CHAPTER 8

Ergonomics

No other topic in this book saw more controversy and political attention in the early twenty-first century than ergonomics. Just what is ergonomics, and why has it generated so much debate? This chapter will address not only the subject of ergonomics as a field of endeavor but also will address why many employers fear that it is a threat to the continued operation of their businesses. The controversy will be scrutinized to determine whether the fear is of ergonomics itself or of how federal enforcement authorities will apply it and whether or not that fear has any basis in fact. We will also explore the regulatory history of the embattled standard that was promulgated in the 1990s and then was immediately set aside by Congress. After the failure of the standard, OSHA has continued to enforce ergonomics practices, especially in certain industries, such as health care and poultry processing, relying upon the General Duty Clause as a basis for citation. OSHA's enforcement actions will be reviewed and some light shed on why OSHA focuses upon certain industries when it looks at ergonomics. Finally, an attempt will be made to map a strategy for success with ergonomics in the arena of occupational safety and health.

FACETS OF ERGONOMICS

A key to understanding the controversy surrounding ergonomics is to understand what ergonomics is and what activities can be considered to be a part of the field. Even the definition of ergonomics is somewhat controversial, so in this text, we will refer to the definition that has been forged by the national consensus committee, which has spent nearly a decade refining the draft ANSI standard for ergonomics:

> *Ergonomics* is a multidisciplinary science that studies human physical and psychological capabilities and limitations. This body of knowledge can be used to design or modify the workplace, equipment, products, or work procedures to improve human performance and reduce the likelihood of injury and illness.
>
> (Work-Related Musculoskeletal Disorders, 2002)

From the definition, it can be seen that the field of ergonomics covers a broad spectrum of activities involving human activity. Reducing the likelihood of injury or illness, as beneficial as that goal is, is only one of the objectives of the field. Improving human performance is another key objective and, historically, may even be more important to the field of ergonomics.

Ergonomic Vehicle Design for Human Performance

Much thought goes into the design of automobiles and, especially, the cockpits of aircraft in order to improve the driver's or pilot's ability to assess problems and take appropriate action in a timely manner. The field of ergonomics has developed design principles based on research that has shown how people react to various stimuli. What we are talking about here is the appropriate interface between human and machine to achieve the best possible result of the machine performing the intended task for the operator controlling it. If the equipment being designed is a vehicle, there are obvious implications for safety, not only of the operator but also of the general public.

There are certain conventions about machine interface that have grown up historically before the word *ergonomics* was ever coined. Some of these conventions tend to cause confusion for the vehicle operator, or the operator of other equipment for that matter. For instance, water faucet valves usually turn on and increase volume by twisting counterclockwise; however, electronic knobs, such as volume controls, usually turn on and increase by twisting clockwise. Other conventions are more consistent, such as the pushing forward of a lever, which usually means "engage" or "go." Other conventions or principles are concerned with the placement of instruments or dials, priorities for the attention of the operator, and rules to avoid inadvertent actuation of critical controls due to their proximity to other frequently used controls. The consideration of these principles, which are for the most part design decisions, is the objective of the practitioner in the field of ergonomics. Design engineers were once thought to be naturally equipped to consider such "commonsense" principles of safe and appropriate design. However, notorious examples of the failure of designers to consider the human interface has led design and development teams to employ experts in the field of ergonomics to provide input to the design process.

Designing Safety Features into Workplace Machines

The workplace safety professional can see examples of the application of ergonomics principles in the design of machine controls, many features of which are specified by safety standards. One example is the design of punch press foot switches. A properly designed standard foot switch for activating a mechanical power press has a cover to prevent the operator or other personnel from accidentally stepping on the pedal or switch, thus causing an accidental cycle of the press ram, which could have disastrous results. Another example is the requirement that crane pendant controls be "dead-man" controls, that is, unless the operator is taking a positive action to depress the control, the spring-loaded button will return to a safe "no-action" position. The reader will recall that this principle was discussed in Chapter 3 under the topic "The Engineering Approach" to the control of hazards. Indeed, consideration of the principles of ergonomics should be included in any engineering approach to addressing equipment hazards.

Sometimes the ergonomics design principle has more to do with human behavioral characteristics than with physical actions, accidental or intentional. The foot switch design principle was simply to prevent accidental actuation. However, sometimes the operator will be motivated to *intentionally* take some dangerous action, to increase a production rate, for convenience, or perhaps for some other reason. An example is seen in the design of two-hand tripping devices for presses or other dangerous machines. Experience has shown that operators will want to take shortcuts in the repetitive elements of a machine cycle to increase production rates. Such shortcuts can be very dangerous. In the case of punch presses, to prevent amputations and serious injuries it is essential that both of the operator's hands are out of the danger zone when the ram is tripped. So, the designer specifies two-hand controls or trips, both of which must be depressed concurrently to activate the press ram and cause the machine to cycle. To counteract the very human motivation to bypass such controls, safety standards specify that two-hand controls be "anti-tie-down." This way, the operator cannot improvise a method of tying down one of the controls so that the machine can be activated with one hand while the other hand is free to facilitate machine loading and possibly be in the danger zone of the machine. An illustration of anti-tie-down design schemes can be seen in Chapter 15 in Figure 15.29. Note that the two-hand palm buttons are partially enclosed in cuplike housings that surround the periphery of the buttons preventing their tie-down by bars, pieces of lumber, etc. Another feature of the palm buttons is that they are often very rounded and smooth so as to not present a flat surface for mounting some type of improvised tie-down device. These design features of the machine can be considered applications of the principles of ergonomics.

Consideration of human behavior principles can also influence the design of machine logic control sequences so that a mistake or malfunction requires the operator to execute a certain prescribed sequence. It makes sense, for instance, that after a malfunction has occurred in an automatic sequence of steps, the machine might be programmed to revert to manual mode and require the operator to restart the automatic sequence from step one or other safe starting point. This seemingly elementary piece of logic has often been overlooked in the design of automatic sequential control of machine cycles, and the result is the development of a potentially dangerous situation. Case Study 8.1 will illustrate this concept.

CASE STUDY 8.1

AUTOMATIC MACHINE CONTROL SEQUENCE

Lead-acid storage batteries contain molded lead plates immersed in an acid solution. The manufacturing process in this case study required that the plates be formed in a hot, platen press operation in which the lead is pressed into shape in a hot, plastic state—too hot to handle, but not as hot as molten lead. Both heat and pressure are needed to complete the forming process.

Because of the necessity of handling dangerously hot workpieces, the process is sometimes automated. In such a process, the serious accident described in this case study injured the operator controlling the process. The workstation was set up to process the lead plate fabrication in several steps inside an enclosure that was not normally entered by the operator. Each step was triggered by sensors, such as mechanical limit switches, that indicated to the logic controller when the previous step was completed and when it was time for the machine to index to the next step. A particular point in the cycle frequently presented a difficulty when the molding platens opened and the completed, hot lead plate dropped out of the mold. Sometimes the lead plate would stick to the upper mold platen, requiring operator intervention. So frequent was this malfunction that the workstation was equipped with a wooden broom handle hanging near the control console so that the operator could stick it into the enclosure and knock the stuck plate out of the upper platen. The serious accident occurred when an operator was unable to knock the lead plate loose with the broomstick and he entered the enclosure to use his gloved hands to shake the plate loose. When he entered the enclosure area, somehow he accidentally brushed against a limit switch that triggered the automatic logic controller to conclude that the platen unloading operation had completed successfully. The programmed logic then set in motion actions to begin the next step in the process, which unfortunately was to close the mating platens. One of the operator's hands was in the danger zone between the platens when they closed with force and high temperature. Fortunately, the man was wearing a glove, but the hot platens still did enormous damage to his hand.

The irony in the story of Case Study 8.1 is that the programmed logic could easily have been devised by the designer to take the machine out of automatic mode whenever an operator was sensed to have entered the danger zone. Even without a sensor, the machine could have been programmed to time each step of the process and check those times so that whenever a plate stuck or some other malfunction occurred that was detected by the failure of a limit switch to be actuated in a reasonable time, the machine could stop and go into manual mode. Thus, the machine would not take another step in the sequence until the operator had returned to the console and either proceeded manually or pressed a "reset" switch. To accomplish this he or she would of necessity be out of the danger zone.

In the foregoing case, it can be argued that the designer cannot be expected to think of every careless thing an operator might do with utter disregard for his or her own personal safety. However, the problem here was with a frequently recurring malfunction, one for which every workstation was already equipped with a broomstick to deal with the problem. It would have been a simple matter to include a logic check in the automatic sequence to flag a situation in which a critical limit switch did not actuate when expected, signaling that the plate had become stuck in the upper platen. The programmed logic could then take the machine out of automatic mode and require the return of the operator to the safe console to restart the sequence on the control panel. This strategy would make sense whether the operator used the broomstick provided or entered the danger zone to free the workpiece. Either way, the machine would wait for operator intervention at the console before blindly going to the next step. The design feature needed in this situation is one that is intended to anticipate the human behavior aspect of the operation and take steps to mitigate the dangerous actions taken by the operator. Therefore, the ergonomic design process for the equipment should consider human behavioral factors as well as physical factors in the operation.

WORKPLACE MUSCULOSKELETAL DISORDERS

Most of the activity and most of the controversy surrounding the enforcement of ergonomics in the workplace has surrounded the field that is currently designated "Musculoskeletal Disorders" or simply "MSDs." MSDs are the most common form of work-related illness in industrialized nations (Brace, 2009). This complicated term is actually a generalization of more specific maladies that have been experienced in the workplace and have received significant attention on the part of both industrial safety and health managers and enforcement authorities. It is this part of ergonomics that has led to so much controversy and subsequent political action reaching a level as high as the U.S. Congress. A little history of the jargon surrounding these specific ailments leading up to the current emphasis on MSDs is in order.

Carpal Tunnel Syndrome

Most of the general public today knows something of the term *carpal tunnel syndrome.* This is a good starting point because much of the early history of the regulation of ergonomics resulted from worker complaints in this category. Carpal tunnel syndrome is a painful, possibly disabling dysfunction of the wrist. The condition is not clearly defined, but is generally thought to result from activities that require repetitive hand motion, especially when the hands are required to be in an awkward posture. Tasks involving rapid production, such as assembly or typing, are often associated with carpal tunnel syndrome. Kroemer, et al. (2001) report that carpal tunnel syndrome has been observed for more than 100 years. However, only recently have attempts been made to explain it and control conditions that may affect it. Kroemer credits Robbins with the first explanation of the anatomical basis for carpal tunnel syndrome in the early 1960s. Figure 8.1 illustrates a cross section of the wrist showing the crowding together of tendons, bones, and nerves within a sheath enclosed by the carpal ligament. The parts of the wrist must move within this sheath to give motion to the fingers in repetitive operations. It is understandable that awkward postures of the hand and wrist would further constrict the carpal tunnel area and give rise to discomfort from the moving parts. It also makes sense that highly repetitive motions would exacerbate the condition.

