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Musculoskeletal Concerns Do Not Justify Failure to Use Safer Sequential Trigger to Prevent Acute Nail Gun Injuries

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Background *Acute nail gun injuries can be controlled significantly by using tools with sequential triggers and training. Concern has been raised that sequential triggers, which require that the nose piece of the gun be depressed prior to pulling the trigger, could increase risk of musculoskeletal problems.*
Methods *We conducted active injury surveillance among union carpenter apprentices to monitor acute injuries and musculoskeletal disorders between 2010 and 2013.*
Results *Acute injury risk was 70% higher with contact trip rather than sequential triggers. Musculoskeletal risk was comparable (contact trip 0.09/10,000 hr (95% CI, 0.02–0.26); sequential 0.08/ 10,000 hr (95% CI 0.02–0.23)).*
Conclusions *Concern about excess risk of musculoskeletal problems from nail guns with sequential triggers is unwarranted. Both actuation systems carry comparable musculoskeletal risk which is far less than the risk of acute injury; there is clearly no justification for failure to prevent acute injuries through use of the safer sequential trigger.*
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KEY WORDS: occupational injury; nail guns; residential carpentry; construction; injury prevention; sequential trigger; musculoskeletal disorder; active surveillance

BACKGROUND

The use of pneumatic nail guns carries substantial risk of acute injury to residential carpenters in wood frame construction where use of these tools is now ubiquitous. Nail gun injuries have been reported to account for 14% of injuries among residential carpenters [Lipscomb et al., 2003b]. Some of these injuries are devastating, resulting in serious life-threatening injuries [Jithoo et al., 2001; Associated Press, 2004, 2005; US Department of Labor, Occupational Safety and Health Administration, 2007; Harris et al., 2008; Englot et al., 2010; Temple et al., 2013]. Acute nail gun injuries are the most common tool-related injury resulting in hospitalization in the construction industry despite the fact that their use is limited to a small portion of the industry working in wood frame construction [Lipscomb et al., 2010b]. The majority of injuries are the result of inadvertent firing of nails associated with use of tools with contact trigger actuation, which allows the user to hold a finger on the trigger and fire the gun rapidly by depressing the nose piece on the gun (bump-firing). Injury risk is half as great among users of tools with sequential actuation, which requires that the nosepiece be depressed first before engaging the trigger in order to fire [Lipscomb et al., 2006, 2008]. Marked reduction in injury rates has been demonstrated with use of tools with sequential actuation and training in safe tool use [Lipscomb et al., 2010a].

Contractors typically purchase power tools, such as these, for use by the carpenters they hire. In 2011, the National Institute for Occupational Safety and Health

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(NIOSH) and the Occupational Safety and Health Administration (OSHA) jointly issued a guidance document for contractors recommending use of the safer sequential trigger as well as provision of training, establishment of work procedures, use of appropriate protective equipment, encouragement of reporting of injuries and provision of appropriate first aid and medical treatment [US Department of Labor, Occupational Safety and Health Administration, 2013].

Following early (1999) occupational surveillance of nail gun injuries in Washington State a number of these recommendations were made including the use of tools with sequential triggers. In addition, because of concern that the repetitive triggering required with sequential activation could contribute to development of trigger finger, recommendations were made to only allow more skilled users access to tools with contact actuation that could be bump-fired [Baggs et al., 1999, 2001]. The magnitude of risk of musculoskeletal problems from nail gun use in general appears to be considerably less than that of acute injury. However, accurate occupational safety and health surveillance is problematic and musculoskeletal problems may be even less likely than acute injuries to be identified in traditional surveillance sources [Blessman, 1991; Morse et al., 2000; Rosenman et al., 2006].

As part of ongoing surveillance and prevention efforts we have monitored nail gun injury experiences of apprentice carpenters in the Midwest United States for over a decade. This report updates findings since 2010. The data include, not only information about acute injuries, but also actively solicited information on musculoskeletal problems related to use of these tools and more in-depth insight related to these events from users including usage patterns and trigger configuration.

METHODS

Active Surveillance Data Collection

Methods used to collect and analyze these data were similar to those we have previously reported [Lipscomb et al., 2006, 2008, 2010a]. Between 2010 and 2013 carpenters enrolled in the apprenticeship programs affiliated with the Carpenters District Council of Greater St. Louis and Vicinity (Carpenters Joint Apprenticeship Program, St. Louis, Missouri and Southern Illinois Carpenters Training Center, Belleville, Illinois) were asked to participate in an active surveillance program.

