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A Proposed National Strategy for the Prevention of Severe Occupational Traumatic Injuries

Abstract

The Association of Schools of Public Health, under a cooperative agreement with the National Institute for Occupational Safety and Health (NIOSH), recently developed and published a proposal for minimizing traumatic injuries in the workplace. Contributing to this effort were over five hundred participants representing industry, government, business, trade unions, voluntary organizations, the professions, and academia. The resulting position paper, reprinted here, establishes a national strategy for the advancement of workplace safety.

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I. Severe Occupational Traumatic Injuries: Problems and Goals

Severe occupational traumatic injuries include serious, often disabling injuries such as amputations, fractures, severe lacerations, eye losses, acute poisonings, and burns. Worker deaths that are immediate, and without a preceding illness, are often the result of severe trauma incurred on the job.

Control of severe occupational traumatic injuries is not possible without a concerted effort by government, academia, private business, and labor. A control strategy that is national in scope must reflect a full spectrum of activities, not only emphasizing information dissemination and implementation of countermeasures but also including injury surveillance and analytical research. Therefore, the recommendations in this report represent not only what can be practically done today but also what should be done in the future. Embodied in these recommendations is a preliminary national strategy that may evolve as more is learned about the etiology and prevention of traumatic injuries and as more individuals and organizations make contributions to the effort.

II. Scope of the National Problem

Severe occupational traumatic injuries (including injuries associated with work-related motor vehicle accidents) pose a continuing and perhaps the major threat to the health and well-being of American workers. The National Institute for Occupational Safety and Health (NIOSH) estimates that at least 10 million persons suffer traumatic injuries on the job each year. About 30 percent (3 million) of these injuries are severe, and at least 10,000 are fatal. Analysis of potential life lost from various causes indicates that "accidents and adverse effects" are the leading cause of loss of potential productive years of life in this country. Occupational trauma is second only to motor vehicle accidents as a reported cause of unintentional death in the United States.

Occupational injuries, of which severe traumatic injuries constitute one of the important components, resulted in 80 million lost workdays in 1983. That same year, occupational injuries cost the United States an estimated $33.4 billion in direct costs (e.g., wage losses, insurance administrative costs, and medical costs) and indirect costs (e.g., time lost by other than injured workers, and administrative costs associated with accident investigation and reporting). This figure may grossly underestimate the extent of total costs to industry and to society at large resulting from occupational injuries and cannot begin to describe the immeasurable toll in human suffering.

National Safety Council estimates show declining rates of occupational fatalities and disabling injuries since the early 1970s, partly as a consequence of a growing workforce. However, the actual number of fatalities has declined slowly and the number of disabling injuries has remained essentially unchanged since 1945.

III. Amenability to Intervention

Several techniques and methods are available to prevent and reduce the severity of traumatic injuries. Traditional approaches include removing the hazard, placing barriers between the hazard and the worker (including the use of personal protective equipment), pre-employment screening to prevent assignment of particularly susceptible individuals (e.g., those incapable of performing the tasks or sustaining the stresses imposed by the tasks), job hazard analysis, improved job and tool design, compliance with regulatory and consensus standards, and training the worker to avoid the hazard. Evidence shows that application of traditional trauma prevention methods by knowledgeable professionals in a positive management environment reduces occupational injuries.

A dual approach is proposed to reduce the burden of such job injuries on the workforce, the economy, and the population of the country.

A. Immediate actions can be taken by interested groups and individuals based on prudent, carefully considered options for trauma prevention programs. These actions involve implementation of already developed and accepted policies and practices to reduce injuries within the context of positive, safety-minded management. Actions that can improve awareness and control of hazards include training; compliance with existing regulatory and consensus standards; better ergonomic design of equipment and jobs; early identification and recognition of emerging hazards; upgraded education of safety and health professionals, engineers, managers, and workers; and targeted, short-term injury control research.

