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An initial analysis of agricultural trauma in South Dakota with an emphasis on work-related injuries

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Cover Page Footnote

INTRODUCTION

Agriculture continues to represent a sector with significant hazards for its workers. In 2017, the United States (U.S.) Bureau of Labor Statistics (BLS) reported 581 fatalities and 47,200 non-fatal occupational injuries that occurred within the agriculture, forestry, fishing, and hunting industry nationwide.[1,2] The rate of fatal work injuries in this sector of the U.S. was noted to be 23.0 per 100,000 full-time equivalent workers.[3] The Midwestern U.S. is well-known for its agricultural contributions to the U.S. economy. Of these states, South Dakota is a rural state in which the agricultural sector supplies 22% of jobs for its workers and has contributed $11.2 billion in total value-added in the year 2019.[4] Furthermore, the sale of agriculture products in 2017 from South Dakota accounted for 3% of total U.S. agriculture sales.[5]

Despite the continued growth of the agricultural industry and its economic impact in South Dakota, there is no established surveillance system for non-fatal agricultural injuries. The U.S. BLS conducts a census of fatal occupational injuries (CFOI) in every state as well as a survey of occupational injuries and illnesses (SOII) in the majority of states. However, South Dakota is one of only six states in which SOII data is not collected.[6]

Other states such as Michigan, Iowa, and Nebraska have designed their own monitoring programs to trend work-related agricultural injuries.[7,8,9] One study in Michigan noted 879 non-fatal work-related injuries identified from data collected at state hospitals that were not identified by the BLS SOII in 2015 and 2016 for Michigan.[7] In Nebraska, the Central States Center for Agricultural Safety and Health created a database to use media reports to track agricultural injuries and fatalities.[9] Our study was modeled after the surveillance systems in Iowa and Michigan, relying on data from the South Dakota Trauma Registry.[8,9] The objective of this study was to conduct a preliminary analysis of trends in agricultural traumatic events in South Dakota

with an emphasis on those which are work-related. To date, no other publication has disclosed

such information for the state of South Dakota, which is especially significant in light of South

Dakota not being represented on the federal level through the BLS SOII.

METHODS

Data Collection

Data elements were requested from the South Dakota Trauma Registry, which is maintained by the South Dakota Department of Health. The SD Trauma Registry collects data from all state trauma centers in South Dakota, which range from Level II-V facilities. IRB approval was not required for this study because data elements were deidentified. A set of ICD-9 and 10 codes were used to determine which injuries from 2016-2018 were agricultural-related, representing the raw data (Table SI).[7,10,11]

The raw data was sorted based on whether the injury was work-related, defined as an injury occurring during paid employment.[12] Duplicate entries were removed by cross-referencing name and date. The resulting work-related agricultural trauma events were coded manually, with attention to job, job-type, mechanism of injury, and injury place to ensure the injuries of interest occurred in the line of agricultural work. Agricultural work involved handling, producing, processing, transporting, or warehousing of farm commodities. Farm commodities included crops and animals.[8]

The total number of traumatic events was calculated for the study time period for the raw data and work-related data subset. These events were categorized by the following: patient demographics, mechanism and setting of injury, injury description and type, injury severity score (ISS), facility level, region, and season. Place of injury was manually coded to combine redundant categories. Dates of traumatic injury were categorized into one of four seasons (fall, spring, summer, or winter), which was determined by the solstice and equinox dates occurring over the data collection period.[13]

ISS is an anatomical score which was designed by Baker *et al* in 1974 to generate an overall indicator of injury severity to better estimate the likelihood of mortality in trauma patients. [14,15] The ISS is derived from the Abbreviated Injury Scale (AIS), which takes into account the body region of a sustained traumatic injury and its severity on a six-point scale, where 1= minor, 2= moderate, 3=serious, 4=severe, 5= critical, and 6=virtually unsurvivable. The body is divided into six regions (head/neck, face, abdomen, chest, extremities, and external), and an AIS is assigned to each body region. The highest AIS scores in the three regions which are considered most severely injured are then squared and summed to calculate the ISS. The ISS ranges from 1-75, with higher scores reflecting greater odds of mortality.

