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Agricultural Injuries: Risk Factors and Severity by Affected Body Part among US (Midwest) Farmers

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ABSTRACT

Objectives: Statistics from the United States Bureau of Labor Statistics indicate that agriculture consistently ranks as the most hazardous industry in the US. To identify specific targets for prevention, we investigated injury risk factor profiles separately for each injured body site. We also characterized the severity of agricultural injuries by injured body site using the type of medical care and lost work time due to injury.

Methods: We used the Central States Center for Agricultural Safety and Health (CS-CASH) surveillance data for 2018 to perform descriptive statistics and regression modeling.

Results: We found that 12% (513/4351) of the participants experienced one or more injuries in the previous 12 months. Compared to female operators, male operators had 3.53 (95% CI: 1.17–10.68) times higher odds of back injury. Operators in livestock production had 2.77 times (95% CI:1.12–6.82), 2.28 times (95% CI:1.25–4.14), and 1.69 times (95% CI:1.10–2.59) higher odds of injury to the chest/trunk, finger, and leg/knee/hip, respectively, compared to operators in crop or mixed production. After adjusting for age and gender, operators who worked full time (vs. part-time) on the farm/ranch had 2.11 times (95% CI:1.03–4.34) higher odds of back injury. Arm/shoulder and leg/knee/hip injuries were more frequent in older age groups.

Conclusions: Prevention measures should be tailored considering specifically livestock producers with emphasis on trainings on proper livestock handling, such as being gentle, establishing routine, keeping distance, and avoiding sudden and loud noise when handling animals. Applying these techniques avoid startling the animals and reduce the risk of injuries.

KEYWORDS
Agricultural injuries; risk factors; body part

Introduction

Agricultural work involves hazardous exposures that can result in adverse health outcomes, including injuries. In the United States (U.S.), the Bureau of Labor Statistics [1] reported that agriculture had the highest rate of recordable non-fatal work-related injuries and illnesses; 5.2 cases per 100 full time equivalent workers (FTE) in 2019. Agriculture also had the highest rate of fatal occupational injuries with 23.1 fatalities per 100,000 FTE workers.[2]

The investigation of injury characteristics, sources, and risk factors provides the basis for developing interventions and preventive measures. Many studies have described injuries by their physical nature (fracture, strain, etc.), type of activity leading to the injury (using machinery, caring for livestock, etc.), work environment, and circumstances related to the injury.[3–6] Few studies have assessed injuries in relation to the cost.[3]

Injury risk factors have been recently described in two systematic reviews where 25 demographic, work environment, behavior, and preventive characteristics were found to have a significant association with agricultural injury. Several characteristics including age, marital status, work experience, off-farm work, alcohol use, smoking, having health problems, and having safety training had conflicting or inconclusive results.[4,5] Some studies have assessed risk factors for farm-related severe injuries. For example, Day et al.[6] identified risk factors for serious farm injuries among male farmers scoring two or higher on the Abbreviated Injury Scale. Other studies investigated risk factors for all injuries vs. serious injuries in agriculture based on cost, lost work time, or medical care received.[7,8] Moreover, one hospital-based study of al

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l occupations described risk factors for severe work-related eye injuries.[9]

While many studies have examined risk factors for agricultural injuries in general or serious injuries, there is limited research assessing risk factors for agricultural injuries affecting specific body parts. Prevention strategies could be tailored more effectively with evidence of injury characteristics and how they differ depending on the body part affected.

The 2018 Central States Center for Agricultural Safety and Health (CS-CASH) surveillance data provided an opportunity to address the identified gap in knowledge regarding the characteristics and seriousness of injuries by specific body site affected. The first aim of this study was to identify injury risk factors by injured body part. The second aim was to determine the frequency of serious injuries and the cost associated with them by injured body site as we defined serious injury in terms of time lost from work and type of care received.

Methods

Study site

This study was conducted in seven U.S. states (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota) as part of the CS-CASH surveillance of agricultural injuries and illnesses. The study population included self-employed farmers and ranchers, called "operators" in this setting.

Data collection

CS-CASH personnel administered the 2018 Farm and Ranch Health and Safety Survey to a sample of 22,440 farmers and ranchers, randomly selected from the Farm Market iD database. Farm Market iD, currently part of DTN Industries, is a commercial entity that provides farm and grower data to marketing, agribusiness, and research organizations.[10] Figure 1 represents the flow

