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RESIDENTIAL BUILDING STAKEHOLDERS' ATTITUDES AND BELIEFS REGARDING NAIL GUN INJURY RISKS AND PREVENTION

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Abstract

Pneumatic nail guns are ubiquitous at residential construction sites across the United States. These tools are noted for the traumatic injuries that can occur from their operation. Different trigger mechanisms on these tools are associated with different levels of risk. Residential building subcontractors and workers, both native-born and immigrant, were brought together in focus groups to discuss their attitudes and beliefs regarding risk factors for nail gun injury as well as barriers to the adoption of safer technology. Participants' comments are organized first by influences on traumatic injury occurrence or prevention and later by sociotechnical system category. Participants attributed influences on *injury risk* to personal and external causation factors in all sociotechnical system categories; however, participants more frequently described influences on *injury prevention* as related to workers' behaviors, rather than to external factors. A discussion of these influences with respect to attribution theory and sociotechnical models of injury causation is presented.

Keywords

residential building construction; nail guns; carpenters; traumatic injury; risk perception

Pneumatic nail guns (PNGs) revolutionized home building late in the 20th century, greatly reducing the labor time required to frame and cover (i.e., sheath) wooden structures. Although pneumatic nail guns, also known as "nailers," are most frequently used for residential building framing, nail guns powered by gas cartridges and rechargeable batteries are also being used. Nail guns automatically feed and drive nails, eliminating the need to manually handle and drive an individual nail using a hammer.

Different types of nail guns are manufactured for various construction (and non-construction) uses. In residential construction, nail guns are used for rough and finishing carpentry tasks involving both repetitive (i.e., roofing, decking, sheathing) nailing and intermittent (i.e., framing, interior finish) nailing. The type of project determines the nail

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characteristic, such as length and diameter. Nail guns utilize a safety engineering control requiring that the tip of the nail gun (workpiece contact) is depressed against the lumber before a nail can be fired [1]. Two distinct nail gun actuation mechanisms are available on framing nail guns to fire a nail. The contact actuation trigger (CAT) mechanism allows nails to be fired when the operator pushes the nail gun workpiece contact against the lumber workpiece, either before or after depressing the trigger. Unlike the CAT, the workpiece contact on a nail gun with a sequential actuation trigger (SAT) must first be pushed against the lumber *before* the trigger is depressed to fire a nail, and the same sequence must be repeated for subsequent nails. The CAT actuation mechanism allows nails to be fired any time the trigger is depressed and the tip contacts an object, while the SAT mechanism protects against unintentional nail discharge when the tip inadvertently makes contact with an object and the trigger is already depressed [2]. In spite of the overwhelming evidence showing safety benefits of the SAT, this trigger mechanism has not been widely adopted. Further, most nail gun manufacturers do not acknowledge the safety differential between the SAT and CAT mechanisms, which has been described in U.S. Patent documents [3] and the European standard for nail guns [4].

NAIL GUNS AND PRODUCTIVITY

The first hand-held PNG appropriate for residential wood framing became available in 1973 [5], but it was during the 1980s and 1990s that portable handheld PNG use accelerated on building and construction sites in the United States. Citing RS Means production standards[1], Haas et al [6] reported residential wood framing productivity hovered around 700 foot-board measures (FBM) per day from 1959 to 1984. Framing productivity increased approximately 30 percent (to 900 FBM/ day) in 1984 and by another 27 percent (to 1,100 FBM/day) in 1996. Haas et al. attributed increases in productivity after 1983 to PNG use, as manual nailing was increasingly replaced by the PNG.

NAIL GUNS AND TRAUMATIC INJURIES

The adoption of nail guns for building construction and home improvement has been accompanied by an epidemic of nail puncture injuries [7]. Nail puncture injuries occurring while driving a nail were uncommon when nails were manually driven with a hammer. Since nail guns became commercially available, reports have appeared in medical journals describing fatal and serious traumatic injuries to the head [8], lower extremities [9], upper limbs [10], chest [11], eyes [12], and other areas of the body. These reports generally provided few details concerning the circumstances of the injury and focused on treatment and outcome, while occasionally advocating for action to reduce the risk of injury.

Several surveillance reports describing nail gun injuries have been published. Washington State Department of Labor and Industries analyzed workers’ compensation data for nail gun injuries occurring from 1990 through 1998 [13]. The overall injury incident rate for building construction workers (Standard Industrial Classification (SIC) Code 15, Building

[1]RS Means, a subsidiary of Reed Construction Data, produces cost estimates for construction activities.

Construction) was 78 incidents/10,000 full-time equivalent (FTE) workers/year, while the incident rate for wood framing tasks was 206/10,000 FTE.

Dement et al. [14] analyzed Ohio Bureau of Workers' Compensation claims (1994-1997) for all Ohio carpenters and the workers' compensation claims for residential construction workers employed by North Carolina Home Builders Association members during 1996 through 1999. Among all claims in the two groups combined, 3.9 percent of claims were nail gun-related (*n* = 516). Nail gun injury rates for residential construction workers in North Carolina were 91 cases/ 10,000 FTE and for Ohio residential carpenters 132/10,000 FTE. Punctures to the hands were the most frequent type of injury in both groups. North Carolina mean medical payments per injury were $1,497 and in Ohio the mean workers' compensation cost per paid lost-time injury was $9,237. The authors analyzed a subset of claims (*n* = 185) that included descriptions of the injury incident and concluded that at least 69 percent of the incidents may have been the result of an unintentional nail gun discharge or misfire.

Using "active surveillance" techniques Lipscomb et al. [15] investigated all acute work-related injuries (*n* = 783) that occurred among a cohort of union apprentice carpenters (*n* = 5,137) working in the residential building industry during 1999-2001 in St. Louis, Missouri. Investigators interviewed 586 carpenters and collected detailed information regarding work-related injuries. Nearly 14 percent (80) of the injuries involved nail gun use. The overall nail gun injury rate based on hours worked in the residential sector for this time period (37 months) was 2.1/200,000 hours. Rates varied with experience: the rate for apprentice carpenters was higher (3.7/200,000 hours) than that for journey-status carpenters (1.2/200,000 hours). During all types of activities, a majority of injuries occurred when the CAT mechanism was used. The authors concluded that 65 percent of the injuries could have been prevented if the nail guns had been equipped with the SAT mechanism.

