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RESEARCH ARTICLE

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A mixed-methods analysis of logging injuries in Montana and Idaho

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Abstract

Background: Despite advances in mechanization, logging continues to be one of the most dangerous occupations in the United States. Logging in the Intermountain West region (Montana and Idaho) is especially hazardous due to steep terrain, extreme weather, and remote work locations.

Methods: We implemented a mixed-methods approach combining analyses of workers' compensation claims and focus groups to identify factors associated with injuries and fatalities in the logging industry.

Results: Inexperienced workers (>6 months experience) accounted for over 25% of claims. Sprain/strain injuries were the most common, accounting for 36% of claims, while fatalities had the highest median claim cost ($274 411). Focus groups identified job tasks involving felling trees, skidding, and truck driving as having highest risk.

Conclusions: Injury prevention efforts should focus on training related to safe work methods (especially for inexperienced workers), the development of a safety culture and safety leadership, as well as implementation of engineering controls.

KEYWORDS
forestry, injury prevention, logging, logging safety, workers compensation

1 | INTRODUCTION

Logging is one of the most dangerous occupations in the United States. According to the Bureau of Labor Statistics (BLS), in 2014, the national occupational fatality rate for all industries was 3.3 workers per 100 000 FTE.[1] During that same period, the occupational fatality rate for forestry workers (NAICS 113) was 92 per 100 000 FTE, 28 times higher than all industries combined.[2] Though logging injuries within the Untied States have decreased over the last 20 years, from 8.9 per 100 FTE in 1994[3] to 5.1 per 100 FTE in 2014,[3] injuries in this sector continue to exceed the rate of total recordable cases for all industries combined (3.2 per 100 FTE).[3]

Within the logging industry, there are different risks based on job task and logging system used. The forestry and logging industry subsector is divided into the following job tasks by the United States Department of Labor: fallers, supervisors, logging equipment operators, and truck drivers.[2] The logging system used determines the number of workers in each of these different job tasks as well as the configuration of equipment. There is a wide range in the possible configurations of machines and processes used in harvesting (ie, logging system). The logging system of choice is dependent on the terrain and region of the harvest, as well as the resources of the contracted logging company. There are two main logging systems for felling trees (conventional chainsaw logging and mechanical logging) and four primary methods for moving felled trees (skidder, horse logging, line skidding, and helicopter logging).[4] In conventional chainsaw logging systems, trees are felled, delimbed, and cut to length by sawyers using a chainsaw.[4] In contrast, mechanical logging systems use feller-bunchers to fell, delimb, and cut the log to the desired length.[4] Moving cut tees from the tree stand to an area (landing) where the logs are loaded on logging trucks is often

performed with skidders. A skidder is a type of heavy vehicle used in a logging operation to pull cut trees out of a forest in a process called "skidding," in which the logs are moved from the cutting site to a landing. At the landing they are loaded onto trucks for transporting to saw mills. When a skidder is unavailable or unable to operate due to terrain, weather conditions, or environmental conditions, horse logging, line skidding, and helicopter logging systems methods used for skidding. In each of the methods, a worker (the hooker/choke setter) is responsible for attaching cables to the logs to be hauled from the site.

The variety of work methods within the logging industry likely contributes to the differences in injury and fatality rates among professional loggers in the United States. Job task, logging system type, and degree of mechanization result in differences in the prevalence, type, and severity of occupational injuries and fatalities.[5] Some research has suggested that increasing mechanization of the industry may decrease the number of injuries and fatalities associated with logging.[6] For example, Myers and Fosbroke[5] found a significant difference in the fatality rate of general logging labor in comparison to machinery operators.[5] General logging labor (ie, fellers, limbers, buckers, and choke setters) had an occupational fatality rate of 371.8 per 100 000, while machinery operators had an occupational fatality rate of 48.5 per 100 000.[5] Further, an analysis of injury claims data before and after mechanization indicated a significant decrease in injury claims when companies transitioned from conventional (ie, chainsaw) logging to feller-buncher tree harvesting.[7]

With modernization and mechanization comes an effort and ability to raise productivity.[6] New technology and equipment has allowed loggers to generate higher yield and harvest on extreme terrain, previously impossible with conventional logging methods. Earlier research on logging injuries and fatalities has identified differences in fatality rates by region.[5] The authors concluded that regional differences may be attributed to timber type, logging system, and terrain. Specifically, mechanization has allowed logging in the Intermountain West (which includes Montana and Idaho) to expand to previously remote areas with higher elevation, steeper slopes, extreme weather, and longer transportation times to processing plants. Previous logging injury research is not readily generalizable to this region due to these factors.

