STEP 3
TRAINING—BUILDING IN-HOUSE EXPERTISE

- **Ergonomics Awareness Training**
- **Training in Job Analyses and Control Measures**
- **Training in Problem Solving**
- **Special Considerations and Precautions**

Identifying and solving workplace WMSD problems require some level of ergonomic knowledge and skills. Recognizing and filling different training needs is an important step in building an effective program.

Training is recognized as an essential element for any effective safety and health program [Colligan 1994]. For ergonomics, the overall goal of training is to enable managers, supervisors, and employees to identify aspects of job tasks that may increase a worker's risk of developing WMSDs, recognize the signs and symptoms of the disorders, and participate in the development of strategies to control or prevent them [Kuorinka and Forcier 1995]. Training employees ensures that they are well informed about the hazards so they can actively participate in identifying and controlling exposures. Common forms of ergonomics training are noted below, along with their objectives. Table 3 lists the categories of employees who should receive the indicated instructions, especially if a team approach is used to analyze job risk factors and develop control measures. Employers may opt to have outside experts conduct these tasks. If so, the outside instructors should first become familiar with company operations and relevant policies and practices before starting to train. Tailoring the instruction to address specific concerns and interests of the worker groups can enhance learning.

ERGONOMICS AWARENESS TRAINING

The objectives for ergonomics awareness training are as follows:

- Recognize workplace risk factors for musculoskeletal disorders and understand general methods for controlling them.
- Identify the signs and symptoms of musculoskeletal disorders that may result from exposure to such risk factors, and be familiar with the company's health care procedures.
- Know the process the employer is using to address and control risk factors, the employee's role in the process, and ways employees can actively participate.
- Know the procedures for reporting risk factors and musculoskeletal disorders, including the names of designated persons who should receive the reports.

Table 3. Ergonomics training for various categories of employees

	All employees	Every employee in suspect problem jobs	Every supervisor of jobs with suspect problems	Every employee involved in job analysis and control development	Ergonomics team or work group members[1]
General ergonomics awareness information[2]	X	X	X	X	X
Formal awareness instruction and job-specific training		X	X	X	X
Training in job analysis and controlling risk factors				X	X
Training in problem solving and the team approach					X

[1]If ergonomics teams are formed, added instruction is needed in team-building and consensus development processes, apart from application of ergonomics techniques.

[2]General ergonomics awareness information for all employees need not require class instruction; it can be disseminated via handouts and all-hands meetings.

TRAINING IN JOB ANALYSES AND CONTROL MEASURES

The objectives for training in job analyses and control measures are as follows:

- Demonstrate the way to do a job analysis for identifying risk factors for musculoskeletal disorders.
- Select ways to implement and evaluate control measures.

TRAINING IN PROBLEM SOLVING

The objectives for training in problem solving are as follows:

- Identify the departments, areas, and jobs with risk factors through a review of company reports, records, walk-through observations, and special surveys.
- Identify tools and techniques that can be used to conduct job analyses and serve as a basis for recommendations.
- Develop skills in team building, consensus development, and problem solving.
- Recommend ways to control ergonomic hazards based on job analyses and pooling ideas from employees, management, and other affected and interested parties.

SPECIAL CONSIDERATIONS AND PRECAUTIONS

Materials for offering awareness training to the workforce are available, including videotapes and pamphlets from NIOSH and other groups (see Trays 3 and 10 of the Toolbox). Employers may prefer to generate their own informational materials tailored to their particular job operations. Persons or groups assigned to or expected to play a key role in ergonomic hazard control work will require added instruction in problem identification, job analyses, and problem-solving techniques. This training is available through short courses publicized in many occupational safety and health publications or through a consultant.

Training objectives are not intended to have workers, supervisors, or managers diagnose or treat WMSDs. Rather, the purpose is to instill an understanding of what type of health problems may be work related and when to refer employees for medical evaluation. The training should include what is known about work and nonwork causes of musculoskeletal disorders and the current limitations of scientific knowledge.

Training should be understandable to the target audience. Training materials used should consider the participants' educational levels, literacy abilities, and language skills. This may mean, for example, providing materials, instruction, or assistance in Spanish rather than English.

Open and frank interactions between trainers and trainees, especially those in affected jobs, are especially important. Employees know their own jobs better than anyone else and often are the source of good ideas for ways to improve them. At a minimum, employees must be given an opportunity to discuss ergonomic problems in their jobs as they see them and engage in relevant problem-solving exercises during the training.

One NIOSH experience in direct worksite training included a demonstration study in which a work group or team approach was adopted for problem solving. Training efforts to prepare the team to perform this function are described in Exhibit 6.

Exhibit 6: Team Training in Ergonomic Problem Solving

University investigators, in partnership with NIOSH, undertook a case study of an ergonomics team approach in implementing control measures to reduce WMSDs at a meatpacking plant. In all, five joint management-labor teams representing different departments, each consisting of 7 to 9 members, were formed. Team-building training consisted of sessions designed to enhance the members' abilities to work together. Team-building activities included

- defining a team,
- determining the goals of an ergonomics team,
- establishing group meeting rules and team roles,
- reviewing guidelines for effective group discussion and constructive feedback, and
- practicing brainstorming exercises and techniques for consensus building.

Consistent with the approaches advocated by experts in team building, the training emphasis throughout was about the way to develop task-oriented skills and positive, interpersonal processes. Forms for documenting team members' responsibilities, records of meetings and actions taken, and other handouts served to reinforce these points.

The ergonomics training given to the teams included using videotaped instruction and practice in job analysis techniques to identify and prioritize jobs needing intervention. The video analysis used a rating technique to determine the extent of hand, wrist, arm, and shoulder movements, as well as the positions of the backs and necks of workers while they performed tasks in their departments. Job analyses used OSHA log entries, observations of job tasks, and worker input about ways to ease the difficulty of those job operations presenting the most stressful problems [Gjessing et al. 1994].

