Mapping Safety Interventions in Metalworking Shops

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Objective: *This paper describes the selection of intervention activities designed to lower machine-related hazards and amputations in small metal fabrication businesses.* ***Methods:*** *Methods included an advisory board, employee discussions, and pilot tests. We used a stepwise intervention mapping process to identify performance objectives, behavioral determinants, and change objectives for two target populations (business owners and employees).* ***Results:*** *Intervention activities for owners were designed to increase knowledge about machine safety, encourage adoption of safety procedures, and motivate improvements in machine guarding. Intervention activities aimed at employees focused on building knowledge and skills of health and safety committee members.* ***Conclusions:*** *The intervention mapping approach led to important insights about program goals and intervention activities. Intervention mapping also ensured a systematic and thorough review of each target population in the context of our research goals.* (J Occup Environ Med. *2007;49:338–345*)

Employee participation and management commitment are among the most important aspects of workplace health and safety.[1–8] In small metal fabrication businesses, owners and managers play a key role in ensuring safe conditions, as they are responsible for providing guarded machines, protective devices, safe work procedures, and employee training in the safe use of machinery. Owners of small businesses, however, generally lack the specific knowledge and skills to identify, assess, and prevent machine-related safety hazards.[3] While recognizing that machinery can be hazardous, they also believe that employees are largely responsible for ensuring that machinery is used safely.[3,9]

Employees also have an important role in workplace health and safety. They must operate machinery with guards and devices in place, wear personal protective equipment (if necessary), and follow safe operating procedures. They require both tools to do their job safely and training to use these tools appropriately. Employees also require support and commitment from managers to conduct their work safely, even in the face of personal, social, and organizational pressures.[6,7,10–12]

The overall goal of our study is the comparison of the effectiveness of interventions aimed solely at owners with those directed at both owners and employees, with the objective of lowering machine-related hazards and amputations in small metal fabrication businesses. This paper describes the selection and design of intervention strategies for each study group. Development and testing of outcome measures are described in

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more detail elsewhere.[13] Study results will be published elsewhere as well.

Reviews of studies of occupational safety and health intervention effectiveness find that investigators often fail to establish a theoretical basis for intervention design or explain how or why interventions are selected.[14–16] In a previous randomized, controlled study of the effectiveness of technical and training interventions on lowering dust exposures in small woodworking businesses, we relied on the PRECEDE-PROCEED planning model for study design.[17,18] While we found this model to be useful in identifying activities for designing, implementing, and evaluating intervention studies, we sought a more systematic approach to the development of intervention activities.

For the current study, we used an approach to intervention design called "intervention mapping," a study planning model that contains a step-by-step process for intervention design integrating behavioral theory, epidemiologic evidence, and target population information.[19] We describe here the application of the intervention mapping model for two target populations (business owners and employees) in small metal fabrication businesses, addressing only those steps in the model that are specific to intervention design.

Materials and Methods

Data Collection

We used multiple methods to gather information about the industry. We consulted with an advisory board, which consisted of owners of small metal fabrication businesses, consultants from the Minnesota Department of Economic Development and Minnesota Occupational Health and Safety Administration (OSHA) machine safety professionals, business association directors, technical school faculty, and a union representative. A variety of machine safety documents, including regulatory and consensus standards, were reviewed.[20,21]

Members of the advisory board provided input throughout the development of interventions and outcome measures. They identified the most common machines, evaluated methods for assessing machine safety, and provided access to businesses for observing machine hazards and employee practices. Members also offered input on the design and content of intervention materials.

We conducted discussions with seven to eight employees in each of two small metal fabrication businesses to gather information about safety conditions and attitudes, and knowledge and beliefs about machine safety. Machine safety audits and intervention materials were piloted at four small metal fabrication businesses.

Intervention Mapping

The intervention mapping process consists of five steps (Fig. 1). In this paper we will focus, in particular, on steps 1, 2, and 3, which address the selection and design of intervention activities. Activities in steps 4 and 5 will be addressed elsewhere.

