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Accident Analysis and Prevention 38 (2006) 973–980

ACCIDENT ANALYSIS & PREVENTION

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Work-related ladder fall fractures: Identification and diagnosis validation using narrative text

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Received 20 September 2005; received in revised form 27 March 2006; accepted 3 April 2006

Abstract

Objective: To identify ladder-related fracture injuries and determine how ladder fall fractures differ from other ladder-related injuries.
Methods: Ladder-related fracture cases were identified using narrative text and coded data from workers' compensation claims. Potential cases were identified by text searches and verified with claim records. Injury characteristics were compared using proportionate injury ratios.
Results: Of 9826 ladder-related injuries, 7% resulted in fracture cases. Falls caused 89% of fractures and resulted in more medical costs and disability days than other injuries. Frequent mechanisms were ladder instability (22%) and lost footing (22%). Narrative text searches identified 17% more fractures than injury codes alone. Males were more likely to sustain a fall fracture than other injuries; construction workers were most likely, and retail workers were the least likely to sustain fractures.
Conclusions: Fractures are an important injury from ladder falls, resulting more serious consequences than other ladder-related injuries. Text analysis can improve the quality and utility of workers compensation data by identifying and understanding injury causes. Proportionate injury ratios are also useful for making cross-group comparisons of injury experience when denominator data are not available. Greater attention to risk factors for ladder falls is needed for targeting interventions.

Keywords: Ladder; Methods; Narrative text; Occupational; Workplace injury; Adults

1. Introduction

Falls are a significant problem in the workplace in terms of deaths, lost work time, and costs to industry (Webster, 2000; Bjornstig and Johnsson, 1992; Kines, 2002; Diggs et al., 2005; Courtney et al., 2001). Falls from ladders are responsible for 16% of all fatal falls and 8% of non-fatal falls (Webster, 2000), and may account for nearly 2% of reported occupational injuries (Bjornstig and Johnsson, 1992).

Compared to all falls, falls from ladders appear to be among the more serious (O'Sullivan et al., 2004; Cohen and Lin, 1991a; Axelsson and Carter, 1995). One emergency department study found that 68% of ladder fall injuries resulted in lost workdays, with an average of 24 days lost per lost workday case (Cohen and Lin, 1991a). Axelsson and Carter (1995) reported that nearly 40% of workers with ladder-related injuries (93% were falls) were absent from work for more than a month, and half of those injured "experienced continuing, possibly permanent disability". Despite the seriousness of ladder injuries, studies of the events surrounding ladder falls have been limited and have only included small sample sizes or restricted population groups (Axelsson and Carter, 1995; Bjornstig and Johnsson, 1992; Cohen and Lin, 1991a,b; Faergemann and Larsen, 2000, 2001; Hill et al., 2002; Muir and Kanwar, 1993; Partridge et al., 1998; Tsipouras et al., 2001; O'Sullivan et al., 2004; Cattledge et al., 1996).

Fractures are one of the most severe outcomes from occupational injuries. In construction for example they resulted in much longer disability durations than other injuries (Courtney et al., 2002). To date, most epidemiologic studies of fractures have focused on events occurring in the general population (especially the elderly), and have not focused on workplace injuries

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0001-4575/$ – see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.aap.2006.04.008

(Black and Cooper, 2000; Davies et al., 2001; Campbell, 1990; Karlsson, 2002; Melton and Cummings, 1987; Raisz, 2005; Ivers et al., 2002; Sawyer et al., 2000; Robinson, 1998; Teh et al., 2003). The demographic characteristics of individuals at risk, and the context of their occurrence may be different for occupational fractures because of different types of exposures, environments, and tasks than the general population, as well as differences in demographic composition. To date most studies of occupational fractures have been clinical studies of specific fracture types (Iizuka et al., 1990; Conti and Silverman, 2002; Campbell, 2002; Oleske and Hahn, 1992; Oleske et al., 1992; Coughlin, 2000; McNamee et al., 1997). Islam et al. (2001) previously reported that the incidence of work-related fractures was higher than previously thought (5.5/1000 workers) based on their study of a state-managed workers' compensation system. While accounting for only 6% of all compensable injuries, fractures were responsible for 13% of the total medical costs. Falls were an important cause of these fractures, but few details on the fall events or contexts were provided. However, among the limited circumstances examined, if ladders were involved in the injury (considered by Islam et al., as "exposure"), a fracture was 1.9 times more likely to occur than other types of injury.

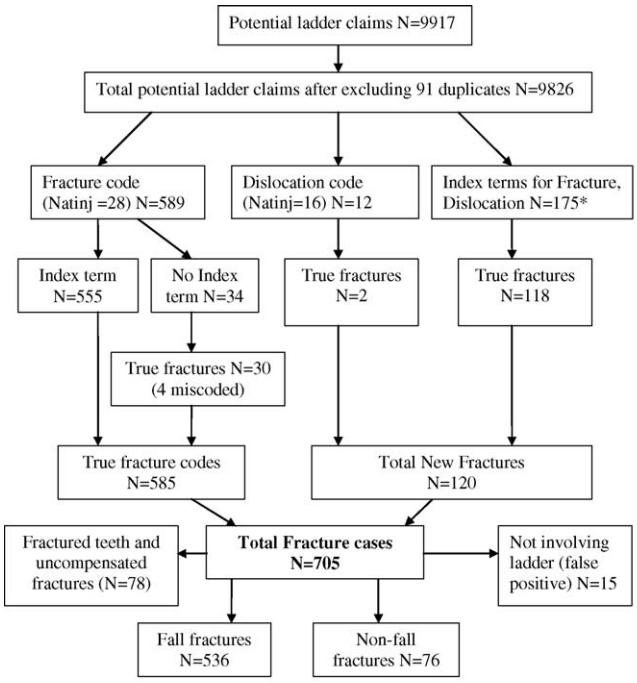
Previously published ladder studies have generally not provided detailed information on the severity and context of ladder-related injuries or how ladder falls that result in a fracture differ from falls that do not result in a fracture. This study uses narrative text analysis to identify ladder cases, confirm fracture diagnoses, and code injury circumstances. It describes the epidemiology of work-related ladder falls involving fractures by age, gender, circumstances, industry, treatment-related costs, and duration of disability, and also compares outcomes specific to ladder fall fractures among different groups. Our investigation was designed to examine whether occupational ladder fall fractures were more likely to result in higher relative costs and more disability time than other ladder-related injuries, and if ladder injuries were more likely to result in fractures in older workers or in specific industries (e.g., construction).

