

Brief Report

Machine Safety Evaluation in Small Metal Working Facilities: An Evaluation of Inter-Rater Reliability in the Quantification of Machine-Related Hazards

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Background Each year there are an estimated 4.2–6.7 amputations per 10,000 workers in the metal fabrication trades in the United States. The Minnesota Machine Guarding Study evaluates the effectiveness of a peer-based technical and educational intervention designed to reduce exposure to amputation hazards among workers in small machining/metal working shops. The study reported here involved the development and evaluation of methods for measuring machine safety, which will be used in the intervention study.

Methods Using OSHA regulations, ANSI standards, and industry best practices, we developed 23 machine-safety scorecards. The safety scores were dependent on the presence or absence of guards, other safety devices and implements, and the presence or absence of acceptable administrative programs. Inter-rater reliability was assessed for the evaluation of eight types of commonly used metal fabrication machines.

Results Of the 23 most common types of machines, there were a sufficient number of machines to evaluate inter-rater reliability for eight types. Three raters in four shops assessed fifty-nine machines. Overall, the kappa statistic ranged from 0.57 to 0.84, indicating good to very good concordance between raters. In general, machines did not fare well with regard to compliance with current standards.

Discussion The ability to assess machine-related hazards is important in industries where it is difficult to identify and count injuries in a timely fashion. Machinists and safety professionals may use this scoring system as a means of reproducible assessment of machine safety. *Am. J. Ind. Med.* 48:381–388, 2005. © 2005 Wiley-Liss, Inc.

KEY WORDS: machine safety; intervention evaluation; hand injury; inter-rater reliability

BACKGROUND AND INTRODUCTION

Amputations are a serious and preventable cause of injury and disability. In 1999, there were about 10,000 cases of non-fatal workplace amputations. Approximately one-third of these victims required at least 31 days away from work to recuperate. Between 1992 and 1999, an average of 21 fatal and 11,000 non-fatal workplace amputations occurred each year [Boyle et al., 2000a; CDC, 2002].

The incidence of occupationally related amputations is highest among workers in metal and wood working

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industries [Olson and Gerberich, 1986; Sorock et al., 1993b; Boyle et al., 2000b; Stanbury et al., 2003]. In 1999, 44% of all nonfatal workplace amputations resulted from workers being caught in running equipment or machinery [CDC, 2002]. In the metal forming industry, the annual rate of non-fatal workplace amputations is 2.9–3.7 per 10,000 full-time workers and exceeds the rate of 1.1–1.6 in all manufacturing businesses by three to four times. The rate of non-fatal amputations per 10,000 workers is even higher in some sectors of the metal working industry, ranging from 4.2 to 6.7 in the fabricated metal products industries [CDC, 2002].

Fingers are involved in approximately 90% of work-related amputations. These injuries may affect a worker's job skills and reduce earning capacity. Results of one study indicated that 22% of workers who sustained finger amputations had to give up their original employment [Gruneberg and Spence, 1974]. Many affected workers are young, with almost one-fourth of injured workers are under 25 and almost one-half under 35 years of age [Boyle et al., 2000a].

Between 1995 and 1997, the Minnesota Sentinel Event Notification System for Occupational Risks (MN SENSOR) surveillance data indicated that machine guards were in use at the time of injury for only one-third of the amputation incidents. Inadvertent activation of equipment, defective tools or machines, or the absence of guarding were reported for almost 75% of amputation injuries and cited by victims as contributing to their injury events [Boyle et al., 2000a,b].

These factors indicate the potentially preventable nature of amputations. Reducing amputations is likely to lead to reduction in other types of upper extremity machine-related trauma (e.g., crush injuries and lacerations). Minnesota workers' compensation data indicate that there were approximately 1,700 upper extremity traumatic (non-cumulative) injuries during 1996–1997 in the metal working industry.

