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Risk of injury by job assignment among federal wildland firefighters, United States, 2003–2007

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Background: Wildland fires cost billions of dollars annually and expose thousands of firefighters to a variety of occupational hazards. Little is known about injury patterns among wildland firefighters.
Methods: We examined non-fatal firefighter injuries among federal wildland firefighters reported to the US Department of the Interior for the years 2003–2007. The risk of disabling injury by job assignment, controlling for demographic and temporal variables, was assessed with logistic regression.
Results: Of the 1301 non-fatal injuries, slips, trips, and falls were the most frequent injury types and sprains/strains were the most common injury. Engine crew workers suffered a third of all injuries. Handcrews and helitak/smokejumper assignments had increased odds of sprains and strains, which were the most common injury overall.
Conclusions: While some injuries are equally prevalent by job assignment, others vary. Identifying hazards leading to these injuries will be essential to develop prevention strategies.

Keywords: Occupational safety, Wildland fires, Epidemiology, Injury risk

Introduction

Wildland fires affect wilderness areas, rural communities, and urban areas, and there is growing concern over the increase in structures built in wildland areas in the United States. On average in the United States, 80 000 wildland fires burn 4.5 million acres each year, costing taxpayers, insurers, and private individuals billions of dollars.[1,2] Fighting these fires requires the combined resources of local, state, and federal agencies as well as volunteers and contractors.

At the heart of the firefighting effort are tens of thousands of firefighters. During 2003–2007, the National Interagency Coordination Center, a national clearinghouse for fire resources within the National Interagency Fire Center in Boise, ID, mobilized over 200 000 firefighters to large wildland fires that required interagency coordination.[3] Despite the number of personnel involved in wildland firefighting efforts, and the hazards to which they are exposed, relatively little is known about non-fatal injuries in this occupational group.

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The majority of research on firefighters has focused on exposure to respiratory hazards and physiological response to training and environmental conditions.[4–6] The few existing studies of injuries have focused on personal characteristics of firefighters rather than occupational duties.[7] To date, information about injuries suffered by wildland firefighters comes from fatality investigations conducted by the involved agency and the National Institute for Occupational Safety and Health and limited publications in peer-reviewed literature.[8] Additional information is provided in descriptive summaries published by the United States Fire Administration and in unpublished project reports.[9–12]

No previous firefighter studies have examined non-fatal injuries by specific occupational tasks. Wildland firefighters engage in a range of varied tasks including clearing brush with hand tools, parachuting to fires, operating bulldozers, ordering supplies, and managing food service operations. To help bridge this critical information gap, we examined fire-related injuries among workers fighting fires on federal land, as reported to the United States Department of Interior over a 5-year period, to evaluate how job assignment affects the cause and type of injury, body

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part injured, and severity of injury reported on wildland fires.

Materials and Methods

Source of data

Information for this analysis was from the United States Department of Interior (DOI) Safety Management Information System (SMIS). The SMIS is the web-based automated reporting system used by the DOI for mandatory reporting of any occupational illness, injury, or 'accident' involving DOI employees, volunteers, contractors, and visitors to DOI facilities. Incidents are reported by the involved employee or by a supervisor and include job-related illness or injury involving a worker's compensation claim, minor injuries not involving a compensation claim, property damage only events, and near-miss events.

In late 2002, the Fire Management Accident Report module was implemented to capture fire-specific information for incidents occurring during any fire management activity on federal land.[13] Using a Freedom of Information Act request, we obtained records for all incidents reported using the Fire Management Accident Report from 2003 through 2007. This study was considered exempt by the University of Iowa Institutional Review Board.

Exposure variables

The main exposure variable was the job to which the injured firefighter was assigned on the fire. Firefighters were categorized in the SMIS into one of eight job assignments: handcrews (subcategorized into types 1 and 2), engine crews, smokejumpers, helitack crews, overhead personnel, camp crews, and other jobs not consistent with the previous categories. After combining smokejumper/helitack and overhead/camp crews due to small samples and shared exposures, we had six categories for analysis.

