



Continued progress in the prevention of nail gun injuries among apprentice carpenters: What will it take to see wider spread injury reductions? ☆

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ABSTRACT

Problem: Nail guns are a common source of acute, and potentially serious, injury in residential construction. **Method:** Data on nail gun injuries, hours worked and hours of tool use were collected in 2008 from union apprentice carpenters (n=464) through classroom surveys; this completed four years of serial cross-sectional data collection from apprentices. A predictive model of injury risk was constructed using Poisson regression. **Results:** Injury rates declined 55% from baseline measures in 2005 with early training and increased use of tools with sequential actuation. Injury rates declined among users of tools with both actuation systems, but the rates of injury were consistently twice as high among those using tools with contact trip triggers. **Discussion and impact:** Nail gun injuries can be reduced markedly through early training and use of tools with sequential actuation. These successful efforts need to be diffused broadly, including to the non-union sector.

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1. Problem

Lack of training and use of tools with contact triggers are known risk factors for acute traumatic nail gun injuries in wood frame construction (Lipscomb, Dement, Nolan, & Patterson, 2006; Lipscomb, Nolan, Patterson, & Dement, 2008). Contact triggers allow the tool to discharge a nail anytime the nose piece of the gun and the trigger are both depressed. This allows rapid fire nailing commonly referred to as “bump nailing” by workers; it also allows nails to be discharged inadvertently following the recoil associated with firing of the tool when the worker still has his or her finger on the trigger. In contrast, the sequential actuation system designed to prevent non-intended firing requires that the nose element be depressed before the trigger in order for a nail to be discharged. Because the center of gravity of the tool is located at the trigger, it is natural for workers to carry the gun with a finger on the trigger (Consumer Product Safety Commission, 2002). The sequential actuation also prevents workers from shooting themselves or a co-worker if the nose of the gun bumps against someone while it is being carried in this manner. While residential carpenters typically supply their own hand tools, power tools such as pneumatic nail guns are usually supplied by the contractor or the business owner for whom the carpenter works. Because there are

currently no safety regulations that require the use of tools with the sequential trigger, this necessitates involvement of owners to reduce dangerous exposures based on the tool actuation systems that they purchase.

Union carpenters spend about four years completing their apprentice training. During this time they typically spend two weeks twice a year in their apprenticeship school where they receive both classroom and shop experiences designed primarily to teach skills, but also to address safety. The remainder of their time is spent on job sites where they work under the supervision of journeymen carpenters. Nail guns have become a very common tool in residential wood frame construction. The tools are easy to operate and their use is common even among very inexperienced workers (Lipscomb, Dement, Nolan, & Patterson, 2003; Lipscomb et al., 2006, 2008). We previously reported injury reductions among carpenter apprentices through access to early training and to tools with sequential triggers (Lipscomb et al., 2008). In this report we present findings from the fourth year of follow-up among this high risk group following an additional year of effort to reduce traumatic injuries caused by pneumatic nail guns.

2. Materials and methods

2.1. The population and data collection procedures

In 2008, as in three previous years, data were collected from union apprentice carpenters enrolled in two training programs in the Midwest for a six-month period. The collection of data for only six

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months avoided asking the same apprentice for data more than once per year as they cycled through the training program. During this period of time (2005–2008) efforts were underway to provide training in safe nail gun use early in their training program. Through collaboration with the union and the local homebuilders associations, access to the safer triggering mechanism was encouraged among local contractors who hired these apprentice carpenters.

Two journeymen carpenters visited classrooms of the apprentices, explained the study, and asked apprentices to complete anonymous surveys. Apprentices were asked to report nail gun injuries they had experienced as well as the hours worked in residential carpentry in the last year and an estimate of hours of nail gun use by triggering mechanism. They were also asked to report training they had in nail gun use and safety, including classroom experiences and on-the-job training through multiple venues including toolbox talks, more formal contractor training programs, and mentoring. All procedures were approved by the institutional review boards at Duke University Medical Center and the Center for Construction Research and Training (CPWR).

