Effectiveness of OSHA Outreach Training on Carpenters' Work-Related Injury Rates, Washington State 2000–2008

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Introduction *Despite the size and breadth of OSHA's Outreach Training program for construction, information on its impact on work-related injury rates is limited.*
Methods *In a 9-year dynamic cohort of 17,106 union carpenters in Washington State, the effectiveness of OSHA Outreach Training on workers' compensation claims rate was explored. Injury rates were calculated by training status overall and by carpenters' demographic and work characteristics using Poisson regression.*
Results *OSHA Outreach Training resulted in a 13% non-significant reduction in injury claims rates overall. The protective effect was more pronounced for carpenters in their apprenticeship years, drywall installers, and with increasing time since training.*
Conclusions *In line with these observed effects and prior research, it is unrealistic to expect OSHA Outreach Training alone to have large effects on union construction workers' injury rates. Standard construction industry practice should include hazard awareness and protection training, coupled with more efficient approaches to injury control.* Am. J. Ind. Med. 60:45–57, 2017. © 2016 Wiley Periodicals, Inc.

KEY WORDS: construction industry; safety-training effectiveness; occupational injury; workers' compensation; cohort study

INTRODUCTION

Safety training is frequently recommended and prescribed for work-related injury prevention. It is a relatively easy intervention to administer and can be carried out face-to-face in a classroom setting or online. The focus is on informing workers, rather than addressing organizational issues, and for workers in the dangerous construction industry, safety training may indeed lead to important increases in worker knowledge and attitudes about occupational safety [Sokas et al., 2009; Williams et al., 2010; Forst et al., 2013] as well as self-reported and objective measures of safety behavior [Trabeau et al., 2008; Kaskutas et al., 2013; Ruttenberg, 2013]. Although evidence supporting safety training's prevention of adverse health outcomes (e.g., injuries, illnesses) is limited [Cohen et al., 1998; Robson et al., 2010, 2012; Mullan et al., 2015], encouraging examples can be found among plumbers/pipefitters [Kinn et al., 2000], laborers [Dong et al., 2004; Williams et al., 2010], carpenters/drywall tapers [Johnson and Ruppe, 2002], residential construction workers [Darragh et al., 2004], and railway construction workers [Bena et al., 2009].

In North America, a noteworthy model of construction worker safety training comes out of the union sector. Workers learn their trade through a jointly-controlled apprenticeship program financed by employers who, in

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turn, are supplied a skilled labor force; in combination with employers' financial incentive to invest in workplace safety efforts [Gillette, 2004; Sitek, 2009], efficient, large-scale, peer-led training [Sinyai et al., 2013] is both feasible and rational. Indeed, the past 20 years has been marked by a rapid increase in construction worker and employer participation in the Occupational Safety and Health Administration's (OSHA) Outreach Training Program. In the early 1990s, the OSHA Training Institute (OTI) moved to make its 10-hr (for entry level workers) and 30-hr (for workers with safety responsibilities) construction hazard awareness courses—then primarily serving public employees—more available to the private sector by authorizing qualified nonprofit OTI Education Centers to train program instructors. Private-sector demand drove explosive growth in "OSHA-10" and "OSHA-30" for construction training. Trainers had issued fewer than 20,000 OSHA-10 and OSHA-30 cards each year in the early 1990s; since 2010, more than 500,000 workers per year have earned an OSHA-10 or OSHA-30 card. Nearly all construction trade unions have incorporated OSHA-10/OSHA-30 training into their apprenticeship curricula; it may be required by an employer [Wilkins, 2011], and some states mandate it prior to working on publicly funded building projects [Sinyai et al., 2013; Taylor, 2015]. The training courses cover the "recognition, avoidance, abatement, and prevention of safety and health hazards in workplaces," and emphasis is placed on instruction related to the top four fatal mechanisms: falls from elevation, electrocutions, struck by events, and caught in/between events. Courses also provide "information on workers' rights, employer responsibilities and how to file a complaint" [OSHA, 2014]. These courses are taught by OSHA Outreach Trainers, who are authorized through a 500-level OSHA Outreach Training course covering topics in the 10- and 30-hr programs as well as instructional approaches.

Safety-forward gains in construction workers' knowledge and attitudes [Sanyang, 2007; Sokas et al., 2009; Wilkins, 2011] and self-reported behavior [Ruttenberg, 2013] have been observed following OSHA-10 training. However, evaluations of the effectiveness of OSHA Outreach Training on rates of construction work-related injury or related outcomes are few [Taylor, 2015]—and not surprisingly so, as they are difficult to accomplish. Such an understanding, however, has been called for to "strengthen and extend the reach of quality training and education in the construction industry" [NORA Construction Sector Council, 2008] with the goal of improving the safety and health of its workforce.

Building on an existing, robust, longitudinal cohort of union carpenters in Washington (WA) State over the years 2000 through 2008, the goal of this study was to explore the effectiveness of OSHA Outreach Training on rates of reported WC claims and associated outcomes (e.g., time loss days, costs).

METHODS

The existing cohort comprised union eligibility and membership files and WC claims data files already linked at the individual level through use of a Carpenters Trusts of Western Washington (CTWW)-assigned unique member number [McCoy et al., 2013]. Union eligibility and membership files, from the CTWW, contain for each carpenter: a unique member number (assigned by CTWW and lacking identifying details), date of birth, gender, monthly hours worked, date of union entry, and union local. The study cohort was limited to individuals who worked at least 3 months of union hours, with observation beginning in the month eligibility criteria were met (i.e., the 3rd month of union work). As in prior research with these data (e.g., [Lipscomb et al., 2014b]), carpenters were assigned a predominant type of work based on the work most commonly performed by the union local to which they belong: residential building, light/heavy/mixed commercial, drywall installation, millwrighting, and piledriving. Some carpenters were affiliated with a union local outside of WA State for which information on the predominant type of work was not available.

