NIOSH

Comments to DOL

ADDITIONAL COMMENTS FROM THE
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
ON
THE OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION
PROPOSED RULE ON
ERGONOMIC SAFETY AND HEALTH MANAGEMENT

29 CFR Part 1910
Docket No. S-777

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

8/24/93

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. Recipient's Accession No.

4. Title and Subtitle NIOSH Testimony on Ergonomic Safety and Health Management by R. W. Niemeier, August 24, 1993

5. Report Date 1993/08/24

6.

7. Author(s) NIOSH

8. Performing Organization Rept. No.

9. Performing Organization Name and Address NIOSH

10. Project/Task/Work Unit No.

11. Contract (C) or Grant(G) No.
(C)
(G)

12. Sponsoring Organization Name and Address

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This testimony provided further comments on the three tiered hierarchy of controls outlined in the ergonomics program management guidelines published by OSHA in 1990 as an intervention strategy for the control of ergonomic hazards. Each of the three controls identified in that document, engineering/ergonomic controls, administrative controls, and the use of personal protective equipment, were described and discussed. The implementation of an ergonomic training program using the steps outlined in the OSHA voluntary training guidelines published in 1992 was described as well. Examples of ergonomic interventions in work situations involving the performance of repetitive tasks, force and/or mechanical stress or vibration exposure, or poor posture or psychosocial stresses were outlined. Tables describing the effectiveness of engineering controls designed to decrease exposure to ergonomic risk factors, control strategies to reduce musculoskeletal injuries, and the effectiveness of ergonomics training were presented.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms NIOSH-Publication, NIOSH-Author, NIOSH-Testimony, Niemeier-R-W, Musculoskeletal-system-disorders, Cumulative-trauma-disorders, Occupational-health-programs, Vibration-exposure, Job-stress, Personal-protective-equipment

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages 27
	22. Security Class (This Page)	22. Price

(See ANSI-Z39.18) *See Instructions on Reverse* **OPTIONAL FORM 272(4-77)**
(Formerly NTIS-35)
Department of Commerce

III. ELEMENTS OF AN ERGONOMICS MANAGEMENT PROGRAM

A. WORKSITE ANALYSIS (Submitted with NIOSH Comments to OSHA dated 2/1/93)

B. HAZARD PREVENTION AND CONTROL

Background

The goal of "hazard prevention and control" is to eliminate, reduce, or control the presence of ergonomic hazards. Ergonomic hazards may be identified as a result of performing a worksite analysis—the details of which were discussed in the previous section, Part A.

By definition, "ergonomic hazard" is a recent term chosen to refer to a set of work-related risk factors that are associated with the development of musculoskeletal disorders. Risk factors commonly associated with ergonomic hazards include: (1) repetitiveness, (2) force/mechanical stress, (3) awkward or static posture, (4) vibration, and (5) work organizational/stress factors [Armstrong et al. 1986; Arndt 1987].[1] In general, ergonomic hazards are present whenever the work demands of a job exceed the capacity of those workers performing the jobs. Moreover, excessive work demands can arise from poorly designed work processes, tools, and/or work stations [Putz-Anderson 1988].

There are many potential ergonomic solutions or interventions for each of the risk factors listed. Table 1 provides examples of relatively simple single-fix solutions that have been recommended by various ergonomic experts for each risk factor [Grandjean 1988; Konz 1979]. To be effective, an ergonomic intervention should serve to reduce the source of the physical stress (i.e., reduce the ergonomic hazard) associated with a particular risk factor. The theory is that by reducing hazard levels, there will be similar reductions in illness and injury rates.

In some cases, proposed ergonomic interventions are simple and consistant with common sense. At the majority of worksites, however, where ergonomic hazards have been identified, a more comprehensive approach is required than can be provided by any of the single-fix solutions, some of which are listed in Table 1. Today, with the complexities of the mechanized work environment, ergonomic solutions often serve as the interface between the "person, machine, and work environment," reflecting the importance of a systems approach to hazard prevention [McCormick and Sanders 1982].

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[1] This list of risk factors for work-related musculoskeletal disorders is not intended to be all inclusive.

NIOSH continues to support a three-tier hierarchy of controls as an intervention strategy for controlling ergonomic hazards. This position was outlined in the "Ergonomics Program Management Guidelines for Meatpacking Plants" [OSHA 1990]. The approaches identified in that document include the following steps in order of preference:

- Engineering or ergonomic design changes to tools, handles, equipment, workstations, work methods, or other aspects of the workplace, often called engineering controls.
- Changes in work practices or organizational and management policies, sometimes called administrative controls.
- Use of personal protective equipment.

A discussion of each of these approaches follows:

1. Engineering/Ergonomic Controls

The preferred method for control and prevention of work-related musculoskeletal disorders is to design the job to match the physiological, anatomical, and psychological characteristics and capabilities of the worker. In other words, safe work is achieved as a natural result of the design of the job, the work station and tools; it is independent of specific worker capabilities or work techniques.

Although the focus of this section is on hazard control, the concept of prevention is best exemplified when the workplace, tools, work station, and work process are designed from the beginning to accommodate the capability and capacities of the workers. Unlike the majority of occupational hazards, however, sources of ergonomic stress are usually hidden or embedded within the job as specialized patterns of movement or tool usage. The result is that ergonomic hazards are often difficult to predict or anticipate during the initial design stage.

Ergonomics is the discipline that strives to develop and assemble information on people's capacities and capabilities for use in designing jobs, products, workplaces and equipment. The goal of ergonomics is to establish through job design, a "best fit" between the human and imposed job conditions to ensure and enhance worker health, safety, comfort, and productivity.

A number of reference works containing ergonomic guidelines for the design of various workplaces have been compiled by Van Cott and Kincaid [1973], Konz [1979], Woodson [1981], Eastman Kodak [1983; 1986], Putz-Anderson [1988], Tichauer [1991], Chaffin and Andersson [1991], and Mital and Kilbom [1992], among others. These strategies apply both to the design of new jobs and the control of hazards in existing jobs. In general, the selection of a design for limiting musculoskeletal stress will depend on existing technology, resources, and employee acceptance; however, numerous studies indicate that designing or redesigning tools, workstations or jobs in accordance with ergonomic guidelines can be effective in limiting worker exposure to ergonomic hazards (Table 2).

Other studies have examined the effectiveness of engineering changes on the incidence rate of musculoskeletal disorders associated with specific job tasks. In a comparison of three approaches to low back injury control, Snook et al. [1978] concluded that worker selection, and training in lifting technique were ineffective, and that designing jobs to fit the capabilities of workers could reduce low back injuries due to lifting by two-thirds. Westgaard and Aaras [1984; 1985] introduced adjustable work stations and fixtures, and counterbalanced tools in a cablemaking company, and found that turnover and absenteeism due to musculoskeletal complaints were reduced by 2/3 over an eight-year period. Companies that have adopted plant- or corporate-wide ergonomics programs consisting of worker training, union-management participative teams, and job analysis and redesign programs, have reported decreases in musculoskeletal injury incidence rates and turnover, and increased productivity [McKenzie et al. 1985; Rigdon 1992; Lutz et al. 1987; Geras et al. (unpublished); LaBar 1992; Echard et al. 1987]. These and other studies describing the effect of various hazard control approaches on musculoskeletal incidence rates are summarized in Table 3.