2.2. Data analyses

Four different outcome measures were used in these analyses. First, we calculated lifetime and 12-month injury prevalence of nail gun injuries using data from all apprentices surveyed; prevalence measures were expressed as a proportion of the surveyed population. Next crude injury rates (incidence density) expressed as injuries per 200,000 hours worked were calculated; these calculations included only residential carpentry hours and allow some comparison to overall injury rates reported through national sources such as the Bureau of Labor Statistics. Confidence intervals (CI) were calculated assuming a Poisson distribution (Haenzel, Loveland, & Sirken, 1962). In the third measure, injury rates were estimated based on actual hours of tool use overall and by triggering mechanism. These rates were based on injuries that occurred when the apprentice was actually using the tool (omitting situations in which the apprentice was injured by a co-worker) in order to use comparable numerators and denominators in our rate calculation. These rates were expressed as injuries per 10,000 hours of tool use. In the event the apprentice reported more than one injury, analyses were limited to the more recent event. Hours of exposure and injury events were stratified by time in the union and time in the trade, trigger mechanism on the tool being used, and training in tool use before injury. Crude injury rates were expressed as injuries per 10,000 hours of tool use. Adjusted rate ratios were calculated using Poisson regression (Nizim, 2000). Covariates of interest in the predictive model included time in the union, time in the trade, triggering mechanism on the tool being used, and whether the apprentice received training prior to injury. Variables were retained in the model based on the likelihood ratio statistic or if their removal changed other risk factors 15% or more. Using these criteria no variables were excluded from the model with a p-value of less than 0.20 (Type III statistic, SAS, Version 8.2).

Finally, the population attributable risk percent was calculated (Hennekens & Buring, 1987) using the rate ratios and the reported estimates of exposure to pneumatic nail guns before training and by actuation system on the tools being used. This measure is calculated as $PAR\% = Pt (RR-1) / Pt(RR-1) + 1 * 100$, where Pt represents the prevalence of the exposure in the population based on the proportion of exposed hours used in the incidence density rates and RR is the rate ratio. The PAR% provides a comparison of the relative proportion of injuries that could be prevented in this population based on removal of the risk factor; in this case by providing training before injury and tools with sequential triggering mechanisms.

These analyses mirrored our earlier reports from these apprenticeship programs allowing us to compare each of these metrics to those reported previously for 2005, 2006, and 2007 (Lipscomb et al.,

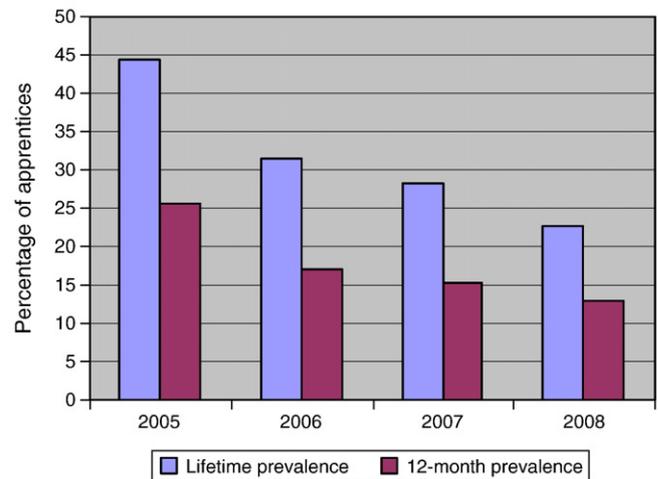


Fig. 1. Reported prevalence of nail gun injuries by year among apprentice carpenters, Carpenters District Council of Greater St. Louis and Vicinity, 2005–2008. 12-month prevalence limited to individuals who worked residential hours in the last year.

2006, 2008). Data from the questionnaires were entered and stored in an ACCESS database (Microsoft, 2007) created in EpiInfo Version 3.3.2 (CDC, 2005) and transferred to SAS Version 8.2 (SAS Institute, 1999–2001) for analyses.

3. Results

Data were collected from 464 carpenter apprentices through anonymous classroom surveys, adding to surveys collected in 2005 ($n = 654$), 2006 ($N = 818$), and 2007 ($n = 490$) previously reported (Lipscomb et al., 2008). The response rate among the apprentices approached was over 95% in each year. These apprentices reported having experienced between zero and four nail gun injuries with a mean of 0.32 and a median of zero. Lifetime prevalence of injury was 22.6% and 12-month prevalence was 13%; both have declined steadily overtime (Fig. 1). The majority of the injuries were self-inflicted, but 12% were caused by another worker who was using the nail gun.

Two-hundred fifty-nine (259) apprentice carpenters worked 276,294 residential hours in 2008 and 35 of them experienced a nail gun injury; the incidence density injury rate was 25.2 (95% CI 17.5, 35.0) per 200,000 hours worked in residential carpentry. The rate of injuries for which medical care above first aid was sought was 16.6 (95% CI 10.5, 24.9) and the rate of injuries for which time was lost beyond the day of injury was 4.3 (95% 1.6, 9.0).