STEP 4
GATHERING AND EXAMINING EVIDENCE OF WMSDs

- **Health and Medical Indicators**
  Following up of worker reports
  Reviewing OSHA logs and other existing records
  Conducting symptom surveys
  Using periodic medical examinations

- **Identifying Risk Factors in Jobs**
  Screening jobs for risk factors
  Performing job analyses
  Setting priorities

Once a decision has been made to initiate an ergonomics program, a necessary step is to gather information to determine the scope and characteristics of the problem or potential problem. A variety of techniques and tools have been used; many provide the basis for developing solutions to identified problems.

HEALTH AND MEDICAL INDICATORS

Following up of Worker Reports

Assuring that employees feel free to report, as early as possible, symptoms of physical stress is a key component of any ergonomics program. Early reporting allows corrective measures to be implemented before the effects of a job problem worsen. As mentioned earlier, individual worker complaints that certain jobs cause undue physical fatigue, stress, or discomfort may be signs of ergonomic problems. Following up on these reports, particularly reports of WMSDs, is essential. Such reports indicate a need to evaluate the jobs to identify any ergonomic risk factors that may contribute to the cause of the symptoms or disorders. Techniques to evaluate jobs are described later.

Reviewing OSHA Logs and Other Existing Records

Inspecting the logs of injuries and illnesses required by OSHA and plant medical records can yield information about the nature of WMSDs, as can workers' compensation claims, insurance claims, absentee records, and job transfer applications. Finding workers in certain departments or operations presenting more of these problems than others (and exhibiting the same types of musculoskeletal disorders) would suggest some immediate areas for study with regard to possible risk factors. Jobs with elevated rates of low back musculoskeletal disorders often also have higher risks for acute injuries due to slips and trips or other safety hazards. In these cases, acute musculoskeletal injuries may also be an important problem.

NIOSH evaluations of alleged work-related musculoskeletal problems begin with an examination of OSHA and medical records to understand the magnitude and seriousness of such problems. These records may also offer leads to jobs or operations that may cause or contribute to musculoskeletal disorders. Exhibits 7 and 8 illustrate the kind of data one might find, the evaluations made to judge the significance of the data, and their use in targeting jobs for ergonomic risk analysis.

Conducting Symptom Surveys

In Exhibit 8, entries from OSHA records and other medical reports documented worker disorders, and information from interviews with workers linked the disorders to workplace factors. Interviews or symptom surveys have been used to identify possible WMSDs that might otherwise go unnoticed. In addition to questions about the type, onset, and duration of symptoms, symptom survey forms may include a body map [Corlett and Bishop 1976; Hales and Bertsche 1992] wherein the respondent is asked to locate and rate the level of discomfort experienced in different areas of his or her body. The assumption is that any discomfort or symptoms may be associated with some increased risk for WMSDs. Compared with OSHA logs, symptom surveys provide a more sensitive way to determine who has symptoms and who does not. A disadvantage of symptom questionnaires is their reliance on self-reports. Other factors besides the presence or absence of WMSDs may influence the reporting of symptoms, and the analysis and interpretation of questionnaire data can be complex.

Hales and Bertsche [1992] offer one example of a symptom survey form (see Tray 4-B of the Toolbox). Such data collection can help identify specific jobs or job elements deserving an ergonomic analysis. Also needed are other questions dealing with the worker's perception of job tasks that induce the discomfort. Exhibit 9 describes a NIOSH health hazard evaluation that used a questionnaire to gather relevant symptom data.

Using Periodic Medical Examinations

A disadvantage of using OSHA logs or company medical information to identify possible cases of WMSDs is the lack of specific or uniform medical information. This limitation

Exhibit 7: Reviewing OSHA Logs

NIOSH was asked to conduct a health hazard evaluation at a plant that fabricates wheels for trucks and busses. Major plant processes involved forming steel stock into the rims and center cores of the wheels, welding them together, and finishing and painting the welded product which was then crated for shipment. One objective of the evaluation was to verify the company's concerns about musculoskeletal problems that seemed related to operations in assembly and disc forming work. NIOSH reviewed the company's OSHA log entries for injuries and illnesses for the past 2 years and found about half (291 of a total of 588 entries) were cases of strains and sprains, carpal tunnel syndrome, tendinitis, bursitis, and other musculoskeletal problems. The musculoskeletal injury rate for the plant was 26.1 injuries per 100 employees. This rate exceeded the expected rate of 10.6 injuries per 100 employees based on the Bureau of Labor Statistics' reports that were then available for the motor vehicle parts industry. Back injury (primarily low back strain) constituted the largest proportion of injuries in the strain and sprain category; the total plant rate for back disorders was 11.3 injuries per 100 workers per year which was 5 times the rate for the industrial workforce as a whole. The rate of back disorders was highest in the Assembly Department (23.7 injuries per 100 workers per year) followed by the Disc Forming Department (20.0 injuries per 100 workers per year). Consequently, job tasks in these two departments became the primary targets for analyzing and controlling risk factors (predominantly repeated, heavy lifting) that could account for the observed musculoskeletal problems [HETA 88-277-2069].

Exhibit 8: Using OSHA Logs and Worker Interviews

On the recommendation of a State occupational safety and health agency and on the basis of their inspection of certain work conditions, the management of a window manufacturing plant asked NIOSH to evaluate the risk of carpal tunnel syndrome among workers engaged in assembling window units. As part of a medical evaluation, NIOSH investigators reviewed OSHA Form 200 logs and pertinent company medical records and held confidential interviews with workers doing the assembly work. Questions asked during the interviews sought information about the symptoms workers experienced since beginning work at the plant, including the date of onset, location, type, severity and timing (during day or night, steady or intermittent), duration, medical and surgical treatment, past medical history, most difficult job tasks, and hobbies. They also asked for suggestions for changes in assembly procedures or tools used to alleviate apparent problems. The following case definition of work-related carpal tunnel syndrome was adopted in assessing these data:

- During the interview, the worker reported pain, numbness, or tingling affecting the median nerve distribution of the hand(s).
- Symptoms lasted at least 1 week or occurred on multiple occasions.
- Symptoms were severe enough to waken the person from sleep.
- Evidence existed of work relatedness in that the symptoms began after starting work at a job involving recognized risk factors for carpal tunnel syndrome (e.g., repetitive hand movements, excessive force, awkward hand positions, pinch grips, etc.).