In response to increasing concern in the 1970s that repetitive type work was causing carpal tunnel syndrome, OSHA began to investigate firms in which operators were required to do such work with their hands—especially, if the work was intricate or required awkward hand postures. However, OSHA had no standard to rely on for writing citations against employers whose employees were experiencing carpal tunnel syndrome. Lacking a specific standard for this situation, OSHA turned to the Section 5(a)(1) General Duty Clause, which was covered in Chapter 4. As is often the case with citations of the General Duty Clause, employers often contested the citations on the grounds that carpal tunnel syndrome is not really what Congress intended back in the 1960s when it drafted the clause to provide general protection against "hazards that

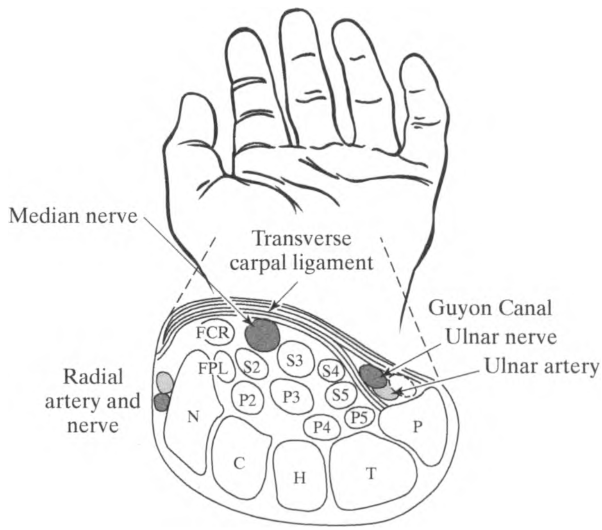


FIGURE 8.1

Schematic view of the carpal tunnel with the tendons of the superficial (S) and profound (P) finger flexor muscles, flexors of the thumb [flexor carpi radialis (FCR), flexor pollicis longus (FPL)], nerves and arteries, carpal bones (P,T,H,C,N), and ligaments.

are likely to cause death or serious physical harm" (to employees). However, OSHA was successful in making some of the citations stick using the General Duty Clause of the OSHA act.

Repetitive Strain Injuries

After scoring some successful citations of companies in which workers were experiencing carpal tunnel syndrome, OSHA began to enlarge its perspective with respect to the phenomenon of sore joints, muscles, and tendons. The carpal tunnel in the wrist was the classic example of the problem, but OSHA ergonomists and the body of professional practicing ergonomists reasoned that the carpal tunnel is not the only part of the body that could be irritated by repetitive motion. What about the neck, for instance? Did not workers get sore necks from jobs that required repeated motion of the head? And then there were sore elbows and sore shoulders. Therefore, the target "hazard" was shifted from "carpal tunnel syndrome" to a much broader term: *repetitive strain injuries*. The term *carpal tunnel syndrome* went completely out of vogue among practicing professionals in the field because it limited the perspective of the practitioner as well as the enforcement powers of the regulatory officials. By the 1990s, the term *carpal tunnel* had become so out of style that it was conspicuously omitted from the definitions in the ANSI standard for ergonomics, and it is only briefly mentioned in the body of the standard as one of several different manifestations of disorders resulting from ergonomics hazards (Work-Related Musculoskeletal Disorders, 2002).

Cumulative Trauma Disorders

Even the term RSI seemed too limiting in scope. Suppose that a worker experienced symptoms even when the job did not involve rapid, repeated motions? Certainly rapid, repeated motions were the most common exposures associated with sore tendons and joints, but some workers were found to experience symptoms even when their jobs did not require this type of activity. An even broader term was needed that would cover any type of trauma resulting from an accumulation of exposure over a period of time, though the worker is not injured from an occasional exposure. Thus, the term *cumulative trauma disorders* (CTDs) replaced RSIs. There is somewhat of a contradiction in the term *cumulative trauma*. The word *trauma*, used alone, means injury, usually violent injury. In Chapter 1, the term *injury*, which relates to safety, was identified as dealing with an acute exposure. Chronic exposures were identified as health hazards. However, the word *cumulative* suggests a building up of chronic exposures, not a single, violent injury. The word *cumulative* apparently carries more weight than the word *trauma*, because CTDs are generally considered a chronic exposure, not an acute one. The term *CTD* had a short life in the late twentieth century, but has since been replaced with another term, *MSD*.

Musculoskeletal Disorders

If one could deal with the seeming contradiction in the term cumulative trauma disorders, it seemed it covered everything. However, there was still a problem with this term besides the contradiction. The problem was that the term itself implied a *cause* of the condition. It seemed inappropriate to assume that the worker had been injured from an accumulation of exposure to a hazard. Even worse, suppose a worker complained about pain in a joint and it could not be established that the worker had cumulative exposure of any kind? So as not to overlook any cause of the disorder, whatever the cause might be, the term *musculoskeletal disorders* (MSDs) became the new term used to describe all of the related worker conditions of this type, including carpal tunnel syndrome, rotator cuff syndrome, DeQuervain's disease, trigger finger, tarsal tunnel syndrome, sciatica, epicondylitis, tendinitis, Raynaud's phenomenon, carpet layers' knee, herniated spinal disc, low back pain, bursitis, and tension neck syndrome (Work-related Musculoskeletal Disorders, 2002). The term *MSD* was modified slightly in the ANSI standard to narrow the focus to work-related exposures. Therefore, as of this writing, the term had finally morphed into *work-related musculoskeletal disorders*, WMSDs. Figure 8.2 illustrates the historical progression in recognizing WMSDs.

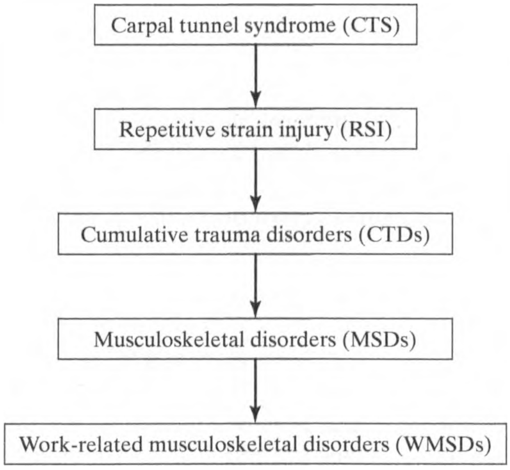


FIGURE 8.2

Historical progression of the recognition of WMSDs.

AFFECTED INDUSTRIES

Two landmark citations by OSHA in the area of ergonomics have been used as a model for the formulation of enforcement policy for controlling the hazard of WMSDs. The cited employers were Beverly Enterprises, a widely distributed provider of health-care services (especially nursing homes) headquartered in Ft Smith, Arkansas, and Pepperidge Farm in Downingtown, Pennsylvania, a maker of biscuits. A principal concern in the nursing home industry is heavy manual lifting on the part of nurses and health-care providers. A principal concern in the food manufacturing and processing industry is carpal tunnel syndrome and other chronic repetitive motion maladies. Meat packing, especially poultry processing, has been another industry that has had considerable Section 5(a)(1) General Duty Clause enforcement actions brought against employers by OSHA.

Certain industries may have particular problems with WMSDs, but one area of concern touches almost every industry, namely, computer terminals. It is estimated that more than half of all office workers in the United States make use of computer terminals in some way in their jobs. Occasional use is not a concern, but workers who sit at a computer terminal all day are reporting eyestrain, headaches, backaches, and neck and shoulder pain. Chapnik and Gross (Chapnik and Gross, 1987) report a Wisconsin study by Sauter that shows a significantly greater incidence of these conditions among computer terminal operators than among other office workers. A consistently higher percentage of the 250 exposed subjects studied reported discomfort compared with the 84 workers who did not use computer terminals in their jobs.

The problem of eyestrain reported in studies of computer terminal operators is no surprise. What has been unexpected is the level of musculoskeletal aches and pains associated with computer terminal operation. There has been increased incidence of repetitive strain injuries, such as tenosynovitis, tendonitis, and carpal tunnel syndrome. OSHA's increased attention to ergonomic hazards, coupled with the dramatic growth in the use of computer terminals, ensures that this subject will remain of vital concern to the safety and health manager.

ERGONOMICS STANDARDS

Citation of Section 5(a)(1) of the General Duty Clause for ergonomics hazards was always a stopgap measure that was used in the absence of a relevant, specific standard for ergonomics. Therefore, throughout the decade of the 1990s, OSHA maintained a goal of developing a standard specifically focused on ergonomics.

OSHA Ergonomics Standard

A decade is a long time to develop and promulgate a standard. For ergonomics, it was never an easy process with representatives of organized labor pushing for a tougher standard and industry pointing out the costs and problems of compliance with a rigid standard. The development effort climaxed in the waning weeks of the Clinton presidential administration as OSHA officials pushed to get a standard on the books before the Bush administration took office. In this, they succeeded with the "11th-hour" final standard officially announced in the *Federal Register* November 14, 2000. The standard allowed industries 11 months to come into compliance, targeting October 15, 2001, as the effective date.

After nearly a decade of negotiation, the final standard emphasized the following main areas:

- Information to employees
- Quick-fix action to eliminate reported WMSDs that meet the "action trigger" defined by the standard or establishment of an ongoing WMSD program

The standard had a "grandfather provision" that permitted employers to continue with established ergonomics programs that met certain minimum criteria. Programs that were implemented to comply with the standard (not grandfathered) were required to have the following elements:

- Management leadership
- Employee participation
- MSD management, including access to a health-care provider (HCP), work restrictions deemed necessary by the HCP, protection of the worker's rights during the work restriction period, and follow-up evaluation of each MSD incident
- Initial and ongoing training of employees
- Program evaluation and follow-up
- Recordkeeping

One can see that documentation is important, as is always true of safety and health programs and standards.

The OSHA Ergonomics Standard had a short life. As soon as the new Congress took office in 2001, the new ergonomics standard was repealed by congressional vote, overriding OSHA's action. When Congress overrides and repeals any agency action, that agency is prohibited from resubmitting a slightly different version in a new promulgation.

Why was the standard overturned by Congress? Basically, industry was afraid of the cost speculated to be incurred in complying with the standard. Fundamental to the controversy over ergonomics is the question "What really constitutes a WMSD?" It is perfectly normal to experience some discomfort when adjusting to a new job. A key element in any ergonomics program, and one that will be noted by regulatory authorities, is whether the worker has an input. It only makes sense that the worker must provide input about which jobs entail discomfort. However, when a worker complains of discomfort, who is to say that it is a genuine WMSD (that might become permanent or disabling) and not just adjusting to a new job? Another controversial issue is over the definition of injury or illness. Just what constitutes an injury or illness? Even if an injury or illness is established, there is always the question of whether it was caused by personal, off-the-job exposures, or by the job itself. Finally, there is the question of remedies. How can the work environment be adequately "fixed?" And how can an injured worker be "cured?" The answer to many of these questions comes down to a judgment call and if there is anything that an employer fears, it is the requirement to comply with a standard that is subject to interpretation or the judgment of the inspector.

