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# Nail Gun Injuries Among Construction Workers

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Pneumatic nail guns greatly increase worker productivity and are extensively used in wood frame building construction, with especially high use in residential construction. One surveillance report of nail gun injuries in Washington State has been published; however, other literature consists largely of case reports and case series in trauma journals. The major objective of the current study was to investigate the occurrence of nail gun–associated injuries among construction workers and to identify preventable work-related factors associated with these injuries.

Nail gun–related injuries occurring among a cohort of 13,347 carpenters in Ohio who worked union hours during the time period January 1, 1994, until September 30, 1997, were identified by matching the cohort with workers' compensation claims made to the Ohio Bureau of Workers' Compensation. We also analyzed workers' compensation claims for North Carolina Home Builders Association members for the period July 1996–November 1999 to identify nail gun–related injuries. Analyses included stratified analyses of claims by nature and body part injured, calculation of nail gun injury rates, and analyses of free text descriptions of injuries.

Overall, nail gun injuries were responsible for 3.9 percent of workers' compensation claims with 8.3 percent to 25.5 percent of claims involving paid lost work time. The overall rate of nail gun injuries (cases per 200,000 work hours) was 0.33 in North Carolina and 0.26 in Ohio, reflecting the greater concentration of wood frame construction workers in the North Carolina population studied. Higher rates of injury were observed for carpenters in North Carolina and among residential carpenters in Ohio. The predominant body part injured was the hands/fingers, with 80 to 89 percent of injuries being nail punctures. Analyses of free text information for puncture injuries found approximately 70 percent of injuries to occur during the framing/sheathing stage of construction. Our data suggest that approximately 69 percent of puncture injuries may be due to an inad-

vertent gun discharge or misfire, preventable in large part by the use of sequential triggers. Worker training and education also are important components of nail gun injury prevention.

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**Keywords** Nail Gun, Nailer, Nail, Pneumatic, Surveillance, Construction, Puncture, Hands, Fingers, Sequential Trigger

Pneumatic nail guns are extensively used in wood frame building construction with especially high use in residential construction. These tools have greatly increased worker productivity as a typical pneumatic nailer can fully sink a 3<sup>1</sup>/<sub>2</sub>-inch nail into tough southern yellow pine or dense Douglas fir in less than a tenth of a second. Given that a typical house will use 50,000–70,000 nails, it is easy to understand the increased production provided by these tools. However, increased productivity has come at the price of increased risk of injury on some construction sites.

Nail guns come in many different configurations and designs depending on their intended use (e.g., framing, roofing, finishing, flooring, etc.). The primary sources of energy used for construction nail guns are pneumatic air pressure supplied by a compressor or explosive charges from cartridges. Electric energized designs and guns that use carbon dioxide cylinders are also available. However, based on our observations at residential work sites our injury studies done in collaboration with the United Brotherhood of Carpenters, as well as the published literature as reviewed below, pneumatic guns are by far the most frequently used in residential construction. Explosive charge-activated guns are used in residential construction for special purposes such as attachments to concrete or steel.

The major objective of the current study was to investigate the occurrence of nail gun–associated injuries among construction workers and to identify preventable work-related factors associated with these injuries. Workers' compensation data for North Carolina residential construction workers and Ohio carpenters were used for this study, which employed both rate-based and case-based surveillance methods.

## LITERATURE REVIEW

The published literature concerning nail gun–related injuries, while abundant, consists largely of case reports and case series. Puncture wounds to the hands, fingers, and other extremities are the predominant injury observed with nail guns;<sup>(1,2)</sup> however, life-threatening injuries to the brain, heart, neck, and eyes have also been reported.<sup>(3–12)</sup> Accidental deaths, homicides, and suicides attributed to nail gun–related injuries also are reported.<sup>(13)</sup> The extent of tissue damage caused by penetrating nails is sometimes made worse by the presence of copper barbs remaining on the nails from the magazine joining strips.<sup>(2,8,14)</sup>

Few reports of systematic surveillance of nail gun injuries are available. An analysis of nail gun injuries in Queensland during 1988–1992 identified 218 cases, with 60 percent of the injuries occurring on construction sites and 80 percent of the workers being carpenters and joiners.<sup>(15)</sup> Twenty percent of the injured required hospitalization. No nail gun injury rates were provided in this report.

Nail gun–related injuries reported to the Workers' Compensation Board of British Columbia during 1973–1982 have been tabulated.<sup>(16)</sup> The annual number of reported cases ranged from 116 to 362 with the most frequent site of injury being the hand and/or fingers (65%) followed by the foot (15.9%), knee (4.0%), eye (3.5%), thigh (3.2%), and wrist (2.8%). No injury rates were provided. These authors suggested that a triggering method that would permit only single firing of nails, rather than a rapid succession, would improve safety.

