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Are plumbing apprentice graduates safer than their non-apprentice peers? Workers' compensation claims among journey level plumbers by apprenticeship participation

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ABSTRACT

Introduction: Apprenticeships combine mentored on-the-job training with related instruction to develop a workforce with the skills sought by employers. Workplace safety is an important component of apprenticeship training. Whether that training results in fewer work injuries, however, is largely unknown. *Method:* We linked Washington's registered apprenticeship data, plumber certification (licensing) data, employment data, and workers' compensation claims to compare claim rates among journey level plumbers (JLP) by apprenticeship participation. We used negative binomial regression models to estimate rates of total claims, wage replacement/disability claims, acute injuries, and musculoskeletal disorders (MSD), adjusted for worker characteristics. *Results:* Among JLP certified between 2000 and 2018, rates among JLP with no apprenticeship training were 46% higher for total workers' compensation claims (adjusted Rate Ratio (aRR) = 1.46, 95% CI: 1.26–1.69) and 60% higher for wage replacement/disability claims (aRR = 1.60, 95% CI: 1.22–2.11), compared to rates among JLP who completed a plumbing apprenticeship. Apprentice graduates experienced a greater decline in the rate of total claims between the 5 years preceding JLP certification and the years after certification (55.3% vs. 41.4% among JLP with no apprenticeship training). Greater rate reductions among JLP apprentice graduates were also observed for acute injuries and MSD, although the decline in MSD was not significantly different from the decline among JLP with no apprenticeship training. *Conclusions*: Successful completion of a plumbing apprenticeship program is associated with fewer work injuries throughout the career of a JLP. Apprenticeships appear to play a key role in reducing work injuries among JLP, especially acute injuries. *Practical Applications*: Apprenticeships are an effective model for reducing workplace injuries. The mechanisms by which apprenticeship training improves workplace safety should be identified to better inform injury prevention efforts among apprentices as well as among workers outside of a formal apprenticeship arrangement.

1. Introduction

Apprenticeships are a longstanding model of workforce development. Available for an increasing array of trades and professions, formal apprenticeship programs registered with the federal government train participants through on-the-job training (OJT) supervised by experienced mentors and related/supplemental instruction (RSI), which may include training seminars, online courses, or classroom instruction at community colleges or technical schools. Employers, labor unions, or business associations develop and sponsor apprentice programs, often supported, in part, through federal and state funding. Most apprenticeship programs take multiple years to complete. Participants earn wages during their apprenticeship, receive a nationally recognized credential upon graduation from the program, and most find employment in their trade immediately upon completion of the program. Acceptance into apprentice programs is often competitive, with applicants outnumbering spaces. Apprenticeships are currently experiencing renewed interest as a means to ensure that workers' skills meet the needs of contemporary employers (US Department of Labor, 2021).

State and federal oversight of apprenticeship programs extends back more than 80 years (National Aprenticeship Act, 1937). Occupation-specific program standards define required hours of OJT for specific work processes, ratio of apprentices to journey-

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level employees, hours of RSI, and wages. Federal regulations require that apprenticeship programs include workplace safety training in both the OJT and RSI (Standards of Apprenticeship, 2022).

The many documented benefits to apprenticeships include higher lifetime earnings and stable employment for apprentice graduates, and higher productivity and lower turnover among employers (Lerman, Eyster, & Chambers, 2009; Reed, Liu, Kleinman, Mastri, Reed, Sattar, & Ziegler, 2012). Increased workplace safety is an assumed benefit of apprenticeship training, in part because of the required safety training, as well as the structured learning environment of apprenticeship programs that can be leveraged to promote workplace safety and health competencies (Guerin et al., 2020). However, there is little evidence to either support or refute the assumption that apprentice training reduces work injuries. Generally, research into health outcomes among apprentices has focused on work-related injuries and illnesses among apprentices compared to more experienced workers, and have highlighted the increased risk of injuries among apprentices (Lipscomb, Dement, Nolan, Patterson, & Li, 2003; Sahl, Kelsh, Haines, Sands, & Kraus, 1997). Less is known about the work-related injury experience of workers who participated in apprentice programs compared to peers with no apprenticeship participation.