OSHA Guidelines

The new OSHA administration ushered in with the Bush administration and the new Congress abandoned the strategy of promulgating a specific standard for ergonomics. In its place, OSHA unveiled a plan to issue guidelines to help control ergonomics hazards. OSHA would issue the guidelines for specific industries and encourage other general industries to construct guidelines of their own. The new strategy emphasized cooperation and the use of exemplary, successful, established ergonomics programs as models for assisting other industries. There was a provision for giving recognition for noteworthy ergonomics programs. There is no question that the new "guidelines" program emphasized the positive and relied on the judgment of the industries to take the initiative in developing programs to foster ergonomics solutions to problems and hazards. Indeed, OSHA pointed to Bureau of Labor Statistics reports that a decline in WMSDs had already been observed. The new guidelines approach de-emphasized enforcement actions, but the new administration retained an enforcement program for ergonomics using Section 5(a)(1) of the Act—the General Duty Clause. The new enforcement procedures emphasized serious hazards and were patterned after successful past prosecutions of industries in which the hazards were clearly serious.

ANSI Standard

During the entire decade of governmental action, promulgation, and OSHA enforcement developments (the 1990s), the private sector was quietly at work developing a general ergonomics standard for voluntary compliance. The form of the standard, written under the supervision and within the framework of the American National Standards Institute (ANSI), was directed at specifying a program for ergonomics in general terms and recognized the need for professional judgment to apply the program to specific work situations. The standard placed importance on the professional qualifications and training of those persons performing the required tasks. The standard specified a WMSD management program that bore a close resemblance to the program requirements specified in the former OSHA standard. The following program components were required in the draft standard:

- Management responsibilities
- Training
- Employee involvement
- Surveillance
- Evaluation and management of MSD cases
- Job analysis
- Job design and intervention

The last two components emphasized the analysis and prevention of future hazards before the occurrence of the WMSD cases. These components of the management plan in the ANSI standard went beyond the management plan requirements specified in the OSHA standard.

WMSD MANAGEMENT PROGRAMS

At this point, one may be wondering what plan to follow to have an effective Workplace Musculoskeletal Disorders program within a given company or plant. It is good strategy to have a working, documented program in place in any workplace that has exposure to hazards that can be categorized as related to WMSDs. It makes sense considering the following:

(a) Worker comfort and basic well-being
(b) Plant productivity
(c) Reduction of workers' compensation claims
(d) Compliance with the safety and health General Duty Clause

Drawing from the consensus of both the ANSI standard and the proposed OSHA standards, the general components that follow are thought to make up an effective WMSD program.

Administration and Support

The program should have both documented and real management support. Employees and supervisors should be trained in the causes and symptoms of WMSDs and be encouraged to report problems. The training also should consider the workplace and the tools and work equipment used to do the work. Proper use, maintenance, and adjustment of these tools and equipment may forestall future occurrences of WMSDs. There should be evidence of employee participation in the program. This is shown by records of employee reporting of WMSD symptoms before such symptoms become a serious problem. Employees also should be seen actually doing the work in accordance with the training they have been given in proper procedures for preventing the occurrence of WMSDs. Employee participation can also be shown in meetings about prevention of WMSDs, employee completion of surveys, and assistance with the design process for work, equipment, and procedures. An important part of the ergonomics program is the suggestion or complaint system. A response should be given to all complaints. This must be done in a timely manner. It is imperative that all complaints be validated and response given, as this will encourage employee participation.

Surveillance

In addition to management involvement, training, and worker participation, a WMSD program should have a provision for what is called surveillance. This facet of the program insures that signs and cues will be used to signal the need for job analysis and the implementation of the principles of ergonomics. One sign of a need might arise from the review of injury and illness records in the facility. An important aspect of this review is looking for trends that might appear by factors such as job titles, departments, operations, or even workstations. These trends can indicate areas of improvement for management or operations that should be given priority in job analysis. Are some job functions more prone to WMSDs than others? Do some departments or managers have a higher incidence rate than others? Another sign might be reports from employees, either of actual WMSD symptoms or perhaps just an employee concern about a situation that might carry a risk of WMSD exposure. The ultimate surveillance tool is an actual survey of any job suspected to be the cause of WMSDs.

Case Management

At the very least, an effective program should respond to WMSD cases as they are reported. This means that provision should be made for diagnosis, treatment, and recognition of necessary time for sufficient and timely recovery from the symptoms of WMSD exposures. To provide effective diagnosis and treatment of WMSDs, competent healthcare providers (HCPs) must be identified by the employer and must be provided the data and support to do their jobs. This might entail visits to the workplace by the HCP or perhaps videotapes of the jobs in question so that the HCP can make knowledgeable recommendations to the employer. Based on his or her knowledge of the symptoms and of the workplace, the HCP may have an opinion about whether the MSDs are work related. In addition, the HCP may have suggestions for modifications to the workstation to eliminate the exposures. The work of the HCP in dealing with specific cases of MSDs and in determining that they are work related culminates in the identification of the need for job analysis, which is explained in the section that follows.

Job Analysis

Earlier, the concept of job surveys was introduced as part of the overall administration of a WMSD management program. The primary objective of job surveys is fact finding. Job analysis, by comparison, is a more detailed and comprehensive study of the workstation and task and is triggered by medical evidence that the workstation or job is the cause of WMSD exposure. With job analysis comes the evaluation of "risk factors" that contribute to the problem. A possible risk factor would be an unusually cold temperature ambient to the workstation. Another might be the posture required for a particular job. Certainly, the amount of force required to be applied and the number of repetitions of a given motion have possible effects upon the incidence of WMSDs. If the workstation is subject to constant vibration, this brings another risk factor to the exposure. The data provided by the in-depth job analysis are the basis for taking corrective action to resolve the problem. Such action, which should be a part of any effective program for WMSDs, is described in the next section.

Job Design and Intervention

Once a problem has been identified, the responsibility is on the employer to rectify the situation. One may recall from Chapter 3 the "three lines of defense" for dealing with health hazards. In the case of WMSDs, only the first two seem relevant: engineering controls and administrative, or work practice, controls. Personal protective equipment, although promoted by some vendors, is not universally accepted as useful in reducing WMSDs.

Engineering controls are generally preferred because they are intended to physically eliminate the hazard instead of specifying procedures to be followed by workers or managers to deal with or mitigate the hazard. The three-lines-of-defense rule applies to health hazards in general, and certainly WMSDs are no exception. The nature of the engineering control will be dictated by the process itself and can be represented by widely varying engineering solutions to problems.

Administrative controls may be easier to achieve than engineering controls for some difficult processes. Konz and Johnson (Konz and Johnson, 2003) have recommended a procedure called *ramp-in* that allows new workers (or existing workers on new jobs) to gradually acclimate to highly repetitive tasks, such as assembly. The new worker is not required to do the job at the same pace as the experienced worker. Then, as the worker learns to perform the task more efficiently and becomes more physically adept at handling the particular repetitive motions required, the work standard can be increased. Johnson states that "(ramp-in) has been shown to be one of the most effective methods of reducing unnecessary discomfort for new employees who perform repetitive tasks." Another attractive feature of the ramp-in procedure is that it accommodates the setting of high standards for productivity; standards that may not be achievable for the new worker but, nevertheless, are reasonable for the worker who has adapted to and become skilled at the task. Since ramp-in involves a change in procedure or the pace of the job, it should be considered an administrative, not an engineering, control. Another common administrative control is to rotate workers on and off difficult, repetitive jobs to reduce the exposure time to the hazard. This common practice is a widely recognized remedy for many different types of health hazards, including noise exposure and exposure to toxic air contaminants, as will be seen in Chapters 9 and 10.

Ergonomics is a complex problem that is not easily solved by engineering or administrative controls. The problem really calls for a deeper analysis, matching problem solutions to the risks determined in an in-depth ergonomic analysis. The following section identifies factors and processes for their mitigation.

ERGONOMIC RISK ANALYSIS

Ergonomic Risk Factors

The following are generally accepted risk factors that can contribute to WMSDs:

- **Force.** The amount of effort needed to accomplish a task
- **Repetition.** The number of times a given task must be accomplished
- **Awkward postures.** When a body part is out of its neutral position
- **Static postures.** When a given posture is maintained for an extended amount of time
- **Vibration.** When a part of the body comes in contact with a vibrating tool or surface

- **Contact stress.** Contact between sensitive body tissues and hard objects
- **Cold temperatures [Environmental].** Exposure to adverse environments such as excessively hot or cold temperatures, air pollutants, noise, and others (Elements of Ergonomics Programs, 1997)

Both OSHA and the World Health Organization (Luttman et al., 2003) discuss the effects of the ergonomic risk factors. Assessment of ergonomic risk factors bears some resemblance to the methods of examining general hazards seen in Chapter 3. Since ergonomics deals with hazards from repetitive exposures, the duration of the exposure becomes a significant factor in determining the magnitude of the hazard. Force represents the magnitude of the task. As force increases, muscles and body tissues are overloaded, sometimes up to the point of failure. Force also induces fatigue, which can increase the susceptibility to injury. Repetition represents the frequency of a task. Even the easiest task performed repeatedly induces fatigue and possible injury. Force and repetition increase the necessary rest cycle from a task. Awkward postures and static postures both impede the flow of blood throughout the areas of the body in which the awkward postures occur. This lack of blood flow increases fatigue in these areas. Awkward posture and static posture are duration factors. Vibration, contact stress, and cold temperatures (environmental) are severity factors. Vibration, contact stress, and cold temperatures (environmental) can all affect nerves and soft tissues. These factors increase the severity of any other factors. An understanding of these factors and their effects is necessary to properly analyze and improve a job or task. For instance, each factor by itself can cause a WMSD. However, their combined effects are often much worse than their singular components (Elements of Ergonomics Programs, 1997). Consider lifting a 20-pound wheel onto an assembly line. The task is not incredibly difficult and could be done by an average person. The task becomes much more difficult when performed 10 times per minute for an 8-hour shift. As the task is repeated, muscle tissues fatigue and become more susceptible to injury. It is the combination of the task and the repetition that generates the problem.

Ergonomic Job Analysis

Ergonomic job analysis involves the identification and ranking of risk factors to determine the expected risk. Many formal analysis tools have been created, such as the Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), NIOSH Lifting Equation, and others. All these tools determine a uniform characteristic for assessing body hazards, place a ranking on the severity of the hazard, and apply a score to the overall task. This score can then be used to evaluate differing tasks on a consistent basis. The scores can then be used to do a post-improvement evaluation of a task and objectively determine whether improvements bettered the task. The process of analysis, improvement, and post-improvement evaluation is demonstrated in the next section on the NIOSH Lifting Equation.