2. Methods

2.1. Identification of ladder-related injuries

Workers' compensation (WC) claims from a large insurance company were used to study ladder-related fractures. The insurer provides coverage for approximately 9% of the national WC market in the United States, which includes a broad range of industries. Claims for injuries occurring from the period 1 January 2000 through 31 December 2000 ($N = 535{,}605$) were examined to identify work-related ladder fall injuries and other work-related ladder injuries (e.g., struck by). Pre-coded data and two narrative text data fields were used in this analysis.

As there was no single code for ladder involvement used consistently across all claim reporting environments, we identified ladder cases from WC claims using a combination of search strategies. First, the narrative text fields containing the description of the injury ("injury description") and injury circumstances ("accident description") were searched to identify potential ladder-related injuries. Based on our earlier approaches on narrative text analyses (Lombardi et al., 2005; Wellman et al., 2004; Lincoln et al., 2004; McCullough and Smith, 1998) we determined that locating the index terms "ladd", "lader", "lander" and "latter" contained in any words in the text fields was the most efficient way to identify potential ladder cases. Once cases were identified, the narrative text was examined to determine if these injuries were truly ladder-related cases. In addition a small proportion of claims involved specific ladder-related codes, which only identified an additional 149 potential ladder injury cases. Of the 9917 potential ladder-related claims identified, 91 were duplicate claims and were therefore excluded.



* In addition, one case not counted as the claim was determined to be ineligible.

Natinj = nature of injury

Fig. 1. Case selection flow chart of ladder fall fractures from year 2000 workers compensation claims; comparison of narrative vs. coded data.

2.2. Selection of fracture cases

An important objective was to select all fracture cases from the available 9826 potential ladder-related injury cases. Because only one NCCI standard "nature of injury" code was available (NCCI, 2005), we used multiple strategies to identify all fractures, as preliminary analyses revealed that some cases with fracture had been coded as other injuries with "multiple injuries" or "dislocations" as the single assigned nature of injury code (Fig. 1). First, cases were identified using the available "nature of injury" code for fractures (code 28). Next, we developed index terms for fractures using the method described earlier for identifying ladder injuries. A search of the "injury" and "accident description" narrative text fields using the terms "frac", "frc", "fx", "broke", "bone", "crack", and "chip" was then conducted to ascertain any other fracture cases which were missed. Index

term searches were also used to identify cases coded as fractures without the index terms in their injury description. In addition we selected all cases coded as dislocation or containing the term "dislocat". For all the above new potential fracture cases identified, and those coded as fractures without fracture index terms, we then reviewed each individual claim to verify if an ICD code for fractures (National Center for Health Statistics, 1997) was assigned in the treatment records, as the injury description often reported suspected or possible fractures and was not updated with the final diagnosis.

2.3. Coding of ladder circumstances

All potential ladder-related fracture cases were reviewed for further coding of the circumstances of the injury. Circumstances were coded using our adaptation of the International Classification of External Causes of Injury (WHO, 2003) and included falls and non-falls (codes available on request). Based on the "injury" and "accident" descriptions, we coded the initiating mechanism, task involved, and the height of the fall (where reported) for all cases. The industry of the injured person was coded in the claims data by 4-digit Standard Industrial Classification (SIC) codes (OMB, 1987).

2.4. Cost and disability estimates

Aggregated costs were based on the claim status as of 6 November 2003 to allow a minimum 2.8 years claim cost development period. Cost calculations were conducted using the methods described earlier by Courtney et al. (Courtney et al., 2002; Webster, 2000) and identified medical and indemnity costs (wage replacement) separately. Open claims costs were estimated based on actual and estimated future indemnity payments. Disability duration was calculated by summing the temporary total and temporary partial disability days.

2.5. Analyses

Injuries of workers engaged in using ladders were described by age, gender, initiating mechanism, body part, task, duration of disability, incurred medical costs, and industry. The 1.6% of total cases with unknown causes (involved a ladder but could not specify mechanism) were included as "non-falls" in our analyses.

The underlying population at risk of reporting a ladder-related injury claim (denominator) was unknown in this study, precluding the calculation and comparison of the incidence rates of serious ladder fall fractures. Proportionate injury ratios (PIRs) were estimated to compare the proportion of serious ladder fall fractures by gender, age, industry, and body part. PIRs and associated 95% confidence intervals were calculated using methods for calculating proportionate mortality ratios (Checkoway et al., 2004; Lombardi et al., 2005; Lipscomb and Li, 2001) and the statistical significance of the observed to expected ratios was assessed using χ^2-tests. The PIR is calculated by comparing the observed proportions of claims of one group of interest (e.g., females in the retail trade) to that which would be expected if they were to have the same injury experience as a reference group of interest (e.g., males in the retail trade). Since proportions must equal 100%, an increase in one nature of injury category will be offset by a decrease in another.