Baggs et al.<sup>(17,18)</sup> analyzed nail gun–related workers' compensation claims in Washington State for the years 1990–1998. A total of 3616 nail gun injuries were identified using a combination of injury source code and injury description for case identification, with 93 percent being classified as “struck by” injuries. The most frequent body part injured was the hand and/or fingers (66.0%), followed by foot (5.9%), thigh (4.6%), wrist (3.8%), knee (3.8%), and toe(s) (2.9%). Of the 3616 nail gun–related claims, 2885 (79.8%) involved only medical treatment and no paid lost time (medical-only claims). About 20 percent of the claims resulted in indemnity payments, which begin after the third day away from work in Washington State. Building construction was the most commonly reported task being performed by injured workers and analyses of nail gun injury claim rates found the highest rates for wood frame building construction (2.06 cases per 200,000 work hours). Interior carpentry work was found to have a rate of 0.66 cases per 200,000 work hours.

Nail gun injuries occur under a variety of circumstances including accidental discharges, nails that ricochet and become airborne, gun double fires, and penetration of the receiving structure.<sup>(3,19)</sup> The primary pneumatic nail gun safety device to prevent accidental discharges is the trigger mechanism, which works in combination with a contact element located in the nose of the gun.<sup>(20)</sup> Several different trigger designs and configurations are employed including:

- “Contact-trip” or “restrictive trigger”—This is a typical design and allows the operator to discharge nails only when both the nose contact and the trigger are simultaneously activated. Most designs allow the gun to fire regardless of whether the operator first pulls the gun's trigger or depresses the nailer's nose contact element, as long as both are activated. Guns with contact triggers can double fire when the recoil action of the nailer lifts the nosepiece from the work and pressure being exerted by the worker depresses the nose contact, causing the gun to fire a second time.
- “Sequential-trip”—This configuration requires that the nose contact element be depressed first and the trigger pulled second for the nail to be discharged. The sequential-trip mechanism makes it more difficult for nails to be discharged unintentionally.
- “Bounce nailing”—Bounce nailing is a technique that can be employed with a contact trip or restrictive trigger design and not with other trigger designs including the sequential-trip. In this configuration the trigger is locked in firing position and the gun fires each time the nailer's nose is depressed. This configuration is used for increased production. Some manufacturers have mechanisms that allow the trigger to be locked for bounce nailing. If the gun does not have a trigger lock, workers will often invent ways of locking the trigger for bounce nailing.

Most pneumatic nail gun manufacturers offer sequential-trip triggers as an option on new equipment and many provide retrofit kits to allow existing guns to be converted to sequential-trip. Another safety feature incorporated in many framing nailers is an “aggressive nosepiece,” which helps hold the device in place for better nail placement, especially during toe-nailing.

The published literature as well as our observations of residential work sites point to several work circumstances and work practices that can contribute to the risk of nail gun injuries. Some examples of these circumstances are depicted in Figure 1. Work frequently involves work in awkward positions and overhead work, contributing to the risk of accidental nail discharge. Nail gun injury risk is increased by work practices such as the worker firing the nail gun while pointed toward himself and holding the gun trigger in the firing position while moving about the work site. Nail methods such as toe-nailing contribute to the risk of nails deflecting and becoming airborne projectiles.

## MATERIALS AND METHODS

### Data Sources

#### *Ohio Carpenters*

Methods used for this study were similar to those previously used to study workers' compensation claims of carpenters in Washington State.<sup>(21)</sup> We identified a cohort of 13,347 working union carpenters and their hours worked by month during the

**Working in Awkward Positions****Working Overhead or Near Edge****Firing Nail Toward Himself****Firing Nail Toward Hand****Finger on Trigger - Not in Use****Toe Nailing****FIGURE 1**

Examples of work circumstances and practices increasing injury risk.

time period January 1, 1994, until September 30, 1997, using health insurance eligibility files provided by Ohio Carpenters Health and Welfare Funds. The cohort was individually matched to files maintained by the Ohio Bureau of Workers' Compensation to obtain data for injuries occurring among cohort members from January 1, 1994 to September 30, 1997. These injuries included medical-only claims and lost-time injuries, defined as those resulting in eight or more days lost from work or payment of indemnity as well as the date of injury, a narrative injury description taken from the first report of injury, return-to-work dates, ICD-9 diagnoses,<sup>(22)</sup> and payment for medical services, wages, and disability settlements. Analyses presented in the publication are based on 4138 claims filed by 3130 people during months of union work.

The Ohio data system uses ICD-9 diagnosis codes rather than the American Standard Method of Measuring and Recording Injury Experience of the American National Standards Institute (ANSI).<sup>(23)</sup> To compare these data with other ANSI coded data, the narrative injury description was reviewed and coded by professionals who perform ANSI coding for the North Carolina Industrial Commission. The ANSI codes indicate the body part affected, nature of the injury, type of event causing the injury (mechanism), and the source or object involved in the injury.

Ohio carpenters work on many different types of construction sites as well as industrial sites; therefore, their use of nail guns varies substantially. The highest use of nail guns occurs in wood frame construction on residential structures, where only a small proportion of Ohio carpenters were employed. To better estimate the risk of nail gun injuries for carpenters in residential construction, we stratified both work hours and injuries by industry classification codes of the National Council on Compensation Insurance (NCCI), which are used by the Ohio Bureau of Workers' Compensation.<sup>(24)</sup> Work hours by month of follow-up for cohort members working for employers with NCCI code 5645 (Carpentry—Detached One or Two Family Dwelling) or NCCI code 5651 (Carpentry—Dwellings—Three Stories or Less) were tabulated as well as nail gun injuries occurring during those months. This procedure allowed calculation of crude nail gun injury rates for carpenters doing residential construction.