A medically confirmed case of probable *work-related* carpal tunnel syndrome was said to exist if the above criteria were met, and the employee had sought medical care and was diagnosed as having carpal tunnel syndrome. Medical records were reviewed to confirm the diagnosis.

A review of OSHA Form 200 logs from over a 3-year period indicated no hand/wrist disorder entries the first year, two entries for hand/wrist pain in the second year, and nine entries for either hand/wrist pain or carpal tunnel syndrome in the third year. As the size of the assembly workforce over the 3-year period remained the same (27 to 28 workers), these data suggested a worsening problem. The medical interviews of all 28 assembly workers indicated five confirmed cases of carpal tunnel syndrome (three surgically treated at the time of the evaluation) and five other possible carpal tunnel syndrome cases. Other health effects included numbness in the ulnar nerve (three workers), ganglionic cysts (two workers), tendinitis (three workers), elbow pain (one worker), neck pain (one worker), and shoulder pain (one worker).

The ensuing ergonomics evaluation of assembly work tasks revealed repetitive hand/wrist manipulations (8 of 12 job tasks requiring 20,000+ movements per shift) with varying degrees of force and bent wrist positions—all risk factors commonly associated with carpal tunnel syndrome. The pressure to increase production and working with defective materials which necessitate using added force to assemble parts were believed to worsen the problem [HETA 88-361-2091].

may make the identification of WMSDs difficult. One optional approach to overcome this limitation is to have each worker undergo a periodic standardized examination that includes a history and physical examination. Such an examination program should be designed and administered by a health care provider. NIOSH has undertaken studies in which physical examinations were given to workers to establish the prevalence of upper extremity musculoskeletal disorders and to establish whether evidence of excessive numbers of cases could be related to certain working conditions. One such study is described in Exhibit 10.

IDENTIFYING RISK FACTORS IN JOBS

Screening Jobs for Risk Factors

Health records or medical examinations and symptom surveys may indicate the nature and extent of musculoskeletal problems in the workforce. Efforts to identify jobs or tasks having

Exhibit 9: Symptom Surveys

NIOSH was asked to evaluate the incidence of upper limb disorders among workers engaged in sewing tasks at a uniform manufacturing company. The request was prompted by employee complaints that included aching, numbness, clumsiness, and swelling of the wrists and hands. OSHA log data were nonexistent in this plant at the time of this 1983 investigation. A medical questionnaire was specially designed to gather data on upper limb symptoms, with particular emphasis on hand/wrist problems. Sections of the questionnaire covered the usual background information (age, sex, occupational history), the present job at the plant, the nature of hand motions (lifting and lowering, pushing and pulling, twisting and turning, screwing, bending and rotating wrists, pinching and grasping with fingers), pain and discomfort areas (neck, shoulders, arms, elbows), the nature of symptoms in hands or wrists (swelling, stiffness, cramping burning, tingling), the time of onset (late night awakenings), and any difficulties with hands and fingers in some everyday tasks (e.g., buttoning shirt, turning key in lock or doorknob, holding tools) plus medical history asking about any injury, surgery, or pre-existing diagnostic problem (e.g., arthritis) that could account for apparent problems. A section of the questionnaire also included a picture of both surfaces of the right and left hands with the instruction to shade in those areas where most of the discomfort or difficulty occurs. A total of 64 of 90 sewing machine operators completed this form. Neck, shoulder, and arm pain were commonly reported by these operators, with the symptom reports rarely dropping below 36% and ranging as high as 80%. The most numerous hand/wrist symptoms were numbness, cramping, and tingling sensations (varying from 43% to 60%). Despite the frequent occurrence among sewers of symptoms suggestive of upper limb musculoskeletal disorders, jobs rated high and low in ergonomic risk factors showed only small differences in the rate of the symptoms reported. Possible reasons for the lack of differentiation are given in the report [HETA 83–205–1702].

Exhibit 10: Use of Diagnostic Tests

In response to a union request, NIOSH conducted a study to evaluate whether cashiers in a major supermarket chain were developing upper extremity musculoskeletal disorders because of their jobs. The evaluation had two major components.

- The first component compared the rate of upper extremity musculoskeletal disorders in the cashiers with the rate in other supermarket workers. For this purpose, physical exams were given to both groups of workers, including range of motion, limb bending, and stretching tests. The workers rated the pain experienced for the maneuvers. Positive responses on these tests for a particular part of the body, together with questionnaire data indicating recurring or prolonged discomfort in the same area (which began after starting work at the supermarket) were defined as a WMSD. To ensure objectivity, these determinations were made by a physician who had no prior knowledge of either the existing disease state or the job titles of the workers.
- The second component consisted of direct observation and a videotape analysis of the cashier's job, measuring the number of items processed, the number of scans, and the number of keyboard entries required of the cashier. These data were used to gauge task repetitiveness, posture factors, the force required, and efficiency of movement for different checkout counter designs.

The study results indicated that the cashiers had a higher rate of upper extremity disorders than other supermarket workers for all parts of the upper body and that those cashiers with longer employment or who spent more hours per week in checkout tasks showed more evidence of such problems. Further analyses in this study sought to isolate certain checkout counter design features, tasks, and work practices as possible stress factors in light of the pattern of musculoskeletal problems noted [HETA 88–344–2092].

known risk factors for musculoskeletal problems can provide the groundwork for changes aimed at risk reduction. Even without clear medical evidence, screening jobs for musculoskeletal risk factors can offer a basis for early interventions. (See the "Proactive Ergonomics" section of this primer.)

