Nail Gun Injuries in Apprentice Carpenters: Risk Factors and Control Measures

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Background *Nail guns increase residential construction productivity but their use is associated with risk of injury.*
Methods *Active surveillance data from 772 apprentice carpenters were used to document the injury risk associated with the use of nail guns and the potential impact of modifiable risk factors. Using reported work hours and nail gun injuries injury rates per 200,000 hr worked in the past year were calculated. Using estimates of hours of tool use, Poisson regression was used to calculate adjusted rate ratios for injury associated with time in the trade, trigger mechanism on the tools and training prior to injury.*
Results *Forty-five percent of these apprentices had sustained a nail gun injury; injury rates in the past year based on hours of work were considerably higher than previously recognized. Those with less than 1 year in the trade compared to those with more than 5 years experience (RR = 2.7; 95% CI 1.2, 5.9) and those with no training in tool use (RR = 2.9; 95% CI 1.9, 4.4) were at greatest risk. After adjusting for experience and training, the rate of injury was twice as high with tools with a contact trip trigger compared to those with a sequential trigger (RR = 2.0; 95% CI 1.2, 3.3).*
Conclusions *Preventive measures should include change to the safer sequential trigger that prevents unintentional firing and early training in safe tool use. Because of the high prevalence of use of tools with contact trip triggers the greatest number of injuries among these apprentices could be prevented with an engineering solution.* Am. J. Ind. Med. 49: 505–513, 2006. *© 2006 Wiley-Liss, Inc.*

KEY WORDS: nail gun; pneumatic nailer; residential construction; carpentry; injury epidemiology

INTRODUCTION

Nail guns, designed to increase production by rapidly sinking nails into dense lumber, are a mainstay of residential construction. Typically powered by air from a compressor, they can also be charge activated or battery powered. As nail guns have become common so have injuries associated with their use [Baggs et al., 1999, 2001; Dement and Lipscomb, 1999; Dement et al., 2003; Lipscomb et al., 2003a,b]. Although the injuries most often involve puncture wounds to the extremities, particularly to the hands or fingers, injuries to other body parts are not uncommon and the injuries are not limited to minor events. There are reports of serious, even devastating, events in the medical literature [Wu et al., 1975; Kizer et al., 1995; Wang et al., 1999; Nadesan, 2000; Jithoo et al., 2001; Webb et al., 2001; Takagi et al., 2003] as well as in the press over the last few years [Associated Press, 1998, 2004, 2005].

Based on analyses of workers' compensation data, Baggs et al. [1999, 2001] estimated injury rates from

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Contract grant sponsor: National Institute for Occupational Safety and Health; Contract grant number: 1 U54 OH008307-02.
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Accepted 13 March 2006
DOI 10.1002/ajim.20325. Published online in Wiley InterScience (www.interscience.wiley.com)

pneumatic nailers of 2.1 per 200,000 hr of work in wood frame construction. These analyses from the State of Washington also revealed increasing injury rates between 1990 and 1998. The same rate of injury was estimated through active surveillance with union residential carpenters but in this population the injury rate among apprentices was three times higher than among journeymen [Lipscomb et al., 2003a]. These easy to operate tools were commonly given to relatively unskilled workers. Thus, the apprentices' high risk was due in part to increased exposure to a potentially dangerous tool.

Nail gun injuries occur under a variety of circumstances including accidental discharges, nails which ricochet and become airborne, gun double fires, and penetration of the receiving structure [Edlich et al., 1986; Beaver and Cheatham, 1999; Dement et al., 2003; Lipscomb et al., 2003a]. The primary pneumatic nail gun safety device to prevent accidental discharges is the trigger mechanism that works in combination with a contact element located in the nose of the gun [ANSI, 1983]. The more common contact trip trigger allows the gun to fire when the contact element of the gun and the trigger are both depressed. This allows the user to use rapid fire "bounce nailing" to increase speed of nailing. The newer sequential trigger, designed to decrease unintentional firing, requires that the nose element be depressed before the trigger in order for the gun to fire. Factors contributing to injuries vary by the triggering mechanism, and data suggest that the majority of injuries from tools with contact trip triggers would be prevented with a sequential triggering mechanism [Dement et al., 2003; Lipscomb et al., 2003a].