#### *North Carolina Home Builders*

Workers' compensation data for these analyses were provided by the Builders' Mutual Insurance Company (BMIC), the self-insured compensation fund for the North Carolina Homebuilders' Association (NCHA). These analyses update and

extend our previous report of data from the NCHA provided earlier from their third-party administrator.<sup>(25)</sup> In 1995, the fund eliminated their third-party insurance administrator and began providing workers' compensation insurance coverage and claims processing internally for approximately 7500 active NCHA members and their subcontractors. Subcontractor coverage is required of the prime contractor unless the subcontractor has other workers' compensation coverage and can show a valid certificate of insurance. Most contractors in North Carolina elect to be covered by the prime contractor. Insurance premiums for subcontractors are collected by the prime contractor based on wages paid by trade and submitted to the fund. The fund conducts periodic audits to be sure that premiums are paid as required.

Computerized claims for NCHA members and their subcontractors were obtained for the period July 1996 through November 1999, with personal identifiers and contractor names removed. These data contain standard information from the first report of injury, including body part injured, nature of injury, mechanism of injury, and a free text description of the injury. BMIC uses a modification of ANSI-coding in their data management. In addition, data are available on whether the injury required medical care or if it resulted in paid lost time (which occurs in North Carolina after the seventh day away from work) and amounts paid for compensation costs and medical care. The occupation, or job, of the injured worker is recorded on the claim. BMIC also provided information on wages paid by trade for 1997 and 1998. Using prevailing wage data estimates for construction trades in North Carolina, these data were used to estimate hours worked by trade and, in combination with injuries by trade, to calculate injury rates by trade.

Over the 42-month study period, 9205 accepted claims were filed with BMIC. At the time the data were obtained for analyses, 93.6 percent (n = 8617) were closed. All claims were included in our analyses. Projected reserves were used for claims that remained open in order to estimate injury costs. Claims were described by cause of injury, body part injured, and nature of injury. During the period of these analyses, BMIC stopped writing insurance coverage for roofers; thus, roofers are not included in trade-specific analyses.

### Identification of Nail Gun Injuries and Free Text Analyses

Both the Ohio and the North Carolina data included a brief free text description (maximally 120 characters) for each injury. In addition to the analyses of coded data, we conducted exploratory studies using this free text data to identify nail gun injury cases and to gain a better understanding of the mechanism of injuries beyond what can be learned from coded information. Methods used for free text data analyses are similar to those previously used to study fall-related injuries.<sup>(25)</sup>

The text description and coded information for all claims for each data source described above were transferred into a Microsoft Access data file. First, approximately 20 percent of the Ohio and North Carolina free text injury descriptions were reviewed in detail to identify key words used in descriptions of

injuries associated with nail guns. Next, an Access query was constructed to identify claims containing the following terms: "gun," "shot," "nailer," "stapler." A tiered search was used to include claims containing the next key word only if not already identified. Finally, all claims selected by the Access structured query were extracted to form the set of nail gun-related injuries of interest. We excluded screw gun injuries but did include injuries such as falls and overexertion if the claim included reference to a nail gun.

Our initial analyses consisted of descriptive summaries of nail gun injuries by nature of injury, body part injured, age at time of injury, and trade (North Carolina data). The distribution of claims by trade groups for the North Carolina data was examined using the coding system previously described by Dement and Lipscomb to group job codes.<sup>(25)</sup> We next analyzed the free text descriptions of the selected nail gun injuries to learn more about circumstances of injuries and some possible prevention measures. First, all cases were read in order to determine patterns of injury and possible causal factors. We then developed a coding scheme for possible causal or contributing factors and reviewed all cases in detail in order to assign codes for numerical analyses. The categories of information were limited by the amount of descriptive data available and are not intended to imply that other factors might not also be related to the risk of injury.

The following categories of information were coded:

- Nail Gun User
- Type of Gun
- Discharge or Misfire Circumstances
- Nailing Position
- Nailing Surface or Method
- Reasons for Projectile Nails
- Board or Object Nail Penetration
- Stage of Construction

### Nail Gun Injury Rate Calculations

For both the North Carolina and Ohio data, we calculated the rate of nail gun injuries based on estimated hours of construction work (cases/200,000 work hours). For calculation of injury rates among the Ohio carpenter cohort, only injuries that occurred during months when the cohort member had worked union hours were included since information was not available on nonunion work time at risk. Age was calculated based on age at the midpoint of the 45-month study period. Total work hours for the cohort were determined by summing all union work hours logged by cohort members during the 45-month study period. Crude nail gun injury rates (cases per 200,000 union work hours) were calculated as well as age-specific rates (5-year age groups).

The procedure used to calculate nail gun injury rates for the North Carolina residential construction worker population was different than used for the Ohio data as work hours by individual workers were not available. For rate calculations, hours worked by trade were estimated using payroll data for BMIC and

prevailing wage data for construction workers in North Carolina. Rates were then calculated for overall nail gun–related claims and trade specific rates. As individual work hours were not available, it was not possible to calculate age-specific rates for the North Carolina population.