2. <u>Administrative Controls</u>

Administrative controls can be defined as policies or work practices used to prevent or control exposure to ergonomic stressors that can result in work-related injury or disease. Examples of administrative controls include the following [OSHA 1990]:

- Work Practices
  - Providing frequent rest breaks to offset undue fatigue in jobs requiring heavy labor or high performance/production rates
  - Limiting overtime work and periodically rotating workers to less stressful jobs.
  - Varying work tasks or broadening job responsibilities to offset boredom and sustain worker motivation.

- Training workers to use work methods that improve posture and reduce stress and strain on the extremities
- Worker placement evaluation

a. Work Practices

Although engineering controls are the preferred method of ergonomic hazard control, there are work situations where modification in work practices may be used as a temporary substitute for engineering controls. Such circumstances, however, should continue to be regarded as potentially hazardous, because the source of the ergonomic hazard remains. Any level of protection afforded by "work practices" is a function of human intervention, that is always subject to the weaknesses inherent in human oversight and control activities. The history of such failures is well documented in the occupational safety and health literature.

Work practices refer to modifications in job rules and procedures that are usually under the control of management or administrators. For example, in office settings where the physical environment (lighting, furniture, and VDT equipment) may already be highly refined and state-of-the-art, changes in work organization and attention to psychosocial factors provide more potential for reducing ergonomic stressors [Kilbom 1988]. Furthermore, administrative controls such as worker rotation, additional rest breaks, and slowing of production rates may be the only method of hazard control available in situations where work tasks are highly variable, there are no fixed workstations, or there are no tools involved in the work (e.g., grocery order selectors, workers in certain types of assembly jobs, sign language interpreters).

The effectiveness of work practice controls has been examined by a number of researchers. One investigation of keyboard operators found that operators who were provided short but frequent rest breaks were more productive than operators receiving only the traditional mid-morning, mid-afternoon and lunch breaks [Swanson et al. 1989]. In a series of four studies of 72 workers performing an overhead assembly task, workers were given control over the duration of their work cycles by initiating a one-minute work pause when needed. Such self-pacing served to minimize local shoulder and arm fatigue, resulting in more consistent levels of performance over the course of the study period [Putz-Anderson and Galinsky 1993].

At a plant employing 124 photographic film rollers, decreasing total work time from 353 to 330 minutes per day, and increasing the number of rest breaks from three to six, resulted in a reduction in cervicobrachial disorder and low back complaints [Itani et al. 1979]. An electromyographic study of five jobs where job rotation had been introduced concluded that job rotation may be more useful for reducing stress associated with heavy dynamic tasks than for reducing static muscular load in "light" work situations [Jonsson 1988a].

b. Training: Worker-Employer

Instructional programs aimed at reducing illnesses and injuries are also frequently promoted as readily available and an economical approach to the control of workplace injury. Training programs range from fundamental instruction on the proper use of tools and materials, to instructions on emergency procedures and use of protective devices. More comprehensive training programs are being developed to prepare the worker to participate in a broader range of worksite safety and health activities. These programs are addressed in Section III.E. of this document.

Because the effectiveness of training programs is difficult to evaluate, the success of many of the training programs has been difficult to establish. Some authors have attributed significant reductions in low back disability and lost time injuries to worker training programs [Glover 1976; Bergquist-Ullman and Larsson 1977]. Other studies indicate that well-planned training programs can have small but significant effects on lifting behavior [Chaffin et al. 1986; Varynen and Kononen 1991].

c. Worker Placement Evaluation

Worker placement evaluation has also been promoted as a method for controlling the risk of overexertion injuries and musculoskeletal disorders. The emphasis here is on matching workers to potentially high-risk jobs, i.e., identifying workers with physical characteristics that will enable them to satisfy job demands that may be excessive to other workers. Worker selection or hiring based solely on physical capacities is generally illegal, as a result of the U.S. Federal Rehabilitation Act of 1973 (29 USC[2] §791 et seq.) and the recent Americans with Disabilities Act of 1990 (42 USC §12101 et seq.). However, once a worker is offered a job, he or she can be tested to determine his or her capabilities as a prelude to job placement.

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[2] United States Code

The success of any placement program is dependent on obtaining accurate information on actual job demands as well as with the accuracy of measurements of worker capacities as they relate to the key job demands. A person's capacity for physical work is almost never a single value; it is determined by several factors including the intensity of the effort; the time of continuous effort; the frequency of repeating the effort; the presence of environmental or mental stressors, such as heat, humidity, and time pressure; and individual characteristics such as age, fitness, and skill level [Rodgers 1988].

To be valid, work capacity tests must be specific to each job of concern. Furthermore, it must be demonstrated that not only does a worker require the capacity to do the work, but that people without that capacity cannot do the job. For example, it is generally accepted that muscular strength is an appropriate job-related criteria for manual materials handling work. However, it is frequently difficult to measure the strength capacities of the worker that most closely reflect those key strength requirements of the job. Moreover, a worker's maximum strength may have little relationship to his or her ability to exert effort frequently or for long durations. Finally, there are many workplace situations where the job demands change.

In some manufacturing operations, products may frequently change, certain seasons may add environmental stresses, and overtime may change the effort requirements. Thus, the assessment of job demands will not be so accurate that it can be relied upon to predict a worker's success or failure on the job in all situations [Rodgers 1988].

There is some epidemiological support for the idea that strength testing could be a useful means of reducing back injury rates. In studies where the appropriate measurements have been made, a higher incidence of back injuries and back pain was found in those jobs demanding high exertion in relation to the worker's own maximal isometric strength [Keyserling et al. 1978; 1980]. However, to date, there are no valid methods for identifying "high risk people," i.e., accurately predicting whether healthy workers are susceptible to musculoskeletal injury from jobs requiring manual lifting and other forms of exertion. Although the use of X-rays, muscle strength tests, tests of physical fitness or flexibility, or other means have been promoted as screening procedures in the past, thus far none have proved successful [Putz-Anderson 1988].

The American Occupational Medical Association concluded that many of these tests should not be used as screening procedures, but rather as special diagnostic procedures available to the physician on appropriate indications for study [Rothstein 1984].

In summary, an advantage of administrative controls is that they can usually be implemented quickly and easily without the need to purchase or modify equipment. Because administrative controls, however, fail to eliminate the source of the hazard, they should be considered temporary solutions for controlling exposure until more permanent engineering controls can be implemented.

