How Well Are We Controlling Falls From Height in Construction? Experiences of Union Carpenters in Washington State, 1989–2008

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Background *Falls from height (FFH) continue to cause significant morbidity and mortality across the construction industry.*
Methods *By linking data on work hours with workers' compensation records, rates of work-related injuries resulting from FFH and associated days away from work were evaluated among a large cohort (n = 24,830) of union carpenters in Washington State from 1989 to 2008. Using Poisson regression we assessed rates of FFH over the 20-year period while adjusting for temporal trend in other work-related injuries. Patterns of paid lost days (PLDs) were assessed with negative binomial regression.*
Results *Crude rates of FFH decreased 82% over the 20-year period. Reductions were more modest and without demonstrable change since 1996 when adjusting for the temporal reduction in other injuries. Younger workers had higher injury rates; older workers lost more days following falls. Rates of PLDs associated with falls decreased over time, but there was not a consistent decline in mean lost days per fall.*
Conclusion *These patterns are consistent with decreased FFH for several years surrounding state (1991) and then federal (1994) fall standards; the decline during this time period exceeded those seen in injury rates overall in this cohort. While crude rates of FFH have continued to decline, the decline is not as substantial as that seen for other types of injuries. This could reflect a variety of things including more global efforts designed to control risk (site planning, safety accountability) and changes in reporting practices.* Am. J. Ind. Med. 57:69–77, 2014. *© 2013 Wiley Periodicals, Inc.*

KEY WORDS: occupational injury; falls from height; construction work; cohort study; injury surveillance

BACKGROUND

Falls from height (FFH) cause significant morbidity and mortality in the construction industry [Sorock et al., 1993; Cattledge et al., 1996; Derr et al., 2001; Courtney et al., 2002; Horwitz and McCall, 2004; Bureau of Labor Statistics, 2010; Shishlov et al., 2011]. Risk is not limited to inexperienced workers and serious injuries cross age and ethnic boundaries [Dong et al., 2009, 2012]. Despite this significant industry burden, work-related FFH are relatively rare events on any given worksite. This makes it difficult, if not impossible, for individual employers or contractors to inform their own prevention efforts based solely on their experiences or those

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of their employees [Hale et al., 2012]. Both the development of "best practices" and regulatory efforts are designed to ensure improved safety based on what has been learned from the injury experiences of many. Even so, such rules and recommendations stimulate controversy in this fast-paced industry where foremen, and workers as well, can feel pressured to meet productivity demands [Lipscomb et al., 2010, 2012; Kaskutas et al., 2012].

We evaluated reported work-related FFH among a large cohort of union carpenters over a 20-year period (1989–2008) to assess the extent to which efforts to control injuries sustained in work-related FFH have been effective. There have been numerous initiatives focused on improving safety on construction sites across the United States during this 20-year period. These analyses update previously described work-related falls of this cohort between 1989 and 1998 [Lipscomb et al., 2003a,b]. Washington State had one of the earlier construction fall protection standards; the Washington Vertical Fall Arrest Standard went into effect in 1991 three years prior the Federal OSHA fall protection standard. There have also been changes in work practices that could considerably alter fall risk as well as the severity of injuries from FFH. Cranes and aerial and scissors lifts have become more common, and mast scaffolding has begun to replace ladders and other scaffolding applications. These newer practices also have the potential to create new risks if used improperly [McCann, 2003; Center for Construction Research and Training, 2009; Harris et al., 2010]. There has also been increasing attention to overall workplace safety and the rapid return of injured workers to the workplace across the industry as costs of workers' compensation increased and major construction employers increased efforts to pre-qualify bidders [Welch et al., 2007].

MATERIALS AND METHODS

Workers' compensation (WC) records from the Washington State Department of Labor and Industries were linked on an individual basis to union records of hours worked each month for a large cohort of carpenters for the 20-year period 1989–2008. The cohort was dynamic with entrances and exits over the observation period. Individuals became eligible for the cohort in the third month they worked union hours. Details on data access and linkage have been reported previously [Lipscomb et al., 1997, 2000, 2003a; 2008a].

The WC data contained date of injury, coded descriptions of body part injured, nature of injury sustained, type of injury, and paid lost days (PLDs; which occurs on the fourth day after injury in Washington). Injury codes were assigned based on American National Standards Institute (ANSI) codes until mid-2005 when coding was changed to the Occupational Injury and Illness Classification System (OIICS), developed by the Bureau of Labor Statistics. Based on injury type codes in either system, events were separated into those resulting from a fall from height and all others. Only injuries that occurred in months of union work were included in the analyses in order to define injuries and hours of work on the same basis for rate calculations.

