.[7,8] Both of these studies used definitions of serious injury that were somewhat similar to our study.

4.2 | Effect of serious injury

In our study, the direction of the associations between risk factors for any injury and for serious injury were similar. However, a stronger association was observed for risk factors for serious injury than that for any injury, which is similar to findings reported in a Finnish study.[8] Frequency distributions for injury characteristics were also similar for all injuries and serious injuries with few exceptions. Using our definition, serious injuries represented fairly large proportion of all reported injuries. However, the probability of a very serious life-threatening injury remains low. Others have reported similar results for injuries that are very serious.[8,17,23] Nonetheless, serious injuries as defined in this study require greater care than minor injuries, and result in more significant costs and a greater disability duration. Individual risk factors for serious injury are discussed below.

4.3 | Risk factors for serious injury

4.3.1 | Age

Middle age (45-54) was a significant risk factor for both serious injury and any injury (Table 4) found in adjusted analyses. The oldest operators (aged 65 years or more) had a lower risk of injury compared to younger ones. A recent systematic review of risk factors for agricultural injury found inconclusive evidence on age as a risk factor from 23 studies. However, weighted analysis, accounting for the population size in each study, indicated the risk of injury increased slightly with age.[24] While arguments have been made about different age groups being at higher risk than others, the evidence from numerous studies still remains relatively unclear. Our finding from this study adds to the literature, showing middle-aged farmers at greatest risk.

4.3.2 | Gender

Univariate analyses showed a greater risk of serious injury in males. This result is in line with 10 studies identified in a systematic review.[25] No study showed the opposite result, females having a greater risk of agricultural injury. Rather than a risk factor in itself, this effect is likely due to division of work tasks by gender. Traditionally, males have performed more crop production and machinery-related tasks, while females have performed more animal husbandry and domestic tasks.[26] Females may have lower exposure to hazardous farm work, which may explain their lower rate of injuries.[22] Karttunen and Rautiainen[18] found a similar distribution of agricultural work tasks and injuries by gender indicating that given similar exposure, there may be no difference in the injury risk by gender. The effect of age was reported on the association between gender and injury; the risk was similar for participants of both genders aged less than 20 years, but was higher in the males of older age.[23] We did not find a similar effect of age on gender. To determine risk differences between the genders, exposure times dedicated to specific tasks should be considered. However, this information is rarely available as it is difficult and costly to measure.

4.3.3 | Work-time

Our univariate and multivariate analyses showed that the risk of serious injury was greater in operators who worked full-time, especially those who worked 74-99% of their time on the farm or ranch. Injuries are more frequent in the spring and fall, which are the busy seasons for planting and harvest.[27] The risk of injury increases with the time of exposure to farm-related tasks. Full-time farmers have greater exposure to some of the risky tasks such as operating machinery, handling animals, and transporting goods.[22] In contrast, two studies reported a higher risk of injury to part-time farmers.[14,20] Working off-farm may result in extended workdays and fatigue when performing farm-related tasks.[20] Full-time farmers may have hired workers to perform tasks for them and this may decrease their exposure to hazardous farm work, and related injuries.[20] In addition, full-time farmers may be able to prevent injuries using their experience and expertise.[28]

4.3.4 | Primary occupation

Primary occupation as farming did not emerge as a risk factor for serious injury, but it was found significant for any injury in the adjusted analysis. Because farming/ranching is one of the most hazardous

occupations, this result is expected. However, other views have been expressed. Farmers may become accustomed to risks in their working environment. Those who farm part-time may, in fact, pay better attention to safety due to their lack of familiarity with farming.[29] Off-farm employment may influence safety culture and norms on the home farm as well. Further research is needed to explore how to target interventions for those with their primary occupation as farming, as well as those who farm as a secondary activity.

4.3.5 | Income from farming

Our univariate analysis showed principal operators who earned more than 50% of their income from farming/ranching had a higher risk of serious injury. Others have found the risk of injury increases with farm income.[30] High income from farming is linked with higher exposure time and injury risk on the farm.[15] Income and worktime variables in our study had a similar trend. For example, principal operators who worked more than 50% of their time and earned more than 50% of their income from farming/ranching had a greater risk of serious injury compared to those who worked less and earned less from farming/ranching.

4.3.6 | Internet access

Our univariate results showed operators with internet access had a higher risk of serious injury compared to those with no internet.[24] reported similar results. They discussed that farms using computers and internet access should have a more systematic approach to farm management and safety. However, operators on modern farms also work long hours and thereby have greater exposure to farm-related activities. In addition, they may have higher levels of stress and urgency to get jobs done in spite of the availability of better management tools.[26] These circumstances can result in an increased risk of injury. However, internet access was not significant in their findings as well as our multivariate analyses. The association was likely confounded by other factors, including farm size and age group.

