Nonfatal Tool- or Equipment-Related Injuries Treated in US Emergency Departments Among Workers in the Construction Industry, 1998–2005

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Background *Individuals in the construction industry are exposed to a variety of tools and pieces of equipment as they work.*
Methods *Data from the National Institute for Occupational Safety and Health (NIOSH) occupational supplement to the National Electronic Injury Surveillance System (NEISS-Work) were used to characterize tool- and equipment–related injuries among workers in the construction industry that were treated in US emergency departments between 1998 and 2005. Based on a national stratified probability sample of US hospitals with 24 hr emergency services, NEISS-Work allows calculation of national injury estimates.*
Results *Over the 8-year period between 1998 and 2005, we estimated 786,900 (95% CI 546,600–1,027,200) ED-treated tool- or equipment-related injuries identified by the primary or secondary source of injury code. These injuries accounted for a quarter of all ED-treated construction industry injuries. Although over 100 different tools or pieces of equipment were responsible for these injuries, seven were responsible for over 65% of the injury burden: ladders, nail guns, power saws, hammers, knives, power drills, and welding tools in decreasing order.*
Conclusions *Current injury estimates and their severity, marked by the proportion of cases that were not released after ED treatment, indicate interventions are particularly needed to prevent injuries associated with use of ladders as well as nail guns and power saws. Attention should focus on design and guarding to more efficiently prevent these injuries rather than simply calling for the training of workers in how to safely use a dangerous tool or piece of equipment.* Am. J. Ind. Med. 53:581–587, 2010. *© 2010 Wiley-Liss, Inc.*

KEY WORDS: construction workers; occupational injury; emergency department; NEISS-Work; tools; equipment

INTRODUCTION/BACKGROUND

Individuals employed in the construction industry routinely work with a wide variety of both powered and non-powered tools and pieces of equipment. Given their high exposure it is not surprising that rates of injuries related to use of power hand tools have been reported to be highest among workers in construction; furthermore, non-power tool injury rates in construction are second only to agriculture [Myers and Trent, 1988]. Based on 2007 estimates from the Bureau

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of Labor Statistics (BLS) Survey of Occupational Injury and Illnesses (SOII), 12% of non-fatal injuries in construction were attributed to tools, instruments, or equipment (Occupational Injury and Illness Classification System (OIICS) Source Code 7) compared to approximately 7% overall [US Dept of Labor, BLS, 2008]. In wood-related construction alone, one-fifth of injuries have been reported to result from use of construction materials or power tools [Waller et al., 1989]. Consistent with their increased potential for energy exchange, power tools tend to produce more serious and costly injuries [Waller et al., 1990; Lipscomb et al., 2003a; Trybus et al., 2008].

Improving our understanding of the epidemiology of tool- and equipment-related injuries, including both their magnitude and nature, can provide guidance for the setting of priorities for control efforts as well as insight into the manner through which risk control might most effectively occur. Because these injuries involve the interface between workers and the equipment or tools they need to do their jobs, it opens the potential to look for ways to design out and guard against dangers. With these thoughts in mind, we used data from the NIOSH occupational injury supplement to the National Electronic Injury Surveillance System (NEISS-Work) to characterize work-related tool and equipment-related injuries in the construction industry that were treated in US emergency departments.

METHODS

Injury estimates for this analysis were obtained from 1998 to 2005 through NEISS-Work. This surveillance system is maintained by Center for Disease Control and Prevention's (CDC) National Institute for Occupational Safety and Health (NIOSH) in conjunction with the Consumer Product Safety Commission's (CPSC) National Electronic Injury Surveillance System (NEISS). NEISS and NEISS-Work cases are mutually exclusive. Tools and equipment were identified solely by BLS Occupational Injury and Illness Classification System categories and do not conform to CPSC consumer product codes. NEISS-Work draws emergency department (ED) treatment data for injuries and illnesses from a stratified probability sample of US hospitals allowing the estimation of national estimates [Derk et al., 2007]. While NEISS-Work captures both illnesses and injuries, the majority of cases are injuries and they are referenced as such in the remainder of this report.

For this analysis, cases were drawn from those working in the construction industry at the time of injury. Details regarding the methods used to identify construction industry injuries using a combination of available data on industry, occupation, and business establishment have been previously described [Schoenfisch et al., in press].

Through NEISS-Work an injury is identified as work-related if the ED chart indicates that the injury occurred while working for pay or compensation, volunteering for an organized group, or during agricultural production-related activities. Case identification is conducted by trained coders at each participating hospital from review of admissions information and review of ED charts. In addition to a brief description of the incident and the associated diagnosis, limited information on the victim (age, sex, race/ethnicity) is captured [Derk et al., 2007].