In order to compare injuries across gender and age groups we used two categories of medical costs and disability duration. High cost injuries were defined as those resulting in $ 5000 or more in direct medical costs and serious disability was defined as those injuries resulting in 28 or more days of disability. These criteria were developed based on consultation with experts. More detailed cut points of costs and outcome were not conducted since it was beyond the scope of this paper and also because of small numbers in some subgroups. All data analyses were performed using SAS PC software version 9.1.2. The Liberty Mutual Research Institute for Safety and the Harvard School of Public Health Human Subjects Committees reviewed and approved the study.

3. Results

3.1. Case identification and selection

A total of 589 claims were identified by the fracture code, of which 555 (94%) contained one or more of the fracture index terms (Fig. 1). Manual review of narrative text for these cases revealed that all cases with the index term were fractures. However, 4 of the 34 cases not containing the index term had been miscoded and after reviewing the individual claims we determined they were not fractures (3 were contusions and the other a sprained knee). Because some fractures could have been coded as dislocations, a review of claims for all 12 dislocation cases containing the index terms uncovered only 2 additional fractures.

A search of the remaining potential ladder injury cases not coded as fractures using the fracture or dislocation index terms identified an additional 175 potential ladder-related fractures. Verification by reviewing electronic claims records found 118 cases to be true fractures (only 7 of the 47 cases identified by "dislocat" were true fractures). In total, 705 cases with fractures were identified among the potential ladder-related cases, of which 120 (17%) were identified only by the narrative text search.

Of the 705 fracture cases identified by initial searches as potential ladder-related injuries 15 (2%) were found on review of the records, to be false positives (i.e., non-ladder cases) (Fig. 1). This includes, for example, cases such as "standing near ladder" or "looking at ladder". In addition we excluded 78 cases from further analyses that were either fractured teeth or uncompensated fractures. These excluded cases included 30 fall fractures cases with only injuries to the teeth which although coded as fractures by NCCI, are not considered fractures according to the International Classification of Diseases (ICD) (National Center for Health Statistics, 1997) but rather as part of the group "open wounds head, neck and trunk" (ICD-9CM 873.63). In addition 23 fall fracture cases (3.5%) which incurred no medical costs or did not lose enough work time to exceed state thresholds for indemnity payments were excluded as we did not have cost or outcome data on these. Among the non-fall fractures the

Table 1
Distribution (number and column percent) of all ladder-related fractures by fall and non-fall, and by gender, age, and body part

	Fall fractures (%)	Non-fall fractures (%)	Total fractures (%)
Gender			
Female	92 (17.2)	20 (26.3)	112 (18.3)
Male	444 (82.8)	56 (73.7)	500 (81.7)
Age			
16–24	65 (12.1)	6 (7.9)	71 (11.6)
25–34	102 (19.0)	18 (23.7)	120 (19.6)
35–44	147 (27.4)	14 (18.4)	161 (26.3)
45–54	140 (26.1)	26 (34.2)	166 (27.1)
55–64	62 (11.6)	8 (10.5)	70 (11.4)
65–79	13 (2.4)	0 (0)	13 (2.1)
Unknown	7 (1.3)	4 (5.3)	11 (1.8)
Body part			
Head/neck	24 (4.5)	8 (10.5)	32 (5.2)
Upper extremity	94 (17.5)	5 (6.6)	99 (16.2)
Hand/wrist	127 (23.7)	25 (32.9)	152 (24.8)
Chest	42 (7.8)	2 (2.6)	44 (7.2)
Back	31 (5.8)	0 (0)	31 (5.1)
Pelvis	6 (1.1)	0 (0)	6 (1.0)
Hip	12 (2.2)	1 (1.3)	13 (2.1)
Ankle/foot	133 (24.8)	26 (34.2)	159 (26.0)
Other lower extremity	43 (8.0)	9 (11.8)	52 (8.5)
Multiple body parts	20 (3.7)	0 (0)	20 (3.3)
Unknown	4 (0.7)	0 (0)	4 (0.7)
Total	536 (87.6)[a]	76 (12.4)[a]	612 (100.0)

[a] Percents here are row percents.

same procedures excluded 25 cases with either fractured teeth or uncompensated fractures.

3.2. Narrative analysis

Among the remaining 612 confirmed ladder-related injury fracture cases occurring at work, almost 88% were falls from a ladder, the remainder were non-fall ladder-related injuries (Table 1). Most cases were males (82%) and there was no significant difference in the distribution of falls and non-fall fractures between males and females. Workers aged 35–54 accounted for 53% of ladder-related fractures and 14% were over age 55 years old (Table 1). There was no significant difference in the distribution of ladder fall and non-ladder fall fractures by age.

The body parts most often fractured were the ankle or foot, hand or wrist, upper extremity and lower extremity (Table 1). Males had a higher percentage of fractures to upper body structures (head/neck, upper extremity, hand/wrist, and chest), while females had a higher percentage of fractures to lower body structures (hip, ankle, foot, other lower extremities) (data not shown).