WC claims data, provided by the WA State Department of Labor and Industries (L&I), contain work-related event details for each claim: date of event; date of claim; claim open/close status; ANSI/OIICS codes describing the event nature, mechanism, body part affected, and source; time loss (TL) status; number of paid TL days (with TL compensation paid after the third calendar day of being medically unavailable for work, not including the day of injury, in WA State); and associated costs. A TL claim is one in which there was not approved work available for the injured worker within the medical restrictions, and this categorization was provided to the researchers by L&I. The number of paid TL days, for state fund claims, is calculated as the number of eligible days minus the number of denied days; for claims from self-insured employers, the number of paid TL days is an estimate, reflecting the amount paid to date divided by the most recent compensation rate. Cost estimates are limited to payment types reported consistently between state fund and self-insured claims (i.e., accident fund dollars). This approach improves the consistency of costs across payers, but it excludes the medical portion of claims costs. All costs are adjusted using the consumer price index to 2015 dollars and assume all dollars were paid on the date of injury. Although the claim pool was extracted April 2010 as part of previous research [McCoy et al., 2013], the extract was updated April 2016 to reflect WA State Department of L&I's current methodology and estimates related to paid TL and costs.

In this study, these files were linked at the individual level to a union carpenter training data file in a similar manner. The training file, provided by the CTWW, is composed of individual-level data on the dates of completed OSHA-10, OSHA-30, and OSHA-500 level courses completed through the Pacific Northwest Regional Council of Carpenters' (PNWRCC) affiliated training centers. These courses are offered through face-to-face, in-classroom instruction.

Several definitions of "trained" were considered initially in this study. Although neither federal OSHA nor WA State requires OSHA-10/-30 completion for construction workers, it is a part of the United Brotherhood of Carpenters and Joiners of North America's construction apprenticeship curriculum standards and is a continuing education criterion for journeymen in some trades. Further, some US states and employers require that workers re-certify every 3–5 years. Thus, an individual carpenters' union work hours were categorized as "trained" if the carpenter completed an OSHA Outreach Training course within the prior 5 years. It is this definition on which the presented analyses are based. However, OSHA Outreach Training completion cards do not expire, and sensitivity analyses were conducted in which a cohort member was defined as "trained" for all time following course completion. Also, given the dynamic nature of the study cohort, a subset of the cohort was in the union prior to January 1, 2000. These "prevalent" members may have completed OSHA Outreach Training prior to cohort entry. For the presented analyses, these members were categorized as "trained" when they completed an OSHA Outreach Training course during the study period, and for the 5 years following course completion. Sensitivity analyses were conducted in which these members were also categorized as "trained" for the first 5 years of follow-up (January 1, 2000–December 31, 2004).

The characteristics of union carpenters and worker-hours with and without OSHA Outreach Training, as well as by type of OSHA Outreach Training course, were described. Time at risk (based on hours of work) and work-related outcomes were stratified by categories of OSHA Outreach Training (yes/no), age, gender, time in the union, predominant type of work, and calendar time. Age, time in the union, and predominant type of work were allowed to vary over time with union work hours and number of events accumulating in the appropriate strata over the 9-year period. Injury rates (number of events/200,000 hr of union work), unadjusted and adjusted rate ratios, and 95% confidence intervals were calculated using Poisson regression, with the natural log of hours worked as the offset variable [Nizam, 2014] and scaling to correct for over-dispersion appropriately (Pearson χ^2/degrees of freedom >1.5). In addition to examining the effect of training on work-related injuries overall, emphasis was placed on the subset of OSHA's "Fatal Four" mechanisms (defined through ANSI and OIICS codes) targeted as part of OSHA Outreach Training: falls from elevation, electrocutions, struck by events, and caught in/between events. For analyses of TL days and costs—outcomes which are highly skewed due to a significant proportion of the cohort with no TL days or costs—negative binomial models [Hilbe, 2011] were used to examine outcome rates, rate ratios, and 95% confidence intervals, with generalized estimating equations (GEE) [Zeger et al., 1988] to account for within-subject correlation.

Finally, recognizing the potential for a differential OSHA Outreach Training effect by time since training, related models were constructed to examine rate ratios before and after such training (Fig. 1). In successive "lagged" models, 6-month increments of time at risk and work-related outcomes following training were removed. This approach allowed assessment of time periods in which the effect of training was more pronounced. For this training intervention, it is plausible to assume an enhanced effect immediately following the training class. It is also plausible to observe a gradually increased effect over time as trained workers spend more time in the field gaining experience applying training-based knowledge.

Study procedures were approved by the Institutional Review Boards of the Duke University School of Nursing, the Duke University Health System, and the Washington State Department of Health and Human Services.

RESULTS

The study cohort is composed of 17,106 carpenters who worked 99,411,000 union hours in WA State between 2000 and 2008 (Table I). Nearly all are male (n = 16,466; 97.7%). The average carpenter age increased from 41.3 years in 2000 to 44.9 in 2005, and down to 42.0 in 2008 [McCoy et al., 2013]. A total of 9,886 WC claims were reported and accepted for the cohort, 18.6% (n = 1,841) of which were TL claims. The rate of injuries overall and TL injuries declined 42% and 47%, respectively over the study period. Though not monotonic, the proportion of injuries with TL declined over time, from 19%–22% in early years of observation to 16%–18% in later years.