Based on the incident description, NIOSH further classifies the associated event or exposure and the source of injury using the Occupational Injury and Illness Classification System (OIICS) [US Bureau of Labor Statistics, 1992].

The frequencies of injuries whose coded primary or secondary source was classified as ''tools, instruments or equipment'' were examined (OIICS Source Division Code 7). The primary injury source code is designed to capture ''the object, substance, element, or bodily motion, which *directly produced the injury*,'' while the secondary source ''identifies the object, substance, or person that generated the source… or contributed to the event or exposure'' (www.bls.gov/iif/osh_oiics_2_3.pdf). The primary source code names the whole tool unless a part separated from the tool or was independent of the ''whole,'' in which case the tool may be listed as the secondary source. Injuries from pneumatic nail guns provide such an example. Injuries resulting from being struck by a nail from a nail gun have a primary source code referring to the nail (metal fastener) and a secondary source code that denotes the nail gun. When necessary, injuries from related sources were combined to achieve reportable stable estimates that protect worker confidentiality. For example, we combined ladder-related injuries regardless of type of ladder as well as all power saws, power drills, and powered welding tools. Further analyses were restricted to tools and equipment for which NIOSH requirements for reliable estimates were met.

National estimates of ED-treated injuries by the type of tool or piece of equipment involved were obtained by summing weights of relevant cases using the weights based on the inverse probability of selection. Confidence intervals were constructed using the classic formulae for the variance of a total from a stratified sample. Variance estimates were based on the pooling of annual variance estimates for a simple stratified sample while accounting for covariance within relatively unchanging hospitals participating in the sample. Injuries resulting from common non-powered hand tools, powered hand tools and equipment were described separately based on the event surrounding the injury and the diagnosis of injuries as well as disposition of the ED visit.

For purposes of this research, NEISS-Work data access was granted to the investigators as NIOSH contractors through a confidential data use agreement. Procedures were also approved by the Duke University Institutional Review Board.

RESULTS

Over the 8-year period between 1998 and 2005, we estimated a total of 786,900 (95% CI 546,600–1,027,200) ED-treated tool- or equipment-related injuries identified by the primary or secondary source of injury code among individuals employed in the construction industry. These injuries accounted for 25% of all construction industry ED-treated injuries during this time.

Although the injuries involved over a hundred different tools and types of equipment, few of them occurred frequently enough to allow the calculation of reliable national estimates.

The distribution and disposition of emergency department visits for the more common tool and equipment related injuries are presented in Table I. Injuries involving ladders were the most common followed by nail guns, power saws, hammers, knives, power drills, and welding tools. Chain saws and fixed saws that are classified as machinery (table, radial, band) are not included with the hand power saws reported. However, the frequency rank of common tool and equipment related injuries would not be altered by including these injuries (see footnote in Table I). The vast majority (98%) of workers with tool- and equipment-related injuries were treated and released from the ED; injuries involving ladders, nail guns, and power saws and drills (in decreasing order) were more likely to result in hospital admission or transfer to another facility than were the other tool- or equipment-related injuries although the numbers were too small to be estimated reliably.

The events associated with injuries by tool or equipment involved are presented in Table II. As expected, injuries related to common powered and non-powered hand tools were most likely to result from contact with an object and the majority of injuries involving ladders resulted from falls. However, a substantial number of injuries involving ladders were associated with contact and bodily reaction and exertion as well although the estimates are small and not reliable. Injuries associated with welding tools were most commonly due to harmful exposures.

The injured body areas varied by whether the injury was associated with a tool or a piece of equipment. Tool-related injuries were much more likely to involve the upper extremities followed by the head and face while equipment injuries involved the upper extremity, lower extremity and trunk nearly equally (Fig. 1). It is of note that eye injuries accounted for 86,100 (95% CI 59,500–112,600) of the tool- or equipment-related injuries or 60% of the injuries involving the head or face.

The more common diagnoses of the injuries also varied by the tool or piece of equipment involved. For example, and not surprisingly, lacerations accounted for 95% of knife injuries (n = 47,500; 95% CI 33,200–65,000) and 65% of power saw injuries (n = 49,100; 95%CI 33,200–65,000) while puncture wounds (n = 58,100; 95%CI 31,500–84,700) and foreign bodies (n = 35,200; 95% CI 19,600–50,800) together accounted for 85% of the nail gun injuries. Thirty percent of ladder injuries were sprains/strains (45,700; 95% CI 28,500–62,900), followed by contusions/abrasions (n = 36,400; 95% CI 25,100–47,600) and fractures (36,000; 95% CI 25,300–46,700).