Union carpenters typically spend 4 years in apprenticeship training. During that time they are enrolled in formal classroom and supervised shop training for 2-week periods twice a year with the remainder of their time in the field. One day per week for 6 months each calendar year, two journeymen carpenters on the research team went into classrooms at the training centers and asked apprentices to complete a short written questionnaire anonymously. Data were collected initially in 2010–2011, with subsequent collection in 2012 and 2013. Collection of data was intentionally limited to 6-month periods to avoid querying any given carpenter more than once in any 12-month period. Participation followed informed consent; signed consent was not required given that the consent form would have created an identifier of participation for the otherwise anonymous surveys. All procedures were approved by the institutional review boards at Duke University Medical Center and the Center for Construction Research and Training (AFL-CIO).

Each carpenter was asked about nail gun training, and injured carpenters were specifically asked whether they had training before their injury occurred. In response to earlier research findings [Dement et al., 2003; Lipscomb et al., 2003a,b] the carpenters' apprenticeship program first initiated nail gun training for early apprentices in January of 2002. Influenced by resources and competing demands, the training has varied over time from classroom presentations with slides, demonstration, and hands-on instruction and supervised tool use, to more basic classroom instruction covering use and safety principals. Some received supervised instruction at school in later years, while others did not.

To provide estimates of 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. Each carpenter was asked to report any nail gun injuries they had experienced including the date of their most recent injury. Because of concern over the potential to increase risk of musculoskeletal injuries with sequential trigger use, we specifically asked about any musculoskeletal problems regardless of whether they had been physician diagnosed or not. Individuals reporting musculoskeletal problems were invited to participate in a more in-depth personal interview covering the nature of their problem and perceptions of work-related risk factors.

Data Analyses

Basic descriptive statistics were used to describe the population, their injury experiences and their work exposures. Crude injury rates (incidence density) based on the report of injuries in the last year were calculated per 200,000 hr of residential carpentry work. 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. In the event that a carpenter had experienced more than one injury in the last year, analyses were only based on the report of the most recent injury. Crude injury rates and rate ratios as well as 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, and training in tool use before injury. Variables were retained in the multivariate models if they were independent risk factors based on likelihood ratio statistics or if their removal changed other risk factors 15% or more. Using these criteria, no variables were dropped from the model with a *P*-value of less than 0.10 (Type III statistic, SAS, Cary, NC; Version 9.3).

RESULTS

Between 2010 and 2013 we collected a total of 2,552 surveys from carpenter apprentices through their training schools; this represented a response rate of 95% among carpenters approached. Some apprentices were surveyed on more than one occasion as they matriculated through the school, but never more than once in a given year. The number of acute nail gun injuries experienced by these carpenters ranged from none to 10 (median = 0; mean = 0.24). Lifetime prevalence of acute nail gun injuries was 13.7% (350/2552). Twenty-four carpenters reported having had a musculoskeletal problem they associated with nail gun use at some point representing lifetime prevalence of less than 1%. Of note, it is not uncommon for carpenters to join the union after having already had some carpentry experience, and 45% (n = 1145) of respondents had been doing carpentry work for over 4 years even though they were in a union apprenticeship.

Nail gun exposure is limited to wood frame construction and further analyses focused on estimating risk in the prior 12 months were limited to those who worked in residential building. There were 1,413 carpenter apprentices who reported working residential hours in the previous 12 months; they worked 1,323,538 residential work hours (mean 937 hr, median 900 hr). Most of these residential carpenters (75%) worked less than 1500 hr in the last year. One hundred nineteen (n = 119; 8.4%) of these carpenters reported having experienced a nail gun injury in the last year representing an injury rate of 18.0 (95% CI 15.0–21.6) per 200,000 hr of residential carpentry work. The vast majority did not seek medical care (n = 84; 70.5%), miss work (n = 104; 87.4%) or report their injury as work-related (n = 94; 79.0%). Thirty-six individuals (30%) sought medical care for their injury or lost work time beyond the day of injury. These criteria approximate an Occupational Safety and Health Administration (OSHA) recordable injury; one-third of those (n = 12) reported their injury as work-related to their supervisor, employer, or workers' compensation. However, 87% (n = 13/15) of those who missed work reported the injury as work-related. Six injuries were inflicted by a co-worker including 5 involving tools with contact triggers and 1 involving a tool with a sequential trigger.