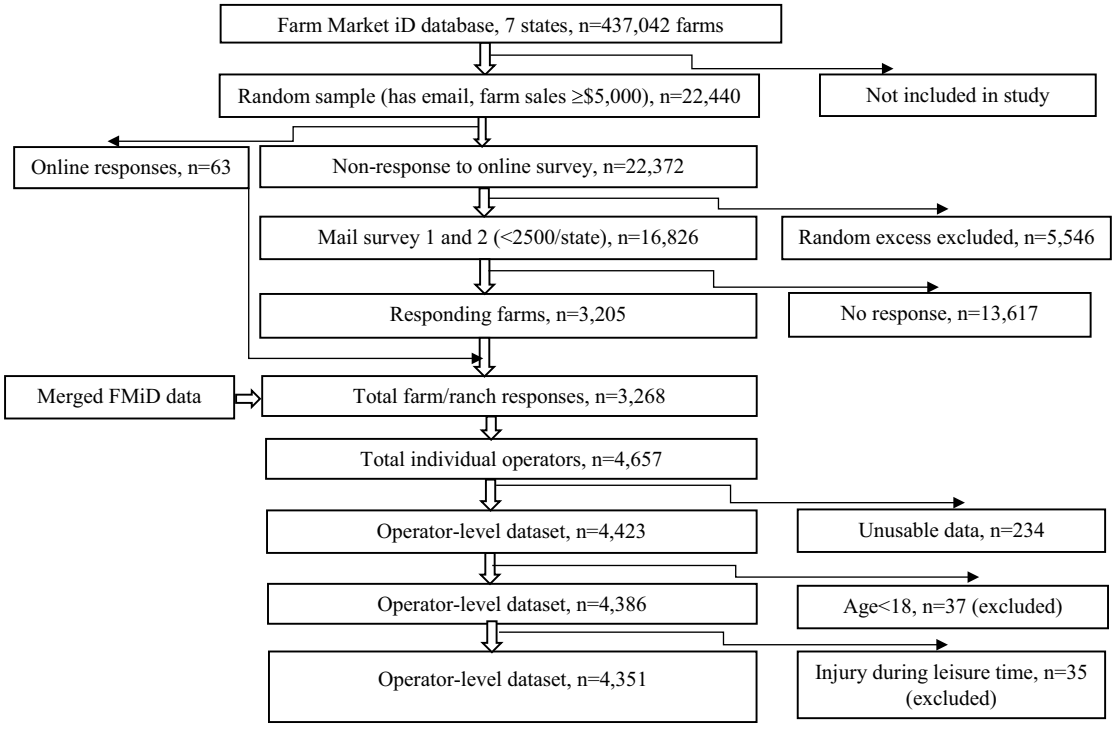

Figure 1. Flow chart showing the selection procedure for creating the dataset for analyses from the farm and ranch health and safety survey, 2018.

chart describing the process of data collection and creation of a dataset for analysis from the Farm and Ranch Health and Safety Survey, 2018. Only farms and ranches with a gross farm income of at least $5000 and an email address listed in the database were included in the sample. Two approaches were used to recruit participants: 1) two emails with a link to a REDCap online survey (n = 22,440), and 2) two mailings to a subset of 16,826 farms and ranches with a four-page questionnaire and postage paid return envelope. The surveys were sent during the Spring and early Summer of 2018 to collect information from operators in the seven-state region, focusing on injury and illness events during the previous 12 months. The survey covered questions about operator demographics, injuries, chronic health conditions, exposures, personal protective equipment use, and use of injury prevention techniques during the previous 12 months. The information was requested for the principal operator and up to two other operators on each farm or ranch. The farm/ranch-level survey responses were merged with production variables from Farm Market iD at the operation level. The final dataset was constructed by creating a record (line) for each operator and duplicating respective farm production variables for each principal, second and third operator included in the survey responses.

Dependent variables

The first question regarding injuries was: "How many farm-related injuries occurred to each operator during the previous 12 months?" The response options were none, 1, 2, and 3 or more injuries. Follow-up questions addressed injury characteristics only for the most serious injury.

Our dependent variables were constructed using the injury characteristics question: "What body part was primarily injured? (Mark only one)." The answer choices were 1- Eye/head/neck, 2- Chest/trunk, 3- Back, 4- Arm/shoulder, 5- Finger, 6- Hand/wrist, 7-Leg/knee/hip, 8- Ankle/foot/toe, and 9- Other, specify. We used all specified body parts injured as outcome variables.

Injury severity was described by questions about the type of care received after the injury (none, doctor visit, hospital), and the lost time ("How much lost farm work time resulted from this injury?"). The type of care received, and the time lost were categorized into two groups (professional care and none) and (less than two days and two days and more), respectively. This categorization was based on the Occupational Safety and Health Administration's (OSHA) definition of recordable injury. OSHA defines a recordable injury as "any work-related injury that result in days away from work" or "any work-related injury requiring medical treatment beyond first aid".[11] We considered that a recordable injury was a serious injury, and we used the two criteria described above to create a dichotomous variable "serious injury" (yes, no). Thus, a serious injury in our study was any injury that required professional medical care and/or any injury resulted in two days or more away from work.