A great deal of ergonomic research has been conducted to identify workplace factors that contribute to the development of musculoskeletal disorders [Kourinka and Forcier 1995; Riihmaki 1991; Garg and Moore 1992; Silverstein et al. 1986; Salvendy and Smith 1981]. NIOSH has recently summarized the epidemiological scientific studies that show a relationship between specific work activities and the development of musculoskeletal disorders [NIOSH, in press]. A variety of non-epidemiological research, including clinical, biomechanical, and psychophysical studies, supports these findings [Pope et al. 1991; Ranney et al. 1995; Szabo and Chidgey 1989; Waters et al. 1993; Chaffin and Andersson 1984; Fransson-Hall et al. 1995; Ulin et al. 1993].

According to the scientific literature, the following are recognized as important risk factors for musculoskeletal disorders, especially when occurring at high levels and in combination. Figure 1 provides illustrations of some of these risk factor conditions. In general, knowledge of the relationships between risk factors and the level of risk is still incomplete. Also, individuals vary in their capacity to adjust to the same job demands. Some may be more affected than others.

- **Awkward postures**

  Body postures determine which joints and muscles are used in an activity and the amount of force or stresses that are generated or tolerated. For example, more stress is placed on the spinal discs when lifting, lowering, or handling objects with the back bent or twisted, compared with when the back is straight. Manipulative or other tasks requiring repeated or sustained bending or twisting of the wrists, knees, hips, or shoulders also impose increased stresses on these joints. Activities requiring frequent or prolonged work over shoulder height can be particularly stressful.

- **Forceful exertions (including lifting, pushing, and pulling)**

  Tasks that require forceful exertions place higher loads on the muscles, tendons, ligaments, and joints. Increasing force means increasing body demands such as greater muscle exertion along with other physiological changes necessary to sustain an increased effort. Prolonged or recurrent experiences of this type can give rise to not only feelings of fatigue but may also lead to musculoskeletal problems when there is inadequate time for rest or recovery. Force requirements may increase with

  — increased weight of a load handled or lifted,

  — increased bulkiness of the load handled or lifted,

  — use of an awkward posture,

  — the speeding up of movements,

  — increased slipperiness of the objects handled (requiring increased grip force),

  — the presence of vibration (e.g., localized vibration from power handtools leads to use of an increased grip force),

  — use of the index finger and thumb to forcefully grip an object (i.e., a pinch grip compared with gripping the object with your whole hand), and

  — use of small or narrow tool handles that lessen grip capacity.

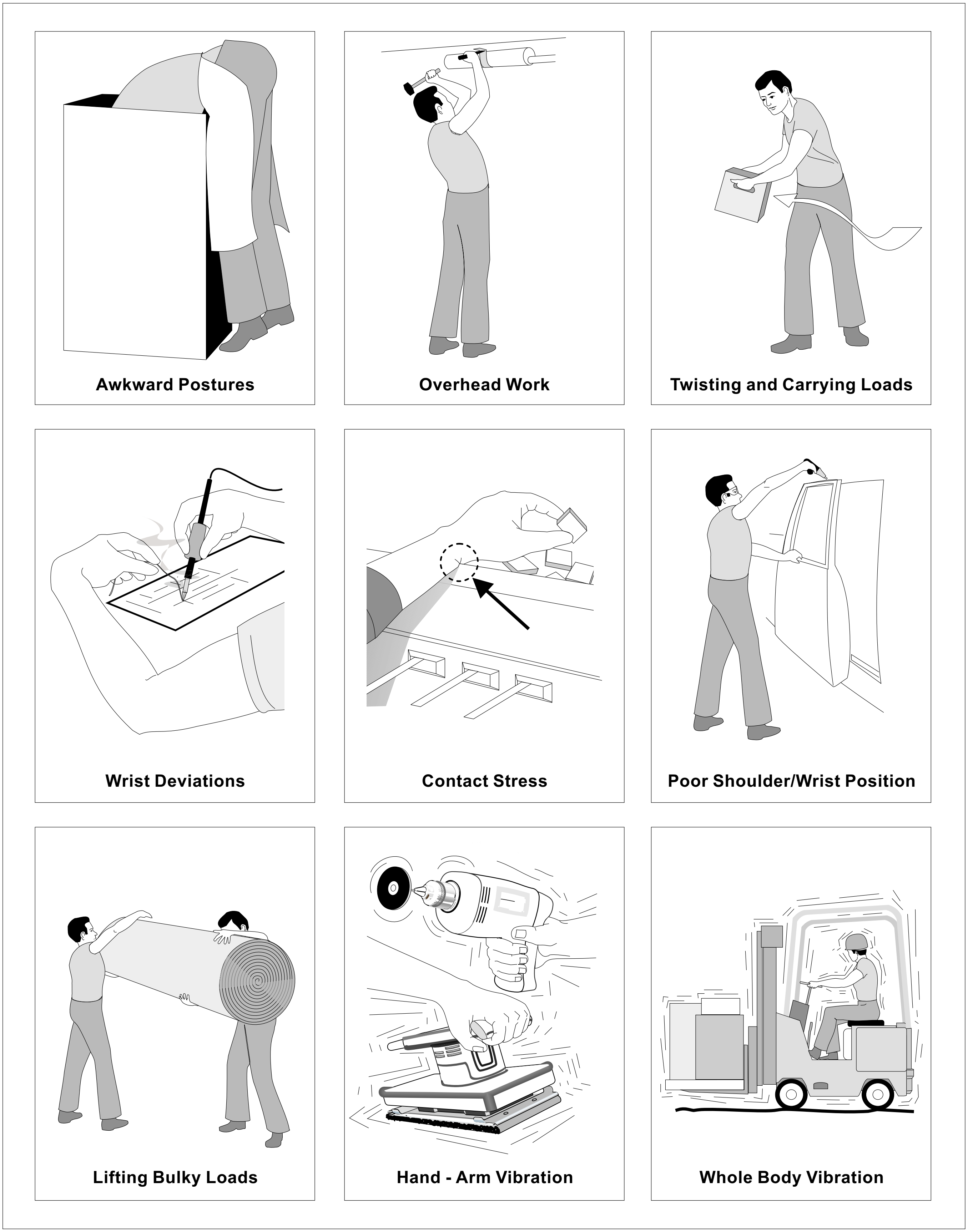

Figure 1. Illustrations of selected risk factor conditions. (Illustrations adapted from UAW-GM Center for Health & Safety [1990]; Putz-Anderson V [1988]; Grant et al. [1995]; Canadian Center of Occupational Safety and Health [1988]; American Meat Institute and Ergo Tech, Inc. [1990].