Falls were the leading cause of ladder-related fractures (Table 2) with slipping or losing balance on a ladder (includes missed step, slip on rung, or falling over backwards) as the most common reason for falling, followed by ladder instability (including ladder slipping, sliding out, tipped backwards, collapsed or bumped) and stepping on or off a ladder. The distribution of initiating mechanism was different in males and females (females had a predominance of ladder fractures as a result of slipping/losing balance) (Table 2). For only 1.6% of cases could we determine no specific mechanism and in 29.3% of falls the text only allowed us to identify them as a definite ladder-related fall. For the 60 fracture fall cases for which the height of the fall was recorded (11%), 41% occurred at a height of 10 feet (3.05 m) or greater (20%, ≥15 ft.) (data not shown). The small number of records with information prevented more detailed analyses, as did any analyses of the task involved.

3.3. Gender, age and industry

The majority of ladder fall fractures occurred in males (83%). Using proportionate analyses to compare fall fractures with all other ladder-related injuries we found that, among all people reporting ladder-related injuries, males were nearly 30% more likely to sustain a fall-related fracture than other injuries (PIR = 1.29), while females were 52% less likely to sustain a fall-related fracture (Table 3). Older age groups with claims for any ladder-related injury were also more likely to sustain a fall-related fracture than were workers in age groups less than 35 years, although the difference was only significant in those 45–54 years of age (PIR 1.33; 95% CI = 1.12–1.57). Analyses by industry showed that workers with ladder-related injuries in construction were the most likely to have sustained a fall-related fracture, while those in retail were the least likely group to sustain a fall-related fracture. However, there were considerable gender differences in ladder fall fractures by industry (Fig. 2); among females the majority (63%) occurred in retail, while among males 28% of ladder fall fractures occurred in con-

Table 2
Distribution (number and column percent) of all ladder-related fractures by initiating mechanism (injury cause); comparison by gender

Initiating mechanism	Female (%)	Male (%)	Total (%)
Falls			
Slipped/lost balance	37 (33.0)	118 (23.6)	155 (25.3)
Ladder instability	15 (13.4)	125 (25.0)	140 (22.9)
Stepping on/off ladder	6 (5.4)	36 (7.2)	42 (6.9)
External ladder cause	2 (1.8)	18 (3.6)	20 (3.3)
Falls with unspecified mechanism	32 (28.6)	147 (29.4)	179 (29.3)
Total falls	92 (82.1)	444 (88.8)	536 (87.6)
Non-falls			
Slip, no fall	5 (4.5)	8 (1.6)	13 (2.1)
External source (no slip/fall)	4 (3.6)	8 (1.6)	12 (2.0)
No external source (but on ladder)	2 (1.8)	3 (0.6)	5 (0.8)
Other ladder-related	9 (8.0)	27 (5.4)	36 (5.9)
Unknown/unspecified mechanism	0 (0)	10 (2.0)	10 (1.6)
Total non-falls	20 (17.9)	56 (11.2)	76 (12.4)
Total	112 (18.3)[a]	500 (81.7)[a]	612 (100.0)

[a] Percents here are row percents.

struction and only 12% in retail. The proportion of females with ladder fall fractures was significantly higher than males in retail (PIR 5.4; 95% CI = 4.1–7.0, data not shown). The small number of women with fractures in each industrial group prevented more detailed analyses in other industries.

3.4. Disability and costs

When using medical cost and disability duration as a proxy for severity, ladder fall fracture cases had worse outcomes as compared to all other ladder injury cases. About 48% of the lad-

Table 3
Proportionate injury ratio (PIR) analyses of ladder-related injuries comparing ladder fall fractures to all other ladder-related injuries by gender, age, and industry

	Fall fracture (%)	All other ladder injuries (%)	Expected fall fracture[a]	PIR[b] (95% CI)
Gender				
Female	92 (2.7)	3332 (97.3)	192	0.48 (0.39–0.59)*
Male	444 (6.9)	5958 (93.1)	344	1.29 (1.17–1.42)*
Age				
16–24	65 (3.7)	1674 (96.3)	97	0.67 (0.52–0.86)*
25–34	102 (4.7)	2073 (95.3)	120	0.85 (0.70–1.04)
35–44	147 (6.1)	2273 (93.9)	131	1.12 (0.95–1.32)
45–54	140 (7.1)	1824 (92.9)	105	1.33 (1.12–1.57)*
55–64	62 (6.7)	865 (93.3)	50	1.24 (0.95–1.59)
65–79	13 (7.1)	169 (92.9)	10	1.33 (0.71–2.28)
Unknown	7 (1.7)	412 (98.3)		
Industry				
Construction	127 (12.7)	870 (87.3)	50	2.53 (2.11–3.01)*
Retail	110 (2.5)	4238 (97.5)	244	0.45 (0.37–0.54)*
Manufacturing	69 (6.4)	1011 (93.6)	58	1.18 (0.92–1.50)
Services	69 (7.2)	891 (92.8)	51	1.34 (1.04–1.70)*
Transportation	46 (4.6)	947 (95.4)	55	0.84 (0.62–1.12)
Finance, RE, Ins	27 (7.9)	315 (92.1)	18	1.49 (0.98–2.16)*
Wholesale	25 (8.4)	273 (91.6)	16	1.59 (1.03–2.34)*
Agriculture	5 (6.0)	78 (94.0)	4.5	1.11 (0.36–2.59)
Mining	3 (10.0)	27 (90.0)	1.6	1.93 (0.39–5.63)
Public admin	1 (12.5)	7 (87.5)	0.4	2.48 (0.03–13.78)
Non-classifiable	0 (0)	6 (100.0)	0.4	0.00 (0.0–10.60)
Not assigned	54 (7.9)	627 (92.1)	36	1.49 (1.12–1.95)*
Total	536 (5.5)	9290 (94.5)		

[a] Expected frequency for fall fractures by category if they had the same distribution by category as those for all other injuries.
[b] The proportionate injury ratio (PIR) is calculated by dividing the observed fall fracture by expected fall fracture within a category.
* Statistically significant (p-value < 0.05).

