Chapter 15

ERGONOMICS

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INTRODUCTION

Ergonomics, the science that explores the working relationship between humans and their working environments, began to evolve in the United States in 1950 due to design problems encountered in military equipment such as airplanes, radar and sonar stations, and tanks.[1,2] Ergonomists study anatomical, physiological, and psychological aspects of workers in their working environments with the goal to optimize worker health, safety, comfort, and efficiency. Ergonomists apply knowledge about human capacities and limitations in worksite, job, task, tool, equipment, and environment design in order to fit the workstation to the worker's comfort and productivity. Ergonomic risk factors are common in today's industry and can lead to injury. Specifically, nonneutral postures and repetitive motions put individuals at risk for repetitive motion injuries.[3] Repetitive high force motions cause work-related musculoskeletal disorders (WMSDs) when individuals adopt nonneutral body postures for extended periods of time.

THE US ARMY ERGONOMICS PROGRAM

Program Regulations

The US Army Occupational Safety and Health Program consists of an occupational safety and an occupational health program at the Department of the Army level. Army Regulation AR 385-10, *The Army Safety Program*,[4] defines the role of the US Army Occupational Safety Program at the major Army command and installation levels. Army Regulation 40-5, Medical Services Preventive Medicine,[5] states that the occupational health program is a medical program that is executed along medical command lines at medical centers and Army community hospitals (US Army Medical Department Activity).[4-6] Table 15-1 lists Army regulations and pamphlets that apply to the ergonomics program.

In 1987 the Occupational Safety and Health Administration (OSHA) issued its first directive on the subject of ergonomics; in 1992, it began the rule-making process, and in 1995 started drafting the ergonomics standard. OSHA issued its Ergonomics Program Standard on November 14, 2000 (29 CFR Part 1910.9000), which became effective on January 16, 2001. The ergonomics standard was later repealed on March 20, 2001 via Senate Joint Resolution 6. Currently, OSHA cites employers under the Occupational Safety and Health Act of 1970, Section 5 of the General Duty Clause[7] when ergonomic issues put workers at risk for injury.

Program Organization

At the installation level, the commander is responsible for executing the ergonomics program. This is accomplished by establishing an ergonomics subcommittee, integrating ergonomics into day-to-day operations, approving an ergonomics policy, supporting an

TABLE 15-1

REGULATORY BASIS FOR AN ERGONOMICS PROGRAM

Regulation	Description
DoD Safety and Occupational Health (SOH) Program, DoD Instruction 6055, August 1, 1998.	DoD instruction that provides policy, procedures, and responsibilities for administration of a comprehensive DoD OSH Program.
Department of the Army Pamphlet 40-21 15 May 2000, August 15, 2003.	Pamphlet that provides guidance for establishing the ergonomics program as an integral part of the Army Occupational Safety and Health program at all Department of Army facilities.
Army Safety Program, AR 385-10, February 24, 2017.	Army regulation that implements safety requirements of federal and defense regulations.
Preventive Medicine, AR 40-5, May 25, 2007.	Army regulation that implements occupational health requirements of federal and defense regulations.

AR: Army Regulation
DoD: Department of Defense
OSH: Occupational safety and health

ergonomics program, and designating an installation ergonomics officer. Based on DA PAM 40-21,[8] the chief of preventive medicine should serve as the chair of the ergonomics subcommittee. Another member of the healthcare team, an industrial hygienist or safety officer, may serve as chair of the ergonomics subcommittee team if that person is more qualified or there is no assigned preventive medicine physician.

An ergonomist must have the requisite training and experience to quantitatively define the level of worksite risk (pounds lifted, repetition rates, push/pull force requirements, etc) and to recommend controls for existing hazards. Typically the installation ergonomics officer is also the occupational medicine physician; the daily ergonomics program support tasks fall to the industrial hygiene staff. The safety officer, installation compensation specialist, occupational therapist, physical therapist, union representative, civilian personnel office representative, and healthcare team are key players in ergonomics team meetings. Figure 15-1 lists ergonomics program components.

