Title
Utilizing Workers' Compensation Claims to Characterize Ergonomically Related Injuries in California Farms

Author
Mendez, Ernesto

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Utilizing Workers' Compensation Claims to Characterize
Ergonomically Related Injuries in California Farms

By

ERNESTO E. MENDEZ

THESIS

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DAVIS

Approved:

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Fadi A. Fathallah, Chair

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Heejung Bang

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Farzaneh Khorsandi

Committee in Charge

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ABSTRACT

California serves as one of leading states in agricultural production in the entire country; it is attributed with planting, cultivating, and harvesting over 400 commodities worth billions of dollars in monetary value. The jobs associated in this industry pose a variety of risks in terms of injuries due to the laborious nature of the tasks performed in this field. Some of the most common injuries are a result of overexertion over prolonged periods. In order to better understand and identify potential ergonomic interventions to prevent these injuries, analysis of injury data is needed to pinpoint the factors that lead to the most prevalent and severe injuries. Utilizing over 6,000 workers' compensation claims reported from 2005 – 2020 by agricultural farming businesses in California, prevalence of injuries, severity, and quantitative trends were characterized from the available data to focus on ergonomically related injuries due to factors such as repetitive motion, lifting, pushing/pulling, etc. Employee age, gender, tenure, nature of injury, injured part of body, and crop type were all analyzed in relation to the total incurred costs for reported claims. Descriptive statistics, chi-square tests, standardized residuals, contingency tables, and regression-modelling techniques were all used to analyze relationships between variables, characterize trends, and express the impact that the most significant of variables had on the total incurred costs. Results indicate that age, tenure, nature of injury and part of body were significantly related to monetary categories for incurred costs. Regression coefficients for age, gender, and part of body injured displayed significant relationships in impacting the log transformation of the total incurred costs for injuries. The results of this study will help in the efforts for better research, design, and implementation of risk reduction procedures and interventions in agriculture.

INTRODUCTION

Agriculture in California is one of the most important industries in the United States. The state accounts for over a third of the country's vegetables and two-thirds of the country's fruits and nuts. It is the leading state for cash farm receipts paid out to farmers and ranchers with an amount of over $50 billion dollars, which accounts for over 13 percent of the nation's total agricultural value [1]. The demographics of the workforce needed to meet the needs of this multi-billion-dollar industry consists of mainly Hispanic immigrant ethnic groups [2]. Due to the composition of this workforce and the nature of the work conducted, many risk factors have been identified in relation to injuries that are commonly sustained while performing the various tasks required to plant, cultivate, and harvest a wide variety of crops. Some of the common personal risk factors include gender, place of birth, and income, while some of the associated injuries include falls, cuts, being struck by an object, and motor vehicle incidents [2]. However, this is not an all-encompassing list that covers the variety of work injuries that one can encounter in this industry.

Nonfatal and fatal injuries in the workplace serves as a multibillion-dollar cost that encompasses a wide range of losses including, but not limited to, medical, indemnity, time loss, wage compensation, fringe benefits, home production, etc. [3-4]. In 2007, the economic burden of these workplace injuries was estimated to be $6 billion for more than 5,600 fatal injuries and $186 billion for more than 8,559,000 nonfatal injuries within the United States [5]. When looking at the impact injuries in agriculture had in the state of California, we see that in a study conducted in 1992, 1.645 million nonfatal injuries surmounted to an estimated $17.8 billion. This estimate in itself was considered conservative for its time as it did not take into account costs associated with pain/suffering, home care, and unaccounted reported injuries [6]. During the same period, agricultural injuries within the United States cost an estimated $4.57 billion, which was calculated by utilizing resources such as national surveys and data from the Bureau of Labor Statistics [3]. More studies that focus on the agricultural industry in California are needed to better indicate the modern impact that injuries have on the workforce today. However, the availability of this injury data in agriculture serves as a continuing challenge. Not only are we limited to few public resources for data analysis, but we also face the problem of underreporting, and hence undercounting, of workplace injuries. In 2011, an estimated 143,436 cases of nonfatal occupational injuries in agriculture were calculated to have been unaccounted for in the United States [7]. That study also utilized public data such as the Survey of Occupational Injuries and Illnesses (SOII), the Quarterly Census of Employment and Wages, and the Current Population Survey from U.S. government sources. While these sources have been valuable, much of the data provided by the U.S. Bureau of Labor Statistics (BLS) have been noted in the past for their limitations and shortcomings. For example, BLS data does not provide detailed information like causative factors that lead to injury, and scientific literature suggests that BLS data also significantly underreports work-related injuries, missing between 61% and 88% of non-fatal injuries [7-8].

Utilizing other sources of data and records would help to address this issue by identifying more cases and information to better research, design, and implement risk reduction procedures and interventions in agriculture. With such a high frequency and cost of work-related injuries, a workers' compensation system is commonly used to assume most of the costs related to work-related illnesses and injuries, regardless of fault [9]. In California, all employers must provide workers' compensation benefits to their employees under the Labor Code Section 3700. Employers have the option of purchasing insurance from either a licensed company, through the

State Compensation Insurance Fund, or self-insure upon state approval [10]. Benefits of this insurance can include medical care, temporary disability benefits, permanent disability benefits, supplemental job displacement benefits, and death benefits [10]. Data from workers' compensation can be useful for conducting research on occupational injuries and illnesses. The way workers' compensation records are collected is consistent with the needs of safety surveillance programs, which can provide information that is usually unavailable through national surveillance sources. These records contain information on medical treatments, costs, outcomes, specific injuries, classes of injuries, cause of disability, duration, and narratives on the incidents that led to injury [11]. All these variables are useful in conducting studies that can quantify risk through monetary amounts and identify factors that indicate what population of workers is more susceptible to the most severe injuries.

The high costs that these workers' compensation claims incur underline the need to better identify, understand, and implement interventions to mitigate the risk factors that lead to these injuries. One area that serves to prevent the incidence of injuries in the agricultural workforce is that of ergonomics. Ergonomics is defined as the science of fitting workplace conditions and job demands to the capabilities of the working population [12]. The Center for Disease Control and Prevention (CDC) and the Occupational Safety and Health Administration (OSHA) refer to ergonomic injuries as primarily musculoskeletal disorders (MSDs), or injuries or disorders of the muscles, nerves, tendons, joints, cartilage, and spinal discs [13]. MSDs may also be known as or encompass the following types of injuries: repetitive stress injuries (RSIs), repetitive motion injuries (RMIs), cumulative trauma disorders (CTDs), or cumulative trauma injuries (CTIs) [14]. Ergonomic injuries are injuries caused by exposure to ergonomic risk factors such as duration, compression or contact stress, awkward positioning or posture, exposure to vibrations or abnormal temperatures, repetition, and forceful exertion or pressure upon a particular body part [15]. The prevalence of these musculoskeletal disorders in agriculture have been difficult to pinpoint due to a variety of reasons. These include unrequired reporting for farming operations with a low number of employees, differences in workers' compensation coverage by state, and nonreporting due to fear from the employee of losing their job. In 2008, the rate for injuries and illnesses in agriculture were, however, calculated to be 5.3 injuries per 100 workers, which was higher than the rates you would find in construction, manufacturing, and goods producing industries [16]. The rate of injuries in agriculture was in itself a conservative estimate that underscores the need to tackle high risk factors such as lifting and carrying heavy loads, sustained or repeated trunk bending, and highly repetitive hand work [16-17]. Another study found that in California, 24% of farm workers reported at least one MSD in 2003-2004, with increases in these cases each year since 1999 [18]. Due to the manual labor-intensive demand of agricultural work, ergonomic interventions are needed to implement best practices and equipment to prevent the onset of injuries.