Nearly three quarters (74.7%; n = 1056) reported access to tools with sequential triggers; 35.3% (n = 524) of the carpenters reported they were required to use tools with the safer sequential trigger. A variety of other conditions were described for use of sequential trigger tools including restriction of apprentice carpenters to tools with sequential triggers in some cases or task-related specifications for one trigger vs the other. For example, some carpenters reported use of contact triggers for sheathing activities and sequential triggers for framing tasks. However, these patterns of use were not consistent with considerable variability across contractors for whom these carpenters worked.

Hours of tool use and injury experiences are stratified by trigger configuration on the tools being used, training before injury, time in the union and in the trade in Table I; these data are based on reports from 743 surveys in which carpenters estimated their hours of tool use by trigger type in the last 12 months. The overall injury rate was 1.2 (95% CI 0.98–1.5) per 10,000 hr of tool use. Fifty-three percent (53%) of reported nailing hours were with tools with sequential triggers, and 85% of these hours occurred after the carpenters reported some training in tool use. Injury rates were 80% higher for use of contact trip tools than tools with sequential triggers (rate ratio= 1.8 (95% CI, 1.2–2.8)), and carpenters were 52% less likely to be injured if they had training in tool use (rate ratio = 0.48 (95% CI0.30–0.78)). Injury rates were over 2-fold higher among those with the least carpentry experience and least time in the union. Time in the trade did not remain a significant predictor of risk when controlling for trigger used, training and time in the union. Even when controlling for experience and training, tools with contact trip triggers carried a 70% greater risk of injury than those with sequential actuation.

Very few workers reported musculoskeletal problems with only 6 carpenters reporting a musculoskeletal injury that had occurred in the last year; this represents an injury rate of 0.09 per 10,000 hr of tool use. Tools with contact triggers had a rate of 0.09/10,000 hr (95% CI, 0.02–0.26) while tools with sequential triggers had a rate of 0.08/10,000 hr (95% CI 0.02–0.23). Five of the six carpenters described their musculoskeletal problems; 4 had problems with tendonitis and one reported difficulty using his right arm after tool use. All three users of tools with sequential triggers reported problems with tendonitis. Issues raised by workers included concern over weight of the tool and the fast pace of residential work; none attributed use to the specific trigger on the tool they used.

DISCUSSION

The rate of nail gun injury based on hours of residential work during this observation period was 56% lower than

TABLE I. Hours of Nail Gun Use and Injury Experience Union Carpenter Apprentices 2010–2013

	Hours of tool use	Injuries	Rate[1] (95% CI)	Rate ratio[1] (95% CI)	Adjusted rate ratio[2] (95% CI)
Trigger					
Contact trip	325420	52	1.6 (1.2 – 2.1)	1.8 (1.2 – 2.8)	1.7 (1.1 – 2.6)
Sequential tial	362008	32	0.9 (0.6 – 1.2)	1	1
Training					
Yes	582016	61	1.0 (0.8 – 1.3)	0.48 (0.30 –0.78)	0.60 (0.37 – 0.98)
No	105412	23	2.2 (1.4 – 3.3)	1	1
Time in trade					
<1 year	61108	17	2.8 (1.7 – 4.5)	2.9 (1.7 – 4.9)	—
1–<2 years	74080	13	1.8 (1.0 – 3.0)	1.8 (0.98 – 3.2)	—
2+ years	552240	54	1.0 (0.7 – 1.3)	1	—
Time in union					
<1 year	188048	39	2.1 (1.5 – 2.8)	2.6 (1.6 – 4.2)	2.4 (1.5 – 3.9)
1–<2 years	149944	17	1.1 (0.7 – 1.8)	1.4 (0.77 – 2.6)	1.5 (0.80 – 2.7)
2+ years	349436	28	0.8 (0.6 – 1.2)	1	1

[1]Rates per 10,000 hr of tool use; calculated with Poisson regression.
[2]Calculated with Poisson regression; adjusted for trigger, training and time in the union.

reported by residential apprentices in 2005 [Lipscomb et al., 2006]. This decline has been observed as early training efforts, and particularly, use of tools with sequential triggers increased in this worker population. Over a third of the residential apprentices we surveyed were required by their contractor to use tools with sequential triggers and another 35% had access to a tool with a sequential trigger if they chose to use one. Based on reported hours of tool use we estimated 52% of nailing time in recent years was with tools with sequential triggers. These findings represent a considerable increase in the use of the safer sequential trigger over time in this geographic area. However, it is of some note that the proportion of trained hours has remained stable in this group from our earlier report while the proportion of hours with a tool with a sequential trigger has decreased slightly from a high of just over 60% in 2008 [Lipscomb et al., 2010a].