Independent variables

Selected individual-level factors used as predictor variables included operator sex (male or female) and age (age groups: 18–44, 45–64, and 65+), operator status (principal operator, operator 2, operator 3), primary occupation (farm/ranch work or other occupation), operation type (farm, ranch, both), and percentage of work time spent in farm/ranch work (less than 75%; 75% and more). Farm-level factors used as predictors included type of production (livestock, corn, hay, and soybeans).

Data analysis

Separate cross-tabulation analyses were conducted for each injured body part per selected operator and farm-level characteristics, and aggregated descriptive statistics were reported.

Moreover, using the Generalized Estimating Equations (GEE) logistic regression model to account for clustering of operators within the same farm/ranch, we performed univariable analyses (unadjusted) on all independent variables with outcome variables (body part injured). Adjusted models were fitted for outcome variable with independents variables that yielded a positive association in the univariable models. We used the SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA) to perform the statistical analyses.

Ethics review and approval

The study was considered exempt by the University of Nebraska Medical Center's Institutional Review Board (#452-11-EX).

Results

1. Descriptive statistics of operator and farm-levels characteristics

The 2018 Farm and Ranch Health and Safety mail survey generated an overall response rate of 19% (3205/16,826). The respondents and non-respondents have very similar farm-level characteristics: growing soybeans 86% vs. 84%, hay 67% vs. 69%, any livestock 46% vs. 46%, cow calf 16% vs. 16%, wheat 40% vs. 47%, dairy 5% vs. 5%, and corn 90% vs. 89%.

A total of 4,351 operators, 14% (615/4351) females and 86% (3704/4351) males were included in the study. One or more injuries in the previous 12 months were reported by 12% (513/4351) of the participants. Among them, 499 operators specified the body part injured. The most often injured body part was the leg/knee/hip, 20% (99/499). It was followed by the arm/shoulder site at 15.6% (78/499) (Table 1).

Male operators were more likely to report leg/knee/hip injury (17%) than injury to any other body part. Participants in the age range between 45 and 64 reported leg/knee/hip injury more frequently (13%) than injury to any other body parts (Tables 2 and 3).

Table 1. Frequency and severity of injuries by body part for the Farm and Ranch Health and Safety Survey, 2018.

Body part injured	Any injury, n (%)[a]	Serious injury, n (%)[b]	Average cost ($)
Eye/head/neck	76 (15.2)	60 (78.9)	28,405
Chest/Trunk	24 (4.8)	20 (83.3)	30,597
Back	75 (15.0)	58 (77.3)	15,066
Arm/shoulder	78 (15.6)	63 (80.8)	12,783
Hand/wrist	55 (11.0)	40 (72.7)	6,282
Finger	49 (9.8)	34 (69.4)	2,356
Leg/knee/hip	99 (19.8)	75 (75.8)	10,533
Ankle/foot/toe	25 (5.0)	19 (76.0)	7,652
Other	18 (3.6)	12 (66.7)	14,883
Missing	14	2	13,797
Total	513 (100)	383 (74.6)	142,353

[a]Count and column percent.
[b]Count and row percentage.

2. Association between operator and farm-levels characteristics with body part injured

The GEE logistic regression univariable analysis showed that compared to participants in the age group of 18–44, the odds of an injury to the arm/shoulder was 5.82 times higher for participants in the age group of 45–64, and 14.02 times higher for participants aged 65 and more (Table 2).

Similarly, the odds of an injury to the leg/knee/hip was 6.52 times higher for participants in the age group of 45–64, and 16.63 times higher for participants aged 65 and more compared to participants in the age group of 18–44 years (Table 3).

The univariable analysis also found an association between livestock production and an increased odds of injury to the arm/shoulder [OR = 1.69], the chest/trunk [OR = 2.70], the finger [OR = 2.16], and the leg/knee/hip [OR = 1.96] (Tables 2 and 3).

Furthermore, the univariable analysis yielded a positive association between gender and back injury. Compared to female operators, male operators had 3.53 times higher odds of back injury (Table 3).

We also conducted a multivariable GEE logistic regression analysis adjusting for age in all the models. We found that compared to participants who did not produce livestock, operators with livestock production had 2.77 times, 2.28 times, and 1.69 times higher odds of injury to the chest/trunk, finger, and leg/knee/hip, respectively (Tables 4).

After adjusting for the age, operators who work full time on the farm/ranch had 2.11 times higher odds of back injury compared to operators who work part-time on the farm/ranch (Table 4).