Disposition is the only measure of severity within the NEISS-Work data but the number of injuries resulting in hospitalization or transfer to another facility were not robust enough to estimate reliable national estimates. However, admissions for powered and non-powered hand tool injuries

TABLE I. Distribution and Disposition of Common Construction Tool- and Equipment-Related Injuries Treated in Emergency Departments, 1998–2005

Tool or equipment (OIICS code)	Estimate (%)	95% CI	Percentage of tool and equipment injuries (%)	Percentage treated and released (%)
Total[a] (OIICS 7)	786,900	546,600–1,027,200	100	98
Non-powered hand tools (OIICS 71)	257,300	181,700–332,900	33	99
Hammers (OIICS 7161)	61,700	37,200–86,200	8	99
Knives[b] (OIICS 7124)	50,000	33,700–66,300	6	99
Powered hand tools (OIICS 72)	332,500	228,200–436,700	42	96
Saws[c] (OIICS 7244)	75,400	51,600–99,200	10	95
Nail guns[d] (OIICS 7291)	110,400	65,000–156,000	14	94
Drills (OIICS 7213)	34,100	20,800–47,400	4	96
Welding tools (OIICS 7260–7263/7269)	33,900	27,800–40,100	4	100
Equipment (OIICS 74–78)	157,800	111,400–204,200	20	91
Ladders (OIICS 74XX)	154,200	109,100–199,300	20	91

[a]All tool- and equipment-related injuries based on primary or secondary source code (OIICS Division Code 7), not limited to more common injuries.
[b]With and without removable blades.
[c]Does not include chain saws or fixed saws (estimate 32,200; 95% CI 26,700–37,600) that are classified as machinery (table, radial, band).
[d]Does not include injuries from stud drivers, screw guns, or staple guns.

TABLE II. Common Events Associated With ED-Treated Injuries by Tool or Equipment Involved, US Construction Industry 1998–2005

Tool or equipment (OIICS codes)	Injury event	Estimate 95% CI	%[a]
Non-powered hand tools			
Hammers (OIICS 7161)	Contact with object	56,200 (34,400–78,100)	91
Knives[b] (OIICS 7124)	Contact with object	49,900 (33,600–66,200)	100
Powered hand tools			
Saws[c] (OIICS 7224)	Contact with object	73,300 (50,300–96,300)	97
Nail guns[d] (OIICS 7291)	Contact with object	109,600 (64,300–155,000)	99
Drills (OIICS 7213)	Contact with object	30,300 (18,400–42,200)	89
Welding tools (OIICS 7260–7263/7269)	Harmful exposure	19,900 (15,700–24,100)	59
Equipment			
Ladders (OIICS 74XX)	Falls	125,500 (90,000–161,000)	81

[a]Percentage of injuries from that tool or equipment represented by the event.
[b]With and without removable blades.
[c]Does not include chain saws or fixed saws that are classified as machinery (table, radial, band).
[d]Does not include injuries from stud drivers, screw guns or staple guns.

most often involved amputations, foreign bodies, serious lacerations, fractures, or punctures. Some of the more serious lacerations were described as having tendon or vascular involvement. A number of more serious lacerations requiring admission were from knives, power saws, drills, and even ladders. Admissions for foreign bodies included injuries involving hammers that resulted in ruptured globes and imbedded nails from nail guns in extremities, as well as the neck, brain, eye and chest. Other admissions for nail gun injuries involved fractures and infections following delayed care-seeking. Ladder injuries that resulted in admission commonly involved fractures and internal organ injuries, most often resulting from falls. No admissions were identified in which the injury source was welding tools.

