National Machine Guarding Program: Part 1. Machine Safeguarding Practices in Small Metal Fabrication Businesses

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Background *Metal fabrication workers experience high rates of traumatic occupational injuries. Machine operators in particular face high risks, often stemming from the absence or improper use of machine safeguarding or the failure to implement lockout procedures.*
Methods *The National Machine Guarding Program (NMGP) was a translational research initiative implemented in conjunction with two workers' compensation insures. Insurance safety consultants trained in machine guarding used standardized checklists to conduct a baseline inspection of machine-related hazards in 221 business.*
Results *Safeguards at the point of operation were missing or inadequate on 33% of machines. Safeguards for other mechanical hazards were missing on 28% of machines. Older machines were both widely used and less likely than newer machines to be properly guarded. Lockout/tagout procedures were posted at only 9% of machine workstations.*
Conclusions *The NMGP demonstrates a need for improvement in many aspects of machine safety and lockout in small metal fabrication businesses.* Am. J. Ind. Med. 58: 1174–1183, 2015.

KEY WORDS: machine guarding; occupational safety; risk management; small business; lockout; tagout

INTRODUCTION

Metal fabrication workers experience high rates of occupational injuries relative to much of the U.S. industrial workforce. According to the Bureau of Labor Statistics (BLS), there were 132 lost-time injuries per 10,000 metal fabrication workers during 2013, compared with the overall U.S. private industry rate of just under 100/10,000 [BLS, 2015]. As of 2013, there were over 83,000 metalworking establishments in the U.S., employing approximately 2.8 million workers. The majority (93%) of these businesses had fewer than 100 employees, 85% had fewer than 50, and 50% had fewer than 10 [US Census, 2015].

Additionally, the rate of work-related amputations is elevated in metal fabrication relative to all manufacturing (3.0/10,000 vs. 0.7/10,000) [BLS, 2015]. For 2013, the BLS recorded 6,160 non-fatal work-related amputations in private industry, with 440 occurring in fabricated metal products manufacturing [BLS, 2015]. Several studies have suggested that the actual numbers may be higher [Leigh et al., 1997, 2004; Pransky et al., 1999; Stanbury et al., 2003; Rosenman et al., 2006; Friedman and Forst, 2007]. An ongoing Michigan surveillance program has consistently reported incidence rates of work-related amputations two or more

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times higher than the BLS both for all industries combined and within metal manufacturing subsectors [Largo and Rosenman, 2009, 2012, 2013a,b].

Machine operators are at high risk for amputations [Boyle et al., 2000; McCall and Horwitz, 2006]. Although risk from specific types of machines has not been well characterized, surveillance data indicate that metal fabrication machinery such as power presses, shears, and powered saws are particularly hazardous, [Boyle et al., 2000; Stanbury et al., 2003; Largo and Rosenman, 2013a] with power presses alone accounting for as many as 12% of workplace amputations [Stanbury et al., 2003].

Several studies have reported an association between deficient machine guarding and increased risk for injury [Shannon et al., 1997; Simonds and Shafai-Sahrai, 1977; Gardner et al., 1999; Bull et al., 2002]. However, these studies lacked data on how machine guarding was assessed [e.g., Gardner et al., 1999; Bull et al., 2002], failed to document type of injuries related to machine use [e.g., Gardner et al., 1999; Bull et al., 2002], did not provide a clear indication that injury rate or prevention was related to specific hazards such as machine guarding [e.g., Bull et al., 2002] or did not measure machine hazards [Shannon et al., 1997].

Circumstances frequently cited in machine-related amputations reported to the Minnesota Sentinel Event Notification System for Occupational Risks (MN SENSOR) included absence of machine guards; improperly installed or adjusted machine guards; inadequately protective guards; and entanglement of clothing, gloves, or cleaning tools [Boyle et al., 2000]. Although surveillance data indicate that implementing machine guarding and safety management programs is likely to prevent many workplace amputations, as with other studies, MN SENSOR did not directly investigate machine hazards.