Handcrews are groups of approximately 20 firefighters who primarily use hand tools (e.g. shovels, rakes, and saws) to construct a line clear of vegetation around a fire as a means of controlling fire spread. Type 1 handcrews ('hotshots') are crews available full-time for deployment to a fire throughout the fire season. They are the most experienced wildland firefighters and are often assigned the most challenging duties. Type 2 crews are composed of regular agency employees temporarily assigned to a fire, firefighters hired for one assignment only, or contract employees. Because types 1 and 2 crews are significantly different in experience and employment, they are considered separately.

Engine crews provide water, hoses, and pumping capability to a fire. Many DOI units (national parks, wildlife refuges, and resource areas) employ one or more engines, although engine crew employees can also be hired on contract. Engine crewmember experience is highly variable but must meet minimum national training requirements. Smokejumper/helitack personnel were combined into one category due to shared exposure to hazards associated with arriving at a fire by air and because the numbers of injuries reported and number of personnel assigned to these jobs is small relative to the other categories. Smokejumpers are experienced firefighters who parachute to fire areas inaccessible by land. Helitack personnel manage helicopter operations and also rappel from helicopters to inaccessible fire locations.

Overhead personnel have supervisory roles, such as incident commander, and oversee firefighting operations and personnel. Overhead jobs may or may not involve firefighting. Camp crews, groups of 10 people who mainly perform general upkeep chores around a fire camp, were included with overhead in this analysis due to their small numbers and their general lack of direct involvement in firefighting activities.

The 'other' category includes assignments such as heavy equipment operators (e.g. bulldozers), food operations, and tree fallers, as well as the approximately 8.5% of records with a missing job assignment.

Potential confounding variables examined were age at injury (17–24, 25–32, and 33–65 years), year of injury, season (early fire season: January–June; peak fire season: July–September; late fire season: October–December) and the time of day of occurrence (day: 6 a.m.–6 p.m.; night: 6 p.m.–6 a.m.). Age categories were defined to create a relatively even distribution across categories. Categories for time of occurrence were based on the standard 12-hour wildland firefighting shifts.

Outcome variables

The outcome variables assessed were the cause of injury, the nature of the injury, the body part injured, and the severity of injury based on whether the injury was reported as disabling (permanent or temporary) or not. Disabling injuries were defined using the Bureau of Labor Statistics standard as involving days away from work, days of restricted work activity or job transfer, or both.[13]

The original 62 causes of injury were collapsed into nine cause categories using the CDC 'Proposed matrix of E-code groupings'.[14] Ten records with missing cause data were combined with the records coded as 'not otherwise classified'. The original 36 categories of nature of injury were collapsed into six categories using the 'Barell injury diagnosis matrix classification by body region and nature of injury'.[15] Poisoning and environmental injury (e.g. animal bites and frostbite), although not included in the matrix, was added as a category because it was a frequently selected option within the SMIS. Ten records where

the nature of injury was missing were included in the 'other or not elsewhere classified' category.

Analysis

Pearson's Chi-square tests of independence were used to test the null hypothesis that the main effect of fire job assignment was independent of the outcome variables and potential confounders. Prevalence odds ratios (ORs) were calculated to describe the distribution of the cause of injury, injury type, and body region among injury cases.

A logistic regression model was developed to evaluate the effect of job assignment on the odds of reporting a disabling injury after controlling for confounding variables that included job assignment, age group, injury year, and season. A logistic model was used to predict the odds of disabling injury compared with non-disabling injury. Hosmer and Lemeshow goodness-of-fit tests were conducted to assess the adequacy of model fit and likelihood ratio tests were conducted to compare the full model with the main effects only model.[16]

Results were considered significant at $P \leq 0.05$. All analyses were completed using SAS v 9.1 and Stata 10.

Results

An SMIS query for Fire Management Accident Report incidents on federal landfor the years 2003–2007 yielded 2245 records. Of those, 575 records were classified as structural fire, training, or work-capacity testing incidents and were excluded from this analysis. Of the remaining records, 366 were classified as occupational illness, leaving a total of 1304 records coded as 'injury (not occupational illness)' that occurred on either a prescribed fire or wildfire. After the three fatalities were excluded, 1301 records remained for analysis.