Rate of change in agricultural workforce

In order to calculate an agricultural traumatic event rate from 2016-2018, the rate of change in the agricultural workforce in South Dakota was estimated over the same time period. The number of hired workers and farm operators/producers was summed from the South Dakota Census of Agriculture, which is conducted every five years by the National Agricultural Statistics Service. According to two censuses, there was a combined total of 76,186 hired workers and farm operators in 2012, and 75,461 combined hired workers and producers in 2017. [16,17] Two censuses were included to trend the South Dakota agricultural workforce over time. An annual rate of change was calculated from these two data points over five years, which showed a decrease of 145 hired workers and operators/producers per year.

Of note, the inclusion of unpaid laborers into each total (101,434 for 2012 and 102,371 for 2017) shows a trend with a growing rather than shrinking workforce, displaying an annual increase of 187 hired workers, unpaid workers, and operators/producers. In other words, the total number of hired workers and farm operators/producers over this time period is decreasing,

whereas the number of unpaid workers is increasing sufficiently to enlarge the workforce, generating a net increase of 332 people annually. Despite this difference in rate of change, unpaid workers were excluded from the sum total of agricultural workers to remain consistent with this study's definition of work-related injuries. The average change of 145 fewer hired workers and operators/producers per year was applied to each study year (2016-2018).

Statistical analysis of traumatic event rate

The work-related agricultural traumatic event rates for Level II, III, IV, and V trauma facilities were calculated as the number of work-related traumatic agricultural events divided by the annual estimated number of hired workers and farm operators/producers for the years 2016-2018. While the majority of individuals presented with multiple injuries from the presenting traumatic event, injury rate was calculated based on the number of traumatic events rather than the total number of injuries to better estimate the frequency of agricultural trauma. Rate ratios and 95% confidence intervals were calculated using the year 2016 as the reference.

To model the traumatic event rate as a function of time (year), negative binomial regression was used. The number and proportion of traumatic events were examined for each year by age, gender, mechanism of injury, and type of injury. To examine trends in agricultural injuries according to severity, the data was stratified using injury severity score (ISS). Trends in minor injuries (ISS 1–8), moderate injuries (ISS 9–15), severe/critical injuries (ISS 16+) were explored separately. Figures 1-3 were generated in R.

RESULTS

A total of 801 agricultural traumatic events were identified between 2016 and 2018, with 231 of these events categorized as work-related. Twelve events were excluded either due to missing data fields or job and job-type categories which were unable to clearly meet the study definition of agricultural work. The resulting 219 events met the study criteria for agricultural work-related traumas. Despite the apparent decline of the workforce each year, the number of work-related injuries has increased over each study year (Figure 1). The agricultural traumatic event rate increased annually, from 71.42 per 100,000 workers in 2016 to 98.06 in 2017, representing an increase of 37.3%, and up to 120.82 in 2018, representing an additional 23.2% (Figure 2).
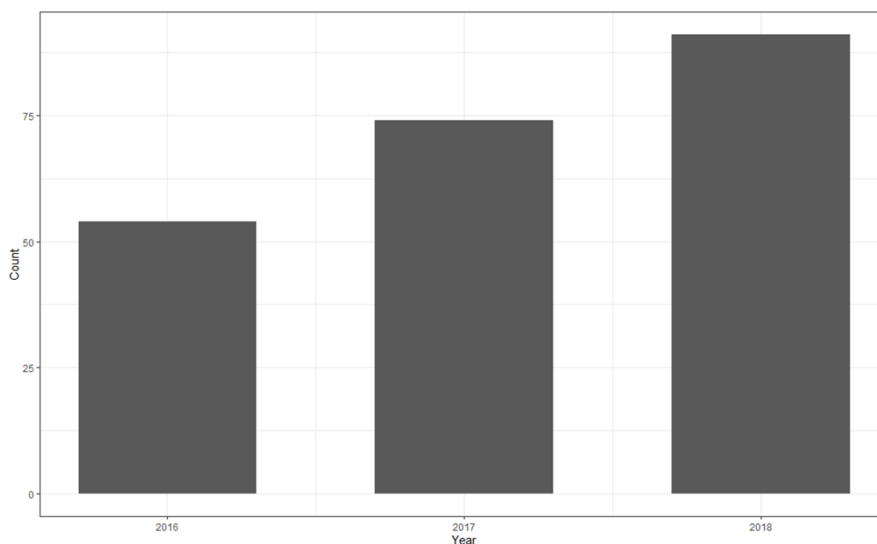
Figure 1. Annual incidence of work-related traumatic agricultural events requiring trauma care in South Dakota, 2016-2018