Despite increased use of tools with sequential triggers, reports of musculoskeletal disorders were relatively rare even when actively solicited. More importantly, no differences were seen in the rate of MSDs based on trigger configuration of the tools being used. The findings are consistent with our earlier findings in which very few musculoskeletal problems were reported by nail gun users compared to the acute injury burden [Lipscomb, 2008]. These findings support the work of Lowe et al. [2014] who found insufficient evidence to contradict safety-based recommendations to adopt sequential triggers based on concern about trigger finger risk.

Most (60%) injured carpenters did not seek any medical care for their injuries. Almost all who missed work beyond the day of injury reported the injury event as work-related to their employer/supervisor. However, less than a third with an injury meeting an OSHA recordable definition based on receiving medical care or lost time beyond the data of injury reported the event as work-related. This means medical care that was received was likely paid out of pocket by the worker or through their union-provided insurance rather than worker's compensation. Given that most of these injuries were puncture wounds to hand and or fingers, this is consistent with numerous other reports that more minor work injuries are less likely to be appropriately represented in national surveillance sources [Azaroff et al., 2002; Shannon and Lowe, 2002; Rosenman et al., 2006].

This work was done in the Midwest United States where there has been considerable attention to reduction of nail gun injuries over the last decade. It was facilitated through longstanding collaboration with two joint union-labor apprenticeship programs which allowed access to a large unionized workforce of carpenter apprentices who were involved in residential building. The work progressed over time from broad injury surveillance efforts [Lipscomb et al., 2003b] to more targeted concerns and hazard surveillance efforts. We have learned a lot about these tools and the dangers associated with them—we have also had ready partners in establishing at least basic training to address risk of these ubiquitous tools in residential building. Provision of training to residential carpenters in the non-union sector is much more challenging.

We previously reported lack of evidence of higher risk of MSD with sequential triggering but due to small numbers the estimates were unstable—similar to those reported here.

Despite specifically asking carpenters about MSDs we did not elicit many reports of such that were associated with use of nail guns. When we did, workers expressed concerns over the weight of the tools, as well as the very rapid nature of work in residential carpentry in general. The latter is particularly ironic given concerns on the part of contractors, manufacturers, and sometimes even workers that the sequential trigger would slow the work in this very fast-paced sector of the construction industry.

CONCLUSIONS

These data support prior recommendations encouraging use of pneumatic nail guns with sequential triggers and training of users to prevent injuries [Baggs et al., 1999; Dement et al., 2003; Lipscomb et al., 2010a; US Department of Labor, Occupational Safety and Health Administration, 2013; Albers et al., 2014]. Consistent with the public health hierarchy of hazard control [Herrick and Dement, 1994; Castillo et al., 2006], the adoption of tools with the safer sequential triggers would offer protection to all users as well as bystanders. We fully support training and believe all users should have access to training before using these dangerous tools. However, it makes more sense to train users how to use the safer tool. Concerns about MSDs being caused by sequential trigger tools is not supported in this work – both actuation systems appear to carry comparable risk of MSDs which is far less than the risk of an acute injury. Clearly, concern about the possibility of musculoskeletal problems does not justify failure to use the sequential trigger, a tool that is demonstrated to prevent acute injuries.

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REFERENCES

Albers J, Lowe B, Lipscomb H, Hudock S, Dement J, Evanoff B, Fullen M, Gillen M, Kaskutas V, Nolan J, et al. 2014. Revisiting pneumatic nail gun trigger recommendations. Prof Saf (in press).

Associated Press. 2004. Man surveys six nails driven into head. Thursday, May 6, 2004.

Associated Press. 2005. Nail embedded in man's skull for 6 days. Monday, January 17, 2005.

Azaroff LS, Levenstein C, Wegman DH. 2002. Occupational injury and illness surveillance: Conceptual filters explain underreporting. Am J Public Health 92(9):1421–1429.

Baggs J, Cohen M, Kalat J, Silverstein B. 1999. Pneumatic nailer ("nail gun") injuries in Washington State, 1990–1998. Safety and Health Assessment and Research for Prevention (SHARP). Department of Labor and Industries, Technical report number 59–1-1999.

Baggs J, Cohen M, Kalat J, Silverstein B. 2001. Pneumatic Nailer Injuries: A Report on Washington State 1990–1998. Professional Safety Magazine 32:33–38.