The union provided information on date of birth, sex, date of union initiation, and union local affiliation for each carpenter. Union carpenters perform a wide variety of construction tasks. The only surrogate for work exposure we had was based on characterization of the primary work of the union local with which each carpenter was affiliated. The categories included light commercial (three stories or less), heavy commercial (including bridge and roadway construction as well as higher rise building), residential construction, drywall installation, millwrighting, and pile driving, as well as a group of carpenters whose primary local assignment was outside Washington.

Injuries from FFH were described based on the body part affected, nature and the type of fall (from a ladder, to a lower level, etc.). Crude incidence density rates were calculated per 200,000 hr worked, as were stratified rates based on categories of age, sex, time in the union, and predominant type of work. Age and time in the union were allowed to vary with time at risk accumulating in the appropriate strata over the 20-year period. To assess higher risk groups within the cohort, Poisson regression was used to calculate adjusted rate ratios using the natural log (ln) of hours worked as the offset variable [Nizim, 2000].

There was a marked decline in work-related injuries in the construction industry across the United States over this 20-year period [Webster, 1999; Center for Construction Research and Training, 2007; Welch et al., 2007; Bureau of Labor Statistics, 2013] including among this cohort of workers [McCoy et al., 2013]. We wanted to assess how well FFH had been controlled in this population while also adjusting for this declining temporal trend. We would expect the ratio of rates of injuries from FFH only or injuries from other causes to be constant over time in the absence of changes affecting FFH only or injuries from other causes (specific regulations, targeted interventions). Typically, when modeling rates or rate ratios using Poisson regression, the natural log (ln) of the rate denominator, a measure of exposure (i.e., hours of work in this case) is included as an offset in the model as we described above. In this assessment we alternatively constructed models of injuries from FFH including the natural log (ln) of the number of non-fall injuries as the offset [Breslow and Day, 1987]. The rate denominator of person-hours of work is identical for both sets of injuries, mathematically canceling each other. Injuries resulting from overexertion (pushing, lifting, etc.) were excluded from this comparison group of injuries because it was felt that reporting of injuries of a musculoskeletal nature may be influenced by other factors than those resulting from more acute events. Claims resulting in paid lost time (PLT) were examined separately from those that required only medical care. Similar methods were used in the previous study of patterns of injuries following the 1991 Washington State Vertical Fall Arrest Standard [Lipscomb et al., 2003b] based on earlier work comparing Poisson regression and autoregressive integrated moving average (ARIMA) models in intervention evaluation [Kuhn et al., 1994].

As an indicator of severity, we were also interested in assessing patterns of PLDs associated with injuries from FFH. We assessed the proportion of injuries from FFH that resulted in PLT by year and the distribution of PLDs. Initially we calculated mean days lost per claim based on all falls that occurred (including those without PLT) and then restricting analyses to those falls that resulted in PLT. Crude rates of PLDs were calculated per 200,000 hr worked by members of the cohort. Negative binomial regression was used to calculate adjusted rate ratios due to the highly skewed nature of the data on PLDs. The negative binomial distribution is sometimes referred to as the gamma Poisson distribution, providing an alternative when the mean and variance are not equal [Hilbe, 2007]. The natural log (ln) of hours worked was the offset variable in these negative binomial models. The goals of these analyses were to explore the burden of PLDs from work due to FFH among subgroups of the population and to assess whether injuries from FFH continued to result in as many lost days from work over time.

All procedures were approved by the institutional review boards at Duke University Medical Center and the Washington State Department of Social and Health Services. Informed consent was not obtained as all analyses were of de-identified secondary data.

RESULTS

We identified 24,830 carpenters who worked 192,371,021 hr of union work in Washington State between 1989 and 2008. Details on this predominantly male (97%) cohort, as well as their overall work-related injury experiences, have been described previously [McCoy et al., 2013]. These carpenters reported 1,511 injuries resulting from FFH representing 5.8% of all WC claims. The proportion of injuries from FFH varied from a high of 8.9% in 1989 to a low of 3.5% in 1996. The falls were most often coded as “fall to a lower level” followed by “falls from ladders” and “falls from platforms” (Fig. 1).