Confidence intervals for all rates were calculated assuming a Poisson distribution for the nail gun injury events.<sup>(26)</sup>

## RESULTS

Table I shows the number of nail gun injuries available for analysis by site as well as the crude rates of nail gun injuries. The total number of cases was 516, with North Carolina providing the most cases. Overall, nail guns accounted for 3.9 percent of all injuries reported to workers' compensation among these workers. The overall crude rate of nail gun injuries (cases per 200,000 work hours) was 0.33 (95% CI = 0.39–0.37) among North Carolina residential construction workers and 0.26 (95% CI = 0.22–0.31) among Ohio carpenters. The proportion of nail gun injuries resulting in lost work time (indemnity cases) was much higher in North Carolina (25.5%) compared to Ohio carpenters (8.3%), this difference being statistically significant ( $p < 0.05$ ). In both states, indemnity payments start after seven days away from work; therefore, the higher proportion of indemnity payments in North Carolina cannot be attributed to differences in the threshold for payments.

The North Carolina residential construction workforce was comprised of all relevant trades, including carpenters who predominately use nail guns. An analysis of nail gun injuries by trade found the rate for carpenters to be 0.91 (95% CI = 0.79–1.04) cases per 200,000 work hours, or about three times the overall rate for all trades. Likewise, restricting the analyses of nail gun injuries in Ohio to workers doing residential construction found a higher nail gun injury rate of 1.32 (95% CI = 0.60–2.50) cases per 200,000 work hours. Our Ohio data also allowed

us to calculate age-specific nail gun injury rates. A higher rate of nail gun injuries was observed for workers aged 20 to 24 (0.69 cases per 200,000 work hours, 95% CI = 0.24–1.14).

Summaries of nail gun injuries by nature and body part injured are shown in Figures 2 and 3. For both populations, the predominant type of nail gun injury was a puncture, accounting for 80 to 89 percent of all injuries associated with the use of nail guns. Fingers and/or hands were the most frequently injured (55 to 57% of cases) although 5 to 15 percent of injuries involved other sites including foot/toes, wrist/arm, leg/knee, and head/eye/face. There were 21 contusions observed with six being from a falling gun and four due to being struck by an air hose as the gun was uncoupled. An additional six contusions occurred due to recoil of explosive charge activated guns.

Workers' compensation costs associated with nail gun injuries varied widely. For North Carolina cases, the mean medical cost was \$1,497 and the mean indemnity cost was \$772; however, the upper end of medical and indemnity costs was \$43,805 and \$104,191, respectively. For Ohio carpenters, the mean cost for nail gun injuries without paid lost time was \$483, whereas the mean cost for paid lost time cases was \$9,237.

Puncture injuries were selected for more detailed analyses of free text information. Figures 4 through 7 summarize these analyses. The number of cases providing useful information for each study factor is shown in these figures. In 96 percent of the cases with useful information ( $N = 415$ ), the nail gun user was injured while 4 percent of workers injured were not working directly with a nail gun but were merely bystanders. Pneumatic nail guns were the source of approximately 98.1 percent of puncture injuries followed by staplers (1.2%). Few puncture injuries ( $N = 2$ ) were due to explosive charge activated guns.

Only a limited number of the claims ( $N = 51$ ) provided useful information concerning the nailing position and 74.5 percent of claims with useful information were described as below the waist. Likewise, few cases ( $N = 36$ ) had details concerning the nailing surface or method. Of the 36 cases with this data, 41.7 percent involved flat surfaces, 5.6 percent toe-nailing, and 8.3 percent nailing through a board or boards.