Facility Reporting

South Dakota is divided into four regions by the SD Trauma Registry, with a total of 49 trauma facilities statewide.[18] In 2016, three facilities were identified as not reporting data to the SD Trauma Registry due to technical complications. Upon correction of these limitations, 98.0% of facilities reported in 2017, with only one trauma facility not reporting. By 2018, 100% of state

trauma facilities were reporting data to the SD Trauma Registry (Table 1). The increase in the number of facilities reporting in regions 3 and 4 may influence the trend of injury rates from 2016-2018. Collecting more data from subsequent years will allow a more accurate assessment of the traumatic injury rate.
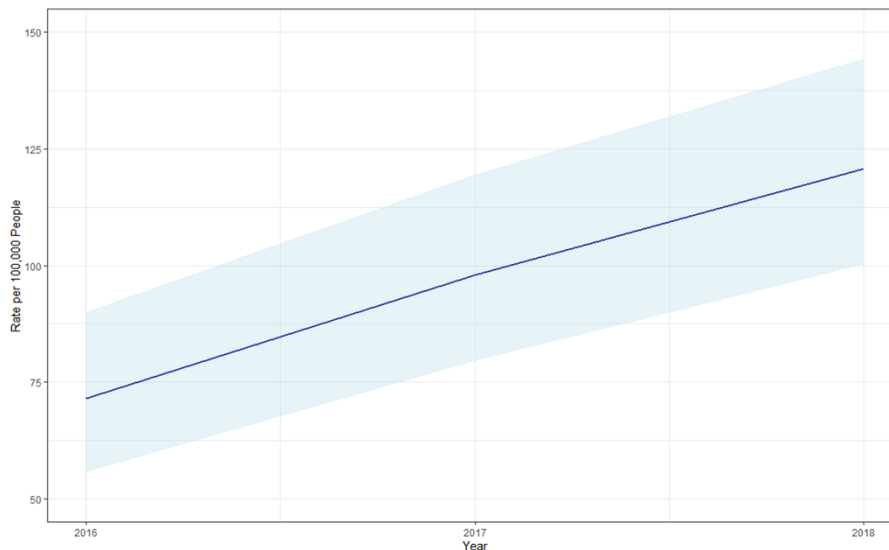
Figure 2. Work-related agricultural traumatic event rate per 100,000 hired workers and farm operators/producers, 2016-2018

Patient demographics

Patient-specific data revealed the vast majority of individuals who sustained agricultural trauma were white males, both in the raw data and work-related subset (Table II). Over the course of the study, men became a significantly increasing proportion of the individuals who sustained work-related agricultural injuries (p=0.043, see Table III). There was not a significant change in rate of injury in any age group. However, the age group 19-65, which accounted for the majority of traumatic events each year, may show a significant increase with another year of data (Table III). The average age of both datasets was similar, at 43.3 for the raw data and 49.2 for the work-related subset. Within the raw-dataset, 20.1% of patients triaged with an agricultural injury were between the ages of 0 and 18 years. In the work-related dataset, only 3.2% of patients were in this age category (Table II).