PURPOSE

Prior to the beginning of the study by the National Institute for Occupational Safety and Health (NIOSH), part of which is described here, anecdotal reports formed the basis of understanding of the barriers to adopting and diffusing the SAT in the construction industry. First, CAT actuation (i.e., bump fire) systems were reported to be associated with greater productivity because they enabled operators to shoot nails with less time between successive nails. Second, there was a perception that repetitive triggering of the SAT resulted in musculoskeletal symptoms due to the need to repeatedly actuate the trigger with flexion of the index finger. These concerns had not been objectively validated or refuted by empirical evidence. NIOSH proposed a two-prong study to investigate: 1) stake-holders' attitudes and beliefs regarding nail gun traumatic injury risks and prevention; and 2) the objective risk of developing stenosing tenosynovitis, a musculoskeletal disorder of the finger-tendon anecdotally attributed to repeated triggering the SAT nail gun. This report concerns the first objective of the study. Findings associated with the second objective have been previously reported [16] and suggest that repetitive finger-tendon motion with SAT use is probably below 60 meters/day and less than levels associated with intense keyboarding work.

In order to explore stakeholders' attitudes and beliefs concerning nail gun injury risks and risk prevention, NIOSH organized 11 focus groups[2]—9 were included in the analysis—with residential building framing subcontractors and workers who regularly used nail guns. The purpose of the focus groups was: 1) to explore residential framing stakeholders' attitudes and beliefs regarding nail gun injury risk factors; and 2) to identify additional beliefs that may inhibit adoption of the SAT and its industry-wide diffusion.

METHODS

The project was designed as a qualitative study to explore attitudes and beliefs of wood framing subcontractors and carpenters/framers about the following: 1) injury hazards associated with nail guns and the relationship between traumatic injury risks and trigger actuation systems; 2) selection and use of the contact trip actuation trigger for non-repetitive, low-volume nailing; and 3) perceptions and implications of trigger actuation systems on productivity. NIOSH partnered with trade, labor, safety, and community organizations to recruit industry stakeholders to participate in the study. Participants ($n = 81$) were selected on the basis of their ability to function as a key informant during the focus group. As such, the selection of participants was not an attempt to produce a random sample and sample size was not a concern. Participants were selected using "stratified purposeful" criteria to ensure participation by those from multiple geographic regions and occupational subgroups (Table 1) [17]. All participation was voluntary, and participants received compensation for their time and expenses.

The demographics and work experience of nail gun users (i.e., both supervisory and non-supervisory carpenters-framers; $n = 59$)[3] were analyzed to determine whether there were significant differences in age, construction experience, or general risk perception between native-born U.S. and immigrant participants. No significant differences (t-test) were observed for PNG safety training experience (pre- and post-initial nail gun use; 41% received no training) or daily nail gun use. Immigrants, however, reported fewer years of experience using a PNG ($p = 0.01$) and reported both construction work and using a nail gun as more "dangerous" ($p < 0.01$) than did native-born U.S. carpenters.

A moderator's guide was prepared with an "inquisitive neutrality" approach that included prefacing comments and use of semi-structured open-ended questions. As responses from successive groups added to our understanding of participants' attitudes and beliefs, it was possible to adjust the questions in the following way: "Previous focus group members have made the following observation: … What is your experience/opinion?" This approach was a key methodological requirement, so that the interview questions not presume relationships between nail gun use, hazards, and production demands. The intent was to allow focus group participants to identify possible relationships, with no more than a general, open-ended question to start the discussion. As participants identified barriers to safe work practices, it was possible to explore these problems as well as solutions for correcting those conditions.

[2]Two focus groups were not included in the analysis due to low participation ($n = 1$) in one and the predominance of non-PNG-users in the other.

[3]Three current nail gun users did not answer the questions.

Focus groups were audio-recorded and transcribed from English or simultaneously translated and transcribed from Spanish to English. Transcripts were coded using QSR NVivo Ver. 8.0 (QSR International, Doncaster, Victoria, Australia), a qualitative data analysis software, by one NIOSH analyst (J.A.). Participants' responses to questions regarding which factors could increase or decrease the risk of traumatic nail gun injury were coded according to: 1) how they influenced (i.e., increased or decreased) the risk of traumatic nail gun injuries; and 2) sociotechnical system criteria (Table 2) [18, 19]. Two co-analysts (S.H., B.L.) independently reviewed the coded transcripts for agreement and consistency. Cases of disagreement in coding between analyst and co-analysts were discussed to reach consensus.

RESULTS

Traumatic injuries described by focus group participants can be categorized as having occurred when an operator intentionally discharged a nail or when a nail was discharged unintentionally. Participants reported that injuries associated with intentional nail discharge occurred with either the SAT or the CAT actuation system; however, injuries occurring during unintended nail discharge were reported only for the CAT actuation system.

Injuries common to both the CAT and SAT actuation systems occurred when nails partially exited the lumber and struck an upper or lower extremity or entirely "missed" the intended target (i.e., plate or stud), sometimes becoming airborne, and struck the body. Injuries reported to occur only with the CAT actuation system involved the safety tip contacting the body while the operator had the trigger depressed. Reports indicate that this typically occurs under the following circumstances: 1) the operator is positioning the gun to the nail insertion point; 2) the operator has inadequate control of the gun during recoil and "double-fires"; and 3) the gun discharges while the operator stands (i.e., not nailing) or walks, climbs, and so forth, while holding the gun. The last scenario was reported to result in injuries to nail gun operators or their co-workers.

Focus group participants described a multitude of factors that were either potential nail gun traumatic injury risks or were protective against injury. Although we describe these risks in terms of socio-technical system categories, no risk is isolated to one category alone. In order to better represent the attitudes and beliefs across focus groups, only factors reported to increase or mitigate risk of nail gun injury in the majority of the focus groups (≥ 5 groups) are reported below.

Factors Influencing Injury Occurrence

Participants in five or more focus groups identified 14 factors, in five sociotechnical categories, influencing the occurrence of nail gun injuries (Table 2). As shown in Table 3, *task-related* factors accounted for 28 percent ($n = 4$) of the identified positive risk factors or influences. The four most frequently described factors were drawn from three sociotechnical categories: 1) Tools/Technology (inherent risk using nail guns, 33%); 2) Individual (careless or unsafe behaviors, 34%; keep contact trip trigger depressed, 31%); and 3) Work organization (work pressure, 32%).