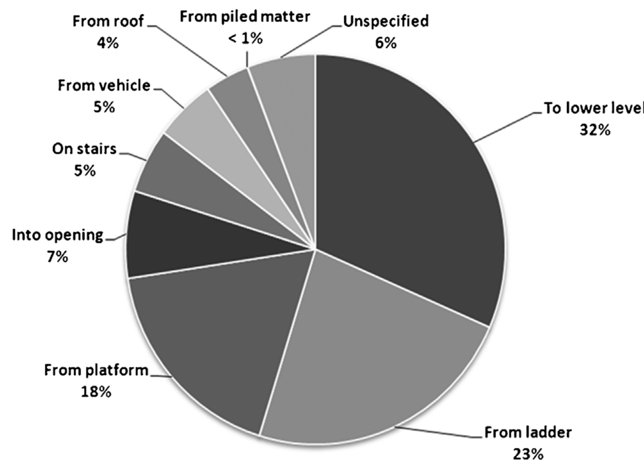

FIGURE 1. Distribution of falls from height (n = 1,511) among union carpenters in Washington State, 1989–2008.

The injuries associated with FFH involved almost all body parts/areas with a third of injuries involving the lower extremities (n = 502; 33.2%). Of note, 17.5% (n = 265) of the injuries involved multiple body parts. The nature of injuries resulting from these falls was sprain or contusion in over half (n = 877; 58.1%) of instances, followed by fracture (n = 232; 15.4%) and multiple injuries (n = 124; 8.2%).

Overall, injuries from FFH occurred at a rate of 1.57 (95% CI 1.47–1.67) per 200,000 hr worked. Younger carpenters had higher injury rates as did those in the apprenticeship period, (i.e., typically the first 4 years of union membership) compared to carpenters over 50 years of age and those with over 6 years of union experience, respectively. Individuals affiliated with union locals that installed drywall or did residential building were at greater risk of FFH than were their union counterparts involved in other types of predominant work (Table I).

There were 570 (37.7%) FFH that resulted in more than 3 lost days from work and, consequently, resulted in PLT. These PLT injuries occurred at a rate of 0.59 (95% CI 0.54–0.64) per 200,000 hr worked. In contrast to all FFH, younger individuals had lower rates of more severe falls resulting in PLT although those with the least amount of union tenure had higher rates of PLT falls just as they had for all FFH. Women also had lower rates of more serious falls. Carpenters affiliated with a union local that did predominantly drywall installation had the highest rates of PLT FFH while pile drivers had the lowest (Table I).

Thirty-eight percent (38%) of FFH resulted in PLT from work with some variation in this proportion by age, gender, time in the union and predominant type of work. Overall, the mean number of lost days for injuries from FFH was 122 days (SD 344; median 0); among the injuries that resulted in PLT the mean number of PLDs was 324 (SD 400; median 1). There was a steady increase in the mean number of PLDs per fall with increasing age. Millwrights had the highest mean number of lost days (based on only 18 events), while pile drivers had the fewest mean days lost per fall (Table II).

The total number of PLDs from injuries associated with FFH was 184,514; this represents 192 (95% CI 180–204) PLDs per 200,000 hr worked or almost 2 PLDs (and 5 total lost days) for every full-time carpenter each year. The rate at which PLDs from injuries resulting from FFH occurred was greatest among carpenters over 40 years of age and among those with 4–6 years of union tenure (based on adjusted rate

TABLE I. Stratified Time at Risk, Frequency of Falls From Height (FFH), Frequency of Falls From Height Resulting in Paid Lost Time, Injury Rates (95% CI) and Adjusted Injury Rate Ratios (95%CI), Union Carpenters, Washington State 1989–2008