3. Personal Protective Equipment

NIOSH continues to support OSHA in recommending personal protective equipment (PPE) as the least preferred intervention strategy for controlling ergonomic hazards [OSHA 1990]. PPE seldom provides complete protection from exposure to a significant hazard; rather it seeks to reduce the exposure to a level that is acceptable [Moran and Ronk 1987].

Traditionally, PPE has afforded protection to the worker by providing a barrier between the worker and the hazard source. Examples of PPE that operate on this principle include respirators, ear plugs, vibration-attenuating gloves, protective eye wear, chemical aprons, safety shoes and thermal protective clothing. Because braces, wrist splints, back belts, and similar devices do not provide a barrier between the worker and the ergonomic hazard, they cannot be considered PPE. Furthermore, most devices (such as braces and splints) that are purported to reduce biomechanical stress on the musculoskeletal system have questionable value. Indeed, there is little research evidence to demonstrate that these devices limit the risk of injury.

Although other examples may exist, the only obvious example of ergonomic PPE that could be identified is vibration-attenuating gloves. Depending on their composition and construction, gloves have been shown to be effective at absorbing much of the vibration energy that would otherwise be transmitted to the hand [Goel and Rim 1987]. However, potential users should be cautioned that gloves generally interfere with grip strength and manual dexterity, thereby increasing the effort required for manual tasks [Mital and Kilbom 1992].

NIOSH has recently revised the lifting equation to reduce and prevent back injuries [Waters et al. 1991]. This equation is an update of the original equation provided in the *Work Practices Guide for Manual Lifting* [NIOSH 1981]. The new equation addresses jobs that require twisting motions and for which the horizontal and vertical positions of the load and the hand/container coupling can be defined. It re-emphasizes the use of engineering methods in preference to administrative procedures for control lifting hazards.

NIOSH will prepare a position statement on the use of back belts to reduce and prevent low back injuries. This statement will be sent to OSHA in the near future.

Conclusion

Preventing or reducing ergonomic hazards is frequently difficult for a number of reasons. In some cases, several factors combine to create a hazard. Overlapping problems can include high production demands, faulty work methods, awkward work station layouts, and ill-fitting tools [Putz-Anderson 1988]. Therefore, improvements addressing one factor may not eliminate the overall risk. Also, interventions effective in one situation may be ineffective in other settings. Most control plans involve compromise and trade-offs to arrive at the most appropriate solution. The solutions will typically require a series of adjustment or fitting trials to ensure effectiveness and worker adoption. In the final analysis, most ergonomic solutions to work-related musculoskeletal disorders are more often affected through incremental and cumulative improvements in the workplace than from a single, major workplace modification.

In summary, NIOSH continues to support a three-tier hierarchy of control (i.e., engineering controls, administrative controls, and PPE) for controlling ergonomic hazards. The effectiveness of any type of hazard control or prevention program is dependent on management commitment and employee participation. Regular monitoring, positive reinforcement, and feedback are necessary to ensure that control policies and procedures are not circumvented for convenience, schedule, or production.

C. **HEALTH SURVEILLANCE** (Submitted with NIOSH Comments to OSHA dated 2/1/93)

D. **MEDICAL MANAGEMENT** (Submitted with NIOSH Comments to OSHA dated 2/1/93)

E. TRAINING AND EDUCATION

The successful implementation of the worksite analysis, hazard control, health surveillance, and medical management elements of the ergonomics management program requires the active and informed involvement of all members of the organization. This applies not only to those employees directly at risk, but also to those whose job responsibilities may influence the ergonomic risks of others (e.g. supervisors, managers, engineers, and purchasing agents). It is, therefore, essential that all risk-related individuals be equipped with the necessary knowledge, skills and incentives to effectively support and participate in the ergonomics management program. Indeed, the absence of this training may itself be viewed as a risk factor, affecting the well-being of the individual worker and the functioning of the organization [Blackburn and Sage 1992].

Training, when used as part of an overall ergonomics management program, has been shown to effectively enhance worker awareness of ergonomic risks [Liker et al. 1990] and protective behaviors [St-Vincent et al. 1989]. A summary of relevant research is presented in Table 4. It should be noted that successful training programs are not intended to be used in isolation or in lieu of engineering, administrative, and PPE controls (as identified in Section III.B.). Rather training programs are intended to enhance the capacity to effectively recognize workplace hazards and to understand and apply appropriate control strategies. It must also be emphasized that even the most effective training program does not insure that skills and practices learned in the training environment will be enacted and sustained in the workplace. A host of factors including the level of organizational commitment, supervisory support, availability of needed resources and equipment, performance feedback, motivational incentives, opportunity for practice, and workplace norms influence the effectiveness of workplace safety practices independently of the quality of training [Goldstein 1975; Campbell 1988; Baldwin and Ford 1988]. For this reason, the training program must be seen as but one element in the organization's overall ergonomics management program.

Training Model

The planning, execution, and evaluation of ergonomic training should follow the model presented in the OSHA voluntary training guidelines [OSHA 1992] which consists of the following steps:

1) Determining if training is needed
2) Identifying training needs
3) Identifying goals and objectives
4) Developing learning activities
5) Conducting the training
6) Evaluating program effectiveness
7) Improving the program

A general description of how these steps should be implemented in an ergonomics training program is provided below.

1. Determining if Training is Needed

Any worksite requiring an ergonomics management program (as determined by the worksite analysis and medical survey described in

Section II) should be required to provide its employees with the training necessary to develop the knowledge and skills to effectively implement the program. Consistent with the approach specified for ergonomic training in related documents [OSHA 1990; NOHSC 1992; Cal/OSHA 1992] training should be provided at two levels:

a) General awareness training for all individuals affected by the ergonomics management program. This may include, in addition to employees directly at risk, supervisors, managers, engineers, purchasing agents, and safety and health committee members whose job responsibilities are related to risk recognition and control.

b) Job/risk-specific training for those individuals and their supervisors employed in high risk jobs as identified by the worksite analysis and medical survey data.

Baseline training at both levels should be provided to all employees during the implementation phase of the ergonomics management program, or at the time of hire for new employees.