Patterns in rates across categories of worker demographic and work-related characteristics are similar to those

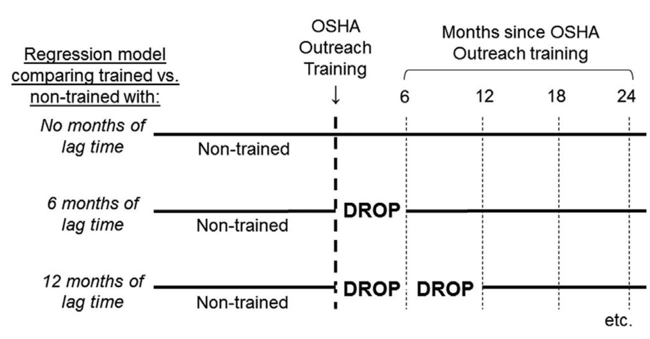

FIGURE 1. Lagging approach.

TABLE I. Stratified Time at Risk (Union Hours Worked), Injury Frequencies, Rates, Adjusted Rate Ratios, and 95% CIs, and Frequencies and Proportions of Injuries With Paid Time Loss (TL) Day(s)

	Number (%) hours worked	# Injuries	Crude rate[a]	Adjusted RR (95% CI)[b]	# (%) Injuries with paid TL day(s)[c]	Adjusted RR (95% CI)[b]
Gender						
Male	97,690,827 (98.3)	9,659	19.8	1.00	1,787 (18.5)	1.00
Female	1,593,862 (1.6)	218	27.4	1.34 (1.17–1.54)	51 (23.4)	1.66 (1.25–2.20)
Missing	*126,311 (0.1)*	*9*	*14.3*	–	*3 (33.3)*	–
Age in years						
<20	471,311 (0.5)	51	21.6	0.81 (0.61–1.08)	2 (3.9)	0.13 (0.03–0.52)
20 to <30	16,221,419 (16.3)	1,795	22.1	0.90 (0.83–0.97)	208 (11.6)	0.45 (0.37–0.54)
30 to <40	28,533,755 (28.7)	2,987	20.9	0.97 (0.91–1.03)	536 (17.9)	0.79 (0.68–0.91)
40 to <50	33,856,566 (34.1)	3,189	18.8	0.96 (0.91–1.02)	709 (22.2)	1.00 (0.88–1.14)
50+	20,187,810 (20.3)	1,855	18.4	1.00	383 (20.6)	1.00
Missing	*140,139 (0.1)*	*9*	*12.8*	–	*3 (33.3)*	–
Years in union						
up to 2	14,279,625 (14.4)	1,748	24.5	1.40 (1.31–1.50)	303 (17.3)	1.54 (1.32–1.79)
2 to <4	9,662,175 (9.7)	1,175	24.3	1.41 (1.31–1.51)	200 (17.0)	1.49 (1.26–1.76)
4 to <6	8,219,056 (8.3)	918	22.3	1.29 (1.19–1.39)	155 (16.9)	1.30 (1.09–1.56)
6 to <8	8,012,907 (8.1)	806	20.1	1.15 (1.07–1.25)	137 (17.0)	1.14 (0.95–1.37)
8 to <10	7,691,103 (7.7)	763	19.8	1.14 (1.05–1.23)	150 (19.7)	1.26 (1.06–1.51)
10+	51,546,133 (51.9)	4,476	17.4	1.00	896 (20.0)	1.00
Type of work[d]						
Residential	2,098,688 (2.1)	257	24.5	1.20 (1.05–1.36)	52 (20.2)	1.62 (1.21–2.17)
Light commercial	8,707,820 (8.8)	937	21.5	1.19 (1.10–1.28)	157 (16.8)	1.21 (1.00–1.45)
Heavy commercial	25,275,054 (25.4)	2,316	18.3	1.00	382 (16.5)	1.00
Mixed commercial	17,911,577 (18.0)	1,728	19.3	1.05 (0.99–1.12)	345 (20.0)	1.26 (1.09–1.46)
Drywall	21,297,545 (21.4)	2,424	22.8	1.23 (1.16–1.30)	496 (20.5)	1.63 (1.43–1.87)
Millwrighting	1,649,279 (1.7)	181	21.9	1.21 (1.04–1.40)	38 (21.0)	1.47 (1.05–2.05)
Piledriving	5,275,405 (5.3)	342	13.0	0.73 (0.65–0.81)	57 (16.7)	0.71 (0.54–0.94)
Out of Washington[e]	16,148,902 (16.2)	1,522	18.8	1.03 (0.96–1.10)	264 (17.3)	1.05 (0.90–1.23)
Missing[e]	*1,046,731 (1.1)*	*179*	*34.2*	*1.60 (1.36–1.87)*	*50 (27.9)*	2.88 (2.11–3.91)

The italicized numbers are those in rows in which the value of the independent variable is missing.
[a] Injuries per 200,000 work hours.
[b] Adjusted for all variables shown.
[c] A TL claim is one in which there was not approved work available for the injured worker within the medical restrictions, with TL compensation paid after the third calendar day of the worker being medically unavailable for work, not including the day of injury, in WA State.
[d] Determined based on the predominant type of work performed by the union local.
[e] "Out of Washington" reflects union carpenters who were affiliated with a local outside of WA State for which information on the predominant type of work was not available. In contrast, type of work was defined as "missing" for carpenters for which union local affiliation was unknown.

reported previously. Adjusted rates of injury were higher among females compared to males, increased with increasing age, and decreased with increasing years in the union [McCoy et al., 2013]. Carpenters belonging to locals whose predominant type of work was residential or drywall installation had the highest rates of injury [Lipscomb et al., 2003a; Schoenfisch et al., 2013, 2014a]. A total of 2,910 (29.4%) injuries were characterized as a Fatal Four mechanism: fall from elevation (5.0%), electrocutions (0.3%), struck by (21.3%), and caught in/between (2.8%). The proportion of Fatal Four injuries with TL—13.4% overall—varied by mechanism: fall from elevation (35.4%), electrocutions (7.1%), struck by (9.0%), and caught in/between (8.5%).