Currently, there is no specific research on logging injury and injury prevention in the Intermountain West. The objective of this study was to implement a mixed-methods approach to identify injury prevention strategies for the logging industry in this region. This research integrates an analysis of workers' compensation data and focus group results to better understand injuries and fatalities. The goal of the analysis is to inform the future direction of logging safety and training in the Intermountain West region.

2 | METHODS

2.1 | Quantitative analysis: Workers' compensation data

Injury claim data were obtained from two workers' compensation providers (Associated Loggers Exchange of Idaho and Montana State Fund), which cover companies active in the logging industry of Montana and Idaho. All injury and fatality claims occurring from July 2010 to June 2014 were obtained from companies in the logging industry (NAICS 113). Injury claim data from each company contained information on demographics, variables related to the time, type, and source of injury, as well as the cost associated with each injury claim. All personal identifiers were removed from the claims by the workers' compensation providers.

Frequency statistics were calculated for demographic and injury claim variables. Chi-squared tests were performed to determine if there was a significant difference in the distribution of variables relating to the timing of claims including day of the week, month of the year, season, and fiscal year. Chi-square tests were performed to determine if there was a significant difference in the number of claims by age group, level of experience, job type, data source, state, claim type, and body part injury. Fisher's Exact Test was used in place of chi-square analysis for cell counts with fewer than five observations. We implemented a Kruskal-Wallis test to determine if differences exist in the mean age and length of experience by job title (sawyer/hooker, equipment operator, truck driver, supervisor/owner, mill operator, and other).

To accurately compare year to year workers compensation costs, all claim values were adjusted to 2015 dollars using the CPI inflation calculator provided by the Bureau of Labor Statistics.[8] Claim values were rounded to the nearest dollar amount. Descriptive statistics (median and range values) for age, length of experience, and claim values were calculated by job type. Kruskal-Wallis tests were performed to determine if significant differences existed in age and length of experience based upon job task. Fisher's exact test was performed to determine if there was a significant difference in the distribution of incident type and nature of injury by job type. Due to the association between nature of injury and incident type, a two-way factorial analysis of variance (ANOVA) was performed to determine if the significant differences seen in the ANOVAs for both nature of injury and incident type by adjusted total claim value were due to the effect of the factors independently, interaction, or due to confounding. As healthcare data costs were highly skewed, we log transformed data for analysis.[9]

As workers' compensation claims data did not follow a normal distribution, a Wilcoxon-Mann-Whitney test was used to determine if there was a significant difference between the median claim value based on level of experience (<6 months vs ≥6 months). Kruskal-Wallis tests were performed to determine if significant differences existed in the median claim values based upon age group, job task, nature of injury, or injury type. Significance for all tests was based on alpha of 0.05.

Data were analyzed using SAS software Version 9.4.[10]

2.2 | Qualitative analysis: Focus groups

The recruitment of focus group participants was conducted among professional loggers attending the annual Intermountain Logging Conference held in Spokane, Washington in 2016. The professional loggers were asked to participate in focus group meetings regarding

their perception of the association between logging tasks and logging injuries and fatalities. A summary of the workers' compensation data related to the nature, extent, and cost of injury, as well as work experience of injured worker was presented to potential participants and served as background information for the subsequent focus group discussions.

As per the methods outlined by Krueger,[11] focus groups were conducted to identify perceptions of work tasks and procedures that professional loggers associated with occupational injuries. An analysis of the focus group discussions and conclusions can often reveal how the topic under study is perceived among group members. As per established focus group methods,[11] the focus moderators encouraged group members to respond to the ideas and perceptions of other focus group participants. There are several advantages to using focus groups as a method of gathering qualitative data.[11] These advantages include (1) the inherent openness and free discussion of specific issues that is created, (2) focus groups are often composed of individuals with similar experiences, (3) the commonalties between participants drives natural and dynamic discussion. Unlike with structured interviews, focus group moderators are able to guide the discussion in order to achieve a deeper understanding of the underlying topic.[11]

Summary statistics from the analysis of workers' compensation data were presented by investigators to focus group participants. The presentation included the most common types of injuries, the number and types of injuries experienced by inexperienced workers, the most expensive injuries and the seasonality of claims. The purpose of the focus groups was to elicit workers' perceptions of the relevant workplace factors that may have led to the types of injuries documented in the workers' compensation data. The investigators conducted two focus group sessions of 90 min duration with the assistance of four logging safety management consultants. Focus group participants were active loggers from Montana and Idaho. Two focus group moderators (EL, JR) posed a series of questions designed to promote group discussion regarding logging practices and occupational injuries. The questions consisted of the following:

- What do you think are the most dangerous tasks (risks) leading to injuries in professional logging?
- How can these risks be prevented?
  - What are the most effective solutions to preventing logging injuries?
  - What can be done to reduce the number of injuries among inexperienced workers?
- What are the barriers to safe logging practice?
- How can safe logging practices be promoted or facilitated?
- How can the logging community improve and protect workers more effectively?