In May of 2003, the International Staple and Nail Tool Association (ISANTA) sponsored a voluntary ANSI standard change calling for the shipping of framing nailers with sequential triggers [ANSI, 2003]. However, many tools with the contact trip trigger remain in use and, while framing nailers are now commonly shipped with sequential triggers, a contact trip trigger is often shipped in the same box making it easy for the purchaser to switch the trigger mechanism.

Quantifying precise exposure, and subsequently risk estimates, is difficult in the construction trades due to the nature of the work. Workers perform a variety of different tasks and, in so doing, use a variety of different tools. The rates described above are based on hours of work and a carpenter does not have the tool in his or her hands at all times. Residential construction workers are dispersed on small work sites. A typical residential crew consists of no more than 4–5 carpenters making direct observation of adequate numbers of workers difficult if not infeasible. We report on active surveillance efforts with union carpenters enrolled in two apprenticeship programs affiliated with the Carpenter's District Council of Greater St. Louis and Vicinity. The project is designed to more clearly document the type of triggering mechanism on the tools the apprentices use, their actual hours of tool use, as well as hours of work, injury experiences, and training in order to more precisely understand their risk associated with the operation of these tools.

METHODS

Data Collection

Between late January and July 2005 data were collected from apprentice carpenters enrolled in the Carpenters Joint Apprenticeship Program in St. Louis, Missouri and the Southern Illinois Carpenters Training Center in Belleville, Illinois. Union carpenters typically spend 4 years in their apprenticeship training. For two periods twice a year they are enrolled in formal classroom training and supervised shop activities at an apprenticeship school with the remainder of their time spent in the field. One day per week two journeymen carpenters on the research team went into classrooms at the participating schools and asked apprentices to complete a short written questionnaire anonymously. The apprentices were given classroom time to complete the questionnaire and forms were collected before the journey men left the classroom. Data were collected over a 6-month period to avoid surveying the same apprentice more than once in the year as they cycled through their training program.

The apprentices where asked to report their time in the trade and in the union apprenticeship program, training in nail gun use, and any nail gun injuries they had experienced including the date of their most recent injury. To provide information on their time at risk the apprentices were asked to report the hours they worked in residential carpentry and an estimate of the usual hours of nail gun use each week over the last year. They were asked to specifically report on the triggering mechanism on the tools they used and their estimate of hours of nail gun use with each trigger mechanism in a typical week in the last year. Apprentices who reported injuries were queried further about their most recent injury including the type of tool and trigger mechanism involved, the circumstances surrounding their most recent injury, and the date of injury. The injured carpenters were also specifically asked whether they had training before the injury occurred.

Analyses

Crude injury rates (incidence density) in the last year were calculated per 200,000 hr of residential carpentry work. Rates were calculated for injuries that required medical care, lost time from work, or either of these to approximate OSHA recordable cases. Injuries were further restricted to those that occurred when the apprentice was using the tool (as opposed to a co-worker) to estimate rates of injury per 10,000 hr of reported tool use in order to define injuries and time at risk on the same basis. Crude injury rates and rate ratios were calculated. Confidence intervals for all rates were calculated assuming a Poisson distribution as described by Haenzel et al. [1962]. Adjusted rate ratios were calculated using Poisson regression [Nizim, 2000] after stratifying hours of tool use and injuries by covariates of interest including time in the union, time in the trade, trigger mechanism on the tool, training in tool use before injury, and the apprenticeship school in which the carpenter was enrolled. Attributable risk percent (AR%), and the population attributable risk percent (PAR%) [Hennekens and Buring, 1987] were calculated to estimate the impact of the modifiable factors we were exploring, namely trigger configuration and training, associated with injury risk in this population of apprentice carpenters. Because we are using incidence density rates we used the proportion of time exposed as our measure of prevalence for these calculations.