B. For the long term, a major effort must be made to more thoroughly describe and study occupational injury incidents and to use the most rigorous methods of science available. Although present interventions are valuable in reducing workplace injury, scientific study is necessary because occupational "safety" is a set of control technologies (e.g., engineering, personal protective equipment, and monitoring) and administrative techniques (e.g., training, written policies, safe work practices) that have not been rigorously tested and validated. As an underdeveloped science, occupational trauma control needs research using the scientific methods that have contributed greater knowledge and prevention efforts in related health and injury fields.

One set of scientific methods, known collectively as epidemiology, has received increasing attention among trauma control professionals. Epidemiologic techniques can help those interested in reducing the incidence and severity of occupational trauma to see more clearly the scope of the problem and the complex relationships among the causal factors operating in the working environment.

IV. Epidemiology: Charting the Course

Epidemiology is a discipline applied to the practice of preventive medicine and public health. Use of epidemiology to evaluate the incidence of traumatic occupational injuries has tremendous potential because these injuries, like chronic and infectious diseases, seem to result from the interaction of a susceptible host and one or more etiologic agents within a particular environment. Furthermore, precedents have been established for the successful application of epidemiologic methods to evaluate injury etiology. For example, epidemiology has been used to assess the association of alcohol with automobile fatalities, the occurrence of falls and poisonings in residential buildings, the incidence of occupational and nonoccupational burn injuries, the factors associated with recreational injuries, and the success of various strategies for survival in disasters.

Epidemiology may serve as a common thread associated with the identification, evaluation, and control activities necessary for the prevention of traumatic injuries. Initially, descriptive epidemiology (e.g., surveillance and cross-sectional studies) is needed to *identify* high-risk exposures and factors. This identification will allow for the generation of scientific hypotheses about causation. Next, analytic epidemiology (e.g., cohort and case-comparison studies) can test the validity of these hypotheses. This analysis will allow for the *evaluation* of potential risk factors and exposures and for suggestions of appropriate control strategies. After designating specific control strategies, epidemiologic field and clinical studies can be used to *evaluate* the efficacy of these strategies. Appropriate surveillance activities can then assess progress in the *control* of traumatic injuries based on implementation of specific preventive strategies.

Surveillance appears to be a key epidemiologic component in the prevention of occupational traumatic injury. This component must be viewed as both an initial activity designed to establish baseline information, and as a continuing activity designed to generate dynamic profiles characterizing

how the national occupational safety experience is changing, and in some instances, why the change has occurred.

Most workplace accidents occur as a result of the coincidence of separate cause-effect sequences, each influenced by multiple factors or stressors. In formulating actions aimed at controlling severe occupational trauma, consideration must be given to the risk factors associated with the following workplace components: the *task,* the working *environment,* the *machine,* and the *worker.* Each set of risk factors represents an area in need of scientific study in the multidisciplinary effort to mitigate occupational trauma through research.

All too often, however, researchers focus on only one of these aspects without considering the total workplace. Modifications in any component of this complex system must be carefully evaluated with a view toward effects on the total system. Traumatic injury research must be specific and painstaking, yet must reflect a balanced, systems-oriented perspective so that the findings will be adaptable to employers' needs; employers, after all, must manage these complex industrial systems. Indeed, the importance of management's role in the prevention of occupational traumatic injuries cannot be overemphasized, and providing managers with valid, useful information is a must.

The present discussion follows the order of the workplace components outlined above. It addresses those risk factors of the workplace components for which we now have sufficient information to implement effective intervention strategies and then examines those risk factors for which critical knowledge gaps must still be explored before meaningful intervention can begin.

V. Prevention Components: What We Know and Can Implement Now

Energy release is associated with the interaction of task, environment, machine, and worker. Traumatic injuries may result from employee exposures to unexpected releases of energy in amounts that the human body cannot tolerate. The release of energy that results in harm is usually due to lack of management control or improper management of the working environment.

Programs established to reduce occupational traumatic injuries must be formulated and implemented by management. Management policies, procedures, and supervision dictate how effective injury prevention efforts will be.