	Time at risk (hr)	Injuries from FFH	Rate (95% CI)[a]	aRR (95% CI)[b]	Paid lost time injuries from FFH	Rate (95% CI)[a]	aRR (95% CI)[b]
Age							
<30	32,542,722	319	2.58 (1.43–4.66)	1.64 (0.88–3.07)	101	0.62 (0.51–0.75)	0.88 (0.73–1.06)
30 to <40	63,159,376	559	1.77 (1.63–1.92)	1.41 (1.19–1.68)	211	0.67 (0.58–0.77)	1.15 (0.99–1.33)
40 to <50	60,781,105	435	1.43 (1.30–1.57)	1.21 (1.02–1.43)	169	0.56 (0.48–0.65)	1.05 (0.91–1.22)
50+	35,415,373	197	1.11 (0.97–1.28)	1	85	0.48 (0.39–0.60)	1
Gender							
Female	3,187,355	22	1.38 (0.91–2.10)	0.93 (0.61–1.42)	3	0.18 (0.07–0.58)	0.35 (0.19–0.64)
Male	188,719,682	1,482	1.57 (1.49–1.65)	1	562	0.60 (0.55–0.65)	1
Time in the union							
<2 years	25,251,790	251	1.99 (1.76–2.25)	1.18 (1.00–1.40)	99	0.78 (0.64–0.95)	1.47 (1.27–1.71)
2 to <4 years	19,336,436	186	1.92 (1.67–2.22)	1.18 (0.99–1.42)	69	0.71 (0.56–0.90)	1.35 (1.15–1.58)
4 to <6 years	16,303,299	145	1.78 (1.51–2.09)	1.11 (0.91–1.34)	49	0.60 (0.45–0.80)	1.13 (0.94–1.34)
6 to <8 years	15,121,172	118	1.56 (1.30–1.87)	0.97 (0.79–1.19)	47	0.62 (0.47–0.83)	1.12 (0.94–1.34)
8 to <10 years	13,873,415	101	1.46 (1.20–1.49)	0.92 (0.74–1.14)	38	0.55 (0.40–0.75)	1.00 (0.82–1.21)
10 years and over	102,484,910	710	1.39 (1.29–1.49)	1	268	0.52 (0.46–0.59)	1
Predominant work							
Drywall	36,673,255	446	2.43 (2.22–2.67)	1.45 (1.20–1.75)	184	1.0 (0.86–1.16)	1.60 (1.35–1.88)
Residential	3,077,068	33	2.14 (1.53–3.02)	1.21 (0.83–1.78)	14	0.91 (0.54–1.54)	1.32 (0.96–1.83)
Millwright	3,497,881	18	1.03 (0.65–1.63)	0.67 (0.41–1.09)	12	0.69 (0.39–1.21)	1.14 (0.81–1.61)
Pile driver	11,275,835	54	0.95 (0.73–1.25)	0.61 (0.45–0.84)	18	0.32 (0.20–0.51)	0.54 (0.40–0.73)
Mixed commercial	43,141,929	344	1.59 (1.43–1.77)	0.99 (0.82–1.20)	126	0.58 (0.49–0.70)	0.95 (0.80–1.13)
Heavy commercial	39,571,780	233	1.18 (1.04–1.34)	0.73 (0.59–0.90)	75	0.38 (0.30–0.48)	0.62 (0.51–0.75)
Out of Washington	34,921,611	215	1.23 (1.08–1.41)	0.77 (0.62–0.95)	77	0.44 (0.35–0.55)	0.72 (0.60–0.87)
Light commercial	18,336,177	146	1.59 (1.35–1.87)	1	56	0.61 (0.47–0.79)	1

Note: Differences in total hours or injuries across age, gender, time in the union and predominant work are due to missing data for some individuals.
[a]Rates expressed as injuries per 200,000 hr of work.
[b]Adjusted for age, sex, tenure, and predominant type of work; Poisson regression.

ratios). There was no difference between the rate of PLDs among men and women. After considering age and time in the union, Individuals affiliated with locals that did predominantly millwrighting had the highest rates of PLDs based on hours worked, followed by those doing heavy commercial work and drywall (Table II).

There was considerable variability in the mean number of PLDs per fall within any given year as well as between years over time. The proportion of injuries from FFH that resulted in PLT increased in the early 1990s (to 46% in 1993–1994) and has declined since then to 23% in 2007–2008 (Fig. 2). Mean number of PLDs for all FFH has not changed appreciably, while mean days lost among injuries resulting in PLDs decreased initially and then increased slightly in more recent years (Fig. 3A,B).

Crude rates of injuries from FFH declined 82% over the 20-year period in a fairly steady pattern. The declines included medical only and PLT injuries, as well as the major categories of falls to a lower level (84% decline), falls from scaffolding/platforms (87% decline), and falls from ladders (66% decline). When accounting for the temporal trend in acute injuries that did not result from a fall from height, reductions were more modest and without demonstrable improvement since 1996. Crude rate reductions were greater for falls that resulted in PLDs than for those that resulted in medical care only (Fig. 4A), while the adjusted reductions were similar (Fig. 4B). It is of note that the PLT rate ratios are less stable than medical only claims because of fewer events.