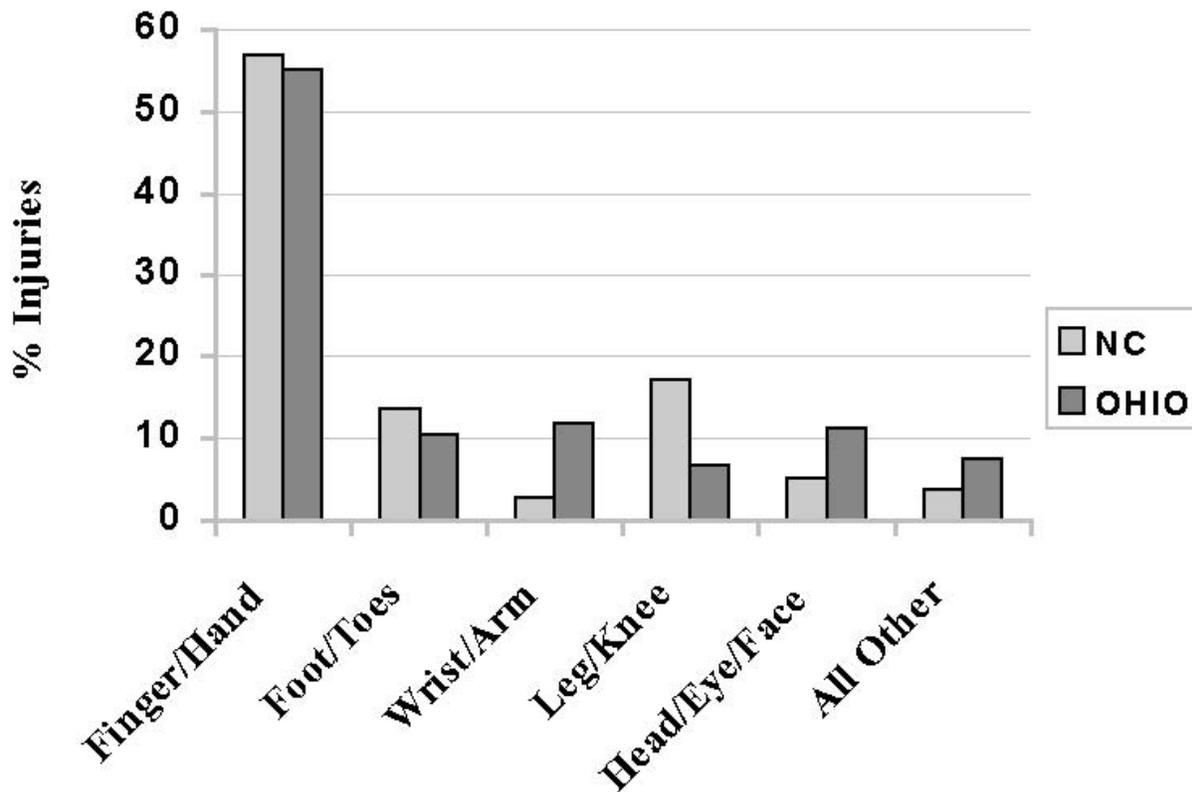
A total of 185 claims provided sufficient information to determine if an inadvertent gun discharge or misfire had occurred (Figure 4). In 68.6 percent of the puncture wound injuries, it could be determined that an unwanted gun discharge had occurred. In 20.5 percent of the cases the gun had either misfired or double fired, with the cause not being further detailed. In 20.0 percent of the cases, accidental contact with the nose trigger mechanism had caused the gun to discharge, and in 19 percent of cases, a worker slipped or fell while holding the nail gun, resulting in a discharge. These latter two circumstances of injury are most likely due to: 1) a bypassed or inoperative trigger safety mechanism, or 2) workers holding the trigger in the firing position while maneuvering around the job site. In 3.2 percent of the cases, it could be specifically determined that the gun had double fired due to gun recoil.

**TABLE I**

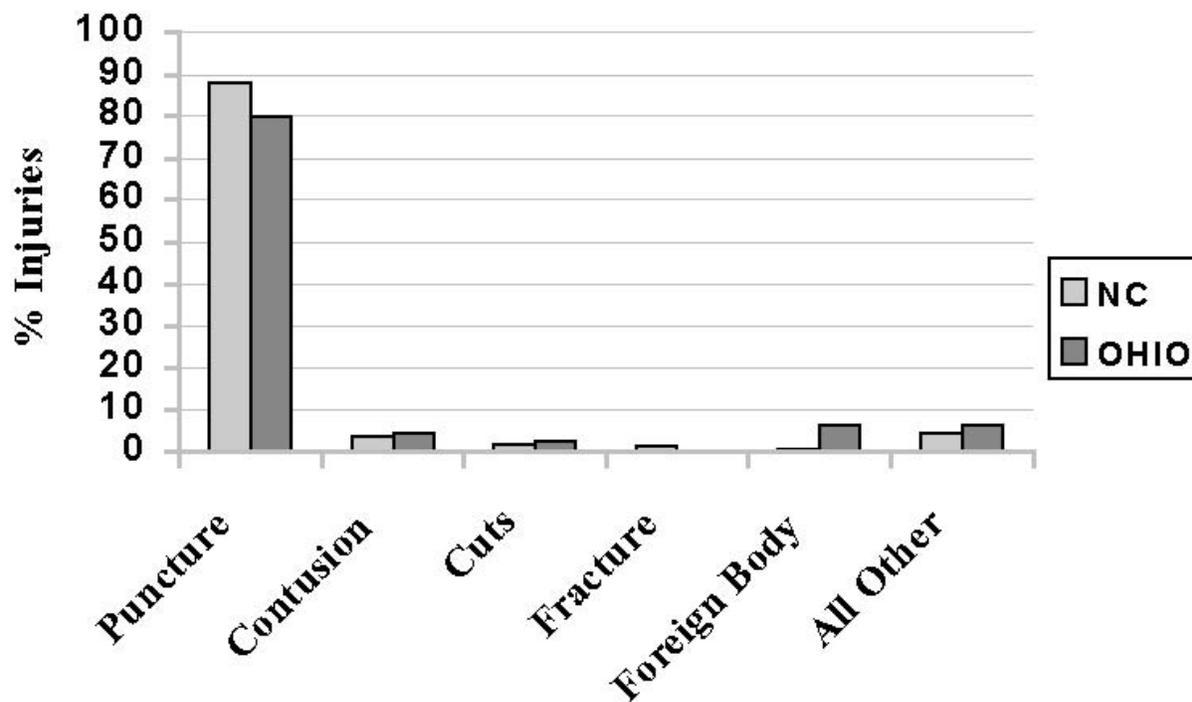
Summary of nail gun injuries and crude injury rates