Table 1 summarizes the time and demographic characteristics of the sample. The distribution of fire job assignment for injuries varied significantly by age at injury, year, and season ($P<0.001$). Age at injury ranged from 17 to 65 years of age. Engine crews and type 1 handcrews had the largest proportions of injuries to young firefighters; overhead/camp crews the largest proportion of injuries to older firefighters. This variation was not observed for the time of day ($P=0.46$).

Almost one-third of smokejumper/helitack (32.5%) crews' injuries and 'other' (30.1%) injuries were reported in 2003. One-quarter (25.4%) of engine crew injuries were reported in 2006. Over half (54%) of type 1 handcrew injuries were reported in 2003 and 2004. Type 2 handcrews reported over one-quarter (28.9%) of injuries in 2006, while one-quarter (26.6%) of overhead/camp crews' injuries were reported in 2007.

The majority of injuries across all jobs were reported July–September consistent with the peak of fire season. However, for engine crews and those

Table 1 Demographic and temporal characteristics of wildland firefighter injuries by fire job assignment, Department of the Interior, 2003–2007

	Fire job assignment						
	Engine crews	Type 1 handcrews	Type 2 handcrews	Overhead camp crews	Smokejumper helitack crews	Other unspecified	All injuries
Characteristic	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)
Number of injuries (%)	437 (33.6)	220 (16.9)	249 (19.1)	79 (6.1)	80 (6.2)	236 (18.1)	1301 (100.0)
Age at injury							$P \leq 0.001$*
17–24 years	195 (44.6)	99 (45.0)	87 (34.9)	11 (13.9)	17 (21.3)	68 (28.8)	477 (36.7)
25–32 years	149 (34.1)	104 (47.3)	118 (47.4)	14 (17.7)	24 (30.0)	95 (40.3)	504 (38.7)
33–65 years	93 (21.3)	17 (7.7)	44 (17.7)	54 (68.4)	39 (48.8)	73 (30.9)	320 (24.6)
Year							$P \leq 0.001$
2003	85 (19.5)	61 (27.7)	54 (21.7)	20 (25.3)	26 (32.5)	71 (30.1)	317 (24.4)
2004	75 (17.2)	58 (26.4)	29 (11.7)	13 (16.5)	17 (21.3)	46 (19.5)	238 (18.3)
2005	86 (19.7)	23 (10.5)	40 (16.1)	14 (17.7)	14 (17.5)	31 (13.1)	208 (16.0)
2006	111 (25.4)	36 (16.4)	72 (28.9)	11 (13.9)	12 (15.0)	45 (19.1)	287 (22.1)
2007	80 (18.3)	42 (19.1)	54 (21.7)	21 (26.6)	11 (13.8)	43 (18.2)	251 (19.3)
Season							$P \leq 0.001$
Early (January–June)	148 (33.9)	52 (23.6)	38 (15.3)	21 (26.6)	22 (27.5)	74 (31.4)	355 (27.3)
Peak (July–September)	251 (57.4)	159 (72.3)	194 (77.9)	53 (67.1)	57 (71.3)	130 (55.1)	844 (64.9)
Late (October–December)	38 (8.7)	9 (4.1)	17 (6.8)	5 (6.3)	1 (1.3)	32 (13.4)	102 (7.8)
Shift							$P=0.4649$
Day shift (06:01–18:00)	332 (76.0)	167 (75.9)	174 (69.9)	57 (72.2)	60 (75.0)	182 (77.1)	972 (74.7)
Night shift (18:01–06:00)	105 (24.0)	53 (24.1)	75 (30.1)	22 (27.9)	20 (25.0)	54 (22.9)	329 (25.3)

Note: **P* values are for Pearson's Chi-square tests of independence, testing the null hypothesis that the main effect and predictors are independent.

with an unspecified job assignment, one-third of injuries occurred during the first 6 months of the year consistent with the types of resources available and firefighting tactics used in early season fires.