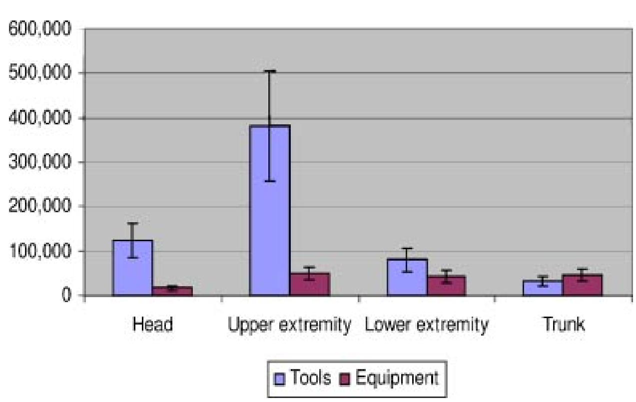

FIGURE 1. Estimates (and 95% CIs) of tool and equipment-related injuries treated in US emergency departments among workers in the construction industry by body area involved, 1998–2005. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

DISCUSSION

Using NEISS-Work data we estimated nearly 100,000 tool- or equipment-related injuries per year were treated in US emergency departments among workers in the construction industry between 1998 and 2005. These injuries accounted for a quarter of all construction industry ED-treated injuries [Schoenfisch et al., in press]. The associated patterns of injuries observed were of no surprise. Tool-related injuries typically resulted from contact with the tool and commonly resulted in contusions, lacerations, or puncture wounds, or from associated debris often resulting in foreign bodies in the eye. Fewer of the injuries associated with powered hand tools and ladders were treated and released than were those associated with non-powered hand tools. These findings are consistent with other reports [Myers and Trent, 1988; Smith et al., 2006; Lipscomb and Jackson, 2007]. The morbidity associated with falls from ladders among construction workers, as well as the risk of ladder use, are also well-established [Lipscomb et al., 2003c; Smith et al., 2006; CPWR, 2007; Kaskutas et al., 2009]. However, the relative contribution of specific tools and pieces of equipment to ED-treated injuries among this population of workers is quite interesting and provides clear guidance for needed injury prevention efforts.

With over 100 different tools and pieces of equipment involved in these injuries, the diversity complicates prevention. However, only seven main categories were responsible for over 65% of the injuries; this information provides direction for intervention priorities that should include two non-powered hand tools, four powered hand tools, and one pieces of equipment; specifically, knives, hammers, power saws, nail guns, drills, welding tools, and ladders, respectively. Injuries from ladders, nail guns and saws were more likely to result in hospitalization or transfer to another facility for treatment.

Additionally, some of the tools and equipment that were responsible for these injuries are used much more commonly across all the construction trades (ladders) while others are used by more restricted groups of construction workers (nail guns, welding tools). Although estimates of the construction workforce are available through the Current Population Survey of the Bureau of the Census, we elected not to use these to estimate injury rates. Given that the available denominator is hours worked (or fulltime equivalents) rather than tool exposure, the resulting rates would be misleading. However, even without rate estimates the relative frequency of injuries from pneumatic nail guns and hand-held power saws, particularly, are quite impressive given that these are tools used largely in wood frame construction; this indicates that risk from these power tools among the exposed population of construction workers is quite high. Based on their frequency as well as the proportion of injuries resulting in hospitalization, these two hand power tools, along with ladders, are prime targets for injury prevention efforts. Our analysis focused on tool- and equipment-related injuries defined by OIICS codes (as are data from the SOII), and did not include machinery, specifically sawing machinery such as table, band, or radial saws that are contained in a stationary frame [US BLS, OIICS, 1992]. Even if these pieces of sawing machinery were considered, nail guns would still have been responsible for more injuries than were powered saws.

There are specific OSHA regulations for the construction industry that set standards for work involving ladders [OSHA, 1926b, 1053] and non-powered and powered hand tools [OSHA, 1926a, Subpart I] including guarding specifications for power saws. The limited text information did not allow us to discern whether the tool being used was the most appropriate one for the task, nor could we determine in how many cases injuries occurred despite adherence to existing regulations compared to circumstances where the regulations were ignored. However, there were clear examples of both latter circumstances. In the case of powered hand saw injuries there were cases in which a missing or broken blade guard was mentioned as well as descriptions of saws kicking back when hitting knots in wood and injuries from reciprocating saws that do not have guards. The latter present guarding design challenges because of the nature of the work they are designed to accomplish.

Nail guns with contact trip triggers have been documented to carry twice the risk of acute injury as those with sequential actuation [Lipscomb et al., 2006, 2008b]. The contact trip design discharges a nail anytime the nose of the gun is depressed and the trigger is pulled, allowing the user to hold a finger on the trigger and ''bump nail'' by bouncing the nose piece against a work surface. This design also allows inadvertent discharge of nails following common recoil of the tool [CPSC, 2002; Dement et al., 2003; Lipscomb et al., 2003b, 2008b]. To prevent such inadvertent discharge of nails, the sequential triggering configuration requires that the nose piece be depressed before the trigger is pulled in order to release a nail. Nail guns (and other pneumatic fasteners) that operate at more than 100 psi pressure at the tool are required to have a safety device on the muzzle or nose piece to prevent ejection of fasteners unless the nose is in contact with the work surface [OSHA, 1926a, Subpart I, 302 (b)], but both actuation systems meet this specification. An industry-sponsored ANSI standard [ANSI, 2002] calls for manufacturers to *ship* framing nail guns with the safer sequential trigger. However, the wording on the standard has allowed continued use of nail guns with the more dangerous trigger.