In the Minnesota Machine Guarding Study (MN-MGS), an intervention effectiveness trial in 40 small (5–100 employees) metal fabrication firms in the Minneapolis-St. Paul metropolitan region, machines were often found to lack barrier guards and other critical safeguards such as emergency stops [Samant et al., 2006; Parker et al., 2009]. Participants in the MN-MGS received a report with detailed recommendations for improving machine guards and were enrolled in a training program for one year. A follow-up evaluation found improvement of 13% for machine guarding and 23% for safety programs [Parker et al., 2009].

The National Machine Guarding Program (NMGP) was a translational research initiative designed to convert findings from the MN-MGS into prevention programs that can be readily implemented by small businesses. This manuscript describes measures of machine safeguarding and presents baseline data characterizing machine safeguarding practices in 221 small metal manufacturing firms across the United States. A companion paper [Parker et al., 2015] describes the results of safety management program evaluations conducted for the same sample.

MATERIALS AND METHODS

The institutional review boards of the Park Nicollet Institute (PNI) and the University of Illinois at Chicago (UIC) approved all study methods and materials.

The NMGP was carried out in partnership with two workers' compensation insurers. The intervention was designed to provide small businesses (3–150 employees) with a sustainable program to prevent machine-related injuries by implementing applicable standards and industry best practices for machine guarding and safety management programs [Yamin et al., 2014]. Findings from the intervention will be presented in future manuscripts.

After an initial inspection of machine safeguarding equipment and business safety management practices, each participating business received a shop-specific action plan with recommendations for improving machine guarding. Participants were also provided with instructional materials and templates for establishing a safety committee, training employees in lockout/tagout (LOTO), and conducting job hazard analyses (JHAs).

Business Recruitment and Demographics

Participants were recruited from client databases managed by the two insurers. Insurance safety consultants were responsible for recruiting businesses and encouraged to enroll as many eligible businesses as possible. The number of eligible businesses per consultant varied from 1 to 20. Participation rate could not be tracked because of a restructuring of the larger insurer's business model that was enacted during the recruitment phase.

Eligible businesses had to meet the following criteria:

- The primary production activity (≥75%) was metal product manufacturing—North American Industry Classification System (NAICS) subsector codes 332 (fabricated metal products manufacturing), 333 (machinery manufacturing), or 331 (primary metal manufacturing).
- The business had at least three but no more than 150 employees.
- For a business with multiple locations, only one location could participate.
- The business purchased workers' compensation insurance from one of the two partner insurance companies.

Safety Consultant Training

Insurance company safety consultants performed all field work. Fifty safety consultants (38 from insurer A; 12 from insurer B) were trained to conduct a comprehensive evaluation of machine safeguarding equipment and related safety programs. Each consultant attended one of four, 2-day applied training courses. Training took place at technical colleges and afforded the opportunity to assess numerous types of metal fabrication equipment. Each trainee received a coding manual to ensure adherence to study protocols and data collection procedures. Safety consultants were also taught to use software developed for data collection. Software facilitated the random selection of machines, as well as machine safety evaluation using pre-tested checklists, and transmission of results to the research team.

Machine Safety Checklists

Checklists were adapted from those used during the MN-MGS [Munshi et al., 2005; Samant et al., 2006], Checklists were developed to measure the level of adherence to Occupational Safety and Health Administration 1910.212 for machine guarding and 1910.147 for lockout and tagout [OSHA, 2014a,b] and American National Standards Institute B11 standards [ANSI, 2009] for machine guarding. Checklists also covered hazard controls such as chip shields, emergency stops, protective eyewear, proper electrical wiring, clamps and other means of securing the work piece, and housekeeping. Table I provides an example of a checklist. Machine safety checklists covered several classes of metal-working machinery (Table II). The complexity of each checklist varied by machine type, with each containing between 25 and 35 questions. All items were grouped into one of four categories: equipment safeguards, LOTO procedures, electrical, and, work practices and environment. Due to the large number and variety of items within equipment safeguards, subcategories were defined within this group in order to organize checklist items and results by distinct aspects of protective equipment (Table I).