NIOSH LIFTING EQUATION

NIOSH has done extensive research to classify the hazards associated with manual lifting. The result is the Revised NIOSH Lifting Equation, a tool used to assign recommended weight limits (RWLs) to a lifting task based on risk multipliers. A lift is characterized by the following parameters:

- Load weight
- Horizontal location of the hands holding the load
- Vertical location of the hands holding the load
- Actual distance of the lift
- Angular measure (amount of twisting required)
- Frequency of lift over a 15-minute period
- Control needed for the lift (Applications Manual for the Revised NIOSH Lifting Equation, 1994)

For obvious reasons, the load weight is the primary component in the lifting equation. The horizontal location of the load with respect to the lifter and the vertical location of the hands relative to the floor are the next parameters. The lifter is dissected by a vertical axis passing through the midsection (Figure 8.3). The further an object is from the axis, the greater the moment arm or torque applied to the lifter as shown in Figure 8.4. In Load A, the torque is double that of Load B, which has the object being lifted at half the distance from the body. Since torque is calculated as the force times the distance from the axis, the same load weight twice as far from the axis applies twice as much torque on the axis. The further a load is from either axis, the further the body must also go out of the neutral position to perform the lift. OSHA defines the neutral body position as one which "requires the least amount of muscle activity to maintain. For example, the wrist is neutral in a handshake position, the shoulder is neutral when the elbow is near the waist, [and] the back is neutral when standing up straight." (Elements of Ergonomics Programs, 1997). OSHA also notes that the further a posture goes from the neutral position, the harder the associated muscles have to work.

The actual distance of the lift characterizes the work involved. A short lift is much easier than a long lift, all other things considered, as work is a function of weight and distance elevated. It should be recognized that it requires approximately the same amount of energy to lower a load in a controlled way as is required to elevate it. Therefore, vertical distance of the lift is measured up or down—in absolute distance.

The angular measure of the lift describes how much the person must twist to perform a lift as is illustrated in Figure 8.5. For instance, in many pick and place operations, the operator lifts the load off a pallet, turns, and places it on a cart. If the cart is close to the pallet, the operator must only twist to place the load. The twisting of the person pulls the back out of its normal alignment and increases disc compression. Therefore, contrary to what one might expect, in this instance it is better to place the cart farther away to prevent the operator from twisting.

Frequency represents the impact of repetition. Repetitive motion is an important issue in the field of ergonomics and will be considered again later in this chapter. Control needed for the lift is also a factor in the difficulty of the lift. Consider a waiter in a restaurant. The difficulty in lifting, balancing, and carrying a tray of full glasses out to a table is much greater than carrying the same weight of dirty dishes back into the kitchen.

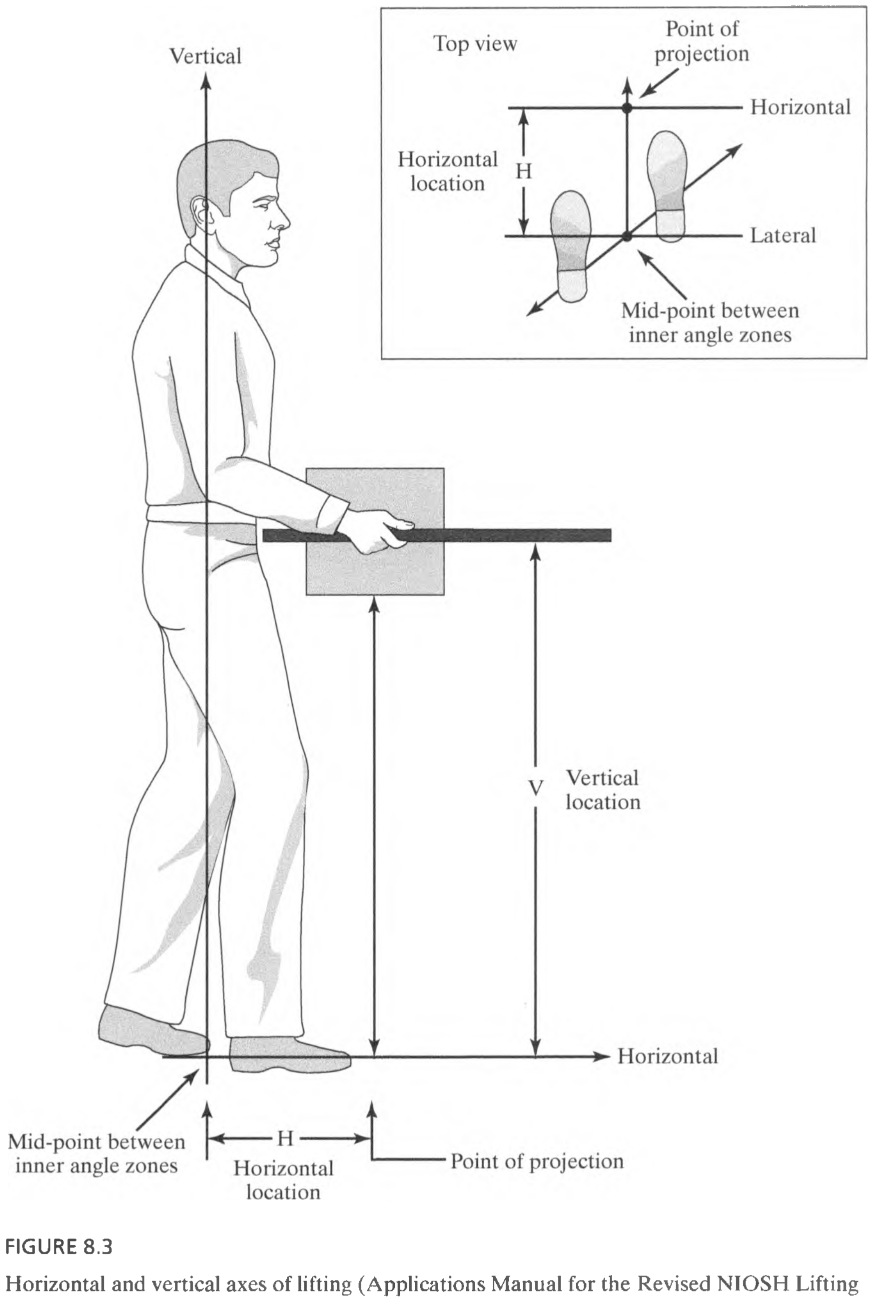


FIGURE 8.3

Horizontal and vertical axes of lifting (Applications Manual for the Revised NIOSH Lifting Equation, 1994).

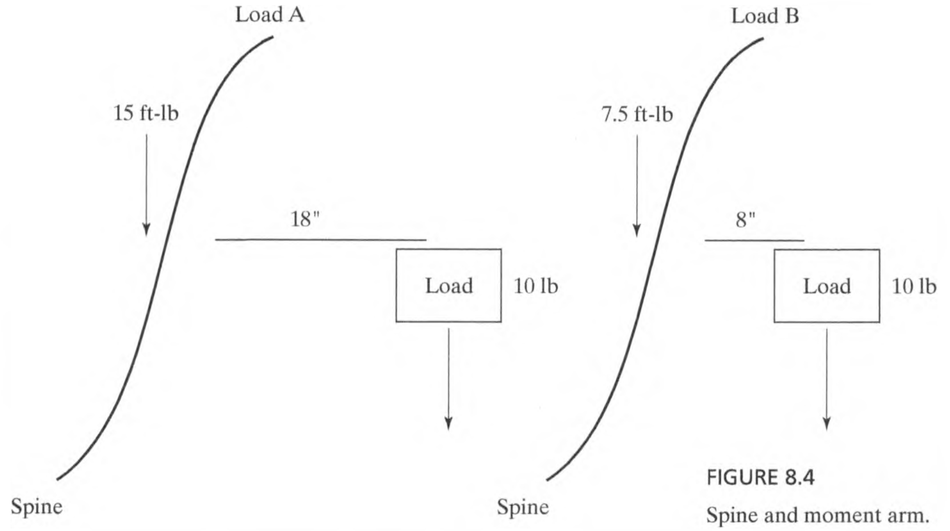


FIGURE 8.4
Spine and moment arm.

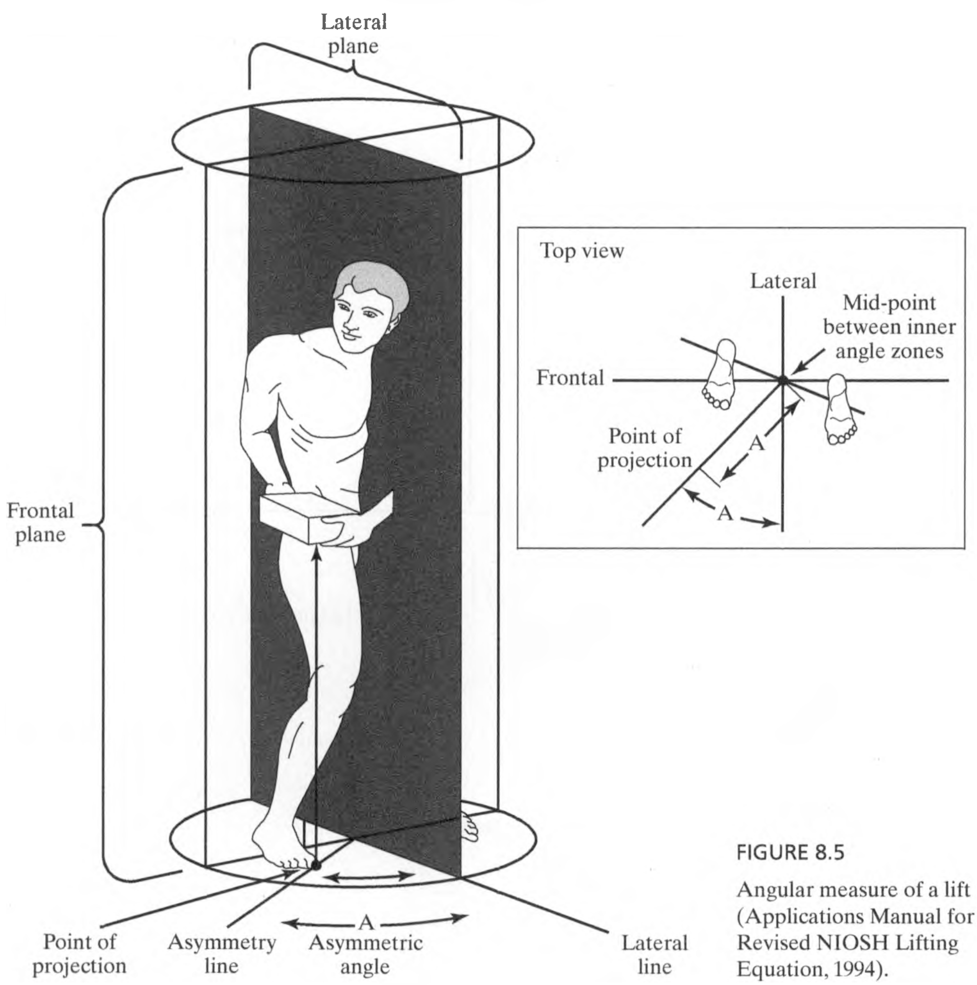


FIGURE 8.5
Angular measure of a lift (Applications Manual for the Revised NIOSH Lifting Equation, 1994).