- **Repetitive motions**

  If motions are repeated frequently (e.g., every few seconds) and for prolonged periods such as an 8-hour shift, fatigue and muscle-tendon strain can accumulate. Tendons and muscles can often recover from the effects of stretching or forceful exertions if sufficient time is allotted between exertions. Effects of repetitive motions from performing the same work activities are increased when awkward postures and forceful exertions are involved. Repetitive actions as a risk factor can also depend on the body area and specific act being performed. (See Table 4 in the main text and Tray 6-B in the Toolbox.)

- **Duration**

  Duration refers to the amount of time a person is continually exposed to a risk factor. Job tasks that require use of the same muscles or motions for long durations increase the likelihood of both localized and general fatigue. In general, the longer the period of continuous work (e.g., tasks requiring sustained muscle contraction), the longer the recovery or rest time required.

- **Contact stresses**

  Repeated or continuous contact with hard or sharp objects such as non-rounded desk edges or unpadded, narrow tool handles may create pressure over one area of the body (e.g., the forearm or sides of the fingers) that can inhibit nerve function and blood flow.

- **Vibration**

  Exposure to local vibration occurs when a specific part of the body comes in contact with a vibrating object, such as a power handtool. Exposure to whole-body vibration can occur while standing or sitting in vibrating environments or objects, such as when operating heavy-duty vehicles or large machinery.

- **Other conditions**

  Workplace conditions that can influence the presence and magnitude of the risk factors for WMSDs can include

  — cold temperatures,

  — insufficient pauses and rest breaks for recovery,

  — machine paced work, and

  — unfamiliar or unaccustomed work.

In addition to the above conditions, other aspects of organization of work may not only contribute to physical stress but psychological stress as well. Scientific research is examining work factors such as performance monitoring, incentive pay systems, or lack of control by the worker to determine whether these factors have a negative effect on the musculoskeletal system [Moon and Sauter 1996]. Another related area of research is to determine which personal, work, or societal factors contribute to acute musculoskeletal disorders developing into chronic or disabling problems.

Screening jobs for these risk factors may involve the following:

- Walk-through observational surveys of the work facilities to detect obvious risk factors
- Interviews with workers and supervisors to obtain the above information and other data not apparent in walk-through observations, such as time and workload pressures, length of rest breaks, etc.
- Use of checklists for scoring job features against a list of risk factors

Of the above three methods, the checklist procedure provides the most formal and orderly procedure for screening jobs. Numerous versions of checklists exist in ergonomics manuals. When checklist data are gathered by persons familiar with the job, task, or processes involved, the quality of the data is generally better. Checklist procedures are also typically used in more complete job analyses (described below). Samples of checklists are found in Tray 5 of the Toolbox.

While screening tools such as checklists have been widely and successfully used in many ergonomics programs, most have not been scientifically validated. Combining checklist observations with symptoms data offers a means of overcoming uncertainty.

Integrating efforts to identify risk factors for musculoskeletal disorders with efforts to identify common safety hazards such as slips and trips should be considered. Jobs with risk factors for musculoskeletal disorders also may have safety hazards.

Performing Job Analyses

Job analysis breaks a job into its various elements or actions, describes them, measures and quantifies risk factors inherent in the elements, and identifies conditions contributing to the risk factors [Putz-Anderson 1988; Keyserling et al. 1993; Grant et al. 1995; ANSI 1996].

Job analyses are usually done by persons with considerable experience and training in these areas. While most job analyses have common approaches, such as a focus on the same set of risk factors described on pages 20 to 22, no "standard" protocol exists for conducting a job analysis to assess ergonomic hazards.

Most job analyses have several common steps. A complete description of the job is obtained. Employees are often interviewed in order to determine if the way the job is done changes over time. During the job analysis, the job is divided into a number of discrete tasks. Each task is then studied to determine the specific risk factors that occur during the task. Sometimes each risk factor is evaluated in terms of its magnitude, the number of times it occurs during the task, and how long the risk factor lasts each time it occurs.

The tasks of most jobs can be described in terms of (1) the tools, equipment, and materials used to perform the job, (2) the workstation layout and physical environment, and (3) the task demands and organizational climate in which the work is performed. Job screening, as described above, provides some of these data. More definitive procedures for collecting information on these components can include the following:

- Observing the workers performing the tasks in order to furnish time-activity analysis and job or task cycle data; videotaping the workers is typically done for this purpose
- Still photos of work postures, workstation layouts, tools, etc., to illustrate the job
- Workstation measurements (e.g., work surface heights, reach distances)
- Measuring tool handle sizes, weighing tools and parts, and measuring tool vibration and part dimensions
- Determining characteristics of work surfaces such as slip resistance, hardness, and surface edges
- Measuring exposures to heat, cold, and whole body vibration
- Biomechanical calculations (e.g., muscle force required to accomplish a task or the pressure put on a spinal disc based on the weight of a load lifted, pulled, or pushed)
- Physiological measures (e.g., oxygen consumption, heart rate)
- Special questionnaires, interviews, and subjective rating procedures to determine the amount of perceived exertion and the psychological factors influencing work performance

Exhibits 11 to 14 illustrate the varied approaches that NIOSH has taken in analyzing and evaluating jobs for apparent risk factors.