For all checklist items, a "yes" response was to be entered only when a safeguard or other item was observed to be in place, sufficiently protective, and in compliance with applicable standards. In cases where a checklist item was not applicable (e.g., a machine operator was not at the workstation so the item on wearing proper safety eyewear could not be answered), "n/a" was entered. When available, machine age (year of manufacture) and manufacturer were also recorded.

Business Machine Safety Evaluation

At each participating business, a safety consultant placed numbered tags on all machines. The range of tag numbers (e.g., 100–135) was entered into the study software, which randomly selected 12 machines for evaluation. To ensure that a variety of machines was evaluated at each shop, no more than three machines could be selected from any one of the 26 machine types. Businesses with as few as six machines were allowed to participate. Assessments were performed only on machines that were in use, set up for operation, or temporarily idled. All checklist responses were entered into the study software, to generate a summary inspection report and action plan for the business. Machines were not included if they were permanently out of service.

Quality Assurance

For quality assurance (QA), pairs of safety consultants simultaneously assessed machines at three businesses. Safety consultants conducted these assessments without discussing observations or sharing notes. A second QA exercise was conducted among 25 safety consultants. Photographs of five different machines (CNC lathe, vertical mill, surface grinder, drill press, and pedestal grinder) were used to develop a web-based test consisting of 50 items from the corresponding checklists.

Data Analysis

Data were transmitted in plain text format to Park Nicollet Institute. Analysis was performed using SAS [SAS Institute, Inc., 2009] and included mean and standard deviation for continuous variables, and frequencies and percentages for categorical variables. Bivariate analyses including χ^2, *t*-test, ANOVA, and Pearson correlation coefficients were used to explore the relationship between the percentage of missing items on machine safety checklists and shop demographics. Multiple regression was used to determine the relationship between machine age and the percentage of missing items on the machine safety checklists.

Two summary scores were calculated using data from the machine safety checklist evaluation:

- *Business-level machine score*: The total number of "yes" responses for all machines evaluated in a business divided by the combined total of "yes" plus "no" responses on all checklists completed at a shop. Items marked "n/a" were removed.
- *Machine-level score*: The number of "yes" responses recorded on an individual machine safety checklist divided by the combined total of "yes" plus "no" responses marked on the checklist. Items marked "n/a" were removed.

In addition, scores were similarly calculated using results within the four categories of items comprising a machine-level score:

- *Equipment safeguards*: A summary measure of items addressing all aspects of protective equipment, consisting of the following six sub-categories: point of operation safeguards, safeguards for other mechanical hazards, power transmission guards, workpiece control,

TABLE I. Drill Press Machine Safety Checklist

Machine Tag #: ________________ Manufacturer: _________________ Year of Manufacture: _______

	YES	NO	N/A
I. Equipment safeguards			
Point of operation safeguards			
Are shields in place at each point of operation?			
Are shields free from cracks and in good condition?			
Safeguards for other mechanical hazards			
Are spring-loaded chuck keys provided?			
Is the chuck guarded?			
Power transmission guards			
Are all moving parts below 7 ft. guarded?			
Is guard free from cracks and in good condition?			
Workpiece control			
Are clamps provided for preventing workpiece movement?			
Operational controls and emergency stops			
Are all controls legibly marked?			
Are all controls accessible without reaching over rotating/dangerous parts?			
Are safeguards in place to prevent unintended activation of any controls?			
Are all foot controls guarded to prevent unintended activation?			
Are all foot control guards free from cracks and in good condition?			
Is there a red mushroom-shaped emergency stop button that stops all hazardous motion?			
Is an emergency stop readily accessible to each operator?			
Lockable disconnects			
Is a lockable disconnect in place for each energy source?			
Are disconnects in plain view?			
II. LOTO procedures			
Are LOTO procedures posted on or near the machine?			
If posted, answer next 4 questions. If not, enter "no" for all 4.			
Does the LOTO procedure contain specific steps for shutting down and locking out each source of hazardous energy?			
Does the LOTO procedure require that stored energy be eliminated prior to placement of lockout devices?			
Does the LOTO procedure contain specific instructions for verifying the effectiveness of lockout devices and other energy control measures before maintenance is performed?			
Does the LOTO procedure contain specific steps for removing LOTO devices and restoring power?			
III. Electrical			
Are all live electrical components properly enclosed and insulated?			
Are all wires in good condition?			
Is machine powered without the use of extension cords?			
Is strain relief securely in place at both ends of drop cords? (Select "N/A" if there is no drop cord.)			
Are drop cord receptacles free of knockouts, holes, or conductive materials?			
Is auxiliary lighting below 7 ft. properly protected against impact?			
IV. Work practices and environment			
Is the work area free of trip hazards?			
Is the machine adequately stabilized?			
Is machine operator wearing safety glasses with side shields?			
Are all safeguards in place when work is performed (e.g., employees do not attempt to bypass guards)?			
Is machine operator's attire free of entanglement hazards?			
Notes			
Is there additional information that you believe would be helpful, to supplement your answers to the questions in this checklist?			
Please use this space to describe any hazards not covered on this checklist, or to provide additional detail on any of the items in this checklist:			