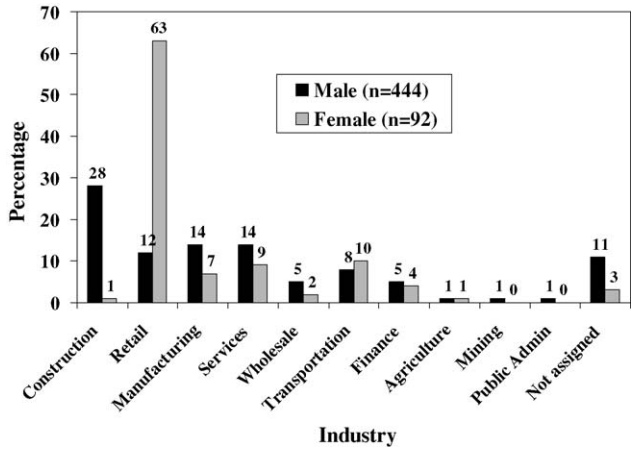


Fig. 2. Comparison of ladder fall fractures by gender and industry.

der fall fracture cases incurred $ 5000 or more in direct medical costs (high cost) compared to only 10% of all other ladder injury cases (data not shown). Similarly 56% of all ladder fall fracture cases had more than 28 days of disability compared to only 12% of the other ladder injury cases. Most of the high cost injury cases (80%) resulted in more than 28 days of disability. Only 35% of fall fracture cases were not high cost or had less than 28 days of disability compared to 86% for other ladder injury cases. Males had a significantly greater proportion of high cost ladder fall fracture injuries than females (49.8% versus 39.1%, respectively, data not shown). The proportion of ladder fall fractures that were high cost also increased significantly with increasing age group (27.5% among 16–34 years olds, 46.9% ages 35–44 years and 50.5% for persons 55 years and older).

4. Discussion

Fractures sustained in work-related ladder falls are a significant problem, more costly, and result in more time off work than other ladder-related injuries. Females had a lower proportion of high cost ladder fall fracture injuries when compared to males and costs increased with increasing age. Further, several groups of workers appear more likely to sustain a work-related ladder fall fracture. Males were nearly 30% more likely to sustain a fall-related fracture than any other ladder-related injuries. Females were more likely to have fractures as a result of slipping/losing balance while males were more likely to fall due to ladder instability. Construction workers experienced a higher proportion of fractures in ladder falls compared to other ladder injuries, while retail workers experienced a lower proportion. To our knowledge this is one of the largest sample of ladder injuries to date and our narrative text analyses provide important new information on case identification and the mechanisms and outcomes for a severe group of injuries. It is also the first such study to look specifically at fracture injuries and examine how ladder fall fractures differ from other ladder-related injuries, including non-fall fractures.

The higher likelihood among males that a ladder injury is a fall fracture may reflect their involvement in more hazardous tasks involving higher heights, or impacting more hazardous surfaces, as suggested by the fact that the highest proportion of male injuries occurred in construction, whereas for females it was in retail. The greater proportion of high cost ladder fractures in males than females also supports this hypothesis, although it could also be influenced by challenges of return to work in construction versus other industries (Courtney et al., 2002). The differences by gender in injury mechanisms may reflect differences in ladder use and type, such as greater use of stepladders in retail industries, or differences in describing mechanisms. However, specific ladder type was infrequently recorded in the "accident" descriptions. The lack of denominator data restricts determining if females have higher rates of injury in retail or other industries, and how rates vary by age. Similarly we cannot say that males have higher rates of fractures from ladder falls, but given that females accounted for over one-third of ladder injuries, we would expect that they might also account for one-third of fractures. However, our PIR analyses show they do not.

The increased proportion of high cost ladder fall fractures among older age groups found in our study is consistent with studies of other injuries which found that older persons are more likely to suffer complications post injury, have prolonged recovery following an injury, and have coexisting health problems that delay full recovery or restrict agility and ability to prevent or recover from a fall (Wang and Schneider, 1999; Summala and Mikkola, 1994; Wegman, 1999, 2000; Wegman and McGee, 2004). However, more detailed analyses of our data, controlling for factors such as injury mechanism, type of fracture, body part injured, or coexisting medical problems, are needed to determine the exact relationship of age and medical costs and is beyond the scope of this paper. Vision, balance and strength also decline with age, which may also increase the risk of falling (Shaheen and Niemeier, 2001; Coy and Davenport, 1991; McCarter, 1990; Wegman and McGee, 2004; Laflamme and Menckel, 1995; Zwerling et al., 1998). Older persons who fall are more likely to sustain a fracture, and more serious and complex fractures (Wegman and McGee, 2004; Kujala et al., 2000; Laflamme and Menckel, 1995; Wang and Schneider, 1999; Raisz, 2005; Black and Cooper, 2000). While in general the frequency of injury decreases with age, the injury severity, including likelihood of death, increases with age. However, the relationship between injury severity and age may also vary by job type (Laflamme and Menckel, 1995; Wegman, 1999, 2000; Wegman and McGee, 2004).

The proportionate analyses also identified important differences by industry categories. The higher proportion of fractures in construction has been discussed earlier and reflects the high risks of serious injury in this industry (Courtney et al., 2002; Kisner and Fosbroke, 1994; Glazner et al., 1998; Ringen, 1994; Cattledge et al., 1996; Lipscomb et al., 2003; Wang et al., 1999).