We linked state databases of licensed certified plumbers, apprenticeship participants, employment history, and workers' compensation claims to compare rates of work-related injuries and illnesses of journey level plumbers (JLP) who completed a plumbing apprenticeship to those who did not complete an apprenticeship. Participation in apprenticeships is not the result of random selection. Factors that lead an individual to choose to enroll in—and complete—an apprentice program may also influence aspects of occupational safety. We used worker and employer characteristics captured in the administrative databases in an attempt to control for some of the underlying differences between apprentices and non-apprentices.

2. Materials and methods

2.1. Journey level plumber data

To work in the plumbing trade in Washington, all workers must be licensed and certified by the Washington State Plumber Certification Program (18.106 RCW). Plumbers achieve journey level certification by fulfilling the state's requirements as a plumber trainee, working 8,000 hours (approximately 4 years) under the supervision of a journey level plumber, completing 8 hours of continuing education annually, and passing the state's plumber exam. Plumber trainees may fulfill the requirements as an apprentice, but apprenticeship is not required to become a certified JLP.

A database of all individuals licensed to perform plumbing work in Washington is maintained by the Washington State Department of Labor & Industries (L&I), and includes the worker's name, date of birth, social security number, trade specialty, certification start and end dates, and active status. It serves as a registry of all workers in the occupation, with entry and exit dates into and out of the profession.

We chose to focus on plumbers rather than other occupations because of the availability of the professional licensing data, and because plumbing apprenticeships are among the occupations with the greatest enrollment (US Department of Labor, 2020). Journey level plumbers were selected over other plumbing specialties (e.g., residential) because the size of the population, stratified by apprenticeship participation status, was sufficient for analysis. The study included JLP certified between January 1, 2000 and December 31, 2018.

2.2. Plumbing apprentice participation

All individuals who enroll in a registered apprentice program in Washington are recorded in Washington's apprentice registry data, also maintained by L&I, which includes the participant's name, social security number, apprenticeship start and end dates, program completion status, and a Standard Occupational Classification code to describe the type of apprentice program.

We identified apprentice program participation among JLP by linking social security numbers across the plumbing licensing data and apprentice registry data. Plumbers were grouped into one of three categories of apprentice program participation: completion of a plumbing apprentice program within four quarters of the JLP certification date; no participation in any apprentice program; or other apprentice program participation – including incomplete plumbing apprenticeship, completion of a plumbing apprentice program more than four quarters from the JLP certification date, or participation in an apprenticeship program for an occupation other than plumbing.

2.3. Work-related injury data

We used Washington workers' compensation claims data to evaluate work injuries among JLP.

In Washington, with few exceptions, employers are required to obtain workers' compensation insurance from the state (referred to as state funded), unless they are approved by the state to self-insure. L&I administers the state funded program, oversees the self-insured program, and maintains records on claims filed through either program. We included both state funded and self-insured workers' compensation claims data, for claims involving wage replacement and/or disability payments and claims limited to medical-aid payments. In Washington, a claimant may be eligible for wage replacement or disability benefits if unable to work following a three-day waiting period.

Workers compensation claims among JLP were identified using the plumber's social security number. We assessed the total number of accepted claims (medical aid-only claims plus wage replacement/disability claims) and wage replacement/disability claims experienced during the JLP's active licensure or through 2019, for plumbers whose licenses were active beyond 2018. We also assessed workers' compensation claims for injuries or illnesses that occurred in the five years prior to the certification start date.

We used Occupational Injury and Illness Classification System (OIICS v1) codes, assigned by L&I staff based on narrative injury descriptions reported on the claim initiation form, to characterize injuries and illnesses. We followed a definition of musculoskeletal disorders based on a combination of OIICS nature of injury and event or exposure codes, developed and validated previously using Washington workers' compensation data (Marcum & Adams, 2017; Silverstein, Viikari-Juntura, & Kalat, 2002; Spector, Adams, & Silverstein, 2011). We defined acute injuries as claims that did not meet the definition of a musculoskeletal disorder and which were assigned an OIICS nature code within the division "Traumatic Injuries and Disorders." Completeness of OIICS codes differs by insurer; nearly all state funded claims in this study were coded while almost 70% of self-insured claims were missing OIICS codes, reflecting the relatively limited injury description data available for self-insured claims. Using the distribution of codes assigned to state funded claims, we randomly assigned OIICS codes to replace the missing values.

