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

General Principles

This section outlines suggestions for development and use of a workplace health surveillance program to identify, record, track and ultimately prevent and reduce work-related musculoskeletal disorders.

Surveillance has been defined as:

> "The ongoing systematic collection, analysis and interpretation of health and exposure data in the process of describing and monitoring a health event. Surveillance data are used to determine the need for occupational safety and health action and to plan, implement and evaluate ergonomic interventions and programs" [CDC 1988].

Components of a Surveillance System

The health surveillance program for a workplace should incorporate both passive surveillance and active surveillance elements.

Passive surveillance is the collection and analysis of data obtained from existing record sources to identify patterns of disease within a workplace group. The record sources are usually readily available and may be used to determine if a work-related musculoskeletal disorder exists, and to detect disease trends in the group at risk.

Active surveillance involves the development of a system to obtain data with which to determine the patterns or trends of work-related musculoskeletal disorders with greater sensitivity than a passive surveillance system. That is, active surveillance might identify symptoms that may be indicators of developing work-related musculoskeletal disorders not captured by classic case definitions, as in the ICD, or identifies factors that may put workers at greater risk for work-related musculoskeletal disorders.

1. **Passive Surveillance**

Information Sources: Record systems or information used for passive surveillance generally are collected for purposes other than surveillance. Types of records that have been successfully used in passive surveillance systems, include OSHA 200 logs, plant clinic records or nurses logs, workers' compensation records, insurance claims, and accident reports. Other records that might be used include absentee records, job transfer applications, and other documented problems about particular jobs.

Evaluation of information: Review of information should occur routinely, e.g., yearly, but the frequency of which may be dependent upon the extent of the problem of work-related musculoskeletal disorders. Specific diagnoses may be coded according to the current version of the International Classification of Diseases (ICD). Calculation of job-specific incidence rates (rate of work-related musculoskeletal disorders appearing for the first time during a specified period), and job-specific prevalence rates (rate of all work-related musculoskeletal disorders occurring during a specified period) will help to identify jobs in which workers have work-related musculoskeletal disorders or are suffering physical discomfort from the jobs. The severity of the problem may be determined by examining the number of disability days.

Incidence (new case) rates (per 100 worker-years per year) may be calculated as follows:

$$\frac{\text{\# new cases during the past 12 months x 200,000 hours}}{\text{\# work hours during the past 12 months}}$$

Prevalence rates (all cases during the period) (per 100 worker-years per year) may be calculated as follows:

$$\frac{\text{total \# cases in the past 12 months x 200,000 hours}}{\text{\# work hours during the past 12 months}}$$

Limitations: Passive surveillance is limited by a number of factors, most of which are specific to the types of information being used. Some information sources, such as the OSHA 200 logs and clinic logs provide varying data quality, particularly in completeness (capture of all appropriate events) and accuracy of entries. Medical logs may also be variable due to the availability of an onsite clinic, management's attitude about the use of the clinic, and training of the clinic staff about occupational safety and health.

Information obtained through workers' compensation records, insurance records and personal medical provider records may vary due to a number of factors. These factors include: a worker's likelihood or ability to seek and obtain medical care, the ability or likelihood of the medical care provider to diagnose work-related musculoskeletal disorders correctly, and variations in data recording in the various record sources.

Surveillance data will be limited by information biases of various types. For example, health outcomes can be misclassified as a result of non-uniformity in the methods used by different data sources to classify specific health conditions. In addition, there will be some degree of underreporting in comparison to questionnaire-defined symptoms that appear to be a more accurate measure of the rate of symptoms and disorders. In general, neither of these problems is a serious problem for a passive surveillance system in which an effort has been made to establish some simple uniform reporting criteria and in which there are no major disincentives for workers to report their health problems. Moreover, the problem of health outcome misclassification is also mitigated by the fact that analysis of this type of data is generally done by body region.