Table I. Trauma facilities reporting by region in South Dakota, 2016-2018

Year	Region	Facility Level	Number reporting	Number not reporting	Total Number
2016	1	II	1	0	1
		III	NA	NA	NA
		IV	2	0	2
		V	6	0	6
	2	II	NA	NA	NA
		III	1	0	1
		IV	1	0	1
		V	8	0	8
	3	II	2	0	2
		III	0	1	1
		IV	2	0	2
		V	12	1	13
	4	II	NA	NA	NA
		III	NA	NA	NA
		IV	3	1	4
		V	8	0	8
2017	1	II	1	0	1
		III	NA	NA	NA
		IV	2	0	2
		V	6	0	6
	2	II	NA	NA	NA
		III	1	0	1
		IV	1	0	1
		V	8	0	8
	3	II	2	0	2
		III	1	0	1
		IV	2	0	2
		V	13	0	13
	4	II	NA	NA	NA
		III	NA	NA	NA
		IV	3	1	4
		V	8	0	8
2018	1	II	1	0	1
		III	NA	NA	NA
		IV	2	0	2
		V	6	0	6
	2	II	NA	NA	NA
		III	1	0	1
		IV	1	0	1
		V	8	0	8
	3	II	2	0	2
		III	1	0	1
		IV	2	0	2
		V	13	0	13
	4	II	NA	NA	NA
		III	NA	NA	NA
		IV	4	0	4
		V	8	0	8

Hospital disposition was assessed for all patients, with the majority of both datasets able to discharge home without services (56.5% and 50.2% for raw data and work-related respectively). Over the study time period, 13 individuals died after the traumatic event, with 7 of these deaths classified as work-related (Table II). The 2017 CFOI attributes six of 30 fatal occupational injuries in South Dakota to agriculture, forestry, fishing, and hunting.[19]

Table II. Characteristics of all patients with agricultural injuries in South Dakota, 2016-2018

		Raw Data Number (%)	Work-related Number (%)
Total cases		801	219
Age (years)	Average age	43.3	49.2
	0-2	8 (1.0)	NA
	3-5	24 (3.0)	NA
	6-10	52 (6.5)	NA
	11-15	46 (5.7)	NA
	16-18	31 (3.9)	7 (3.2)
	19-29	101 (12.6)	34 (15.5)
	30-49	155 (19.4)	54 (24.7)
	50-64	211 (26.3)	79 (36.1)
	65-80	151 (18.9)	38 (17.4)
	>80	20 (2.5)	6 (2.7)
	Unknown	2 (0.2)	1 (0.5)
Gender	Male	604 (75.4)	203 (92.7)
	Female	196 (24.5)	15 (6.8)
	Unknown	1 (0.1)	1 (0.5)
Race	White	687 (85.8)	198 (90.4)
	American Indian	60 (7.5)	5 (2.3)
	Asian	9 (1.1)	3 (1.4)
	Hispanic*	8 (1.0)	6 (2.7)
	Black	1 (0.1)	NA
	Unknown	36 (4.5)	7 (3.2)
Hospital disposition at DC/transfer	Home w/o services	453 (56.5)	110 (50.2)
	Inpatient care	243 (30.3)	71 (32.4)
	Rehab/long-term care	27 (3.4)	13 (5.9)
	Skilled nursing facility	25 (3.1)	7 (3.2)
	Home w/ services	15 (1.9)	4 (1.8)
	Died	13 (1.6)	7 (3.2)
	Intermediate care facility	7 (0.9)	1 (0.5)
	Left against medical advice	2 (0.2)	1 (0.5)
	Unknown	16 (2.0)	5 (2.3)

*The authors of this study are aware that identifying a person as Hispanic falls under ethnicity rather than race, however Hispanic was recorded as a racial category at the triaging facilities.