Blessman JE. Differential treatment of occupational disease v occupational injury by workers' compensation in Washington State. J Occup Med 33(2):121–126.

Castillo DN, Pizatella TJ, Stout NA. 2006. Injuries. In: Levy B, Wegman D, Baron SL, and Sokas RK, editors. Occupational and environmental health: Recognizing and preventing disease and injury, 5th edition. Philadelphia, PA: Lippincott, Williams, and Wilkins. pp. 471–487.

Dement JM, Lipscomb HJ, Li L, Epling CA, Desai T. 2003. Surveillance of nail gun injuries among construction workers. Appl Occup Environ Hyg 14:665–676.

Englot DJ, Laurans MS, Abbed K, Bulsara KR. 2010. Removal of nail penetrating the basilar artery. Neurosurg Rev 33(4):501–504.

Harris EB, Booher K, Flotten AS. 2008. Delayed femoral shaft fracture secondary to nail gun injury: A case report. J Orthop Trauma 22(7):501–503.

Herrick R, Dement J. 1994. Industrial hygiene. In: Rosenstock L and Cullen M, editors. Textbook of clinical occupational and environmental medicine. Philadelphia, PA: WB Saunders Co. pp. 169–193.

Jithoo R, Govender ST, Nathoo N. 2001. Penetrating nail gun injury of the head and chest with incidental pericallosal artery anerysm. S Afr Med J 91(4):316–317.

Lipscomb HJ, Dement JM, Nolan J, Patterson D. 2003a. Nail gun injuries in residential carpentry: Lessons from active injury surveillance. Injury Prev 9:20–24.

Lipscomb HJ, Dement JM, Li L, Nolan J, Patterson D. 2003b. Work-related injuries in residential and drywall carpentry. Appl Occup Environ Hyg 18(6):479–488.

Lipscomb HJ, Dement JM, Nolan J, Patterson D. 2006. Nail gun injuries in apprentice carpenters: Risk factors and control measures. Amer J Indus Med 49:505–513.

Lipscomb HJ, Nolan J, Patterson D, Dement JM. 2008. Prevention of traumatic nail gun injuries in apprentice carpenters: Use of population-based measures to monitor intervention effectiveness. Amer J Indus Med 51:719–727.

Lipscomb HJ, Nolan J, Patterson D, Dement JM. 2010a. Continued progress in the prevention of nail gun injuries among apprentice carpenters: What will it take to see wider spread injury reductions?. J Saf Res 41(3):241–245.

Lipscomb HJ, Schoenfisch AL, Shishlov K, Myers D. 2010b. Nonfatal tool and equipment-related injuries treated in U.S. emergency departments among workers in the construction industry, 1998–2005. Amer J Indus Med 53(6):581–587.

Lowe B, Albers J, Hudock S, Krieg E. 2013. Finger tendon travel associated with sequential trigger nail gun use. IIE Trans Occup Ergon Hum Factors 1:109–118.

Morse T, Dillon C, Warren N. 2000. Reporting or work-related musculoskeletal disorder to workers compensation. New Solut 10-(3):281–292.

Nizim A. 2000. Poisson regression. In: Kleinbaum DG, Kupper LL and Muller KE, editors. Applied regression analysis and other multivariate methods, Third Edition. Boston: PWS-Kent Publishing Co. pp. 687–709.

Rosenman KD, Kalush A, Reilly MJ, Gardiner JC, Reeves M, Luo Z. 2006. How much work-related injury and illness is missed by the current national surveillance system?. J Occup Environ Med 48:357–365.

Shannon HS, Lowe GS. 2002. How many injured workers do not file claims for workers' compensation benefits? Am J Ind Med 42(6):467–473.

Temple AD, Fesmire FM, Seaberg DC, Severance HW. 2013. Cardiac injury due to accidental discharge of nail gun. J Emerg Med 44(2):161–163.

U.S. Dept of Health and Human Services (NIOSH) and Department of Labor (OSHA). 2011. Nail Gun Safety: A Guide for Construction Contractors. DHHS (NIOSH) Publication Number 2011-202; OSHA Publication Number 3459–8-11. Available at http://www.cdc.gov/niosh/docs/2011–202/ (Accessed September, 2013).

US Department of Labor, Occupational Safety and Health Administration. Inspection Report 1032500, #309967933. Fatality/Catastrophe Report April 18, 2007.