3. Serious injury and body part injured

Out of the 513 injuries reported, 383 (74.66%) were classified as serious injuries based on the OSHA recordable injury criteria. The body part with the highest proportion of serious injuries was the chest/trunk area (83%) followed by the arm/shoulder (81%). The lowest proportion of serious injuries concerned the finger area (69%) (Table 1). In terms of cost of medical care, the

Table 2. Descriptive statistics and crude association of operator and farm-level characteristics with each body part injured for the Farm and Ranch Health and Safety Survey, 2018 (part I) (n = 4,351)[a].

	Eye/head/neck		Chest/trunk		Back		Arm/shoulder	
Variables	Yes n (%)[b]	OR (95% CI)[c]	Yes n (%)[b]	OR (95% CI)[c]	Yes n (%) [b]	OR (95% CI)[c]	Yes n (%) [b]	OR (95% CI)[c]
Individual factors:								
Sex								
Male	67 (89.3)	1.40 (0.67–2.93)	19 (79.2)	0.68 (0.25–1.84)	71 (94.7)	**3.53 (1.17–10.68)**	72 (92.3)	2.06 (0.89–4.79)
Female	8 (10.7)	Reference	5 (20.8)	Reference	4 (5.3)	Reference	6 (7.7)	Reference
Missing	1	N/A	0	N/A	0	N/A	0	N/A
Age group								
45–64	36 (47.4)	0.61 (0.19–1.89)	15 (62.5)	1.27 (0.17–9.30)	42 (56.0)	1.38 (0.41–4.62)	49 (62.8)	**5.82 (1.33–25.37)**
65+	22 (28.9)	0.47 (0.09–2.61)	4 (16.7)	1.44 (0.07–28.36	20 (26.7)	1.63 (0.27–9.93)	21 (26.9)	**14.02 (1.54–127.78)**
18–44	18 (23.7)	Reference	5 (20.8)	Reference	13 (17.3)	Reference	8 (10.3)	Reference
Operator status								
Principal operator	57 (75.0)	1.20 (0.47–3.05)	18 (75.0)	1.58 (0.29–8.68)	62 (82.7)	2.19 (0.66–7.24)	64 (82.1)	1.66 (0.61–4.52)
Operator 2	14 (18.4)	1.44 (0.22–9.28)	5 (20.8)	2.49 (0.08–75.38)	10 (13.3)	4.79 (0.44–52.37)	10 (12.8)	2.74 (0.37–20.48)
Operator 3	5 (6.6)	Reference	1 (4.2)	Reference	3 (4.0)	Reference	4 (5.1)	Reference
Primary occupation								
Farm/Ranch	67 (88.2)	1.42 (0.71 2.86)	21 (87.5)	1.28 (0.38–4.36)	68 (91.9)	2.44 (0.99–6.01)	72 (93.5)	2.82 (1.12–7.12)
Other	9 (11.8)	Reference	3 (12.5)	Reference	6 (8.1)	Reference	5 (6.5)	Reference
Missing	0	N/A	0	N/A	1	N/A	1	N/A
Primary operation								
Farm	56 (77.8)	0.70 (0.36–1.33)	18 (78.3)	1.25 (0.29–5.37)	62 (84.9)	0.98 (0.43–2.26)	58 (76.3)	0.52 (0.29–0.96)
Both	5 (6.9)	0.34 (0.05–2.37)	3 (13.0)	1.93 (0.02–154.53)	2 (2.7)	0.95 (0.08–11.54)	3. (4.0)	0.14 (0.02–0.88)
Ranch	11 (15.3)	Reference	2 (8.7)	Reference	9 (12.3)	Reference	15 (19.7)	Reference
Missing	4	N/A	1		2	N/A	2	N/A
Full time status								
75–100%	59 (77.6)	1.26 (0.73–2.17)	17 (70.8)	0.87 (0.35–2.16)	64 (86.5)	**2.53 (1.27–5.03)**	64 (82.0)	1.69 (0.94–3.05)
Less than 75%	17 (22.4)	Reference	7 (29.2)	Reference	10 (13.5)	Reference	14 (18.0)	Reference
Missing	0		0	N/A	1		0	N/A
Farm level factors:								
Livestock production								
Yes	44 (57.9)	1.53 (0.97–2.42)	17 (70.8)	**2.70 (1.10–6.63)**	37 (49.3)	1.08 (0.67–1.75)	47 (60.3)	**1.69 (1.07–2.67)**
No	32 (42.1)	Reference	7 (29.2)	Reference	38 (50.7)	Reference	31(39.7)	Reference
Corn production								
Yes	69 (90.8)	0.98 (0.45–2.13)	21 (87.5)	0.70 (0.21–2.37)	69 (92.0)	1.11 (0.48–2.60)	68 (87.2)	0.68 (0.33–1.40)
No	7 (9.2)	Reference	3 (12.5)	Reference	6 (8.0)	Reference	10 (12.8)	Reference
Hay production								
Yes	51 (67.1)	0.90 (0.56–1.46)	18 (75.0)	1.35 (0.48–3.77)	53 (70.7)	1.05 (0.62–1.78)	61 (78.2)	1.59 (0.93–2.74)
No	25 (32.9)	Reference	6 (25.0)	Reference	22 (29.3)	Reference	17 (21.8)	Reference
Soybean production								
Yes	66 (86.8)	1.06 (0.55–2.06)	18 (75.0)	0.47 (0.19–1.22)	70 (93.3)	2.35 (0.94–5.88)	60 (76.9)	0.53 (0.31–0.92)
No	10 (13.2)	Reference	6 (25.0)	Reference	5 (6.7)	Reference	18 (23.1)	Reference