2. Identifying Training Needs

a) General Awareness Training

A number of general awareness courses regarding the nature and control of ergonomic hazards are currently available through federal (e.g., NIOSH, OSHA Training Institute), university (e.g., continuing education programs at 12 of the 14 NIOSH-funded Educational Resource Centers), and labor organizations (e.g., Workplace Health Fund). Model course contents have also been proposed by Rohmert and Laurig [1977] and Smith and Smith [1984]. At a minimum, all individuals receiving general awareness training should be sufficiently informed as to be able to:

1) Describe the general nature, symptoms, and types of work-related musculoskeletal disorders

2) Describe the risk factors associated with work-related musculoskeletal disorders

3) Describe the prevention and control strategies for abating ergonomic hazards

4) Describe the organization's procedures and policies regarding the reporting of work-related musculoskeletal disorders

5) Describe the organization's procedures and policies for reporting perceived ergonomic risks

6) Describe the membership, structure, and general operation of the organization's ergonomic management program

7) Regulations, standards, etc. regarding ergonomic hazards

b) Job/Risk-Specific Training

In addition to the awareness training described above, additional job/risk specific training should be provided to those employees and their supervisors who are at risk from ergonomic hazards as identified in the worksite analysis and medical survey. The content of this training will be dictated by the findings of the worksite and health surveillance activities. Nevertheless, at a minimum, the training should enable the employees to demonstrate an understanding of the:

1) Specific tasks or operations associated with their jobs which pose ergonomic risks (results of worksite analysis)

2) Proper use of tools, devices, and equipment provided to control identified risks

3) Proper engineering, work practice, and administrative controls available to reduce identified risks

4) Procedures for recommending job redesign or control strategies for reducing risk

3. Identifying Training Objectives

Following a determination of the training needs, performance objectives should be specified. Objectives should be clear, directly observable, measurable, and action-oriented. The objectives should describe exactly what the trainee should know and be able to do following training [Gagne and Briggs 1979] and specify the conditions under which these behaviors should be performed [Smith and Delahaye 1987; Komaki et al. 1980]. Because of the variability of ergonomic hazards and related controls across job operations and worksites, training objectives will be situationally specific. Objectives will be identified by the medical surveillance, worksite analysis, and hazard control components of the program.

4. Developing Learning Activities

The mode or method of training should be tailored to the individual worksite and job/task. Size of the organization and available resources, worker demographics, the nature of the work being performed, and other factors will influence the type of learning activities most appropriate. Regardless of the strategy employed, allowance should be made for active rehearsal of the trained skills and behaviors, performance feedback both during training and on-the-job, and remedial or additional instruction when initial training fails to provide trainees with skills and knowledge stated in the course objectives.

5. Conducting the Training

The training should be conducted at a language and educational level compatible with backgrounds of the individuals to be trained. Individuals should be provided with an overview of the materials to be learned as the goals and objectives of the training. This will allow the trainees to determine if they have received adequate instruction relative to organizational expectations. Even materials that are well-learned during training will have to be periodically refreshed. The question here is when or how often should retraining be provided following the initial baseline training to ensure maintenance of the knowledge and skills specified in the goals and objectives. From an empirical perspective, the question is unanswerable in a generic sense. Few systematic field studies of training techniques and retention rates have been conducted to date, and those that are available, vary along important dimensions. Rubinsky and Smith [1971], for an example, report that the positive effects of training on the safe use of grinders using a simulated accident technique began to diminish after only four weeks. The safe donning of self-contained, self-rescuer respirators showed a degradation of skills three months following training [Vaught et al. 1988]. A 30 to 45 minute slide presentation on the proper use of equipment and tools, housekeeping and general safety procedures increased safe work behaviors among vehicle maintenance workers, relative to baseline levels, for up to 45 weeks after training when supervisory feedback was provided 2-3 times a week [Komaki et al. 1980]. The retention rates of learned behaviors vary as a function of a multitude of content (e.g., complexity and nature of the task), trainee (e.g., motivation, aptitude), instructional design (conditions of practice, sequencing of materials) and environmental/organizational (e.g., corrective feedback, reinforcement) variables [Kyllonen and Alluisi 1987; Fendrich et al. 1988].

At a minimum, refresher training (both awareness and job/risk specific) should be provided annually to maintain employee motivation, to reaffirm organizational commitment, and to allow a forum for employee feedback, all factors which have been shown to greatly affect the transfer of training [Baldwin and Ford 1988; Campbell 1988]. In addition, targeted training should be delivered on an "as needed" basis when the medical surveillance data or worksite analysis of an existing or modified job indicate a training need.

6. Evaluating the Program

A plan for evaluating the effectiveness of the training should be developed at the same time that the course objectives and content are formulated. The evaluation should focus on the skills and knowledge specified in the training objectives and provide information on the extent to which the training brought attendees to the desired level of proficiency. The evaluation should occur at two levels [Cole et al. 1984]. The first, a formative evaluation, is conducted concurrently with, or immediately after, training to assess the clarity, organization, and comprehensibility of the instruction. This is to assure that individuals are learning what they should be learning. Surveys, focus groups, interviews, self-assessment tests, and behavioral demonstrations are common methods for formative evaluation. Information learned here should be used to refine the training program.

The second type of evaluation is a summative evaluation which is conducted following the return to work to determine if individuals are actually practicing what they have learned. On-the-job performance, worksite analysis (Section III.A.), and illness and injury data (Section III.C.) may be used for this purpose. If the formative evaluation indicates that learning occurred, but the summative evaluation indicates no change in organizational performance, this may indicate that the training was not relevant to the actual job/task, or that other aspects of the overall ergonomics management program (e.g. supervisory support, availability of resources, and perceived management commitment) may be deficient.

7. Improving the Program

If the evaluations performed above indicate that the training did not meet objectives, review of the training program, along with the other elements of the ergonomics management program, should be performed and revisions made.

Table 1

EXAMPLES OF ERGONOMIC INTERVENTIONS

1. Repetitiveness
   - a. Use mechanical aids
   - b. Enlarge work content by adding more diverse activities
   - c. Automate certain tasks
   - d. Rotate workers
   - e. Increase rest allowances
   - f. Spread work uniformly across workshift
   - g. Restructure jobs

2. Force/Mechanical Stress
   - a. Decrease the weight of tools/containers and parts
   - b. Increase the friction between handles and the hand
   - c. Optimize size and shape of handles
   - d. Improve mechanical advantage
   - e. Select gloves to minimize effects on performance
   - f. Balance hand-held tools and containers
   - g. Use torque control devices
   - h. Optimize pace
   - i. Enlarge corners and edges
   - j. Use pads and cushions

3. Posture
   - a. Locate work to reduce awkward postures
   - b. Alter position of tool
   - c. Move the part closer to the worker
   - d. Move the worker to reduce awkward postures
   - e. Select tool design for work station

4. Vibration
   - a. Select tools with minimum vibration
   - b. Select process to minimize surface and edge finishing
   - c. Use mechanical assists
   - d. Use isolation for tools that operate above resonance point
   - e. Provide damping for tools that operate at resonance point
   - f. Adjust tool speed to avoid resonance

5. Psychosocial Stresses

   a. Enlarge workers' task duties
   b. Allow more worker control over pattern of work
   c. Provide micro work pauses
   d. Minimize paced work
   e. Eliminate blind electronic monitoring