Our 2017 data demonstrates two deaths which are attributed to working in agriculture. The job type of 88.6% of those sustaining work-related injuries during the study period pertained to agriculture, forestry, and fishing (Table IV). However, hunting was not included in the present study and may explain the difference between the 2017 CFOI data and this study's fatality data for 2017.

Injury characteristics

The large majority of traumatic events for both the raw data and work-related subset were classified as blunt trauma, with amputation/crushing/other injury making up the largest category of work-related injury type, followed by fracture (Tables III and V). Fracture injuries showed a significant increase over time (p<0.001) while burn injuries showed a significant decrease over the study period (p<0.001). The most common mechanism of work-related injury was different for each study year, with none of the mechanisms showing a significant trend over time. However, machinery and transportation injuries are increasing with marginal significance, and another year of data may generate a significant trend (Table III).

Each year, roughly half of all traumatic events generated an ISS between 1 and 8 (Table V, Figure 3). Over the study period there is a decrease in the percentage of injuries with an ISS of 16 or greater (Figure 3). Differences in injury coding training among rural facilities with lower patient volume and the frequent need to transfer trauma patients to higher level trauma facilities before a full catalog of injuries is performed may cause variations in ISS reporting. The top three areas where traumatic events occurred, totaling more than 75% of events, were "other farm location", "farm field", and "barn" (Table V).

Table III. Annual number of work-related injuries in South Dakota by age group, gender, mechanism, and type with regression estimates, 2016-2018

		2016 total (%)	2017 total (%)	2018 total (%)	Intercept	Slope	p-value of slope
Age	0-18	2 (3.7)	2 (2.7)	4 (4.4)	0.67	1.00	0.333
	19-65	38 (70.3)	59 (79.7)	73 (80.2)	21.67	17.50	0.073
	66-80	12 (22.2)	11 (14.9)	12 (13.2)	11.67	0.00	1.000
	80+	2 (3.7)	2 (2.7)	2 (2.2)	2.00	0.00	1.000
Gender	Male	50 (92.6)	69 (93.2)	84 (92.3)	33.67	17.00	0.043*
	Female	4 (7.4)	5 (6.8)	6 (6.6)	3.00	1.00	<0.001*
Mechanism	Machinery	4 (7.4)	7 (9.5)	11 (12.1)	0.33	3.50	0.052
	Fall	12 (22.2)	16 (21.6)	16 (17.6)	10.67	2.00	0.333
	Transportations	6 (11.1)	12 (16.2)	22 (24.2)	-2.67	8.00	0.091
	Struck by/Against	9 (16.7)	28 (37.8)	19 (20.9)	8.67	5.00	0.647
	Natural/Environment	1 (1.9)	0 (0.0)	0 (0.0)	1.33	-0.50	0.333
	Cut/pierce/fire/burn/assault/suicide/firearm/undetermined	5 (9.3)	1 (1.4)	1 (1.1)	6.33	-2.00	0.333
	Other specified/unspecified	17 (31.5)	10 (13.5)	22 (24.2)	11.33	2.50	0.728
Type	Fracture	20 (37.0)	34 (45.9)	48 (52.7)	6.00	14.00	<0.001*
	Head injury/SCI/Nerves	6 (11.1)	16 (21.6)	21 (23.1)	-0.67	7.50	0.121
	Amputation/crushing/other injury	23 (42.6)	12 (16.2)	10 (10.1)	28.00	-6.50	0.242
	Open Wound	1 (1.9)	3 (4.1)	4 (4.4)	-0.33	1.50	0.121
	Internal organ/BV injury	1 (1.9)	4 (5.4)	6 (6.6)	-1.33	2.50	0.073
	Burn	2 (3.7)	1 (1.4)	0 (0.0)	3.00	-1.00	<0.001*
	Dislocation/Sprain	1 (1.9)	3 (4.1)	2 (2.2)	1.00	0.50	0.667