Evaluation of effective safety programs has established that the most important component of such programs is management's commitment from the top down. Such programs contain basic elements such as safety policy statements, assignment of safety responsibilities through all levels of management, establishment of safety performance accountability, identification of hazards in the workplace, establishment of control measures (in accordance with regulatory and consensus safety standards), employee involvement in hazard identification and control, safety training for employees, accident investigation policies, and planning for emergencies. Management accepts the responsibility of tying these elements together so that the nucleus of the industrial system (task, environment, machine, worker) can function with the least possible unforeseen interruption.

A. Task-Oriented Strategies: Modifying the Job

Failure to follow established standards for work practice is considered responsible for a large portion of occupational injuries and deaths. Reduced numbers of injuries and deaths can result from the increased use of effective work practices.

Safe work practices exist for many hazardous operations. Control methods exist for all energy sources found in United States workplaces. The extent of occupational injury incidence indicates that employers either are unaware of the hazards inherent in their operations, or the appropriate control strategies, or are unable or unwilling to effectively implement those strategies. This indicates weaknesses in dissemination and employers' safety programs.

Employers can use job hazard analysis as a technique to identify job hazards and appropriate preventive countermeasures. All job tasks should be analyzed individually from the perspective of identifying obvious, anticipated, or foreseeable hazards. Of course, not all hazards are immediately obvious or can be reasonably foreseen. Programs should include timely reassessment or monitoring activities to detect previously unknown or undetected hazards. Appropriate preventive countermeasures can then be applied to eliminate or reduce risk to the worker from those hazards, including modifications to the task. Job hazard analysis is an important approach because hazards can often be anticipated. This is clearly better than reacting to a hazard after a traumatic event.

Although the effectiveness of known countermeasures has not been determined, increased implementation of appropriate safe work practices and procedures is anticipated to have a major impact on reducing national injury and death rates.

B. Environment-Oriented Strategies: Changing the Work Environment

The working environment includes the physical environment, the psychosocial environment, and the political/economic environment. Of these, the physical environment is the most amenable to immediate action. The impact of broader environmental issues on the incidence of traumatic injuries must be carefully studied.

The influence of factors in the physical environment (e.g., layout and condition of the facility, illumination, temperature, relative humidity, noise, vibration) on the productivity and safe performance of occupational tasks has been studied for more than 50 years. Based on consensus and standard industry practice, guidelines have been developed for the control of these potential physical stressors to minimize direct bodily insult or trauma. Compliance with these guidelines can help to reduce the risk of occupational injury. The principal obstacles to wider application of known controls are inadequate information dissemination and inadequate safety program management. Cost constraints can also inhibit adoption of necessary environmental controls.

Many private sector organizations have developed safety and health prevention programs that have demonstrated trauma reductions and worker health enhancement. Means should be sought through trade associations, the National Safety Council, labor organizations, insurance organizations, and others to influence other companies to incorporate the essential aspects of such effective programs into programs of their own.

C. Machine-Oriented Strategies: The Safe Machine

Machines are assemblages of parts designed to transmit or modify the application of power, force, or motion to perform predetermined functions. Workers use a wide variety of machines to be more productive. The various forms of energy associated with machines, if not adequately controlled, can result in traumatic injuries to workers. Numerous measures known to control this release of energy should be applied in the workplace.

1. Standards

Regulatory and consensus standards now exist to protect workers in various ways from interaction with specific industrial machines. Many of these protective measures propose the placement of barriers between the worker and recognized hazardous energy sources associated with the machinery. These barriers range from guards placed on moving pieces of machinery to protective equipment worn by workers. References to recognized controls can be found in the occupational safety and health standards and appropriate publications by consensus organizations such as the American National Standards Institute.

2. Manufacturer Safeguards

Manufacturers are continually seeking to build a better "mousetrap." State-of-the-art technology can be geared toward producing a safer and a more functional machine. Employers should take advantage of proven developments when procuring machines. At a minimum, procurement procedures should require that newly purchased machinery meet all appropriate currently recognized regulatory and consensus standards.