TABLE 2

SELECT STUDIES DEMONSTRATING EFFECTIVENESS OF ENGINEERING CONTROLS FOR REDUCING EXPOSURE TO ERGONOMIC RISK FACTORS

STUDY	TARGET POPULATION	PROBLEM/ RISK FACTOR	CONTROL MEASURE	EFFECT
Miller, Ransohoff and Tichauer (1971)	Surgeons (bayonet forceps)	Muscle fatigue during forceps use, frequent errors while passing instruments	Redesigned forceps (increase surface area)	Reduced muscle tension (determined by EMG, fewer passing errors)
Armstrong, Kreutzberg and Foulke (1982)	Poultry cutters (knives)	Excessive muscle force during poultry cutting tasks	Redesigned knife (reoriented blade, enlarged handle, provided strap for hand)	Reduced grip force during use, reduced forearm muscle fatigue
Knowlton and Gilbert (1983)	Carpenters (hammers)	Muscle fatigue, wrist deviation during hammering	Bent hammer handle, decreased handle diameter	Less strength decrement after use, reduced ulnar wrist deviation
Habes (1984)	Auto workers	Back fatigue during embossing tasks	Provided cut out in die (reduce reach distance)	Reduced back muscle fatigue as determined by EMG
Goel and Rim (1987)	Miners (pneumatic chippers)	Hand-arm vibration	Provided padded gloves	Reduced vibration transmitted to the hand by 23.5 - 45.5%
Wick (1987)	Machine operators in a sandal plant	Pinch grips, wrist deviation, high repetition rates, static loading of legs and back	Provided adjustable chair and bench-mounted armrests, angled press, provided parts bins	Reduced wrist deviation, compressive force on L5/S1 disc (from 85 to 13 lbs)
Little (1987)	Film notchers	Ulnar deviation, high repetition rates, pressure in the palm of the hand imposed by notching tool	Redesigned notching tool (extended, widened and bent handles, reduced squeezing force)	Reduced force from 12-15 to 10 lbs, eliminated ulnar wrist deviation, increased productivity by 15%
Johnson (1988)	Power hand tool users	Muscle fatigue, excessive grip force	Added vinyl sleeve and brace to handle	Reduced grip force as determined by EMG
Fellows and Freivalds (1989)	Gardeners (rakes)	Blisters, muscle fatigue	Provided foam cover for handle	Reduced muscle tension and fatigue buildup as determined by EMG
Andersson (1990)	Power hand tool users	Hand-arm vibration	Provided vibration damping handle	Reduced hand-transmitted vibration by 61-85%
Radwin and Oh (1991)	Trigger-operated power hand tool users	Excessive hand exertion and muscle fatigue	Extended trigger	Reduced finger and palmar force during tool operation by 7%
Freudenthal et al. (1991)	Office workers	Static loading of back and shoulders during seated tasks	Provided desk with 10 degree incline, adjustable chair and table	Reduced moment of force at L5-S1 by 29%, at C7-T1 by 21%

STUDY	TARGET POPULATION	PROBLEM/ RISK FACTOR	CONTROL MEASURE	EFFECT
Miller, Ransohoff and Tichauer [1971]	Surgeons (bayonet forceps)	Muscle fatigue during forceps use, frequent errors while passing instruments	Redesigned forceps (increase surface area)	Reduced muscle tension (determined by EMG, fewer passing errors)
Powers, Hedge and Martin [1992]	Office workers	Wrist deviation during typing tasks	Provided forearm supports and a negative slope keyboard support system	Reduced wrist extension
Erisman and Wick [1992]	Assembly workers	Pinch grips, wrist deviation	Provided new assembly fixture	Eliminated pinch grips, reduced wrist deviations by 65%, reduced cycle time by 50%
Luttmann and Jager [1992]	Weavers	Forearm muscle fatigue	Redesigned workstation (numerous changes)	Reduced fatigue build-up as indicated by EMG, improved quality of product

TABLE 3

SELECT STUDIES OF THE EFFECTIVENESS OF VARIOUS CONTROL STRATEGIES FOR REDUCING MUSCULOSKELETAL INJURIES

STUDY	TYPE OF WORK TASK	NUMBER OF WORKERS	METHOD OF INTERVENTION	SUMMARY OF RESULTS	ADDITIONAL COMMENTS
Jonsson (1988b)	Telephone assembly, manufacturing printed circuit cards, glass blowing, mining work	25 total workers studied	Job rotation	Job rotation in light duty tasks not as effective as in dynamic heavy duty tasks	Measured static load in trapezius muscle with EMG
Westgaard and Aaras (1984; 1985)	Production of cable forms	100 workers	Introduced adjustable workstations and fixtures, counterbalanced tools	Turnover decreased, musculoskeletal sick leave reduced by 2/3 over 8 year period; productivity increased	Positive effects of interventions verified by reductions in trapezius muscle EMG
Itani et al. (1979)	Photographic film rolling workers	124 total workers in two groups	Reduced work time, increased number of rest breaks	Reduction in cervicobrachial disorder and low back complaints; improved worker health	Post intervention productivity 86% of preintervention levels
Luopajarvi et al. (1982)	Food production packing tasks	200 workers	Redesigned packing machine	Decreases in neck, elbow, and wrist pain	Not all recommended job changes implemented; workers still complain
McKenzie et al. (1985)	Telecommunications equipment manufacturer	6600 employees	Redesigned handles on powered screwdrivers and wire wrapping guns; instituted plant-wide ergonomics training program	Incidence rate of repetitive trauma disorders decreased from 2.2 to .53 cases/200,000 work hours and lost days reduced from 1001 to 129 in three years	Data inadequate for rigorous statistical evaluation
Rigdon (Wall Street Journal 1992)	Bakery	630 employees	Formed union-management CTD committee; work station changes, tool modifications, improved work practices	CTS cases dropped from 34 to 13 in 4 years, lost days reduced from 731 to 8	Union advocated more equipment to reduce manual material handling
Lutz and Hansford (1987)	Manufacturer of sutures and wound closure products	>1000	Introduced adjustable work stations and fixtures, mechanical aids to reduce repetitive motions, job rotation	Reduced medical visits from 76 to 28 per month	Results based on two departments with 33 employees; company enthusiastic about exercise program
Silverstein et al. (1987)	Investment casting plant	136 workers	Specific ergonomic changes not mentioned	No relationship between ergonomic changes and prevalence of hand-wrist CTDs	Ergonomic changes did not reduce the risk of studied jobs
Jorgensen et al. (1987)	Airline baggage loaders	6 males	Introduced a telescopic bin loading system	Local muscular load on the shoulders and low back reduced	Measured EMG of the trapezius and erector spinae muscles