The moderators introduced all questions initially and then elicited feedback for each individual question sequentially. Group responses, which were based upon a consensus group approach, were recorded by the investigators. All focus group participants provided consent for participation in the research. Participant names or other unique identifiers were not recorded. Participants received education credits from their respective professional logging associations for attending and participating in the focus group sessions. To receive professional credit for participation, the focus group participants signed in on a list managed by their respective professional logging associations. To maintain focus group confidentiality, researchers did not have access to the list of participant names and there was no association between participant names and focus group opinion. The demographic information associated with the focus groups was provided by the professional logging associations. All research protocols were approved by the Institutional Review Board of the authors' academic institution.

3 | RESULTS

3.1 | Descriptive claim characteristics

A total of 801 workers' compensation claims were analyzed for the period July 2010 to June 2015 (Table 1). Workers between ages 50 and 59 had the highest proportion of claims (27%) and the mean length of employment at the time of injury was 74.52 months (SD = 105.84). Approximately 26% of claims occurring to employees with less than 6 months of experience (Figure 1). Chi-square tests indicated significant differences in the number of claims by day of the week ($\chi^2 = 234.89$, df = 6, $p < .0001$), month of the year ($\chi^2 = 67.12$, df = 11, $p < .0001$), season ($\chi^2 = 54.43$, df = 3, $p < .0001$), and fiscal year ($\chi^2 = 23.34$, df = 4, $p = 0001$). Mondays accounted for the greatest proportion of claims (21.22%), claims decreased by day of the week with only 14 workers' compensation claims occurring on Sundays (1.75%). The highest number of claims occurred in the months of July (10.5%), August (10.5%), and September (10.7%), while the lowest number of claims occurred in March (4.0%) and April (3.25%). The spring season only accounted for 111 claims while the autumn, summer, and winter seasons accounted for 240, 233, and 217 claims, respectively. Fiscal year (FY) 2014 (July 2013-June 2014) accounted for 196 of 801 (24.47%) of claims, while FY 2011 accounted for only 113 (14.11%) of claims.

Table 2 details the demographic data and average cost of claim by job task within the industry. All dollars amounts were adjusted for inflation to the 2015 dollar value before analysis. A Kruskal-Wallis Test determined there was a significant difference in the average age by job task type ($\chi^2 = 144.84$, df = 5, $p < .0001$) (Figure 2), as well as the average length of employment by job task type ($\chi^2 = 95.04$, df = 5, $p < .0001$) (Figure 3).

Claim characteristics of incident type and nature of injury varied significantly based up job type (Table 3). Fisher's exact test indicated a significant difference in the type of incidents that occur based upon job task ($p < .0001$), as well as a significant difference in the nature of injury based upon job task ($p < .0001$). The most common incident type for sawyers and hookers was struck by injuries (51.3%), followed by falls (19.9%). The incident type for other job tasks was different than that of the sawyers and hookers, with falls being a more prominent incident type than struck by injuries for equipment operators, supervisors or

TABLE 1 Frequency and descriptive statistics for injury and fatality claims

Categorical variables (*N* = 801)	Percent (chi-square test for homogeneity *p*-value)
Age group	
Under 20	2.14%
20-29	21.73%
30-39	20.85%
40-49	18.84%
50-59	27.51%
60 and over	8.92%
	(*p* < .0001)
Length of employment	
<6 months	25.92%
≥6 months	74.08%
	(*p* < .0001)
Job title	
Sawyer/Hooker	47.69%
Equipment operator	22.35%
Truck driver	17.85%
Other	5.74%
Supervisor	5.74%
Mill operator	0.62%
	(*p* < .0001)
Fiscal year	
2011	14.11%
2012	21.35%
2013	19.10%
2014	24.47%
2015	20.97%
	(*p* < .0001)
Season	
Spring	13.86%
Summer	29.09%
Autumn	29.96%
Winter	27.09%
	(*p* < .0001)
Data source	
ALE	79.65%
MSF	20.35%
	(*p* < .0001)
State	
Idaho	64.17%
Montana	35.83%
	(*p* < .0001)
Claim type	
Medical only	57.68%
Temporary disability	21.85%
Permanent disability	20.10%
Fatal	0.37%
	(*p* < .0001)
Body part	
Lower extremity (thigh, knee, lower leg, shin, and calf)	17.60%
Upper extremity (upper arm, shoulder, collarbone, elbow, and forearm)	17.60%
Multiple body parts	12.86%
Back/hip	12.23%
Hand/wrist (wrist, hand, palm, fingers, knuckles, and thumb)	11.61%
Ankle/foot (ankle, foot, heel, and toes)	7.62%
Eyes	5.62%
Ears/nose/mouth	5.49%
Trunk/internal injuries	5.24%
Neck	2.25%
Other	1.37%
Head	0.50%
	(*p* < .0001)