[a]Participants with no injury were included in the analysis as the control group.
[b]column percent.
[c]unadjusted Odd Ratio (OR); 95% Confidence interval (CI); bolded estimates are significant.

Table 3. Descriptive statistics and crude association of operator and farm-level characteristics with each body part injured for the Farm and Ranch Health and Safety Survey, 2018 (part II) (n = 4,351)[a].

	Hand/wrist		Finger		Leg/knee/hip		Ankle/foot/toe	
Variables	Yes n (%)[b]	OR (95% CI)[c]	Yes n (%)[b]	OR (95% CI)[c]	Yes n (%)[b]	OR (95% CI)[c]	Yes n (%)[b]	OR (95% CI)[c]
Individual factors:								
Sex								
Male	48 (88.9)	1.37 (0.58–3.22)	46 (93.9)	2.74 (0.81–9.27)	87 (87.9)	1.21 (0.66–2.24)	24 (96.0)	4.00 (0.54–29.61)
Female	6 (11.1)	Reference	3 (6.1)	Reference	12 (12.1)	Reference	1 (4.0)	Reference
Missing	1	N/A	0	N/A	0	N/A	0	N/A
Age group								
45–64	31 (56.4)	0.58 (0.16–2.03)	28 (57.1)	0.48 (0.14–1.67)	64 (64.6)	**6.52 (1.71–24.86)**	12 (48.0)	0.61 (0.09–4.37)
65+	8 (14.5)	0.44 (0.07–2.90)	5 (10.2)	0.33 (0.05–2.16)	25 (25.3)	**16.63 (2.23–123.94)**	7 (28.0)	0.48 (0.03–9.13)
18–44	16 (29.1)	Reference	16 (32.7)	Reference	10 (10.1)	Reference	6 (24.0)	Reference
Operator status								
Principal operator	42 (76.4)	4.95 (0.59–41.41)	36 (73.5)	0.96 (0.35–2.62)	71 (71.7)	1.49 (0.60–3.68)	20 (80.0)	2.09 (0.28–15.79)
Operator 2	12 (21.8)	24.51 (0.35–174.89)	9 (18.4)	0.93 (0.13–6.89)	23 (23.2)	2.22 (0.36–13.55)	4 (16.0)	4.39 (0.08–249.57)
Operator 3	1 (1.8)	Reference	4 (8.1)	Reference	5 (5.1)	Reference	1 (4.0)	Reference
Primary occupation								
Farm/Ranch	45 (81.8)	0.86 (0.43–1.75)	44 (89.8)	1.63 (0.65–4.08)	89 (89.9)	1.72 (0.89–3.32)	23 (92.0)	2.19 (0.52–9.25)
Other	10 (18.2)	Reference	5 (10.2)	Reference	10 (10.1)	Reference	2 (8.0)	Reference
Primary operation								
Farm	41 (83.7)	1.12 (0.44–2.85)	39 (79.6)	0.72 (0.28–1.87)	76 (77.5)	0.69 (0.40–1.21)	20 (83.3)	1.10 (0.75–2.21)
Both	3 (6.1)	1.41 (0.09–23.21)	2 (4.1)	0.37 (0.02–6.52)	7 (7.2)	0.33 (0.06–1.77)	0 (0)	1.06 (0.09–3.06)
Ranch	5 (10.2)	Reference	8 (16.3)	Reference	15 (15.3)	Reference	4 (16.7)	Reference
Missing	6	N/A	0	N/A	1	N/A	1	N/A
Full time status								
Less than 75%	13 (24.1)	Reference	7 (14.3)	Reference	18 (18.2)	Reference	4 (16.0)	Reference
75–100%	41 (75.9)	1.16 (0.61–2.20)	42 (85.7)	2.25 (0.99–5.12)	81 (81.8)	1.65 (0.98–2.76)	21 (84.0)	1.90 (0.65–5.54)
Missing	1	N/A	0	N/A	0	N/A	0	N/A
Farm level factors:								
Livestock production								
Yes	28 (50.9)	1.15 (0.67–1.96)	32 (65.3)	**2.16 (1.18–3.97)**	63 (63.6)	**1.96 (1.30–2.97)**	9 (36.0)	0.62 (0.27–1.41)
No	27 (49.1)	Reference	17 (34.7)	Reference	36 (36.4)	Reference	16 (64.0)	Reference
Corn production								
Yes	49 (89.1)	0.83 (0.32–2.17)	44 (89.8)	0.87 (0.34–2.23)	82 (82.8)	0.47 (0.28–0.80)	23 (92.0)	1.15 (0.27–4.89)
No	6 (10.9)	Reference	5 (10.2)	Reference	17 (17.2)	Reference	2 (8.0)	Reference
Hay production								
Yes	40 (72.7)	1.19 (0.64–2.22)	33 (67.3)	0.89 (0.48–1.64)	81 (81.8)	**2.01 (1.20–3.35)**	19 (76.0)	1.40 (0.56–3.50)
No	15 (27.3)	Reference	16 (32.7)	Reference	18 (18.18)	Reference	6 (24.0)	Reference
Soybean production								
Yes	43 (78.2)	0.57 (0.29–1.13)	39 (79.6)	0.60 (0.29–1.22)	86 (86.9)	1.07 (0.59–1.92)	20 (80.0)	0.64 (0.24–1.71)
No	12 (21.8)	Reference	10 (20.4)	Reference	13 (13.1)	Reference	5 (20.0)	Reference