D. Human-Oriented Strategies: Managing the Worker

The most complex and the least measurable component of the task/environment/machine/worker model is the worker. To some safety practitioners, a worker is characterized by the behaviors exhibited in the workplace that influence systems output. Many of these practitioners believe that human behavior is totally unpredictable and uncontrollable. To others, a worker is a set of abstracted attributes: occupation, sex, age, part of body injured, etc. Still others see the worker as the sum of the effects produced by the working environment: stress, injury or illness, disability, fatigue, motivation, productivity or nonproductivity, absenteeism, etc. To some, a worker is a set of psychologic and physiologic capabilities and limitations. Perhaps the most successful practitioners in the area of traumatic injury control see the worker as their most valuable resource, to be carefully nurtured and protected.

Of course, human beings are all of these characteristics and more. Thus, a variety of people need to be involved in the study of tasks, working environments, machines, and workers to comprehend the worker as both an entity and a functioning part of larger systems. Individuals with training and experience in behavioral sciences, ergonomics, biomechanics, biomedical engineering, and related scientific and engineering fields are needed to study the control of occupational traumatic injury and to provide critical knowledge regarding the human components of industrial systems.

1. Training

Training is an integral component of trauma prevention. From the earliest days of childhood, we are taught to look both ways before crossing the street or, more recently, to buckle our seat belts after getting into a car. As a result, some of us do these things automatically. However, most of us are not trained early in life for the vocation we may have as adults. As a consequence, we get a job and learn firsthand about its inherent dangers.

Strong evidence indicates that knowledgeable, well-trained workers can avoid injury while performing hazardous work, and that untrained, uninformed workers can be injured under almost risk-free conditions. NIOSH field investigations of fatalities associated with confined spaces have shown that lack of awareness or recognition of the hazards, by both managers and workers, and lack of training in hazard awareness may be major factors contributing to occupational fatalities. Government agencies, notably the Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration (MSHA), have addressed the need for training through standards and educational resources. Although these various regulatory agencies require training, the degree and level of training are seldom specified, resulting in extreme differences in the application of training among similar industries or within the same industry. Also, existing regulations may not cover certain high-risk groups at all, and therefore even minimal training in hazard awareness and control is not provided.

A key activity in the development of training programs is identification of training components that combine to produce a successful program. The establishment of a model training program could ensure that a wider population of workers is provided more uniform and basic training in hazard awareness and trauma control. Of course, such models would require tailoring to meet the specific needs of particular industries, worker populations, and facilities.

Employees in such high-risk occupations as punch press operators, crane operators, industrial truck operators, over-the-road truck drivers, agricultural workers, and workers in many occupations who are exposed to the hazards inherent in confined work spaces, trenches, and chemical handling tasks should be primary targets for such training.

2. Hazard Communication

Effective communication through information dissemination, education, and training could have an immediate positive impact on the incidence of work-related injuries and deaths. Certain workplace energy hazards, or intrinsically dangerous operations such as confined space entry and excavations work, might be effectively mitigated by implementing a program comparable to the OSHA hazard communication standard addressing workplace chemicals (29 CFR 1910.1200). Requiring employers to provide workers with information and training on particularly hazardous aspects of their work could substantially reduce traumatic injuries associated with those hazards.

3. Known Interventions

When surveillance, particularly at the organizational level, identifies the high incidence of a type of injury associated with a high risk industry, occupation, or task (e.g., foot injuries in a foundry), known intervention methods (e.g., protective footwear) should be applied. Training and reinforcing the worker to be aware of the high probability of traumatic injuries are important components of an intervention program. By providing the worker with the tools and knowledge to avoid traumatic injuries, intervention strategies serve as effective models toward prevention efforts.

4. Rehabilitation

Rehabilitation services, available through several programs, provide retraining in different occupations for workers suffering permanent disabling injuries at work. Such programs will increase in importance with the decrease in the number of younger workers entering the workforce and the national trend toward an older workforce.