During the 9-year study period, 1,017 union members took 1,089 OSHA Outreach Training courses through the PNWRCC-affiliated training centers. Of these, 7% (n = 67) took more than one OSHA Outreach Training course. Most of the courses taken were "OSHA-10 Construction" (85%), followed by "OSHA-30 Construction" (10%) and "OSHA-500 (or OSHA-502) Construction" (3%). The number of completed courses was generally steady over time, averaging 135 union members completing courses per year, with the exception of a noticeable drop in 2005/2006 to an average of 73 members completing courses per year, a 46% decrease. Although the average number of union worker hours per year during 2005 and 2006 were 8% lower than that observed in other years, the proportion of union carpenters and hours categorized as "apprentice" (i.e., <4 years in union) declined from 39% to 29% in 2000, respectively, to lows of 18% to 13% in 2005, and back to 46% to 37% in 2008.

When the individual-level training data were merged to the study cohort of members who contributed at least 3 months of union hours, 57.5% (n = 585) of these union carpenters who took OSHA Outreach Training during 2000–2008 did not link to the study cohort which was limited to carpenters with at least 3 months of union hours. Analyses related to the characteristics of workers taking OSHA Outreach Training, as well as those related to the effectiveness of OSHA Outreach Training, are based on training data from the 432 carpenters who linked to the study cohort. They completed 464 OSHA Outreach Training classes.

Most OSHA Outreach Training took place in carpenters' early years in the union, and particularly in the first year for carpenters completing OSHA-10 training (Table II). Over 78% of OSHA-10 training was among carpenters who were likely in apprenticeship programs (i.e., <4 years in union). By predominant type of work, carpenters doing light/heavy commercial work had a higher proportion of trained hours compared to carpenters in other trades, and drywall installers had a lower proportion of trained hours.

Rates of reported and accepted WC claims for work-related injury were 17.4 per 200,000 union hours worked among "trained" members, compared to 19.9 per 200,000 union hours worked among "non-trained" members ($RR_{Trained\ vs.\ Non\text{-}Trained}$ 0.87, 95% CI 0.72–1.06) (Table III). This relative difference did not vary significantly across categories of age or calendar time, and it was similar for the subset of injuries of a Fatal Four mechanism (RR 0.82, 95% CI 0.56–1.19). The protective effect was more apparent among carpenters in their apprenticeship years (<4 years in the union; 18.6 vs. 24.5 injuries per 200,000 work hours, RR 0.76, 95% CI 0.54–1.07) and among carpenters with a predominant type of work of drywall installation (7.7 vs. 22.9 injuries per 200,000 work hours, RR 0.34, 95% CI 0.15–0.75). No significant difference was observed in the proportion of injuries resulting in paid TL days (trained: 21.2%; non-trained: 18.6%), the median number of paid TL days per TL injury (trained: 105; non-trained: 92), or the rate of TL injury by training status (RR 1.00, 95% CI 0.65–1.53). Unadjusted and adjusted analyses yielded similar findings; the unadjusted estimates are presented.

The number of paid TL days per 200,000 hr worked was lower among trained carpenters (trained: 547 per 200,000 union hours worked; non-trained: 1,752 per 200,000 union hours worked). Similar patterns were observed for rates of associated costs (trained: $0.79 per union work hour; non-trained: $1.92 per union work hour). Efforts were made to examine rates and relative rate differences of paid TL days and costs between trained versus non-trained workers using negative binomial regression and GEE. However, models often did not converge, and resulting estimates were unstable.

In lagged analyses, an increasingly protective effect of training was observed with increasing time since training, although results are statistically non-significant (e.g., $RR_{36\text{-month lag}}$ 0.66, 95% CI 0.35–1.25). This protective effect was greater among carpenters with <4 years in the union, compared to their more experienced counterparts (Fig. 2).

TABLE II. Stratified by Years in the Union, OSHA Training Courses Completed by Union Carpenters Through the PNWRCC Training Centers, 2000–2008

	OSHA-10 (n = 377)		OSHA-30 (n = 76)	
Years in the union	**n**	**%**	**n**	**%**
<1	250	(66.3)	26	(34.2)
1 to <2	31	(8.2)	4	(5.3)
2 to <4	15	(4.0)	6	(7.9)
4 to <6	16	(4.2)	7	(9.2)
6 to <8	9	(2.4)	7	(9.2)
8 to <10	14	(3.7)	3	(3.9)
10 to <20	24	(6.4)	12	(15.8)
20+	18	(4.8)	11	(14.5)

TABLE III. Injury Frequencies, Time at Risk, Rates, Rate Ratios, and 95% CI of WC Claims for Injury by OSHA Outreach Training, Overall and by Worker Age, Time in the Union, Type of Work, and Calendar Year