(Continues)

owners, and truck drivers. The incident type distribution for equipment operators mirrored that of truck drivers with falls being the most prevalent accident type followed by overexertion and struck by injuries. Two out of three fatality claims recorded during this period occurred to sawyers/hookers, with the third occurring to a truck driver. Across all job types, sprain/strains were the most

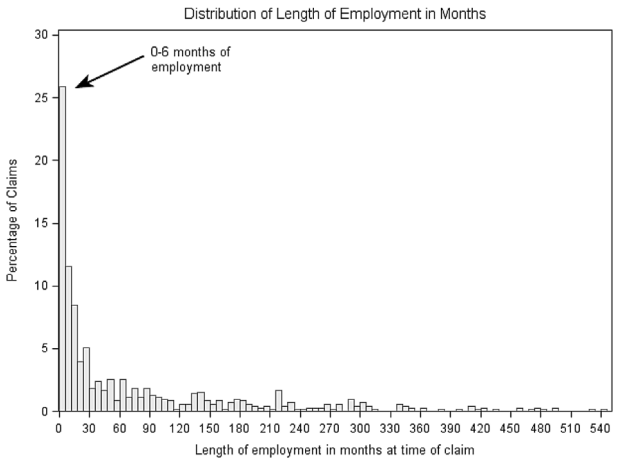

FIGURE 1 Distribution of the worker's length of employment in months at the time of workers' compensation claim

TABLE 2 Demographics and claim values by job task

Job task	*n*	Median age (range)	Median length of experience in months (range)	Median adjusted medical claim value (range)	Median adjusted indemnity claim value (range)	Median adjusted total claim value (range)
Sawyer/ Hooker	382	34	11.50	$1354	$0.00	$1988
		(18-64)	(0-413)	(0-398 558)	(0-237 358)	(0-565 549)
Equipment operator	179	49	45.00	$2520	$0.00	$2698
		(19-73)	(0-492)	(0-845 387)	(0-295 523)	(0-1 155 171)
Truck	143	50	36.00	$1,057	$0.00	$1,208
Driver		(17-73)	(0-434)	(0-812 044)	(0-409 363)	(0-1 021 543)
Other	46	47	64.00	$1010	$0.00	$1046
		(18-68)	(0-456)	(0- 41 978)	(0- 56 736)	(0- 70 143)
Supervisor/ owner	46	55	201.00	$2083	$0.00	$2098
		(31-65)	(10-540)	(0-149 866)	(0-170 445)	(0-320 773)
Mill operator	5	37	6.00	$409	$0.00	$409
		(32-54)	(0-88)	(0-93 125)	(0-113 672)	(0-206 797)
Total	801	44	24.00	$1,354	$0.00	$1,920
		(17-73)	(0-540)	(0-845 387)	(0-409 363)	(0-1 155 171)

common nature of injury. Although both nature of injury and incident type were significant when run as independent ANOVAs, a two-way ANOVA identified that when both variables were included in the model of total cost, only the main effect due to nature of injury was significant ($F = 2.55$, $p = 0.0135$).

3.2 | Cost analysis

There was no significant difference in the median cost of the total claim values based upon age group ($\chi^2 = 8.45$, df = 5, $p = 0.13$), experience level ($\chi^2 = 3.18$, df = 1, $p = 0.0745$) or job task ($\chi^2 = 10.38$, df = 5, $p = 0.0651$). However, median total claim cost was significantly different by incident type ($\chi^2 = 32.23$, df = 9, $p = 0.0002$).. Equipment overturns, caught between, and overexertion type claims had the highest median total claim values at $5,961 (Range = $539-1 155 171), $5,409 (range = 138-184 587) and $3,551 (range = $0-320 773), respectively. Vehicle collisions ($280, range = $0-7 730) and animal bites and stings ($303, range = $122-1 250) had the lowest median claim values.