Study parameter	NC residential construction	Ohio carpenters
Years of claims covered	1995–1999	1995–1997
Number of workers/contractors studied	7500	13,487
Number of compensation claims analyzed	9205	4138
Nail gun injury claims analyzed	377	139
Percent medical-only claims	74.3%	91.7%
Percent indemnity claims	25.5%	8.3%
Crude nail gun injury rate (cases/200,000 hours) and 95% confidence intervals	0.33 (0.29–0.37)	0.26 (0.22–0.31)

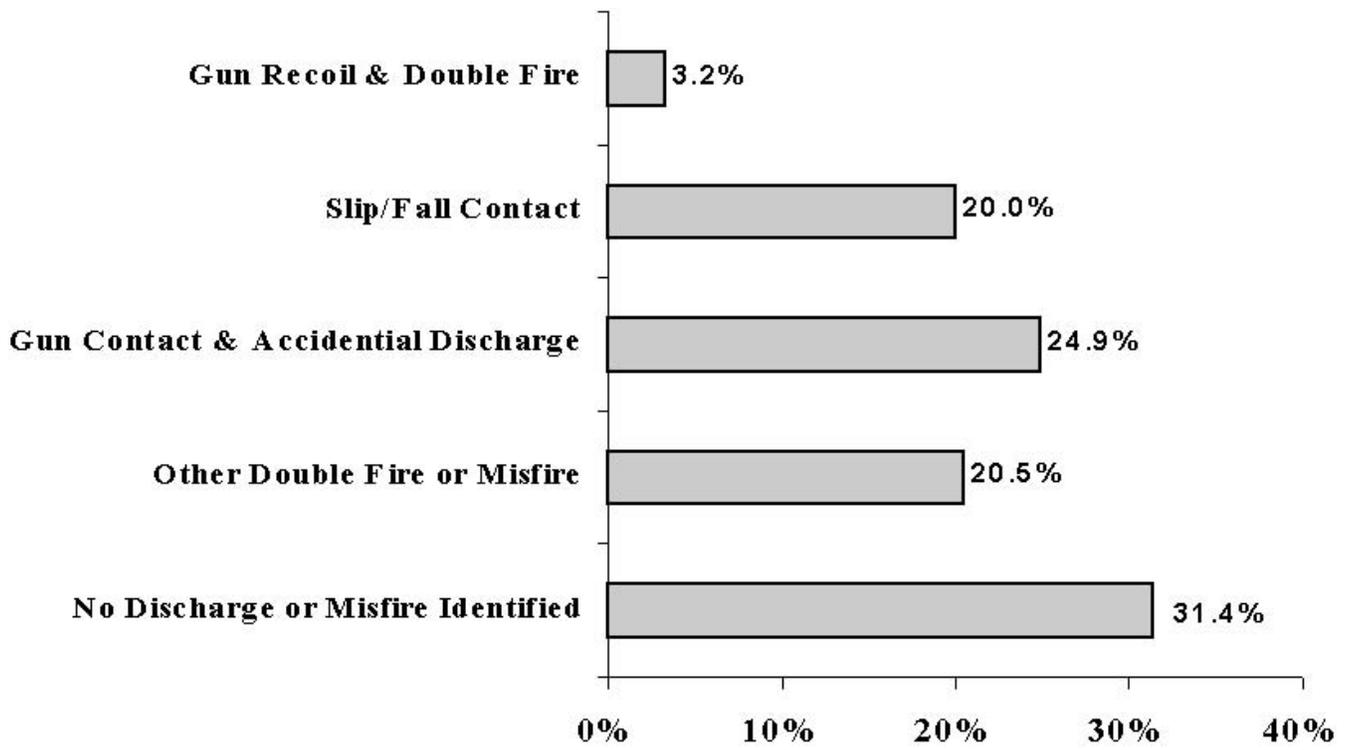
*Note:* Overall, nail guns were involved in 3.9 percent of the workers' compensation claims filed by these construction workers.