Tool-Based Risks—Participants mentioned a number of injury risks specifically related to pneumatic nail gun technology, including the following: 1) nail guns are inherently dangerous given their intended function; 2) traumatic injury risk increases with use of the contact trip (CAT) actuation system; and 3) the hand-tool interface (i.e., grip and trigger design) on certain nail guns increases the risk of traumatic injury due to unintentional activation.

Participants in eight focus groups indicated that nail gun use in general increased traumatic injury risks.

> It might make (framing) easier, but all around it's shooting a projectile at a high speed to go through hard materials. It's just dangerous to work with.
>
> —Union carpenter, St. Louis, MO
>
> The potential is there for a lot of injuries just due to the amount of fasteners that obviously have to be in place.
>
> —Carpenter, Morgantown, WV

Many participants (n = 12), especially those born in the United States, described the risk of nail gun use and requisite safety practices as similar to those involving the handling and shooting of a firearm.

> [You] pull out a nail gun, it's no different than pulling out a rifle or a pistol. That sucker can kill ya.
>
> —Union subcontractor, St. Louis, MO
>
> [It's] better that they don't even try [to use a nail gun] unless they receive training beforehand because they are dangerous. To me, they can be considered like a firearm.
>
> —Crew leader, Phoenix, AZ

Participants described how contact trip (CAT) actuation system nail guns can fire a nail without the operator's intending to do so. Unintended nail gun activation can occur under several scenarios, such as waiting or walking with the trigger depressed, positioning the nail gun, or with a "double fire" when the gun recoils and the safety tip contacts an object and the trigger has not been released.

> If it [CAT nail gun] bounces back and hits … and you still got a hold of the trigger, it could push the safety down and fire it again.
>
> —Union subcontractor, St. Louis, MO

Some participants attributed workers' inclination to keep the trigger squeezed when the nail gun was being held, but not used for nailing, to the design of certain CAT nail gun triggers and hand grips.

> [T]he way the guns are made, just holding on to it, the framers [nail guns] are fairly heavy and you gotta grip, you're squeezing the trigger. It's a bit too convenient to

> wrap your fingers around it and have it in the position where you can shoot someone or accidently have it go off.
>
> —Subcontractor, Morgantown, WV

Task-Related Risks—Despite the introduction of the nail gun, framing a wood structure still requires the framer to hold one piece of lumber, such as a stud, plate, fire blocking or fascia, while nailing it to another piece of lumber with the 8- to 9-pound nail gun, held in the other hand. The proximity of the hand grasping the lumber to the nail insertion point introduces a significant risk of injury.

> I was actually working with [name withheld] when he was … framing a basement and putting blocks in between the joists. And he was holding the block with his hand and he shot the nail and he shot the nail at an angle, and it stuck right in the side of his hand.
>
> —Union carpenter, St. Louis, MO

> [You] get twisted lumber and say it's a two by six wall, it's more common that you have to try and force that stud over. And in the act of twisting the stud with your left hand or right hand, however you're handed … your hand's in line with the nailer head. And when you're twisting that and you're trying to push in there's a greater chance to give yourself one.
>
> —Carpenter, Morgantown, WV

Lumber quality or density (i.e., hardness) can also be a factor. Hitting a knot in the lumber could cause the nail to change direction and partially or completely exit the lumber and strike the hand.

> I have had it happen before where that—if it [the nail] blows out the end of that knot, if that knot's a hollow knot, it'll shoot right through that plate.
>
> —Union carpenter, St. Louis, MO

Nailing in difficult-to-access areas increased the risk of injury because workers have less control handling the bulky nine-pound tool when an extended reach is required, vision is obstructed, or there's too little space to work.

> We've found that … if they don't have the right size ladders and they can't reach the top, yeah, they're doing things like this, right? And it's either going through the wood at an angle or it's they're shooting their hands.
>
> —Subcontractor, Phoenix, AZ

Missing the "target" altogether and having a nail become airborne was described as a serious risk. This was sometimes related to work pace while nailing a plate to studs, poor control of the nail gun on the recoil shot, or nailing shear/decking and missing the studs or joists behind them.

> Or … going through a wall where you're not hitting your framing lumber directly behind the sheathing. It's got enough power to send a 2-3/8 ring shank right

> through half-inch OSB [oriented strand board] and into the house where other people are working. I've been shot like that.
>
> —Carpenter, Morgantown, WV

Individual Actions—Individual behaviors most frequently described by participants included careless or unsafe acts; keeping the CAT/nail gun trigger squeezed/depressed when not intending to discharge a nail; and disabling or overriding a safety feature on the nail gun. Participants frequently characterized careless or unsafe acts as a lack of "common sense" or as breaking of recognized safe work practices due to inattention, bad habits, inexperience, fatigue, machismo, and "competitive" behaviors.

> When you're framing a wall, you're supposed to shoot down, but a lotta people start from the bottom and they come up. And if you're shooting quick, pop, pop, pop, pop, framing the wall fast, you might miss it and pop a nail off the top of the wall and it just goes flying.
>
> —Union carpenter, St. Louis

> You say "this won't happen to me" and you go quickly and suddenly start trusting too much. You shoot yourself."
>
> —Crew leader, Phoenix, AZ

> If accidents happen, maybe it is because you are not careful, because you know the danger that you run using the guns if you don't (use) the gun right.
>
> —Carpenter, Austin, TX

Thirty-one percent of participants identified keeping the trigger depressed on the CAT nail gun when not intending to shoot a nail as a major problem. They acknowledged this practice was both a common behavior and a potential risk for injury. Many described this as a "habit" or "carelessness," while others believed that two factors combined—the weight of the nail gun (8 to 9 pounds) and the design of the trigger and hand-grip—made it difficult to hold the gun without depressing the trigger.

> And you got your finger on there and … instead of taking your finger off and not thinking right, you have your finger on and you bump up against something and possibly fire [a nail].
>
> —Union carpenter, Chicago, IL

> And that is a major problem if they don't take their finger off the trigger. And that's where the problems come in on those accidental ones [i.e., shots].
>
> —Subcontractor, Phoenix, AZ

Speaking of a specific nail gun model, one subcontractor was less critical of the operator and shared the following comment.