2. Active Surveillance

Data Sources: Data can be obtained through periodic worker health surveys. The surveys should collect information on current and past symptoms, anatomical location, and duration and frequency of the symptoms. An advantage of questionnaires is that they are usually easy to administer and provide a quick method for identifying worker's perceptions of hazards and sources of discomfort. One particularly common and easy-to-use format is the "body part discomfort survey." The worker is given a picture of the body and asked to rate the level of comfort/discomfort experienced in different parts [Corlett 1976]. Similarly, the chief advantage of questionnaires and interviews is that they are often successful at eliciting information about job-related complaints and symptoms that would otherwise go undocumented. If large numbers of workers in a specific job or department report job-related discomfort, an investigation of tool, workstation layout, or job design may be indicated.

Symptoms have been the principal method to determine the prevalence and incidence of work-related musculoskeletal disorders in several scientific studies [Siverstein et al. 1986; Bongers 1992; Pope et al. 1991]. Symptoms have been one of the principal outcome measurements in studies of the effectiveness of therapeutic procedures including surgical procedures and exercise programs [Silverstein et al. 1988]. Not only have ergonomists traditionally used changes in the symptoms by body region to evaluate the effectiveness of intervention efforts that lead to redesigned work station layouts and processes, but in NIOSH studies it has been found that over seventy percent of workers with moderate or severe symptoms have at least one positive physical finding on a concurrent physical examination [Baron et al. 1992].

A simple questionnaire should be used that is based on the questionnaire in the OSHA Ergonomics Program Management Guidelines for Meatpacking Plants [OSHA 1990]. Alternatively, the standardized Nordic questionnaires are acceptable for the analysis of musculoskeletal symptoms or a simple postural discomfort scale [Kuorinka et al. 1987].

A questionnaire should identify the location of symptoms, whether they are present at the time the questionnaire is administered, and some measures of their severity. The advantage of the simpler questionnaires is that a smaller facility with limited resources could easily administer and analyze the data. The slightly longer surveys are still easy to administer, but would allow a more sophisticated analysis of the problem, particularly for companies with a large workforce or multiple facilities.

Written questionnaires are relatively inexpensive to administer--workers can complete them at their convenience, and responses can be kept anonymous. A limitation of questionnaires, however, is that they can yield limited information. Symptom surveys are usually sensitive to work-related musculoskeletal disorders, but are poor at discriminating specific disorders or indicating the cause of the complaint. Factors such as the length of the questionnaire, the wording of the instructions, and the time and method of administration have a significant impact on the rate of response and the reliability of the data.

Evaluation of Data: Job-specific incidence and prevalence rates can be calculated using a variety of case definitions, e.g., symptoms only or symptoms and an abnormal physical examination, neither of which are found in passive surveillance data. Information on the severity and frequency of symptoms should be used in determining which problems should be given the highest priority. The definitions and formulas for calculation of incidence and prevalence are included in the section on Passive Surveillance.

Frequency of Surveys: Surveys should be initiated as follows:

a. When evidence from passive surveillance or job analysis suggests an increase in work-related musculoskeletal disorders or a preponderance of ergonomic stressors;

b. Before and after institution of new jobs/tasks/tools/and process changes;

c. When new workers are hired, they should complete a symptom questionnaire prior to beginning work.

Limitations and Issues on Active Surveillance:

a. Active surveillance programs are generally more costly to conduct than passive surveillance;

b. Active surveillance programs depend on the accuracy of worker responses;

c. Questions must be worded so that they are understood by the workers, e.g., pretest the questions to insure that the respondents understand the information that is needed and multi-lingual versions should be created if needed;

d. Workers must understand the purpose of the surveys;

e. The effect of repeatedly asking the same questions over an extended period, as in yearly or periodic health interviews, has not been determined.

D. MEDICAL MANAGEMENT

A medical management program should promote early detection and prompt recovery from work-related musculoskeletal disorders when these disorders are not prevented. The program should also prevent aggravation of musculoskeletal disorders that could occur in workers due to non-occupational activities. Not only can work cause these disorders but it can aggravate them. The specific goals of medical management are the elimination or reduction of symptoms and functional impairment, and a return to work in a manner consistent with protecting the health of the worker.