Step 1: Define Program Objectives

The first step in the intervention mapping process involves the identification of overall program goals and performance objectives (ie, changes in individual behaviors or environmental conditions). Each performance objective is then evaluated for underlying determinants (ie, "Why does a particular behavior or situation occur?"). This goal is accomplished by drawing on constructs from relevant health behavior theories. Personal, social, and environmental determinants are all considered. Learning or change objectives are then identified to describe what needs to happen for each determinant and performance objective.

Step 2: Select Methods and Strategies

The goal of the second step is to identify the best techniques for influenc-

Fig. 1. Intervention Mapping Steps.

ing changes in behavior or workplace conditions. Strategies are selected with input from theory and practice.

Step 3: Design a Program Plan

The third step involves the adaptation of existing tools or the development of new materials to fit the performance objectives and methods identified in steps 1 and 2. Expert evaluation and pretesting with a representative population are both important to ensuring successful implementation.

Step 4: Adoption and Implementation Plan

This step addresses the issues of time, intensity, and resources needed to implement the intervention.

Step 5: Monitoring and Evaluation Plan

At this step, a protocol is developed for measuring intervention delivery and implementation, in addition to the outcomes of the effectiveness of the intervention at improving levels of machine and workplace safety.

Results

Program and Performance Objectives

The overall goal of the Minnesota Machine Guarding Study is to bring about improvements in machine and workplace safety. We will compare the effectiveness of interventions aimed at one (business owners) or two target populations (owners and employees). Each target population is considered separately for the identification of change objectives. Strategies are then selected for each intervention group (owners alone or owners combined with employees).

Business Owners

In the case of business owners, failure to provide safe machinery and a safe environment contributes to employee injury. Literature reviews, our previous studies, and discussions with advisory board members indicate that most owners of small metal fabrication shops are aware of the importance of machine safety but lack knowledge of best practices and regulatory requirements for employee protection. Lack of resources and time may also impede efforts to improve workplace safety.[3,22,23]

We learned from advisory board discussions and shop tours that many small metal fabrication businesses operate old equipment that is difficult to retrofit with safety devices. We also learned from advisory board members that Minnesota OSHA visits a small fraction of these businesses each year, owners will generally not seek input from OSHA, and many owners' first experiences with OSHA follow a serious employee injury (eg, an amputation). In 2003, failure to meet machine-guarding requirements accounted for 15% of all OSHA citations in Minnesota.[24]

In addition, our review and discussions with business owners showed that the regulatory standards addressing machine safety are complex and difficult to understand or interpret without specialized knowledge. Resources for interpreting these standards are limited and not tailored to small business owners. Owners generally do not have on-site staff with the specialized knowledge necessary to workplace safety and have limited access to external advice (ie, from consultants or insurance companies). Business and trade associations generally do not provide sufficient information or resources for machine safety. Validated machine safety evaluations were not available prior to those developed for this study (described elsewhere).[13]

Our program goal is to motivate owners to provide well-guarded machines and safe operating conditions and procedures. Below is a list of the specific performance objectives for owners:

- Be able to assess the adequacy of safety in their business.
- Be familiar with methods for improving business and machine safety.
- Include employees in decision-making and problem solving for improving machine and shop safety.
- Support skill-based training of employees in machine and business safety.
- Support employee suggestions for improvements in machine and business safety.
- Make improvements to machine guarding and related employee training.
- Make improvements in machine safety policies and programs.