There have been few studies where ergonomically related injuries have been linked to workers' compensation claims in agriculture. The purpose of this study was to characterize the severity and trends of injuries in California agriculture through total incurred costs of workers' compensation claims. This was accomplished through looking at the relationships of the variables of "crop type worked on", gender, "part of body" injured, "nature of injury," employee age at injury, and employee tenure. Utilizing descriptive statistics, chi-square tests of association, standardized residuals, and regression models, we sought to find out which variables are significantly related to the total incurred costs per injury claim. This allows for the identification of risk factors that lead to the most severe of injuries, where targeted ergonomic interventions can have the most impact.

METHODS

Data Source

The dataset used in this study was obtained from a large private insurance company headquartered in a Western state of the United States. The company insures a large number of workers in the agricultural industry. In order to focus on ergonomically related injuries, the parent data set, which contained a total of 24,003 claims in California, was first filtered by "nature of injury" to narrow our scope in accordance with the definition of ergonomic injuries from OSHA and the CDC. Once identified, the nature of injury was further filtered by "nature of accident," "part of body," and "accident description." These variables provided the invaluable information along with the injury (accident) description, which revealed detailed information about the specifics of the incident, including accident narrative and body part(s) involved. This allowed for a more granular understanding of which injuries truly had an ergonomic factor to them. The final filtered data resulted in a total of 6,307 claims dated from March 2005 to February 2020, which were analyzed in this study. For more detailed information on the data set filtering process, please refer to appendix A. Furthermore, an additional variable of employee's "tenure" was calculated as the difference between the date of hire and the injury date. This provided information on how long (in years) an employee had been working at the company before sustaining the injury. A full list of the variables examined in this study is shown in Table 1. The "total incurred" cost (variable 11 in Table 1) was considered as the main outcome of interest, as this variable serves as a proxy measure of severity [19-21].

Table 1. List of Variables in Dataset.

No.	Variable	Description
1	Crop Type	Vineyard, Orchard/Grove, Berry
2	Date of Injury	Date on which the injury occurred
3	TD Day	Temporary disability days
4	Date of Hire	Date on which the present company hired the injured worker
5	Gender	Gender of injured worker
6	Date of Birth	Date of birth of injured worker
7	Claim Type	Type of Claim: Indemnity or Medical
8	Claim Status	Status of the Claim: Open, Closed, or Re-Opened
9	Age at Injury	The age of the injured worker at the time of injury
10	Accident Description	Short vignette of incident resulting in injury, e.g., "Employee was lifting a twenty-pound box of strawberries from the conveyor belt when she felt pain in lower back."
11	Total Incurred (Outcome)	Total monetary cost incurred to include medical, indemnity, and miscellaneous payments.
12	Medical Incurred	Monetary cost for just medical
13	Indemnity Incurred	Monetary cost for just indemnity
14	Nature of Injury	Describes the type of injury such as strain, sprain, hernia, etc.
15	Part of Body	Body part(s) injured
16	Nature of Accident	Main cause of injury, e.g., "Lifting, pushing, reaching, repetitive motion, etc."

Data Analysis

Many of the variables listed in Table 1 are categorical variables. Hence, initial analysis in the form of descriptive statistics began with frequencies/counts, percentages, contingency tables, and graphs. Descriptive statistics provide a quick overview of the set of data without having to consider each individual observation, which allows for the construction of figures and tables that help identify patterns and trends [22]. This served as the first step into identifying common injury types, costs over time, and distribution of claims over each variable. For example, Figure 1 and 2 provide example graphs created from the parent dataset with the 24,003 claims, and the focused dataset with 6,307 claims, respectively, which exhibit the frequencies of injuries by month. The trends that we see here are an increase of injuries occurring for both datasets in the spring and summer months, with a lower frequency of injuries during the Fall and Winter months.

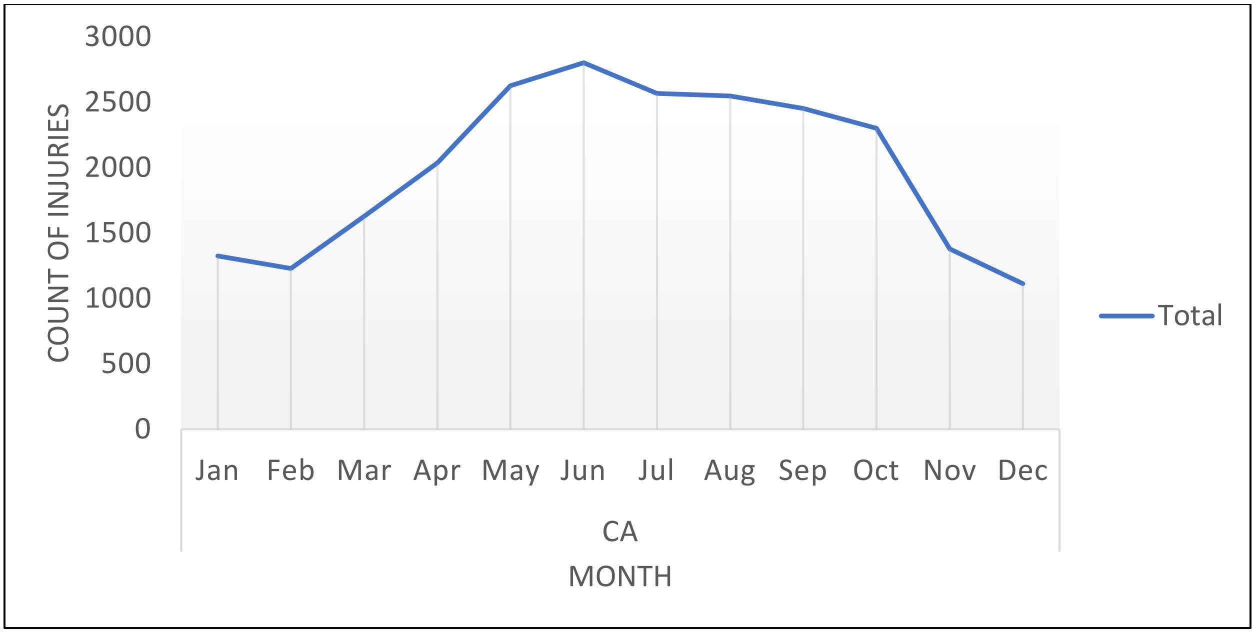

Figure 1. Frequencies of Injuries by Month from Parent Dataset.