	OSHA Outreach Training in past 5 years						
	Yes			No			
	Hours	# Injuries	Rate[a] (95% CI)	Hours	# Injuries	Rate[a] (95% CI)	Rate ratio[b] (95% CI)
Injuries, Overall	1,138,147	99	17.4 (14.3–21.2)	98,272,853	9,787	19.9 (19.5–20.3)	0.87 (0.72–1.06)
By carpenter age							
<30 years	269,493	26	19.3 (13.1–28.3)	16,423,237	1,820	22.2 (21.2–23.2)	0.87 (0.59–1.28)
30 to <40 years	356,751	27	15.1 (10.4–22.1)	28,177,004	2,960	21.0 (21.2–23.2)	0.72 (0.49–1.05)
40+ years	506,276	45	17.8 (13.3–23.8)	53,538,101	4,999	18.7 (18.2–19.2)	0.95 (0.71–1.28)
By time in the union							
Apprentices (<4 years)	355,427	33	18.6 (13.2–26.1)	23,586,374	2,890	24.5 (23.6–25.4)	0.76 (0.54–1.07)
Journeymen (≥4 years)	782,720	66	16.9 (13.3–21.5)	74,686,479	6,897	18.5 (18.0–18.9)	0.91 (0.72–1.16)
By predominant type of work							
Commercial	676,655	70	20.7 (16.4–26.2)	51,217,796	4,911	19.2 (18.7–19.7)	1.08 (0.85–1.37)
Drywall	155,565	6	7.7 (3.50–17.2)	21,141,980	2,418	22.9 (22.0–23.8)	0.34 (0.15–0.75)
Other[c]	300,541	20	13.3 (9.00–20.6)	24,871,732	2,282	18.4 (17.6–19.1)	0.73 (0.47–1.13)
By calendar year							
2000–2002	74,999	13	34.7 (20.1–59.7)	31,806,516	3,806	23.9 (23.2–24.7)	1.45 (0.84–2.50)
2003–2005	347,504	29	16.7 (11.6–24.0)	27,597,535	2,713	19.7 (19.0–20.4)	0.85 (0.59–1.22)
2006–2008	715,644	57	15.9 (12.3–20.7)	38,868,803	3,268	16.8 (16.3–17.4)	0.95 (0.73–1.23)

[a]Events per 200,000 work hours.
[b]Compares rate of injury among trained versus rate of injury among non-trained.
[c]Includes residential, piledriving, millwrighting, and work out of WA State.

DISCUSSION

Effect of OSHA Outreach Training on Rates of Injury and Related Outcomes

Within a dynamic 9-year cohort of union carpenters, data from union membership, eligibility, and training files were linked at the individual level to WC claims data to explore the relationship between OSHA Outreach Training and work-related injury events, overall and stratified by calendar time, worker characteristics, and predominant type of work. Data suggest OSHA Outreach Training resulted in a 13% reduction in rates of injury overall; this finding was not statistically significant and was attenuated in adjusted analyses. The more pronounced effect of training among carpenters in their apprenticeship years (though not statistically significant) has similarities to patterns observed by Dong et al. [2004] who evaluated the effect of safety training on rates of work-related injury among union laborers in WA State over 2 years in the mid-1990s. The authors saw a 12% reduction in injury rates among trained versus untrained workers, and this effect was greater among younger workers (42% reduction; 95% CI 0.35–0.95)—a finding the authors attributed to less informal on-the-job training and a greater propensity of younger and less experienced workers to benefit from injury prevention training material [Dong et al., 2004]. Similar findings from the current study suggesting that training may be most effective in carpenters' early years of work is noteworthy, as this is the time these workers were shown to be at greatest risk of injury. Appropriately, it is also the time resources are utilized to provide training through the apprenticeship program. A large proportion of OSHA

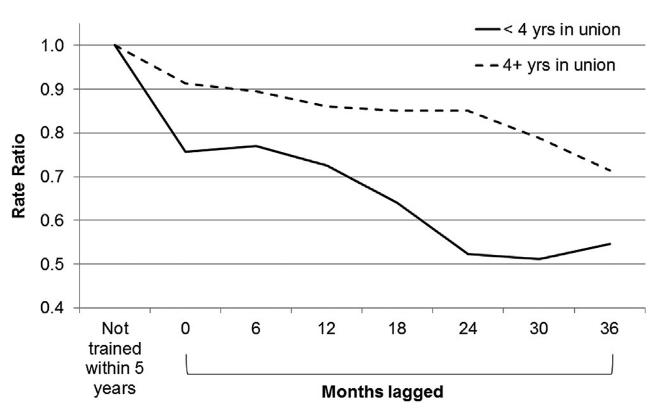

FIGURE 2. Rate ratios comparing work-related injury rates surrounding OSHA Outreach Training, lagged by increasing amounts of time post-training and stratified by years in the union.

Outreach Training courses, particularly OSHA-10, were taken by carpenters during their first year in the union.

A protective, significant effect of training was observed among carpenters whose predominant type of work was drywall installation. Drywall installers have high rates of work-related injury compared to workers in other construction trades, including in this cohort of union carpenters [Lipscomb et al., 2000, 2003a,b, 2015b,c; Schoenfisch et al., 2013, 2014a,b], perhaps allowing more of an effect of OSHA Outreach Training to be observed. Also, it is possible that carpenters who receive OSHA Outreach Training are more likely to work for safer contractors; this pattern may be particularly true for carpenters in the drywall trade. Finally, drywall installers' injury incidence is characterized by a relatively large proportion of events resulting from struck by/against and falls [Lipscomb et al., 2003c, 2014a; Schoenfisch et al., 2013], two mechanisms that are emphasized in the OSHA Outreach Training curriculum. However, in this study analyses specific to these and other Fatal Four events do not support that suggestion. It is notable that a large proportion of struck by events experienced by these union carpenters are abrasions, cuts, and bruises associated with contact with hand tools or materials (e.g., fasteners, wood), rather than events focused on as part of the training curriculum (e.g., struck by collapsing structure, hit by moving vehicle).