The injury estimates described here are limited to those treated in US emergency departments and, obviously, they do not represent a full capture of injury events associated with tools and equipment in the construction industry. However, ED data should be a particularly good source of information on acute injuries that are serious enough to require immediate attention. Additionally, these injuries captured through NEISS-Work do not require the filing of a worker's compensation claim or an employer's reporting in order for an injury to be counted as work-related as BLS SOII records do. In the recent call for improved surveillance mechanisms outlined in the new National Occupational Research Agenda (NORA) [NIOSH, 2008], the importance of surveillance sources, such as NEISS-Work, that do not require employer reporting or the filing of a compensation claim should not be overlooked or neglected.

Additionally, even though many US construction workers do not have private health insurance coverage [CPWR, 2007], due to the Emergency Medical Treatment and Active Labor Act (EMTALA) legislation, emergency departments are obligated to provide care to all patients encountered without regard to health insurance status [Naradzy and Wood, 2006]. With the growing recognition of underreporting of work-related injuries [Shannon and Lowe, 2002; Leigh et al., 2004; Fan et al., 2006; Rosenman et al., 2006] including some of the specific ones we investigated [Lipscomb et al., 2008b] this is a definite strength of the data. Unfortunately, the NEISS-Work sample is not robust enough to support analyses of the more serious hospitalized cases due to the unstable estimates that result from limited case capture.

It should be noted that because most tool injuries reported in emergency departments resulted in treatment and release (no admission) does not necessarily mean that that these injuries are all of minor consequence or severity. Admission practices of hospitals changed in the period preceding these analysis, in effect raising the bar for the severity of injuries deemed admissible. Data presented in the National Hospital Discharge Survey [Graves and Gillum, 1994] show a steady decline in the national rate of hospital admissions culminating in a drop of 29% between 1980 and

1994. These changes in admission practices would have occurred shortly before the start of the study period analyzed here. Waller et al. [1990] reported mean days of work disability following ED treated wood construction-related injuries to be 12 days, most of which occurred among non-hospitalized patients.

CONCLUSIONS

Based on both frequency and severity of associated injuries, prevention efforts need to focus on injuries associated with the use of ladders as well as nail guns and hand-held power saws. While some investigators have emphasized training as a control measure [Becker et al., 1996], addressing prevention of tool- and equipment-related injuries through attention to the design and appropriate guarding is consistent with the public health hierarchy of hazard control [Robertson, 1992; Herrick and Dement, 2005; Castillo et al., 2006] in addition to training workers how to use the *more safely designed* tool or piece of equipment. These engineering approaches could more efficiently prevent injuries than a sole focus on modifying how individual workers can be taught to safely use a dangerous tool or piece of equipment.

Adequately protecting workers exposed to work at height is a tremendous challenge despite considerable knowledge of control measures. Workers must have access to ladders appropriate for the task at hand and they must be used appropriately (e.g., pitch, staking, use of safe access and egress techniques). Ladders are ubiquitous in construction and it is not uncommon for seasoned workers to assume less experienced co-workers know how to use them safely [Lipscomb et al., 2008b]. This is also an area of injury prevention that may be addressed effectively through the growing emphasis on prevention-through-design that calls for the use of systems that are inherently safer and attention to spatial considerations to reduce worker hazards [Toole and Gambetese, 2008]. Such actions that diminish the need for portable ladders could reduce the serious events caused by falls as well as musculoskeletal injuries associated with their use.

Given the recent demonstration of substantial control of injuries from pneumatic nail guns with a switch to the safer sequential trigger, as well as training of new users [Lipscomb et al., 2008b], consideration should be given to regulation and enforcement that specifically calls for such. Engineering solutions are particularly relevant and important to control risk associated with use of nail guns and power saws given the challenges of providing adequate training for large numbers of tool users. These users now include immigrant workers who are not English-speakers as well as consumers. As the risk of injury from use of construction tools and equipment is extended to the general public [Lipscomb and Jackson, 2007] through low-cost access at home improvement outlets, this becomes a wider public health concern encompassing both consumer protection as well as worker safety.

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