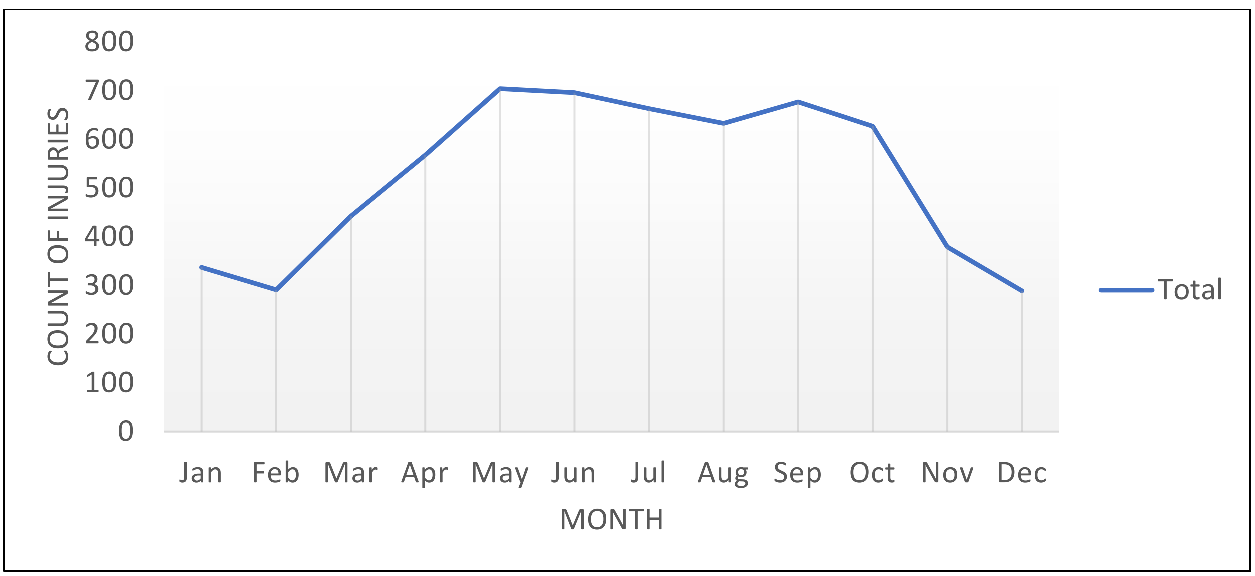

Figure 2. Frequencies of Injuries by Month from Focused Dataset.

The chi-square test of association was used to identify the dependence of the response variable of total incurred to the predictor variables of “crop type,” gender, “part of body”, “nature of injury,” age, and tenure. Categories for total amount incurred and age were created based off similar studies done utilizing workers’ compensation data [8, 23]. Claim amount categories were less than $3,000, $3,000 to $9,999, and greater than or equal to $10,000. Age categories began with less than or equal to 25 years old and increased, in increments of 5 years, until reaching the age of 60 or greater. After looking at contingency tables and calculated expected variables, standardized residuals were calculated between total amount incurred categories and the explanatory variables of interest.

The chi-square test of association operates under the null hypothesis of statistical independence between two variables with an alternative hypothesis of statistical dependence. The test statistic is calculated by taking the summation of the squared difference between observed and expected values divided by the expected values where the expected values are calculated using row and column totals over the entire sample size [24]. The p-value is then calculated and represents the right-tail probability of the observed chi-squared test statistic for a chi-square distribution with degrees of freedom (df):

$$df = (r - 1)(c - 1)$$

where, r is the number of rows and c is the number of columns

After conducting the test of association, the next step would be to identify the nature and strength of the association between the dependent and independent variables of interest. Standardized residuals can provide the information of when a residual is large enough to indicate a departure from independence that is unlikely due to chance [24]. The standardized residual is calculated as the difference between the observed value and expected value of a variable divided by its standard error [24]. A residual is positive when the observed frequency is greater than the expected frequency, which indicates that we see a greater than expected value for that row and column observation. On the other hand, a negative residual is shown when the expected frequency is greater than the observed frequency, which indicates that we see a less than expected value for that row and column observation. The formula for the standardized residual is listed as follows:

$$Standardized\ Residual = \frac{f_o - f_e}{\sqrt{f_e(1 - row\ proportion)(1 - column\ proportion)}}$$

Linear regression techniques were used to create models that would accurately describe the outcome of total amount incurred based on the independent variables of interest. Regression models seek to display the relationship between the explanatory variables and the response variable [24]. Due to the skewness of the continuous monetary amounts, log transformations of the outcome variable were performed. Logarithmic transformations of variables in a regression model serve as a common method to handle instances where non-linear relationships exist between variables; they are also useful in transforming highly skewed variables into variables with an approximately normal identity [25]. The variable of part of body was also collapsed into four categories of other, lower parts of the body, upper parts of the body, and lower back. Various studies have utilized similar techniques to model costs in the health care system to identify which variables have a significant impact on the outcome of interest. For example, linear regression models with log transformations of cost as an outcome were fit to determine the costs of esophageal and pancreatic cancers in two studies where age and calendar year were used as the independent variables [26-27]. Single predictor models were initially created to analyze individual variable effects on the outcome of costs. After analyzing the single predictor models, forward selection techniques were utilized to choose multiple variables to create the multiple regression model. All statistical and descriptive analyses and graphing were performed with STATA software (ver. 16.0, StataCorp LLC, College Station, TX).

RESULTS

Descriptive Analysis

Utilizing descriptive statistics, we can summarize the data that consists of the filtered 6,307 claims in order to understand the information they provide. Again, the variables of interest were age, crop type, gender, tenure, part of body, and nature of injury for the outcome variable of “total incurred.” The first step was to look at and describe the demographic variables within the dataset.

Age and Gender

Table 2 provides details on the frequencies of injuries by gender. We see that males accounted for approximately 70% of the injuries as displayed by the pie chart in Figure 3. Looking at age as a continuous variable, we see that the average age for all the workers was approximately 38 years old. Figure 4 shows the distribution of age among all cases with outliers on the higher end of the box plot. The youngest employee was 17 with the oldest being 82. When we stratify by gender, the average age for a male employee was 39 with female employees averaging approximately 37 years (Table 3). When we look at age as a categorical variable (Table 4), we see that 50% of the agricultural work force that sustained ergonomic related injuries were under the age of 40. The trend that we see here are less ergonomic injuries incurred at older ages. Overall, we had a total of 1,777 females and 4,529 males, 15 of which were missing data on their age.

Table 2. Gender Counts and Percentages.

Gender	Frequency	Percent
Female	1,777	28.18%
Male	4,529	71.82%

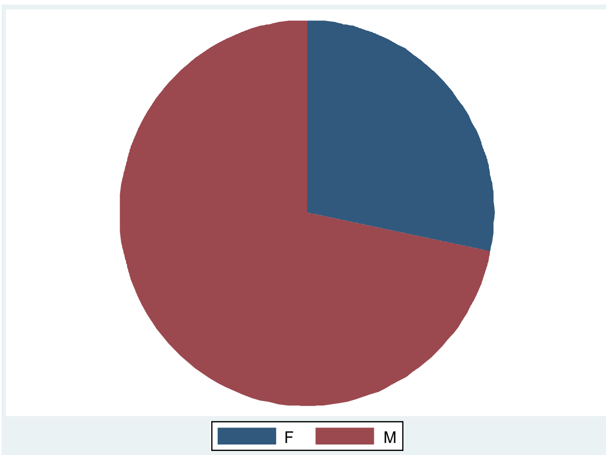

Figure 3. Gender Pie Chart.

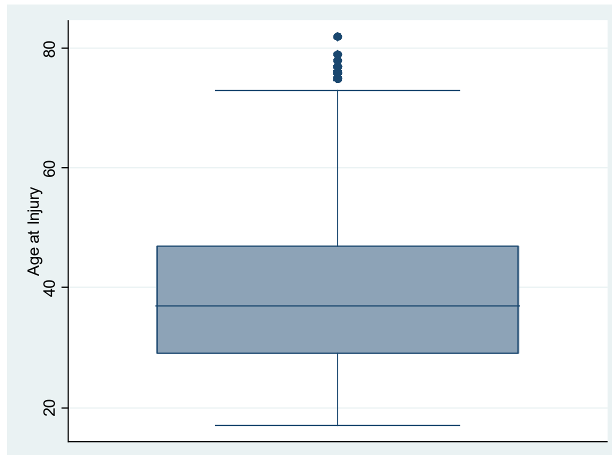

Figure 4. Box Plot of Age.

Table 3. Average Age of Employees by Gender.