The distribution of cause, nature, and injured body part by job assignment is summarized in Table 2. Both cause and nature of injury were significantly associated with job assignment ($P<0.001$) but body part was not ($P=0.07$). The two most common causes of injury were slips/trips/falls (28.1%) and equipment/tools/machinery (20.9%). Transportation was the least commonly reported cause of injury for all job assignments (3.0%).

Overall, sprains and strains were the most often specified nature of injury (29.4%). Slightly less than half of all injuries suffered by engine crewmembers (45.0%) and by smokejumper/helitack crews (45.0%) were sprains and strains. For all job assignments, fractures and dislocations (3.9%) and burns and other heat-related injuries (6.9%) were least frequently specified. Poisoning and environmental exposure type injuries accounted for about one-fifth (21.6%) of all injuries, but was the nature of injury reported in over one-third (36.4%) of injuries to type 1 handcrews. Contusions and wounds accounted for another one-fifth (21.0%) of all injuries and were seen with similar frequency across all fire job assignments.

The lower extremity (35.2%) was the most frequently injured body part, followed by the upper extremity (22.5%). Almost one-quarter (23.8%) of smokejumper/helitack crews' injuries were to the head or neck, while 16% of overhead/camp crews' injuries were back injuries. For injuries where the body part was specified, abdominal/thoracic injuries were least common.

The prevalence ORs for specific causes and types of injury and body part are reported in Table 3. Significant differences in the prevalence odds were noted particularly for injuries caused by burns and smoke where, with the exception of overhead/camp crews, the odds of this type of injury were significantly reduced for all jobs relative to engine crews. Type 1 handcrews were significantly less likely than engine crews to have injuries related to equipment, tools, and machinery [OR: 0.6; 95% confidence interval (CI): 0.4–0.9] but more likely to have poisoning/environmental exposure injuries (OR: 2.3; 95%CI: 1.5–3.6). Type 2 Handcrews had significantly increased odds for slips, trips, and falls (OR: 1.4; 95%CI: 1.0–2.0). Transportation injuries were most frequent among other/unspecified occupations.

An increase in the prevalence odds was observed for type 2 handcrews (OR: 1.4; 95%CI: 1.0–2.0) and

Table 2 Cause of injury, nature of injury, and injured body part for wildland firefighters by fire job assignment, Department of the Interior, 2003–2007