STUDY	TYPE OF WORK TASK	NUMBER OF WORKERS	METHOD OF INTERVENTION	SUMMARY OF RESULTS	ADDITIONAL COMMENTS
Jonsson (1988b)	Telephone assembly, manufacturing printed circuit cards, glass blowing, mining work	25 total workers studied	Job rotation	Job rotation in light duty tasks not as effective as in dynamic heavy duty tasks	Measured static load in trapezius muscle with EMG
Geras et al. (unpublished)	Rubber and plastic parts workers	87 plants of a national company	Introduced an ergonomics training and intervention program; added material handling equipment, work station modifications to eliminate postural stresses	Lost time at two plants reduced from 4.9 and 9.7/200,000 hours to .9 and 2.6, respectively over 4-year period	Key to success has been increased training, awareness of hazards and improved communication between management and workers
LaBar (1992)	Household products manufacturer	800 workers	Introduced adjustable workstations, improved the grips on hand tools, improved parts organization and work flow	Reduced injuries (particularly back by 50%)	Company also has a labor-management safety committee that investigates ergonomics-related complaints
Orgel et al. (1992)	Grocery store	23 employees	Redesigned checkstand to reduce reach distances; installed a height-adjustable keyboard; trained workers to adopt preferred work practices	Lower rate of self-reported neck, upper back, and shoulder discomfort; no change in arm, forearm, wrist discomfort	Study lacked a control group
Kilbom (1988)	Reviews intervention programs in various industries	14 studies		Concludes that job redesigns are most effective, but as the physical environment improves, work organization and psychosocial factors become more important	
Echard et al. (1987)	Automobile manufacturer		Redesigned tools, fixtures, and work organization in assembly operations	Reduced long-term upper extremity and back disabilities; reduced CTS surgeries by 50%	
Snook et al. (1978)	Insurance company survey	200 surveys	Selection of workers; training in lifting technique; design of lifting tasks to fit worker capabilities	Selection and training not effective; matching job demands to worker capabilities can reduce injuries by 2/3	Authors also conclude that 1/3 of low back injuries will occur no matter what hazard control approach is used
Drury and Wick (1984)	Shoe manufacturer	6 work sites	Work station redesign	Reduced postural stress; increased productivity	Trunk and upper limbs most affected by changes

TABLE 4

SELECTED STUDIES DEMONSTRATING EFFECTIVENESS OF ERGONOMICS TRAINING

AUTHORS	TASK (INDUSTRY)	SAMPLE	STUDY DESIGN	MEASURES	RESULTS
Brown et al. [1992]	Varied (Municipal)	74 workers w/job back injury history	Before - After 6 wk. Back School Non-equivalent controls	Records study: Lost time, lost time cost, medical cost, total cost	Trained workers had sig. before-after gains on all measures; fewer injury reports than controls
Orgel et al. [1992]	Check-out (Grocery)	23 workers	Before - After; no controls Training was part of ergonomics program	Self-report of discomfort	Ergonomics program resulted in some decrease in medication requirements and recovery days
Liker et al. [1990]	Ergonomic job analysis (Varied)	147 OSH specialists	Before - After Lecture-based training	Knowledge and physical stress estimation skills	Substantial gains in knowledge but not skills; simplistic analysis models preferred
Dortch & Trombly [1990]	Assembly by hand (Electronics)	18 workers	Before - After Handouts vs. handouts + demonstrations vs. controls	Behavior observation	Trained groups had reduced traumatizing movements when compared with controls
Genaidy et al. [1989]	Lifting and carrying (Packaging)	21 M workers	Before - After w/controls 8 Physical training sessions	Psychophysical endurance, ratings of perceived exertion	Psychophysical endurance doubled after training; perceived exertion did not change
St-Vincent et al. [1989]	Lifting (Geriatric hospital)	32 orderlies	12-18 months After only 12h classroom training	Trained behavior observers using a behavior grid	Procedures from training rarely used in horizontal moves; more frequently used for vertical
Rosenfeld et al. [1989]	Varied (Pharmaceutical)	522 workers	Before - After Physical training vs. social activity	Self-report of perceived workload, efficiency, fatigue	Physical training group had higher perceived workload but lower fatigue post training
Liker et al. [1989]	Many tasks (Auto and air conditioning mfg.)	4 Plants: 2 U.S. 2 Japan	Before - After changes by ergonomics committee; no controls	Qualitative: Worksite observations Records review	Both training by experts (U.S.) and peer or supervisor training (Japan) contributed to completion of job redesigns
Geras et al. [unpublished]	Varied (Auto mfg.)	Unknown # plant leaders	Before - After Training course + proactive ergonomics program	Lost time incidence rates	Substantial reductions in incidence rates after program was initiated
Chaffin et al. [1986]	Lifting (Warehouse)	33 material handlers	Before - After 2 4-hour training sessions	Expert analysis of random video-taped lifts	Post-training lifts were better on 2 of 5 criteria

AUTHORS	TASK (INDUSTRY)	SAMPLE	STUDY DESIGN	MEASURES	RESULTS
McKenzie et al. [1985]	Varied (Communications mfg.)	6,600 workers	Before - After Training for ergonomics task force professionals only as part of ergo. program	Repetitive motion incidence rates	Reduced incidence rates corresponded with program implementation
Smith & Smith [1984]	Supervision Textile mfg.	100 supervisors	After only; no controls	Self-reports of attitudes toward ergonomic activities	Substantial support for ergonomics activities
Scholey [1983]	Lifting (Geriatric hospital)	4 F nurses	Before - After Handouts + psysio-feedback + demonstration + practice	Truncal stress (outcome) Task analysis Behavior observation	Training was effective for 3 nurses but not for a less experienced nurse in a more demanding ward
Dehlin et al. [1981]	Lifting (Geriatric hospital)	45 F with low back symptoms	Before - After Fitness training vs. lifting technique training vs. controls	Self-reports of perception of work, low-back insufficiency, and determination of physical work capacity	Negligible differences; fitness training resulted in greater perceived need for information and less perceived exertion
Snook et al. [1978]	Lifting (Varied)	192 surveys	After only Training vs. no training	Self-report of insurance reps on their most recent claim	No training effects on injury incidence
Rohmert & Laurig [1977]	Varied (Auto mfg.)	195 workers	Before - After 4-day training course; no controls	Written questionnaire	Increased correlation between course time devoted to topic and importance rank

REFERENCES

Andersson [1990]. Design and testing of a vibration attenuating handle. Int J Industr Ergonomics 6(2):119-126.

Armstrong TJ, Kreutzberg KL, Foulke JA [1982]. Laboratory evaluation of knife handles for thigh boning. Ann Arbor, MI: University of Michigan, NIOSH Procurement No. 81-2637.

Armstrong TJ, Radwin RG, Hansen DJ, Kennedy KW [1986]. Repetitive trauma disorders: job evaluation and design. Hum Factors 28(3):325-336.

Arndt R [1987]. Work pace, stress, and cumulative trauma disorders. J Hand Surg 12A:866-869.

Baldwin TT, Ford JK [1988]. Transfer of training: A review and directions for future research. Personnel Psychology 41:63-105.

Bergquist-Ullman M, Larsson U [1977]. Acute low back pain in industry: a controlled prospective study with special reference to therapy and confounding factors. Acta Orthopedica Scandinavia 170:1-117.