Data from the questionnaires were entered and stored in an ACCESS database [Microsoft, 1997] created in EpiInfo Version 3.3.2 [Centers for Disease Control and Prevention, 2005] and transferred to SAS Version 8.2 [SAS Institute, Inc, 1999–2001] for analyses. A schematic of the responses used in each step of the analyses is presented in Figure 1.

RESULTS

Over the 6-month period, 772 apprentice carpenters completed the nail gun questionnaire. Characteristics of the respondents are summarized in Table I. Time since beginning the apprenticeship program ranged from less than 1–10 years although only two reported having started their union training more than 5 years ago. It is not uncommon for apprentices to have worked in the trade prior to joining the union and is consistent with our finding that only 13% had less than a year in the trade although 26.5% had been in the union less than a year. Months worked as carpenter in the last year varied from 1–12 (mean 10.6, median 12). Nearly 90% (n = 676) of these apprentices had worked in residential carpentry in the last year with their months of work ranging from 0–12 (mean 8.7; median 11).

Three hundred forty-six (44.5%) apprentices reported that they had sustained a nail gun injury at some time. The number of injuries ranged from 1–10 with a mean of 1.6 among the injured; 20% reported two injuries and 13% reported three or more injuries. Apprentices were asked for more detail on their most recent injury. The vast majority reported injuries from framing nailers (89%; n = 308) followed by interior finish nailers (5.8%; n = 20). The remaining injuries (5.2%; n = 18) were caused by a mix of nailers including roofing, siding, and positive placement nailers used to secure joists. Seventy-eight percent (n = 271) of the tools associated with these injuries had contact trip trigger mechanisms and 19% (n = 66) had sequential triggers. In nine cases (2.6%) the injured apprentices reported they did not know the trigger type of the tool associated with their injury including one carpenter who used both types of tools who attributed his injury to cumulative trauma and three carpenters who were injured by someone else.

In Table II the frequencies of circumstances surrounding the most recent injuries are presented by trigger mechanism; these mechanisms are not mutually exclusive. Penetration of the nailing surface, accidental discharge of the tool, and airborne nails were most common. Overall, 12% of injuries (n = 45) were inflicted by a co-worker and 5% (n = 16) were related to repetitive use. The greatest proportion of injuries from nail guns with contact trip triggers was associated with unintentional discharge of the gun while the greatest proportion of injuries associated with sequential triggers involved penetration of the nailing surface. Three individuals who reported their injury related to accidental discharge of a sequential trigger tool had been injured by a co-worker, and one reported the tool had double-fired earlier in the day. Over 40% of the contact trip injuries (n = 110) occurred when the carpenter was "bounce or bump nailing." Of note, five individuals injured with sequential trigger tools also reported this activity; this would indicate that the sequential trigger had been altered or they reported the triggering mechanism incorrectly.

The frequency of injuries and injury rates based on hours of work in residential carpentry are presented in Table III for the apprentices who worked residential at some time in the preceding year. Medical and lost-time injuries are reported separately, as are injuries resulting in either. The group worked an estimated 814,287 residential hours in the last year during which time 168 apprentices (25.7%) reported having had an injury. This represents an injury rate of over 40 per 200,000 hr of work. Although the vast majority of the injured carpenters did not seek medical care or miss time from work for their injuries, the medical and lost time injury rates are quite high at 9.6/200,000 and 6.6/200,000 hr of work, respectively.

Using reports of hours of tool use by trigger mechanism we explored predictors of injury in the last year. These analyses are limited to 529 individuals who reported their hours of tool use by trigger mechanism. The 125 individuals who were excluded from the analyses had similar distributions of hours worked in residential in the last year, time in the union and time in the trade as the remainder of the study population. They also reported similar injury experiences but they were less likely to have had training (38.4% not trained compared to 17.6%; $P < 0.0001$). After excluding 22 injuries inflicted by a co-worker 125 nail gun injuries remained for these analyses.