Findings related to the subset of injuries that resulted from a Fatal Four mechanism (i.e., falls from elevation, electrocutions, struck by events, and caught in/between events), were similar to those observed among injuries overall. Given the focus on prevention of Fatal Four event mechanisms in the OSHA Outreach Training program curricula, this pattern may reflect something other than a training effect (e.g., trained carpenters working for safer contractors). Limited statistical power precluded the ability to further examine Fatal Four events by specific mechanisms. Differences in knowledge have been observed across injury mechanism subtypes, with greater gains for falls and electrocution [Forst et al., 2013].

Lagged analyses were suggestive of an improved effect of training with increasing time since training, particularly for less experienced carpenters. Although these findings are imprecise and should be interpreted with caution, the trend suggests the trained group seems to be becoming more skilled as the amount of time since training increases. Such a pattern could reflect improved application of training concepts on-the-job with increased time since training. It is also plausible that the pattern observed in lagged analyses, as well as the general effect of training overall, reflects a propensity for trained (vs. non-trained) workers to be hired by and choose to work for safer contractors, as well as the potential for trained workers to be more likely to remain with (and gain a familiarity with) these safer contractors over time. Differences by time in the union may be driven by overall improvements in task-based—including safety-related—competence with increased time in the field, reducing the magnitude of the effect of training in this more experienced group.

No difference was observed in the proportion of injuries resulting in paid TL, median number of paid TL days per TL injury, or rates of TL injury by training status. However, the rates of paid TL days and costs were lower among trained workers. The data were not robust enough to allow exploration of this finding beyond a comparison of simple rates, and they beg similar questions as to the meanings behind such differences. OSHA Outreach Training may effectively reduce rates of severe work-related injury events. It may also be associated with an increased propensity for workers to report less-severe events, either through increased knowledge of reporting processes or increased likelihood of working for a contractor who encourages reporting of work-related injury events (even minor events) and has hazard identification and injury control strategies in place.

Sensitivity analyses were conducted to compare the presented findings to those obtained when removing the 5-year expiration on carpenters' training. Thus, a member who completed OSHA Outreach Training remained categorized as "trained" any time following training. With this change, no meaningful differences were observed in the effect of training, including on rates of work-related injury overall (RR 0.92, 95% CI 0.78–1.10) and those with paid TL days (RR 1.07, 95% CI 0.74–1.56). Sensitivity analyses were also conducted in which prevalent members were categorized as "trained" at the start of study follow-up, only being categorized as "not trained" if they did not complete an OSHA Outreach Training course within 5 years. Prevalent members made up 52.9% (n = 9,057) of the cohort, and they contributed 76.8% (hours = 76,364,977) of the time at risk. At entry into the study cohort these members had a median of 9.5 years in the union (range 0.5–44.5). With this change and adjusting for potential confounders, change was observed in the effect estimate related to rates of work-related injury overall (RR 1.12, 95% CI 1.03–1.22), but not for that of rates of paid TL injuries (RR 1.04, 95% CI 0.76–1.42).

The observed effects of training on rates of injury and related outcomes as captured through WC claims reflect important practices that cannot be explored through use of this dataset alone. Safety training could reduce rates of WC claims through improved hazard awareness and control (e.g., increased PPE use) and ultimate prevention of work-related injuries and/or the severity of work-related injuries. It is plausible that such benefits of highly effective training will "spill over" to non-trained workers. Trained workers may be less likely to injure other workers on site, or they may be more likely to speak up when they see unsafe practices or working conditions [Dong et al., 2004; Williams et al., 2010; Forst et al., 2013; Ruttenberg, 2013]. For example, in Forst et al. [2013] trained workers described making other workers aware of hazards, talking with supervisors about hazards, and taking on informal safety leadership roles. It is also plausible that such effects stem from broader constructs that support safety, namely the union's ability to influence norms about workers' safety at an industry level, including through the continued provision and growth of the long-standing construction apprenticeship program [Sinyai et al., 2013]. The potential "public good" created indirectly through training, though not captured using data from this study, could reduce the magnitude of an observed protective effect of OSHA Outreach Training on WC claims rates. Similarly, a protective effect of training may not be fully apparent if training increases the propensity to report injury events through the WC system by educating workers on their rights to a safe workplace and providing encouragement and instruction on how to report injuries when they do occur [Dong et al., 2004; Williams et al., 2010; Forst et al., 2013; Ruttenberg, 2013].

These scenarios highlight the difficulty of clearly interpreting effect estimates. Further, they do not rule out the possibility that a null or muted effect of OSHA Outreach Training on rates of work-related injury reflects, in part, ineffective teaching methods [Wilkins, 2011] or barriers to applying training-based knowledge on worksites [Williams et al., 2010]. Regarding the former, there is concern OSHA Outreach Training courses do not incorporate adult learning theories or fully consider the diversity of learners' characteristics (e.g., age, years and types of experience in the industry, language spoken, work demands/organization) which vary by trade [The Center for Construction Research and Training, 2013] and may influence learning styles and needs [Wilkins, 2011].

Apprenticeship Participation and Attrition

Related to the emphasis on training in carpenters' early years in the union are the issues of apprenticeship program participation and attrition of active apprentices. In this study, a significant decrease in the number of union carpenters receiving OSHA Outreach Training was observed in 2005/2006, mirroring lower proportions of union carpenters and union worker hours categorized as apprentices during that time period. Such patterns may reflect important secular trends that drive entry into and retention in construction apprenticeship programs, as well as economic demand for apprentices on site.