Age (years)	Mean	Std dev	Low	High	Missing
Total	38.4	12.2	17	82	15
Male	39.1	12.6	17	82	11
Female	36.6	10.7	17	77	4

Table 4. Age Group Counts and Percentages.

Age Group	Frequency	Percent
≤ 25	989	15.72%
26-30	959	15.24%
31-35	975	15.50%
36-40	862	13.70%
41-45	744	11.83%
46-50	645	10.25%
51-55	447	7.11%
56-60	333	5.29%
≥61	337	5.36%

Crop Type and Tenure

After looking at the demographic variables, the next step was to describe the variables related the work and work environment. Many ergonomic related claims came from berry farms, followed by vineyards, and finally orchards and groves (Table 5). A similar pattern of injury distribution by crop type can be seen by looking at the frequencies in the parent dataset as well (Table 6). Looking at tenure as a continuous variable in the form of years, the least amount of time before an injury occurred was less than a year, with the highest amount being approximately 55 years (Table 7). This variable had 1,110 missing values and outliers that skewed the observations towards the higher values (Figure 5). Looking at the tenure categories, we see that over half of the injuries that occurred were for employees that had been working in their occupation for less than 2 years (Table 8).

Table 5. Crop Type Counts and Percentages.

Crop Type	**Frequency**	**Percent**
Berry Farm	3,039	48.19%
Orchard and Grove	1,016	16.11%
Vineyards	2,251	35.70%

Table 6. Crop Type Counts and Percentages for Parent Dataset.

Crop Type	**Frequency**	**Percent**
Berry Farm	9,774	40.72%
Orchard and Grove	5,386	22.44%
Vineyards	8,843	36.84%

Table 7. Average Tenure of Employees before Injury.

Tenure (years)	**Mean**	**Std dev**	**Low**	**High**	**Missing**
	4.4	6.5	0 (<1 year)	55	1,110

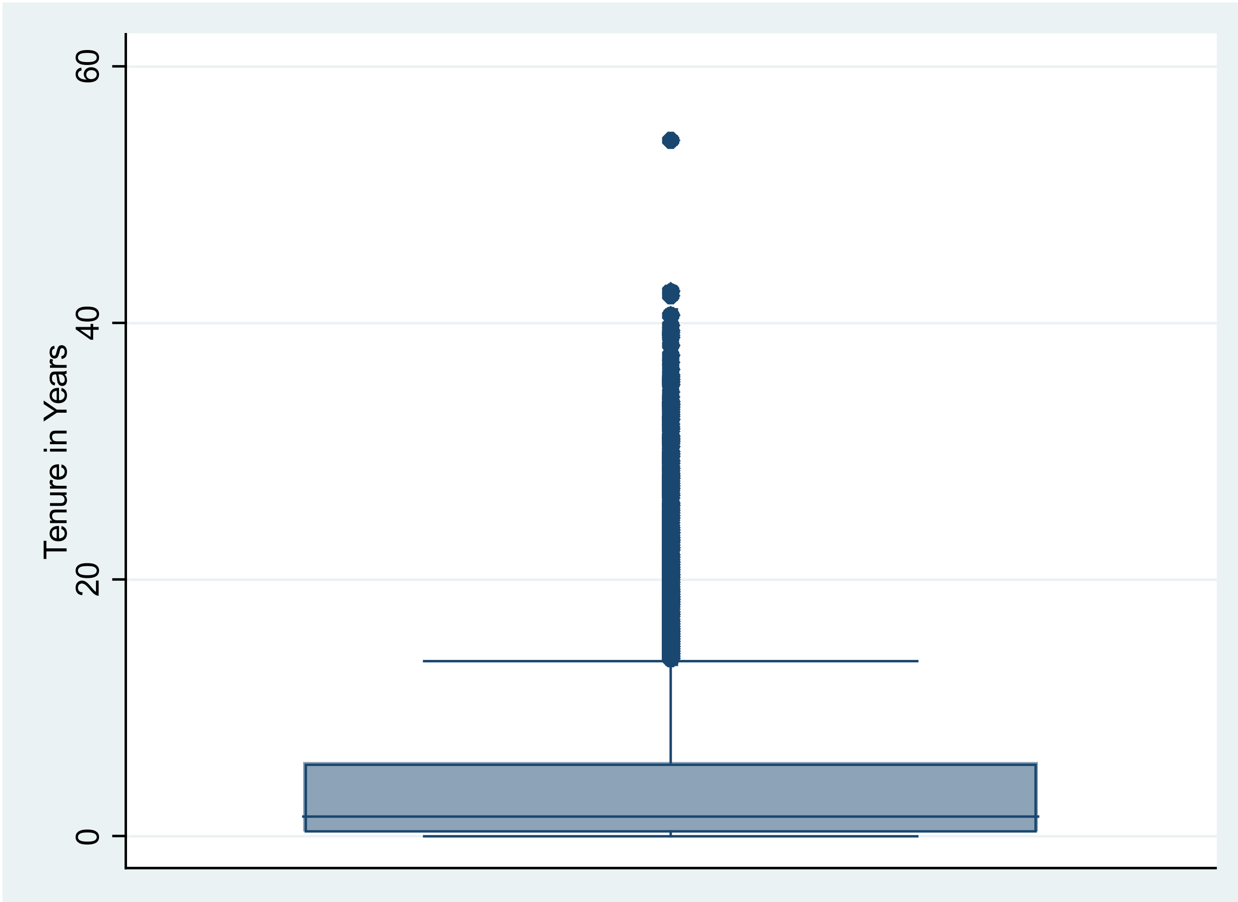

Figure 5. Box Plot of Tenure.

Table 8. Tenure Group Counts and Percentages.

Tenure Categories	Frequency	Percent
<1	2,152	41.42%
1-2	1,017	19.57%
3-5	766	14.74%
6-10	622	11.97%
11-20	437	8.41%
>20	202	3.89%

Part of Body and Nature of Injury

Finally, we looked at the injury variables of part of body injured and nature of injury (Table 9 and 10, respectively). The most injured part of the body was the lower back area followed by the lower and upper extremities. The highest frequency for nature of injury was strain and sprain, which made up over 70% of all ergonomic injuries in the dataset.

Table 9. Part of Body Counts and Percentages.

Part of Body	Frequency	Percent
Abdomen/Groin	311	4.93%
Chest/Ribs/Sternum	101	1.60%
Hip	74	1.17%
Internal and Body Systems	120	1.90%
Lower Back Area	2,658	42.15
Lower Extremities	899	14.26%
Multiple Body Parts	402	6.37%
Upper Extremities	860	13.64%
Other	69	1.09%

Table 10. Nature of Injury Counts and Percentages.

Nature of Injury	Frequency	Percent
Other	211	3.35%
Carpal Tunnel	19	.30%
Dislocation	12	.19%
Hernia	89	1.41%
Inflammation	45	.71%
Multiple Phys. Inj.	399	6.33%
Multiple Phys. Psych. Inj	13	.21%
Cumul. Inj.	321	5.09%
Occup. Dis.	5	.08%
Sprain	783	12.42%
Strain	4,409	69.92%

The outcome of interest that we aimed to look at was total monetary cost (Total Incurred). Looking at the histogram (Figure 6) of all the claims, there is a clear skew towards the left, indicating a higher frequency of claims under $200,000. When categorized under three (3) different groups, we can confirm that approximately 65% of claims resulted in a total cost of less than $3,000, while approximately a quarter of them were over $10,000 (Table 11). When analyzing total incurred as a continuous variable, we see that the average cost for an injury was approximately $15,000 with the lowest cost being $0 and the highest $713,030 (Table 12).