DISCUSSION

The fact that reported work-related injury rates have declined markedly in the last two decades in the United States likely represents some real improvements in occupational safety. However, there is considerable discourse that these declines may reflect other factors as well. For example, Azaroff et al. [2002] described a variety of conceptual filters that have the potential to influence patterns of injury

TABLE II. Paid Lost Days (PLDs) From Falls From Height, Percentage of Falls From Height Resulting in Paid Lost Days, Mean Paid Lost Days for Falls From Height and Falls From Height That Resulted in Paid Lost Time, Crude Rate of Paid Lost Days and Adjusted Rate Ratios, Union Carpenters in Washington State, 1989–2008

	Number of PLDs from FFH	Percentage of FFH with PLDs	Mean PLDs per FFH[a] (95% CI)	Mean PLDs per PLT FFH[a] (95% CI)	Crude rate of PLDs[b] (95% CI)	aRR[c] (95% CI)
Age (95% CI)						
<30	24,786	32	78.9 (51.4–121.3)	230.8 (173.2–307.7)	152.3 (143.04–162.08)	0.44 (0.18–1.04)
30 to <40	54,757	38	98.0 (71.0–135.1)	259.5 (212.8–316.6)	173.4 (162.82–184.49)	0.40 (0.18–0.85)
40 to <50	55,987	39	128.7 (89.4–185.3)	328.5 (263.1–410.1)	184.2 (172.99–196.02)	1.05 (0.42–2.62)
50+	47,772	43	242.5 (141.1–416.7)	558.3 (408.3–763.3)	269.8 (253.32–287.05)	1
Gender						
Female	2,992	14	136.0 (26.6–695.5)	974.0 (180.3–5262.2)	187.7 (176.29–199.76)	
Male	180,181	38	121.6 (141.1–416.7)	316.7 (28.0–358.3)	190.9 (179.30–203.17)	
Time in the union						
<2 years	25,274	39	97.7 (60.1–158.9)	234.8 (174.7–315.5)	200.18 (187.97–212.98)	0.74 (0.32–1.71)
2 to <4 years	18,665	37	100.8 (57.4–176.9)	274.2 (192.6–390.3)	193.06 (181.28–205.41)	0.90 (0.39–2.06)
4 to <6 years	16,533	34	114.0 (60.4–215.2)	336.0 (221.7–509.2)	202.82 (190.45–215.80)	2.09 (0.82–5.36)
6 to <8 years	14,642	40	124.0 (61.2–251.6)	308.7 (201.0–474.1)	193.66 (181.84–206.06)	1.16 (0.48–2.80)
8 to <10 years	8,585	38	85.0 (39.7–182.0)	225.9 (140.9–362.3)	123.76 (116.21–131.68)	1.23 (0.45–3.35)
10 years and over	100,815	38	142.2 (106.7–189.5)	375.5 (314.2–448.7)	196.74 (184.74–209.33)	1
Predominant work						
Drywall	54,364	41	120.4 (83.8–173.0)	292.7 (235.8–363.2)	296.48 (278.39–315.45)	2.30 (0.81–6.53)
Residential	3,403	42	103.1 (27.2–390.5)	243.1 (111.4–530.5)	221.19 (207.69–235.34)	0.94 (0.29–3.06)
Millwright	5,739	67	318.8 (52.6–1933.6)	478.3 (205.9–1110.8)	328.14 (308.13–349.14)	7.37 (1.99–27.27)
Pile driver	4,310	33	79.8 (28.2–226.1)	239.4 (120.3–476.6)	76.45 (71.78– 81.34)	0.13 (0.04–0.44)
Mixed commercial	42,023	37	122.5 (81.0–185.1)	321.7 (247.8–417.7)	194.81 (182.93–207.28)	1.61 (0.59–4.38)
Heavy commercial	24,896	32	107.3 (64.9–1777.3)	331.0 (236.3–463.7)	125.83 (118.15–133.88)	2.73 (0.98–7.60)
Out of Washington	23,998	36	111.9 (66.3–189.1)	313.7 (224.4–438.5)	137.44 (129.06–146.24)	0.52 (0.19–1.42)
Light commercial	22,560	38	154.5 (82.1–291.0)	395.6 (267.8–584.4)	246.07 (231.66–261.82)	1

[a]Negative binomial regression.
[b]Rates expressed as number of paid lost days per 200,000 hr of work.
[c]Adjusted for age, time in the union, and predominant type of work; negative binomial regression.