The Occupational Safety and Health Administration (OSHA) introduced several machine guarding standards in 1971. Specific OSHA regulations have also been developed for lockout and tagout procedures (e.g., OSHA 1910.147) as well as machine safety (OSHA 1910, subpart O) [OSHA, 2004a]. Many of these regulations were adopted from early American National Standards Institute (ANSI) standards developed prior to 1971. The ANSI has also developed standards for machine safety and evaluation over the life cycle of a machine (ANSI B11) [ANSI, 2002].

Interpretation of OSHA's and ANSI machine guarding regulations and guidelines is difficult, due to their voluminous nature and technical content. These difficulties are compounded in small businesses, which often lack the occupational safety and health resources necessary to interpret and implement standards.

In response to the need for interventions to lower the risk and rate of amputations in small metal working businesses,

we proposed the Minnesota Machine Guarding Program. When completed, this NIOSH-funded study will compare the effectiveness of two different educational interventions in small metal working businesses (10–100 employees). It will test the hypothesis that the availability and use of machine guarding will be greater after an intervention directed at both the owners and workers in comparison to an intervention directed only at owners. In order to do this study, an instrument was needed to assess the safety of the machines. An extensive search revealed no validated instruments for quantitative assessment of machine safety.

We describe here the development and appraisal of a machine safety scorecard. The scorecard will be used in the main intervention study to measure baseline and follow-up conditions in metal fabrication shops. Scorecard results will also be used to tailor intervention activities for each site. We developed scorecards for assessing the safety of 23 different machines in eight categories and measured inter-rater reliability in four small metal working businesses.

MATERIALS AND METHODS

Advisory Board Activities

An Advisory Board was convened consisting of shop owners, safety engineers, a representative from the Minnesota Occupational Safety and Health Administration (MNOSHA), and a union representative from affected trades. The Advisory Board was asked to assist with all aspects of shop evaluation as well as intervention development, and implementation.

Among other tasks, members identified the most common machines in use within the metal working trades. They also recommended that we provide owners and workers with interactive access to OSHA and ANSI machine guarding standards. Safety engineers on the Advisory Board provided the study with proprietary machine guarding checklists as a starting point for the development of machine safety scorecards.

Developing a Machine Safety Scorecard

Initially, scorecards were developed for simpler machines such as pedestal grinders. As we progressed, scorecards were developed for larger and more complicated machines such as mechanical power presses. These machines were considered more complicated from a safety point of view because the nature of their use is variable as well as having a large number and type of parts that require guarding.

For example, a mechanical power press may be used for operations involving a worker's hands within or outside of the area of the die (i.e., point of operation). The guarding needed for each of these operations is different depending on the type of operation. A mechanical power press used in a hands-out-of-die configuration (i.e., working outside the pinch

point) can be adequately guarded with a barrier guard. When the same machine is used in a hands-in-die configuration, more complex guarding (e.g. two hand controls, pull backs, light curtains) is required.

All scorecards were reviewed for completeness and accuracy by staff from MNOSHA, a safety consultant, two machinists, and two machine shop owners. Four experts (two machinists, a MNOSHA machine guarding consultant, and a safety engineer) then independently rated the importance of each item. The four experts were subsequently brought together to develop a consensus on the importance of each item as well as the accuracy and completeness of the scorecards. A consensus was reached for all scorecards.

Machine scorecards form the basis of the quantitative assessment of machines within shops. During this pilot study, shop personnel were provided a summary of each machine that was evaluated within their shop, a graphic presentation of how their machines compared with those in other shops, and a complete set of machine scorecards, and related documentation for their use. Personnel in all pilot shops were trained in the use of the machine scorecards as part of a larger intervention program. All materials were used as part of a larger randomized intervention trial.

Inter-Rater Reliability

We measured the reproducibility of the machine safety scorecards by comparing their use by three different raters (machinist, industrial hygienist, and safety consultant). All of the raters were experienced in hazard evaluation. Two of the raters received 2 days of training. The third rater, a machinist, was experienced in machine evaluation and had worked for several years assessing machine safety. This rater had received prior training in machine assessment.