Effectiveness

There is evidence that early treatment of low back pain and work-related musculoskeletal disorders of the upper extremity reduces their severity, duration of treatment and ultimate disability [AAOS 1991; Flowerdew and Bode 1942; Thompson et al. 1951; Haig et al. 1990; Leavitt et al. 1971; Frymoyer et al. 1983; Lutz and Hansford 1987; Mayer et al. 1987]. Accordingly, medical management policies that encourage workers to report symptoms early and employers to send their symptomatic worker for prompt medical evaluation and treatment may reduce the long-term severity and disability from these work-related musculoskeletal disorders. In addition, these policies create the conditions for an effective health surveillance system.

Because the scientific studies suggest that early intervention may be more effective than late intervention, and since, in general, the cost of care generally increases as these disorders become severe and chronic, medical management protocols should be directed at both mild and severe disorders. The evaluation and treatment approaches for early, mild or intermittent disorders are generally simple and can be provided by many different types of health care providers.

Medical Management Protocol Requirements

1. General Principles of Medical Management

Several principles should underlie the development of either voluntary or mandated medical management protocols. These include:

a. definition of work-related musculoskeletal disorders,

b. promotion of early reporting of symptoms and the avoidance of disincentives (e.g., reprisal) that may discourage reporting,

c. prompt access to care by the symptomatic worker,

d. the emphasis of non-surgical, therapeutic measures (e.g., rest) over surgical procedures in most cases, and

e. medical monitoring following an injured worker's return to work to prevent the recurrence of the disorder; and

f. establishment of an appropriate recovery period.

The clinical course of most work-related musculoskeletal disorders can be divided into three phases: acute (less than one month from the onset), subacute (one to three months), and chronic (greater than 3 months). Chronic disorders that are severe enough to prevent return to work are associated with a poor prognosis. In an attempt to alter this poor prognosis, a number of comprehensive rehabilitation programs have been developed. There is limited evidence that these programs may be partially successful in returning injured workers to employment [Feuerstein 1992].

2. Health Care Provider

Any health care provider with training in work-related musculoskeletal disorders who is licensed and/or registered and practicing within the scope of their license and/or registration could develop a medical management protocol. However, the concepts of primary and secondary prevention should be incorporated in the training of the health care providers. Training and education should be strongly encouraged that address the causes of work-related musculoskeletal disorders, appropriate methods of clinical evaluations, identification of job hazards by workplace inspection, review of written job description or videotape recording of work processes, and the benefits of early evaluation should be strongly encouraged.

3. Job Evaluations

Job evaluations are predictive to some extent of risk of developing work-related musculoskeletal disorders. As discussed earlier, the overall epidemiological, biomechanical, and psychophysical laboratory studies support the basic hypothesis that physical job factors such as force, repetition, and awkward posture are associated with elevated rates of symptoms and disorders. A reasonable extension of this body of scientific studies is that workers with work-related musculoskeletal disorders are at higher risk if they continue to be exposed once the condition develops.

4. Periodic Walkthroughs

These have been recommended in the OSHA Meatpacking Guidelines [OSHA 1990]. As stated earlier in this section, the health care provider should understand the specific job risk factors for each patient or worker who is being evaluated.

5. Rehabilitative Medical Management

As stated earlier, evidence exists to support early intervention and treatment of work-related musculoskeletal disorders in order to decrease the cost, severity, and days of disability. The following recommendations are not meant to substitute for sound medical practice. Standards of medical care change over time; therefore, it is the responsibility of the treating health care provider to render care consistent with current clinical practice.

a. Early Reporting

All workers should receive training regarding the signs and symptoms of work-related musculoskeletal disorders and be encouraged to report such symptoms to their employer. Such reporting allows for prompt evaluation, and, if necessary, treatment of the symptoms. Early treatment of many medical conditions, including musculoskeletal disorders has been shown to reduce their severity, duration of treatment, and ultimate disability [Flowerdew and Bode 1942; Thompson et al. 1951; Haig et al 1990; Leavitt et al. 1971; Frymoyer et al. 1983; Lutz and Hansford 1987; Mayer et al. 1987]. Workers must not be subject to reprisal or discrimination based on such reporting. Employers should also address any financial or other disincentives that discourage workers from reporting their symptoms.