TABLE 8.1 Multipliers for the NIOSH Lifting Equation

Horizontal multiplier		Vertical multiplier		Distance multiplier	
H (inches)	HM	V (inches)	VM	D (inches)	DM
≤ 10	1	0	0.78	≤ 10	1
11	0.91	5	0.81	15	0.94
12	0.83	10	0.85	20	0.91
13	0.77	15	0.89	25	0.89
14	0.71	20	0.93	30	0.88
15	0.67	25	0.96	35	0.87
16	0.63	30	1	40	0.87
17	0.59	35	0.96	45	0.86
18	0.56	40	0.93	50	0.86
19	0.53	45	0.89	55	0.85
20	0.5	50	0.85	60	0.85
21	0.48	55	0.81	70	0.85
22	0.46	60	0.78	> 70	0
23	0.44	65	0.74		
24	0.42	70	0.7		
25	0.4	> 70	0		
> 25	0				

Asymmetry multiplier	
A (deg)	AM
0	1
15	0.95
30	0.9
45	0.86
60	0.81
75	0.76
90	0.71
105	0.66
120	0.62
135	0.57
> 135	0

Coupling multiplier		
Coupling Type	CM	
	V < 30 in	V ≥ 30 in
Good	1	1
Fair	0.95	1
Poor	0.9	0.9

Frequency modifier						
F (lifts per minute)	≤ 1 hour		1 hour but ≤ 2 hours		2 hours but ≤ 8 hours	
	V < 30	V ≥ 30	V < 30	V ≥ 30	V < 30	V ≥ 30
≤ .2	1	1	0.95	0.95	0.85	0.85
0.5	0.97	0.97	0.92	0.92	0.81	0.81
1	0.94	0.94	0.88	0.88	0.75	0.75
2	0.91	0.91	0.84	0.84	0.65	0.65
3	0.88	0.88	0.79	0.79	0.55	0.55
4	0.84	0.84	0.72	0.72	0.45	0.45
5	0.8	0.8	0.6	0.6	0.35	0.35
6	0.75	0.75	0.5	0.5	0.27	0.27
7	0.7	0.7	0.42	0.42	0.22	0.22
8	0.6	0.6	0.35	0.35	0.18	0.18
9	0.52	0.52	0.3	0.3	0	0.15
10	0.45	0.45	0.26	0.26	0	0.13
11	0.41	0.41	0	0.23	0	0
12	0.37	0.37	0	0.21	0	0
13	0	0.34	0	0	0	0
14	0	0.31	0	0	0	0
15	0	0.28	0	0	0	0
>15	0	0	0	0	0	0

Source: Applications Manual for the Revised NIOSH Lifting Equation, 1994.

In addition to a practical review of the components of the NIOSH Lifting Equation, a more technical understanding is also needed. The NIOSH Lifting Equation is the product of a load constant and a rating for each of the multipliers. This product is the recommended weight limit (RWL) for a given set of factors (multipliers). Since the multipliers for a lift can be different at the origin of the lift and the destination of the lift, an RWL is calculated for origin and the destination separately. The load constant (LC) is 51 pounds. Each multiplier is assigned a value from zero to 1. Therefore, if a person could lift 51 pounds in a perfect situation, a multiplier of 0.8 would reduce the overall RWL by 20%. The values of these multipliers are given in Table 8.1, while Table 8.2 illustrates the determination of the actual value for each multiplier.

The NIOSH Lifting Equation then appears as:

$$LC * HM * VM * DM * AM * FM * CM = RWL$$

Once the RWL has been calculated, a lifting index (LI) is determined. The LI is the actual load weight divided by the RWL. The resulting value is a measure of physical difficulty associated with the lifting task. An LI of 1 or less indicates a task that a majority of people could accomplish relatively safely. This does not mean that everyone can perform the task safely, or that an average person will not be injured while performing the task. It also means that a task with an LI of greater than 1 does not necessarily indicate someone will be injured while performing that task. It should be noted that, however, precise the individual coefficients may appear, the equation has an element of subjectivity, especially in the coupling multiplier. A Case Study 8.2 illustrate the calculations used to implement the NIOSH Lifting Equation.

TABLE 8.2 Multiplier Values and Definitions

Determining the multiplier values

Multiplier	Variable	Use
Horizontal multiplier	HM	The horizontal distance of hands from the midpoint of the body
Vertical multiplier	VM	The vertical distance of the hands from the floor
Distance multiplier	DM	The absolute distance traveled during the lift, either up or down
Asymmetry multiplier	AM	The angular measure in degrees that the operator must rotate from the forward facing position
Frequency multiplier	FM	How often a lift is performed in lifts per minute. The multiplier is determined based on the duration of the task, the vertical location of the hands, and the lifts per minute
Coupling multiplier	CM	The quality of the hand contact during the lift. This is determined by quality and by the location of the hands during the lift

Source: Summarized from the Revised NIOSH Lifting Equation (Applications Manual for the Revised NIOSH Lifting Equation, 1994).

CASE STUDY 8.2

GROCERY RETAIL RESTOCKING

An essential task in grocery retail is the restocking of gallon milk in the dairy section. Milk arrives in four 1-gallon containers per tote. Each pallet has 27 totes per pallet, stacked three wide by three deep by three high. The person restocking must remove totes from the pallet and place them on a cart to take to the floor. When the restocker is unloading the pallet, he or she places the cart next to the pallet. For this assessment, make the following assumptions:

- The weight of the tote is 8.5 pounds/gallon or 42 pounds plus 1 pound for the tote.
- The pallet height is 8 inches.
- Each tote has the following dimensions: 12.75 in L * 12.75 in D * 10.5 in H.
- The cart base sits at 12 inches.
- In this case, the two most extreme lifts can be assessed: the bottom totes on the pallet and the top totes on the pallet. It is assumed that totes on the cart will only be stacked one tote deep.
- The horizontal distance of the hands from the midsection is 12.75/2 or 6.375 inches.
- The vertical distance at the lowest tote is 8 in. + 10.5 in. or 18.5 in. and 8 in. + 3*10.5 in. or 39.5 in. for the highest. At the end of the lift, it is at 12 in. + 10.5 in. or 22.5 in. on the cart.
- The restocker currently lifts and twists 90 degrees to place the tote on the cart. Therefore the angle is 0 at the origin and 90 degrees at the destination.
- The lifts occur at a rate of 3 per minute and last less than 1 hour.
- Since the totes have solid handles that are easily accessible, the coupling is good.

The following is the computation for the lowermost totes at the origin of the lift:

$$LC * HM * VM * DM * AM * FM * CM = RWL$$
$$51 * 1.0 * 0.89 * 1.0 * 1.0 * 0.88 * 1.0 = 39.94$$

With the appropriate multipliers from Table 8.1:

LC = 51
HM = 1.00 (distance of 6 inches)
VM = 0.89 (vertical distance of 19 inches)
DM = 1.00 (distance traveled of 4 inches)
AM = 1.00 (straight forward)
FM = 0.88 (3 lifts per minute at a vertical distance of <30 inches
CM = 1.00 (good coupling)

The resulting lifting index at the origin is LI = 43/39.94 = 1.08.
For the lift at the destination:

$$LC * HM * VM * DM * AM * FM * CM = RWL$$
$$51 * 1.0 * 0.93 * 1.0 * .71 * 0.88 * 1.0 = 29.63$$

With the appropriate multipliers from Table 8.1:

LC = 51
HM = 1.00 (distance of 6 inches)
VM = 0.93 (vertical distance of 23 inches)
DM = 1.00 (distance traveled of 4 inches)
AM = 0.71 (angle of 90 degrees from straight forward)
FM = 0.88 (3 lifts per minute at a vertical distance of <30 inches)
CM = 1.00 (good coupling)

The resulting lifting index at the destination of the lift is LI = 43/29.63 = 1.45.
The following is the computation for the uppermost totes at the origin of the lift:

$$LC * HM * VM * DM * AM * FM * CM = RWL$$
$$51 * 1.0 * 0.93 * 0.94 * 1.0 * 0.88 * 1.0 = 39.23$$

With the appropriate multipliers from Table 8.1:

LC = 51
HM = 1.00 (distance of 6 inches)
VM = 0.93 (vertical distance of 40 inches)
DM = 0.94 (distance traveled of 17 inches)
AM = 1.00 (straight forward)
FM = 0.88 (3 lifts per minute at a vertical distance of <30 inches)
CM = 1.00 (good coupling)

The resulting lifting index at the origin is LI = 43/39.94 = 1.10.
For the destination:

$$LC * HM * VM * DM * AM * FM * CM = RWL$$
$$51 * 1.0 * 0.93 * 0.94 * 0.71 * 0.88 * 1.0 = 27.86$$

With the appropriate multipliers from Table 8.1:

LC = 51
HM = 1.00 (distance of 6 inches)
VM = 0.93 (vertical distance of 23 inches)
DM = 0.94 (distance traveled of 4 inches)
AM = 0.71 (angle of 90 degrees from straight forward)
FM = 0.88 (3 lifts per minute at a vertical distance of <30 inches)
CM = 1.00 (good coupling)

The resulting lifting index for the destination is LI = 43/27.86 = 1.54.
The NIOSH Lifting Equation shows that these tasks are above the LI. The main danger associated with the lift is the twisting performed in placing the tote on the cart. This can be improved by moving the cart back to force the restocker to completely turn and place the tote on the cart. This would reduce the LI to close to 1.

The knowledgeable safety and health manager will recognize that manual lifting is a complex task that is affected by all of the multipliers in the NIOSH Lifting Equation.

SOURCES OF ERGONOMIC HAZARDS

There are four sources of ergonomic hazards: the work itself, the workstation, the characteristics of the work piece or tools, and the environment in which the work is done (Elements of Ergonomics Program, 1997). Each can be the subject of numerous discussions.

The Work Itself

The manner in which work is performed is the first major source of ergonomic hazards. Several examples are using hands as a hammer to mate two separate parts (excessive force), repetitive tasks such as assembly line work or palletizing (repetition), excessive manual material handling force/awkward postures), tasks which require the body to assume awkward positions such as overhead work or confined space work (awkward postures). Some simple solutions to these issues are given in the same order: ensuring that the right tools accompany each task such as a padded or rubber mallet for assembly work, job rotation or enlargement for excessively repetitive tasks, material handling assists such as overhead hoists or powered palletizers, and increased rest cycles for extra-difficult work. In an aviation assembly task, a tool balancer was used to support a heavy hydraulic tool, changing the way the task was done. This allowed the operator to comfortably manipulate a tool weighing over 30 pounds; see Figure 8.6.

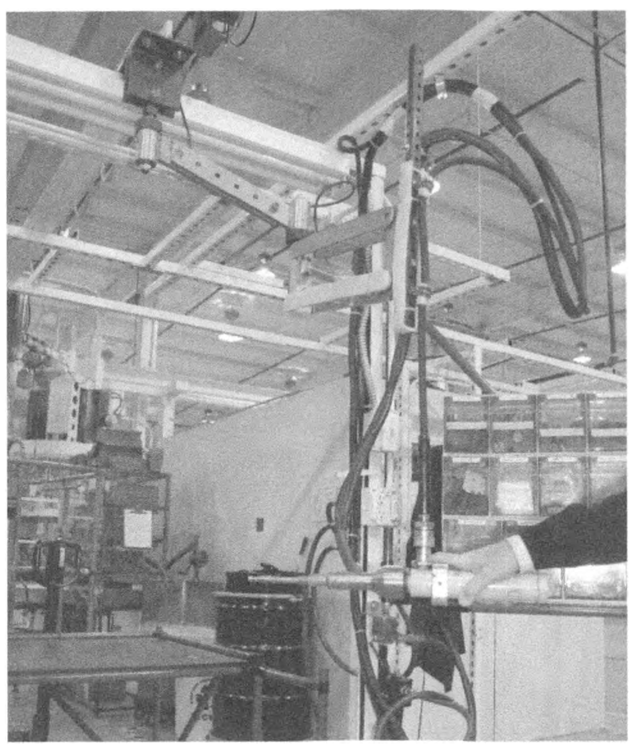


FIGURE 8.6

Use of tool balancer to manipulate heavy tool (*courtesy*: Pratt & Whitney).