	Fire job assignment						
	Engine crews	Type 1 handcrews	Type 2 handcrews	Overhead/ camp crews	Smokejumper/ helitack crews	Other unspecified	All injuries
Characteristic	***N* (%)**	***N* (%)**	***N* (%)**	***N* (%)**	***N* (%)**	***N* (%)**	***N* (%)**
Number of injuries (%)	437 (33.6)	220 (16.9)	249 (19.1)	79 (6.1)	80 (6.2)	236 (18.1)	1301 (100.0)
Cause of injury							$P\leq0.001$*
Bites/stings	32 (7.3)	18 (8.2)	16 (6.4)	3 (3.8)	4 (5.0)	29 (12.3)	102 (7.8)
Burns and smoke	66 (15.1)	9 (4.1)	16 (6.4)	9 (11.4)	4 (5.0)	12 (5.1)	116 (8.9)
Equipment, tools, and machinery	96 (22.0)	32 (14.6)	51 (20.5)	17 (21.5)	19 (23.8)	57 (24.2)	272 (20.9)
Poisoning/environmental exposure	47 (10.8)	48 (21.8)	27 (10.8)	3 (3.8)	3 (3.8)	20 (8.5)	148 (11.4)
Slips, trips, and falls	111 (25.4)	59 (26.8)	79 (31.7)	26 (32.9)	26 (32.5)	64 (27.1)	365 (28.1)
Struck by, against	28 (6.4)	14 (6.4)	16 (6.4)	6 (7.6)	7 (8.8)	15 (6.4)	86 (6.6)
Transportation	12 (2.8)	3 (1.4)	2 (0.8)	4 (5.1)	3 (3.8)	14 (5.9)	38 (3.0)
Other/unspecified	45 (10.3)	37 (16.8)	42 (16.9)	11 (13.9)	14 (17.5)	25 (10.6)	174 (13.4)
Nature of injury							$P\leq0.001$
Burns and heat-related	36 (8.2)	9 (4.1)	18 (7.2)	6 (7.6)	8 (10.0)	13 (5.5)	90 (6.9)
Contusions and wounds	96 (22.0)	43 (19.6)	43 (17.3)	22(27.8)	15 (18.8)	54 (22.9)	273 (21.0)
Fractures and dislocations	18 (4.1)	7 (3.2)	6 (2.4)	5 (6.3)	3 (3.8)	12 (5.1)	51 (3.9)
Sprains and Strains	117 (26.8)	55 (25.0)	85 (34.1)	22 (27.9)	36 (45.0)	67 (28.4)	382 (29.4)
Poisoning/environmental exposure	98 (22.4)	80 (36.4)	42 (16.9)	9 (11.4)	7 (8.8)	45 (19.1)	281 (21.6)
Other/unspecified	72 (16.5)	26 (11.8)	55 (22.1)	15 (19.0)	11 (13.8)	45 (19.1)	224 (17.2)
Injured body part							$P=0.067$
Abdominal/thoracic	35 (8.0)	24 (10.9)	24 (9.6)	3 (3.8)	3 (3.8)	19 (8.1)	108 (8.3)
Back	37 (8.5)	17 (7.7)	23 (9.2)	13 (16.5)	8 (10.0)	23 (9.8)	121 (9.3)
Head/neck	95 (21.7)	32 (14.6)	41 (16.5)	16 (20.3)	19 (23.8)	40 (17.0)	243 (18.7)
Lower extremity	154 (35.2)	69 (31.4)	102 (41.0)	26 (32.9)	28 (35.0)	79 (33.5)	458 (35.2)
Upper extremity	90 (20.6)	57 (25.9)	45 (18.1)	16 (20.3)	20 (25.0)	65 (27.5)	293 (22.5)
Other/unspecified	26 (6.0)	21 (9.6)	14 (5.6)	5 (6.3)	2 (2.5)	10 (4.2)	78 (6.0)

Note: **P* values are for Pearson's Chi-square tests of independence, testing the null hypothesis that the main effect is independent of outcome.

smokejumper/helitack crews (OR: 2.2; 95%CI: 1.4–3.7) relative to engine crews for sprains and strains. Overhead/camp crews (OR: 0.4; 95%CI: 0.2–0.9) and smokejumper/helitack crews (OR: 0.3; 95%CI: 0.2–0.7) had significantly decreased odds for poisoning and environmental injuries as compared to engine crews, while type 1 handcrews had an increased odds for these injuries. Few associations between injured body part and job assignment were significant, although those with other/unspecific job assignments were more likely to have upper extremity injuries.

Table 4 summarizes the logistic model for disabling injuries. A total of 180 (13.8%) of the injuries were reported as either permanently or temporarily disabling. Seventeen percent of injuries reported by type 2 handcrews and those classified as 'other' were disabling. Overhead/camp crews reported the smallest proportion of disabling injuries at 8.9%. The largest proportion of disabling injuries was reported in 2004 (19.8%) and in the peak and late fire season (79.4%).

A Hosmer and Lemeshow goodness-of-fit test suggested that the model using three levels of season might be a poor fit for the data ($X^2=16.91$; $P=0.03$), which is likely a result of the small number of injuries reported in the late season. Thus, we report the complete logistic model using only two levels of season (early and peak/late season) which exhibited no lack of fit ($X^2=6.97$; $P=0.54$). A likelihood ratio test comparing the full model with the main effects only model showed that the full model had significant explanatory improvement over the simpler model ($X^2=16.05$; df=3; $P<0.05$).

Logistic regression modeling showed that few job assignments were associated with injury severity as measured by whether or not the injury was reported as permanently or partially disabling after controlling for age at injury, year, and season of occurrence. The only job assignment associated with disabling injury was the other/unspecified category (OR: 1.5; 95%CI: 1.0–2.4). The odds of severe injury were elevated in 2004 relative to 2003 (OR: 2.1; 95%CI: 1.3–3.5). The odds of severe injury were elevated for combined peak and late season injuries relative to early season injuries (OR: 1.5; 95%CI: 1.0–2.3).