An initial multivariate Poisson regression model was constructed including apprenticeship school, time in the trade, time in the union, trigger mechanism, training and a term representing the interaction of training and triggering mechanism. Insignificant terms were removed one at a time from the model if their removal did not change the other

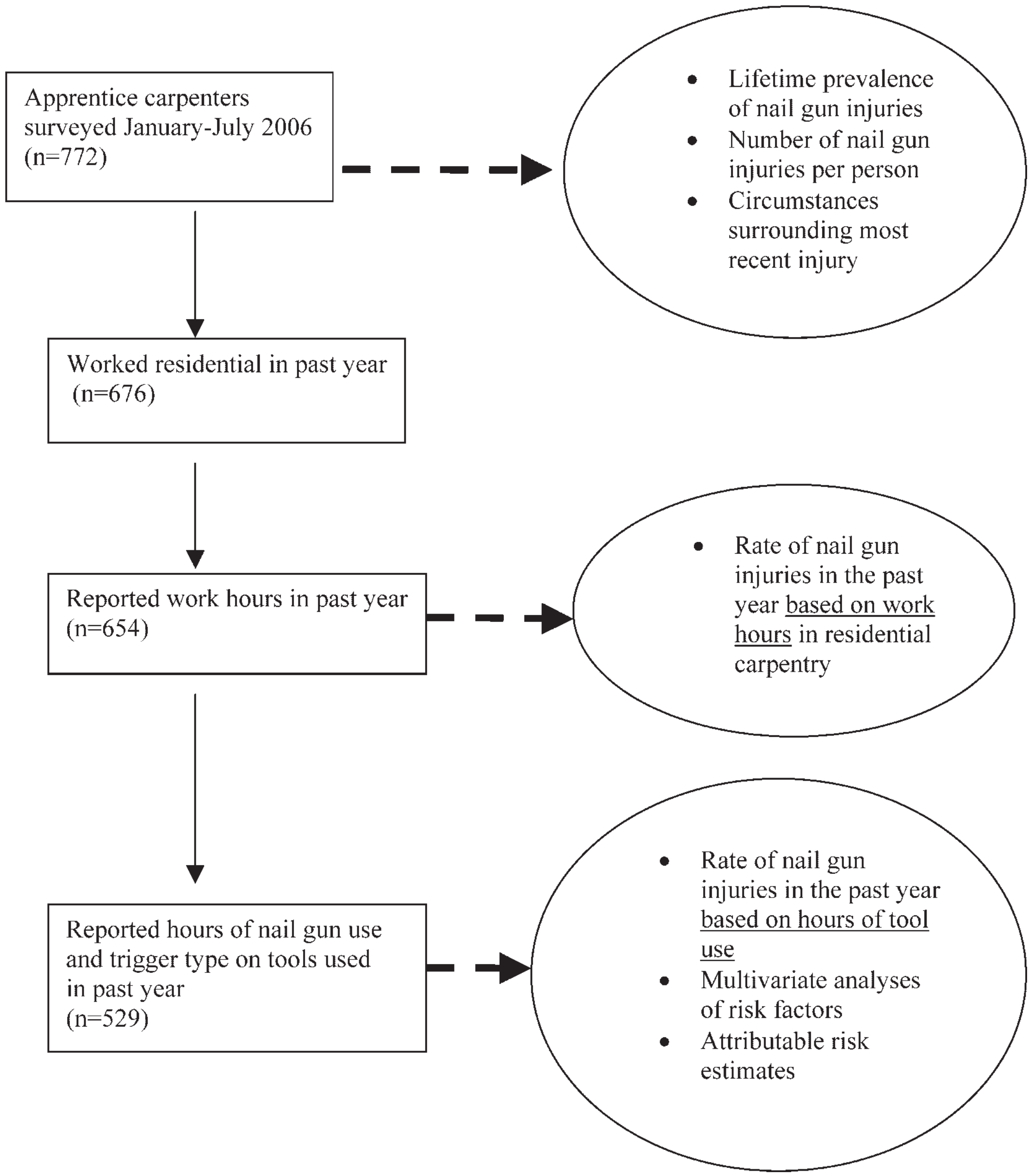

FIGURE 1. Schematic of analyses used to evaluate nail gun injuries among union apprentice carpenters, St. Louis, Missouri and Southern Illinois, 2005.

parameter estimates 10% or more. The interaction term was the first term removed followed by apprenticeship program (RR = 1.0). After adjusting for time in the trade, training and trigger configuration, time in the union was also an insignificant predictor of injury in the last year. However, its subsequent removal from the model significantly altered the estimates for time in the trade and it was returned to the model. The adjusted rate ratios from the final model are presented in Table IV with the distribution of hours of tool use, injuries, and crude rates (per 10,000 hr of tool use) and rate ratios.