To differentiate claimants working as plumbers at the time of injury or illness from those employed in some other occupation,

we used the Washington State Risk Classification system (a method for setting insurance premiums by grouping types of work according to risk). To compare claims at the same point in their development, we evaluated claim costs incurred at one-year post-injury, converted to 2018 US dollars using the Consumer Price Index to adjust for inflation. Analysis of costs are limited to state funded claims because of missing or incomplete data among self-insured claims.

2.4. Employment data

To calculate claim rates, hours worked by JLP were extracted from the Washington Unemployment Insurance (UI) database, which includes quarterly records of employer-reported wages and hours worked for each worker in the state covered for unemployment insurance, by worker name and social security number. Using the JLP social security numbers, we extracted quarterly employment data for the five years preceding the license start through the license end date or 2019Q4, whichever occurred first. We excluded from the analysis JLP for whom no wage and hour data was found in UI, as we could not estimate hours-based injury rates among this group. Individuals not found in the UI data may be self-employed, employed out of state, or out of the work force. Self-employed individuals (with no employees) who meet the state's definition of an independent contractor are exempt from both Washington's workers' compensation insurance coverage and unemployment insurance coverage (Revised Code, 2002). JLP with wage and hour data reported in UI were considered to be employed for wages, and included in the final analysis.

2.5. Statistical analysis

Differences in characteristics between the three categories of plumbing apprenticeship status (completed plumbing apprenticeship, never enrolled in apprenticeship, participated in some apprenticeship training) were assessed using chi square tests for homogeneity of proportions. To test for differences in continuous variables following either normal or non-normal distributions, we used analysis of variance and Kruskal-Wallis tests, respectively.

We used negative binomial regression models to estimate rates of accepted claims, rates of wage replacement/disability claims, rates of accepted claims for acute injuries, and rates of accepted claims for musculoskeletal disorders. To account for underlying differences between the apprenticeship groups, the final regression models were adjusted for year of initial JLP certification, worker age at JLP certification, number of employers during JLP license, size of employer, license for plumbing specialty other than JLP, hours worked in plumbing industry prior to JLP certification. Level of significance was chosen as $\alpha = 0.05$. Analyses were performed using SAS 9.4.

3. Results

3.1. Apprenticeship participation among journey level plumbers

There were 4,086 plumbers with initial JLP certification between January 1, 2000 and December 31, 2018. Of those, 18.9% (773) JLP completed a plumbing apprenticeship program within four quarters of their JLP certification, 9.1% (373) had some participation in an apprenticeship program, and 72.0% (2,940) did not appear in the apprenticeship registry data. In total, 72.5% of JLP had wage and hour data identified in UI, although identification in UI differed by apprenticeship status. Nearly all plumbing apprentice graduates had wage and hour data reported in UI (768 out of 773, 99.4%), while a smaller portion of JLP who never enrolled in an apprentice program were reported in UI (2,202 out of 2,940, 74.9%) (Table 1). Plumbers with no wage and hour data reported in UI were excluded from further analysis.

3.2. Worker characteristics by apprenticeship participation

Apprentice graduates differed from those who never enrolled in an apprentice program across several characteristics (Table 2). On average, apprenticeship graduates were younger at the start of their JLP certification, became a JLP later in the study period, worked more hours each quarter as a JLP, worked for larger employers, and worked for more employers ($p < 0.05$ adjusted for post hoc pairwise comparisons). Conversely, JLP who never enrolled in an apprentice program tended to be older at their initial JLP certification, enter the profession earlier in the study period, work fewer hours each quarter, work for a smaller employer, and work for fewer employers during their JLP license.

For most measures, JLP with some apprenticeship participation (the 357 individuals who enrolled in but discontinued a plumbing apprenticeship [48%], completed a plumbing apprenticeship more than four quarters from JLP certification [34%], or completed an apprenticeship other than plumbing [18%]) fell in between apprenticeship graduates and never enrollees. For example, at the time of initial JLP certification, they were older than apprenticeship graduates and younger than never enrollees. One exception was holding another type of plumbing license – of the three groups, JLP with some apprenticeship participation were most likely to have another type of plumbing license in addition to the JLP license.