While a job analysis enables a person to characterize ergonomic risk factors, the question of what level or amount of exposure is harmful to the musculoskeletal system is a difficult one. Some have argued against the overuse of simple guidelines [Buckle et al. 1992; Leamon 1994], while others have recognized that, despite the limitations of current guidelines, many contain sufficiently useful information to identify potentially risky work activities [Karwowski 1993; Waters et al. 1993; Winkel et al. 1992]. While acknowledging the limitations of current knowledge, NIOSH and others conducting job analyses have used a variety of approaches to provide answers best suited for the specific workplaces under study. One approach calculates the muscle strength required to perform a certain job task and estimates the fraction of the working population that possesses the required strength. A second approach asks workers in the laboratory to judge acceptable work conditions by engaging them in tasks that impose different physical demands. A third method compares the forces generated in a part of the body when performing specific work tasks and compares it with a level believed to be harmful. Tray 6 of the Toolbox section contains references to and information about these and other approaches.

NIOSH recommends the use of the NIOSH lifting equation as one useful approach in both the design of new lifting tasks and in the evaluation of existing lifting tasks [Waters et al. 1993; Waters et al. 1994]. Other assessment tools are also available for evaluating such tasks [Chaffin and Andersson 1991; Marras et al. 1993, 1995; Hidalgo et al. 1995]. Population data depicting human strength capacities can be helpful in designing and evaluating jobs [Snook and Ciriello 1991]. Tables indicating standing and seated height and reach distances that can accommodate various proportions of the worker population [Kroemer and Kroemer-Elbert 1994] can also be helpful. Comparing job analysis results with such references can yield estimates of the percentage of the population that may be especially affected by these job conditions. In some NIOSH evaluations, efforts have been made to duplicate the specific stresses observed in the job to calculate forces on joints and limbs and to arrive at risk determinations [Habes and Grant, in press]. Computerized 2- and 3-dimensional biomechanical models can predict the percentage of males and females capable of exerting static forces in certain postures [Chaffin and Andersson 1991]. Westgaard and Winkel [1996, p. 87] recently summarized the strengths and weaknesses of current guidelines by concluding that "at present, guidelines to prevent musculoskeletal disorders can only give directions, not absolute limits." These authors believe the best guidelines must consider the level, duration, and frequency of exposure.

Table 4 presents the reference levels or limiting conditions used by NIOSH to rate risk factors of consequence to the musculoskeletal problems under investigation. (For the scientific justification of each guideline or approach, the reader is referred to the references indicated in Table 4.) In some instances these determinations were based on more than one rating procedure. For example, judgments of problematic lifting conditions in many NIOSH investigations have been derived both from use of the NIOSH lifting equation [Waters et al. 1993; Waters et al. 1994] as well as the Michigan computerized 2- and 3-dimensional analyses [Chaffin and Andersson 1991].

The entries in Table 4 are offered as illustrative examples of reference levels or guidelines. The actual risk to each worker depends not only on the current level of exposure to risk factors, but also on their physical capability, their past medical history, concurrent nonwork exposures, and

Exhibit 11: Cabinet Manufacturing Work Setting

The site was a cabinet manufacturing company in which basic work processes involved sawing rough lumber, planing cabinet panels and parts, sanding and painting, assembly, and packing and shipping. A total of 17 jobs representing one full production of a kitchen cabinet were first screened on the basis of job descriptions and walk-through observations for risk of both musculoskeletal disorders and traumatic injury. Five job tasks (three lifting tasks and two pushing and pulling tasks) were selected for more in-depth analyses because of their linkage with excessive back strain and sprain reports among the workers. Videotapes and still photos were taken of the job tasks, along with workstation measurements. (NIOSH protocols for analyzing videotapes of job operations are described in Tray 5-H of the Toolbox.) Frequencies, weights, and heights of loads lifted were noted together with measurements of initial and sustained push forces. Applying the NIOSH 1980 lifting equation formula for defining lift weight limits and the Michigan 2-dimensional static strength prediction program showed that the three lifting jobs presented conditions warranting control actions to reduce risk of overexertion or back injury. (Information about these two techniques is included in Tray 6 of the Toolbox.) Initial and sustained push forces for the other two jobs were rated against maximal acceptable values reported in the literature for 50% of the male and female population. One of these two tasks (pushing stacking bunks) exceeded these values and was judged potentially hazardous; recommendations for risk reduction were offered [HETA 88–384–2062].

Exhibit 12: Window Balance Systems Manufacturing Work Setting

The site was a plant that produced window balance systems. The product was made from either stamped, roll-formed aluminum or extruded vinyl. Both metal fabrication and extrusion operations were performed at the plant. All 12 jobs in the assembly department were targeted for analyses on the basis of earlier State inspection reports describing conditions associated with the development of carpal tunnel syndrome. These jobs were observed in a plant walk-through and videotaped for later analyses. Information was collected concerning the number of employees engaged, the task elements, the number of pieces assembled per work shift, the tools used, the difficulties workers perceived in the job, and worker suggestions for improvements. Measurements were also taken of work surface heights (both worktable and conveyor). A review of the videotape in real time and slow motion yielded data on repetitiveness of movements, awkward hand/wrist and shoulder postures, and indicators of muscular force requirements. The task cycle times were derived from these observations, along with the number of hand/wrist motions (flexion, extension, ulnar and radial deviation, pinching) and the number of unnatural shoulder positions. Particularly extreme postures were noted in the videotape analyses as one means for rating muscular force exerted. Other bases for rating force were the number of forceful manipulations in a given job cycle, the size and type of tool used, and the weight of the product handled.

Jobs were rated for ergonomic stress to prioritize interventions needed to eliminate the stress. The job ratings were determined by combining the observed level of repetitiveness or movements per day with the level of force. Three levels of repetitiveness were defined and assigned values. A value of "1" was given for jobs with low (fewer than 10,000) movements per day, "2" for jobs with medium (10,000–20,000) movements per day, or "3" for high (more than 20,000) movements per day. Average and peak levels of force were also judged by the investigators and given ratings of "1" or "2" (low force), "3" (medium force), or "4" or "5" (high force).

The total stress score for each job was determined by adding the assigned values for the repetition and force. Two jobs (pulling springs to attach them to window liners and hooking springs into window liners) were found to represent the greatest musculoskeletal stress when rated in this way. However, all of the assembly jobs were found to pose problems requiring ergonomic hazard control actions [HETA 88–361–2091].