Based on estimates of actual tool use, injury rates were 1.3 (95% CI 0.9, 1.8) per 10,000 hours of use. As with the prevalence measures, injury rates have declined since 2005 (Fig. 2). The distribution of injuries and hours worked are presented in Table 1 with the

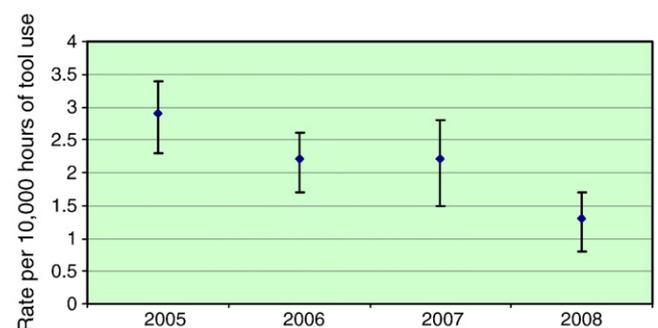


Fig. 2. Nail gun injury rates (and 95% confidence intervals) per 10,000 hours of tool use, apprentice carpenters, Carpenters District Council of Greater St. Louis and Vicinity, 2005–2008.

Table 1
Stratified rates, rate ratios, and adjusted rate ratios of self-inflicted nail gun injuries based on hours of tool use among apprentice carpenters, Carpenters District Council of Greater St. Louis and Vicinity, 2008.

	Injuries	Hours of exposure	Rates ^a (95% CI)	Rate Ratios	
				Crude	Adjusted (95% CI) ^b
Time in union					
<1 year	3	18012	1.7 (0.35, 5.0)	2.3	–
1–<2 years	12	82156	1.5 (0.78, 2.6)	2.0	
2+ years	3	39772	0.75 (0.16, 2.2)	1	
Time in trade					
<1 year	2	5596	3.6 (0.44, 13.0)	3.6	–
1–<2 years	5	42780	1.2 (0.39, 2.8)	1.2	
2+	10	94204	1.0 (0.48, 1.8)	1	
Trigger mechanism					
Contact	11	54764	2.0 (1.0, 3.6)	2.4	2.1 (0.77, 5.5)
Sequential	7	85176	0.82 (0.33, 1.7)	1	1
Any Training					
No	3	14328	2.1 (0.41, 6.4)	2.1	1.9 (0.19, 1.4)
Yes	13	128252	1.0 (0.53, 1.7)	1	1

^a Rates are expressed per 10,000 hours of tool use.

^b Poisson regression results.

corresponding rates and rate ratios. In multivariate analyses, individuals who used tools with contact triggers and those who had not had training both had a twofold risk of injury compared to their co-workers who used tools with sequential triggers and who had training. When considering training and trigger mechanism on the tools the carpenters used, time in the trade and time in the union were not significant predictors of injury. These rate estimates are based on 184 individuals who reported hours worked in residential carpentry in the last year and hours of nail gun use by triggering mechanism; 18 experienced nail gun injuries. These individuals were similar to those who did not report hours of use based on their time in the union and time in the trade.

For the first time, in 2007 more than half of the nail gun exposure time in this population was with the sequential trigger mechanism (Fig. 3); this increased to 61% in 2008. In this union environment most of the apprentices received some training in tool use prior to injury even in 2005, but through efforts at their school as well as through contractor training efforts, the proportion injured before they receive training declined to 10% in 2008. Based on PAR% calculations, 9.2% of nail gun injuries in this population would be prevented by training before injury while 30.0% would be prevented by switching to tools with sequential actuation.

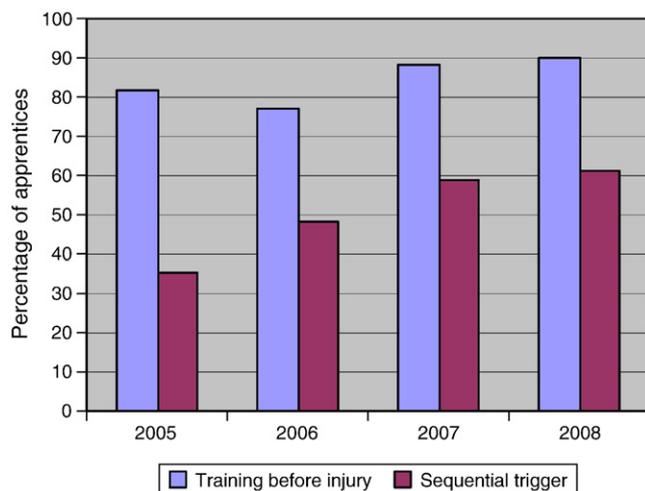


Fig. 3. Proportion of hours of tool use with training and sequential actuation nail guns by year, apprentice carpenters, 2005–2008.