There were significant differences in median total claim costs by the nature of injury ($\chi^2 = 129.99$, df = 7, $p < .0001$). Fatalities had the highest median total claim cost at $274 411 (Range = $170 762-

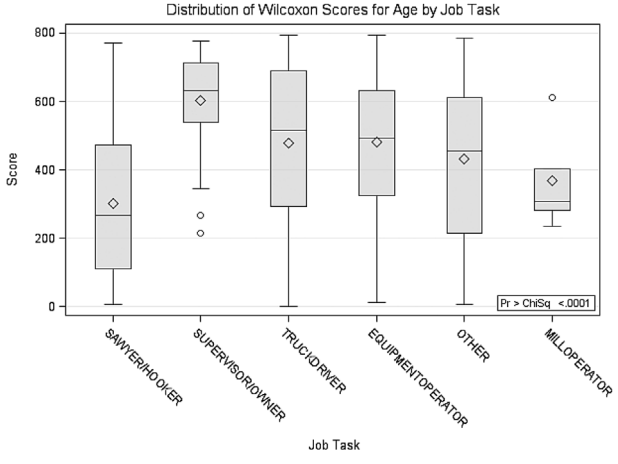

FIGURE 2 Kruskal-Wallis Box plot for age by job task

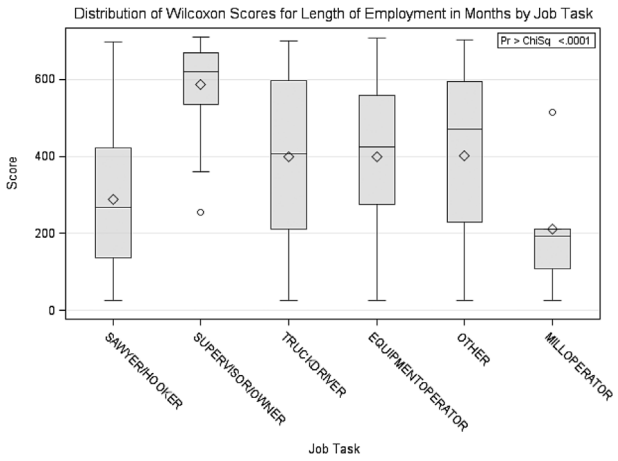

FIGURE 3 Kruskal-Wallis Box Plot for length of employment in months by job task

TABLE 3 Incident type and nature of injury distribution by job task

Job task	*n*	Incident type	%	Nature of injury	%
Sawyer/Hooker	382	Struck by	51.31	Sprain/Strain	29.58
		Fall	19.90	Contusion/Abrasion	20.94
		Overexertion	6.02	Laceration/Puncture	15.97
		Other	5.24	Other	11.52
		Involuntary movement	4.19	Fracture/Dislocation	13.61
		Caught between	4.97	Multiple injuries	6.02
		Voluntary movement	5.76	Head trauma	1.83
		Equipment overturn	0.0	Fatal	0.52
		Animal bite or sting	2.36		
		Vehicle collision	0.26		
Equipment operator	179	Struck by	22.35	Sprain/Strain	41.90
		Fall	28.49	Contusion/Abrasion	17.32
		Overexertion	11.73	Laceration/Puncture	11.17
		Other	12.85	Other	13.41
		Involuntary movement	10.06	Fracture/Dislocation	9.50
		Caught between	3.91	Multiple injuries	5.03
		Voluntary movement	3.91	Head trauma	1.68
		Equipment overturn	6.15	Fatal	0.0
		Animal bite or sting	0.0		
		Vehicle collision	0.56		
Truck Driver	143	Struck by	15.38	Sprain/Strain	42.66
		Fall	33.57	Contusion/Abrasion	16.78
		Overexertion	20.98	Laceration/Puncture	11.19
		Other	12.59	Other	13.29
		Involuntary movement	7.69	Fracture/Dislocation	15.38
		Caught between	4.20	Multiple injuries	0.0
		Voluntary movement	0.0	Head trauma	0.0
		Equipment overturn	1.40	Fatal	0.70
		Animal bite or sting	0.0		
		Vehicle collision	4.20		
Other	46	Struck by	28.26	Sprain/Strain	32.61
		Fall	23.91	Contusion/Abrasion	32.61
		Overexertion	10.87	Laceration/Puncture	13.04
		Other	17.39	Other	17.39
		Involuntary movement	10.87	Fracture/Dislocation	2.17
		Caught between	8.70	Multiple injuries	0.0
		Voluntary movement	0.0	Head trauma	2.17
		Equipment overturn	0.0	Fatal	0.0
		Animal bite or sting	0.0		
		Vehicle collision	0.0		
Supervisor/Owner	46	Struck by	17.39	Sprain/Strain	50.00
		Fall	32.61	Contusion/Abrasion	13.04
		Overexertion	13.04	Laceration/Puncture	10.87
		Other	8.70	Other	8.70

(Continues)

TABLE 3 (Continued)