> They're just holding on to it [trigger]. There is no way for them to slide their hand back so they're not on the trigger.
>
> —Subcontractor, Phoenix, AZ

Many participants believe that nailing fast increased the risk of traumatic injury. Although the operator controls the nailing cycle on a building site, participants described both individual and organizational incentives for nailing fast.

> At least 85 percent of the time, I would say [work] speed is the main culprit of nailing accidents.
>
> —Union carpenter, Morgantown, WV

> If you're ricocheting or missing or misfiring, you're going too fast, 'cause you can't control where you're putting that gun.
>
> —Union carpenter, Chicago, IL

Some participants described the intentional disabling of nail gun safety features, such as removing the spring from the tip of the CAT nail gun, as something that occurred with earlier nail gun models as opposed to current practice. (Removing the spring could result in a nail discharge by just pulling the nail gun trigger.)

> They [CAT nail guns] are a big risk if you don't use the spring they have. A lot of people take it off. They don't know how dangerous that is.
>
> —Crew leader, Phoenix, AZ

> The ones that took it [tip spring] out, they were told to keep [it] in their pockets [and] if the safety guy came through to put 'em back in.
>
> —Union carpenter, Chicago, IL

Work Organization—Two general types of "work pressure" were described as being associated with increased risk of traumatic injuries. One type of pressure came from representatives of the subcontractor or project owner to increase production. This pressure coincided with concern about getting fired, which motivated them to work faster, cut corners, or violate safety requirements.

> I was the same way. I just wanted to get it finished. I want to make my hours. I don't wanna get fired. I don't want the boss to eyeball me… . [You're] gonna do whatever it takes to get it done.
>
> —Union subcontractor, St. Louis, MO

> [The] pressure that the supervisor, the foreman, and even your fellow coworkers always put on you … hurry up … hey, look, we have to finish … your own kind puts pressure on you, on the one hand … so you end up racing… you take off the spring.
>
> —Carpenter, Phoenix, AZ

The second type of pressure involves production incentives for individual or work crew performance, including piece-work and securing additional work, which may incentivize risk-taking, as workers and crew members attempt to maximize their wages.

> I really don't remember how many times I've shot myself. But I think the main thing to do with that is the speed. I was a pieceworker… . The speed is the greatest thing to do with hitting yourself I think. It's just goin' way too fast.
>
> —Subcontractor, Seattle, WA

> There are various groups [i.e., production crews] … and that group that finishes first is given the next house … so the people start accommodating accordingly… if there are 20 houses you finish last, well now you're not going to get another house and the one that works quicker gets another house and another house, and so on.
>
> —Carpenter, Austin, TX

Extra-Organizational Environment—Participants described the socioeconomic pressures influencing nail gun injury risk in the industry, such as the downward pressure on the prices that builders/ developers paid for framing houses.

> [They] got us cut so tight on these bids. Everybody's trying to go so quick and compete with each other and a lotta times safety's out the window when you got so many hours to build a house.
>
> —Union carpenter, St. Louis, MO

Small subcontractors operate on a low profit margin, especially when the home-building industry is depressed, which affects their ability to invest in safety interventions, including training programs.

> We only make money on the labor we provide. So we have no profit except our manpower. So that's what restricts how much time you can spend [on safety training], because that's our overhead.
>
> —Subcontractor, Seattle, WA

In the focus groups with immigrants, some participants described how pressure to perform could take advantage of workers' legal and economic vulnerability.

> [They] know we need the work. They know that they can use us because they know that we are … undocumented. If they [ask us] to do something that someone here can't do … they know that if they tell me to do it, I will do it. [We] have more dangers, us Hispanics. They can tell us what they want and they know that we are not going to say anything. Why? Because they know that we are afraid to speak up.
>
> —Carpenter, Austin, TX

Factors Influencing Injury Prevention

Injury-preventing factors identified and discussed in focus groups are shown in Table 4. In general, fewer specific injury prevention comments were provided in focus groups. Participants in five or more focus groups identified seven factors that they believed could reduce traumatic nail gun injury risk. Factors most frequently described were the need for safety training (36%), safe nailing work practices (36%), on-site supervision (25%), and effective risk communication materials (20%).

Tool/Technology Factors—Few participants outside of St. Louis described having used a sequential actuation trigger (SAT) system on a nail gun and several reported not knowing a "single shot" nail gun was available, other than a specialized positive placement nail gun (used to shoot nails into pre-drilled holes on metal straps and hangers on lumber)[4]. Correspondingly, St. Louis carpenters and subcontractors provided the majority of comments (n = 6) supporting the general use of the sequential actuation system to reduce the risk of traumatic injury. The St. Louis United Brotherhood of Carpenters and area union subcontractors had previously participated in studies with researchers from Duke University [13] investigating the causes of nail gun injuries.

> I'm not so much concerned about me getting hurt anymore now that we switched to the gray [sequential actuation] triggers. They are 10 times safer than the orange [contact trip actuation] ones.
>
> —Union carpenter, St. Louis, MO
>
> [We] found that the sequential trigger's pretty much stopped our gun accidents. We've gone two years without one.
>
> —Union subcontractor, St. Louis, MO

Other participants supported providing new carpenters with the sequential trigger until they developed the skill to use a nail gun with the contact trip actuation system.

> …[P]eople that are new to the industry, those are the people that [should] have the individual fire [sequential actuation]. And it's not till later that they [should] allow 'em to use a gun that is bump fire [contact trip actuation].
>
> —Subcontractor, Phoenix, AZ

Many participants shared ideas for nail gun design changes, including nail gun weight, balance, and trigger size and placement. Several participants suggested the nail guns should use a trigger guard to make it more difficult to keep the trigger depressed when holding the gun but not shooting nails.

Task-Related Factors—Participants in all six English-language focus groups—framers and subcontractors alike—emphasized the importance of "safe" work practices for preventing traumatic nail gun injuries. The most common practice described was keeping the hand and other parts of the body a "safe" distance from the nail insertion point.

> So if you teach those guys to hold their hand back a little ways—and then if it [nail] misses the stud—it doesn't hit their hand. Just simple stuff like that.
>
> —Union subcontractor, St. Louis, MO

There were varying opinions regarding the "safe" distance that the hand or other body part should be from the nail insertion point, ranging from 3 to 12 inches.

> You should not have your hand within 3 inches of the nailing place.