b. Access to Care

Workers reporting signs and/or symptoms suggestive of work-related musculoskeletal disorders should be evaluated by an appropriate health care provider before the worker's next workshift. This is consistent with the risk of continued exposure as discussed earlier.

c. Summary of Health Care Providers' Evaluation

The health care provider who recommends a specific treatment plan for a symptomatic worker should first conduct a medical history to obtain an appropriate characterization of the symptoms, description of work activities, and a past medical history including past trauma to the symptomatic area, prior treatment of musculoskeletal disorders, non-work activities such as hobbies, and other existing diseases.

In assessing the role of work in causing musculoskeletal symptoms and disorders and determining whether a symptomatic worker can continue to work safely, the health care provider will, in general, need to understand the worker's job tasks by visiting the workplace, viewing jobs tasks recorded on videotape, reviewing written description of job tasks, and results of job analysis.

d. Interventions

Resting the symptomatic area, and reduction of soft tissue inflammation are the mainstays of treatment [Howard 1937; Howard 1938; Thompson et al. 1951; Thorson and Szabo 1989; Chipman et al. 1991; Moore 1992; Rempel et al. 1992]. The symptomatic area can be rested by:

(1) Reducing or eliminating worker exposure to biomechanical stressors (forceful exertions, repetitive activities, extreme or prolonged static postures, vibration, direct trauma). This is best accomplished by engineering controls in the workplace.

(2) When engineering controls are not feasible, or until effective controls can be installed, worker exposure to ergonomic hazards can be reduced through restricted duty, rest breaks, job rotation, or temporary job transfer. The principles of restricted duty and temporary job transfer are to reduce or eliminate the total amount of time a worker is exposed to ergonomic stressors [Lederman and Calabrese 1986; McKenzie et al. 1985]. A list of jobs with the lowest ergonomic risk should be developed. The ergonomic risk factors and the muscle-tendon groups required to perform those jobs should be listed.

The precise amount of work reduction for workers on restricted duty cannot be determined; however, the following principle applies: the degree of restriction should be proportional to symptom severity and intensity of the job's biomechanical stressors. Likewise, caution must be used in deciding which jobs are suitable for job transfer because differing job titles may pose the same biomechanical demands on the same muscles and tendons [OSHA 1990].

(3) Complete removal from the work environment should be reserved for severe conditions, or in workplaces where the only available jobs contain biomechanical stressors that would aggravate the existing condition.

(4) Immobilization devices, such as splints or supports, can help rest the symptomatic area [Howard 1937; Howard 1938; Thompson et al. 1951; Thorson and Szabo 1989; Chipman et al. 1991; Moore 1992; Rempel et al. 1992]. These devices are especially effective off-the-job, particularly during sleep. Wrist splints, typically worn by patients with possible carpal tunnel syndrome, should not be worn at work unless the health care provider determines that the worker's job tasks do not require wrist deviation or bending [Putz-Anderson 1988; Kessler 1986]. Immobilization should be prescribed judiciously and monitored carefully to prevent muscle atrophy [Rempel et al. 1992; Curwin and Stanish 1984]. These recommendations do not preclude use of immobilization devices for patients with special needs due to underlying medical conditions.

(5) The health care provider should evaluate an injured worker's hobbies, recreational activities, and other personal habits that result in exposure to biomechanical stressors and advise the worker about the effects of continued exposure [Thorson and Szabo 1989; Chipman et al. 1991; Moore 1992].

e. Treatment for Soft-Tissue Inflammation

(1) Cold Therapy

Although no clinical trials have been performed on the effectiveness of cold therapy on the affected area, most clinicians consider this useful to reduce the swelling and inflammation associated with tendon-related disorders [Thorson and Szabo 1989; Chipman et al. 1991; Rempel et al. 1992; Simon 1991]. Cold therapy has effects on the local circulatory system (vasoconstriction) [Olson and Stravino 1972; Thorsson et al. 1985], and local muscle-tendon tissue (decreased metabolism) [Yackzan et al. 1984]. This reduced supply and demand for blood results in reduced effusion, edema, and swelling. In addition to pain reduction from the reduced swelling, cold therapy reduces the nerve conduction from pain receptors [Kaplan and Tanner 1989].