ERGONOMICS RISK FACTORS

Occupational Risk Factors

Repeated biomechanical stress and microtrauma can cause WMSD injuries that evolve over time into a painful, debilitating state involving muscles, tendons, and nerves. Back pain, tendonitis, tenosynovitis, bursitis, and nerve entrapment syndromes are all examples of work-related injuries that can be caused by ergonomic risk factors. Ergonomic risk factors such as poor posture, repetition, duration, forceful exertions, mechanical compression, vibration, and cold temperature can decrease blood flow to muscles, nerves, and joints and lead to nerve compression, tendon damage, muscle strain, and joint damage. Prolonged exposure to these risk factors can lead to permanent damage and debilitating medical conditions. There is often a multiplicative risk of developing WMSDs when individuals perform a single task with multiple ergonomic risk factors. Those tasks should be targeted for engineering redesign and administrative controls.

Position or Nonneutral Postures

The terms "position" and "nonneutral posture" are used interchangeably in ergonomics literature. Nonneutral postures are defined as extreme or excessive bending or twisting of the back and upper and lower extremities. Examples include prolonged elbow or shoulder elevation often seen in overhead work; low lifting, which bends the back forward; and typing on a standard keyboard. Some common causes of nonneutral postures are inadequate workspace design, poor hand tool design, and improper lifting.

Repetition

Repetition is the act of performing the same task over and over. Machine- and production-based operations in industrial settings require workers to complete

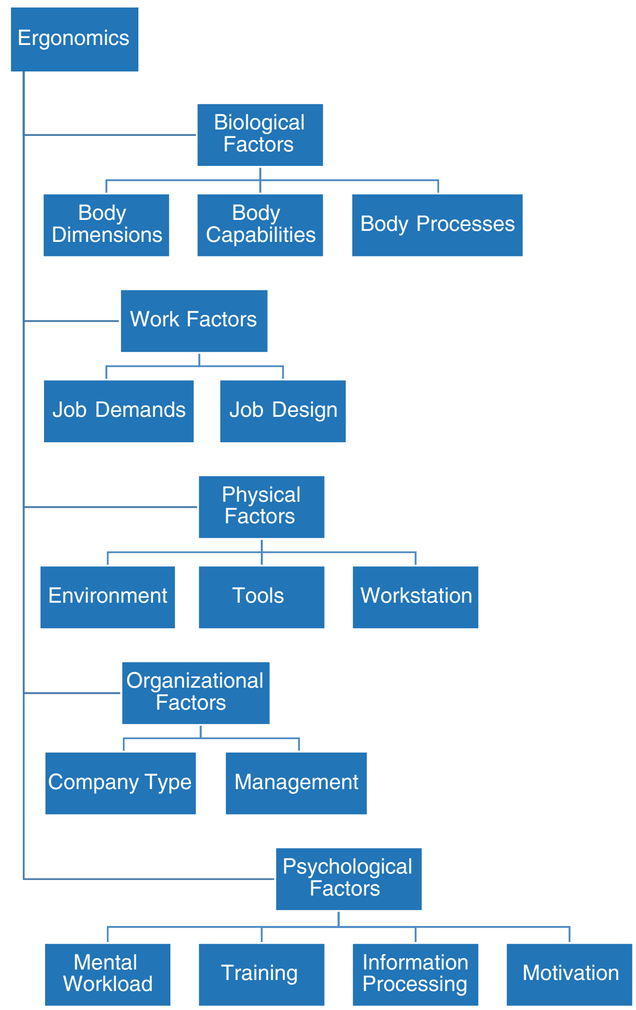

Figure 15-1. Multiple factors comprise ergonomics. Consideration of all factors ensures workers benefit from ergonomic interventions.
Data Source: California Department of Industrial Relations, Cal/OSHA Consultation Service. *Ergonomics in Action: A Guide to Best Practices for the Food-Processing Industry*. Oakland, CA: DIR; 2003.

tasks that last less than a few minutes. These tasks can put workers at risk when performed for 2 or more hours per day. Muscles, tendons, and nerves need sufficient time to properly recover; repetitious work may not allow sufficient recovery time and tissue injury may occur.[9] Also, there may be more than one type of ergonomic risk factor present, and repetitious work, when combined with the other risk factors such as forceful exertions, mechanical compression, poor posture, vibration, and cold temperature, may exacerbate the tissue injury.