Discussion

Wildfire suppression utilizes varied personnel assigned to tasks as diverse as building firelines with a shovel to food preparation, and these jobs assignments expose workers to different hazards. Among our study population, injuries caused by contact with heat or smoke comprised less than 10% of the

Table 3 Prevalence odds ratios (OR) for cause and nature of injury and body part injured by job assignment for injuries reported by DOI wildland firefighters, 2003–2007

	Fire job assignment (engine is reference)				
	Type 1 handcrews	Type 2 handcrews	Overhead/ camp crews	Smokejumper helitack crews	Other unspecified
Characteristic	OR [95% confidence interval (CI)]*	OR (95%CI)*	OR (95%CI)*	OR (95%CI)*	OR (95%CI)*
Cause of injury					
Bites/stings	1.1 (0.6–2.16)	0.9 (0.5–1.6)	—	—	**1.8 (1.0–3.0)**
Burns and smoke	**0.2 (0.1–0.5)**	**0.4 (0.2–0.7)**	0.7 (0.3–1.5)	—	**0.3 (0.2–0.6)**
Equipment, tools, and machinery	**0.6 (0.4–0.9)**	0.9 (0.6–1.3)	1.0 (0.5–1.7)	1.1 (0.6–1.9)	1.1 (0.8–1.7)
Poisoning/environmental exposure	**2.3 (1.5–3.6)**	1.0 (0.6–1.7)	—	—	0.8 (0.4–1.3)
Slips, trips, and falls	1.1 (0.8–1.6)	1.4 (1.0–1.9)	1.4 (0.9–2.4)	1.4 (0.8–2.4)	1.1 (0.8–1.6)
Struck by, against	1.0 (0.5–1.9)	1.0 (0.5–1.9)	1.2 (0.5–3.0)	1.4 (0.6–3.3)	1.0 (0.5–1.9)
Transportation	—	—	—	—	**2.2 (1.0–4.9)**
Other/unspecified	**1.8 (1.1–2.8)**	**1.8 (1.1–2.8)**	1.4 (0.7–2.9)	**1.9 (1.0–3.6)**	1.0 (0.6–1.7)
Nature of injury					
Burns and heat-related	**0.5 (0.2–1.0)**	0.9 (0.5–1.6)	0.9 (0.4–2.3)	1.2 (0.6–2.8)	0.7 (0.3–1.3)
Contusions and wounds	0.9 (0.6–1.3)	0.7 (0.5–1.1)	1.3 (0.8–2.4)	0.8 (0.5–1.5)	1.1 (0.7–1.5)
Fractures and dislocations	0.8 (0.3–1.9)	0.6 (0.2–1.5)	1.6 (0.6–4.4)	—	1.3 (0.6–2.6)
Sprains and strains	0.9 (0.6–1.3)	**1.4 (1.0–2.0)**	1.1 (0.6–1.8)	**2.2 (1.4–3.7)**	1.1 (0.8–1.5)
Poisoning/environmental exposure	2.00 (1.4–2.9)	0.7 (0.5–1.1)	**0.4 (0.2–0.9)**	0.3 (0.2–0.7)	0.8 (0.6–1.2)
Other/unspecified	0.7 (0.4–1.1)	**1.4 (1.0–2.1)**	1.2 (0.6–2.2)	0.8 (0.4–1.6)	1.2 (0.8–1.8)
Injured body part					
Abdominal/thoracic	1.4 (0.8–2.4)	1.2 (0.7–2.1)	0.5 (0.1–1.5)	0.5 (0.1–1.5)	1.0 (0.6–1.8)
Back	0.9 (0.5–1.7)	1.1 (0.6–1.9)	—	—	1.2 (0.7–2.0)
Head/neck	0.6 (0.4–1.0)	0.7 (0.5–1.1)	0.9 (0.5–1.7)	1.1 (0.6–2.0)	0.7 (0.5–1.1)
Lower extremity	0.8 (0.6–1.9)	1.3 (0.9–1.8)	0.9 (0.5–1.5)	1.0 (0.6–1.6)	0.9 (0.7–1.3)
Upper extremity	1.4 (0.9–2.0)	0.9 (0.6–1.3)	1.0 (0.5–1.8)	1.3 (0.7–2.2)	**1.5 (1.0–2.1)**
Other/unspecified	1.7 (0.9–3.0)	0.9 (0.5–1.8)	1.1 (0.4–2.9)	—	0.7 (0.3–1.5)