TABLE II. Metal Fabrication Machinery Included in the Study

Computer numerically controlled (CNC) and screw machines
CNC lathe
CNC mill
Screw machine
Cutting/shearing/sawing machines
Bandsaw—horizontal
Bandsaw—vertical
Ironworker
Metal shear
Milling/drilling/boring machines
Drill press
Lathe—horizontal
Mill—horizontal or vertical
Presses
Hydraulic power press—automatic feed
Hydraulic power press—manual feed
Mechanical power press—automatic feed
Mechanical power press—manual feed:
Full revolution clutch press
Partial revolution clutch press
Turret punch press
Sanding/grinding machines
Belt sander
Disc sander
Pedestal grinder
Precision honing machine
Surface grinder
Other Metal-forming machines
Electrical discharge machinery (EDM)
Hydraulic press brake
Laser cutting machine
Mechanical press brake
Roll forming machine

operational controls and emergency stops, and lockable disconnects.

- *LOTO procedures*: Five items addressed the presence and completeness of LOTO procedures for each machine.
- *Electrical*: Six items addressed the condition and configuration of electrical wiring for each machine.
- *Work practices and environment*: Between six and eight items on each checklist addressed conditions of the work area and employee work practices such as wearing proper safety eyewear.

The kappa statistic was calculated for data collected at sites evaluated by paired safety consultants for QA testing. Established benchmarks for interpreting strength of agreement for categorical data were then applied [Landis and Koch, 1977]. The kappa statistic was also used to evaluate results of the web-based QA test taken by safety consultants.

RESULTS

Business Recruitment and Demographics

Between January 2012 and August 2013, baseline evaluations were conducted at 224 businesses in 31 states. The majority (67%) were located in seven states, with the highest number in Wisconsin (33) and Minnesota (28). Two participating businesses with more than 150 employees were removed from the analysis. One additional business was removed because random selection of machines was not performed. The final sample included 221 shops (Table III).

Businesses enrolled by insurer A (N = 198) had fewer employees on average than those from insurer B (N = 23) (Table III). For both combined, the average size was 30 employees (SD = 28; median = 18; range 3–150). The mean business-level machine score was not significantly different between participants enrolled by the two insurers ($P = 0.26$), although when adjusted for business size (number of employees), there was a 5%

TABLE III. Business Demographics

Demographic category	Insurer A	Insurer B	Combined
Number of evaluators	38	12	50
Geographic regions			
Northeast: CT, DE, MA, ME, NJ, NY, PA, VT, NH	28	23	51
Southeast: AL, AR, FL, GA, KY, NC, SC, TN, VA	38	0	38
North central: IA, IL, IN, MI, MN, SD, WI	106	0	106
Southwest: AZ, KS, MO, NE, NM, TX	26	0	26
Number of employees			
All shops	198	23	221
3–10	58	2	60
11–29	80	2	82
30–49	30	6	36
50–150	30	13	43
Demographic comparison			
Mean business size	26 (SD = 24)	63 (SD = 42)	$P = 0.0004^*$
Mean years in business	30 (SD = 17)	32 (SD = 15)	$P = 0.71^*$
Business-level machine scores			
Mean score	74% (SD = 9%)	71% (SD = 13%)	$P = 0.26^*$
Mean score, adjusted for business size	LSmean = 74% (SE = 1%)	LSmean = 69% (SE = 2%)	$P = 0.02^*$

LSmean, Least square mean (mean score adjusted for business size).
*All *P*-values for this table are for difference between insurers.

difference ($P = 0.02$) (Table III). Subsequent analyses were performed using the combined sample of 221 businesses.