[a]Participants with no injury were included in the analysis as the control group.
[b]column percent [c] unadjusted Odd Ratio (OR); 95% Confidence interval (CI); bolded estimates are significant.

Table 4. Multivariable analysis of the associations between operator and farm-level characteristics with body part injured for the Farm and Ranch Health and Safety Survey, 2018 (n = 4,351)[a].

Variables	Arm/Shoulder [b] OR (95%CI)[b]	Chest/Trunk [b] OR (95% CI)[b]	Back[b] OR (95% CI)[b]	Finger[b] OR (95% CI)[b]	Leg/knee/hip[b] OR (95% CI)[b]
Sex (male vs. female)			0.36 (0.12–1.07)		
Primary occupation (Farm/Ranch vs. other)	3.50 (1.28–9.62)*				
Operation type					
Farm vs. ranch	0.57 (0.29–1.07)				
Both vs. ranch	0.18 (0.03–1.24)				
Full time status (75–100% vs. less than 75%)			**2.12 (1.03–4.34)***		
Livestock production (Yes vs. no)	1.39 (0.85–2.31)	**2.77 (1.13–6.82)**		**2.28 (1.25–4.14)***	**1.69 (1.10–2.59)***
Corn production (Yes vs. no)					
Hay production (Yes vs. no)					**1.71 (1.01–2.92)***

[a]Participants with no injury were included in the analysis as the control group.

[b]Generalized estimating equation (GEE) multivariable analysis was performed separately for each outcome variable shown in the table (column) and adjusted for age and the independent variables (row) that showed a positive association with the outcome variable in the univariable analysis (adjusted OR have been reported in the table for the independent variables included in each model). Based on the univariable analysis, models differ in the type and number of independent variables for each outcome variable included. For example, for the model with Arm/shoulder as outcome variable, the independent variables included age, primary occupation, operation type, and livestock production. Meanwhile, regarding the model with Chest/Trunk as outcome variable, the independent variables included age and livestock production.

[c]OR = adjusted Odds ratio; CI = confidence interval. * Adjusted OR >1.

highest average cost (insurance and out-of-pocket) reported was for injuries affecting the chest/trunk body part. The second highest cost of care involved injuries to the eye/head/neck body site.

Discussion

We found in the univariable analysis that age greater than 45 years was associated with arm/shoulder and leg/knee/hip injury. A study of risk factors for low back injury among Iowa farmers found age less than 45 years as a risk factor for a low back injury (OR = 3.32; 95% CI 1.75–6.20).[12] Studies in farmers have showed conflicting results regarding age as a risk factor for injury, in general.[4,5] The arm/shoulder and leg/knee/hip comprise the largest joints in the body and with age, these joints become prone to injury. We found very high odds of injury to these body sites in older age group, but the confidence intervals of the estimated odd ratios were wide, highlighting an important reminder of the uncertainty of the estimate, and that subsequent studies on the same population could find different estimates.