[4]NIOSH researchers found that nearly all PNGs used on single- and multi-family residential building sites were supplied by subcontractors or builders even where workers were considered to be "independent contractors."

—Union carpenter, St. Louis, MO

> I just hold it [back] six inches or a foot. ‘Cause the first time I shot myself was ‘cause it ricocheted off the top of the plate. My hand was holding the stud maybe like five inches [away].
>
> —Union carpenter, Chicago, IL

Several participants provided what appear to be competing suggestions for the safest nailing sequence for fastening studs to plates when building exterior and interior walls of a structure. One allows the operator to move his hand away from the nail insertion point before shooting a nail and the other reduces the risk of the nail missing or exiting the edge of the lumber and becoming airborne.

> I think the one we all probably can agree on is shooting the first nail in the bottom when you’re framing a wall. Shoot the bottom nail first… . [K]eep that other hand away from there in the first place.
>
> —Subcontractor, Phoenix, AZ

> [W]hen I frame a wall …I do the top nail first. That’s my most consistent shot putting that first nail about an inch and a half down. Then I put the other one in ‘cause it’s just a reaction shot.
>
> —Union carpenter, St. Louis, MO

One possible explanation for the discrepant views on shooting the top or bottom nail first may be related to the type of nail gun actuation system. The Phoenix subcontractor used the CAT nail gun for all framing, while the St. Louis carpenter used the SAT for wall framing. The St. Louis carpenter suggested that more precise placement of the SAT was possible and therefore facilitated shooting the top nail first, while all nails “bumped” using the CAT could be considered “reaction” shots. Other recommended work practices included keeping the body out of the potential nail trajectory, avoiding hitting knots in the wood, and nailing blocking between studs before walls are raised.

Individual Action—Workers’ experience and skill operating a nail gun was considered a significant factor in avoiding traumatic injuries, though it was disproportionately mentioned by subcontractor participants.

> Guys that use them a lot and have been using ‘em a long time don’t seem to have a lotta trouble.
>
> —Union subcontractor, St. Louis, MO

A related theme shared by both carpenters and subcontractors was the importance of operators’ awareness of the risk of injury, which some believed would improve after someone experienced a nail gun injury.

> You’re gonna hit a knot. I didn’t know a knot would make the nail come up and go into my finger. You learn those things.
>
> —Carpenter, Seattle, WA

Work Organization—The importance of employer-based nail gun safety training was mentioned in eight focus groups and supported by 36 (44%) participants. Training programs favored included formal programs with written tests, on-site toolbox talks, and one-on-one hands-on instruction. The use of formal nail gun safety training for new hires was described in St. Louis focus groups with United Brotherhood of Carpenters' Union carpenters and union subcontractors and by Phoenix non-union subcontractors. While contractors in both cities believed their training programs had resulted in the reduction of traumatic nail gun injuries, St. Louis contractors were more likely to have described limiting the use of the CAT trigger to "flat" work, like decking and sheathing.

> And I'll tell ya, when we went to our training program, which was probably 15 years ago, we saw gun accidents drop dramatically, but we still had gun accidents.
>
> —Union subcontractor, St. Louis, MO

> We reduced the amount of nail gun injuries substantially just by increasing the amount of training.
>
> —Subcontractor, Phoenix, AZ

Regardless of the use of formal safety training, participants in framer and sub-contractor focus groups described the need for hands-on safety training.

> … [My] personal opinion is you can't really have it [training] where you sit down in a class and teach somebody to be safe with the nail guns. They'll never get anything out of it. You can show them all the pictures on the wall over there and take 'em out and put a couple of shots in some boards, but until you get out there and you're in the environment, you're not doing 'em any good.
>
> —Union carpenter, St. Louis, MO

> This is a trade of hands and the skills are gonna come from using your hands and being trained how to use 'em properly. And … on-the-job training is probably the most efficient way of training, big or small company, [it] doesn't make a difference.
>
> —Union subcontractor, St. Louis, MO

Coinciding with the preference for hands-on training, several subcontractors described the importance of "situational" training to increase awareness of job tasks recognized to carry greater injury risk.

> Now we do situational training. There are a million different combinations you can get into as a framer. [A] lot is common sense stuff after you've been doing it for a while, but I'll walk a new guy through. Say, "Look, when you're shooting the last stud on a wall be careful 'cause you can miss the end of the wall and shoot yourself in the fingers."
>
> —Subcontractor, Seattle, WA

Most subcontractors believed that safety training was something that "new" workers needed, as opposed to experienced workers. Differences in how training occurred, including levels of formality, seemed to differ according to the size of the subcontractors' workforce.

> … ifI ever had to go big again …I would actually try more training out the gate to save myself the misery of the injuries and the time loss claims.
>
> —Subcontractor, Seattle, WA

The content of safety training materials was discussed in all focus groups. Most comments indicated that safety communication materials could have more impact on young and/or new workers if it graphically depicted the potential harm a traumatic nail gun injury could cause. For many, this perspective coincided with the belief that injuries resulted from "unsafe" or careless actions, because young and inexperienced workers did not recognize the potential seriousness of a nail gun injury.

> I think if they had something a little bit graphic to show 'em what can really happen with these guns, I think it might put the fear of God into some of these younger kids and they would have more respect for those pneumatic tools.
>
> —Union subcontractor, St. Louis, MO

> These images tell a lot to some of these guys. They don't think about it 'til you see it. You see a nail buried in some guys hand like this and they're like, "Oh, okay. Maybe I will keep 12 inches away."
>
> —Subcontractor, Phoenix, AZ

> Making them watch a video of a real accident … what can happen or the damage that it can cause.
>
> —Carpenter, Austin, TX

The role of on-site supervision was the second most frequently mentioned tactic to reduce traumatic injuries. Participants believed that supervisors and more experienced workers needed to observe new employees and provide feedback when they saw them doing something that could result in injury.

> If you see them on the job doing something [and] they could potentially … hurt themselves or shoot themselves you correct it and then go back and check them the next day.
>
> —Subcontractor, Seattle, WA

Participants in the immigrant focus groups described how some prospective workers will exaggerate their work experience fearing that they will not be hired if they are truthful.