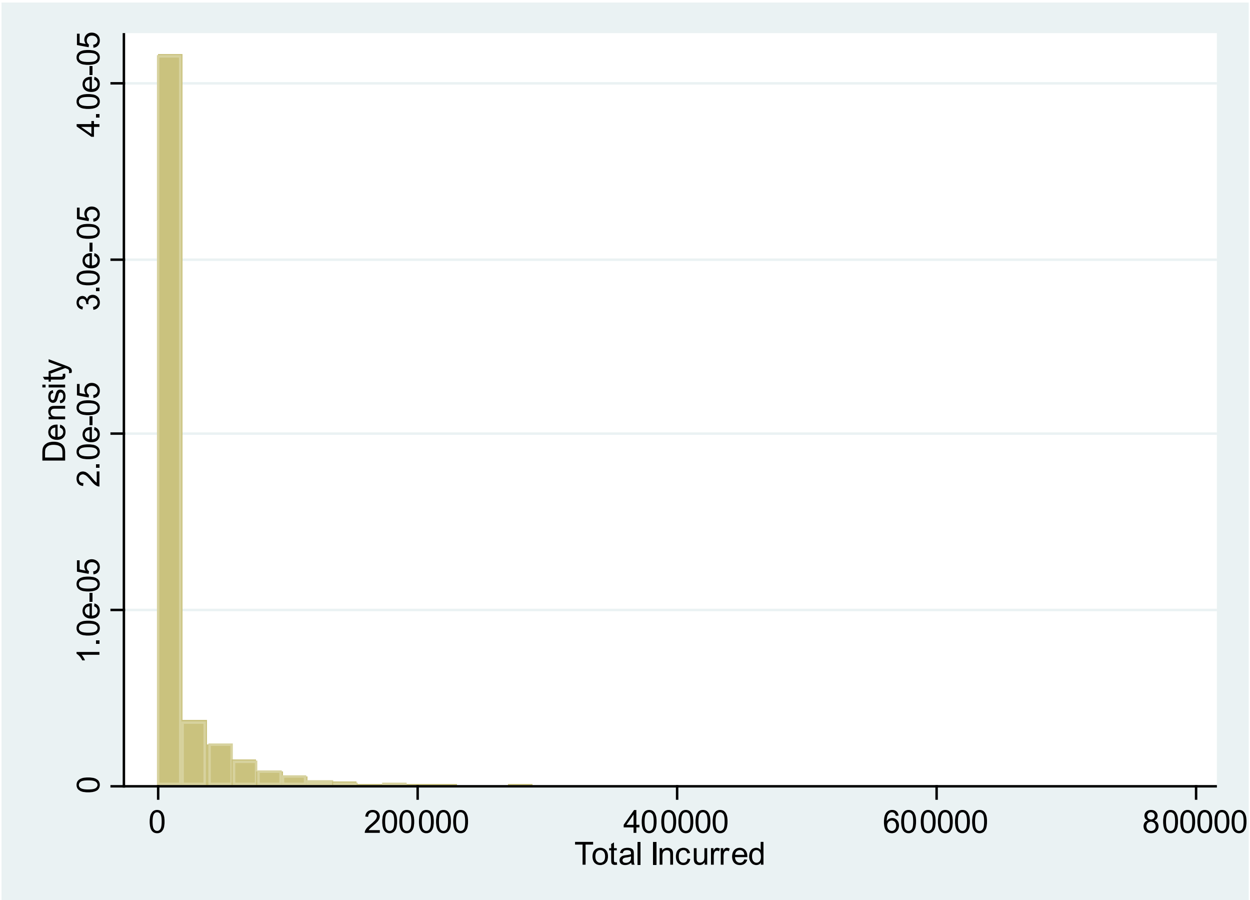

Figure 6. Histogram of Total Incurred ($).

Table 11. Total Incurred Group Counts and Percentages.

Total Incurred Categories	**Frequency**	**Percent**
<$3,000	4,051	64.65%
$3,000 - $9,999	626	9.99%
$10,000≤	1,589	25.36%

Table 12. Total Incurred Descriptive Statistics.

Total Incurred	**Mean**	**Std dev**	**Low**	**High**	**Missing**
Total	$15,015	$37,696	$0	$713,030	40

Contingency Tables and Residual Analysis

To explore the relationship between categorical variables (age, tenure, nature of injury, and part of the body), contingency tables, adjusted residuals, and the chi-square test of association were utilized.

Age

Table 13 displays the tabulation of the age categories among the total incurred categories. Of the 6,306 claims, only 6,251 had data for total amount incurred and age. The distribution of number of claims based on total amount indicates that nearly 75% were less than $10,000, which suggests that smaller claim amounts are more predominant for ergonomic injuries within agricultural work. The distribution of claims based on age group shows that over 70% of the claims were for employees less than 45 years old, and over 45% came from employees less than 35 years old. Next, examining the standardized residuals helped identify a pattern and direction for the claims by age. Starting with the less than $3,000 category, we see a higher observed count than the expected count in the cells for younger employees. The residuals gradually lower and turn negative, indicating a less than expected count for older employees. The opposite pattern can be seen for the greater than or equal to $10,000 category. We see a less than expected observed count for younger employees, and more than expected count the older employees get for the high claim amount category. The middle category of between $3,000-$9,999 shows little deviation between the observed and expected counts, except for the youngest group that indicates a less than expected amount of injuries for employees less than 25 who fall between those monetary cost categories.

Table 13. Relationship between Age Categories and Total Incurred.

	Claim Amount			
Age Group (years)	**<$3,000 ($n_{ij}$)(SR)**	**$3,000-$9,999 (n_{ij})(SR)**	**≥$10,000 ($n_{ij}$)(SR)**	**Total (n_i)(%)**
<25	816 (13.2)	59 (-4.6)	108 (-11.3)	983 (15.7%)
26-30	699 (6.0)	89 (-0.8)	166 (-6.1)	954 (15.3%)
31-35	653 (2.0)	80 (-2.0)	236 (-0.8)	969 (15.5%)
36-40	509 (-3.3)	94 (1.0)	251 (2.9)	854 (13.7%)
41-45	424 (-4.3)	85 (1.5)	228 (3.7)	737 (11.8%)
46-50	359 (-4.8)	73 (1.2)	210 (4.5)	642 (10.3%)
51-55	236 (-5.3)	58 (2.2)	151 (4.3)	445 (7.1%)
56-60	171 (-5.0)	42 (1.7)	118 (4.4)	331 (5.3%)
>60	169 (-5.6)	46 (2.3)	121 (4.6)	336 (5.4%)
Total (n_j)(%)	4,036 (64.6%)	626 (10.0%)	1,589 (25.4%)	6,251 (100%)

Pearson Chi-Squared = 316.55; df = 16; $p < 0.0001$ and alpha = 0.05; N = 6,251

Tenure

Table 14 displays the tabulation of the tenure categories within the total incurred categories. Of the 6,306 claims, only 5,169 had data for both employee tenure and amount incurred. The distribution of the number of claims by tenure indicates that approximately 60% of ergonomic injuries were sustained by employees who had two (2) or fewer years of work experience. Furthermore, almost three quarters of all the injuries would fall among workers who had five (5) or less years of work experience in agriculture. Overall, the trend we see for all three monetary groups, the fewer frequencies of claims are, the longer an employee works in his or her occupation. When examining the residuals, we see a higher than expected amount for the less than $3,000 category for employees with less than a year of tenure. This shifts towards a negative residual, indicating less small claim injuries for longer tenured employees. We see the opposite effect for claims greater than or equal to $10,000. Looking at the residuals for the claim amounts of between $3,000-$9,9999, there were no extreme deviations of the observed amounts that would indicate a pattern or higher/lower than expected amounts.