The majority of published ladder studies have only small sample sizes (usually under 100). We also found only two ladder studies that used more than purely descriptive statistics. One used secondary data and had limited findings with regard to ladder safety (Coleman, 1981), and the other case control study (Cohen and Lin, 1991b) did not use multivariate analyses, adjust for frequency of ladder use between cases and controls, and largely only examined personal risk factors.

The strengths of our study are our large sample size and the linkage of injury event and outcome with information on cost and disability. The workers' compensation (WC) insurer covers a diversity of industries across the U.S., and our data are potentially more representative of the national experience than the earlier ladder studies with small sample sizes in restricted populations. Our study also confirms other reports promoting the value of narrative text data to enhance WC claims data for analytic study (Lombardi et al., 2005; Lincoln et al., 2004; Wellman et al., 2004; Sorock et al., 1997). Narrative text searches identified 17% more fractures than were identified by the single nature of injury code for fractures alone and we were able to verify both coded and suspected fractures with medical reports. The text records provide a valuable tool for checking the accuracy of diagnostic codes in administrative databases especially as the injury codes are often assigned when the initial claim is made and usually not subsequently updated.

The narrative text analyses also enabled us to specifically identify ladder-related injuries, which is often not possible in many coded databases that use only general codes such as "falls from elevation". Our ability to provide detailed coding of fall circumstances from the text enabled us to provide more detailed understanding of fall circumstances than the earlier study of occupational fractures (Islam et al., 2001).

It is possible that the index terms did not identify all fractures or ladder terms, but the numbers are likely to be small and not alter our findings. While we were not able to verify through detailed coding of injury mechanisms all of the 9290 other potential ladder cases identified by our search strategies, only 2% of the fracture cases reviewed were false positives. In addition the available exposure information (case only data) did not permit the calculation of rate-based risk factor information on the most hazardous situations or activities performed on ladders. Our study shares some of the same limitations as other workers' compensation claims studies. Workplace injury reports are vulnerable to a variety of filtering effects and employer, location and state variations in reporting and recording practices for workers' compensation may limit the results (Webb et al., 1989; Smith et al., 2005). We did however restrict ourselves only to compensable claims (medical costs or paid disability days) which may limit the influence of this reporting variation.

There are also limitations associated with utilizing proportionate analyses. One limitation is that the sum of proportionate ratios must be equal to one. Therefore, the magnitude of a high ratio is offset by relative or corresponding lower magnitude of other ratios, making the ratios of the different injury categories interdependent. However, proportionate analyses (e.g., proportionate mortality ratio or PMR) which are similar to the PIR have proven to be useful as indicators of risk (Checkoway et al., 2004; Lombardi et al., 2005; Lipscomb and Li, 2001), and provided important new information in our study.

5. Conclusions

Our study clearly identifies that fractures are a significant and costly injury in work-related ladder falls and result in higher medical costs and more disability days than other ladder injuries. This study provides useful information on the work contexts involved in serious ladder injuries particularly differences by circumstances and industry in addition to those by age and gender. It also expands on our use of narrative text analysis to validate injury diagnoses, in addition to its use to identify cases. More studies are needed to define more specific injury mechanisms and address modifiable risk factors. Greater attention to risk factors for ladder falls is necessary to guide development of interventions to prevent ladder falls, and direct future training and targeted prevention efforts.

Acknowledgements

Research support was provided in part by NIOSH ERC Grant T42 CCT122961 and Center to Protect Workers' Rights Cooperative Agreement U54 OH008307.

References

Axelsson, P.O., Carter, N., 1995. Measures to prevent portable ladder accidents in the construction industry. Ergonomics 38 (2), 250–259.

Bjornstig, U., Johnsson, J., 1992. Ladder injuries: mechanisms, injuries and consequences. J. Safety Res. 23 (1), 9–18.

Black, D.M., Cooper, C., 2000. Epidemiology of fractures and assessment of fracture risk. Clin. Lab. Med. 20 (3), 439–453.

Campbell, A.J., 1990. Falls, fractures and drugs. N.Z. Med. J. 103 (903), 580–581.

Campbell, J.T., 2002. Foot and ankle fractures in the industrial setting. Foot Ankle Clin. 7 (2), 323–350.

Cattledge, G.H., Schneiderman, A., Stanevich, R., Hendricks, S., Greenwood, J., 1996. Non-fatal occupational fall injuries in the West Virginia construction industry. Accid. Anal. Prev. 28 (5), 655–663.

Checkoway, H., Pearce, N., Kreibel, D., 2004. Research Methods in Occupational Epidemiology, 2nd ed. Oxford University Press, New York, New York, pp. 70–72.

Cohen, H.H., Lin, J.L., 1991a. A retrospective case–control study of ladder fall accidents. J. Safety Res. 22 (21–30).

Cohen, H.H., Lin, L.J., 1991b. A scenario analysis of ladder fall accidents. J. Safety Res. 22, 31–39.

Coleman, P.J., 1981. Epidemiologic principles applied to injury prevention. Scand. J. Work Environ. Health 7 (Suppl. 4), 91–96.

Conti, S.F., Silverman, L., 2002. Epidemiology of foot and ankle injuries in the workplace. Foot Ankle Clin. 7 (2), 273–290.

Coughlin, M.J., 2000. Calcaneal fractures in the industrial patient. Foot Ankle Int. 21 (11), 896–905.

Courtney, T.K., Matz, S., Webster, B.S., 2002. Disabling occupational injury in the US construction industry, 1996. J. Occup. Environ. Med. 44 (12), 1161–1168.