Job task	n	Incident type	%	Nature of injury	%
		Involuntary movement	2.17	Fracture/Dislocation	10.87
		Caught between	10.87	Multiple injuries	6.52
		Voluntary movement	13.04	Head trauma	0.0
		Equipment overturn	2.17	Fatal	0.0
		Animal bite or sting	0.00		
		Vehicle collision	0.00		
Mill Operator	5	Struck by	40.00	Sprain/Strain	60.00
		Fall	40.00	Contusion/Abrasion	20.00
		Overexertion	20.00	Laceration/Puncture	20.00
		Other	0.0	Other	0.0
		Involuntary movement	0.0	Fracture/Dislocation	0.0
		Caught between	0.0	Multiple injuries	0.0
		Voluntary movement	0.0	Head trauma	0.0
		Equipment overturn	0.0	Fatal	0.0
		Animal bite or sting	0.0		
		Vehicle collision	0.0		

412 613), followed by multiple injuries ($17 138, Range = $538-1 155 171) and fractures/dislocations ($11 466, Range = $0-1 021 543). Contusions/abrasions had the lowest median claim cost with a median adjusted claim value of $810 (Range = $0-565 549).

3.3 | Results from focus groups

Sixty-three professional loggers ranging in age from their early 20s to more than 60 years participated in the focus groups (Table 4). The majority (42) of loggers worked in Idaho, were male and employed as equipment operators. During the focus group sessions, many of the owners who were also equipment operators indicated that they had experience in most of the work tasks throughout their logging career. Nearly 40% of the participants were greater than 50 years old.

Information from the two focus groups were summarized and analyzed into common themes (Table 5). The first objective of the focus group discussions was to identify the most dangerous aspects of the various work tasks conducted by professional loggers (Table 5). Both focus groups identified sawyers and hookers as the job positions at greatest risk for occupational injuries and fatalities. The occupational tasks and variables that they specifically identified as having the highest risk leading to injury included hand felling with chainsaws, falling trees and branches, getting hit by the skyline carriage, and being hit by a tree that was snagged on objects while skidding.

Drivers and mechanics were the job positions considered the next most dangerous. When discussing occupational risks and injuries to truck drivers, the loggers identified sprains and strains as a major issue. Ankle sprains, for example, were not uncommon and often sustained

TABLE 4 Demographic distribution of focus group participants

Focus group participants					
Sex	n	Job title	n	Age range	n
Male	58 (92%)	Operator/Owner	23 (37%)	21-25	2 (3%)
Female	3 (5%)	Operator/Not owner	25 (40%)	26-30	6 (10%)
Unknown	2 (3%)	Sawyer/Hooker	3 (5%)	31-35	4 (6%)
		Truck driver	12 (19%)	36-40	9 (14%)
				41-45	7 (11%)
				46-50	10 (16%)
				51-55	9 (14%)
				56-60	9 (14%)
				>60	7 (11%)
Total	63	Total	63	Total	63

TABLE 5 Focus group discussion of tasks, risks, and injuries by job task

Job task	Risks and injuries
Sawyers and Hookers	Falling tree branches and limbs
	Hand felling
	Falls
	Working on steep slopes
	Struck by injuries
	Butt of swinging trees
	Carriage (During Line Skidding)
	Logs (During Line Skidding)
	Entry level position (inexperienced workers)
	Fatigue (8-10 hour workday)
Truck drivers	Manually placing stake extensions
	Poor positions
	Slippery work area
	Heavy, awkward lift
	Falls
	Driving distance/time to mills
	Vehicle collisions
	With other vehicles
	Single vehicle-slide off road due to weather conditions
Equipment operators	Falls from equipment
	Prolonged sitting
	Equipment overturns
Mechanics	Heavy lifting
	Twisting and bending to access engines
	Back injuries
	Hand and finger injuries

when they jumped or fell out of truck cabs or logging equipment, rather than using the steps. Truck drivers also reported upper limb strain injuries due to the manual installation of heavy stake extensions on the logging trailer. The extensions allow the trailer to carry more logs. This task involves manually lifting several four-foot metal extensions (30-40 lbs. each) overhead while standing on a narrow, often slippery surface several feet above the ground on the truck trailer. While engineering controls exist for improving this work task, many drivers have yet to install the new devices due to cost of retrofitting their current system. Truck drivers also reported high risk of road accidents due to poor drivers on the highway as well as driver fatigue from traveling long distances (8-10 hr routes were common) to saw mills for wood processing. Both truck drivers and equipment operators mentioned long hours of sitting as a contributor of low back pain.

The fifth job position considered to have increased risk of occupational injuries was for heavy equipment mechanics. The equipment mechanics indicated that their job tasks often involved manual lifting and handling of heavy equipment parts, twisting and bending in awkward upper limb and trunk positions and prolonged static (and often awkward) positions to access engine and other areas of equipment. Low back injuries and hand and finger injuries were common body areas affected.

After discussing the job tasks, injuries and risk, the focus groups were directed to the question of how risks and be prevented (Table 6). Common themes related to injury prevention discussed included improving safety communication (common risks, risks associated with unique situations), safety culture and safety leadership skills, job and safety training (especially for new hires), situation awareness, and ensuring proper and consistent use of personal protective equipment. Specifically, within communication, ensuring that frequent safety meetings occur, whether formal or informal, as well as ensuring that safety issues are corrected and addressed as soon as they observed were topics discussed within both focus groups.