Regardless of apprenticeship participation, one in three plumbers experienced an injury or illness resulting in a workers' compensation claim accepted for medical aid payments, disability, or wage replacement benefits.

3.3. Workers' compensation claim characteristics by apprenticeship participation

Table 3 presents select characteristics of workers' compensation claims by apprenticeship status, for work-related injuries or illnesses experienced as JLP. Several claim characteristics showed no significant difference by apprenticeship participation. Eighty-three percent of claims occurred among JLP performing plumbing work (based on risk classification) and one quarter of claims were eligible for wage replacement and or disability benefits. Median claim costs of state funded claims did not differ significantly across the three groups.

Claims among JLP with no apprenticeship participation were more likely to be insured by the state fund (90.4% among JLP with no apprentice training compared to 83.9% among JLP apprentice graduates and 84.1% among JLP with some apprentice training, based on post hoc pairwise comparisons). State fund claims among JLP with no apprenticeship participation were more likely to result in days of missed work than JLP with any apprenticeship participation ($p < 0.05$ adjusted for post hoc pairwise comparisons).

Acute injuries were the most common injury type. JLP with any apprenticeship training had a greater percent of claims lacking a nature of injury classification, attributable to an overrepresentation of both non-classified claims and apprenticeship participation among the self-insured. Stratified by insurer, the distribution of the nature of injury did not differ by apprenticeship participation. Additionally, injury type did not differ by apprenticeship participation for state funded and self-insured claims combined, after random reassignment of non-classified values to a nature of injury mirroring the distribution among state funded claims.

Table 1
Study inclusion by plumbing apprenticeship status among journey level plumbers.

	JLP who completed plumbing apprentice	JLP with some apprentice training	JLP with no apprentice training	Total
JLP identified	773 (100%)	373 (100%)	2940 (100%)	4086 (100%)
Excluded: No wage/hour data in UI	5 (0.6%)	16 (4.3%)	738 (25.1%)	759 (18.6%)
Included: Wage/hour data In UI	768 (99.4%)	357 (95.7%)	2202 (74.9%)	3327 (81.4%)

Table 2
Characteristics of Journey Level Plumbers (JLP) employed for wages by plumbing apprenticeship participation. Data for continuous variables are presented as mean (standard deviation) or median (Q1, Q3). Data for categorical variables are presented as number (%).

	JLP who completed plumbing apprentice	JLP with some apprentice training	JLP with no apprentice training	Stat. sig.[a]
Total JLP	768 (100.0)	357 (100.0)	2202 (100.0)	
Age at initial JLP certification, mean yrs (std dev)	32.0 (6.6)	34.8 (8.0)	37.6 (9.1)	p <.0001
Year of initial JLP certification				p <.0001
2000–2004	140 (18.2)	94 (26.3)	741 (33.7)	
2005–2009	227 (29.6)	109 (30.5)	615 (27.9)	
2010–2014	251 (32.7)	83 (23.2)	401 (18.2)	
2015–2018	150 (19.5)	71 (19.9)	445 (20.2)	
Hours worked per quarter as JLP, mean (std dev)	456 (82)	425 (97)	420 (127)	p <.0001
Employer size: average FTE of employer, median (Q1, Q3)	170.9 (56.4, 410.2)	149.4 (34.2, 399.6)	60.8 (17.2, 211.2)	p <.0001
Number of employers a plumber worked for over the course of their JLP license, median (Q1, Q3)	3 (2, 6)	3 (2, 7)	2 (1, 4)	p <.0001
Other plumbing license[b]				p <.0001
No	718 (93.5)	271 (75.9)	1830 (83.1)	
Yes	50 (6.5)	86 (24.1)	372 (16.9)	
Workers' compensation claims accepted for injuries experienced as JLP				NS
0 claims	516 (67.2)	233 (65.3)	1446 (65.7)	
1+ claims	252 (32.8)	124 (34.7)	756 (34.3)	

Std dev = Standard deviation.
FTE = Full time equivalent; calculated as 1 FTE = 2000 hrs.
Q1, Q3 = First quartile, third quartile.
NS = No significant difference between groups.
[a] Stat. sig. = statistical significance of difference among groups of apprenticeship participation ($p < 0.05$ = statistically significant), based on analysis of variance, Kruskal-Wallis tests, or chi square tests for homogeneity of proportions, for continuous variables with normal distribution, continuous variables with non-normal distribution, and categorical variables, respectively.
[b] Residential, residential service, pump & irrigation and domestic well, backflow.