VI. Prevention Components: What Knowledge Do We Need

Because the basic elements of effective safety programs are known, management can operate such programs efficiently and profitably to reduce occupational injuries. However, to progress in this endeavor, management must have access to cost-effective, scientifically proven methods that reduce injuries, and it must have more information to help allocate limited resources for occupational safety programs. Information valuable to management would include:

- Risks presented in measurable terms
- Methods developed to assess workplace hazards and controls
- Criteria to select workers for specific task, environment, machine, and worker interrelationships
- Components of effective safety training programs
- Means of assessing worker stress indicators in relation to safe job performance
- Access to proven safe work practices and procedures

A. Task-Oriented Strategies: Modifying the Job

Scientific validation is needed for the established countermeasures relating to task procedures. In general, established countermeasures represent the best judgment of the trauma control community, but they have not been demonstrated through rigor-

ous scientific studies to be effective. Recommended procedures for specific tasks would certainly be more readily accepted and used if they were demonstrably effective in reducing worker injury and death. in addition, measurement of the effectiveness of a particular countermeasure would be invaluable in demonstrating the cost-effectiveness to employers, managers, and the public in general.

B. Environment-Oriented Strategies: Changing the Work Environment

1. Physical Environment

Although guidelines are available for controlling harmful environmental agents, the influence of these agents on the incidence of occupational traumatic injuries has not been defined. For example, some initial investigations of the potential detrimental effect of such agents on optimal safety performance have been conducted, but much research lies ahead.

2. Psychosocial Environment

A major impediment to traumatic injury control is the notion, prevalent in the general population, that "accidental" injuries are not preventable. In addition, two fundamental components of the national psychology—risk taking behavior and the perception of personal immunity from injury—extend quite naturally into the working environment. The psychosocial environment, as it influences the perception of hazard and risk taking, is amenable to modification through the techniques of advertising, information dissemination, and social interaction. For example, the decline in cigarette smoking in the United States can be attributed in large part to two closely related factors: 1) the shift from media saturation with "pro-smoking" advertising toward a more balanced media presentation of smoking (with some media legally prohibited from "pro-smoking" advertisements) and 2) the evolution from an absence of clear scientific and clinical evidence to a flood of information propelled by the Surgeon General's anti-smoking campaign.

The approach of environmental modification, including efforts to influence coverage by the mass media, should be exploited through a serious concerted effort. Messages must be specific, supportable, and persuasive. General themes such as "safety first" or "think safety" have been minimally effective, if at all. Clearly, modifying public perception to the degree that 1) traumatic injuries are no longer regarded as resulting from "chance" occurrences beyond human control, and 2) the large number of injuries and deaths attributed to work-related trauma are no longer morally acceptable, will represent a quantum leap for a national preventive effort.

3. Political/Economic Environment

a. Changing Work Force

The composition of the work force in the United States has changed dramatically over the past 3 decades. Some industrial sectors are growing much faster than others. For example, from 1950 to 1980 the rates of increase in employment ranged from 14 percent in mining, 28 percent in transportation, and 33 percent in manufacturing, to 170 percent in government, 173 percent in finance, and 234 percent in the service sector.

Fundamental shifts in national employment patterns have continued into the 1980s, such as rapidly increasing numbers of women and increasing participation of certain ethnic minority groups in the work force. Other changing patterns are likely to continue, with some estimates suggesting that less than 10 percent of the national work force will be blue-collar workers by the mid-1990s. The changing economic environment characterized by the exportation of blue-collar jobs and polarization of the work force into professional, technical, managerial, and service occupations has not been fully accommodated by a corresponding change in the thrust of safety program application.