Raters were trained at three locations: a technical school, a metal stamping facility, and a custom metal fabrication shop. The comments and suggestions of the raters led to modifications to the scorecards. A safety engineer and consultant from MNOSHA reviewed modifications. Changes were made to improve the specificity in identifying machine hazards using the scorecards.

As part of their training, each rater scored every machine in a large custom fabrication facility. The results for each rater were compared and differences were adjudicated prior to leaving the shop floor. This was done to assure consistency among raters as well as to refine the criteria used to score each item on different machines.

To minimize subjectivity, raters received machine-specific listings of OSHA and ANSI standards for each item on the scorecards. For example, emergency stops could not be just a red stop button. Rather, the stop button needed to be readily accessible and mushroom shaped. Similarly, safety blocks used during repair and maintenance had to be visible, near the machine, and made from a non-crushable material.

Decision criteria were compiled into a single list and provided to the raters. Lists were updated on an ongoing basis during the training period. To evaluate inter-rater reliability, the three raters were asked to score selected machines at four pilot locations. Prior to scoring, all non-portable machine tools in the shop were compiled onto a complete list and numbered by one of the three raters. Machines were then randomly selected to reflect a range of complexity and type. Except for one shop, all machines were assessed during the same day. This was done to assure that machine configuration was not changed between raters. Raters worked individually and did not discuss their decisions during the evaluation.

Data Analysis

Data were entered into a Microsoft Access database and analyzed using SAS statistical software [The SAS System, 2000]. Inter-rater reliability was assessed using the kappa statistic [Fleiss, 1981], which ranges from -1 to $+1$. A value of $+1$ indicates complete agreement among the raters while a value of zero or less indicates very little agreement. According to Craigie et al. [2002] and Landis and Koch [1977], a kappa value equal to or greater than 0.75 represents excellent reliability, and a value between 0.4 and 0.74 represents fair-to-good reliability.

RESULTS

Advisory Board Activities

The Advisory Board identified 23 machines commonly used in metal fabrication. In addition, they helped identify the most common products and processes found in the Twin Cities metropolitan area.

Shops

Inter-rater reliability was assessed in four pilot shops. Shop one was a custom stamping facility, a second fabricated metal fixtures, a third made custom cabinets and metal casings, and the fourth fabricated custom metal parts and safety devices. All shops had been in business between 50 and 55 years. The smallest shop had 18 employees of whom 14 worked in the shop and the largest had 91 employees of whom 79 worked in the shop. Advisory Board participants owned two shops and two shops were recruited with assistance from members of the Advisory Board.

Developing a Machine Safety Scorecard

We developed a scoring system to measure different aspects of machine safety. Each scorecard followed the same general format: guarding the machine at the point of

operation; guarding of moving parts that might be potentially accessed by the worker; adequate labeling of safe work practices and machine specifications; readily accessible and protected operational and emergency controls; proper disconnects that can be locked and tagged; and general work environment (e.g., free from debris). These items represent elements of the machine or a machine-related safety program that if missing or faulty would increase the likelihood of injury.

In addition, we followed the principles for machine guarding operations that include: preventing worker contact with moving parts; firmly secured to the machine; preventing objects from falling into moving parts; creating no new hazards; not interfering with work; and allowing safe lubrication. We also determined that lockout/tagout procedures were key to ensuring machines were used safely [OSHA, 2005; OSHA, 2004b; Martin, 1992].

An example of a scorecard for a pedestal grinder is seen in Figure 1. Every item or element for each machine is given a

priority 1, 2, and 3. To reflect the importance of these priorities, these scores were weighted 6, 3, or 1, respectively. Each machine could receive a maximum score of 100 if all items were present and of an acceptable standard. The score for each item is 1 if it is rated “yes” for being acceptable, 0 if it is rated “no”, or 0.5 if it was not assessable at the time of evaluation. Scores were provided the appropriate weighting by item and priority and then summed.