(2) Oral Anti-Inflammatories

Most clinicians consider these agents (aspirin or other non-steroidal anti-inflammatory agents) useful to reduce the severity of symptoms either through their analgesic or anti-inflammatory properties [Howard 1937; Howard 1938; Thompson et al. 1951; Thorson and Szabo 1989; Chipman et al. 1991; Moore 1992; Rempel et al. 1992; Simon and Mills 1980].

(3) Steroid Injections

For some disorders resistant to conservative treatment, local injection of an anesthetic agent with a corticosteroid may be indicated [Howard 1937; Howard 1938; Thompson et al. 1951; Thorson and Szabo 1989; Chipman et al. 1991; Moore 1992; Rempel et al. 1992].

(4) Ancillary Treatment Modalities

There is little scientific information that either establishes or refutes the efficacy of other treatment modalities for diagnoses encompassed under the term, work-related musculoskeletal disorders. Most clinicians consider physical and occupational therapy a valuable adjunct for treatment through its use of stretching and strengthening programs [Thorson and Szabo 1989; Chipman et al. 1991; Rempel et al. 1992; Curwin and Stanish 1984; Lane 1991].

(5) Referral to Specialists

Many, if not most, work-related musculoskeletal disorders improve with the above conservative measures. If the symptoms do not improve within the expected time frames, referral to an appropriate specialist is indicated. The expected time frame for resolution of symptoms depends on the type, duration, and severity of the condition, in addition to the underlying health of the worker.

Precise time intervals for follow-up evaluation, referral, improvement, and recovery cannot be stated in this submission. Algorithms to assist occupational health nurses through the process of evaluating, treating, and follow-up of workers with work-related musculoskeletal disorders have been developed [OSHA 1990; Hales and Bertsche 1992]. These algorithms are not meant to dictate medical practice, but to provide guidance to practicing occupational health nurses.

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 indicatethat 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.

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EXAMPLES OF ERGONOMIC CHECKLISTS

Table 4. Michigan's Checklist for Upper Extremity Cumulative Trauma Disorders*

Risk Factors:	NO	YES
1. Physical Stress:		
1.1 Can the job be done without hand/wrist contact with sharp edges?	[ ]	[ ]
1.2 Is the tool operating without vibration?	[ ]	[ ]
1.3 Are the worker's hands exposed to temperature > 70° F?	[ ]	[ ]
1.4 Can the job be done without using gloves?	[ ]	[ ]
2. Force:		
2.1 Does the job require exerting less than 10 lbs of force?	[ ]	[ ]
2.2 Can the job be done without using finger pinch grip?	[ ]	[ ]
3. Posture:		
3.1 Can the job be done without flexion or extension of the wrist?	[ ]	[ ]
3.2 Can the tool be used without flexion or extension of the wrist?	[ ]	[ ]
3.3 Can the job be done without deviating the wrist side to side?	[ ]	[ ]
3.4 Can the tool be used without deviating the wrist side to side?	[ ]	[ ]
3.5 Can the worker be seated while performing the job?	[ ]	[ ]
3.6 Can the job be done without "clothes wringing" motion?	[ ]	[ ]
4. Workstation Hardware:		
4.1 Can the orientation of the work surface be adjusted?	[ ]	[ ]
4.2 Can the height of the work surface be adjusted?	[ ]	[ ]
4.3 Can the location of the tool be adjusted?	[ ]	[ ]
5. Repetitiveness:		
5.1 Is the cycle time longer than 30 seconds?	[ ]	[ ]
6. Tool Design:		
6.1 Is the thumb and finger slightly overlapped in a closed grip?	[ ]	[ ]
6.2 Is the span of the tool's handle between 5 and 7 cm?	[ ]	[ ]
6.3 Is the handle of the tool made from material other than metal?	[ ]	[ ]
6.4 Is the weight of the tool below 4 kg (note exceptions to the rule)?	[ ]	[ ]
6.5 Is the tool suspended?	[ ]	[ ]

["No" responses are indicative of conditions associated with the risk of CTDs.]