4.3.7 | Retirement status

We found that operators who reported being retired had a lower risk of serious injury compared to those who were not. Retired farmers likely have less exposure to farm work, which should decrease the risk of serious injury. This association was not found in the multivariate model as it was likely confounded by work hours, land acreage, and principal operator's percent of income from farming.

4.3.8 | Type of agricultural operation

The serious injury rate was higher for operators on ranches compared to those on farms (3.28 vs. 2.58 serious injuries/100 workers). Further, operators on ranches had 1.42 times greater risk of any injury than operators on farms, after controlling for confounders. These results indicate ranches likely have a more hazardous environment than farms. This type of comparison of injury rates among agricultural operations (farms vs. ranches) may be the first of its kind although many studies have found raising livestock increases the risk of injury.[14,23,31–33] In one study of 7420 households, 20.1% of injuries were attributed to animals ($n = 1016$ injuries from animals, $n = 5045$ total injuries).[32] Animal-related injuries are common and serious,[32] and therefore, working on ranches could be more hazardous than working on crop farms. Further efforts should explore the mechanisms by which injuries occur at ranches.

4.3.9 | Field crop harvest

The current study showed operators who harvested field crops such as soybeans, wheat and corn, had a higher risk of serious injury compared to those who did not harvest field crops. However, Belgian researchers have reported crop-growing farmers operate machinery safely compared to farmers who work on mixed farms, leading to decreased risk of injury.[29] In the current study, half the responding farms that harvested field crops also raised animals. Hence, it is difficult to compare the risk by farm type because crop farms and dairy or beef farms may have different predominant sources of injury—machinery versus animals. Both of these sources of injury are common, and mixed farms can have both. In addition, there are machinery used on mixed and animal farms that are not commonly used on crop farms. We did not find field crop harvest as a significant risk factor in our adjusted analyses. The association between field crop harvest and serious injury was likely confounded by operator age, land in use, and principal operator's income from agricultural operation. To characterize the risk of injury from individual sources, future research should explore risk differences across different types of farms.

4.3.10 | Tractors of 100 horsepower

Univariate analyses showed having larger tractors (100 hp and over) increased the risk of serious injury and any injury, while having 40-99 hp tractors increased the risk of any injury only. Crop farming is predominant in the central states region, and the vast majority of cultivation, planting, and other field work is done with larger tractors. According to our adjusted analysis, larger tractors were not significantly associated with serious injury. This association was confounded by exposure time and total land in operation; operators who used 100 hp tractors and worked long hours or operated larger land areas had the higher risk of serious injury. Future studies should address the risk of tractor-related injury from using tractors of different sizes. The presence of roll-over protective structures (ROPS) on tractors should also be considered. ROPS are mandatory in the United States. only for hired workers on farms with 11 or more employees.[34]

4.3.11 | Land in use and sales

According to our univariate and multivariate results, operating large land areas was associated with a higher risk of serious injury. Others

have reported similar results.[13,14,20,35,36] Those operating larger land areas may work longer hours.[35] They may also have higher livestock density and economic pressure to enhance production.[6] Larger farms also tend to employ more workers, with more tillable acres, thereby increasing the likelihood of work-related injuries.[37] Higher farm sales was a significant risk factor for serious injury in univariate analysis but not in the multivariate analysis. This association was confounded by land in use, work hours and principal occupation (farming/ranching vs. other).

4.4 | Strengths

This study is based on surveillance data on agricultural injury of self-employed farmers and ranchers in a seven-state region in the central U.S. This study addresses a gap in current U.S. injury surveillance; most of which covers hired workers only. National surveillance of agricultural operators and youth on farms has been conducted by NIOSH, but this surveillance has been discontinued. These national surveys provided useful information about injury rates and trends specific to targeted populations over time. However, the injury rates in these surveys are much lower than we have observed (6.91 for all injuries and 2.40 for serious injuries, on average). It is likely the NIOSH surveys had significant under-reporting. Other large surveys and surveillance systems have produced rates closer to ours and our surveillance may provide a better representation of the true injury incidence in agriculture in the selected states. Our survey also targeted several operator and farm characteristics, which allowed us to evaluate a range of risk factors for injury. Detailed information on risk factors helps target injury prevention studies and prevention strategies to meet the unique needs of affected high-risk subpopulations.

The current study had a relatively large sample size that represents 21% of the U.S. farms/ranches. The sample allowed identification of common risk factors for injury. The 3-year data were collected using a validated survey instrument and a moderate response rate was achieved. Therefore, we believe the results of this study are valid, reliable, and generalizable.