Note: *ORs significant at $P \leq 0.05$ are in bold type; results for cells with less than five injuries are not reported.

injuries. In addition, in comparison to engine crews, type 1 and type 2 handcrews, and those whose job assignment was not classified, were significantly less likely to report fires/burns as the cause of injury. Although smoke-related respiratory conditions could be classified as illnesses and therefore not included in our data set, the low percentage of burn, heat, and smoke injuries suggests that prevention strategies need to consider many types of hazards beyond the fire itself.

The most common injury cause was slips, trips, and falls, which were equally dispersed among all job assignments. Keifer and Mangan also found that falls were a common cause of injury for workers on the two large fires from the 2002 fire season.[17] These injuries were most frequent among job assignments working closely with the fire, which often involves unpredictable movements and uncharted terrain. Injuries from equipment, tools, and machinery were also frequent, and these were highest among the job assignments that work with heavier equipment, such as engine and smokejumper/helitack crews. Since these injuries were frequent among all job assignments, it is possible that some of the risk factors are common among all assignments, or that a great diversity of different hazards contributes to fall risk. Environmental as well as behavioral risk factors could be important, including factors such as fatigue and heat stress.

The increased prevalence of transportation-related injuries in the 'other' job type may be due to the types of duties that other personnel are assigned. This group includes occupations that are more likely to be involved in the transport of equipment or personnel, such as bulldozer operators and semi-tractor transporters, water tender operators, and airplane and helicopter pilots. These are all. Risk factors for firefighting-related transportation injuries may be similar to other industries that provide transportation in difficult terrain or acute situations, such as logging or search-and-rescue operations. Translation of prevention measures from these industries may be a promising approach.

Sprains and strains were the most frequently reported type of injury. Both type 2 handcrew and smokejumper/helitack crews exhibited elevated odds for these types of injuries relative to engine crews. Type 2 handcrews spend up to 12 hours per day on the fireline using hand tools such as shovels and rakes to create a line bare of vegetation to contain a fire. They often will hike to the fire carrying heavy, awkward equipment. The terrain in which they work is likely to be uneven, unstable, and steep. All these factors elevate the risk of a sprain or strain.

Type 1 handcrews exhibited elevated odds for injuries related to environmental exposures,[18] whereas overhead/camp crews exhibited a reduced odds compared to engine crews. Many of these

Table 4 Adjusted odds of disabling injury (permanent or temporary) for wildland firefighters, Department of the Interior, 2003–2007

	Disabling injuries	Non-disabling injuries	
Characteristic	*N* (%)	*N* (%)	Odds ratio (95% confidence interval)*
Number of injuries	180 (13.8)	1121 (86.2)	
Job assignment			
Engines	53 (12.1)	384 (87.9)	Reference
Handcrew — type 1	28 (12.7)	192 (87.3)	1.0 (0.6–1.7)
Handcrew — type 2	42 (16.9)	207 (83.1)	1.5 (0.9–2.3)
Overhead/camp crew	7 (8.9)	72 (91.1)	0.7 (0.3–1.7)
Smokejumper/helitack	10 (12.5)	70 (87.5)	1.0 (0.5–2.2)
Other/unspecified	40 (17.0)	196 (83.0)	1.5 (1.0–2.4)
Age group			
17–24 years	71 (14.9)	406 (85.1)	Reference
25–32 years	66 (13.1)	438 (86.9)	0.8 (0.6–1.2)
33+ years	43 (13.4)	277 (86.6)	0.9 (0.6–1.4)
Injury year			
2003	35 (11.0)	282 (89.0)	Reference
2004	47 (19.8)	191 (80.2)	2.1 (1.3–3.5)
2005	25 (12.0)	183 (88.0)	1.2 (0.7–2.1)
2006	41 (14.3)	246 (85.7)	1.4 (0.9–2.3)
2007	32 (12.7)	219 (87.2)	1.3 (0.7–2.1)
Season			
Early (January–June)	37 (10.4)	318 (89.6)	Reference
Peak and late (July–December)	143 (15.1)	803 (84.9)	1.5 (1.03–2.3)