Abbreviations: SCI = spinal cord injury, BV = blood vessel
*Rate of change significantly different compared to other injury or patient characteristics

Table IV. Job and job types of injured agricultural workers in South Dakota, 2016-2018

		Number (%)
Job	Farming, fishing, and forestry occupations	179 (81.7)
	Architecture and engineering occupations	13 (5.9)
	Construction and extraction occupations	6 (2.7)
	Transportation and material moving occupations	4 (1.8)
	Installation, maintenance, and repair occupations	4 (1.8)
	Sales and related occupations	3 (1.4)
	Production occupations	1 (0.5)
	Life, physical, and social science occupations	1 (0.5)
	Arts, design, entertainment, sports, and media	1 (0.5)
	Other	5 (2.3)
	Unknown	2 (0.9)
Job Type	Agriculture, forestry, fishing	194 (88.6)
	Other Services	8 (3.7)
	Construction	6 (2.7)
	Manufacturing	2 (0.9)
	Natural resources and mining	1 (0.5)
	Transportation and public utilities	1 (0.5)
	Unknown	7 (3.2)

Comparing the raw data to the work-related subset, injuries occurred more commonly during the summer and spring months in the larger population, but more commonly in the spring and fall for those injuries which were work-related (Table V). One explanation is that the relatively large proportion of pediatric injuries in the raw data-set (20.1%) compared to the work-related dataset (3.2%) is reflected in the seasonality of injuries, as children are home on the farm during the summer months and in school the rest of the year (Table II).

The largest proportion of patients in both data sets were seen at Level II trauma facilities, although the patients with work-related injuries were more evenly distributed amongst Level II, IV, and V facilities. Furthermore, the majority of patients went to facilities located in region 3, representing the Eastern portion of the state (Table V, Figure 4). Using the 2018 county and state U.S. Census Data for South Dakota, the total population was 882,235, distributed among 66 counties. Within region 3 alone resides 49.9% of the total state population, even with the exclusion of Charles Mix county from the 19 other counties within region 3.[20] The high

population density in region 3 may well explain why the majority of patients who sustained

agricultural injuries were provided care at those facilities.

Table V. Characteristics of all agricultural injuries in South Dakota, 2016-2018

		Raw Data	Work-related
		Number (%)	Number (%)
Total cases		801	219
Injury type	Blunt	745 (93.0)	190 (86.8)
	Penetrating	33 (4.1)	17 (7.8)
	Burn	12 (1.5)	5 (2.3)
	Unknown	11 (1.4)	7 (3.2)
Injury severity score	1 to 8	378 (47.2)	109 (49.8)
	9 to 15	213 (26.6)	47 (21.5)
	16+	82 (10.2)	21 (9.6)
	Unknown	128 (16.0)	42 (19.2)
Place of injury	Other farm location	346 (43.2)	107 (48.9)
	Farm field	229 (28.6)	65 (29.7)
	Barn	58 (7.2)	27 (12.3)
	Sports and athletic area	17 (2.1)	NA*
	Recreation/wilderness area	13 (1.6)	NA
	Other specified places	13 (1.6)	2 (0.9)
	Road/street/highway	11 (1.4)	NA
	Other trade areas	8 (1.0)	5 (2.3)
	Other place on private residence	8 (1.0)	NA
	Industrial/construction area	2 (0.2)	1 (0.5)
	Slaughterhouse	1 (0.1)	1 (0.5)
	Supermarket/store/market	1 (0.1)	1 (0.5)
	Unknown/unspecified place	94 (11.7)	10 (4.6)
Facility Level	II	386 (48.2)	82 (37.4)
	III	45 (5.6)	11 (5.0)
	IV	172 (21.5)	65 (29.7)
	V	198 (24.7)	61 (27.9)
Region	1	186 (23.2)	18 (8.2)
	2	133 (16.6)	48 (21.9)
	3	385 (48.1)	116 (53.0)
	4	97 (12.1)	37 (16.9)
Season	Summer	271 (33.8)	50 (22.8)
	Spring	240 (30.0)	66 (30.1)
	Fall	193 (24.1)	67 (30.6)
	Winter	93 (11.6)	36 (16.4)
	Unknown	4 (0.5)	NA