Courtney, T.K., Sorock, G.S., Manning, D.P., Collins, J.W., Holbein-Jenny, M.A., 2001. Occupational slip, trip, and fall-related injuries—can the contribution of slipperiness be isolated? Ergonomics 44 (13), 1118–1137.

Coy, J., Davenport, M., 1991. Age changes in the older adult worker. Work 2, 38–46.

Davies, J.C., Manning, D.P., Kemp, G.J., Frostick, S.P., 2001. The rising number of underfoot accidents after the menopause causes both fractures and non-fracture injuries. QJM 94 (12), 699–707.

Diggs, B.S., Lenfesty, B., Arthur, M., Hedges, J.R., Newgard, C.D., Mullins, R.J., 2005. The incidence and burden of ladder, structure, and scaffolding falls. Acad. Emerg. Med. 12 (3), 267–270.

Faergemann, C., Larsen, L.B., 2000. Non-occupational ladder and scaffold fall injuries. Accid. Anal. Prev. 32 (6), 745–750.

Faergemann, C., Larsen, L.B., 2001. The mechanism and severity of non-occupational ladder fall injuries. J. Safety Res. 32, 333–343.

Glazner, J.E., Borgerding, J., Lowery, J.T., Bondy, J., Mueller, K.L., Kreiss, K., 1998. Construction injury rates may exceed national estimates: evidence from the construction of Denver International Airport. Am. J. Ind. Med. 34 (2), 105–112.

Hill, C., Johnston, K., Authur, M., Brand, D., Pearson, S., Mullins, R., Trunkey, D., 2002. Falls from ladders. Paper presented at: Proceedings of the Sixth World Conference. Injury Prevention Control: Injuries, Suicide and Violence: Building Knowledge, Policies and Practices to Promote a Safer World, 2005. pp. 606–607. Also available at: Book of abstracts, Proceedings of the Sixth World Conference. Chapter 4. Home and Industrial Safety. pp. 91–92. http://www.inspq.qc.ca/pdf/publications/InjuryPreventionControl2002.asp?A=4 (accessed 9-1-05).

Iizuka, T., Randell, T., Guven, O., Lindquist, C., 1990. Maxillofacial fractures related to work accidents. J. Craniomaxillofac. Surg. 18 (6), 255–259.

Islam, S.S., Biswas, R.S., Nambiar, A.M., Syamlal, G., Velilla, A.M., Ducatman, A.M., Doyle, E.J., 2001. Incidence and risk of work-related fracture injuries: experience of a state-managed workers' compensation system. J. Occup. Environ. Med. 43 (2), 140–146.

Ivers, R.Q., Cumming, R.G., Mitchell, P., Peduto, A.J., 2002. Risk factors for fractures of the wrist, shoulder and ankle: the Blue Mountains Eye Study. Osteoporos. Int. 13 (6), 513–518.

Karlsson, M., 2002. Does exercise reduce the burden of fractures? A review. Acta Orthop. Scand. 73 (6), 691–705.

Kines, P., 2002. Male occupational falls from heights: in-depth analyses. Ph.D. Thesis. University of Denmark, Department of Civil Engineering, Construction Management, Lyngby, Denmark. Available at: http://www.ami.dk/upload/bilag/Kines-PhD-Thesis.pdf (accessed 9-1-05).

Kisner, S.M., Fosbroke, D.E., 1994. Injury hazards in the construction industry. J. Occup. Med. 36 (2), 137–143.

Kujala, U.M., Kaprio, J., Kannus, P., Sarna, S., Koskenvuo, M., 2000. Physical activity and osteoporotic hip fracture risk in men. Arch. Intern. Med. 160 (5), 705–708.

Laflamme, L., Menckel, E., 1995. Aging and occupational accidents: a review of the literature from the last three decades. Safety Sci. 21, 145–161.

Lincoln, A.E., Sorock, G.S., Courtney, T.K., Wellman, H.M., Smith, G.S., Amoroso, P.J., 2004. Using narrative text and coded data to develop hazard scenarios for occupational injury interventions. Inj. Prev. 10 (4), 249–254.

Lipscomb, H.J., Li, L., 2001. Injuries among teens employed in the home-building industry in North Carolina. Inj. Prev. 7 (3), 205–209.

Lipscomb, H.J., Li, L., Dement, J.M., 2003. Falls among union carpenters. Am. J. Ind. Med. 44 (2), 148–156.

Lombardi, D.A., Pannala, R., Sorock, G.S., Wellman, H., Courtney, T.K., Verma, S., Smith, G.S., 2005. Welding related occupational eye injuries: a narrative analysis. Inj. Prev. 11 (3), 174–179.

McCarter, R.J., 1990. Age-related changes in skeletal muscle function. Aging (Milano) 2 (1), 27–38.

McCullough, P.A., Smith, G.S., 1998. Evaluation of narrative text for case finding: the need for accuracy measurement. Am. J. Ind. Med. 34 (2), 133–136.

McNamee, R., Kemmlert, K., Lundholm, L., Cherry, N.M., 1997. Injuries after falls at work in the United Kingdom and Sweden with special reference to fractures in women over 45. Occup. Environ. Med. 54 (11), 785–792.

Melton III, L.J., Cummings, S.R., 1987. Heterogeneity of age-related fractures: implications for epidemiology. Bone Miner. 2 (4), 321–331.

Muir, L., Kanwar, S., 1993. Ladder injuries. Injury 24 (7), 485–487.