*Lifshitz, Y., and Armstrong, T. A design checklist for control and prediction of cumulative trauma disorders in hand intensive manual jobs. Proceedings of the 30th Annual Meeting of Human Factors Society, 837-841, 1986.

GENERAL JOB INFORMATION

STUDY ID: |__|__|__| [1-3]

FORM NUMBER: |0|1| [4-5]
FORM REVISION: |0|1| [6-7]

1. How long have you worked with your present employer? YEARS |__|__| MONTHS |__|__| [8-11]

2. What is your current JOB TITLE:_________________ |__|__| [12-13]

3. How long have you worked in this job? YEARS |__|__| MONTHS |__|__| [14-17]

4. Select the most appropriate description of your JOB SITUATION:

   1 Full-time permanent employee
   2 Full-time temporary employee
   3 Part-time permanent employee
   4 Casual
   5 Other _______________ (SPECIFY) |__| [18]

5. Select the description that comes closest to your present WORK SHIFT:

   1 Rotating eight-hour shift
   2 Rotating twelve-hour shift
   3 Permanent day shift
   4 Permanent evening shift
   5 Permanent night shift
   6 Other_______________ (SPECIFY) |__| [19]

6. How long have you worked the shift you circled above? YEARS |__|__| MONTHS |__|__| [20-23]

7. IF you work on a rotating shift, what ROTATION PATTERN do you follow?

EIGHT-HOUR SHIFT	TWELVE-HOUR SHIFT:
1 DAY to EVENING to NIGHT	4 DAY to NIGHT
2 NIGHT to EVENING to DAY	5 NIGHT to DAY
3 No set pattern	6 No set pattern

|__| [24]

8. How many times a week do you change shifts?

   1 0 times [I don't change]
   2 2 times
   3 More than 2 times
   4 On call
   5 Standby
   6 Non standard work week
   7 Other_____________ (SPECIFY) |__| [25]

9. How many hours do you normally work per week in your job? |__|__| [26-27]

10. How many hours overtime do you work in your job in an average week? |__|__| [28-29]

11. How many hours per week do you work on any other job? |__|__| [30-31]
    [PLEASE MARK "|0|0|" IF NO OTHER JOB]

Ergonomics Checklist by Kellerman, van Wely, and Williams (1963).

A. DIMENSIONS

1. Has a tall man enough room?
2. Can a petite woman reach everything?
3. Is the work within normal reach of arms and legs?
4. Can the worker sit on a good chair? (height, seat, back)
5. Is an armrest necessary, and (if so) is it a good one? (Location, shape, position, material)
6. Is a footrest required, and (if so) is it a good one? (Height dimensions, shape, slope)
7. Is it possible to vary the working-posture?
8. Is there sufficient space for knees and feet?
9. Is the distance between eyes and work correct?
10. Is the work plane correct for standing work?

B. FORCES

1. Is static work avoided as far as possible?
2. Are vices, jigs, conveyor belts, etc., used wherever possible?
3. Where protracted loading of a muscle is unavoidable, is the muscular strength required less than 10% of the maximum?
4. Are technical sources of power employed where necessary?
5. Has the number of groups of muscles employed been reduced to the minimum with the aid of countersupport?
6. Are torques around the axis of the body avoided as far as possible?
7. Is the direction of motion as correct as possible in relation to the amount of force required?
8. Are loads lifted and carried correctly, and are they not too heavy?

Biomechanics Checklists

Following are two checklists which may assist you in applying Biomechanics to your tasks and machine design. You want a yes answer to each question.