Over half of union members who received OSHA Outreach Training during the study period did not link to the study cohort, which was restricted to members who worked union hours in at least three calendar months. Similar linkage patterns have been observed in the authors' prior work with these data and are not surprising given the literature on construction apprentice attrition and retention. Using data (1989–1995) from the Apprenticeship Information Management System compiled by the Department of Labor's Bureau of Apprenticeship Training, Bilginsoy [2003] reported that nearly half (47%) of construction apprentices exited their program prior to completion; the average length of a cancelled apprenticeship was 27 months. Analyses of data from the same source for the years 1996 through 2003 [Glover and Bilginsoy, 2005] highlighted that 60% of construction apprentices exited before program completion. In Oregon, and consistent with national trends, data from 2005 suggest carpenters in Oregon had one of the lowest apprenticeship completion rates of all the licensed trades (31%) [Byrd and Weinstein, 2005], an observation the authors attributed to a lower incentive to complete programs due to work availability.

From a statistical perspective, exclusion of members who did not link to the study cohort is justified, as they would contribute minimal, if any, time at risk in analyses. From a practice perspective, particularly as it relates to training, the patterns are quite noteworthy. Apprenticeship programs provide workers with 3 or 4 years of highly structured in-classroom and on-the-job training in skills specific to their construction trade. In theory, the programs are efficient: Employers and unions provide financial support to train apprentices who accept lower wages during their training, employers' costs are recovered in workers' latter apprenticeship years as the apprentice becomes more productive, and the apprentice is able to make up for their lower wages throughout a higher-wage career [Bilginsoy, 2003]. This theoretical efficiency is weakened when apprentices exit the program prior to completion [Bilginsoy, 2003]. Although demographic and work characteristic data were missing for the majority of the 585 union members with OSHA Outreach Training who did not link to the study cohort, their training was predominantly OSHA-10 (95%) as expected. These concerns of attrition do not mean training should not occur. Even individuals who leave the union construction workforce should receive early basic hazard awareness training, which could be viewed as a "cost of doing business."

Limitations and Strengths

In this study, the effect of training on rates of WC claims was examined. Measuring WC claims activity is not the same as measuring occupational injuries. A substantial scholarly literature has documented the failure of OSHA and WC claims data to adequately capture workplace injury events [Azaroff et al., 2002; Shannon and Lowe, 2002; Leigh et al., 2004; Fan et al., 2006; Rosenman et al., 2006; Friedman and Forst, 2007; Welch et al., 2007; Government Accountability Office, 2009; Lipscomb et al., 2013, 2015a; Wuellner and Bonauto, 2014]. Reasons include changes in reporting requirements, employers' intentional or unintentional meeting of reporting requirements, and employees' distaste for the administrative process or fear of employer retaliation. Employees suffering an injury may decline to report it, opting instead to seek other means of treatment coverage or simply live with job-related pain. Researchers have documented a substantial gap between the incidence of occupational injury and the reported injury rate. In one study, 30% of carpenter apprentices completing confidential surveys said that adverse workplace events were "rarely" or "almost never" reported [Lipscomb et al., 2013]. In another, more than one quarter of plumbing and pipefitting journeymen acknowledged suffering a workplace injury they did not report [Taylor et al., 2013]. Recent research suggests insured construction workers rely, in part, on private health insurance for occupational hazards of their trade, rather than filing a WC claim [Lipscomb et al., 2009a,b, 2015b; Schoenfisch et al., 2014a; Dale et al., 2015].

Finally, there are several well-known characteristics of the cohort data relevant to this study. First, no direct measures of job tasks or work-related exposures are available in this cohort. However, the predominant type of work performed by the union local with which the carpenter is affiliated provides a meaningful categorization for analyses. Also, the cohort data do not include ethnicity or language spoken. In some trades, minorities represent a large proportion of workers in the Pacific Northwest. For example, it estimated that 50% of union drywall installers are Spanish-speaking. This is a high-risk, high-priority population for which needed efforts [NORA Construction Sector Council, 2008] have been made to deliver targeted safety training [Williams et al., 2010; Wilkins, 2011; Forst et al., 2013]. Additionally, we recognize that we are gathering data from union carpenters who are part of an apprenticeship program, limiting the generalizability of findings. In a Massachusetts survey of construction workers, union status was the most important predictor of OSHA-10 card status [Roelofs, 2012] (though OSHA cards and union status were likely overrepresented in this convenience sample). In this same survey, union membership was also positively associated with greater training frequency. In a study of construction workers in Ontario, Canada [Amick et al., 2015], union construction firms had higher rates of injury with no lost time and lower rates of injury with lost time compared to non-union firms. The authors suggested workers in union firms may have fewer barriers to reporting work-related injuries, as well as lower risk of injury through training and hazard control. Finally, the training data in this study come from training centers affiliated with the PNWRCC; information on these carpenters' training through other means (e.g., other training centers, online courses) was not available.

This study demonstrates both the utility and importance of robust, longitudinal surveillance data in the appraisal of long-term evaluations of the effectiveness of workplace safety interventions, as well as the very real challenges in clearly evaluating training effects in this dangerous industry. Such exploration of construction workers' training and injury experience outside of this dynamic cohort is unrealistic, if not impossible, in the open shop environment or otherwise. Time at risk and reported injuries were well defined, allowing for the calculation of injury rates and their examination over time surrounding documented training. The experiences of these union carpenters reflect their work across diverse construction trades, the characterization of which was possible through regular interaction with industry leaders over the past two decades. Finally, our focus on the union segment of the industry, with existing union apprenticeship programs, labor-management relations, and (in this case) a longstanding collaborative partnership with an academic research team, allowed the research questions to be addressed and provided the foundation needed to carry out this work with the resources available through a small study funding mechanism.