3.4. Rates of workers' compensation claims by apprenticeship participation

Rates of workers' compensation claims were lowest among JLP apprentice graduates and highest among those with no apprenticeship training, for total claims and wage replacement/disability claims, both unadjusted, and adjusted for underlying differences in the populations (Table 4). The unadjusted rate of total accepted claims was 70% higher among JLP with no apprentice training, compared to apprentice graduates. The adjusted rate of total accepted claims (controlling for differences in year of initial JLP certification, worker age at initial JLP certification, number of employers as JLP, size of employer, license for plumbing specialty other than JLP, and workers' compensation claim rate in the five years prior to JLP certification) was 46% higher among JLP with no apprentice training, compared to apprentice graduates.

Claim rate ratios were greater for wage replacement/disability claims, where unadjusted rates among non-apprenticeship participants were more than twice as high as rates among apprenticeship graduates. After controlling for covariates, rates among never enrollees still exceeded rates among apprenticeship graduates by 60%.

Claim rates among the group of JLP with some apprenticeship training fell in between the rates among non-participants and apprenticeship graduates, although the rates among JLP apprentice graduates and JLP with some apprenticeship participation were not significantly different.

3.5. Workers' compensation claim rates over time by apprenticeship participation

3.5.1. Claim rates by benefit type

In the five years preceding JLP certification, rates of wage replacement/disability claims were lower among apprentice graduates than among JLP with no apprentice training, while rates of total claims did not differ significantly by apprenticeship participation (Table 5).

For all three apprentice groups, rates in total accepted claims declined from the five years preceding the JLP license to the period of the JLP license. Rates of total accepted claims among JLP apprentice graduates declined the most (55.3%, 95% CI: 48.8%–61.0%), exceeding the 41.4% decline (95% CI: 35.9%–46.4%) among JLP with no apprenticeship participation. Declines were smaller for wage replacement/disability claims, estimated at less than 30% among JLP apprenticeship graduates and among JLP with no apprenticeship participation, and did not differ significantly by apprenticeship participation.

3.5.2. Claim rates by injury type

Injury-specific rates based on original injury codes were similar to estimates based on reassignment of missing values; only rates based on reassigned missing values are presented in Table 5. In the five years preceding JLP certification, rates of acute injuries did not differ significantly by apprenticeship participation, while rates of musculoskeletal disorders were marginally lower among

Table 3
Characteristics of workers' compensation claims among Journey Level Plumbers (JLP) employed for wages by plumbing apprenticeship participation. Data presented as number (%), unless otherwise noted.