Table 14. Relationship between Tenure Categories and Total Incurred.

	Claim Amount			
Employee Tenure (years)	**<$3,000 ($n_{ij}$)(SR)**	**$3,000-$9,999 (n_{ij})(SR)**	**≥$10,000 ($n_{ij}$)(SR)**	**Total (n_i)(%)**
<1	1412 (4.0)	193 (-2.0)	531 (-3.0)	2,136 (41.3%)
1-2	647 (0.7)	107 (0.6)	259 (-1.2)	1,013 (19.6%)
3-5	467 (-1.1)	75 (-0.2)	222 (1.3)	764 (14.8%)
6-10	378 (-1.1)	74 (1.7)	169 (0.7)	621 (12.0%)
11-20	249 (-2.5)	44 (.09)	141 (2.6)	434 (8.4%)
>20	97 (-4.4)	25 (1.2)	79 (4.0)	201 (3.9%)
Total (n_j)(%)	3,250 (62.9%)	518 (10.0%)	1,401 (27.1%)	5,169 (100%)

Pearson Chi-Squared = 40.80; df = 10; p < 0.0001 and alpha = 0.05; N = 5,169

Nature of Injury

Table 15 displays the tabulation of the nature of injuries (NOIs) among the total incurred categories. Of the 6,306 claims, 6,266 had information for both total claim amount and nature of injury. The leading NOI for all three categories was strain for ergonomically related injuries, making up approximately 70% of all the claims, with the next highest category of sprains only making up about 12% of all injuries. When we start to examine the residuals, we see higher than expected amount in strains for lower cost injuries, but less than expected for the highest and middle monetary category. For sprains, we do not see any extreme deviations from the expected values based on the residuals. Another notable nature of injury includes Hernias, which display low frequency, but higher than expected counts in the top two monetary claim categories, indicating the severity that these injuries can eventually result in. The other NOI that displays a similar pattern is “other cumulative injuries,” which encompasses a variety of factors and work behaviors that are characterized by multiple exposures and task repetition. What we see with this variable is cumulative injuries over time on the body resulting in higher costs as time passes.

Table 15. Relationship between Nature of Injury and Total Incurred.

	Claim Amount			
Nature of Injury	**<$3,000 ($n_{ij}$)(SR)**	**$3,000-$9,999 (n_{ij})(SR)**	**≥$10,000 ($n_{ij}$)(SR)**	**Total (n_i)(%)**
All Other	137 (0.1)	24 (0.7)	50 (-0.6)	211 (3.4%)
Carpal Tunnel	2 (-4.8)	2 (0.2)	14 (5.1)	18 (0.3%)
Dislocation	7 (-0.5)	2 (0.8)	3 (-0.03)	12 (0.2%)
Hernia	22 (-7.8)	27 (6.5)	39 (4.1)	88 (1.4%)
Inflammation	30 (0.7)	6 (0.9)	7 (-1.4)	43 (0.7%)
Mult Phys Inj	297 (4.4)	37 (-0.5)	63 (-4.5)	397 (6.3%)
Mult Phys Psych	1 (-4.3)	5 (3.4)	7 (2.4)	13 (0.2%)
Other Cumul Inj	103 (-12.5)	84 (10.0)	133 (6.8)	320 (5.1%)
Other Occup Dis	3 (-0.2)	1 (0.7)	1 (-0.3)	5 (0.1%)
Sprain	510 (0.6)	57 (-2.6)	210 (1.1)	777 (12.4%)
Strain	2,939 (6.1)	381 (-5.2)	1,062 (-3.1)	4,382 (69.9%)
Total (n_j)(%)	4,051 (64.7%)	626 (10.0%)	1,589 (25.4%)	6,266 (100%)

Pearson Chi-Squared = 334.9; df = 20; $p < 0.0001$ and alpha = 0.05; N = 6,266

Part of Body

Table 16 displays the tabulation of the parts of body (POB) injured among the total incurred categories. Of the 6,306 claims, 6,266 had information for both total claim amount and part of body injured. For ergonomic injuries in agriculture, we see that the overall frequency of injuries sustained in the lower back are predominant in all three monetary categories. Lower back injuries make up approximately 42% of all injuries, with the second highest frequently injured part of body being the lower extremities at 14%. Looking at the standardized residuals for part of the body, we see higher than expected counts for notable areas such as the chest/ribs/sternum, abdomen/groin, and the neck/head/shoulders/upper back across the monetary categories.

Table 16. Relationship between Part of Body Injured and Total Incurred.

	Claim Amount			
Part of Body	**<$3,000 ($n_{ij}$)(SR)**	**$3,000-$9,999 (n_{ij})(SR)**	**≥$10,000 ($n_{ij}$)(SR)**	**Total (n_i)(%)**
Abdomen/Groin	166 (-4.1)	68 (7.2)	75 (-0.5)	309 (4.9%)
Chest/Ribs/Stern	93 (5.8)	2 (-2.7)	6 (-4.5)	101 (1.6%)
Hip	53 (1.4)	6 (-0.5)	14 (-1.2)	73 (1.2%)
Internal and Body Systems	52 (-4.9)	28 (4.9)	40 (2.0)	120 (1.9%)
Lower Back	1,693 (-0.8)	226 (-3.2)	724 (3.2)	2,643 (42.2%)
Lower Extremities	574 (-0.4)	82 (-0.9)	240 (1.1)	896 (14.3%)
Mult Body Parts	312 (5.8)	41 (0.2)	47 (-6.5)	400 (6.4%)
Neck/Head/Shoulders/Upper Back	473 (-3.7)	78 (-0.3)	254 (4.3)	805 (12.9%)
Other	63 (4.7)	5 (-0.8)	1 (-4.6)	69 (1.1%)
Upper Extremities	572 (1.7)	90 (0.6)	188 (-2.3)	850 (13.6%)
Total (n_j)(%)	4,051 (64.7%)	626 (10.0%)	1,589 (25.4%)	6,266 (100%)

Pearson Chi-Squared = 215.2; df = 18; $p < 0.0001$ and alpha = 0.05; N = 6,266

Regression Analysis

Single predictor models were created utilizing the log of the total incurred as the outcome. The independent variables of interest were used as the explanatory variables to analyze main effects and create a multiple regression model. Across the single predictor models and final multiple regression model, coefficient estimates were similar for age, part of body, and gender. Tenure, crop type, and nature of injury had significant coefficients in the models, where they served as the only predictor; however, when paired with the other variables, they were not statistically significant based on a p-value of 0.05. Table 17 displays the final regression model and respective coefficient estimates for age, part of body, and gender as the explanatory variables, with the response variable being the total incurred in log form. Table 18 depicts the coefficient estimates when each variable was individually predictive for the log of total incurred.