> And so the first thing you [the supervisor] have to do is observe—to watch. If you observe you're going to see whether he knows how to work or not. New people who come to work are going to say they know how to do the job. But you can find out by watching—the way he holds the gun—whether he knows or not.
>
> —Crew leader, Phoenix, AZ

Contrasting Perspectives

Focus groups were organized to solicit the views of diverse groups among residential building stakeholders, including U.S.-born union and non-union carpenters-framers, union and non-union subcontractors, and immigrant carpenters-framers. Not all viewpoints were equally represented among these groups, however, given the small number of participants and non-random convenience selection of participants. Therefore, what follows may only be suggestive of possible differences among the groups.

Immigrant workers were more likely to describe factors influencing injury occurrence, offering fewer suggestions regarding injury prevention factors. Among the injury influences described, immigrants commented disproportionately on the risks of disabling nail gun safety features (62%), work pressures (69%), production incentives (56%), and socioeconomic pressures (72%). Immigrant participants did not comment on five injury occurrence factors (e.g., design of nail gun hand-grip and trigger, holding work piece and nailing) discussed in five or more focus groups. These differences could be due to the use of two different moderators for the English- and Spanish-language focus groups despite the expectation that the same questions would be asked in each. However, given the preponderance of undocumented (unauthorized) immigrant workers in the focus groups, concerns related to various types of work pressure are consistent with other reports [20, 21].

Union carpenters and union subcontractors in St. Louis were more likely to describe the CAT system as an injury risk and report having used nail guns with a SAT system. St. Louis has been a focal point for nail gun injury prevention research, and many residential carpenters have participated in these research activities. In addition, some union subcontractors have stopped using the contact trip actuation system or have restricted its use to “flat” work, such as installing subfloors. Non-union subcontractors were more likely to focus on the injury influence of “careless/unsafe” behaviors than union contractors, while subcontractors in general suggested the following injury prevention influences: workers’ skill and experience (70%); supervisors’ role (85%); and safety training (72%).

Participants described numerous positive (increasing) and negative (decreasing) injury risk influences (factors) related to pneumatic nail gun use during residential building framing. In order to represent the attitudes and beliefs of participants, the analysis was again limited to only factors repeated in five or more of the nine focus groups.

Factors in all sociotechnical categories were included among those that participants associated with influences on injury occurrence, though more than half of comments (62%) were related to inappropriate operator (individual) behaviors or task-related factors. Factors expected to influence injury prevention were less inclusive of all sociotechnical categories, and factors related to worker behaviors—or employer actions to modify operator behaviors —accounted for 75 percent of the comments.

One purpose of the study was to learn whether stakeholders were aware of carpenters who had developed stenosing tenosynovitis (“trigger finger”) due to repetitive use of the SAT nail gun. Although routine use of the SAT-equipped guns was limited to stakeholders in the St. Louis market and occasionally in Phoenix and Morgantown, no participant reported that he or someone he knew had developed trigger finger/stenosing tenosynovitis as a result of using a nail gun with the SAT mechanism. Some St. Louis carpenters who had reported that their employer switched to SAT-equipped nail guns reported temporary increased hand fatigue.

> When we first started using those sequentials your hand hurt for a few days getting used to it.
>
> —Union carpenter, St. Louis, MO

Several participants indicated they believed the possibility of developing trigger finger existed; however, they hadn't developed the disorder and could not describe anyone they knew who had.

DISCUSSION

Stakeholders' descriptions of nail gun injury risk and prevention influences can be discussed relative to both attribution theory and sociotechnical models of injury causation. Recognizing how stakeholders attribute causation, whether accurate or not, is useful for developing injury interventions. Sociotechnical models can be used to identify all potential factors related to a building project that may increase the risk of injury, especially those temporally and spatially distant from the job site and the accident or injury event.

Discussing how people "make sense" of events, including occupational injuries, Dejoy [22] cited attribution theory and proposed that "causes are typically categorized along three major dimensions: *locus of causation*, *stability*, and *controllability*." The *locus of causation* refers to the identification of either *internal* (personal) or *external* (contextual or situational) factors to explain causation. *Stability* indicates whether the cause is more or less *temporary* or *permanent*. *Controllability* refers to the belief that the cause is *controllable* or *uncontrollable*, though this construct may be more difficult to assess when the *locus of causation* is *external*. Both *stability* and *controllability* are described as continuums, rather than polar opposites.

The *locus of causation* for the top six injury occurrence influences participants described in this study (Table 3) were divided between *personal* and *external* injury occurrence influences. Influences attributed by discrete individuals to *personal* factors included careless/unsafe behavior (n = 28), keeping the contact trigger depressed (n = 25), and work pace (n = 17). Influences attributed to *external* factors included the inherent risk of using the nail gun (n = 26), work pressure (n = 26), and socioeconomic pressure (n = 18). Participants' responses concerning injury prevention influences (Table 3) provide some insight into beliefs regarding the two other components of attribution theory—*stability* and *controllability*.

Participants identified both *personal* and *external* injury causation factors, while the prevention influences that were described primarily addressed issues associated with improving operator performance (*personal*) using nail guns. All top prevention influences (Table 4) addressed the need to modify worker behavior (i.e., *personal*)—use of safe nailing practices (n = 29), safety training (n = 29), on-site supervision (n = 20) and effective risk communication materials (*n* = 16). Like *individual* factors, *task-based* factors involve some degree of operator control over how the task is completed, if not conceptualized and organized. Combined, these factors afford considerable opportunity for work practice variability, including actions that may be described as intentionally careless or unsafe; or unintentional errors due to a lack of training or experience, physical fatigue, or errors of perception.

In promoting the performance and task-based interventions previously described, participants seem to indicate that injury occurrence influences are unstable (i.e., subject to individual change) and controllable (i.e., training, experience, improved work practices). A minority (*n* = 12) suggested use of the nail guns with sequential actuation systems by all or new nail gun users, which was the only recommendation addressing an *external* injury occurrence influence.

Organizational issues, including safety climate, organizational safety performance, and economic factors, "can serve to shape or limit the attributions of workplace participants" [22]. Although safety climate was not a planned topic of discussion, most participants had worked for small subcontractors and described weak or nonexistent safety and health programs. Most carpenters (54%) reported that they had not received any nail gun safety training before first using the tool, while 41 percent reported they had never received any nail gun safety training. Other organizational issues mentioned that influence the operation of nail guns and other work practices, included economic pressures such as incentive payments, the amount builders paid subcontractors for work, and the economic recession. These organizational and "extra-organizational" factors are largely beyond the control of individual workers and subcontractors, which may explain why few injury prevention influences (Table 4) were proposed to address them. And to the extent that individual factors, such as sensory capacities, perception, skill, and technique do make a difference, it's understandable that stakeholders would gravitate toward the *personal* causal explanation, which they believe they can control.