Carpenters who had not had training in nail gun use and those in their first year in the trade were at particularly high risk of injury. Exposure to tools with contact trip trigger mechanisms carried twice the risk of exposure to tools with sequential triggers after adjusting for these other risk factors. Six of these injuries were attributed to repetitive use by the apprentice; one in a sequential trigger user and five in contact trip users resulting in estimated rates per 10,000 hr of tool use of 0.07 (0.002, 0.39) and 0.18 (95% CI 0.06, 0.42), respectively.

All the apprentices reported their training experiences and those who had been injured were queried as to whether their training occurred before they experienced an injury. However, because many reported training from more than one source we could not discern clearly which types of

TABLE I. Characteristics of Apprentice Carpenters Surveyed (n = 772), St. Louis, Missouri and Southern Illinois, 2005

	Frequency (percentages[a])
Apprentice program	
St. Louis	532 (68.9%)
Southern Illinois	240 (31.1%)
Time in union	
<1 year	200 (26.5%)
1 to <2 years	250 (33.1%)
2 years or longer	306 (40.5%)
Time in carpentry trade	
<1 year	97 (12.8%)
1 to <5 years	485 (63.7%)
5 years or more	180 (23.6%)
School	
St. Louis	532 (68.9%)
Southern Illinois	240 (31.1%)
Worked residential in last year	676 (87.6%)

[a]Percentages are based on number that responded to each item.

training occurred before injury. The most common training reported was hands on instruction (71%; n = 375), followed by training in their apprenticeship school (56%; n = 291), tool box talks (37%; n = 196), or required contractors training (18%; n = 93). The apprentices sometimes described their training as coming from co-workers as well as fathers or uncles who were carpenters. A carpenter injured after training volunteered having received his instruction from his foreman immediately after sustaining his injury.

The attributable risk estimates for contact trip trigger mechanism and training are presented in Table V. The attributable risk percent (AR%), which estimates the proportion of injuries that could be prevented in the last year among the exposed, is slightly greater for training (64.3%)

TABLE II. Circumstances Surrounding Injury[a] by Type of Trigger Mechanism, Most Recent Nail Gun Injury Reported by Apprentice Carpenters, St. Louis, Missouri, and Southern Illinois, 2005

	Contact trip (n = 271)	Sequential (n = 66)	Unsure (n = 9)
	Frequency (%)[b]		
Nail penetrated board or surface (177)	122 (46.0)	49 (75.4)	5 (55.6)
Accidental discharge (168)	149 (55.4)	17 (25.8)	2 (22.2)
Airborne nail (159)	130 (48.3)	24 (36.4)	4 (44.4)
Repetitive use (16)	13 (4.9)	2 (3.1)	1 (12.5)
Co-worker was using tool (43)	31 (11.5)	9 (13.6)	3 (33.3)

[a]Categories are not mutually exclusive so column totals do not equal 100%.
[b]Percentages are based on number who answered each question.

TABLE III. Injuries From Nail Guns in the Last Year, Residential Carpenter Apprentices (n = 654)[a], St. Louis, Missouri and Southern Illinois, 2005

	Frequency	Rate per 200,000 hr of work (95% CI)
Overall	168	41.3 (35.3, 48.4)
Sought medical care	39 (23.2%)	9.6 (6.9, 13.1)
Missed time from work	27 (16.1%)	6.6 (4.3, 9.6)
Sought medical care OR lost time from work	42 (25.0%)	10.3 (7.4, 14.0)

[a]654/676 (96.7%) who worked residential reported months worked in the last year and an estimate of hours worked each month.

than for trigger mechanism (56.4%). However, the population attributable risk percent (PAR%), which represents the proportion of injuries that could have been prevented in the last year in the population if the exposure of interest were eliminated, is nearly twice as high for trigger mechanism because of the higher prevalence of exposure; 65% of hours of nail gun use among these apprentices was with contact trip triggers while only 18% of the hours were by apprentices who reported no training in tool use.