*This category was excluded from the definition of agriculture work-related injuries as it did not involve the handling, producing, processing, transporting, or warehousing of farm commodities.
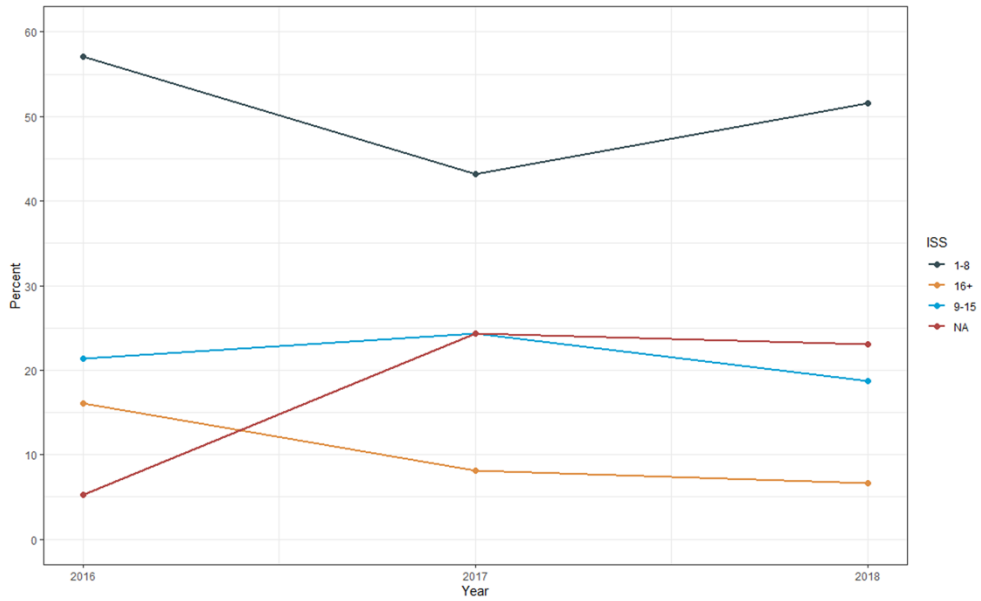
Figure 3. Annual proportion of injuries by injury severity score (ISS), 2016-2018
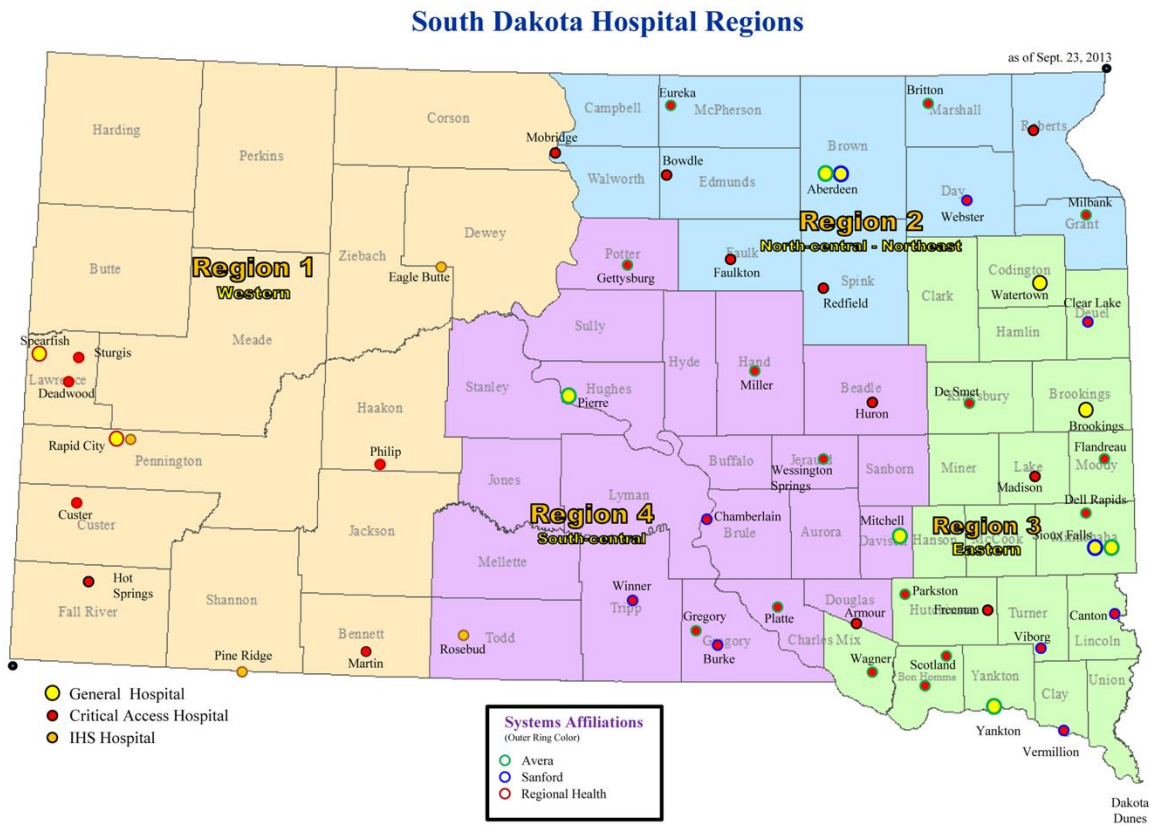