Blackburn JD, Sage JE [1992]. Safety training and employer liability. Technical & Skills Training 3(5):29-33.

Brown KC, Sirles AT, Hilyer JC, Thomas MJ [1992]. Cost-effectiveness of a back school intervention for municipal employees. Spine 17(10):1224-1228.

Cal/OSHA [1992]. Cal/OSHA's proposed ergonomics regulation — section by section breakdown. State of California/Occupational Safety and Health Administration.

Campbell JP [1988]. Training design for performance improvement. In: Campbell JP, Campbell RJ & Associates, eds. Productivity in organizations: new perspectives from industrial and organizational psychology. San Francisco: Josey-Bass.

Chaffin D, Andersson GBJ [1991]. Occupational biomechanics. 2nd ed. New York, NY: Wiley.

Chaffin DB, Gallay LS, Woolley CB, Kuciemba SR [1986]. An evaluation of the effect of a training program on worker lifting postures. Int J Industr Ergonomics 1:127-136.

Cole HP, Moss J, Gohs FX, Lacefield WE, Barfield BJ, Blyth DK [1984]. Measuring learning in continuing education for engineers and scientists. Phoenix, AZ: Oryx.

Dehlin O, Berg S, Andersson GBJ, Grimby G [1981]. Effect of physical training and ergonomic counselling on the psychological perception of work and on the subjective assessment of low-back insufficiency. Scand J Rehabil Med 13:1-9.

Dortch HL, Trombly CA [1990]. The effects of education on hand use with industrial workers in repetitive jobs. Amer J Occup Ther 44:777-782.

Drury CG, Wick J [1984]. Ergonomic applications in the shoe industry. In: Proceedings of the international conference on occupational ergonomics, pp. 489-93.

Eastman Kodak Company [1983]. Ergonomic design for people at work. Vol. 1. New York, NY: Van Nostrand Reinhold Company, Inc.

Eastman Kodak Company [1986]. Ergonomic design for people at work. Vol. 2. New York, NY: Van Nostrand Reinhold Company, Inc.

Echard M, Smolenski S, Zamiska M [1987]. Ergonomic considerations: engineering controls at Volkswagen of America. In: Ergonomic interventions to prevent musculoskeletal injuries in industry. Industrial Hygiene Science Series, ACGIH, Lewis Publishers, pp 117-31.

Erisman J, Wick J [1992]. Ergonomic and productivity improvements in an assembly clamping fixture. In: Kumar S, ed. Advances in industrial ergonomics and safety IV. Philadelphia, PA: Taylor & Francis, pp. 463-468.

Fellows GL, Freivalds A [1989]. The use of force sensing resistors in ergonomic tool design. In: Proceedings of the Human Factors Society 33rd Annual Meeting, pp. 713-717.

Fendrich DW, Healy AF, Meiskey L, Crutcher RJ, Litte W, Borne LE [1988]. Skill maintenance: literature review and theoretical analysis (AFHRL-TP-87-73). Brooks AFB, TX: Air Force Human Resource Laboratory.

Freudenthal A, van Riel MPJM, Molenbroek JFM, Snijders CJ [1991]. The effect on sitting posture of a desk with a ten-degree inclination using an adjustable chair and table. Appl Ergonomics 22(5):329-336.

Gagne RM, Briggs LJ [1979]. Principles of instructional design. 2nd ed. New York, NY: Holt, Rinehart & Winston.

Genaidy AM, Mital A, Bafna KM [1989]. An endurance training programme for frequent manual carrying tasks. Ergonomics 32:149-155.

Geras DT, Pepper CD, Rodgers SH [1988]. An integrated ergonomics program at the Goodyear Tire & Rubber Company. Unpublished.

Glover JR [1976]. Prevention of back pain. In: Jayson M, ed. The lumbar spine and back pain. New York, NY: Grune and Stratton.

Goel VK, Rim K [1987]. Role of gloves in reducing vibration: an analysis for pneumatic chipping hammer. Am Ind Hyg Assoc J 48(1):9-14.

Goldstein IL [1975]. Training. In: Margolis BL, Kroes WH, ed. The human side of accident prevention. Springfield, IL: Thomas.

Grandjean E [1988]. Fitting the task to the man: a textbook of occupational ergonomics. 4th ed. London, UK: Taylor and Francis.

Habes DJ [1984]. Use of EMG in a kinesiological study in industry. Appl Ergonomics 15(4):297-301.

Itani T, Onishi K, Sakai K, Shindo H [1979]. Occupational hazard of female film rolling workers and effects of improved working conditions. Arh hig rada toksikol 30:1243-1251.

Johnson SL [1988]. Evaluation of powered screwdriver design characteristics. Hum Factors 30(1):61-69.

Jonsson B [1988a]. The static load component in muscle work. Eur J Appl Physiol 57:305-310.

Jonsson B [1988b]. Electromyographic studies of job rotation. Scand J Work Environ Health 14(1):108-09.

Jorgensen K, Jensen B, Stokholm J [1987]. Postural strain and discomfort during loading and unloading flights: an ergonomic study. In: Asfour SS, ed. Trends in ergonomics/human factors IV. North Holland: Elsevier Science Publishers B.V., pp. 663-673.

Keyserling WM, Herrin GD, Chaffin DB [1980]. Isometric strength testing as a means of controlling medical incidents on strenuous jobs. JOM 22(5):332-36.

Keyserling WM, Herrin GD, Chaffin DB, Armstrong TJ, Foss ML [1978]. Establishing an industrial strength testing program. Am Ind Hyg Assoc J 41(10):730-36.

Kilbom A [1988]. Intervention programmes for work-related neck and upper limb disorders: strategies and evaluation. Ergonomics 31(5):735-47.

Knowlton RG, Gilbert JC [1983]. Ulnar deviation and short-term strength reductions as affected by a curve-handled ripping hammer and a conventional claw hammer. Ergonomics 26(2):173-179.

Komaki J, Barwick KD, Scott LR [1980]. Effect of training and feedback: Component analysis of a behavioral safety program. J Appl Psychol 65:261-270.

Konz S [1979]. Work design. Columbus, OH: Grid Publishing Co.

Kyllonen PC, Alluisi EA [1987]. Learning and forgetting facts and skills. In: Salvendy G, ed. Handbook of Human Factors. New York, NY: Wiley.

LaBar G [1992]. A battle plan for back injury prevention. Occupational Hazards, 29-33.

Liker JK, Evans SM, Ulin S [1990]. The strengths and limitations of lecture-based training in the acquisition of ergonomics knowledge and skill. Int J Industr Ergonomics 5:147-159.

Liker JK, Nagamachi M, Lifshitz YR [1989]. A comparative analysis of participatory ergonomics programs in U.S. and Japan manufacturing plants. Int J Industr Ergonomics 3:185-199.