DISCUSSION

To better understand the risk associated with nail gun use we collected data directly from apprentice carpenters, a group previously documented to have both high injury rates and a disproportionate share of tool use among union carpenters. They were approached through their training programs providing an efficient means to collect data from a large number of workers in a relatively short period of time. The data indicate that approximately half of the carpenter apprentices sustain a nail gun injury before they finish their 4-year apprenticeship training, and it is not uncommon for them to have been injured more than once. Of those working in residential carpentry, 25% reported an injury in the last year. Approximately, 12% of injuries were associated with a tool being used by someone else demonstrating significant risk at times the apprentices are not actually using the tool themselves.

The injury rates from nail guns among apprentice carpenters are substantially higher than recognized. Our rate calculations are based only on the report of the most recent injury in the last year and, as such, they may still underestimate the full magnitude of the problem. It is recognized that the overall injury rates in the last year are alarmingly high and we do not mean to imply they all are of a serious nature or that they should appear in workers' compensation records. However, the current rate estimate for injuries resulting in medical care or lost time from work is nearly three times higher (10.3 vs. 3.7/200,000 worked) than we previously estimated for nail gun injuries meeting an

TABLE IV. Poisson Regression Results, Nail Gun Injuries in the Last Year Among Residential Apprentice Carpenters ($n = 529$) Based on Reported Hours of Tool use, St. Louis, Missouri and Southern Illinois, 2005

	Injuries	Hours	Crude rate[a] (95% CI)	Crude rate ratio	Adjusted[b] rate ratio (95% CI)
Time in carpentry trade					
<1 year	29	44572	6.5 (4.4, 9.4)	3.4	2.7 (1.2, 5.9)*
1 to <5 years	78	290228	2.7 (2.2, 3.4)	1.4	1.4 (0.79,2.7)
5 years or longer	17	89752	1.9 (1.1, 3.0)	1	1
Time in union					
<1 year	43	97628	4.4 (3.1, 6.0)	2.2	1.7 (0.92, 3.3)
1 to <2 years	46	155012	3.0 (2.2, 4.0)	1.5	1.6 (0.92, 2.6)
2 years or more	34	167600	2.0 (1.4, 2.5)	1	1
Training					
No	48	78484	6.1 (4.5, 8.1)	2.8	2.9 (1.9, 4.4)**
Yes[c]	77	347836	2.2 (1.8, 2.8)	1	1
Trigger mechanism					
Contact trip tool	100	275112	3.6 (2.9, 4.4)	2.3	2.0 (1.2, 3.3)**
Sequential tool	25	151208	1.6 (1.0, 2.4)	1	1

[a]Rates are per 10,000 hr of reported tool use.
[b]Covariance matrix adjusted (scaled deviance = 1.0); unscaled deviance = 1.3 (62.7 with 48 df).
[c]Training occurred before injury.
*Statistically significant at <0.05.
**Statistically significant at <0.01.

OSHA recordable definition in apprentice carpenters from this area using reports from contractors [Lipscomb et al., 2003a]. It cannot be confirmed that the injuries that resulted in lost time from work or medical care would meet an OSHA recordable definition; it is possible some of the medical care received would qualify as first aid or that lost time from work was only on the day of injury. However, we do believe the high rates indicate significant safety problems associated with the use of these tools. Our findings should be viewed in the context of growing documentation of the under-estimation of injury rates in construction in general [Lipscomb et al., 1996; Glazner et al., 1998] and in residential construction specifically [Dement and Lipscomb, 1999; Shah et al., 2003; Lipscomb et al., 2003d,e].