Improving individual workers' awareness of nail gun safety hazards and improving their skill using the tool may result in some reduction in injuries, but they cannot remove the actual risk factor or influence. "What is needed instead," according to Leather [23], "is a scheme of understanding and explanation which emphasizes the multiplicity of accident causation, especially the interrelation of individual, organizational and job variables."

One multifactoral model that has been validated in two studies [24, 25] is the *constraint-response* accident/injury causation model. The *constraint-response* model assumes "that the central feature in accident causation is inappropriate human behavior" at all levels of activity —from project concept and planning (i.e., building owner) to site activity (i.e., construction crew)—and proposes to "map the potential contributions of all participants within the project organization to the accident causation process" [24].

In this model, causal factors are classified according to the temporal and spatial proximity to the immediate accident/injury circumstances and event [25]. *Proximal* or *shaping* factors are situations or conditions present on the job site that can "lead directly to accident causation" should an inappropriate action or response occur, such as a nail gun double-fire at the end of a recoil event. Haslam et al. [25] identified the following *proximal/shaping* factors in their analysis of construction accidents/injuries:

- worker factors—attitudes/motivations, knowledge/skills, supervision, health/fatigue;
- site factors—site constraints, work scheduling, housekeeping; and
- material/equipment factors—design, specification, supply/availability/maintenance.

Distal factors or *originating influences* are found further upstream in a construction project and have been identified as conditions or circumstances that can "lead to the introduction of *proximal factors* in the construction process" [24]—such as not having developed controls to prevent the double-firing of a nail gun. The following distal (originating influences) factors were identified by Haslam et al [25]: client requirements, economic climate, construction education, permanent works design, project management, construction processes, safety culture, and risk management.

Proximal/shaping factors and *distal originating influences* can function as *constraints* that may lead stakeholders at all levels of the project to make decisions that result in actions that lead to unintentional injury. *Constraints* are the economic, social, political, organizational, technological, environmental or individual factors which may be present or may surface during the life of the construction project. Stakeholders' actions or *responses* relative to project constraints can "intentionally or unintentionally" introduce a hazard (referred to as a *pathogen*), increasing the potential for an accident/injury to occur [24]. All stakeholders have an opportunity to "initiate, influence or control" hazards in the project from the planning and design phases to the on-site building activities. However, stakeholders "in higher positions of authority have more potential to produce [hazards] than people in lower positions because of their wider influence on the process" [21].

Suraji et al. [24] analyzed 500 construction accidents and reported that *inappropriate construction operation* was involved in 88 percent of the cases, while *inappropriate operative action* and *inappropriate construction planning* were identified in 30 percent and 29 percent of cases, respectively. Haslam et al. [25] investigated 100 relatively minor construction industries "accidents" and found that root-cause *originating (distal)* influences were involved in 94 percent of the incidents, while the following *proximal*/*shaping* factors were less influential— *materials*, *the workplace*, *equipment*, and *worker/work team*. The implications of this model are significant given that *originating/distal influences* are pervasive yet temporally and spatially distant from the job site and injury events, and thus not subject to modification by site workers.

Mapping participant responses using the constraint-response model resulted in a similar hierarchy of responses. Although this study did not attempt a deep analysis of specific injury events, participants' perceptions of injury occurrence and prevention influences are compatible with the *constraint-response model*, which may provide some insight into the range of injury prevention interventions that could be considered. The influences on traumatic nail gun injury occurrence and prevention that participants described varied in both spatial and temporal distance from the usual location where injuries occur. Participants described how worker/crew actions in the context of the building site, and the use of building materials and tools/equipment influenced the production of traumatic nail gun injury. *Constraints* antecedent to these actions included *proximal/shaping factors* and *originating influences* identified by Haslem et al [25]. Proximal/shaping factors included *worker/crew* factors (e.g., inadequate training, skill and experience; production incentives and work pressure); *site* factors (e.g., difficult-to-reach/ access locations, “stick building” lumber-joining techniques), *materials* (e.g., lumber hardness and knots) and tools/*equipment* (e.g., use of the contact trip actuation system). *Originating influences* (*distal factors*) included socioeconomic pressure (economic recession, subcontractor competition); reliance on the “inherently unsafe” nail gun and poor nail gun design; “precarious” employment practices; and lack of or inadequate safety training.[5] The number of factors or influences that participants described unrelated to direct work activities suggests some participants intuited a multi-causal explanation of accident/injury causation.

Specialty trade subcontractors in the home-building industry are predominantly small firms with nearly 80 percent of subcontractors employing fewer than 10 employees [26]. In addition, the Internal Revenue Service reported that in 2007 “there were almost 600,000 non-employer firms in residential construction and almost 2 million in specialty trade contracting” [27]. Smaller firms have been shown to have less control over the work process and fewer resources, thus diminishing their ability to comply with occupational safety and health requirements [28–31]. Researchers have shown a relationship between subcontracting and diminished safety and health in building construction [32–34]. In a highly competitive industry like home-building [27], competition among subcontractors—especially framing subcontractors, who typically are paid only for the labor they bring to the job—can result in the reduction in price to a level that disincentivizes compliance with worker safety and health regulatory requirements and/or best practices. David Weil [35] proposed focusing regulatory compliance efforts “at higher levels of industry structures” to improve compliance with Department of Labor regulations, and identified home builders as the “lead firm” in the industry. Home builders are responsible for project planning and supply chain subcontracting and have greater resources necessary to facilitate compliance than do small subcontractors.

CONCLUSION

This study was designed to identify attitudes and beliefs among residential wood framing stakeholders regarding nail gun injury risk and prevention. While it was beyond the scope of the study to exhaustively map causal factors for specific injury events, participants’ comments provide insight into their perception of a range of influences that increase the risk of nail gun injury. Union-affiliated subcontractors and carpenters in St. Louis, with experience using both CAT and SAT systems, described injury prevention benefits (e.g., preventing unintentional nail discharge) after adopting the SAT-equipped nail guns, especially for “stick building” framing tasks. However, residential building stakeholders

[5]The absence of a “negative risk influence” that participants perceived to mitigate risk could increase the potential for injury. For example, participants described how an operator’s lack of skill and experience could increase the potential for injury.

without SAT experience were more likely to associate increased risk of traumatic nail gun injury with an operator action (e.g., keeping the trigger depressed when not nailing) or the nailing task. Some participants, however, described various factors beyond the control of individual workers or subcontractors, consistent with *originating/distal* influences described earlier.