Exhibit 13: Grocery Warehouse Setting

The site was a large grocery warehouse with the focus on order selector jobs. Order selectors load cases of grocery items from warehouse shelves to pallets according to a "picking order" (a listing of the items and quantities to be picked), the order of picking the items, and their locations (aisle and slot numbers) in the warehouse. In terms of job tasks, the order selector routine is to drive a pallet jack to the location of the items in the warehouse, lift the items from the shelves, carry them to the pallet, and lift or lower the items onto the pallet and place labels on the items. The order selector then proceeds to the next item on the order list, and the procedure is repeated. After the entire list of orders is picked, the order selector wraps or tapes the stacked cases together and places the loaded pallet on the loading dock for transport from the warehouse. Order selection is known as a physically demanding job. One objective of the NIOSH evaluation was to assess the potential risk associated with the manual lifting tasks just described. Before the evaluation, a standard incentive program was installed at this warehouse to establish a "fair amount of time" for order selecting activities. Achieving 100% of the standard was considered a "day's work." Order selector performance was averaged over a week, and employees were disciplined for performance that fell below 95% of the standard. Workers who exceeded the standard were rewarded with additional pay or paid time off.

Techniques used to assess the potential risk associated with the manual lifting tasks performed by the order selectors included the following:

- Weight measurements of the objects lifted
- Videotape, still photos, and angular measurements of the body postures of workers carrying out the lifting tasks
- Use of a motion monitor to record the motion of the trunk as it may affect the forces on the intervertebral joints of the spinal column
- Time activity analysis of the manual lifting routines of the order selectors, including work-rest cycles
- Use of portable heart monitors and oxygen consumption meters to measure the energy expenditure in the course of carrying out regular order selector activities

Information on load weights and body postures were systematically recorded for five representative lifting tasks that workers and the NIOSH investigators judged as having a high risk of potential for injury. These data served as input to the Michigan 3-Dimensional Static Strength Prediction Program for estimating compressive forces on the lower back and muscle strength requirements for designated lifts. The data were also used in the NIOSH revised lifting formula for recommending weight limits based on the characteristics of a specific lifting task. The evaluations for the five tasks by both the Michigan and NIOSH procedures found all loads to be clearly excessive. In addition, the lumbar movements constituting these tasks, as analyzed and measured in terms of flexion angle of the trunk and lateral and twisting velocity, combined with lifting rate and other factors, indicated a high risk of low back injury based on the models developed by Marras [Marras et al. 1993].

The mean metabolic rates as measured by oxygen consumption were above the value (5.0 kcal/min) recommended in the literature as an upper limit for young male workers during an 8-hour workday. Observed heart rates were also high. Two of the three workers had average heart rates exceeding 110 beats/min, the suggested maximum acceptable for the majority of healthy workers [Astrand and Rodahl 1986].

Time-motion analyses of the data collected indicated that the average frequency of lifts during the normal activities of the selectors was 4.1 lifts/min. This lifting rate, coupled with observed loads averaging 30.4 lb, would probably result in fatigued muscles, especially since a high percentage (53%) of the lifts required extreme trunk flexion and reaches above shoulder height. Calculations for these lifting conditions were well above the upper limits recommended by the NIOSH lifting equation [Waters et al. 1993].

Data collected in this evaluation provided for workers' perceptions of the physical effort required by their jobs and the job demand versus the control they felt they had in their work routines. Findings here indicated "hard physical effort" as the average response, which correlated well with the heart rate and oxygen consumption monitoring already described. Responses to the job demand and control questions, when compared with other worker groups, showed order selecting to be a high demand and low control job. Informal interviews with workers revealed their concern over the work standards and their inability to control the pace of their jobs. The literature associates this combination of job attributes with increased stress and job dissatisfaction [HETA 91–405–2340].

Exhibit 14: Office Setting

The sites were offices in two State governmental agencies in which more than 500 workers performed data entry tasks using VDTs. Questionnaires administered to the total sample of workers indicated a significant prevalence of constant musculoskeletal discomfort, with the greatest number localized to the trunk area, followed by the neck, buttocks, arm/shoulders (particularly on the right side), and, lastly, the lower legs. The specific design features of 40 workstations, representing a subsample of those used by this worker group, were analyzed to determine the extent to which they could account for the complaints. In all cases, the keyboard in these units was positioned immediately in front of the worker, with the document placed either to the left or right or between the keyboard and the display. Documents were manipulated mostly with the left hand, with the right hand used exclusively for keyboard operation. Wrist rests were not available, and flexibility in keyboard and video display placements was limited. Work tables and chairs lacked adjustable features. Various measurements and observations were made at these workstations during actual VDT work, including seat pan heights and compression seat back height, keyboard height, seated postures of the workers, upper arm angles, document distances, head tilt, gaze angle, and chair tilt and swivel. Statistical techniques were used to predict the amount of musculoskeletal discomfort from the aforementioned ergonomic variables. This analysis was performed by the region of the body affected and indicated the ergonomic factors, both singly and in combination, that could account for significant amounts of the reported discomfort in that area. The results showed, for example, that leg discomfort increased when the lower leg length exceeded the seat pan height and when the seat pan was soft. With regard to arm/shoulder discomfort, height discrepancy between the positions of the elbow and the keyboard proved to be a significant predictor as did long reaches to documents with the left arm. Less neck and trunk discomfort was found for erect sitting postures compared with stooped or slouched positions and as the height of the backrest was lowered in relation to the length of the operator's back. These and other findings served as the basis for offering suggestions about workstation configurations that could alleviate the discomfort problems [Sauter et al. 1991].

many other factors. These reference levels have varying degrees of scientific justification. Each was useful in a specific NIOSH workplace investigation aimed at reducing WMSDs.

Setting Priorities

In Exhibits 11 to 14, certain job tasks were targeted for more intensive analysis to verify the existence of risk factors for musculoskeletal disorders.