Table 17. Multiple Regression Model Output for Log of Total Incurred.

ln(Total)	Coefficient	Standard Error	t	P > |t|	95% Conf. Interval
Part of Body					
Lower Back	.75	.11	6.8	0.00	.53 - .97
Lower POB	.47	.12	3.89	0.00	.23 - .70
Upper POB	.41	.12	3.58	0.00	.19 - .64
Age	.04	.003	17.26	0.00	.04 - .05
Gender					
Male	-.40	.07	-5.89	0.00	-.54 - -.27
Constant	5.5	.14	39.18	0.00	5.2 - 5.8

Table 18. Singe Predictor Regression Model Coefficient Estimates.

ln(Total)	Coefficient	Standard Error	t	P > |t|	95% Conf. Interval
Part of Body					
Lower Back	.71	.11	6.3	0.00	.49 - .93
Lower POB	.52	.12	4.22	0.00	.28 - .76
Upper POB	.50	.12	4.28	0.00	.27 - .73
Age	.04	.003	16.46	0.00	.04 - .05
Gender					
Male	-.23	.07	-3.32	0.00	-.37 - -.09

For part of body, we see that all categories have a significant impact on the cost, or severity of an injury. Lower back had the largest coefficient in affecting the outcome (95% CI .53-97), followed by lower parts of the body (95% CI .23 - .70), then upper parts of the body (95% CI .19 - .64). When we look at age as a continuous variable, we can interpret that with each unit increase in age, we can expect to see an increase in the expected value of the outcome by $e^{.04}$. In a single predictor model, when the values of the estimated coefficients are small, we can convert them to percentages for quick interpretation [25]. Hence, for age, we can interpret that for every 1 unit increase in age, we can approximately see an expected increase in the log of the total incurred by 4%. For gender, we see that being a male results in a negative association with the log total incurred due to the negative sign in the estimated coefficient. This indicates that being male has less of an impact on the cost of the ergonomic injury than being a female.

DISCUSSION

Ergonomic injuries in Californian agriculture are a major source of medical, indemnity, and miscellaneous costs for workers' compensation claims. Analyzing records from major insurance companies allows for better understanding of trends, variables, and severity of these injuries. There have been few studies in the past that looked specifically at these types of injuries, and usually the data that is utilized for those studies come from public sources that contain their own limitations. Workers' compensation claims provide invaluable information that is not always available to the public and can serve to better identify contributing factors and help prevent the most prevalent of injuries.

In this study, analysis was conducted on a variety of variables with the outcome of interest being total incurred cost for an ergonomic claim. Utilizing descriptive statistics and contingency tables, we were able to identify key characteristics for this area of interest. Starting with gender, we see that many of these cases came from male employees. This supports findings from prior studies, which indicate that males are 28% percent more likely to report an injury and that being male serves as a strong predictor for the incidence of workers' compensation claims [28-29]. In addition, we see that males also have an overall higher frequency of occupational injuries and illnesses across all states in the U.S. [30]. However, when analyzing the effect of gender on cost in the regression model, we see that being male actually led to a negative association with the log of the total incurred, while being female actually led to a positive association in the log total. To analyze to what effect being female would have an impact on the regression model, the baseline category was switched to male in the Gender variable, which resulted in an estimated coefficient of 0.4. Further analysis revealed higher average costs for these injuries in females when compared to males from both the parent and focused data sets.

These findings differ from previous studies, which found that males have nearly double the cost for non-fatal occupational injuries and illnesses, and that male workers experience longer compensation benefit durations and higher median costs for musculoskeletal injuries [31-32]. However, these studies looked at costs across different industries and occupations; more studies analyzing the costs of ergonomic injuries specifically in agriculture would help depict a more accurate representation within the field.

Looking at age and tenure, we see that many of the injuries are occurring in younger workers, and with those who have less work experience. In addition, these injuries incur lower total costs (<$3,000) when compared to the other end of the spectrum, where we see the older population having a lower frequency of injuries but incurring higher costs. Age also serves as a significant variable in the regression model indicating higher costs for a workers' compensation claim as an employee gets older. These findings support past studies, which found that younger and inexperienced workers are at a higher risk of sustaining an injury, while older workers are more predisposed to incurring higher costs for their injuries [31, 33-34]. Looking at these trends in future studies will help develop more targeted interventions when trying to address either the incidence of low-cost ergonomic injuries or more chronic and severe musculoskeletal disorders.

When looking at what area of the body is most impacted by agricultural work and what the most prevalent type of injury is for ergonomic injuries in this field, it comes to no surprise that lower back strains and sprains have the highest frequencies in the workers' compensation claims. It has been well documented in past studies that injuries in the lower back region of the body account for a higher percentage of cases and costs for treatment due to the common and chronic nature of these type of injuries [31, 34-35]. This is further displayed by the largest estimated coefficient in the regression model for the variable of part of body injured. Injuries to the lower back have the highest impact on the log of the total incurred cost when compared to other parts of the body. They also have a spread across the 3 different monetary categories, which shows the different levels of severity these injuries can have with a higher than expected count in the over $10,000 category.

After looking at the results of this study, interventions should be focused on tackling ergonomic injuries with an emphasis on conducting safety training for young and newly hired workers. Previous studies have found that making training material more comprehensible and inclusive to workers increases the effectiveness and efficacy of knowledge retention and adherence to safety behaviors. This can include having visual factors, interactive portions, and translated materials for different languages for the content presented [36]. To make a significant impact, training must focus on affecting safety knowledge, behaviors, and attitudes and beliefs; hence, translating into better health outcomes [37]. However, safety training is just one portion to tackle the most common of injuries, as the nature of work required in the agriculture is inherently labor intensive. This is where we can turn to ergonomics for the development of both administrative and engineering interventions. For administrative approaches, we can look towards scheduling breaks and alternating tasks as to not overexert one portion of the body [17]. In a study that looked at rest break interventions in stoop labor tasks, a 5-minute rest break for every work hour improved the symptoms of repetitive motion for hand harvesting strawberries, and inserting bud grafts into young citrus trees [38]. When looking at engineering interventions, there are three classes of interventions: altering workspace and worker interface, engineering mechanical aids or protection workers, and creating fully or partially mechanized operations [39]. Examples of these engineering controls include alternate tools (e.g., handle-carriers for potted plants, pneumatically powered cutters, bucket carriers, etc.), motorized equipment (picking platforms), and worker aids (load/weight transferring devices) [17, 39-42].

Limitations and Future Work

Even with the valuable information that workers' compensation claims provide, there are still limitations inherent in the use of observational claims data. The exclusion of employees younger than 17 limits the analysis to adults and as a result, does not cover the adolescent population within agriculture that is more commonly seen in this industry than others. In addition, the issue of underreporting and the undercount of injuries can also affect the generalizability of these results to the entire US population. We were also limited to claims filed within the state of California and through one specific insurance provider. Finally, the payment amounts for total costs were a snapshot in time that may not show the final costs for the reopened or currently opened claims. Future studies in this area would help address these issues and build upon the findings of this study. Analyzing the costs of reaggravated or reinjured body parts for ergonomic injuries can serve to better indicate the severity for certain nature of injuries. Furthermore, creating regression models that look at the interactions of certain variables and how they translate to injury severity can also help strengthen the understanding of risk factors that lead to the most debilitating injuries. Finally, quantifying the impact that administrative and engineered interventions have on the incidence and severity of injuries would help in evaluating which preventative measures effectively work better at addressing risk factors.

CONCLUSION

Workers' compensation claims were utilized to look at ergonomic injuries in agriculture for the state of California. Due to the size of this industry within the state and the nature of work required to perform farming tasks, the prevalence of musculoskeletal disorders have resulted in costly injuries, which underscore the severity and impact on the quality of life for the workers affected. Further studies to develop feasible interventions are needed to reduce the incidence of such injuries. Further analysis into ergonomic injuries and the costs they incur for different populations with varying demographics would help in identifying groups and characteristics that are more at risk and would greatly benefit from targeted interventions.