Business-level Machine Scores

A total of 2,632 machines were evaluated at the 221 study sites. The requisite 12 machines were evaluated in all but seven businesses. The average business-level machine score was 73% (SD = 11%; range = 43–97%), with mean scores of 80% or higher for each of the four assessment categories except LOTO procedures (mean = 9%) (Table IV). Mean scores for subcategories within the equipment safeguards group were relatively high aside from point of operation safeguards (mean = 67%) and safeguards for other mechanical hazards (mean = 72%).

Business-level machine score was not significantly related to business size (Table V). Within the four subcategories, no significant relationship with business size was observed except for LOTO procedures ($P = 0.006$). Business-level machine score did not differ significantly based on geographic location, years in business, or between participants under the jurisdiction of a federal (n = 123) or state-based (n = 98) OSHA program.

TABLE IV. Business-Level Machine Scores for 221 Business

	Mean %	SD
Equipment safeguards	80	10
Point of operation safeguards	67	19
Safeguards for other mechanical hazards	72	16
Power transmission guards	92	11
Workpiece control	83	15
Operational controls and emergency stops	83	11
Lockable disconnects	87	19
LOTO procedures	9	24
Electrical	92	10
Work practices and environment	89	9
Business-level machine score (total)	73	11

Machine-Level Scores

Average machine-level scores were highest for CNC/screw machines and lowest for milling/drilling/boring machines (Table VI). Among the four category scores, range across machine classes was widest for equipment safeguards (62–93%). A perfect score for equipment safeguards was received by 621 machines (24%) and 943 (36%) received a score of 80–99%. However, 658 (25%) received a score ≤67% (data not shown in table).

TABLE V. Business Size and Machine Safety Scores

		Business-level machine score	Equipment safeguards	LOTO procedures	Electrical	Work practices and environment
Size range	n	Mean %	Mean %	Mean %	Mean %	Mean %
All shops	n = 221	73	80	9	92	89
3–10 employees	n = 60	72	78	3	93	89
11–29 employees	n = 82	74	81	7	92	90
30–49 employees	n = 36	74	81	12	92	88
50–150 employees	n = 43	75	82	19	89	87
	P-value	0.08	0.09	0.006	0.08	0.37

TABLE VI. Assessment Machine Scores by Class of Machinery

	Score as percent of correct responses (SD)				
Machine class	Machine-level score	Equipment safeguards	LOTO procedures	Electrical	Work practices and environment
CNC/screw machines (N = 722)	80 (9)	93 (10)	7 (25)	96 (12)	93 (15)
Cutting/shearing/sawing (N = 337)	78 (14)	86 (14)	12 (31)	90 (20)	87 (22)
Milling/drilling/boring (N = 704)	62 (15)	62 (18)	9 (27)	91 (17)	88(20)
Presses (N = 105)	75 (15)	83 (16)	21 (38)	92 (17)	92 (15)
Sanding/grinding (N = 562)	76 (14)	80 (16)	7(25)	90 (18)	89 (20)
Other (N = 202)	74 (14)	83 (17)	17 (34)	92 (15)	89 (18)
All machines (N = 2,632)	73 (15)	80 (19)	10 (28)	92 (17)	90 (19)

TABLE VII. Number of Machines for Which the Age Could Be Determined

Machine class	Total assessed	Number: age known (%)	Mean age in years (SD)
CNC/screw machines	722	477 (66)	14 (10)
Cutting/shearing/sawing	337	124 (37)	25 (17)
Milling/drilling/boring	704	243 (35)	33 (18)
Presses	105	44 (42)	32 (15)
Sanding/grinding	562	134 (24)	31 (19)
Other metal-forming	202	101 (50)	19 (13)
Total for all machines	2632	1123 (43)	22 (17)