Finally, the focus groups were asked what the logging community could do to ensure worker safety more effectively. Ideas included consistency in safety practices and requirements among landowners, enforcement of existing safety laws, use and availability of GPS technology for the location of injury and evacuation sties, and ensuring that all workers had access to training and knew evacuation procedures and the area's available emergency resources.

4 | DISCUSSION

The logging industry in the Intermountain West region of Idaho and Montana presents a challenge for occupational injury and fatality prevention. Due to the terrain, remoteness of the region, and availability of emergency services, logging injuries and fatalities in this region are an ongoing challenge. While there are many similarities between the results of the present study and the work of other researchers throughout the country and world, there are also differences due to the unique attributes of the region, which contribute to differences in harvesting practices, techniques, and occupational culture.

Previous research in the logging industry has focused on the annual rate and characteristics of injuries[5,12–15,17,18] the effects of mechanization,[6,7,18–20] worker's perceptions of the occupational risk,[6,17] as well as the development of training strategies.[16,21,22] This study presents new research to the field of logging injury analysis though use of mixed-methods approach to analyze region-specific injury and fatality data and presenting observations from professional loggers with insight on causation and prevention of injuries.

Our findings support the findings of Laschi et al, that workdays on a Monday were determined to have the highest percentage of accidents, as well as the work of Albizu-Urionabarrenetxea et al, that most injuries occured during the spring and fall seasons. Laschi et al attribute the finding that Mondays have the highest injury rate over other days of the week to workers' lower attention levels and carefulness on the day after a weekend.[23] Our work also supports previous research in that falling and processing job tasks were found to

TABLE 6 Prevention ideas and barriers to safe logging practices

Prevention ideas	Barriers
Enhanced safety culture from the top down	Tough and independent work culture
Training in safety leadership	Resistance to change
Frequent and consistent safety meetings with crew	Lack of leadership
Correct and address dangerous situations when they are observed	Drug/Alcohol use
Encourage taking lunch breaks	Personnel and family issues migrating to job site
Consider using break time to encourage communication between team	Cost and Production- Thin Margins
Empower workers to speak up during unsafe situations or when they do not know how to safely/properly preform work tasks	Cost to implement safety programs
Ensure safety is a priority from the top town (from the mills and the land owners)	Limited personnel to complete same amount of work
Change in land management is providing consistency in safety expectations across worksites	Limited number of workers entering industry
Discussion of defensive driving and incident prevention during driving	Limited amount of formalized training available for new hires. Training is provided by employer at the job site.
Discussion on proper tree felling techniques	
Discussion on proper hooking techniques	
Lockout tagout training	
Reduce driver's injuries during stake extension tasks	
Provide lifting equipment, PPE, and guarding for mechanics	

contribute to a disproportional number of injuries within the industry. Lefort et al reported that the majority of workers' compensation claims were attributed to struck-by injury types (58%), followed by falls (14%).[14] The results of the present study determined that struck-by injuries were attributed to 35% of all claims, while falls were responsible for 25% of claims in the Intermountain West region. The relatively higher prevalence of falls in the Intermountain West region may be due to the steep terrain, or due to wet or frozen conditions present during the autumn and winter seasons. While many previous studies focus on analysis and reporting of incident types (struck-by, fall, caught between, etc.), the results in the present study suggest that incident type and nature of injury (sprain/strain, laceration, fracture) are associated and the effect seen in the cost of claim can be attributed to nature of injury rather than incident type.

Sprain and strain injuries have been a substantial contributor to the number and cost of workers' compensation claims in the logging industry. A study of injuries in the logging industry of Louisiana suggested that a shift was occurring in the type of injuries from primarily lacerations to sprain and strain injuries. The study period took place during the shift from conventional to mechanized logging and suggested that the reason for the change in injury type was due to mechanization.[14,24] The authors believed that this switch was due to the declining number of workers who are actively involved in manual felling and the shift to mechanized operations. However, with the decline in laceration injuries, there was an increase in the number of injuries due to falls (specifically falls from machinery and vehicles).[14] With the shift in injury type due to mechanization, there is evidence that as logging becomes more mechanized, "the accident rates decline, but the severity of the injuries increases."[14] Due to the steepness of terrain present throughout the Intermountain West region, it has not been possible to use mechanized felling systems in all timbered areas. Due to the inability to mechanize, lacerations still contribute to almost 15% of injuries. Additionally, in the Intermountain West region, the high number of strain and sprain injuries cannot solely be attributed to falls from equipment and vehicles. For example, the most common injuries sustained by fallers and hookers (during manual felling) were sprain/strain injuries. The Intermountain West region may present a different set of hazards to fallers and hookers due to the terrain and conditions of their work. These conditions (such as unstable, steep, and slippery surfaces) may contribute to the higher number of sprain/strain injuries rather than laceration type injuries usually present during falling and hooking job tasks.