The seriousness of injury was defined using the type of medical care, work loss days, and the expenses for the injury. Our study may provide a more representative cross-section of serious injuries in the farm and ranch operator population compared to hospital-based studies and clinical reports. Although hospital-based studies provide in-depth information about the medical aspect of injury, the data from these studies represent only a fraction of serious injuries that occur on the farm.[6,13,23,] In addition, farm-related risk factor information may not be sufficiently captured from these sources.

5 | LIMITATIONS

The response rate in this study was moderate. The significant non-response could have led to a selection bias, where those with prior injuries could have a greater interest to respond. Self-reporting of injury incidents involves the possibility of recall bias, resulting in an incorrect estimation of the risk and/or misclassification of the severity of injury. Some operators could have responded to the survey because they had serious injuries they could remember easily compared to minor injuries they could not readily recall. The concern of recall bias has been expressed in other large studies evaluating risk factors. These included U.S. studies with data collected from five states,[27,38] and Finnish studies that analyzed farm injuries using national administrative records.[8,18] Pratt and colleagues[13] controlled recall bias by validating the injury outcomes by comparing them to medical records. Because of the large sample size of our study compared to Pratt and colleagues, and other administrative challenges (no identifier information), we were unable to use this validation methodology.

Similar to our study, many researchers have used 12 months as the recall period,[14,21,27,31,39–41] while the recall period was as short as 2 months in one study.[13] Other U.S. surveillance studies had the recall period of two to three years.[9,10,42] Tanzanian researchers suggested the longer recall period may underestimate the injury incidence.[39] Unlike other research studies, we did not assess the seriousness of injury using the physical nature of injury.[3,4,6,43] In this study, the survey questions did not include probing of responses. Besides, the criteria employed for serious injury was used previously.[7,8,39] These measures may have overcome the limitation of self-reporting to some extent.

Last, we did not investigate the fundamental metric of exposure—work hours spent on individual farm tasks. In the absence of these important data, the risk differences could be confounded. Primary occupation and income from farming/ranching, work-time on the operation, off-farm work, retirement status, tillable acres, and other variables in this study may reflect working hours but they could not accurately represent working time by each individual in specific work tasks. Future studies that evaluate risk factors based on time spent on individual tasks would provide improved estimates of risk of agricultural injuries. No doubt, as[27] stated, implementation of such a monumental measure is difficult.

6 | CONCLUSIONS

Agricultural injury is an important public health issue. Farming/ranching is a hazardous enterprise and farm workers are exposed to risks from machinery, large animals, or other sources in their day-to-day lives. Injuries commonly occur among farm and ranch operators, and many of the injuries are serious. Serious injuries lead to a greater physical and economic burden on the operator compared to minor injury. Results of this surveillance study showed the risk of serious injury tends to be greatest in operators of middle age (45-54 years), those who work nearly full-time (75-99% of the time), and those who operate farms/ranches with large land areas (1000 acres or more). Further research and prevention efforts should be directed to populations with these risk factors with consideration for co-occurring risk factors. Intervention studies should also consider these risk factors as potential confounders.

AUTHORS' CONTRIBUTIONS

Dr. Jadhav conceptualized the idea of the work. He conducted analysis of secondary de-identified data. He wrote the initial draft of the manuscript and revised it to address inputs and edits suggested by co-authors. He is accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Dr. Achutan provided intellectual contribution to the work. Using his expertise in occupational health and safety, he provided overall guidance to this work in this area. As a senior biostatistician, Dr. Haynatzi provided supervision for statistical analyses. He examined the analyses for accuracy and integrity. Dr. Rajaram provided critical inputs from an external reviewer's perspective. She also provided guidance to improve the quality of the work in general. As a world-renowned agricultural injury expert, Dr. Rautiainen provided general supervision of this work. He formed the design of the work, and provided infrastructure to perform this work. Dr. Rautiainen managed acquisition of the secondary de-identified data from USDA NASS. He provided vital edits and suggestions that improved the quality of the work and also provided the final approval of the version of the manuscript to be published.

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ETHICS APPROVAL AND INFORMED CONSENT

This study was exempted from the requirements of review and informed consent set by the biomedical institutional review board of the University of Nebraska Medical Center because we analyzed secondary data collected and de-identified by USDA NASS.

DISCLOSURE (AUTHORS)

The authors declare no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

Steven Markowitz declares that he has no conflict of interest in the review and publication decision regarding this article.

DISCLAIMER

None.

ORCID

Rohan Jadhav http://orcid.org/0000-0002-9000-6654

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