Furthermore, our univariable analysis yielded an association between gender and back injury. This finding corroborates with the literature where a study reported a higher prevalence of back pain in male farmers[13] and a systematic review found 10 studies that reported a positive association between male gender and agricultural injuries in general.[4] Gender itself may not explain this finding, but rather the difference in farming roles based on gender. Another study reported older age and the duration of tractor operations as predictors of farm-related low back pain.[14]

Our study also found that livestock production was positively associated with injury to the chest/trunk, the finger, and the leg/knee/hip in the adjusted model. Close contact with large farm animals involves situations where workers can be pushed, kicked, bit, stepped on, or run over, and this may explain the association between livestock production and injury to the above-mentioned body parts. Many studies have reported livestock as one of the three leading causes of agricultural injuries along with farm machinery and falls.[15] Kica and Rosenman[16] reported that injuries caused by cows accounted for 31.5% of all non-fatal farm-related injury cases found in 2015–2016 clinical records from all Michigan's hospitals (134).

The most common body part injured in our study was the leg/knee/hip followed by the arm/shoulder. In contrast, Kica and Rosenman[16] reported that an upper limb was the most frequently injured (38.2%) followed by a lower limb (23.7%). Their study did consider risk factors for these body part injuries.

Our analysis also showed that when controlling for age, operators who worked full time (vs. part-time) on the farm/ranch had increased odds of

back injury. Farm work commonly involves heavy lifting and prolonged sedentary field work with machinery, which may cause more back injuries in full-time operators due to increased exposure time.

Eye, head, and neck injuries represented 15.2% of all injuries in our study. We did not find any association between age, gender, and injuries affecting the head and neck area. A hospital-based study that evaluated the epidemiology of farm-related head injuries reported that men and adults aged 40–59 years were frequently affected and falls and tractors were the primary injury source.[17]

Besides livestock production, we did not investigate the primary object that caused injury to a body part; this information was not available for farmers with no injury. In a systematic review of upper limb's injuries, almost 2/3 of the studies reported agricultural machinery as the most frequent cause of farm injuries.[18]

Injury to the chest/trunk resulted in more serious injuries and highest cost of care compared to other body parts. Many of these injuries were caused by livestock, where workers can be pushed by large animals against gates and fences. The chest/trunk encompasses vital organs such as the heart and lungs and injury to those organs is likely to be serious and result in high medical expenses. Jadhav et al.,[7] using a different definition of serious injury found that most serious injuries affected the lower extremity (leg/knee/hip, foot), back, and head. In fact, they defined serious injury as "an injury that resulted in at least half-day of lost work-time, professional medical care (outpatient or hospitalization), and expenses of $1000 USD or greater with out-of-pocket and insurance costs combined."

However, our study showed that injury to any other body part could also be serious. Hence, the need to work safety to prevent the occurrence of injuries in general through ergonomic engineering control, administrative measures, safety training and the use of personal protective equipments.

Strengths and limitations

Our study had the advantage of a relatively large sample size and subjects who reported at least one injury, 4351 participants, 513 of them injured. The availability of farm-level and individual-level variables enabled consideration of a large number of risk factors.

The low response rate (19%) is a limitation to this research. The use of a single language (English) and the lack of incentive may have impacted the participation rate. Although respondent characteristics regarding demographic and farm production factors were similar with non-respondents, differences in injury status that could not be assessed between non-respondent and respondents may have introduced a selection bias in our study resulting in an overestimation of the frequency of our outcome variables.

Conclusions

We conducted this study to identify the risk factors of injuries by affected body part and to determine the frequency of serious injuries per body part injured. To our knowledge, no previous study has done a comprehensive assessment of injuries risk factors by affected body part.

We discovered that the leg/knee/hip and arm/shoulder were most frequently affected by agricultural injuries. Risk factors included the operator's older age and livestock production. Additionally, male gender and full-time farming status predicted higher odds of back injury. Regarding injury severity, the chest/trunk followed by the arm/shoulder resulted in more cases of serious injury requiring professional medical care with lost work time.

Prevention measures should be tailored to protecting all body parts during farming activities and follow the hierarchy of controls from the most effective to the least effective: engineering, administrative, and the use of personal protective equipment (PPE). For engineering control measures, the National Institute for Occupational Safety and Health (NIOSH) recommends for example, the use of newer machinery that have built-in safety features such as tractors with roll-over protective structure (ROPS) and power take-off (PTO) guards. Additionally, to prevent overturn fatalities, NIOSH recommends that manufacturers equip each tractor with a ROPS and a seat belt.[19] Safety training on livestock handling should include modules such as approaching cattle from the proper angle (side

of front) to avoid startling them reducing the risk of injury. Additionally, farmers should be gentle, establish routine, keep their distance, and avoid sudden and loud noise when handling animals.[15] Administrative measures include work rotation, providing break time during the work schedules to reduce exposure to the farm hazard, therefore help prevent the occurrence of farm-related injury.[20] Personal protective equipment (PPE) are the last resort control measures recommended during many farm activities to prevent injury. Common PPE include helmet, goggle, gloves, and protective shoes.[20]