Five injuries associated with repetitive use were reported in 2008, including four among users of nail guns with contact trip triggers and one in a user of a tool with sequential actuation, these included: tendonitis, hand stiffness, limited mobility in a finger, and carpal tunnel syndrome. The associated rates were 0.12 (95% CI 0.003, 0.67) and 0.73 (95% CI 0.15, 2.1) for sequential and contact trip trigger use, respectively.

4. Discussion

These data demonstrate significant progress in reducing acute injuries among union carpenters enrolled in apprenticeship training at two schools in the Midwest between 2005 and 2008 using a variety of metrics to monitor morbidity. Lifetime and 12-month prevalence rates declined as did injury rates based on hours of work in residential carpentry. Injury rates based on estimates of actual tool use declined 55%. The latter measure obviously used a better denominator to quantify risk, but does not capture risk of injury inflicted by a co-worker.

These reductions in injuries over a four-year period were seen as more apprentices received early training in tool use and as they had increasing access to tools with the safer sequential trigger mechanism. In each year the risk of injury was twice as high among carpenters who used tools with contact trip triggers and among those without training. As measured in the PAR% estimates, consistently switching to the safer sequential triggering mechanism would make more impact on the injury reduction in the population (Lipscomb et al., 2008). No increase in musculoskeletal problems was observed as use of tools with sequential triggers, which require the nose piece of the gun be depressed before the trigger is pulled in order to discharge a nail, became more common. These disorders were rarely reported and our estimates are quite imprecise, however, the risk associated with contact trip use was nearly six times higher than that associated with use of tools with sequential triggers. Since this group is now reporting over 60% of their nailing time with the sequential trigger, they are a good population for continued active surveillance of potential musculoskeletal concerns.

It is of interest that we observed an increase in the rate of injuries for which the apprentices sought medical care over time and we saw more injuries reported to workers' compensation. We attribute this to the increased attention given to this common injury, including encouragement by instructors for the apprentices to seek appropriate care. Apprentices previously reported failure to report to workers' compensation for a variety of reasons including pressure from peers to accept nail gun injuries as the norm, pressure from employers or supervisors not to report the injury, and lack of perceived seriousness of a number of injuries (Lipscomb, Nolan, Patterson, & Dement, 2010). Still, it is of note that despite the fact that only 43% of those who sought medical care for their injury reported it through the workers' compensation system, the injury rates are quite high compared to reports through the BLS. For example, in 2005 BLS estimated rates of non-fatal injuries and illnesses with days away from work among carpenters to be 2.5 per 100 full-time workers (CPWR, 2007), yet these apprentices reported nail gun injuries that required at least a day away from work at the rate of 4.3 per 100 full-time workers.

We have acknowledged before that our measures are based on serial cross-sectional data from self-reports of apprentice carpenters (Lipscomb et al., 2006, 2008). This was a situation where use of a randomized trial was not feasible for numerous reasons. Contractors are responsible for the purchase of these pneumatic tools and the safety of their own workforce. Apprentices often work for more than one employer before finishing school, which would create significant potential contamination of groups. Training for apprentices was already underway at the apprenticeship school and among some contractors. Given that we previously saw reduced risk with increasing time in the union and in the trade, we do not believe that longitudinal follow-up of a cohort of apprentices would have been as useful as these data. While we acknowledge there is likely

some error in the actual recall of hours of tool use, we do not know of any reason that the recall would be differential based on triggering mechanism; and we believe the relative risk measures are reasonable and that the data overall provide strong evidence of effectiveness of training and sequential trigger use in this population of apprentices over time.

The data from this last year of collection are not as robust as those collected earlier; the hours of residential work were over 60% less than what they had been among apprentices surveyed in 2005 at baseline, reflecting the effect of the economic decline on residential building. Consequently, our estimates of risk are less precise. However, we emphasize that the strength of these data lie in the patterns over time, rather than statistical significance or even precision, which demonstrate marked and consistent decline in rates of injury over a four-year period as sequential trigger use expanded to the majority of residential work hours and the vast majority of these apprentices received some training in tool use before they experienced an injury.