The key takeaways from this study are:

- Gender: Males have a higher frequency of ergonomic injuries but less severe when compared to females
- Age: The older an employee is, the more severe of an injury they can incur
- Tenure: Shorter tenure has a higher frequency of low-costing injuries compared to longer tenure
- Part of Body: The lower back is the most impacted POB in terms of frequency and accounts for the most severe of injuries when compared to other body parts
- Nature of Injury: Strains are the number one NOI, where we see a higher than expected amount for lower costing injuries
- Crop Type: Berry farms have the highest frequency of injuries in both the ergonomic and non-ergonomic datasets

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Appendix A.

Final Data Set: Filtered by State, Nature of Injury, and Nature of Accident

1. **Full data set:** 25,352 cases
2. **Removed**: All Florida Cases:
    a. 24,003 cases left
3. **KEEP**: strain, sprain, all other, mult phys inj, null, other cumul inj, inflammation, hernia, dislocation, other occup dis, mult phys psych, and carpal tunnel
4. **REMOVE**: contusion, laceration, foreign body, puncture, fracture, dermatitis, crushing, heat prostration, syncope, infection, burn, concussion, psyche/stress, poisoning/chems, no phys injury, amputation, rupture, resp disorders, heart attack, vascular, vision loss, dust disease, contagious disease, poison(not cum), angina pectoris, hearing loss, loss of hearing, severance, electric shock, asphyxiation
    a. 14,161 cases
5. Further analysis of kept variables
    a. All Other
        i. **REMOVE**: abnormal air pres, absorb/ingest, animal/insect, caught in/under, caught/puncture, chemicals, collision/obj, collision/vehic, contact with, expl/flare back, foreign bdy/eye, hand tool/utens, hit/falling obj, hit/lifted obj, hit/lifting obj, hit/mtr vehicle, hit/obj other, hit/station obj, hit/tool, mach, machinery, motor vehicle/noc, non phys cause, obj lift/handle (all cutting), obj handled, workers/patient, wield or throw, vehicle upset, fall/diff level, fall/ldr, scaff, fall/liq grease, fall/same level, fall slip trip, into openings, on stairs, other misc, rob/crim asslt, rub/abrade, slip/no fall, strain/jumping, strain/use mach, strike/step, struck/injured, strain/injury twisting
        ii. **KEEP**: cumulative, repetitive motion, strain/holding, strain/injury, strain/lifting, strain/pushing, strain/reaching
    b. Dislocation
        i. **REMOVE**: caught in/under, fall/diff level, fall/ldr, scaff, fall/same level, fall/slip/trip, hit/mtr vehicle, machinery, hit/tool/mach, hit/station obj, motor vehicle, strain/use mach, struck/injured, twisting
        ii. **KEEP**: strain/holding, strain/injury, strain/lifting, strain/pushing

c. **Hernia**

   i. **REMOVE**: collision/obj, collision/vehic, fall/liq grease, fall/same level, fall/slip/trip, slip/no fall,

   ii. **KEEP**: cumulative, other misc, strain/holding, strain/injury, strain/lifting, strain/reaching, twisting, strain/use mach

d. **Inflammation**

   i. **REMOVE**: absorb/ingest, animal/insect, caught in/under, caught/puncture, chemicals, contact with, cut/power tool, dusts/gases/etc, fall/same level, fall/slip/trip, foreign bdy/eye, hand tool/utens, hit/falling obj, obj lift/handle, on stairs, other misc, rub/abrade, slip/no fall, step/sharp obj, strike step, struck/injured,

   ii. **KEEP**: cumulative, repetitive motion, strain/holding, strain/injury, strain/lifting, strain/pushing, strain/reaching, strain/use mach, twisting

e. **Mult phsy Inj**

   i. **REMOVE:** absorb/ingest, animal/insect, caught in/under, caught/puncture, chemicals, collision/obj, collision/vehic, contact with, contact/hot obj, cut/power tool, fall/diff level, fall/ldr scaff, fall/liq grease, fall/same level, fall/slip/trip, fire or flame, foreign bdy/eye, hand tool/utens, hit/falling obj, hit/lifted obj, hit/lifting obj, hit/moving prts, hit/mtr vehicle, hit/obj,other, hit/station obj, hit/tool mach, into openings, machinery, motor vehicle, obj lift/handle, object handled, on ice or snow, on stairs, rob/crim asslt, rub/abrade, slip/no fall, steam/hot fluid, step/shar obj, strike/step, struck/injured, temp extremes, twisting, vehicle upset, welding oper, workers/patient,

   ii. **KEEP**: repetitive motion, strain/holding, strain/injury, strain/lifting, strain/pushing, strain/reaching, strain/use mach,

f. **Mult phsy psych**

   i. **REMOVE**: absorb/ingest, animal insect, non phys cause, other misc, rob/crim asslt, step/sharp obj, strain/injury

   ii. **KEEP**: cumulative

g. **Null**

   i. **REMOVE**: absorb/ingest, animal/insect, caught in/under, caught/puncture, collision/obj, collision/vehic, fall/diff level, fall/ldr scaff, fall/liq grease, fall/same level, fall/slip/trip, fire or flame, foreign bdy/eye, hand tool/utens, hit/falling obj, hit/lifting obj, hit/moving parts, hit/mtr vehicle, hit obj,other, hit/station obj, hit/tool mach, into openings, machinery, motor vehicle, non phys cause, null, obj lift/handle, object handled, on stairs, other misc, rub/abrade, slip/no fall, strain/use mach, strike/step, struck/injured, temp extremes, twisting, vehicle upset, workers/patient

ii. **KEEP**: cumulative, repetitive motion, strain/holding, strain/injury, strain/jumping, strain/lifting, strain/pushing, strain/reaching,

h. Other cumul inj

i. **REMOVE**: absorb/ingest, animal/insect, non phys cause, other misc, twisting

ii. **KEEP** :cumulative, strain/holding, strain/injury, strain/lifting, strain/pushing, strain/reaching,

i. Other occup dis

i. **REMOVE:** absorb/ingest, non phys cause, other misc, rub abrade

ii. **KEEP**: cumulative

j. Sprain

i. **REMOVE:** animal/insect, caught in/under, collapse mat'l, collision/obj, collision/vehic, expl/flare back, fall/diff level, fall/ldr scaff, fall/liq grease, fall/same level, fall/slip/trip, hit/falling obj, hit/lifted obj, hit lifting obj, hit/moving parts, hit/mtr vehicle, hit/obj, other, hit/station obj, hit/tool, mach, into openings, machinery, motor vehicle, obj lift/handle, object handled, on ice or snow, on stairs, other misc, slip/no fall, step/sharp obj, strain/jumping, strike/step, struck/injured, twisting, vehicle upset, workers patient,

ii. **KEEP**: cumulative, repetitive motion, strain/holding, strain/injury, strain/lifting, strain pushing, strain/reaching, strain/use mach, wield or throw

k. Strain

i. **REMOVE**: animal/insect, caught in/under, collapse mat'l, collision/vehic, continual noise, expl/flare back, fall/diff level, fall/ldr scaff, fall/liq grease, fall/same level, fall/slip/trip, hit/falling obj, hit/lifted obj, hit/lifting obj, hit/moving parts, hit/mtr vehicle, hit/ obj other, hit/station obj, hit/tool mach, into openings, machinery, motor vehicle, obj lift/handle, object handled, on stairs, other misc, slip/no fall, step/sharp obj, strain/jumping, strike/step, struck/injured, twisting, vehicle upset, workers/patient,

    ii. **KEEP**: cumulative, repetitive motion, strain/holding, strain/injury, strain/lifting, strain pushing, strain reaching, strain/use mach, wield or throw

6. **Final Filtered Data Set:** 6,307 Cases