The assignment of a priority to each item was based on two factors: general consensus among the experts that an injury might occur if an item (e.g., a barrier guard) was missing or not properly functioning, and the potential severity of an injury. High priority items were those that are most likely to cause a serious injury if missing or faulty. Medium priority items were those that were likely to cause less severe injuries or injury was unlikely to occur but might be less severe if it took place. Low priority items were those requiring remediation to reach full compliance with ANSI or OSHA standards, but were unlikely to cause serious injury if

Item	Present	Absent	Not Assessable	Priority
Tongue guard				
Present	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1
Distance from wheel not more than ¼ inch	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2
Good condition (no cracks, clean)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1
Yellow color	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	3
Tool-rest				
Distance from wheel 1/8 inch or less	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1
Good condition	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1
Yellow color	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	3
Moving Parts (belts, pulleys, chains, sprockets) guard				
Guard present	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1
Guard yellow in color	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	3
Moving parts orange in color	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	3
Guard in good condition (no cracks, clean)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1
Abrasive wheel				
Good condition (not cracked)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1
Coasting time less than 1 minute	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	3
Rated speed of the grinding machine does not exceed the rated speed of the grinding wheel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1

FIGURE 1. Sample Machine Guarding Scorecard: Pedestal Grinder*; the Minnesota Machine Guarding Study. *This is a partial scorecard due to the length required for more complete publication. Scorecards may be obtained by contacting the authors.

absent. If an item could not be evaluated at the time of inspection it was labeled as not assessable.

For example, an emergency stop that is accessible to the machine operator is required for all machinery and was given a priority one. However, the color of the emergency stop was rated separately and was given a priority level three (a stop should be red with a yellow background). On the other hand, the absence of a barrier guard was considered a level one priority due to the likelihood and severity of any injury resulting from a person's hand being caught in a die.

Scorecards were accompanied by drawings of each type of machine with critical parts labeled. The scorecards were formatted for ease of use and data scanning. Information describing how to score each item was provided to the raters.

Because criteria used by OSHA and ANSI are not identical, evaluation criteria for the checklists were based on what was judged to be most protective and effective in preventing worker injury. In the absence of epidemiological data linking machine type (e.g., punch press, horizontal lathe) to injury incidence or severity it was not possible to ascertain which machines were more or less dangerous. Thus, we decided that all machines were equally dangerous and carried equal weighting in an overall score of a business' machine safety.

Inter-Rater Reliability

The overall mean score for the 25 machines assessed in each shop were 74.5, 69.4, 66.6, and 73.2, respectively. Three raters assessed a total of 179 machines at four businesses. Hereafter, data are presented for those eight categories that contained at least five machines assessed by all three raters—a total of 59 machines.

As shown in Table I, the score for individual machine types ranged from 34 to 72. Hydraulic power presses received the highest scores (71–72) and full-revolution mechanical

presses with hands in die received the lowest (34–45). Scores for pedestal grinders were the most variable, with standard deviations ranging from 10 to 14 for the high, medium, and low priority items. Variability for all other machines was generally much less (standard deviations ranging from 3 to 10). Most machines received scores in a fairly narrow mid-range (55–65).

Most machines had kappa statistics for all items demonstrating fair to good reliability (0.4–0.75) (Table II). In general, medium priority items were scored with higher reliability (kappa > 0.8) than those with low or high priority. Only the full revolution press with hands in die fell below this level (kappa = 0.63).

The reliability of both high and low priority items was generally lower and more variable across all machine types, ranging from 0.5 to 0.8. Full revolution presses with hands in die were the most difficult to assess, showing kappa values between 0.5 and 0.63 for high, medium, and low priority items.

The mechanical power press—hands in die full revolution (MPP-hands in)—shows a low mean score of 41.1/100. The kappa statistic as shown in Table II for this machine although considered acceptable at 0.57 is at the lower end of the spectrum obtained for the different machines. One reason for the low kappa could be to the complex nature of the MPP-hands in die, which is also true of other mechanical power presses.