A discussion of how the work is performed of necessity must include a discussion of manual lifting.

Manual Lifting

The Bureau of Labor Statistics found that back injuries were 18.6% of all injuries resulting in lost time in 2013 (Injury Facts, 2016). In 1995, there were approximately 900,000 disabling back injuries, with half being caused by lifting (How to Lift and Carry Safely, 2005). Ironically, one cannot find a general OSHA standard for lifting, so most of Chapter 14 deals with safety standards for various types of material handling equipment, such as lift trucks, cranes, and slings. However, ergonomics is more focused upon lifting, because it depends upon the human operator and applies stresses upon the human body. Manual lifting is one of the most studied subjects in ergonomics, but to date the studies are still inconclusive. It is not clear what weight limits a person can lift safely, and, despite all of the training "to lift with the legs, not with the back," back injuries continue to be prevalent, even in the industries that emphasize "proper" lifting techniques. Even NIOSH, the federal agency charged with the mission of studying hazards and recommending standards, has little respect for the benefits of training in proper lifting. This is evident in the following quote from the NIOSH "Work Practices Guide for Manual Lifting":

> Yet, so long as it is a legal duty for employers to provide such training or for as long as the employer is liable to a claim of negligence for failing to train workers in safe methods of MMH (Manual Material Handling), the practice is likely to continue despite the lack of evidence to support it.

It is no wonder that OSHA has not seen fit to promulgate a general standard on lifting or on training for lifting! The success of training in controlling manual lifting hazards is unclear. A recent study in 2008 in the British Medical Journal found that there was no difference in lower back pain in subjects who received training in correct lifting and those who did not. The study suggests that either training is not effective in changing worker habits, or that the current training modes do not properly address the factors contributing to lower back pain (Martimo et al., 2008).

Another method of controlling the hazard is preemployment physical testing or screening to select personnel for lifting tasks. However, there are problems with this strategy also. In any preemployment test, the employer must use care not to discriminate against classes of employees. There is also the difficulty of devising a test that is really representative of the lifting operations of the actual job. If the test does not determine whether a person can do the actual job, it is ineffective and may be unfairly discriminatory. And since the passage of ADA (Chapters 2 and 4 of this book), employers may be required to make reasonable accommodations for applicants who are unable to meet the lifting requirements of the job.

Back Belts

Many times the improvement of a task is not a significant improvement at all. Such is the case in the use of back belts. Supporting belts worn around the waist are often worn by persons who do heavy lifting as a part of their job. The implication is that such belts prevent injury to the lower back. NIOSH decided to test this assumption in a preliminary study reported in 1994 and again in the late 1990s in what has been described as "the largest study of its kind ever conducted." The study examined incidence rates for workers' compensation claims for back injuries. The following comparisons were made:

(a) Workers who wear back belts every day versus those who never wear them or, if they do wear them, do so only occasionally (once or twice per month)

(b) Employers who require back belts versus employers for whom back belt use is voluntary

Both hypotheses showed no statistical significance in the difference between the groups in the incidence rates for workers' compensation claims. Besides the workers' compensation claims, the study also examined "self-reported back pain" and again the results showed no statistical significance in the difference between the groups. The study lasted 2 years and involved interviewing 9377 employees at 160 stores nationwide (Back Belts, 2002).

In light of the NIOSH findings, why do workers still wear back belts? One reason may be that the worker or employer is uninformed or unconvinced by the NIOSH study. Another explanation is that workers derive some other benefit from wearing the back belts. Workers may gain comfort in the back belts, or perhaps they like to project the image that they have a strenuous job. Remember that, although the NIOSH study found that the back belts could not be shown to be of any benefit in preventing back injuries, it did not find that the back belts did any harm either. People just may like to wear them, even if they aren't the answer to preventing back injuries.

Workstation

The workstation, or in absence of a dedicated workstation the location in which the work is performed, is the second major source of ergonomic hazards. The workstation must be made to accommodate the individual, not the other way around. Since human dimensions vary greatly, what is comfortable for one individual is not necessarily comfortable for another. Workstation design allows the workstation to accommodate different individual characteristics such as height, reach, and work tasks. Individuals should be able to adjust the work surface or their position relative to it so that they can maintain good neutral positions. This can be done through adjustable height workstations or simple step stools. When elevating the operator, care should be taken to ensure that one hazard does not cause another (fall hazards). Reach is also important. The primary tools and or work to be done should be within the operator's reach. The workstation should be designed for the task to be done the right way as well. If a part must be spun or turned around, such as inspection work or assembly work, a turntable should be used to allow the operator to turn the part with ease. Rotation or manipulation should be considered for necessary movement in all three axes of movement. Consider a spray paint application process. If the part is left stationary, the operator must either move around the part or lift it in order to completely apply paint. However, if the part is suspended and allowed to rotate along the axis of suspension, the operator can paint it and turn it as needed to reach all parts as in Figure 8.7. In another instance, consider a recently machined, hub-shaped component. After machining, the surfaces

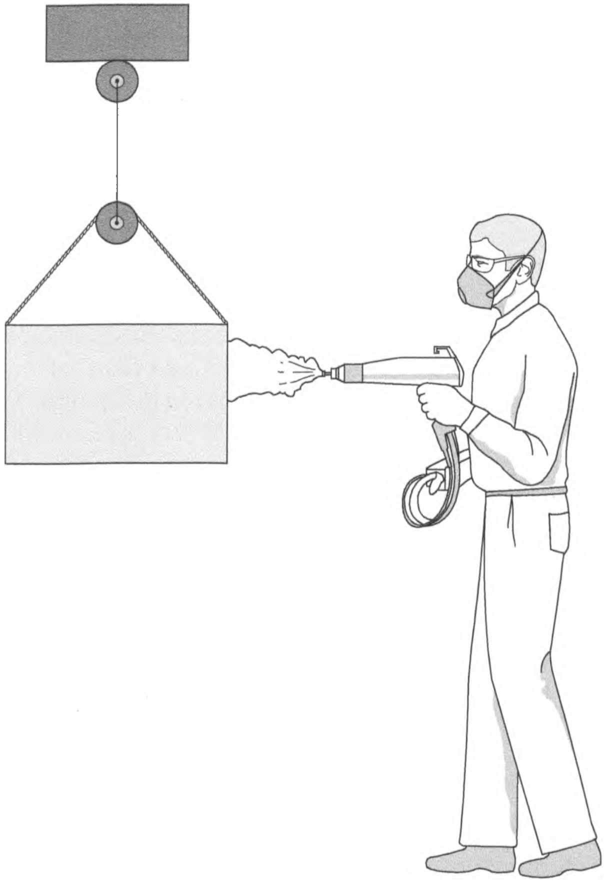


FIGURE 8.7

Suspension of workpiece to aid in painting.

must be touched up with an abrasive wheel or other media. If the workpiece can be placed on two sets of wheels which allow free rotation, the operator can more easily touch up and inspect the hub as in Figure 8.8. One other common workstation design is a roller conveyor on which a workpiece can be pushed along rather than lifted, as depicted in Figure 8.9.

In addition to considerations at the workstation, ergonomics should be addressed during the transportation and handling of the workpiece from operation or machine to machine. The tools used can range from simple carts and dollies (Figure 8.10) to lift tables and other devices (Figure 8.11), to remove the risk associated with the material handling. Sometimes the solution can be as simple as delivering material to be processed onto a platform raised to the proper height without the necessity of employing a lift table. The benefits for large, awkward workpieces are evident in Figure 8.12.

Besides the objective of changing the workplace so that workers in general can handle lifting tasks, there are many special requirements for accommodating special groups of people. The age of ADA has brought about a heightened sensitivity to the

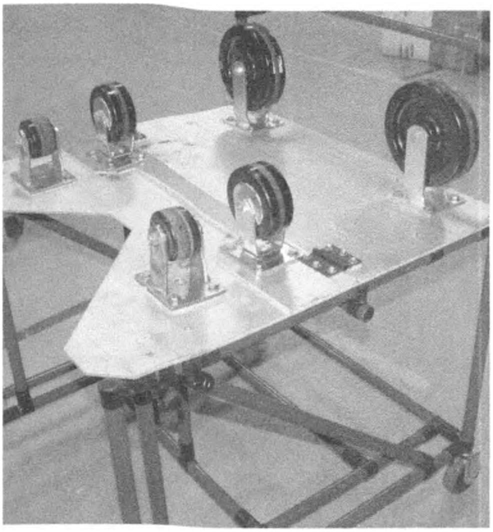


FIGURE 8.8

Depiction of wheels used to rotate cylindrical work-piece (*courtesy*: Pratt & Whitney).

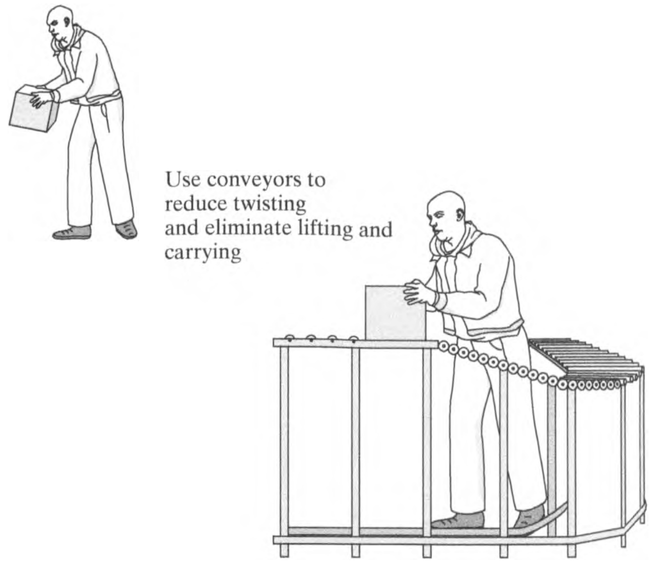


FIGURE 8.9

Conveyor workstation (Elements of Ergonomics Programs, 1997).

limitations and variations among the population of human workers. One very visible variation *not* to consider is gender. Granted, it is undeniably true that there are *general* (average) physical differences between males and females, but beware of generalizing upon these physical differences and excluding a worker because of gender alone. For instance, the average man can lift a heavier load than the average woman, but there are exceptions. Some men are weaker than the average woman and cannot lift as heavy a load, and some women can lift more than the average man. Qualification for a job