	Claims among JLP who completed plumbing apprentice	Claims among JLP with some apprentice training	Claims among JLP with no apprentice training	Stat. sig.[a]
Claims	428 (100.0)	220 (100.0)	1530 (100.0)	
Insurer				p <.0001
State Fund	359 (83.9)	185 (84.1)	1383 (90.4)	
Self-insured	69 (16.1)	35 (15.9)	147 (9.6)	
Benefits paid				NS
Medical aid only	335 (78.3)	169 (76.8)	1119 (73.1)	
Wage replacement or disability	93 (21.7)	51 (23.2)	411 (26.9)	
Risk classification				NS
Plumber	359 (83.9)	174 (79.1)	1276 (83.4)	
Other than plumber	69 (16.1)	46 (20.9)	254 (16.6)	
Nature of injury				p < 0.05
Traumatic Injuries and Disorders	264 (61.7)	123 (55.9)	924 (60.4)	
Musculoskeletal disorders	97 (22.7)	57 (25.9)	418 (27.3)	
Diseases and non-traumatic conditions	15 (3.5)	15 (6.8)	76 (5.0)	
Not classified	52 (12.1)	25 (11.4)	112 (7.3)	
Nature of injury, "not classified" re-assigned				NS
Traumatic Injuries and Disorders	297 (69.4)	142 (64.5)	998 (65.2)	
Musculoskeletal disorders	112 (26.2)	61 (27.7)	448 (29.3)	
Diseases and non-traumatic conditions	19 (4.4)	17 (7.7)	81 (5.3)	
Not classified	0 (0)	0 (0)	3 (0.2)	
Injury event or exposure				NS
Contact With Objects And Equipment	189 (44.2)	88 (40.0)	612 (40.0)	
Bodily Reaction And Exertion	129 (30.1)	72 (32.7)	543 (35.5)	
Falls	26 (6.1)	17 (7.7)	131 (8.6)	
Exposure to Harmful Substances, Environments	24 (5.6)	11 (5.0)	60 (3.9)	
Other events or exposures[b]	9 (2.1)	6 (2.7)	45 (2.9)	
Not classified	51 (11.9)	26 (11.8)	139 (9.1)	
Time loss days paid[c]				p < 0.05
0 days	328 (91.4)	161 (87.0)	1146 (82.9)	
1–30 days	9 (2.5)	8 (4.3)	91 (6.6)	
31–100 days	6 (1.7)	5 (2.7)	64 (4.6)	
>100 days	16 (4.5)	11 (5.9)	82 (5.9)	
Claim costs one year post injury[c,d]				
Total claim costs, median (Q1, Q3)	$820 (490, 2510)	$770 (490, 2620)	$910 (460, 3010)	NS
Medical aid costs, median (Q1, Q3)	$820 (480, 2320)	$730 (490, 2380)	$840 (450, 2760)	NS

NS = No significant difference between groups.
Q1, Q3 = First quartile, third quartile.
[a] Stat. sig. = statistical significance of difference among groups of apprenticeship participation (p < 0.05 = statistically significant), based on analysis of variance, or chi square tests for homogeneity of proportions, or Kruskal-Wallis tests, for categorical variables and continuous variables with non-normal distribution, respectively.
[b] Includes Transportation Accidents, Fires And Explosions, Assaults And Violent Acts.
[c] Limited to State Fund claims because of missing values among self-insured claims.
[d] Workers' compensation claim costs incurred at 15 months post injury.

Table 4
Workers' compensation claim rates and rate ratios among Journey Level Plumbers (JLP) employed for wages by plumbing apprenticeship participation.

	Unadjusted estimates		Adjusted[a] estimates	
	Claim rate[b] (95% CI)	Rate ratio (95% CI)	Claim rate[b] (95% CI)	Rate ratio (95% CI)
Accepted claims				
Completed plumbing apprentice	74.3 (65.5–84.3)	referent	73.1 (63.4 –84.3)	referent
Some apprentice training	97.9 (82.3–116.5)	1.32 (1.06–1.63)	84.2 (70.5–100.5)	1.15 (0.93–1.43)
No apprentice training	126.4 (117.7–135.9)	1.70 (1.47–1.97)	106.4 (97.8–115.8)	1.46 (1.26–1.69)
Wage replacement/disability claims				
Completed plumbing apprentice	16.4 (12.9–20.9)	referent	16.6 (12.7–21.7)	Referent
Some apprentice training	22.5 (16.1–31.7)	1.37 (0.91–2.08)	18.2 (13.1–25.3)	1.10 (0.73–1.65)
No apprentice training	34.5 (30.8–38.6)	2.10 (1.61–2.73)	26.6 (23.2–30.4)	1.60 (1.22–2.11)

CI = Confidence Interval.
[a] Claim rate adjusted for: year of initial JLP certification, worker age at initial JLP certification, number of employers as JLP, size of employer, license for plumbing specialty other than JLP, and workers' compensation claim rate in the five years prior to JLP certification.
[b] Claims per 1,000 FTE.

JLP apprentice graduates. The change in rates of acute injuries before and after JLP certification differed by apprenticeship participation, with JLP apprenticeship graduates experiencing a greater decline in acute injuries than JLP with no apprenticeship training (59.7% vs 43.1%, respectively). Declines in rates of musculoskeletal disorders were statistically similar, although the rate among JLP

Table 5
Workers' compensation claim rates in the 5 years before initial Journey Level Plumber (JLP) certification and the years during JLP license, among JLP employed for wages by plumbing apprenticeship participation.