The high number of injuries occurring to inexperienced, young workers (Figure 1) is highly concerning seeing as more than 25% of all claims occurred to workers in their first 6 months on the job. A literature review by Albizu-Urionavarrenetxea et al suggests that the primary reason many studies find a correlation between lack of experience and injury rate is due to inexperienced workers' lack of awareness of the possible occupational risks and hazards.[24] Adequate training and apprenticeship programs should be in place to provide the background knowledge and skill set required for safely preforming essential job functions.[24] The results of this study determined that the most common injuries for inexperienced workers in the logging industry are due to tasks related to falling and hooking or vehicle collisions. Injuries from falling can be prevented using a combination of personal protective equipment (PPE) and training. Training should focus on how to identify safe escape paths during tree falling as well as identifying hazards present in the environment such as dead tops, snags, and nearby trees.

Prior research has also identified the importance and need for adequate training on safe driving habits and machine and tool use.[14,24] In addition, the most frequently cited violation of federal safety standards was lack of adequate logging operations training.[14] Studies highlight the importance of using a participatory approach with the end-user in order to develop relevant safety training,[22] yet little research or case studies have been published on the implementation and evaluation training programs in the logging industry using a participatory approach.

The use of participatory action research, such as focus groups with end-users, to develop ideas for safety interventions, has been shown to be highly effective at identifying practical applications of research or developing new areas of study.[25,26] Participatory action research is a continuous, interactive process with input from the community/stakeholders and the researchers. Benefits of using a participatory approach include end-user perspective and buy in, and results in locally tested outcome.[25]

As shown in the present study, end-users can assist in identifying risks as well as solutions for occupational injuries. Previous research by Nieuwenhuis and Lyons,[17] identified similar barriers to health and safety in the logging industry including: financial restrictions, pressure of work, and lack of training.[17] The same study surveyed workers on potential intervention strategies and found that 45% of surveyed workers suggested topics that included enhanced safety training.[17]

4.1 | Limitations

There are several limitations present in the currently study design. Use of workers' compensation claim data relies upon complete and thorough investigation and reporting by the provider. Additionally Alamgier et al,[27] suggest that logging industry may have similar problems with injury reporting as the agricultural industry, in that many injuries are lost to surveillance due to "work on small firms that may remain unprotected from federal regulations, and therefore escape the capture of routine surveillance systems . . . and incomplete reporting from unpaid family workers, small employers, the self-employed, and owners and partners in unincorporated firms."[27]

Due to limited information on the number of employees in the workforce, demographic composition of the workforce, duration of the work week, and seasonal differences in productivity and hours worked, it was impossible to calculate injury and fatality rates. The lack of denominator data are further complicated in that data such as demographics and hours worked vary based upon region. Therefore, nationwide estimates of productivity and workhours would not provide an accurate representation when performing regional analysis. Future research should focus on overcoming these limitations to more adequately investigate rates of injury due to demographic factors such as age and experience.

5 | CONCLUSIONS

The results of the present research provides the background for developing focused injury prevention strategies aimed at reducing injuries and fatalities in the logging industry. The mixed-methods approach used in the present study provides a more comprehensive understanding of logging injuries, their nature, costs and associated factors than a single methods approach. The insight from this study can be used to direct future intervention and training strategies. Injury prevention efforts in the Intermountain West region should focus on training related to safe work methods (especially for inexperienced workers), the development of a safety culture and safety leadership, as well as implementation of applicable engineering controls.

AUTHORS' CONTRIBUTIONS

Elise Lagerstrom: Conception and study design, study design, data acquisition, analysis and interpretation of the work, manuscript drafting. Sheryl Magzamen: Study design, analysis and interpretation of the work, manuscript drafting, critical review, final approval of manuscript. John Rosecrance: Conception and study design, data acquisition, analysis and interpretation of the work, manuscript drafting, critical review, final approval of manuscript.

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ETHICS APPROVAL AND INFORMED CONSENT

The Institutional Review Board (IRB) Coordinator (Colorado State University, IRB ID: 102-17H) has reviewed this project and has declared the study exempt from the requirements of the human subject protections regulations with conditions as described above and as described in 45 CFR 46.101(b): Category 2 – Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects'

responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation. Category 4 – Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. Verbal informed consent was obtained from focus group participants.

DISCLOSURE (AUTHORS)

The authors report no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

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

DISCLAIMER

None.

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