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References

1. United States Bureau of Labor Statistics. Washington (DC). Table 1. Incidence rates of nonfatal occupational injuries and illnesses by selected industry and case types, private industry. https://www.bls.gov/news.release/osh.t01.htm. February 28 2021.
2. United Bureau of Labor Statistics. Washington (DC). Number and rate of fatal work injuries, by industry sector. https://www.bls.gov/charts/census-of-fatal-occupational-injuries/number-and-rate-of-fatal-work-injuries-by-industry.htm. February 07 2021.
3. Rautiainen RH, Ohsfeldt R, Sprince NL, et al. Cost of compensated injuries and occupational diseases in agriculture in Finland. *J Agromedicine*. 2005;10(3):21–29. doi:10.1300/j096v10n03_03. PubMed PMID: 16537313.
4. Jadhav R, Achutan C, Haynatzki G, Rajaram S, Rautiainen R Risk factors for agricultural injury: a systematic review and meta-analysis *J Agromedicine* 2015 Oct 2;20 4 434–449 10.1080/1059924X.2015.1075450
5. Jadhav R, Achutan C, Haynatzki G, Rajaram S, Rautiainen R Review and meta-analysis of emerging risk factors for agricultural injury *J Agromedicine* 2016 Jul 2;213 284–297 10.1080/1059924X.2016.1179611
6. Day L, Voaklander D, Sim M, et al. Risk factors for work related injury among male farmers. *Occup Environ Med*. 2009 May 1;66(5):312–318. doi:10.1136/oem.2008.040808.
7. Jadhav R, Achutan C, Haynatzki G, et al. Injury risk factors to farm and ranch operators in the Central United States. *Am J Ind Med*. Oct 2017;60(10):889–899. doi:10.1002/ajim.22757.
8. Rautiainen RH, Ledolter J, Donham KJ, et al. Risk factors for serious injury in Finnish agriculture. *Am J Ind Med*. May 2009;52(5):419–428. doi:10.1002/ajim.20688.
9. Ahn JY, Ryoo HW, Park JB, et al. Epidemiologic characteristics of work-related eye injuries and risk factors associated with severe eye injuries: a registry-based multicentre study. *Ophthalmic Epidemiol*. Apr 2020;27(2):105–114. doi:10.1080/09286586.2019.1683868.
10. DTN [Internet]. Make the right business decisions in an ever-changing landscape. https://www.dtn.com/agriculture/agribusiness/?utm_source=website&utm_medium=redirect&utm_campaign=farmmarketid. November 18 2021.
11. Occupational Safety and Health Administration (OSHA). Osha injury and illness recordkeeping and reporting requirements. https://www.osha.gov/recordkeeping. October 10 2021.
12. Sprince N, Park H, Zwerling C, et al. Risk factors for low back injury among farmers in Iowa: a case-control study nested in the agricultural health study. Occup Environ Hyg. 2007 Jan 1;4(1):10–16. 10.1080/15459620601067266
13. Xiang H, Stallones L, Keefe TJ Back pain and agricultural work among farmers: an analysis of the Colorado farm family health and hazard surveillance survey. *Am J Ind Med*. 1999 Mar;35(3):310–316. doi:10.1002/(SICI)1097-0274(199903)35:3<310::AID-AJIM12>3.0.CO;2-D.
14. Essien SK, Bath B, Koehncke N, Trask C Saskatchewan farm injury cohort study team. association between farm machinery operation and low back disorder in farmers: a retrospective cohort study. *J Occup Environ Med*. 2016 Jun;58(6):e212–7. doi:10.1097/JOM.0000000000000746.

15. Dogan KH, Demirci S. *Livestock production: Livestock-handling related injuries and deaths*. Rijeka (Croatia): InTech; 2012.
16. Kica J, Rosenman KD Multisource surveillance for non-fatal work-related agricultural injuries *J Agromedicine* 2020 Jan 2 251 86–95 10.1080/1059924X.2019.1606746
17. Paton GR, Hagel L, Fourney DR Hospitalized head and spine injuries on Saskatchewan farms. *Can J Neurol Sci*. 2014 Jul;41(4):436–441. doi:10.1017/S031716710001845X.
18. Mucci N, Traversini V, Lulli LG, Baldassarre A, Galea RP, Arcangeli G upper limb's injuries in agriculture: a systematic review *Int J Environ Res Public Health* 2020 Jun 23 1712 4501 10.3390/ijerph17124501
19. Centers for Disease Control and Prevention. National Institute for Occupational Health and Safety (NIOSH). Agricultural Safety. https://www.cdc.gov/niosh/topics/aginjury/crops/default.html. 2021 February 20 2022.
20. Centers for Disease Control and Prevention. National Institute for Occupational Health and Safety (NIOSH). Hierarchy of Controls. https://www.cdc.gov/niosh/topics/hierarchy. February 20 2022.