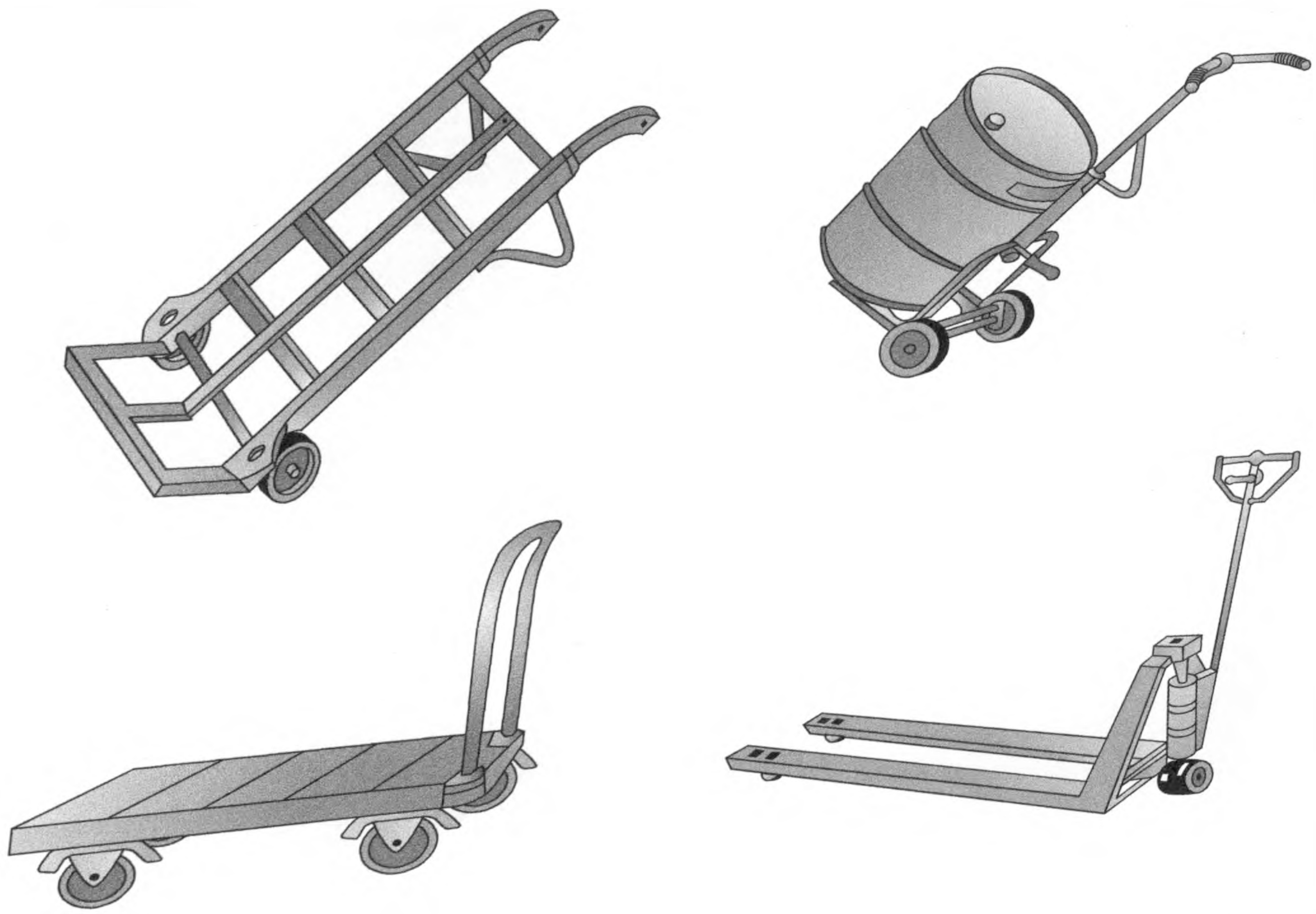
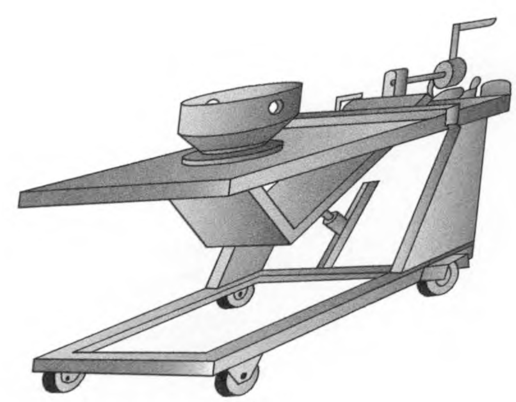


FIGURE 8.10
Simple carts and dollies.



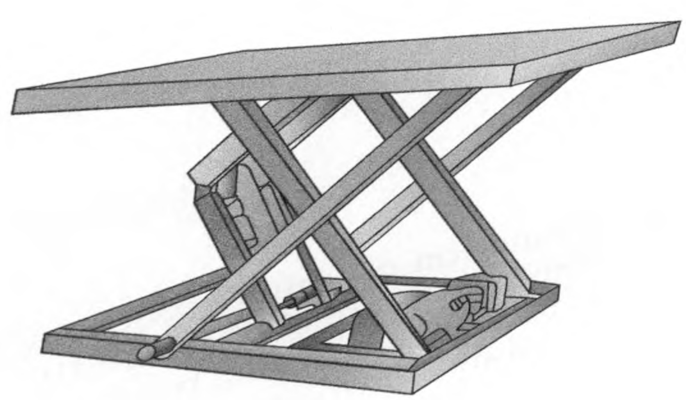


FIGURE 8.11
Lift tables.

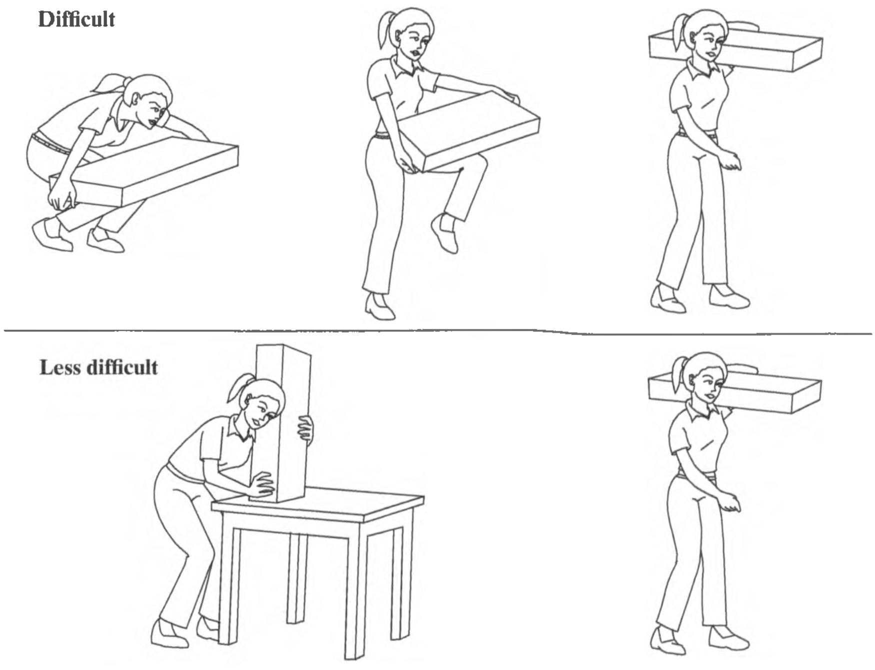


FIGURE 8.12

Store materials at the proper height.

should be based upon measurable physical characteristics, not upon gender. The Civil Rights Act of 1964, the Americans With Disabilities Act, and other societal movements that began in the latter part of the twentieth century have made the once-common practice of gender stereotyping appear ludicrous. Witness the following classic excerpt from a serious book on safety written in 1943:

> Mechanical aptitude makes boys play with trains, and lack of it makes girls play with dolls. To women, machinery is foreign to everything they have ever known or experienced, and quite bewildering ... A woman should not be expected to acquire more than a few simple mechanical skills, but the task given her may be designed to require high performance standards because of her finger dexterity ... This does not mean that in the training of women they will intuitively find the safe way to do their work. On the contrary, they seem always to fall naturally into unsafe and awkward habits. However, when the plant designs the safe manner of operation and so instructs them, they will respond favorably to it, but they require more constant supervision (Foremanship and Accident Prevention in Industry, 1943).

My, how the world has changed since these words were written only a few decades ago! The foregoing quotation is not intended to ridicule the author, but rather to illustrate the dramatic changes in attitudes that have occurred in scarcely half a century. Authors, including the authors of this book, run the risk of becoming dated, as society and future discovery make their writings obsolete.

Other human characteristics might need accommodation in the workplace. Examples are height—either short or tall—vision problems, and hearing problems. Age, like gender, is another sensitive characteristic to avoid in making generalizations about worker capability. Although many research studies have shown general differences among age groups, there are always exceptions, and specific physical capabilities of individual applicants should be measured and fit to the job, avoiding general, discriminating judgments about persons because of their age.

Creativity and ingenuity during the design or redesign of workstations can lead to great results for the worker, and are often relatively inexpensive. Two creative designs will be shown that eliminated multiple hazards. In the first instance, workers were required to inspect a large, metallic, jet-engine case. The case was cone-shaped and hollow on the inside. Owing to inspection criteria, very-high-tolerance, flat tables were required. The worker had to climb into the part to perform the inspection. There was barely room for the worker, much less than the equipment. In addition, the worker had to hunch over in order to fit, often for long periods of time. The solution was elegant. A team took a relatively inexpensive auto lift and fitted it with a very precise and level table with a hole in the middle. The operator could raise the lift, enter, and lower it over themselves. In addition, the process was much faster. In Figure 8.13, the workstation can be seen.

Another creative solution was the improvement of an automated welding process. The process had an extremely heavy table that was pulled out to load parts and then pushed back in. The area inside the booth was then sealed and air evacuated in order to weld in a vacuum. Even though it was on rollers, the table was extremely heavy and required two people to move it. An engineer in the plant had seen a spare hydraulic pump in storage and purchased a relatively inexpensive cylinder. This cylinder was placed in line to push the table in and pull it out. The engineer designed the cylinder with a couple so that it could remain outside the vacuum chamber. The cylinder can be seen in Figure 8.14.

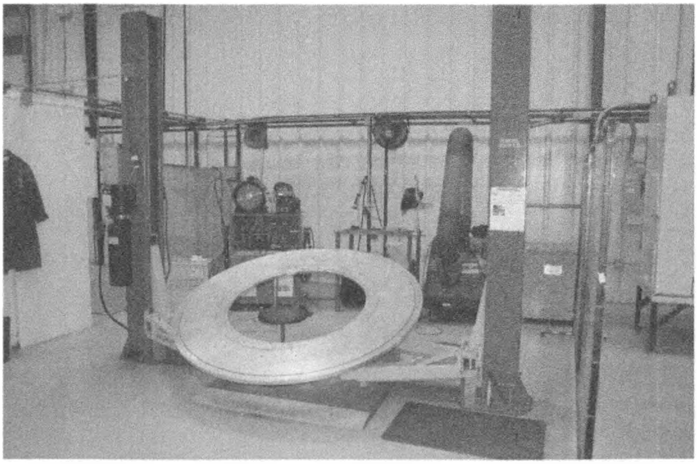


FIGURE 8.13

Car lift inspection table (*courtesy*: Pratt & Whitney).