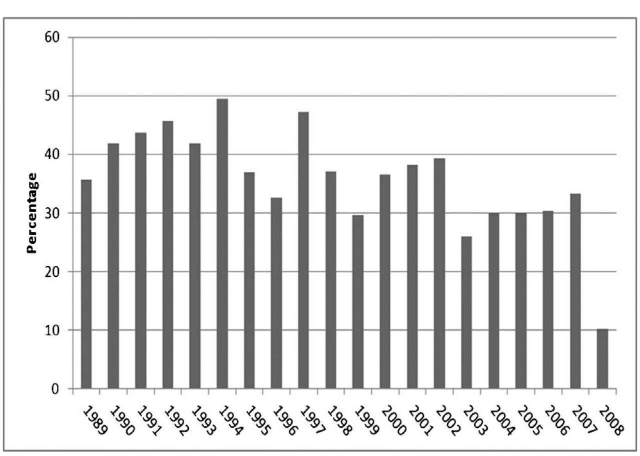

FIGURE 2. Proportion of injuries resulting from falls from height that resulted in paid lost time by year, union carpenters Washington State 1989–2008.

reporting. Although difficult to quantify, the influence of these other factors on reported work-related injury rates should not be ignored; the "truth" likely represents a mix of effects.

While crude rates of injury from FFH have continued to decline among members of this cohort, changes in rates above what was seen for injuries overall in the last decade were not observed. This finding is consistent with what appeared to be a plateau in the decline in falls observed in earlier analyses of this cohort approximately 5 years after the 1991 Vertical Fall Arrest Standard in Washington State [Lipscomb et al., 2003b]. The rate of PLDs declined significantly over time among members of this cohort [McCoy et al., 2013] but the mean number of PLDs per fall did not. The mean number of PLDs per fall increased slightly in the later years of observation of this cohort. These findings indicate that the overall burden of lost time has decreased due to injury rate

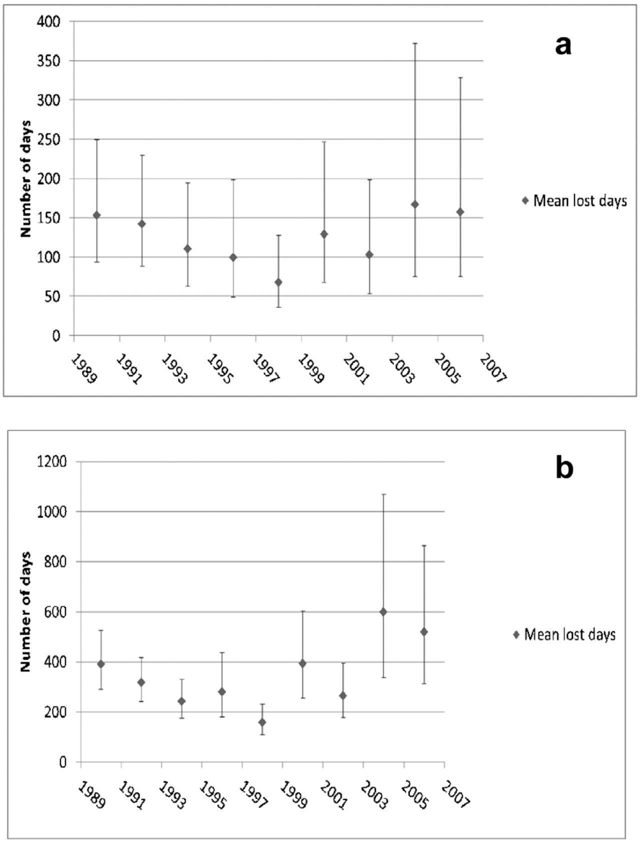

FIGURE 3. **A**: Mean lost days by year, all injuries resulting from falls from height, union carpenters Washington State, 1989–2008. **B**: Mean lost days by year, limited to injures from falls from height that resulted in paid lost time, union carpenters Washington State, 1989–2008.