Age was obtained for 43% (1,123) of machines (Table VII). Overall mean age was 22 years (range = 0–83 years), with milling/drilling/boring machines being the oldest (mean = 33 years) and CNC/screw machines the newest (mean = 14 years). When machines were sorted into four age strata (Table VIII), equipment safeguards scores decreased significantly with increasing age for all machines combined ($P < 0.0001$) and within most classes of machinery. Within a business, mean machine age was calculated for the 87 shops in which age was known for at least six machines. Mean machine age did not differ significantly with business size ($P = 0.61$).

Regression modeling showed that each year of machine age corresponded to a 0.5% decrease in equipment safeguards score (SE = 0.03%; $P < 0.0001$). The effect was smaller on machine-level score—a drop of 0.3% per year of machine age (SE = 0.02%; $P < 0.0001$)—as the relationship between age and scores was very slight for electrical (−0.1%/year; SE = 0.03%; $P = 0.01$) and work practices and environment (−0.1%/year; SE = 0.03%; $P = 0.03$), and non-existent for LOTO procedures (0.0%/year; SE = 0.03%; $P = 0.82$).

Quality Assurance

The kappa statistic for combined total responses collected at all three shops was 0.74 (substantial agreement) [Landis and Koch, 1977]. Average score on the 50-item web-based evaluation was 93%. Kappa statistic for the 25 safety consultants who took the on-line quiz ranged from 0.65 to 1.00 (mean 0.87).

DISCUSSION

State-based injury surveillance indicates that amputations remain a persistent problem within industrial settings and that violation of OSHA machine guarding regulations and related standards is common [Friedman et al., 2013; Largo and Rosenman, 2015]. Baseline data from the NMGP demonstrate that there is a need to improve many aspects of machine safety in small metal fabrication businesses. On average, 33% of guards at the point of operation were missing or inadequate. These results are comparable to the MN-MGS, which found that 38% of guards were missing [Samant et al., 2006].

NMGP shops were lacking an average of 28% of safeguards for mechanical hazards outside the point of operation. Examples of these hazards include rotating lead screws (on lathes), automated feed lines, periphery of abrasive wheels, and length of sanding belts and other moving or rotating parts such as pinch points—those parts of the machine where a body part or article of clothing may be caught and pulled in, causing serious injury.

TABLE VIII. Machine Age and Equipment Safeguards Score

	Mean equipment safeguard score (N)					Mean equipment safeguard score (N)	
Machine class	≤10 years	11–25 years	26–49 years	≥50 years	*P*-value for trend across age strata	All machines, age known	All machines, age unknown
CNC/screw machines	96 (215)	93 (219)	88 (37)	78 (6)	<0.0001	94 (477)	91 (245)
Cutting/shearing/sawing	92% (28)	91% (39)	86% (46)	75% (11)	<0.0001	88% (124)	86% (123)
Milling/drilling/boring	73% (24)	66% (63)	63% (109)	63% (47)	0.03	65% (243)	60% (461)
Presses	66% (2)	89% (12)	84% (26)	77% (4)	0.77	84% (44)	82% (61)
Sanding/grinding	86% (16)	85% (46)	78% (53)	79% (19)	0.02	81% (134)	79% (428)
Other metal-forming	94% (27)	86% (52)	79% (17)	88% (5)	0.001	87% (101)	80% (101)
Total for all machines	93% (312)	87% (431)	75% (288)	71% (92)	<0.0001	84% (1123)	76% (1509)

Businesses participating in this study had lockable disconnects on 87% of machines; however, LOTO procedures were posted and adequate on only 9% of machines. Lockable switches for disconnecting sources of power to a machine during maintenance and repair are a basic component of LOTO. However, equipment such as lockable disconnects will only protect workers if used properly in accordance with correctly written LOTO procedures and employee training. Posting LOTO procedures at machine workstations ensures that machine-specific LOTO instructions will be available at the workstation for use when service or maintenance is performed [Rutter, 2005]. Although OSHA regulations [OSHA, 2014b] do not require LOTO procedures to be posted on each machine, the advisory panel convened for this study considered this to be an important means of facilitating correct LOTO practices.