Without prompting, subcontractor and worker participants described associations among risk influences in a number of ways. Subcontractors and carpenters alike attributed *careless and unsafe behaviors* (e.g., missed plate/stud, kept hand too close to nail insertion point, kept trigger depressed when not nailing) to a number of external influences, including a lack of training, skill, or experience necessary to work safely. Additionally, many framers, especially immigrants, believed that production incentives and pressure from employers or peers to work faster could result in “careless” or “unsafe” behaviors.

Non-immigrant participants were more likely to attribute perceived *nail gun design characteristics*, such as the contact trip actuation system, the configuration and location of nail gun triggers, and the nail gun hand-grip design, to increased risk of traumatic injury. Finally, participants described how they believed *socioeconomic pressures* exerted influence on management and work practices (e.g., utilizing production incentive systems that increased the work pace, not providing on-the-job safety training, and taking advantage of undocumented workers’ legal status) that increased the risk of traumatic nail gun injury.

Studies suggest [36, 37] and St. Louis stakeholders concur that wider adoption of the SAT system for wood framing would reduce the occurrence of traumatic injuries due to unintentional nail gun discharge. Compliance with existing nail gun safety training requirements [38] may address unintentional *careless and unsafe behaviors* [39], though it may have less effect on similar actions adopted in response to organizational and socioeconomic pressures. The results of this study suggest, however, that nail gun injury prevention strategies will be less than optimal if they focus primarily on changing workers’ behaviors, while neglecting the injury risk connected to distal influences [25]. Residential building industry stakeholders operate within a sociotechnical system that includes organizational and socioeconomic constraints. Features of this system include a preponderance of small firms (< 10 workers), pyramid subcontracting, inter-firm competitive pressures (especially during lean or recessionary periods), easy entry into many subspecialty trades, a large percentage of legitimately self-employed tradespeople, extremely low labor union density, the misclassification of workers as self-employed independent contractors, extremely scattered job sites, a high percentage of undocumented workers, and macroeconomic pressures [40, 29]. These organizational and contextual features can negatively impact the ability of a small firm or individuals to adopt best safety practices.

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Table 1

Focus Group Participants

Focus group	Location	Language	Participants
Union subcontractors[a]	St. Louis, MO	English	9
Subcontractors[a]	Phoenix, AZ	English	10
Union carpenters	St. Louis, MO	English	10
Union carpenters	Chicago, IL	English	7
Carpenters—Subcontractors[b]	Seattle, WA	English	10
Carpenters—Subcontractors[b]	Morgantown, WV	English	8
Carpenters[c]	Phoenix, AZ	Spanish	8
Carpenters	Phoenix, AZ	Spanish	9
Carpenters	Austin, TX	Spanish	10
Total			81

[a]Framing subcontractors' owners, managers, supervisors or safety staff.

[b]Includes small framing subcontractors; "working" owners, foreman, and carpenters.

[c]Non-foreman crew leaders of immigrant workers.

Table 2

Socio-Technical System Taxonomy

Socio-technical category	Description
Machinery, tools & equipment	Tools, equipment and materials
Job task[a]	Work processes and elements of job
Individual	Individual characteristics, including knowledge, experience, attitudes, and behavior
Work organization	Industry and firm management systems
Environment	Worksite physical—worksite terrain and climatic conditions Worksite social—familial and friendship Social economic—political, legal and economic conditions that impact work (aka extra-organizational)

[a]Can be subsumed under "work organization."

Table 3

Factors Influencing Nail Gun Traumatic Injury Occurrence

Socio-technical category	Factors[a]	Number of focus groups[b] (N = 9)	Comments[c] n (%)	Rank[d]
Machinery, tools & equipment	Inherent risk using nail gun	8	26 (33)	2
	Design of nail gun hand-grip and trigger	5	12 (15)	7
	Use “contact trip” trigger	7	12 (15)	7
Job task	Nail missing plate or studs	7	12 (15)	7
	Holding lumber and nailing	5	10 (12)	9
	Lumber knot or hardness	5	10 (12)	9
	Difficult to reach/access nailing area	5	9(11)	10
Individual	Careless or unsafe behavior	9	28 (34)	1
	Keep “contact trip” trigger depressed	8	25 (31)	3
	Work pace/nailing speed	6	17 (21)	5
	Disable or over-ride safety mechanism	5	15 (19)	6
Work organization	Work pressure	7	26 (32)	2
	Production incentives	6	11 (13)	8
Extra-organizational environment	Socioeconomic pressure	7	18 (22)	4

[a] Factors influencing traumatic injury occurrence discussed in 5 or more focus groups.

[b] Number of focus groups (FG) in which the Risk Factor was described.

[c] Indicates the number of discrete individuals (n) and the percent (%) of participants (n = 81) who mentioned the risk category.

[d] Rank refers to the relative popularity of the topic; the lower the number indicates it was mentioned by more participants.

Table 4

Factors Influencing Nail Gun Injury Prevention

Socio-technical category	**Factors**[a]	**Number of focus groups**[b] **(*N* = 9)**	**Comments**[c] ***n* (%)**	**Rank**[d]
Machinery, tools & equipment	Use nail gun with sequential trigger	6	12 (15)	4
Job task	Safe nailing work practices	6	29 (36)	1
Individual	Operator skill and experience	6	10 (12)	5
	Operator awareness of hazard	6	10 (12)	5
Work organization	On-site supervision	7	20 (25)	2
	Safety training	8	29 (36)	1
	Effective risk communication materials	7	16 (20)	3

[a] Factors influencing traumatic injury prevention described in 5 or more focus groups.

[b] Number of focus groups (FG) in which the Risk Factor was described.

[c] Indicates the number of discrete individuals (n) and the percent (%) of participants (n = 81) who mentioned the risk category.

[d] Rank refers to the relative popularity of the topic; the lower the number indicates it was mentioned by more participants.