Remodernization, associated with increased use of computers and automated or programmable machines (robots), is rapidly expanding. These factors create a unique and dynamic environment that challenges proponents of traumatic injury prevention and control to anticipate change. Development of positive prevention-oriented planning must occur in parallel with industrial change, not follow it.

b. Emerging Technology

We must begin immediately to apply to problems of the future those organizational and technical lessons learned at such a high cost in the past. After all, our failure to consider the potential hazards of the "new" technologies of yesteryear (e.g., mass production, basic chemicals, and iron and steel) allowed an exorbitant toll in unnecessary injuries and deaths through the years, even to this day. Newly emerging technologies such as genetic engineering, robotics, computers, and space commercialization are prime candidates for study. To address potential emerging problems will require:

- The widest possible application of existing safety technology
- Development of research programs for safety technology at the centers of the emerging technologies
- Specialized surveillance programs keyed to anticipated problem areas

c. New Hazard Control Techniques

Innovation in techniques for the recognition, analysis, and mitigation of hazards and the management of risk is slowly emerging from extensions of econometrics, policy analysis, reliability engineering, and operations research. However, no formal body of information, discipline, or center of excellence now exists to nurture these new approaches to the safety question. Consideration should be given to establishing a center for research into the nonmechanistic arena of safety.

d. Economic Issues

In 1982, $22.5 billion was paid for workers' compensation insurance coverage or approximately $275 per worker covered. Yet the National Safety Council estimates that all workers would need to produce additional goods or services with a value of $330 per worker to offset the cost of worker injuries. This finding may indicate that compensation insurance rates are not high enough to provide a positive incentive for reducing occupational trauma. In addition, the "liability proofing" that compensation coverage conveys to the employer may provide a further disincentive to prevention programs. Nonetheless, the present compensation system for occupational injuries is important to the nation's working men and women and, although perhaps not ideal, it should be maintained and strengthened.

The economic incentives and disincentives associated with workers' compensation are being carefully analyzed by the insurance industry, private economics-oriented research organizations, and governmental components. Analyses have been undertaken to determine the savings that can be realized through emphasis on prevention, but much work is needed in this area. The emergence of the newly created Workers' Compensation Research Institute (WCRI) is evidence of the increasing attention being focused on understanding the complex economic forces that influence occupational traumatic injury and fatality incidence and the efforts to control these outcomes.

Insurance rates are increasing, the work force is maturing as fewer and fewer young people enter the job market, and labor shortages in key occupations can be anticipated. These influences will require a more enlightened approach to management commitments to worker safety. It is encouraging that many employers are beginning to recognize the negative economic impact that traumatic injuries have in lost workdays, high medical costs, loss of productivity, and increases in insurance rates and liability claims. Programs should be undertaken to identify the true costs of injuries and fatalities and to more clearly show the econom-

ic consequences of trauma. For greater impact, these findings should be specific for industry and occupation; and the results should be widely disseminated.

Furthermore, the human element of this issue of occupational trauma insurance has dimensions beyond just compensation insurance. The cost of not only compensation insurance but of disability and product-liability insurance must be considered as well. From the designer's perspective, liability—especially third party liability—appears to be the driving force. This may operate as a negative force by pushing up disability costs for trauma and related compensation. The cost relationships between these competing insurance elements, whether positive or negative, have never been examined from the perspective of occupational trauma. Studies of this should be undertaken and recommendations made for changes as appropriate.

C. Machine-Oriented Strategies: The Safe Machine

Present concepts of safe machines generally involve installation of barriers or enclosures around hazardous machine parts to prevent accidental worker contact. Although these concepts seem to be effective, employees working with or around machines still experience numerous injuries. This finding implies that several potential problems exist with either the barrier concept or the lack of knowledge of other factors contributing to injuries. Moreover, the large body of voluntary consensus standards for machinery should be reevaluated and refined where appropriate, and wider compliance should be promoted. Establishing and including the current technical basis for each standard as part of the guidelines would enhance user understanding and acceptance and would facilitate necessary revision.

Scientific studies must be performed to determine the efficacy of barrier methods and to provide managers with expected rates of injury reduction through application of these methods. Motivational and behavioral elements, such as piece wage rates, should be evaluated with the associated injury problem.