Evaluation of the raters indicated that one individual consistently scored lower than the other two. The two raters whose results matched closely were offered training in the time frame immediately preceding the study, in the same facilities by the same trainer. However, the rater that depreciated the kappa had received his training at a different time and in a different format.

As seen in Table II, the mean score for the eight different machines rarely reached 70 out of a possible 100 points.

TABLE I. Scores for Eight Categories of Machines Rated by the Three Observers: Mean and Standard Deviation; the Minnesota Machine Guarding Study

Machine type ^a	Rater 1 mean (standard deviation)	Rater 2 mean (standard deviation)	Rater 3 mean (standard deviation)	All raters
DP	53.9 (4.3)	52.1 (3.9)	60.3 (3.1)	55.4
HPP	71.8 (5.0)	72.4 (4.5)	71.1 (3.3)	71.8
MPPHIFR	34.2 (6.8)	44.3 (5.5)	44.8 (3.3)	41.1
MPPHIPR	63.2 (5.3)	60.3 (3.4)	66.8 (2.0)	63.4
MPPHO	60.2 (6.0)	58.2 (6.6)	65.6 (6.9)	61.3
MS	63 (4.5)	62.4 (5.8)	60.4 (4.3)	62.1
PG	57.1 (10)	50.4 (10)	51.4 (14)	52.9
VMM	44.8 (7.6)	51.6 (6.3)	49.4 (9.7)	48.6

^aDP, drill press; HPP, hydraulic power press; MPPHIFR, mechanical power press hands in die full revolution; MPPHIPR, mechanical power press hands in die part revolution; MPPHO, mechanical power press hand out of die; MS, metal shear; PG, pedestal grinder; VMM, vertical milling machine.

TABLE II. Reliability of Three Raters of Machine Safety; the Minnesota Machine Guarding Study

Machine type ^a	Number of machines (N = 59)	Kappa statistic			
		All items	High priority items	Medium priority items	Low priority items
DP	10	0.75	0.64	0.89	0.62
HPP	7	0.84	0.77	0.91	0.74
MPPHIFR	8	0.57	0.52	0.63	0.54
MPPHIPR	9	0.71	0.60	0.87	0.53
MPPHO	9	0.73	0.65	0.81	0.71
MS	5	0.67	0.51	0.80	0.67
PG	5	0.79	0.60	0.88	0.82
VMM	6	0.72	0.63	0.80	0.76

^aDP, (fill in) DP, drill press; HPP, hydraulic power press; MPPHIFR, mechanical power press hands in die full revolution; MPPHIPR, mechanical power press hands in die part revolution; MPPHO, mechanical power press hand out of die; MS, metal shear; PG, pedestal grinder; VMM, vertical milling machine.

These scores indicate that few machines were likely to be fully guarded and in compliance with current machine guarding recommendations and requirements. In addition, the small range of scores between raters confirms the generally high kappa statistics that were found.

DISCUSSION

The primary goal of this development and testing phase of the Minnesota Machine Guarding Program was to create an easy-to-use method for analyzing and prioritizing the amputation and other injury hazards of metal working machines and ensuring that machines were in compliance with current standards. Scorecards were developed in such a way as to accurately reflect the true status of a machine while minimizing subjective opinions about their potential to cause injury.

Scorecards were also developed in a way that allows machine operators to assess their own equipment, prioritize the remediation of problems, compare and rate themselves against a consistent standard, and provide machine-specific access to the applicable OSHA and ANSI standards. Scorecards are provided to owners and workers along with instructions with regard to each item on a machine. These descriptions facilitate their use by minimizing the need to search for standards and use voluminous documentation.

The scorecards accomplish two basic functions: They allow for the quantification of machine safety for epidemiological purposes; and they allow for the identification and prioritization of safety-related problems within a specific shop.