Figure 4. Regional distribution of all hospitals in South Dakota

DISCUSSION

Our study establishes an initial analysis of trends in agricultural injuries occurring in South Dakota for the first time in the state's history. The complete collection of agricultural trauma data by the SD Trauma Registry is quite new, with increased facility reporting between 2016 and 2018. As more data is collected, our local surveillance system can be improved, and further injury trends can be identified.

One of the limitations of the BLS SOII is its exclusion of self-employed owner/operators, family workers, federal government employees, or farms with fewer than 11 employees. According to data from 2017, 83% of farms in South Dakota are owned by families or individuals, with only 1% of farms being held by non-family corporations.[17] Consequently, the SOII is likely to vastly underestimate the number of work-related agricultural injuries if it were implemented in South Dakota. A 2014 study by Leigh, Du, and McCurdy estimated that the SOII missed a startling 77.6% of illnesses and injuries occurring on crop and animal farms nationwide in 2011.[21] Continuing to use data from the SD Trauma Registry to survey and analyze trends in agricultural injuries may be a more effective surveillance system.

Using data from the SD Trauma Registry in our study has allowed for the reporting of agricultural injuries which are treated in one of the state's hospitals without relying on injury reporting from employers. Doing so may avoid underreporting of such injuries by employers who may intentionally or unintentionally fail to report eligible workers' compensation claims.[22] Analysis of our agricultural data enables South Dakota to assess trends in all agricultural traumatic events and is not limited to those which are work-related. Surprisingly, despite the agricultural workforce appearing to decrease every year, the rate of traumatic injury has increased by 37.3% between 2016 and 2017 and by 23.2% between 2017 and 2018. As

mentioned previously, including the number of unpaid workers reverses the rate of change in the workforce from a negative to positive rate, which is something that must be more closely examined.

Future studies could better identify injury patterns and assess outcomes. For example, one Canadian study examined delays in emergency care among those who sustained agricultural injuries and the association of a delay with long-term outcomes such as death or disability following the injury.[23] More data on injury trends, long-term outcomes, and identification of barriers to care will allow for greater understanding of the hardships faced by agricultural workers and better guide efforts aimed at injury prevention.

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