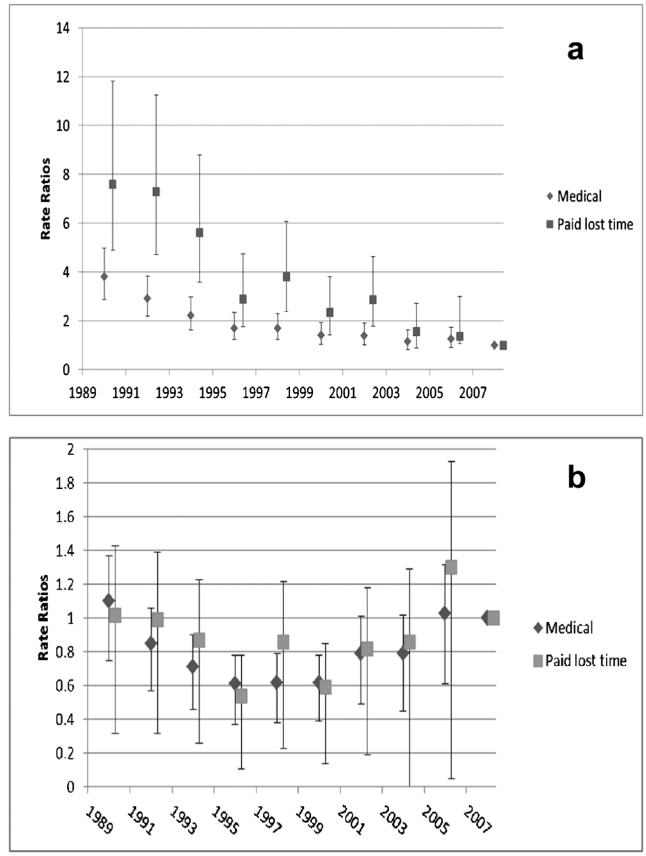

FIGURE 4. **A**: Crude incidence rate ratios for medical only injuries and paid lost time injuries sustained in falls from height, union carpenters Washington State, 1989–2008*. **B**: Adjusted[1] incidence rate ratios for medical only injuries and PLT injuries sustained in falls from height, union carpenters Washington State, 1989–2008. *Two-year time periods compared to 2007–2008. [1]Adjusted for temporal trend in non- fall from heights, excluding overexertion injuries.

declines while injuries from FFH remain as significant as they have been, at least in terms of this measure of morbidity.

The rate of FFH in these workers' compensation records decreased steadily with increasing age perhaps reflecting learning and experiences gained over time that are protective. However, we cannot be sure that the differences we observed across age (and time in the union) are not related to reporting differences. The fact that older carpenters had lower rates of FFH, but greater mean lost days per fall, could indicate a propensity of younger workers to file more WC claims for less serious falls or for older workers to feel more secure in their ability to take time away from work without fear of job loss. We present this as an additional consideration to the assumption that all of this effect is related to older workers having more serious falls [Schwatka et al., 2012] or more serious outcomes from similar falls. While non-occupational falls tend to be a more serious public health problem among older adults, the broad influence of the context of work must be recognized when considering explanations for observed patterns of injuries captured through workers' compensation records such as these.

Through these robust analyses of construction workers, it is clear that the magnitude of the decline in FFH has been minimal since 1996 when consideration is given to the secular reduction in the rate of other injuries. However, this does not mean that the gains observed are not important—they may not be related directly to efforts focused on prevention of FFH, but other efforts to control injury risk may have also played a role in helping prevent falls. It has been documented in Washington State that inspections, citation, and even consultations to a lesser extent, may influence safety practices surrounding more than the aspect of work in violation [Foley et al., 2012].

Limitations

Numerous factors may have had a role in preventing FFH including workplace safety standards (Washington State Standard; Federal OSHA) and changes in a number of workplace practices. For example, increasing use of mast scaffolding to replace ladders and other scaffolding applications as well as use of aerial and scissor lifts could influence the risk of falls and the severity of injuries from falls. As is often the case with injury surveillance data, we lacked any direct exposure information that would allow us to consider exposure time to different work conditions or methods.

We assigned all lost days to the year in which the fall occurred and the resulting PLT may be truncated in later years. However, we did not obtain these data until May of 2010, thus allowing at least 16 months of follow-up for the claims to have matured. Our only measure of type of work came from union local assignments, and we had no measures of exposure to work at height.