The injured apprentices were not asked if they had reported their injury to their employer or filed a workers' compensation claim, however, a number volunteered that they had not done so. Reasons for non-reporting included the norm for someone to just ''pull the nail out,'' sometimes cleaning the wound with first aid supplies on site and sometimes wrapping them with duct tape. It is clear that these injuries are common and often minor in nature. However, some workers with significant injuries such as fractures were encouraged not to seek medical attention and some described peer–pressure not to report injuries when incentives were provided for safe work sites.

Not surprisingly, those without any training and with the least amount of experience in the trade are at particularly high risk. Tools with contact trip triggers carried twice the risk of injury of tools with sequential triggers after adjusting for training and experience. The data do not demonstrate evidence of greater risk of

TABLE V. Attributable Risk of Nail Gun Injuries in the Last Year for Work with a Contact Trip Trigger Mechanism and no Training in Tool use, Apprentice Carpenters St. Louis, Missouri and Southern Illinois, 2005

	Contact trip trigger mechanism	No training in tool use
Attributable risk % = (RR−1/RR)×100	$2.3-1/2.3 \times 100 = 56.5\%$	$2.8-1/2.8 \times 100 = 64.3\%$
Population attributable risk % = Pt (RR−1)/ Pt(RR−1)+1 ×100	$1.3/2.9 \times 100 = 45.8\%$	$0.65/2.9 \times 100 = 24.5\%$

RR, relative risk in exposed compared to unexposed (Ie/Io); in this case the rate ratio. Pt, prevalence of exposure in total study population; based on distribution of hours at risk used in incidence density rates.

repetitive trauma with the sequential trigger. However, because so few injuries were attributed to repetitive trauma (<5%), statistical power is not adequate to make a conclusive statement in this regard.

Strengths and Limitations

It is recognized that this report has a number of limitations. The data are based on self-report from apprentices. To decrease error associated with recall they were asked for estimates of work hours and hours of tool use in the past year only, and analyses of rates (crude and multivariate modeling) were limited to injuries and time at risk in the past year. Even so, data from 125 carpenters could not be used in the rate calculations by hours of tool use or the multivariate analyses because they did not report estimates of hours of tool use. Some of the data loss could have been minimized with an administered questionnaire but the cost would have been much greater. Although these apprentices had similar work hours, injury experiences and time in the trade as the remainder of the study population, they were less likely to have had training in nail gun use and our inability to include them in analyses could be a source of error. The apprentices reported a variety of training experiences, and our inability to adequately evaluate which are more effective is not an insignificant limitation. Lastly, the analyses did not include other potentially important covariates that might help more fully understand the risk associated with the use of these tools. For example, the speed of work in this very fast-paced sector of the construction industry could influence injury rates significantly especially among carpenters with less experience. The characteristics of the workers who caused injuries to their co-workers were not identified and this information could also have been informative.

There are a number of strengths in these analyses. This is the first report in which injury rates are estimated based on actual hours of tool use instead of hours of work as a carpenter or full-time work equivalents (FTEs) allowing a more reasonable estimate of risk associated with tool use. Without doubt, there is some error associated with recall of hours of tool use. However, there is no reason for differential error in reporting based on the type of trigger mechanism on the tool. Consequently, the exact rate estimates per hours of tool use may lack precision, but there is greater confidence in the rate ratio measures. Additionally, the distribution of self-reported hours of work in residential construction is consistent with those previously obtained from official reports of work hours from the union [Lipscomb et al., 2003b,c] indicating that the apprentices surveyed made accurate reports of their work hours in the past year allowing reasonable confidence in the rate estimates based on hours of work.

The study population was intentionally limited to apprentice carpenters based on knowledge of their higher level of risk from earlier surveillance work [Lipscomb et al., 2003a]. The ability to collect a substantial amount of information on injuries and patterns of tool use in a relatively short period of time through the apprenticeship schools is a significant strength of this work. Over 90% of apprentices in each classroom participated in the survey consistent with previous high participation of union carpenters in this geographic area in safety research [Lipscomb et al., 2003a,b,c]. It is felt that this is a reflection of the collaboration of the union in the research project and is due, in large part, to the collection of data from carpenters by carpenters.