Task Element Checklist

1. Is the element necessary?
2. Are all movements, holds, and delays necessary?
3. Is the back straight?
4. Is the back free from twisting?
5. Are elbows by the side of the body?
6. Are wrists straight?
7. Are movements natural and ballistic?
8. Is work area free of obstructions?
9. Are stop switches, controls, lock outs, and guards convenient and adequate?
10. Is the weight lifted less than 32.2-1.2 x the number of lifts per minute and is the weight carried less than 32 lbs.?

Machine Design Checklist

1. Is equipment operated with back erect, no twisting, supported if seated, foot rest if standing?
2. Are controls and materials near stomach and in sequence of use?
3. Can operator's movements be ballistic?
4. Can equipment be operated with straight wrists?
5. Are readouts and gages simple, in sequence, and do not require head movements?
6. Are handles and surfaces not applying pressure on small skin areas?
7. Are stop and off switches where operator will be?
8. Are guards easy to remove and replace without tools?
9. Does equipment require minimum tools which are displayed in order of use?
10. Is there accumulation of material before and after machine operation?

Inspection Checklist

Job ______________________________ Location __________________

- ☐ Twisting, "clothes-wringing" motions of the wrist.
- ☐ Working with a bent wrist.
- ☐ Vibrating tools.
- ☐ Poor handgrips on tools.
- ☐ Repetitive hand, arm and shoulder movements.
- ☐ Arms and elbows high or outstretched.
- ☐ Controls or materials beyond easy reach of the worker.
- ☐ Working with a bent neck.
- ☐ Working with a bent spine or leaning over excessively.
- ☐ Lifting, loading or unloading from improper heights.
- ☐ Excessive twisting or stretching of the back.
- ☐ Excessive pushing or pulling on loads.
- ☐ Excessive standing.
- ☐ Working in an immobile position for too long.
- ☐ Improper heights of work surfaces and chairs.

Evaluation form

ERGONOMIC JOB ANALYSIS

date ____ / ____ ____ ________________ analyst no. [ ]

Firm/workplace ________________ Department ________________

Job ________________ Work site ________________

Equipment, machines ________________

Job description, work phases (1,2,3...) ________________

Drawing of the work site and photograph

	Analyst's rating					Worker's assessment				Comments
1 Work space			3	4	5	++	+		--	
2 General physical activity			3	4	5	++	+		--	
3 Lifting			3	4	5	++	+		--	
4 Work postures and movements			3	4	5	++	+		--	
5 Accident risk			3	4	5	++	+		--	
6 Job content			3	4	5	++	+		--	
7 Job restrictiveness			3	4	5	++	+		--	
8 Worker communication			3	4	5	++	+		--	
9 Difficulty of decision making			3	4	5	++	+		--	
10 Repetitiveness of the work			3	4	5	++	+		--	
11 Attentiveness			3	4	5	++	+		--	
12 Lighting			3	4	5	++	+		--	
13 Thermal environment			3	4	5	++	+		--	
14 Noise			3	4	5	++	+		--	

Recommendations ________________

1 Work space
1 Horizontal work area
2 Working height
3 Viewing
4 Leg space

Mark, if defect occur:
5 Seat
6 Hand tools
7 Other equipment

additional analyses

analyst's rating [ ] worker's assessment

2 General physical activity

analyst's rating [ ] worker's assessment

3 Lifting
lifting height [ ] normal [ ] low
weight of load ___ kg handhold distance ___ cm
number of loads lifted
lifting conditions

analyst's rating [ ] worker's assessment

4 Work postures and movements

	basic rating	duration (h/day)	rating corrected
neck-shoulders	[ ]	___	[ ]
elbow-wrist	[ ]	___	[ ]
back	[ ]	___	[ ]
hips-legs	[ ]	___	[ ]

analyst's rating [ ] worker's assessment

5 Accident risk

accident risk: [ ] small [ ] considerable [ ] great [ ] very great

accident severity: [ ] slight [ ] minor [ ] rather serious [ ] very serious

1 2 3 4 5 6 7 8 9 10 11 — See the booklet for the corresponding numbers

analyst's rating [ ] worker's assessment

6 Job content

analyst's rating [ ] worker's assessment

7 Job restrictiveness

analyst's rating [ ] worker's assessment

8 Worker communication and personal contacts

analyst's rating [ ] worker's assessment

9 Decision making

analyst's rating [ ] worker's assessment

10 Repetitiveness of the work cycle length ___ min

analyst's rating [ ] worker's assessment

11 Attentiveness

observation period % of cycle length: [ ] under 30 [ ] 30-60 [ ] 60-80 [ ] over 80