Employees

Our previous work with employees in small woodworking businesses showed that if dust control was available (which occurred about 50% of the time), it was generally used by employees (95% of the time). On the other hand, most ventilation systems were operating at only 65% efficiency due to poor design or inadequate maintenance.[25]

In metal fabrication businesses, data suggest that adequate machine guarding is not available for many machines. Surveillance of amputation injuries from 1995 to 1997 in Minnesota found that guards were not in use for two-thirds of machine-related injuries. Inadvertent equipment activation, malfunctioning tools or machinery, and inadequate or defective guards or the absence of guarding were the most frequent causes of injuries.[26,27] In Norway, the lack of safety devices and failure to wear personal protective equipment were associated with a 2-fold increased risk of injuries in small metalworking businesses.[28]

Our program goal for employees is 2-fold. Employees should use safety equipment and follow safe working procedures and policies, when available. They also need methods for promoting the availability of safety equipment and procedures when these are missing. Our specific performance objectives for this target population include the following:

- View machine safety more positively.
- Use guards and other safety de-

TABLE 1
Examples of Change Objectives for Business Owners and Employees

Performance Objective	Determinant			
	Environment	Self-Efficacy	Reinforcement	Situation
Business owners				
Able to assess adequacy of shop safety	Have accessible and useful information	Use this information more confidently	See improvements in shop safety scores and employee satisfaction	View shop safety as important to their business
Become familiar with range of safety improvements	Receive recommendations for improvements	Identify problems and solutions more confidently	See improvements in machine safety scores	Make improvements in machine safety with a more positive outlook
Employees				
Able to assess machine safety	Have opportunity to develop more knowledge and skills in machine safety	Solve machine safety problems more confidently	See improvements in machine and shop safety	Perform work more safely
Participate in health and safety decision-making	Have opportunity to participate in machine safety improvements	Make machine-safety decisions more confidently	Participate in health and safety committees	View their work and workplace more positively

vices (including personal protective equipment).
- Follow policies and procedures.
- Be able to assess machine safety.
- Become familiar with safety improvement processes.
- Participate in health and safety decision-making.

Personal and Environmental Determinants

Expert consultation and review of the literature suggest that constructs from Bandura's Social Cognitive Theory are most appropriate to these two target populations.[29] We selected four theoretical constructs as most relevant to our program goals:

- *Self-efficacy* is defined as a person's confidence to perform a particular behavior. Improvements in self-efficacy are accomplished by encouraging small steps in behavior change.
- *Reinforcements* are external responses to an individual's behavior that increase (or decrease) its likelihood of occurrence. Rewards and incentives are employed to bring about improvements in this aspect of behavior.
- *Environment* consists of factors that are physically external to the individual. Improvements in an individual's social environment at work, for example, can be obtained by improving the social support they receive from coworkers.
- *Situation* is a person's perception of their environment (eg, safety climate). To improve an individual's situation, misperceptions are corrected and healthy viewpoints promoted.

We selected these constructs because they are amenable to change, can be measured, and are relevant to the performance objectives for both target populations. These constructs have also been evaluated by other investigators in similar studies of workplace safety.[30–33]

Change Objectives

We constructed separate matrices for owners and employees showing the interface of each performance objective and behavioral determinant. At each point, we identified the specific change we expected as a result of intervention activities. An example is shown in Table 1.

Intervention Methods and Strategies

Using brainstorming and input from advisory board members, we identified specific methods and strategies for eliciting change in each of the determinants. We considered methods such as information transfer, role modeling, skill building, problem solving, goal setting, active learning, incentives, social support, and guided practice and reinforcement.[34–36]

We created a second matrix, which identifies the effect of each strategy on the specific performance objective in the context of each determinant (see Table 2 for examples). We first considered owner objectives, since one intervention was aimed solely at this target population. Intervention activities were designed to increase owners' knowledge about machine safety, encourage adoption of machine safety procedures and policies, and motivate improvements in machine guarding.

We then considered interventions aimed primarily at employees. Input from advisory board members indicated that an educational intervention with all production employees would not be accepted by business owners due to time constraints. Thus, we focused on making health and safety committees more effective by building members' knowledge and skills. We encouraged the creation of a committee for businesses lacking one.