As we mentioned earlier, training in the apprenticeship school and among some contractors had begun prior to our observation of this group in response to earlier reports of high injury rates among apprentices (Lipscomb et al., 2003). We do not have measures of the quality of the training received and the exact school curriculum continues to evolve due to competing demands and priorities. However, this is the reality of the world in which these apprentices and their instructors function. Furthermore, it is obvious that neither construction skills nor safety can be comprehensively addressed in school training of these apprentices. In fact, by design in the union environment of apprenticeship training as well as out of necessity, some of that responsibility falls to journeymen supervisors and contractors. This has even greater implications for the non-union residential workforce in the United States who have no apprenticeship training.

The majority of injuries from pneumatic nail guns involve puncture wounds to the hand and fingers (Baggs, Cohen, Kalat, & Silverstein, 1999, 2001; Dement, Lipscomb, Li, Epling, & Desai, 2003; Lipscomb, Dement, Li, Nolan, & Patterson, 2003; Lipscomb & Jackson, 2007). However, very serious injuries have been documented in the trauma literature (Beaver & Cheatham, 1999; Jithoo, Govender, & Nathoo, 2001; Kizer, Boone, Heneveld, & Orozoco, 1995; Takagi, Mori, Murase, & Hirose, 2003; Wang, Chen, & Tsai, 1999; Webb, Ramsey, Dignan, & Drinkwater, 2001; Wu, Tham, & Oon, 1975), in the press in recent years (Associated Press [AP], 1998, 2004, 2005; Broadwater, 2007), and through OSHA investigation. One such investigation (U.S. Department of Labor, 2007) involved a 26 year-old residential carpenter who died following an unobserved fall while using a nail gun. He was found with a nail of about 3 inches through his brain stem which resulted in his death. The OSHA investigator concluded that "he apparently fell with his finger on the trigger." The safety mechanisms on the tool were found to be in use and functioning, in this case, exactly as a contact trigger operates. Had this worker fallen with a nail gun with a sequential trigger in his hand he would have to have pulled the trigger *after* the nose piece contacted his skull to have incurred this injury.

4.1. Conclusions and implications for the industry

Documentation of the marked reduction in this traumatic injury of wood frame construction among union carpenter apprentices is gratifying. Because the vast majority of residential construction in the United States is not done by union labor, efforts are needed to expand this success to others, including those employed in the non-union sector. These data provide no evidence indicating that concerns about possible musculoskeletal outcomes should delay action to prevent the much more common acute traumatic injuries.

A variety of safety professionals could play instrumental roles in the diffusion and adoption of basic training requirements and use of tools with sequential actuation systems. For example, the delivery of training in the non-union sector is particularly challenging since most carpenters do not go through formal apprenticeship programs. Efforts to reach individuals involved in technical training programs, at the high school level and beyond, are indicated as are efforts to develop effective training or refresher programs that can be used on small construction sites. Attention is called for to assess effectiveness of mentored training and ways to improve early training among non-English speakers as well (O'Connor, Loomis, Runyan, Abboud dal Santo, & Schulman, 2005).

Use of the safer sequential triggering mechanism should be mandated, but until such regulation is in place the purchase of nail guns with the safer actuation mechanism should be encouraged. It is of note that this is not a new call (le Nobel & Wing, 1987); the patent for the safer trigger is over 30 years old (Burke, Lemon, & Shippee, 1974). To accomplish this end, outreach is needed to homebuilders who purchase tools as well as vendors and those who rent tools to users. Involvement of safety professionals and workers' compensation carriers could also be helpful.

Nail gun injuries are common, they can be costly (Lipscomb, Dement, & Behlman, 2003), and they are potentially very serious. The risk factors associated with their use are well-established, and feasible abatement methods have now been demonstrated. The most recent voluntary industry sponsored ANSI standard (ANSI, 2003) is weak, calling for shipment of framing nailers with sequential triggers, but not their use. This has allowed manufacturers to ship a contact trigger in the box with the tool with the sequential trigger. Although there are no OSHA regulations calling for use of sequential triggers or minimal training requirements, the general duty clause could also be invoked by OSHA compliance officers to call for and enforce both. Such actions could prevent many injuries and rare, but senseless, deaths associated with use of this tool.

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