Strengths

A major strength of this report lies in the linkage of data to clearly define a large work cohort, their hours of work, and their reported work-related injuries over this 20-year period. Washington State has a low threshold for state reporting which gave us the opportunity to look at patterns of less serious events and falls that resulted in PLT from work. Access to information on events that involved FFH as well as other injury mechanisms allowed us to compare patterns of injuries over a period when there were marked declines in work-related injury rates across the construction industry. By adjusting for trends in other acute injuries in the same cohort over a significant period of time, we were able to control for any "filters" that influenced reporting of injuries over this 20-year period, given these would be expected to be comparable across different types of injuries—especially if restricted by some measure of severity, like PLT. Thus the "adjusted" decline in injuries from FFH should reflect how much better falls were controlled compared to other mechanisms of injury in the same population. This approach does not require any adjustment for change in the workforce; the same individuals in any given year were used to compare injury rates from FFH and other events as we adjusted for secular trend. Additionally, the analyses of PLDs allowed us to explore a measure of severity of FFH over the 20-year period as well as the overall burden of lost days based on hours the cohort worked. Still, relatively small numbers and considerable variability in outcome measures, like PLT, make it more difficult to clearly understand observed patterns.

There is a growing concern about the provision of an evidence base for occupational safety intervention efforts [Occupational Safety and Health Review Group, 2012], yet doing so can be challenging. Evaluation over a substantial amount of time is essential in occupational safety research when interventions are expected to have a latent effect and to consider sustained effects. In assessing the quality of studies for inclusion in systematic reviews, protection from secular change is considered important [EPOC, 2008]. Yet long-term evaluations will always be influenced by many factors that can be difficult to measure and control for [Lipscomb et al., 2009]. Changes in work practice over a 20-year period are expected but unpredictable, and they may influence injury risk and reporting. Understanding effects of control measures is not simple as the answer is contextual and time dependent; our conclusions should rely on synthesis of different patterns observed and inference. It is these challenges for which observational data, such as these, may be best suited.

CONCLUSIONS

Despite concerns that reductions in work-related injury rates are not reflective of the true state of workplace safety [Azaroff et al., 2002; Welch et al., 2007] there is evidence from analyses of these data that progress has been made in reducing rates of injury from FFH among members of this construction cohort in the last 20 years. The fact that crude rates of FFH have continued to steadily decline, even if we cannot ascribe all of the effect to activities specifically related to fall prevention, is still positive.

Despite the observed progress, work at height is inherent in construction and efforts are still clearly needed to continue to address this work hazard. FFH can be unforgiving; significant injury can occur even from relatively low heights with the difference between a minor and a devastating injury sometimes only the surface onto which the worker falls [DHHS, 2000; Courtney et al., 2002; Lipscomb et al., 2003c]. There is evidence specifically from Washington State that regulation and enforcement as well as some consultation activities can reduce work-related injury rates [Nelson et al., 1997; Foley et al., 2012]. There is also the need for detailed surveillance efforts as work practices change. This was illustrated in the work of McCann [2003] in describing falls from aerial lifts; equipment designed to facilitate work can create unexpected hazards.

Consistent with the public health hierarchy of controls, there are calls for attention to efforts that can reduce exposure [Watterson, 2007; Shishlov et al., 2011], and it is clear that efforts to design out unprotected work at height are needed [Toole and Gambetese, 2008]. We know inexperienced workers encounter fall hazards early in their apprenticeship training when they may not be prepared to negotiate them; use of fall protection and worksite mentorship are not always adequate or consistent with best practices or regulation [Lipscomb et al., 2008b; Kaskutas et al., 2013]. Construction workers' training should target safety communication and mentoring skills with workers who will lead work crews. Work crew leaders also need support from management to take time to address safety concerns as they arise as well as access to equipment to enhance the safety of the work; this makes employers important targets for regulatory efforts and training programs that emphasize obligations to provide safer work places as called for by Menzel and Shrestha [2012]. Supervisor bonuses and competition for work may also contribute to unsafe work practices [Roelofs et al., 2011]. Events caused by time pressures must be recognized as stemming from unrealistic demands [Gravseth et al., 2006; Roelofs et al., 2011; Lipscomb et al., 2013] that may be fostered through arrangements such as piecework contracts. While defined piece work is typically not sanctioned in a union workforce, union workers are aware of the "allowed" time to complete tasks [Lipscomb et al., 2013] which may still create pressures to work more quickly than may be safe.

Industry leaders, safety professionals, researchers, and especially those making decisions about health and safety policy should remember that serious, untoward events on construction sites often involve "failures in planned risk control" and that construction projects are influenced by "political practices, the effects of health and safety regulations and regulatory function, the market and societal status and priorities" [Hale et al., 2012]. This means that while falls may be appropriately approached from a biomechanical or psychophysical perspective as loss-of-balance incidents [Hsiao and Simeonov, 2001; Simeonov et al., 2003], considerations for the broader context in which construction work is done will be important in the understanding of and control of these events as well.

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