National Center for Health Statistics, 1997. Official ICD-9-CM Guidelines for Coding and Reporting. Centers For Disease Control, Hyattsville, MD.

National Council on Compensation Insurance (NCCI), 2005. WCIO Workers Compensation Data Specifications Manual. NCCI, Boca Raton, FL. Available at: https://www.ncci.com/NCCI/index.aspx (accessed 8-26-05).

Oleske, D.M., Hahn, J.J., 1992. Work-related injuries of the hand: data from an occupational injury/illness surveillance system. J. Commun. Health 17 (4), 205–219.

Oleske, D.M., Hahn, J.J., Leibold, M., 1992. Work-related injuries to the foot. Data from an occupational injury/illness surveillance system. J. Occup. Med. 34 (6), 650–655.

Office of Management and Budget (OMB), 1987. Standard Industrial Classification Manual, US, 1987. Executive Office of the President, Washington DC. Available at: http://www.osha.gov/pls/imis/sicsearch.html (accessed 5-10-05).

O'Sullivan, J.O., Wakai, A., O'Sullivan, R.O., Luke, C., Cusack, S., 2004. Ladder fall injuries: patterns and cost of morbidity. Injury 35, 429–431.

Partridge, R.A., Virk, A.S., Antosia, R.E., 1998. Causes and patterns of injury from ladder falls. Acad. Emerg. Med. 5 (1), 31–34.

Raisz, L.G., 2005. Clinical practice. Screening for osteoporosis. N. Engl. J. Med. 353 (2), 164–171.

Ringen, K., 1994. National conference on ergonomics, safety, and health in construction summary report. Am. J. Ind. Med. 25 (6), 775–781.

Robinson, C.M., 1998. Fractures of the clavicle in the adult. Epidemiology and classification. J. Bone Joint Surg. Br. 80 (3), 476–484.

Sawyer, J.R., Flynn, J.M., Dormans, J.P., Catalano, J., Drummond, D.S., 2000. Fracture patterns in children and young adults who fall from significant heights. J. Pediatr. Orthop. 20 (2), 197–202.

Shaheen, S., Niemeier, D., 2001. Integrating vehicle design and human factors: minimizing elderly driving constraints. Transport. Res. Part C 9, 155–174, Available online via: http://repositories.cdlib.org/itsdavis/UCD-ITS-REP-01-06.

Smith, G.S., Wellman, H.M., Sorock, G.S., Warner, M., Courtney, T.K., Pransky, G.S., Fingerhut, L.A., 2005. Injuries at work in the US adult population: contributions to the total injury burden. Am. J. Public Health 95 (7), 1213–1219.

Sorock, G.S., Smith, G.S., Reeve, G.R., Dement, J., Stout, N., Layne, L., Pastula, S.T., 1997. Three perspectives on work-related injury surveillance systems. Am. J. Ind. Med. 32 (2), 116–128.

Summala, H., Mikkola, T., 1994. Fatal accidents among car and truck drivers: effects of fatigue, age, and alcohol consumption. Hum. Factors 36 (2), 315–326.

Teh, J., Firth, M., Sharma, A., Wilson, A., Reznek, R., Chan, O., 2003. Jumpers and fallers: a comparison of the distribution of skeletal injury. Clin. Radiol. 58 (6), 482–486.

Tsipouras, S., Hendrie, J.M., Silvapulle, M.J., 2001. Ladders: accidents waiting to happen. Med. J. Aust. 174 (10), 516–519.

Wang, E., Dement, J.M., Lipscomb, H., 1999. Mortality among North Carolina construction workers, 1988–1994. Appl. Occup. Environ. Hyg. 14 (1), 45–58.

Wang, S., Schneider, L., 1999. An aging population: fragile—handle with care. In: Proceedings of the National Highway Traffic Safety Administration, Available at: http://www-nrd.nhtsa.dot.gov/departments/nrd-50/ciren/um_fragile.html (accessed 5-13-03).

Webb, G.R., Redman, S., Wilkinson, C., Sanson-Fisher, R.W., 1989. Filtering effects in reporting work injuries. Accid. Anal. Prev. 21 (2), 115–123.

Webster, T., 2000. Workplace Falls. Compensation and Working Conditions. Spring, pp. 28–38.

Wegman, D., McGee, J., 2004. Health and Safety Needs of Older Workers. National Academies Press, Committee on the Health and Safety Needs of Older Workers, National Research Council, Washington, DC. Open book format available on line at: http://www.nap.edu/catalog/10884.html (accessed 7-22-05).

Wegman, D.H., 1999. Older workers. Occup. Med. 14 (3), 537–557.

Wegman, D.H., 2000. Occupational Health: Recognizing and Preventing Work-Related Disease and Injury, 4th ed. Lippincott, Philadelphia.

Wellman, H.M., Lehto, M.R., Sorock, G.S., Smith, G.S., 2004. Computerized coding of injury narrative data from the National Health Interview Survey. Accid. Anal. Prev. 36 (2), 165–171.

WHO Working Group on Injury Surveillance Methods, 2003. WHO Working Group on Injury Surveillance Methods. International Classification of External Causes of Injuries (ICECI): Data Dictionary, version 1.1a. Consumer Safety Institute, Amsterdam and AIHW National Injury Surveillance Unit, Adelaide, 2003. Available at: http://www.iceci.org/ (accessed 7-22-05).

Zwerling, C., Whitten, P.S., Davis, C.S., Sprince, N.L., 1998. Occupational injuries among older workers with visual, auditory, and other impairments. A validation study. J. Occup. Environ. Med. 40 (8), 720–723.