The data were collected in the early part of 2005 and, as such, provide a picture of the current level of risk of these apprentices in residential construction. This report is based on a unionized workforce; the St. Louis and Southern Illinois area is the only area of the US with a large unionized residential workforce. The apprentices are quite homogenous—over 95% are white males. One could argue that their experiences may be different from those of other residential carpenters but we do not believe their injury experience is likely to be worse than that of others relatively new to the residential workforce in the US. These apprentices are enrolled in an organized training program. Many had training in tool use in their school and from contractors by whom they are hired. In many areas of the country, the residential carpentry workforce is increasingly an immigrant, oftentimes non-English speaking workforce for whom training is more challenging and oftentimes neglected [O'Connor et al., 2005].

CONCLUSIONS

A public health approach to this injury problem would focus on solutions that diminish risk for the greatest number of workers. The greatest reduction in injuries in this population would come through a change to tools with sequential triggers; this is largely a function of the high prevalence of exposure to contact trip triggers. It is unfortunate that an existing engineering control for this common tool is not the norm on most residential work sites. These data show evidence that the safer tools with sequential triggers are making their way to work sites. However, over 25 years after the patent for the sequential trigger was filed [Burke et al., 1972] and 2 years after the voluntary ANSI standard change calling for shipment of larger framing tools with sequential triggers, these carpenters report that nearly two-thirds of their work hours with these tools are still being done with the more dangerous trigger mechanism. Nail guns remain in use for a considerable period of time; existing tools with contact trip triggers will likely remain on sites for a number of years. These facts raise questions about the effectiveness of a voluntary industry standard particularly when the more dangerous contact trip trigger is often shipped in the same box.

Perhaps because the magnitude of injury risk has been largely unrecognized and the tools are easy to operate, they are often in hands of residential carpenters with little experience. Lack of training in tool use is a significant risk factor for injury even when considering the trigger mechanism on the tool and the construction experience of these apprentice carpenters. A number of apprentices we studied had training after they had been injured, pointing out the need for early training.

As sequential triggers become more common in the workplace the potential impact of effective training will become even greater. Besides operating procedures and maintenance, there are a number of previously identified elements that should be included in training. Both tools require proper placement of the hand and body in relation to the firing end of the tool and they should be used with proper protective equipment such as eye protection. They can be difficult to operate safely in awkward positions or with a non-dominant hand and although many carpenters have become dependent on nail guns there are times when a hammer might be a better tool choice. There are conditions that are associated with ricocheting of nails that operators of the tools should be aware of. Some of the newer, dense laminated beams are more difficult to penetrate than wood; this contributes to ricocheting or projectile nails as can knots in wood or striking another nail [Baggs et al., 1999, 2001; Dement et al., 2003; Lipscomb et al., 2003a].

These data clearly indicate that measures currently in place to prevent injuries from nail guns are not adequate to protect apprentice carpenters. Prevention of nail gun injuries in this population should focus on advocating for, or perhaps regulating, the use of the safer sequential trigger and early training in tool use. Active surveillance efforts with this population will continue. Injury rates by trigger mechanism will be monitored and understanding the impact of different training approaches and contributions of other potential risk factors will be a continuing focus.

ACKNOWLEDGMENTS

We would like to acknowledge the Carpenters District Council of Greater St. Louis and Vicinity, the Home Builders Association of Greater St. Louis and the Home Builders Association of Southern Illinois for their partnership in this work. We particularly want to thank the instructors at the Carpenters Joint Apprenticeship Program in St. Louis, Missouri and the Southern Illinois Carpenters Training Center in Belleville, Illinois for allowing us into their classrooms and for their enthusiasm for preventing injuries among their trainees. Lastly we want to thank the apprentices who provided the data that made the analyses possible. This work was supported by a cooperative agreement between the Center to Protect Workers' Rights and the National Institute for Occupational Safety and Health (1 U54 OH008307-02).

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