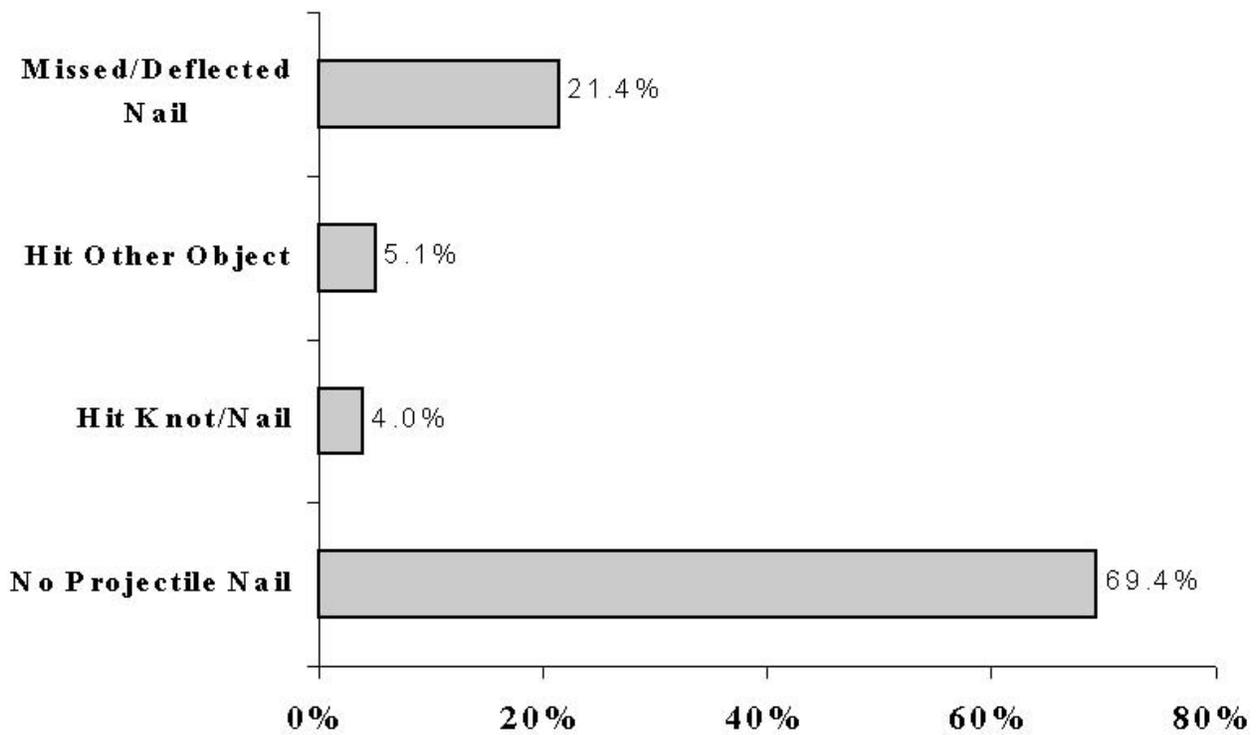
**FIGURE 2**  
Nail gun injuries: body part injured.



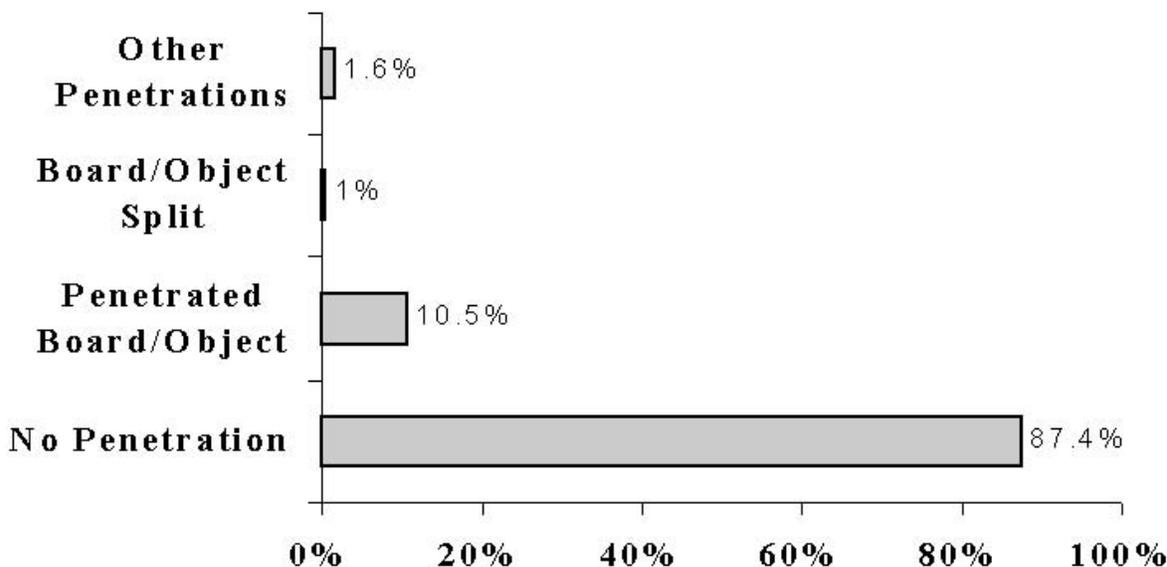
**FIGURE 3**  
Nature of nail gun injuries.