Most workers are aware of hazards at the point of operation (i.e., the place where a tool cuts a piece of material). However, there are many aspects of machine guarding that are often neglected. The complexity and voluminous nature of machine guarding standards means that machines are often

inconsistently guarded and safety personnel and machine operators overlook many aspects of machine safety.

Machine scores from our pilot study in four small metal working businesses indicate that few machines are likely to be fully guarded and in compliance with current machine guarding regulations and standards. Although the number of shops and machines in this pilot study is small, overall scores for machine guarding were low. This was true for items in all three priority categories.

We demonstrated that different trained raters can reliably score machines, and scorecards are a useful and valid instrument for assessing baseline and follow-up evaluation of machine safety. Items necessary to machine safety were determined by evaluating the literature and by seeking input from experts. Pilot testing was used to document the decisions necessary for properly identifying the status of each item.

The Minnesota Machine Guarding Program scorecards were developed as a means of machine-related hazard analysis in which dangerous processes are identified and preventive measures can subsequently be implemented [Mattila, 1985, 1988, 1989; Mattila and Kivi, 1991]. In a study by Feldman et al. [1987], biomechanical analysis of workers in an electronics assembly plant was used to assess risk for carpal tunnel syndrome. Similarly, there have been other risk assessments done by measuring an entity that serves as a proxy for the actual injury itself [Babski-Reeves and Crumpton-Young, 2003].

Machine safety scores are dependent on the presence or absence of guards and other devices and implements on the machine. In many respects, these scores are similar to biomechanical risks described above [e.g., Babski-Reeves and Crumpton-Young, 2003]. However, it is difficult to link machine safety scores directly to the prevention or incidence of new injuries. This problem arises because the

relative infrequency of events would require a large and costly study.

Machines used in the metal working industry are often dangerous because they have many moving parts operating at high speeds and pressure. In addition, there is the risk of unsecured metal stock being shot at workers at high speeds, it is also possible that a machine part (e.g., grinder wheel) or product might explode causing serious injuries to the operators or those in the vicinity of the machine.

Injuries result from missing guards, failure to use guards when they are available, or failure to follow safe procedures. Thus, guarding and the programs, policies, and procedures that govern their use are both key to preventing machine-related injuries.

The major limitation of shop scorecards is the inability to link them back to epidemiological data on hand injury. Data are not available that examine the relationship between different aspects of machine guarding programs (e.g., lock out/tagout, barrier guards) and the occurrence of amputation and other hand injuries. Boyle et al. [2000a] note the persistent absence of machine guards at the time amputation injuries occur; however, the data do not indicate the type of machine in use at the time of injury. Stanbury et al. [2003] indicate that power presses are a major cause of amputation injury, however there is no delineation why injuries took place.

The second limitation of this study is the inability to determine which items related to machine safety were the most critical. In the absence of data on what parts of machines cause hand injuries and amputations, it was necessary to convene a group of experts to make a decision as to which items were critical and which items were of potentially less importance. Thus, a consensus panel determined the importance each items.

CONCLUSIONS

In the current study, we found good inter-rater reliability in the evaluation of serious machine-related hazards. Using machine safety scores (rather than injury rates) as a measure of outcome offers a potentially useful instrument in the evaluation and management of risk. Just as repetitive motion, which is measurable, represents one of the risk factors for the outcome of carpal tunnel syndrome, we propose the use of machine safety scores as a means of measuring injury risk. Scorecards may also be used by workers to consistently assess hazards within their work environment.

These scorecards offer a potentially strong epidemiological instrument that can be used as a proxy for injury data. Even when surveillance data can be used to track a problem such as amputation injury [e.g., see Boyle et al., 2000a,b], data are compiled from a wide geographic area and it is not

possible to assess in a timely fashion those machines that caused injury.