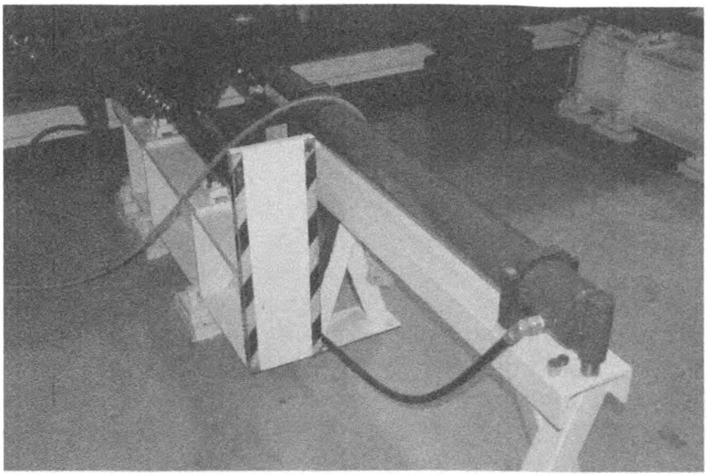


FIGURE 8.14

Hydraulic cylinder to push weld table. Note the table to the upper left (*courtesy*: Pratt & Whitney).

Office workers are not immune to the effects of poor ergonomics. Over the last decade, many advances have been made in adapting the workstation to the worker. These include improvements in seating and desks. A trend is emerging for desks that provide the opportunity to sit or stand. This allows the worker to change positions on a regular basis while still working at a computer. Not only do these changes improve worker ergonomics but also improve employee morale.

Workpiece

A third major source of ergonomic hazards is from characteristics of the workpiece or tools. Sometimes there are inherent dangers in the workpiece. For instance, in live hanging, poultry workers must grasp live chickens or turkeys and hang them by their feet (Poultry Processing Industry E-tool, available by searching the OSHA website). The workpiece itself is heavy and moving. The processing rate of the operation is usually very high. To minimize risk, workers in these lines rotate often to different tasks. In some instances, the tool causes vibration stress. In such instances, the tool handle can be fitted with antivibration wrap. Tool calibration and maintenance can possibly reduce unwanted vibration.

Work Environment

A fourth source of ergonomic hazard comes from hazards encountered in the work environment. It is the facet of ergonomics that relates to the safety and health of workers' focuses on the physical environment that surrounds the worker in the workplace. For most workplaces, the most important consideration in this regard is temperature. What limits of hot and cold temperatures are reasonable for the work environment, and what temperatures are optimal for various tasks? Ergonomics attempts to scientifically determine these temperature parameters and apply them to the workplace. Humidity is also a factor. Sometimes, the demands of the job require a worker to work in a hot or a cold environment, and the consideration then becomes a matter of appropriate duration. How long a worker should be exposed to a work environment of a given temperature? If the temperature extremes are severe, a last resort is clothing to protect the worker and produce a microenvironment inside the clothing that is within acceptable limits. A principle studied in Chapter 3, the "three lines of defense," can be applied to this aspect of ergonomics. The control of the work environment through air conditioning or other means to control temperature and humidity to acceptable levels can be seen as the engineering approach, the strategy of first choice in dealing with the environment. If the engineering approach does not work, the strategy of administrative or work practice controls can be applied by rotating workers into and out of hot or cold environments so that the duration of their exposures is reasonable and within limits. The last line of defense is protective clothing, which is usually advisable in conjunction with the second line of defense, the rotation of workers to limit exposure.

For all of the attention that has been given to hot and cold work environments, OSHA has not been successful in promulgating a standard to address this hazard. As with many other facets of ergonomics, the hazards do not present a clear profile for absolute control by mandatory standards. Workplaces vary a great deal, and a universal standard for rigid limits of hot and cold have not received acceptance by the public. Hot or cold environments may violate the comfort level of some workers, but they do not violate legal limits. On a voluntary basis, employers usually control work environments in the interest of employee well-being and productivity, refuting the notion that employers will do nothing for employees' well-being unless required by legal standards.

Another aspect of the air, besides its temperature or humidity, is pollution. In this regard, OSHA and other regulatory agencies pay close attention to acceptable levels of pollution by various toxic air contaminants. This subject is so important that it is reserved for special treatment in Chapters 9 and 10.

Some miscellaneous considerations for special work environments should be mentioned at this point. Some workers must work under water, an environment that obviously requires special consideration and personal protective equipment. This work environment was at first overlooked by OSHA, but later a Diving standard was promulgated to protect these special workers. Even more exotic an environment is that of astronauts in outer space. Weightlessness, radiation, and the vacuum of outer space are all elements to be dealt with in the astronauts' environment. These unusual work environments may not be relevant to the mission of most safety and health managers, but they are mentioned here because the field of ergonomics does not overlook these unusual environments as scientists study the strange effects they may have upon the human body.

SUMMARY

The field of ergonomics is an opportunity and also a problem for the safety and health manager. The field has much to offer in relieving the discomfort of workers doing repetitive, sometimes disabling, tasks. It also has the potential of raising productivity to new levels. However, there are problems. The causes of individual cases of musculoskeletal disorders are not always clear. Often, activities that are not work related either cause or contribute to the problem. Treatment of individual cases can be difficult and outright cures illusory. Engineering and administrative controls also may be only partially effective in eliminating the problem. Personal protective equipment may have no value at all in reducing lifting injuries or other WMSDs. Problems such as these raise questions and employer doubts about whether ergonomics programs can be cost effective in reducing hazards and raising productivity. Employer uproar over a mandatory OSHA ergonomics standard resulted in a congressional override of the standard before it could ever take effect. In place of a rigid standard, guidelines have been suggested that give industries a great deal of latitude in devising programs that fit their own operations. The challenge to the safety and health manager will be to retain the good features and potential of ergonomics in an environment of voluntary compliance, not rigid enforcement.

EXERCISES AND STUDY QUESTIONS

8.1 Describe the general categories of the field of ergonomics.

8.2 What is the primary ergonomics hazard addressed by occupational safety and health regulatory authorities?

8.3 Regulatory authorities have focused on workplace musculoskeletal disorders for approximately two decades; however, the terminology has changed over this period. What term was first used to refer to these disorders, and what other terms have been used as the focus has evolved up to the present?

8.4 In the absence of a specific standard for enforcement, what authority has OSHA used to cite ergonomics hazards?

8.5 What is the relationship between the ANSI standard and the OSHA standard for ergonomics?

8.6 What are the primary objections to an OSHA standard for ergonomics?

8.7 Are there gender differences in the physical qualification to do manual labor? If so, how should these differences be handled by employers qualifying workers for jobs?

8.8 What has research shown about the utility of back belts worn by workers for protection against back injury?

8.9 Describe the role ergonomics plays in the design of vehicle cockpits.

8.10 Describe some examples of the application of ergonomics as found in the OSHA standards.

8.11 Explain some problems with the rule "Lift with your legs, not with your back."

8.12 Is the incidence of workplace musculoskeletal disorders increasing or decreasing? Justify your answer and explain possible causes.

8.13 Work environments can have an impact on employees. How could the three lines of defense be applied to addressing work environment concerns?

8.14 What role did the U.S. Congress play in the enforcement powers of the government with respect to ergonomics hazards?

8.15 What is a possible solution for ergonomic hazards associated with excessively repetitive tasks?

8.16 What is a good policy for employers with respect to employee decisions to buy back belts and wear them to work?

8.17 Describe some design features for punch presses that incorporate the principles of ergonomics.

8.18 Discuss some problems associated with training employees in proper lifting techniques.

8.19 Outline some basic elements in a program for workplace musculoskeletal disorders.

8.20 Compare management responsibilities for firms that have employees who have reported musculoskeletal disorders compared to firms which do not have employees who have reported such disorders.

8.21 Name some industry classifications that have been reported to have employee exposure to workplace musculoskeletal disorders.

8.22 What landmark cases in federal enforcement of citations for workplace musculoskeletal disorders have been used as models for current enforcement activities?

8.23 Describe two advantages of the "ramp-in" procedure for jobs susceptible to WMSD hazards.

8.24 Would you consider "ramp-in" to be an engineering control or an administrative control. Explain your reasoning.

8.25 Describe the application of the classical "three lines of defense" to workplace musculoskeletal disorders.

8.26 What is meant by a multiplier value of zero for any of the Revised NIOSH Lifting Equation?

8.27 If a job has an LI greater than 1, can the task still be performed safely?

8.28 Given the following lifting task and RWL, what can be done to improve it?

$$51 * 0.91 * 0.96 * 0.88 * 0.66 * 0.72 * 0.90 = 16.77$$

8.29 Calculate the RWL and the LI for the following task. As forgings exit a cooling bath, they are loaded into various tumblers for finishing. Each forging weighs 15 pounds and is lifted from a conveyor that is 36 inches high to a tumbler that is 48 inches high. The forgings are relatively small, so the hands are only 5 inches from the waist. The process completes a forging every 10 seconds. The coupling is considered fair, and the operator works a full 8-hour shift.

8.30 Worker complaints of what type motivated the development of the ergonomics standard?

8.31 Identify the seven generally accepted risk factors that can contribute to workplace musculoskeletal disorders.

8.32 One strategy for controlling lifting hazards is to use preemployment physical testing to screen employees for the job. What problems are associated with this strategy?

8.33 What is the current meaning of the abbreviation MSD?

8.34 Explain the difference between job rotation and ramp-in period.

8.35 Why is twisting while lifting detrimental to worker safety?

8.36 Give an example of how the needed control of the lift can increase the difficulty of the lift.

8.37 What device might be provided to a worker required to manipulate a heavy tool?

8.38 How does workstation design impact ergonomic hazards?

8.39 What physical characteristics of the difference in individual abilities should not be used in workplace design?

RESEARCH EXERCISES

8.40 Search the Internet for the latest developments of the ANSI standard for ergonomics or workplace musculoskeletal disorders.

8.41 Find several distributors of back belts and list the benefits claimed for these products.

8.42 Examine literature promoting the sale of automobiles. Can you find any reference to ergonomics?

8.43 Research some of the ergonomic assessment tools available online. Which ones appear to be broad in scope and which ones appear to be more focused in scope? How would you use the different types of assessment tools in practice?

8.44 Review the OSHA E-tool on ergonomics. What does OSHA recommend as basic aspects of a process for protecting workers?

8.45 OSHA has several guidelines for specific industries to protect workers from ergonomic hazards. Review two of these and identify what is the ergonomic hazard and how does the guideline address it?

STANDARDS RESEARCH QUESTION

8.46 The OSHA standard for ergonomics was overturned by the U.S. Congress, so the OSHA General Industry standard contains no standard for ergonomics. Search the OSHA website for OSHA's current strategy or approach for dealing with ergonomics. In your own words, summarize this approach in a brief paragraph. In your summary, address whether OSHA intends to continue citing ergonomics hazards, and, if so, under what standard.