**FIGURE 4**  
Nail gun discharge/misfire.



**FIGURE 5**  
Projectile nails.



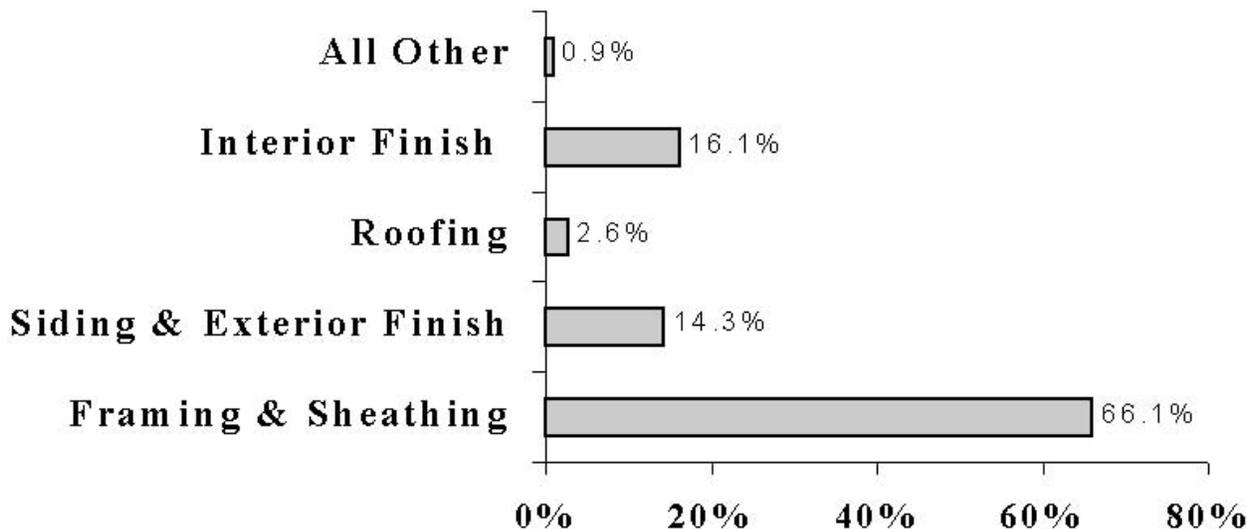
**FIGURE 6**  
Nail penetrations.

Airborne or projectile nails were involved in approximately 41 percent of the puncture injuries (Figure 5). The most common causes of projectile nails were nails missing the intended nailing surface or being deflected from the surface being nailed. A smaller proportion of projectile nails occurred when nails ricocheted for a variety of other reasons including hitting other nails, wood knots, and other materials such as metal truss fasteners.

Less than 13 percent of puncture injuries resulted from nails penetrating the board or receiving surface and entering the hand/fingers or other body part (Figure 6). Simple penetrations were the most common with a smaller portion of

such injuries occurring when the board or nailing surface split.

The vast majority of reported nail gun injuries (66.1%) occurred during the framing and sheathing stage of construction, followed by roofing (16.1%) and exterior siding and finish (14.3%) as shown in Figure 7. This was not unexpected as framing nailers are typically more powerful, large numbers of fasteners are needed at this stage, nailing positions are more awkward, and the construction site is typically less well organized. Also, nailing of sub-floors and sheathing is often done using the faster bounce nailing method, which is more prone to injury.



**FIGURE 7**  
Stage of construction.

## DISCUSSION

These analyses have shown that nail guns are involved in about 4 percent of construction injuries in our data and approximately 80 to 88 percent of nail gun injuries are punctures. Punctures to the hands/fingers are the predominant injury; however, other body parts also are involved. The distribution of injury sites is similar to that observed by Baggs et al. for Washington State.<sup>(17,18)</sup>

The proportion of nail gun–related compensation claims involving paid lost time ranged from 8.3 percent to 25.5 percent in our data with a statistically higher proportion of indemnity cases in North Carolina. This is in the same range as observed by Baggs et al.<sup>(17,18)</sup> who showed that approximately 20 percent of nail gun injuries in Washington State involved paid lost time, which begins after the third day away from work.

Our data for Ohio show higher nail gun injury rates for younger workers. Unfortunately, we do not have sufficient information to determine whether this higher rate is due to younger workers being more prone to injury or greater daily use of nail guns.

Our case-based analyses provide some additional insight into the causes of nail gun injuries and possible means of prevention. These data suggest that approximately 69 percent of puncture injuries may be due to an inadvertent gun discharge or misfire, preventable in large part by use of sequential triggers. This conclusion is supported by data collected as part of an ongoing construction injury surveillance project in the St. Louis area, where more detailed information on injuries is collected.

Our preliminary data have shown the majority of puncture injuries caused by nail guns involve bypassed or inoperative trigger safety mechanisms. Properly operating sequential triggers appear to be a reasonable and effective mechanism to prevent many of these injuries. Also, greater emphasis on training of workers concerning proper use and maintenance of nail guns and nail gun safety mechanisms is needed. Most manufacturers of nail guns provide worker training materials and materials are available from several other sources.<sup>(27–32)</sup>

Our analyses of nail guns have several strengths and limitations. Strengths include collections of data from two states covering multiple years; availability of over 500 nail gun injuries for analyses; and free text data, which allowed for more in-depth analyses. A limitation of our analyses is the sparseness of descriptive information for many injuries, which limits causal analyses. We also do not know if our cases are nationally representative, especially for cases with useful free text data; however, our results are consistent with surveillance data from Washington State and St. Louis, suggesting reasonable generalizability.

## CONCLUSIONS AND RECOMMENDATIONS

Nail gun–related injuries are common in residential construction, with the most common injury being penetrating wounds to the hands and fingers, although injuries occur frequently to other

body sites. More than 70 percent of puncture injuries occur during the framing and sheathing stage of construction. Proper use of sequential triggers would appear to be a reasonable and effective intervention to prevent many of these injuries, in combination with effective worker training and education. Additional studies are needed to evaluate the efficacy of these interventions and the effectiveness of intervention programs.

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