Both machine guarding and LOTO are among the most frequent reasons for OSHA citations. For all U.S. manufacturing (NAICS 31, 32, 33) firms with fewer than 250 employees, the OSHA general machine guarding standard [OSHA, 2014a] was the fourth most frequently cited standard for the 12-month period ending September 2014, accounting for 7% (1,686/22,789) of all citations [OSHA, 2015a]. LOTO was the second most frequently cited standard, comprising 9% (2,040/22,789). This was exceeded only by hazard communication, which comprised just under 10% of citations [OSHA, 2015a].

Within the same parameters, fabricated metal products manufacturing (NAICS 332) was the most cited industrial sub-sector for machine guarding (610 citations); machinery manufacturing was second (189 citations). Other frequent machine-related citations for this sector included abrasive wheel machinery, power transmission apparatus, and mechanical power presses. Metal fabrication was also the most cited sub-sector for LOTO, accounting for 26% (538/2,040) of LOTO citations in all manufacturing, and far exceeding the next highest sub-sectors of food (186 citations) and wood product manufacturing (182) [OSHA, 2015a].

In the MN-MGS, 20 out of 40 shops had received an OSHA inspection within 1 year prior to the intervention. There was no difference in machine guarding audit score between those receiving an inspection and not ($P = 0.64$) [Samant et al., 2006]. The ongoing failure of metal fabrication businesses to implement adequate machine guarding and LOTO practices indicates a need for OSHA to continuously target machine guarding and LOTO. Although it is difficult to assess, it is also likely that OSHA inspectors need to more methodically and comprehensively evaluate machines to assure that all aspects of machine safety are assessed, a need also noted by Friedman et al. [2013].

NMGP data support previous research [Gardner et al., 1999] finding that older machines were both widely used and less likely than newer machines to be properly guarded. The effect of machine age may be challenging to overcome, as financial resources and technical expertise are often required to retro-fit guards. While safeguards for metal fabrication machinery can cost hundreds or thousands of dollars, these costs should be weighed against the economic and personal cost of serious traumatic injuries: The average total cost to a business of a workplace amputation is estimated at $133,000, $111,000 for a crush injury, and $95,000 for a fracture [OSHA, 2014c].

LIMITATIONS

There are several limitations to the data presented here. Simultaneous assessment of machines was performed by pairs of trained safety consultants at a few shops to assess inter-rater reliability. However, it was not possible to complete this process with all safety consultants. The insurers determined it was too costly to have more than a few consultants test inter-rater reliability because of travel expenses, logistical considerations, and additional days spent away from regular loss control work. However, 25 consultants participated in a web-based quality assurance exercise, which demonstrated consistency of responses.

An additional limitation is that participating businesses were not randomly selected. The insurers recruited as many clients as possible who met study eligibility criteria. Neither safety performance nor loss history were a prerequisite for participation. Recruiting over 200 businesses to participate in an intervention was challenging even for insurance safety consultants who had ongoing and long-term relationships with owners and managers. The original intent was to recruit businesses with 100 or fewer employees, however, difficulties related to recruitment as well as needs expressed by the insurers led us to increase the size of participating businesses to 150. In retrospect, this was fortuitous as it allowed greater stratification by size.

CONCLUSIONS

Baseline results from the NMGP point toward opportunities to improve important aspects of machine safety in small metal manufacturing businesses. Safeguards were frequently absent or inadequate for hazardous areas of machines such as the point of operation and other moving parts. Elements of critical machine safety programs such as LOTO were also found lacking. An integrated approach to machine safety should include enhancements to safeguarding equipment as well as low-cost measures such as development and posting of machine-specific LOTO procedures. OSHA inspections should ensure the assessment of all aspects of machine guarding. This effort should be enhanced by the implementation of new OSHA reporting requirements for amputation injuries [OSHA, 2015b].

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