- In Exhibits 11 and 12, finding *cases of musculoskeletal disorders* prompted the followup analysis.
- In Exhibit 14, complaints of *musculoskeletal discomfort*, established through questionnaires, were the basis for sorting out possible work-related causes.
- The physical demands or *risk factors* of the job described in Exhibit 13, even without medical or symptom data, presented strong risk implications for potential WMSDs, thus triggering the analysis.

These three scenarios offer a basis for setting priorities for undertaking risk factor analyses and implementing control measures. Specifically, jobs associated with cases of musculoskeletal problems deserve the highest consideration in followup efforts to identify risk factors and implement control actions. Jobs in which current cases have been identified should receive immediate attention, followed by those in which past records have noted a high incidence or severity of WMSDs despite the lack of current cases. Priority for job analysis and intervention should be given to those jobs in which most people are affected or in which work method changes are going to be taking place anyway.

Jobs associated with worker complaints of fatigue and discomfort should be ranked next in deciding needs for followup job analysis and possible interventions.

Finally, where screening efforts suggest the presence of significant risk factors for musculoskeletal disorders, more detailed job analyses should be done to assess the problem potential. Ratings of high or extreme levels of risk factors, especially occurring in combination, may indicate a need for control actions. While appearing last in the priority order, taking steps to reduce apparent risk factors for musculoskeletal disorders is a preventative approach.

Table 5 summarizes the priority considerations in deciding about the need for job analyses and consequent control interventions for addressing WMSDs.

Table 4. Reference levels used in rating job risk factors for musculoskeletal disorders

Risk factor or risk condition	Reference levels used in NIOSH evaluations
Excessive reach	Based on body measurement data indicating comfortable or normal seated and standing arm reach distances for the majority of the male and female population (see Tray 6 of the Toolbox).
Lifting loads	*NIOSH Work Practices Guide* first used in defining acceptable loads to be lifted [NIOSH 1981]. Revised NIOSH lifting equation for recommended weight limits proposed in 1993 [Waters et al. 1993; Waters et al. 1994]. Applies to standing, two-handed, smooth lifting and lowering of stable objects in unrestricted spaces. Calculations take account of the horizontal distance of load from the body, vertical locations of hands at the beginning and end of lift, vertical distance of the load moved, frequency rate of lifting, balance, and coupling factors (see Tray 6 of the Toolbox).
	Michigan 2- and 3-Dimensional Static Strength Prediction Program which estimates, for lifting tasks, the amount of compressive force at the lumbo-sacral disc [Chaffin and Andersson 1991] (see Tray 6 of the Toolbox).
	Model of risk of low back disorders as a function of workplace characteristics and trunk motion characteristics (e.g., lift rate, trunk bending, twisting motion) [Marras et al. 1993, 1995] (see Tray 6 of the Toolbox).
Pushing or pulling loads	Initial and sustained forces of loads pushed or pulled at variable rates that are judged acceptable for 90% of the female work population [Snook and Ciriello 1991] (see Tray 6 of the Toolbox).
Whole-body vibration	International Standards Organization (ISO) Dose System for Whole Body Vibration indicating vibration levels in three dimensions with limiting times for fatigue decreased proficiency [ISO 2631/1, 1985] (see Tray 6 of the Toolbox).
Hand/arm vibration	American National Standards Institute (ANSI) daily exposure limits [ANSI S3.34. 1986] and American Conference of Governmental Industrial Hygienists (ACGIH) [ACGIH 1996] values for judging whether estimated worker task exposure levels are excessive (see Tray 6 of the Toolbox).
Repetition rate	Both the number of hand manipulations per 8-hour work shift and the task cycle time have been used to rate this factor. Task cycle times of 30 sec or less were defined as high repetition; cycle times greater than 30 sec as low repetition. For hand manipulations, high repetitiveness was described as more than 20,000 manipulations per 8-hour work shift; medium repetitiveness as between 10,000 and 20,000 manipulations per 8-hour work shift, and low repetitiveness as less than 10,000 manipulations per 8-hour work shift [HETA 88–361–2091; HETA 88–180–1958]. A recent proposed repetition guideline believed to be more protective is cited by Kilbom [1994] (see Tray 6-B of the Toolbox). This guideline also considers other areas of the upper extremity. Each area may have a different ability to tolerate repetitious activity. At the same rate of repetitions some specific acts such as pinching may be less well tolerated than others. This is an example of complexities that current guidelines may not address adequately.
Force and energy demands of work tasks	Relative ratings on a 5-point scale used to classify task performance as requiring high, medium, and low levels of force [HETA 88–180–1958; HETA 88–361–2091].
	Criterion of 5.0 kcal/min as measured by oxygen consumption used as a limit for energy expenditure [Astrand and Rodahl 1986] (see Tray 6 of the Toolbox).

Table 5. Determining priorities for job analyses and control actions

Priority and action	Nature of available information: Current cases of WMSDs for persons in select jobs	No current cases, but past plant records indicate WMSDs in select jobs or departments that have not changed	No current or past cases, but worker complaints and symptom surveys suggest WMSDs in select jobs or departments	No cases, reports of WMSDs, or complaints, but job screening and checklists suggest high risk factor potential in select jobs
Priority for followup analyses and control actions	Immediate need	Priority is second only to the need to address more current cases	Third in priority; resolving problems at an early stage is commendable	While last in priority, this effort is preventive; most positive of all actions
Type of followup job analyses needed	Perform job analyses to sort out and rate job risk factors for observed cases	Perform job analyses to sort out and rate risk factors for jobs with highest number or severity of past WMSDs and largest work group at risk	Perform job analyses to sort out and rate risk factors for jobs having frequent WMSD complaints and symptoms	Perform job analyses to sort out and rate risk factors for jobs with the highest problem potential (based on screening observations)
Focus needed for control actions	Control actions should be focused on reducing the highest rated risk factors in current jobs linked with the greatest number of cases	Control actions should be focused on reducing the highest rated risk factors in jobs with the highest number or greatest severity of past WMSDs for the largest work group at risk	Control actions should be focused on reducing the highest rated risk factors in jobs having frequent WMSD complaints and symptoms	Control actions should be focused on reducing the highest rated risk factors for WMSDs before any are reported