Program Plan

Owner-Only Intervention Group

For businesses where we would intervene only with owners, we decided

TABLE 2
Selected Intervention Strategies for Business Owners and Employees

	Determinant							
	Environment		Self-Efficacy		Reinforcement		Situation	
Change Objective	Owner-Only	Owner-Employee	Owner Only	Owner-Employee	Owner-Only	Owner-Employee	Owner-Only	Owner-Employee
Owner is able to assess the adequacy of shop safety	Report from research team	Report from research team; health and safety committee	Tailored information from research team	Information from research team; health and safety committee	OSHA grant assistance	OSHA grant assistance; health and safety committee	Interactions with research team	Interactions with research team; health and safety committee
Owner includes employees in decision-making	Research team encourages owners to share report with employees	Research team encourages report sharing; health and safety committee conducts audits			Research team shares survey results and comparison with other businesses	Research team shares survey results; health and safety committee encourages employee involvement		Health and safety committee encourages view of employees as partners
Owner supports skills-based training of employees		Employees participate in health and safety committee				Employees are more positive and productive after participating in health and safety committee		Owners see improvements in safety and employee morale following health and safety committee activities
Employees are able to assess machine safety		Health and safety committee activities provide opportunities for machine safety assessment		Health and safety committee hands-on training with checklists; peer trainer models decision-making for employees; Peer trainer encourages employee involvement				Health and safety committee activities
Employees participate in health and safety decision-making		Health and safety committee activities provide opportunities for machine safety assessment		Health and safety committee activities build confidence about assessing machine safety before each job		Employees receive feedback when evaluating machine audits		Employees discuss results of audits with management during health and safety committee meetings
Employees use guards and other safety devices		Health and safety committee activities improve the efficacy and availability of guards and related administrative programs		Health and safety committee activities build confidence about using guards and safety devices		Health and safety committee activities reward improvements in employee understanding and use of guards		Health and safety committee meetings provide opportunities to discuss inadequate guards and devices

that information transfer, social support, goal setting, and incentives were the most appropriate methods. Below is a list of the activities that were undertaken at these businesses:

1. Presentation and discussion of a written report containing results of machine and shop safety audits and employee surveys, using color graphics to highlight high priority items and compare results with other businesses. The report was accompanied by a cover letter summarizing the most important findings and recommended actions.
2. Presentation and demonstration of a compact disc containing the following:
   a. Twenty-three machine safety checklists and links from each checklist item to a "plain English" version of the relevant American National Standards Institute (ANSI) and OSHA standards. Each checklist was accompanied by user instructions and a diagram illustrating each machine.
   b. Tailored programs for lockout/tagout, hazard recognition, and safety committees.
   c. List of resources including local machine-guarding vendors and a link to the OSHA on-line training materials.
   d. Information about the Minnesota OSHA grant process and a model grant application.
   e. Placards for 23 different machines, identifying hazards.
   f. Guidelines for a model safety committee.
   g. Training materials on machine safety for health and safety committees.
3. Further assistance was also provided if requested by the owner.

Worker and Owner Intervention Group

At the sites where we would intervene with both owners and employees, we focused on building the skills and knowledge of a health and safety committee, in addition to the activities listed above for the owner-only group. If a site did not have a health and safety committee, we asked them to identify a group of at least three people with at least two production employees and one manager with safety responsibility. Machine safety audit and survey results were used to tailor information and skills training for each committee.

The health and safety committee intervention focused on problem solving, information transfer, skill building, social support, role modeling, and goal setting. A peer trainer met with health and safety committee members during four monthly meetings, the goals of which were to build knowledge about machine safety, develop and practice skills in evaluating machines, and promote safety committee processes and functions (Fig. 2).

Conclusions

Businesses that actively engage employees in safety decision-making also experience lower rates of injuries and illnesses.[12,28,37,38] However, very few small firms report having participatory safety programs.[39] Our review of the literature and discussions with community members showed that health and safety committees are generally present in companies with more than 25 employees (as required by Minnesota OSHA regulations) and would be considered an acceptable point of intervention, even in smaller companies.