Longer-term evaluations such as this are uncommon, and this study also demonstrates the complexity of training effectiveness evaluations and the related importance of framing an analytical approach and interpreting results in context. Although statistical power was limited to address all of the planned analyses, the framework presented provides a guide for future research considerations. For us, however, the process raises questions as to when and what types of training effects it is appropriate to assess in isolation.

Relevance and Practical Application

In 1998 and again in 2010, the National Institute for Occupational Safety and Health commissioned systematic reviews of the academic literature assessing the effectiveness of occupational safety and health training programs [Cohen et al., 1998; Robson et al., 2010]. These reviews, along with another [Robson et al., 2012], concluded training was effective in increasing hazard awareness and safety-forward behaviors of trained workers. However, they pointed to the paucity of research demonstrating that occupational safety training can improve health outcomes as well as a lack of well-designed controlled studies.

Our findings of only very modest, if any, effects of OSHA Outreach Training on union carpenters' injury rates are reasonably consistent with prior reports. However, we do not echo earlier calls for controlled studies of OSHA Outreach Training at this point. Such training is not likely to ever be delivered in a randomized controlled manner. It never happens in isolation, and even OSHA-10 training can be variable depending on the instructor's points of emphasis based on their expertise and experiences, delivery method (e.g., face-to-face or online), and learners' characteristics (e.g., language spoken, trade, and history in the industry). Additionally, studies must consider the time needed for an intervention effect to be observed, the potential "spill-over" of a training effect, as well as the mobility of construction workers from project to project and often employer to employer, and the influence of work organization on worker behaviors.

Despite our findings and position on future evaluative work, we are not calling for a stop to these basic training efforts. OSHA Outreach Training for construction was devised to broadly provide basic hazard awareness, largely about the more common causes of fatalities, across a very diverse and dangerous industry. We view the fact that this training for workers has become more common as a very positive step. Not only can it increase knowledge and behaviors related to specific work hazards and adverse safety outcomes [Sanyang, 2007; Sokas et al., 2009; Ruttenberg, 2013], but it may also have positive effects on workers' general health and safety literacy, self-efficacy, leadership skills, and communication within construction crews—particularly when well-aligned with the characteristics and needs of the target trainee population [Williams et al., 2010; Wilkins, 2011; Forst et al., 2013].

However, we also caution that training—particularly of this nature—has long been recognized as a lower-tiered intervention in the public health hierarchy of hazard control [Herrick and Dement, 1994] including for acute work-related injuries [Castillo et al., 2011; Lipscomb and Schoenfisch, 2014], and it should not be expected to significantly impact injury rates in isolation. Although training as an intervention may be viewed more favorably from feasibility and cost perspectives to approaches on the higher tiers of the hierarchy of hazard control, training should be considered as a supplement to—rather than an alternative for—approaches known to be more effective at preventing work-related injuries, such as elimination or substitution of a hazard.

Although we were not able to characterize the union members with OSHA Outreach Training who did not link to the study cohort, the concerns of apprentice attrition are noteworthy. As the demand for a skilled construction workforce increases, efforts to improve the enrollment and retention of individuals in construction apprenticeship programs are called for to meet future construction labor force needs. Specifically, there is a need to better understand construction apprentices' in-class and on-the-job experiences and identify practices that improve construction apprenticeship enrollment and retention [Bilginsoy, 2003; Glover and Bilginsoy, 2005].

CONCLUSION

Construction worker training in hazard awareness, injury prevention and mitigation, workers' rights, and how to report adverse work-related events should be standard practice. Yet, such training alone cannot be expected to prevent work-related injuries to a significant degree in this dangerous industry. Training does not address organizational issues that broadly influence worker safety [Dekker et al., 2013], but rather focuses on informing workers in hazard awareness and protection. For such reduction to be realized, more concrete and efficient injury prevention approaches that eliminate or reduce hazardous exposures must be made available to workers. As expected, these data do not demonstrate the likelihood that OSHA Outreach Training alone meaningfully decreases injury rates among union construction industry workers, although noteworthy benefits may be observed among less experienced workers and within specific trades (e.g., drywall installation).

The paucity of evaluations on the effectiveness of OSHA Outreach Training on construction work-related injuries is understandable, and current methodological challenges inherent in such conduct limit the interpretation of effect estimates. In addition to working to overcome these challenges, future studies should focus on improving the accessibility, quality, and relevance of such training, as well as its application in practice. Regardless of the study design, evaluations that focus on outcomes alone will be inherently limited without information on intervention fidelity, including an understanding of application of training concepts on site and factors that influence trainees' decisions about safe practices they are being taught.

AUTHORS' CONTRIBUTIONS

Drs. Schoenfisch and Lipscomb oversaw the design of the project, and Dr. Schoenfisch worked with relevant parties to ensure the acquisition of study data. Mr. Adams' expertise in the prior cohort build was drawn on in the current project, and he oversaw the update to the data extract. Dr. Schoenfisch performed all statistical analyses and worked with Dr. Lipscomb to synthesize findings and produce a draft of the report. All authors made significant contributions to the interpretation of study findings and revision of the draft report. All authors have approved the final version to be published and agree to be accountable for all aspects of the work.

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The work was carried out at the Duke University School of Nursing. Study procedures were approved by the Institutional Review Boards of the Duke University School of Nursing, the Duke University Health System, and the Washington State Department of Health and Human Services. Verbal or written informed consent was waived for these retrospective analyses of de-identified data.

DISCLOSURE (AUTHORS)

The authors report no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

Steven Markowitz declares that he has no competing or conflicts of interest in the review and publication decision regarding this article.

DISCLAIMER

The contents of this report are solely the responsibility of the authors and do not necessarily represent the official views of the CPWR or NIOSH.

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