	Claim rate before JLP[a,b] (95%CI)	Claim rate during JLP[a,b] (95%CI)	Percent decline (95%CI)
Rates by benefit eligibility			
Accepted claims			
Completed plumbing apprentice	163.6 (145.9–183.3)	73.1 (63.4–84.3)	55.3% (48.8%–61.0%)
Some apprentice training	174.8 (147.5–207.3)	84.2 (70.5–100.5)	51.8% (41.3%–60.5%)
No apprentice training	181.5 (166.5–197.9)	106.4 (97.8–115.8)	41.4% (35.9%–46.4%)
Wage replacement/disability claims			
Completed plumbing apprentice	22.6 (17.3–29.5)	16.6 (12.7–21.7)	26.5% (+2.1%–47.1%)
Some apprentice training	35.1 (25.0–49.4)	18.2 (13.1–25.3)	48.2% (21.5%–65.9%)
No apprentice training	37.5 (31.8–44.2)	26.6 (23.2–30.4)	29.2% (16.0%–40.3%)
Rates by injury type[c]			
Claims for acute injuries			
Completed plumbing apprentice	124.3 (109.5–141.2)	50.2 (42.8–58.9)	59.7% (52.5%–65.7%)
Some apprentice training	112.2 (93.6–134.5)	53.8 (44.0–65.7)	52.1% (39.6%–62.0%)
No apprentice training	124.6 (113.2–137.2)	70.9 (64.4–77.9)	43.1% (37.0%–48.7%)
Claims for musculoskeletal disorders			
Completed plumbing apprentice	31.3 (24.8–39.3)	18.6 (14.6–23.8)	40.4% (22.0%–54.5%)
Some apprentice training	50.6 (38.3–66.7)	22.7 (17.0–30.3)	55.1% (36.0%–68.5%)
No apprentice training	44.5 (38.0–51.9)	29.1 (25.3–33.6)	34.5% (22.4%–44.7%)

CI = Confidence Interval.
[a] Claim rate adjusted for: year of initial JLP certificate on, worker age at initial JLP certification, number of employers as JLP, size of employer, license for plumbing specialty other than JLP, and workers' compensation claim rate in the five years prior to JLP certification.
[b] Claims per 1,000 FTE.
[c] Missing injury classification codes (more common among self-insured claims) were randomly assigned codes to mimic the distribution of codes assigned to state funded claims.

apprentice graduates was lower than the rate among JLP with no apprentice training (18.6 vs 29.1 musculoskeletal disorder claims per 1,000 FTE, respectively).

4. Discussion

This is the first study to our knowledge to compare rates of occupational injuries and illnesses of workers at a similar point in their shared career, differentiated by apprenticeship participation. Our findings suggest that plumbers who complete apprenticeships experience fewer work injuries throughout their career compared with plumbers with no apprenticeship participation. Moreover, apprenticeships appear to play a key role in reducing work injuries, especially acute injuries.

With a focus on workplace safety in both the OJT and RSI, the apprenticeship model provides many opportunities to develop occupational health and safety competencies among workers early in their careers. The details of the safety training are not specified in many program standards (as one plumbing apprentice program simply noted, "Safety instruction is included in every quarter's curriculum of this craft" (Washington State Apprenticeship and Training Council, 2021a), and likely vary by apprenticeship program. But the multi-faceted approach to teaching workplace safety is exemplary of interactive forms of instruction more likely to prevent work injuries and illnesses (Burke et al., 2006). Looking at injury rates across the three study groups, with injury rates among JLP with some apprenticeship participation falling in between the never enrollees and the apprenticeship graduates, suggests that workplace safety increases with higher levels of apprenticeship participation.

Another possible explanation for our findings is that apprenticeships are a proxy indicator for worker safety. Apprenticeship participation is not the result of randomization. Participation in an apprenticeship occurs when an individual elects to apply to a program and an apprenticeship grants admission into the program. We were unable to account for all underlying differences between apprentice graduates and plumbers who never enrolled in an apprenticeship, including whether never enrollees would have met apprenticeship program enrollment criteria (e.g., one Washington plumbing apprenticeship program requires that applicants prove proficiency in high school or college algebra and pass a multi-panel drug test) (Washington State Apprenticeship and Training Council, 2021b). The admission process may differentially favor workers with a predisposition for workplace safety competencies, individuals who experience fewer workplace injuries during the training period, and adopt workplace safety principles more readily.