Little RM [1987]. Redesign of a hand tool: a case study. Semin Occup Med 2(1):71-72.

Luopajarvi T, Kuorinka I, Kukkonen R [1982]. The effects of ergonomic measures on the health of the neck and upper extremities of assembly-line packers - a four year follow-up study. In: Noro, ed. Tokyo, Japan: Proceedings of the 8th Congress of the International Ergonomics Association, pp. 160-161.

Luttmann A, Jager M [1992]. Reduction in muscular strain by work design: electromyographical field studies in a weaving mill. In: Kumar S, ed. Advances in industrial ergonomics and safety IV. Philadelphia, PA: Taylor & Francis, pp. 553-560.

Lutz G, Hansford T [1987]. Cumulative trauma disorder controls: The ergonomics program at Ethicon, Inc. J Hand Surg 12A(5 Part 2): 863-66.

McKenzie F, Storment J, Van Hook P, Armstrong TJ [1985]. A program for control of repetitive trauma disorders associated with hand tool operations in a telecommunications manufacturing facility. Am Ind Hyg Assoc J 46(11):674-78.

Miller M, Ransohoff J, Tichauer ER [1971]. Ergonomic evaluation of a redesigned surgical instrument. Appl Ergonomics 2(4):194-197.

Mital A, Kilbom A [1992]. Design, selection and use of hand tools to alleviate trauma to the upper extremities: Part II - The scientific basis (knowledge base for the guide). Int J Industr Ergonomics 10:7-21.

Moran JB, Ronk RM [1987]. Personal protective equipment. In: Salvendy G, ed. Handbook of human factors. New York, NY: John Wiley & Sons, pp. 876-894.

NIOSH [1981]. Work practices guide for manual lifting. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 81-122.

NOHSC [1992]. Guidance note for the prevention of occupational overuse syndrome in the manufacturing industry. Commonwealth of Australia: National Occupational Health and Safety Commission.

Orgel DL, Milliron MJ, Frederick LJ [1992]. Musculoskeletal discomfort in grocery express checkstand workers: an ergonomic intervention study. JOM 34(8):815-18.

OSHA [1990]. Ergonomics program management guidelines for meatpacking plants. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration, OSHA Publication No. 3123.

OSHA [1992]. Training requirements in OSHA standards and training guidelines. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration, OSHA Publication No. 2254 (revised).

Powers JR, Hedge A, Martin MG [1992]. Effects of full motion forearm supports and a negative slope keyboard system on hand-wrist posture while keyboarding. Atlanta, GA: Proceedings of the Human Factors Society 36th Annual Meeting, pp. 796-800.

Putz-Anderson V [1988]. Cumulative trauma disorders: a manual for musculoskeletal diseases of the upper limb. Philadelphia, PA: Taylor & Francis. Submitted with NIOSH comments to OSHA dated 2/1/93.

Putz-Anderson V, Galinsky T [1993]. Psychophysically determined work durations for limiting shoulder girdle fatigue from elevated manual work. Int J Ind Ergonomics 11:19-28.

Radwin RG, Oh S [1991]. Handle and trigger size effects on power tool operation. In: Proceedings of the Human Factors Society 35th Annual Meeting, pp. 843-847.

Rigdon JE [1992]. The wrist watch: how a plant handles occupational hazard with common sense. The Wall Street Journal, 9/28/92.

Rodgers SH [1988]. Job evaluation in worker fitness determination. In: Occupational Medicine: State of the Art Reviews. Philadelphia, PA: Hanley & Belfus, Inc.

Rohmert W, Laurig W [1977]. Increasing awareness of ergonomics by in-company courses — a case study. Appl Ergonomics 8:19-21.

Rosenfeld O, Tenenbaum G, Ruskin H, Halfon S-T [1989]. The effect of physical training on objective and subjective measures of productivity and efficiency in industry. Ergonomics 32:1019-1028.

Rothstein MA [1984]. Medical screening of workers. Washington, DC: Bureau of National Affairs.

Rubinsky S, Smith NE [1971]. Evaluation of accident simulation as a technique for teaching safety procedures in the use of small power tools. Washington, D.C.: U.S. Govt. Printing Office, DHEW Publication (HSM) 72-10000.

Sanders MS, McCormick EJ, eds. [1982]. Human factors in engineering and design. Sixth edition. New York, NY: McGraw-Hill.

Scholey M [1983]. Back stress: the effects of training nurses to lift patients in a clinical situation. Int J Nursing Studies 20:1-13.

Silverstein B, Fine L, Stetson D [1987]. Hand-wrist disorders among investment casting plant workers. J Hand Surg 12A(5):Part 2:838-44.

Smith BJ, Delahaye BL [1987]. How to be an effective trainer (2nd ed.). New York: Wiley.

Smith LA, Smith JL [1984]. Observations on in-house ergonomics training for first-line supervisors. Appl Ergonomics 15:11-14.

Snook SH, Campanelli RA, Hart JW [1978]. A study of three preventive approaches to low back injury. JOM 20:478-481.

St-Vincent M, Tellier C, Lortie M [1989]. Training in handling: an evaluative study. Ergonomics 32:191-210.

Swanson NG, Sauter SL, Chapman LJ [1989]. The design of rest breaks for video display terminal work: a review of the relevant literature. In: Mital A, ed. Advances in industrial ergonomics and safety I.

Tichauer ER [1991]. Ergonomics. In: Clayton and Clayton, eds. Patty's Industrial Hygiene and Toxicology. 4th rev. ed. Vol. 1B, General Principles. New York, NY: Wiley.

Van Cott H, Kincaid R [1973]. Human engineering guide to equipment design. Washington, DC: Superintendent of Documents, U.S. Government Printing Office.

Vayrynen S, Kononen U [1991]. Short and long-term effects of a training programme on work postures in rehabilitees: a pilot study of loggers suffering from back troubles. Inter J Industr Ergonomics 7:103-110.

Vaught C, Brnich MJ, Kellner HJ [1988]. Effect of training strategy on self contained self rescuer donning performance. Mine Safety Education and Training Seminar, Bureau of Mines Information Circular. U.S. Department of the Interior, Report IC 9185, pp. 2-14.

Waters TR [1991]. Strategies for assessing multi-task manual lifting jobs. In: Proceedings of the Human Factors Society 35th Annual Meeting, pp. 809-813.

Westgaard RH, Aaras A [1984]. Postural muscle strain as a causal factor in the development of musculo-skeletal illnesses. Appl Ergonomics 15(3):162-74.

Westgaard RH, Aaras A [1985]. The effect of improved workplace design on the development of work-related musculo-skeletal illnesses. Appl Ergonomics 16(2):91-97.

Wick JL [1987]. Workplace design changes to reduce repetitive motion injuries in an assembly task: a case study. Semin in Occup Med 2(1):75-78.

Woodson WE [1981]. Human factors design handbook. New York, NY: McGraw-Hill.