Notes: *Odds ratios reported are adjusted for all other variables in the table. Hosmer and Lemeshow goodness-of-fit statistics: $X^2=6.97$; $P=0.54$. Likelihood ratio test comparing full model to main effects only model: $X^2=16.05$; df=3; $P<0.05$.

injuries were likely related to exposure to toxic plants, particularly poison oak found in the western states. In a previous study, it was estimated that one-third of forestry workers in the west coast states were disabled by poison oak at some point during a fire season.[19] Most type 1 handcrews will participate in multiple western fire assignments each season. Since type 1 handcrews are considered national resources, they travel outside their home regions to fight the frequent fires in the western states.

We did not find any association between the type of job assignment as recorded in these data and the severity of the injury after controlling for age at injury and the year of occurrence. Although there was no association with job assignment, we did observe significant variations in injury severity in the year of occurrence and in the season. After controlling for job, age, and season, injuries reported in 2004 had significantly increased odds for disabling injury than those in 2003. Of note, the 2004 fire season was unusual in that much of the activity occurred in Alaska. The 6.5 million federal acres burned in Alaska was 82% of the total acreage burned in the United States in 2004 and was more than eight times Alaska's 10-year average acreage. During a 2-day period in mid-June, Alaska received 17 000 lightning strikes.[20] We were not able to identify how many of the 2004 injuries occurred in Alaska, but firefighters regularly assigned to Alaska would have worked long hours over many days increasing both their overall risk of injury and of severe injury.

A 50% increase in the odds of severe injury after controlling for job, age, and injury year was noted for peak and late season injuries relative to early season injuries. Fatigue may be a contributing factor, but firefighting tactics and terrain also vary over the fire season. Early fires are more likely to be in the southeast, and engines and mechanized equipment are frequently sufficient to fight these fires. Temperatures and humidity are generally more moderate and fires are of shorter duration. Peak season fires tend to occur in the western United States where the terrain is often rugged, and the temperatures can be high and the humidity low. Access is frequently difficult and may involve travel on narrow mountain roads, hiking several miles, or flying in by helicopter. Much of the fire suppression is accomplished through the use of hand tools by hand crews, which we found to have frequent injuries. A closer examination of the circumstances surrounding these injuries is needed to identify the associated risk factors.

This study has several limitations. Differential reporting of injuries by severity and job category occurs primarily based on type of employment status which is related to job assignment. There was evidence that more severe injuries were more often reported in type 2 handcrews and for injuries with no job specified, but the difference did not reach statistical significance. In both cases, personnel are less likely to be regular agency employees, meaning that a supervisor would need to enter the incident information. This would be more likely to occur in cases severe enough to trigger a workmen's compensation claim. We created age categories to achieve an even distribution, rather than reflect developmental stages, which may limit our understanding of risks by age.

The data discussed here were limited to injured firefighters only. We had no access to information about firefighters who were not injured. As a result, we were not able to estimate the overall burden of injury or to examine possible risk factors for the injury itself, only the severity of the injury after it had occurred. Because the dataset lacked personal identifiers, we also could not identify cases in which a firefighter reported multiple injuries during the study period.

This was the first study to examine wildland firefighter job assignments associated with non-fatal injury characteristics. Focusing on injury to wildland firefighters will increase awareness of the daily hazards faced during wildfire suppression and provide for the development of evidence-based injury prevention strategies.

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