attention demanded: [ ] superficial [ ] average [ ] rather great [ ] very great

analyst's rating [ ] worker's assessment

12 Lighting
illumination intensity ___ lx, recommended value ___ lx, ___ %
glare [ ] no [ ] some [ ] much

analyst's rating [ ] worker's assessment

13 Thermal environment temperature measurements (°C)

average ___ °C
airflow rate m/s ___

sitting / standing — at head height / ankle level

analyst's rating [ ] worker's assessment

14 Noise

Estimated or measured noise level ___ dB(A)

work demands
verbal communication [ ] concentration [ ]

analyst's rating [ ] worker's assessment

SUPPLEMENTAL NOTES FOR METABOLIC CHECK LIST

Question

1. line/machine paced: The time to complete one unit is determined by the speed of an assembly line or by the speed of a machine. The worker has little or no control over the allowed time to complete a unit.
   leader paced: Work is performed by a team. One team member determines the pace of the entire team.
   standard paced: The worker must meet a daily production standard or quota but is able to work at his/her own pace with little outside influence.
   self paced: The worker sets his/her own pace. No formal standard or quota exists.

2. Does the worker have difficulty performing the job in the allotted cycle time?

   never - The worker is able to perform the job in the allotted cycle time for all cycles.
   sometimes - The worker is having difficulty performing the job in the allotted cycle time for some cycles . but not all cycles.
   usually - The worker is having difficulty performing the job in the allotted cycle time for most cycles and can only rest during break periods.

4. Does the worker walk faster than a normal pace?
   A "normal pace" is approximately 3 to 4 miles per hour. Discretion must be used to determine if the job requires the worker to walk fast or if the worker chooses to walk fast.

6. Does the worker bend or stoop below the knees repeatedly?
   never - The worker maintains an upright posture throughout the day.
   sometimes - The worker must bend down to reach below the knees 1 - 3 times per minute.
   usually - The worker must bend down to reach below the knees 4 or more times per minute.

7. never - The job function does not require the worker to wear a respirator or a complete protective suit under any circumstances.
   sometimes - The job function may require the worker to wear a respirator or a complete protective suit.
   usually - The worker must wear a respirator or a complete protective suit on a regular or routine basis.

5/11/90

JobNumber ____________________

BASIC JOB CHECK LIST
METABOLIC CHECK LIST

Note: When filling out this checklist, record what you observe on the day of this analysis.

1. Is the job cycle line/machine paced? leader paced? (work teams) standard paced? self paced?

	never	sometimes	usually	element
2. Does the worker have difficulty performing the job in the allotted (i.e. standard) cycle time?	o	√	√	
3. Does the worker appear out of breath ?	o	√	*	
4. Does the worker walk faster than a normal pace?	o	√	√	____
5. Does the worker climb up or down more than 3 steps during the cycle?	o	√	√	____
6. Does the worker bend or stoop below the knees repeatedly?	o	√	*	____
7a. Is a respirator worn? (Note: This does not include dust masks, goggles, or welding shields. It does include any type of air-supplied respirator or any type of full or half-face respirators used to protect against toxic vapors or gases.)	o	*	*	____
b. Is a complete protective suit worn? (Note: This does not include hair protection or coveralls such as those used in welding areas. It does include all-enclosing impervious suits used to protect against toxic materials.)	o	*	*	____

Total Score = ____ ____ * ____ ____
(No. of *'s) (No. of √'s)

Comments:

/90

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%

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)
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%
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

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
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
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	

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
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
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

AUTHORS	TASK (INDUSTRY)	SAMPLE	STUDY DESIGN	MEASURES	RESULTS
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

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