REFERENCES

- American National Standards. 2002. Standards for machine tools: ANSI B11-13. McLean, VA: American National Standards Institute.
- Babski-Reeves K, Crumpton-Young L. 2003. The use of continuous exposure data for predicting CTS in fish processing operators. *Ergonomics* 46:747–759.
- Boyle D, Parker D, Larson C, Pessoa-Brandao L. 2000a. Nature, incidence, and cause of work-related amputations in Minnesota. *Am J Ind Med* 37:542–550.
- Boyle D, Larson C, Parker D, Pessoa-Brandao L. 2000b. Medical, personal, and occupational outcomes for work-related amputations in Minnesota. *Am J Ind Med* 37:551–557.
- Centers for Disease Control, National Institute for Occupational Safety and Health. 2002. Amputations: A continuing workplace hazard! Retrieved March 5, 2003 from the World Wide Web: http://www.cdc.gov/niosh/sbw/public_health/pdfs/jeffbrown.pdf
- Craigie M, Loader B, Burrows R, Muncer S. 2002. Reliability of health information on the internet: An examination of experts ratings. *J Med Internet Res* 4:e2.
- Feldman RG, Travers PH, Chirico-Post J, Keyserling WM. 1987. Risk assessment in electronic assembly workers: Carpel tunnel syndrome. *J Hand Surg (Am)* 12A(Pt 2):849–855.
- Fleiss JL. 1981. The measurement of inter-rater agreement. In: *Statistical methods for rates and proportions*, 2nd edition. New York: John Wiley & Sons, Inc., p 212–236.
- Gruneberg R, Spence AJ. 1974. Finger amputations and ability to work. *Hand* 6:236–242.
- Landis JR, Koch GG. 1977. The measurement of observer agreement for categorical data. *Biometrics* 33(1):159–174.
- Martin KJ. 1992. Machine safety. Proper safeguarding techniques. *AAOHN J* 40:279–283.
- Mattila MK. 1985. Job load and hazard analysis: A method for the analysis of workplace conditions for occupational health care. *Br J Ind Med* 42:656–666.
- Mattila M. 1988. Job load and hazard analysis: A co-operative approach to identify and to prevent ergonomic and other hazards at work. In: Aghazadeh F, editor. *Trends in ergonomics/human factors V*. New York: North Holland, p 559–565.
- Mattila M. 1989. Improvement in the occupational health program in a Finnish construction company by means of systematic workplace investigations of job load and hazard analysis. *Am J Ind Med* 15:61–72.
- Mattila M, Kivi P. 1991. Hazard screening and proposals for prevention by occupational health service: An experiment with job load and hazard analysis at a Finnish construction company. *J Soc Occup Med* 41:17–22.
- Occupational Safety and Health Administration (OSHA). 2004a. Occupational safety and health administration standards, updated on their website (2004). U.S. Department of Labor. Available at: www.osha.gov. Accessed, August 25, 2005.
- Occupational Safety and Health Administration (OSHA). 2004b. Fact sheet. Lockout/Tagout Available at: http://www.osha.gov/OshDoc/data_General_Facts/factsheet-lockout-tagout.pdf. Accessed August 25, 2004.
- Occupational Safety and Health Administration (OSHA). 2005. Machine guarding eTool. Available at: <http://www.osha.gov/SLTC/e-tools/machineguarding/intro.html>. Accessed, August 25, 2005.

Olson D, Gerberich S. 1986. Traumatic amputations in the workplace. *J Occ Med* 28:480–485.

Sorock G, Smith E, Hall N. 1993a. An evaluation of New Jersey's hospital discharge database for surveillance of severe occupational injuries. *Am J Ind Med* 23:427–437.

Sorock GS, Smith E, Hall N. 1993b. Hospitalized occupational finger amputations, New Jersey, 1985 and 1986. *Am J Ind Med* 23:439–447.

Stanbury M, Reilly M, Rosenman K. 2003. Work related amputation in Michigan, 1997. *Am J Ind Med* 44:359–367.

The SAS System. 2000. Cary: SAS Institute Inc.