As demonstrated in a comprehensive review of employee health and safety training, higher levels of employee engagement or direct involvement in the learning process lead to greater improvements in knowledge and fewer negative outcomes (eg, injuries).[34] Training that develops knowledge in stages, utilizes behavioral modeling, and focuses on learner performance will result in more employee engagement than passive learning methods (eg, lectures, videos, or pamphlets).

An intervention with health and safety committees allows engagement of owners, managers, and employees. In a 1984 survey of large businesses in Massachusetts (more than 500 employees), unionized businesses were more likely to have a joint union-management safety committee (67%) than nonunionized

Session 1 (Month 1) • Provide background information on machine guarding principles • Describe machine safety scorecards and illustrate with shop-specific example • Assign shop-specific scorecard for evaluation prior to session 2 • Review health and safety committee procedures • Describe elements of a machine guarding program
Session 2 (Month 3) • Compare results of committee and researcher machine scorecard evaluations and use results to review information presented in session 1 • Further describe health and safety procedures and functions • Assign additional shop-specific scorecards for evaluation prior to session 3 • Describe elements of a lockout/tagout program
Session 3 (Month 6) • Compare results of committee and researcher machine scorecard evaluations • Discuss specific elements of their business' machine guarding and lockout/tagout programs • Identify methods for improving current programs • Assign additional shop-specific scorecards for evaluation prior to session 4 • Completion of written evaluation
Session 4 (variable) • Compare results of committee and researcher machine scorecard evaluations • Address specific topics identified by group • Describe OSHA grant application process

Fig. 2. Health and Safety Committee Meetings—Format and Content.

businesses (49%). An in-depth evaluation of 12 businesses found that the presence of a health and safety committee was highly negatively correlated with OSHA complaints.[1] However, we could find no studies where health and safety committees were the target of an intervention.

As found in a previous intervention study in small woodworking businesses,[18] input from advisory board members was the key to assuring that interventions would be accepted by business owners and employees. Pilot testing the intervention materials with each target population was also an important step in finalizing their design. Owners wanted assurance that focusing only on high-priority items would guarantee no future OSHA citations, which prompted changes in our phrasing of recommended actions. Based on input from health and safety committee members, we added more photographs showing "safe" and "unsafe" situations, as well as more opportunities for hands-on practice with machine audit forms. We refined the approach used by peer trainers to ensure the right mix of personal anecdotes and safety information. More assignments between meetings were added, and the fourth session was made optional. Spacing of sessions was also adjusted to allow more time for completing the assignment.

In general, the implementation of our interventions proceeded relatively smoothly. We accomplished scheduling by establishing an agreement on all dates at the time of enrollment. Written and telephone reminders one week and one day before each site visit were generally successful at keeping interventions on schedule. Careful tracking, the development of a list of frequently asked questions with appropriate responses, and regular staff meetings and communication were keys to ensuring that interventions were implemented in a timely manner. Further details on study design, implementation, and results will be published elsewhere.

Intervention mapping is a powerful and systematic approach for identifying underlying determinants of workplace health and safety outcomes expected of an intervention, as well as the specific methods for bringing about improvements. This approach has been used in a range of settings for a variety of health outcomes, such as school-based programs for nutrition, violence prevention, and health education.[40–42] This model, and other planning models, have enjoyed only limited application in the development of occupational health and safety interventions, however. When used in tandem with pilot tests of intervention activities and outcome measures,[18] such models yield important information that ensures uniform implementation at multiple sites.

In summary, we found that using a mapping approach to link key determinants and change objectives led to important insights about our program goals and intervention activities. Intervention mapping also ensured a systematic and thorough review of each target population in the context of the research goals.

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Erratum

In the article, "Use of Medical Insurance Claims Data for Occupational Health Research," by Mark Cullen et al, published in the October 2006 issue (volume 48, Number 10), the affiliation of one of the authors, Kanta Sircar, PhD was incorrect. That affiliation is solely Yale Occupational and Environmental Medicine Program, Departments of Internal Medicine and Epidemiology and Public Health.