Machines are being designed to operate faster and with greater reliability in quality control of the product. Production systems are becoming more automated with management goals of totally automated production lines, and new technologic uses of energy are being applied within these systems. These design concepts should take into account safe methods of feeding and removing stock materials and the stressors on workers to keep the automated system running. This should lead to development of controls that minimize human (both manager and worker) error and limit the speed and travel of machines within human reaction tolerances.

D. Human-Oriented Strategies: Managing the Worker

1. Age and Traumatic Injuries

America's population is aging. By the year 2040, an estimated 68.4 million people—one American in four—will be over the age of 65. The 18- to 24-year-old work force, which has traditionally evidenced the highest traumatic injury incidence rates, is declining in size. As the work force gets older, age-related risk factors for traumatic injuries increase. Older workers give up speed for accuracy, are slower to react in quickly changing situations, and have reduced range of motion compared with their younger counterparts. In addition, they may have less tolerance for changing environmental conditions, such as extreme heat or cold. Although older workers are often considered more cautious and even more productive than their younger counterparts, the decreasing influx of young workers may force older workers to remain in high-risk jobs or activities longer. Therefore, larger numbers of injuries to older workers seem likely, not so much because of diminished physical and sensory capabilities, but because of increased exposure.

Given the changing age of the United States work force, employers have already begun to study ways to attract and keep younger workers. Careful planning will be necessary to reduce traumatic injuries with consideration of the risk characteristics of both young and older workers.

2. Training

As our economy changes from heavy industry to service, training will become more important, particularly as new and sophisticated equipment and systems are introduced into the workplace to increase productivity.

Training the worker is an art as well as a science. To master their jobs, and, as a result, to reduce their odds of incurring traumatic injuries, workers have basically been trained in four levels of technology: 1) the worker supplies power and control, such as using a box wrench to tighten a nut, 2) the tool supplies power and the worker controls it, such as using a hand-held power screw gun to drive in a screw, 3) both power and information are supplied, but the worker is in control, such as in a paper-making plant, and 4) power, control, and information are supplied in a self-monitoring system, and workers intervene only if something goes wrong, such as in a nuclear power plant or when an autopilot is activated in an airplane.

In many industrial processes technology is rapidly leaving levels one and two and moving toward levels three and four. Computer technology has made this possible at an accelerated rate. Training of workers and retraining of older workers have become issues that will be of greater importance in the future. Research is needed on the ability of workers to control entire systems and to provide quick, controlled, and reliable responses when problems arise.

The mere provision of training does not ensure that a traumatic event will not occur. The adequacy of training, retraining, and post-training policies and practices needs evaluation to determine appropriate prevention strategies for particular groups of workers in selected work settings. The need for retraining could be evaluated by analyzing surveillance data on the components of traumatic events or investigations of near-misses.

3. Behavior

Human behavior and its relationship to safe work activity have received little if any research attention. Why do workers circumvent safety devices? Why do they attempt to rescue a fallen worker in a confined space only to die themselves in the rescue attempt? What outside workplace forces stimulate or mitigate such behavior? Such issues must be addressed in the context of the current workplace. Practical techniques of positive reinforcement must be improved and applied for safe work practices.

a. Motivational Factors

Changes toward more service activities, the maturing of the work force, and the decline of the 18- to 24-year old population have already stimulated major corporations to reexamine the factors that motivate workers. Such studies have focused on economic considerations, with workers hired and maintained on the basis of their motivation to produce. Some attention has been devoted to motivational issues, such as studies of different reinforcing strategies, which may be important to the reduction of trauma in the workplace. More such studies should be undertaken.

b. Employee Participation

In the future, reducing traumatic injuries will involve more group participation than it has in the past. Recently, quality circles, formed in the automobile industry to bring workers, unions, and management together to discuss work issues including safety, have proved to be extremely productive. However, the impact of such participative processes on worker safety has not been fully evaluated scientifically.

In automobile plants, workers have been aiding management in a smoother transition from one technology to another as manual materials handling and assembly give