An alternate explanation for the differences in injury rates, aside from the safety training received as an apprentice, is that work tasks differ by apprenticeship participation, with individuals who never participated in an apprenticeship engaged in work activities that are inherently more dangerous than the work assigned to apprenticeship graduates. Two aspects of this study, however, challenge this hypothesis, suggesting instead that the study groups faced similar occupational hazards. First, restricting the study to the specific worker group of journey level plumbers helps limit the variability of job hazards. Second, characteristics of the workers' compensation claims among JLP, which differed little by apprenticeship participation, supports the assumption that JLP face similar workplace risks, regardless of apprenticeship participation.

Workplace safety is complex, reflecting not only individual worker knowledge and actions, but also organizational factors (DeJoy, Gershon, Murphy, & Wilson, 1996). Apprenticeship programs may be promoting workplace safety as much through the training of individual workers as through the engagement with employers. This is most evident in employer development of training programs, but may also manifest as a talent pipeline by which employers with a strong commitment to safety preferentially hire apprentice graduates or sponsor apprenticeship programs. Additional research is needed to identify the mechanisms by which apprenticeship programs impact workplace injuries and illnesses.

Although not the focus of the study, the high rates of workplace injuries and illnesses during the training period preceding professional certification observed here and noted in other studies of apprentices demonstrate a need for enhanced injury prevention efforts during the apprentice training (Kaskutas et al., 2010; Lipscomb et al., 2003, 2008). The smaller decline in rates of musculoskeletal disorders – often debilitating and expensive injuries, and

documented to occur among apprentices (Anton et al., 2020; Rosecrance, Cook, Anton, & Merlino, 2002) – highlights a need for effective prevention efforts throughout a worker's career.

5. Limitations

To measure work-related injuries, we used workers' compensation claims, a data source known to undercount the true occurrence of injuries (Biddle, Roberts, Rosenman, & Welch, 1998; Fan, Bonauto, Foley, & Silverstein, 2006; Shannon & Lowe, 2002). Disincentives for filing a workers' compensation claim, including peer pressure, employer pressure, and unfamiliarity with the system (Azaroff, Levenstein, & Wegman, 2002; Lipscomb, Nolan, Patterson, Sticca, & Myers, 2012; Rosenman et al., 2000) are likely present in all three study groups. Assuming the magnitude of the undercount is similar across the three groups of apprenticeship participation, the claim rate ratios likely would not change if we were able to account for underreporting.

Incomplete injury classification data may have impacted estimates of injury-specific claim rates, which we calculated after randomly assigning OIICS codes to the 6.7% of claims (for injuries before or during JLP license) that were not originally classified. We chose this approach over omitting non-classified claims from the estimates, which differentially would have excluded self-insured claims. To examine the impact of this approach, we modeled injury-specific rates using the original OIICS codes, and found results to be similar to those based on the re-assigned codes. Lack of cost data among self-insured claims limited our ability to describe fully the workers' compensation claim costs. Despite these limitations, more complete data are unlikely to substantially change our findings.

Our findings from this program evaluation are not necessarily generalizable to apprenticeship programs for occupations other than plumbing or in other jurisdictions. Depending on specific occupational hazards, training requirements, and employment opportunities, the magnitude of the association between apprenticeship participation and workplace safety may differ by trade. State-level variation in the administration of apprenticeship or professional licensing programs may lead to dissimilar results in other jurisdictions. Finally, these findings may not hold for self-employed independent contractors (American Community Survey estimates suggest that 8.8% of Washington plumbers are self-employed) and others not reported in the UI or workers' compensation data.

6. Conclusion

Apprenticeships are an effective model for reducing workplace injuries. Identifying the mechanism by which apprenticeship training improves workplace safety (e.g., mentorship by experienced workers, relationships with employers, specific components of the safety training, or some combination) could have implications for decreasing occupational injuries and illnesses not only among apprentices, but also among workers outside of a formal apprenticeship arrangement.

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Declarations of Interest

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