Duration

Duration is the length of continuous effort required to perform a task. The longer the duration, the longer the recovery time needed to ensure the design of non-fatiguing jobs. The amount of necessary recovery time is dependent on the level of effort required to perform the task.[10] A general rule of thumb is that highly repetitive tasks, regardless of effort, should be designed for 50 minutes of work and 10 minutes of rest per hour. Overtime work should be avoided whenever possible because it lengthens the workday and decreases the body's recovery time the following day.

Forceful Exertions

Individuals must exert force to accomplish an occupational task. The force applied to lift weights, overcome friction, and correct for poor postural alignment while working can stress muscles and tendons beyond their capacity and lead to damage of muscles, tendons, ligaments, cartilage, bones, and nerves.

Mechanical Compression

Mechanical compression is contact between the body and any external object. Damage to soft tissues can occur when they are exposed to high force requirements (excessive force spread over a small surface area), which increase fatigue and risk for WMSDs. A common example of mechanical compression is using the base of the palm as a hammer. Due to the velocity and impact of the palm contacting an object, irritation and swelling to the underlying muscles, nerves, tendons, and blood vessels may occur. Medical compression worksite incidents commonly occur when workers use tools that have sharp or hard handles, carry objects on the shoulder, and type on a keyboard while resting the wrist on a hard-edged surface.

Vibration

Workers who come in contact with vibrating machines, vehicles, and equipment are exposed to occupational vibration. Vibration can either transmit energy to the whole body through a seat or platform, or to the hands or affected body part through direct contact (known as segmental vibration). Permanent tissue damage can occur during prolonged whole-body or segmental vibration exposure.

Cold Temperature

Cold temperatures lower the core body temperature and can reduce sensory and motor nerve conduction and impair circulation to peripheral tissues. Exposure to temperatures between 50°F (10°C) and 68°F (20°C) reduces manual dexterity, and can accentuate symptoms of nerve impairment such as numbness and tingling.

Individual Risk Factors

Age, gender, smoking, level of physical activity, strength, and abnormal anthropometric measurements are well-known individual risk factors for ergonomic WMSD. Preexisting conditions such as arthritis, bursitis, and joint pain predispose individuals to ergonomic injuries. Also, inefficient work methods such as holding a tool incorrectly may cause an individual to exert excess force. People with individual risk factors may be more susceptible to ergonomic injuries.

RECOGNIZING HAZARDS

From an ergonomics perspective, all work hazards can be traced to one or more ergonomic risk factors. Job analysis is useful for identifying problematic tasks and jobs that illustrate safe levels of task factors and effective work design. Minimizing or eliminating known ergonomic risk factors reduces the risk of WMSD. A well-trained ergonomist can target risk factors, make workstation improvements quickly at little or no cost, and plan for risk factor corrections that require more time and resources.

Active Surveillance

The ultimate goal of active surveillance is to identify hazards and improve workstations before an injury occurs. Injury prevention is critical to reducing injuries and disability in the workforce and lowering workers' compensation costs. The presence of one risk factor should trigger an active surveillance survey. Trained ergonomics personnel should survey all workstations and observe task performance at least once a year and conduct walk-through surveys for any new or significantly changed job, process, equipment, or method. Worker interviews during walk-throughs can help identify issues with tasks, tools, and workstation design. For example, an interview may reveal that workers manually move 50-lb boxes because a lift table dedicated to that task is broken.

Symptom questionnaires and worksite surveys allow workers to self-report ergonomic risk factors often before injuries occur. The ergonomist can gain insight about worksite issues and prioritize job tasks that require more detailed assessments. It is important to note that workers need a basic knowledge of musculoskeletal disorders for self-reported techniques to work.[11] The attachment at the end of this chapter is an example of a short ergonomics survey tool that health and safety personnel may use to identify ergonomic risk factors.

Health and safety personnel must conduct surveillance to identify WSMD cases with correctable ergonomic risk factors. For example, a laboratory worker seeks medical care for hand and wrist pain and the occupational history indicates worksite ergonomic risk factors exist at the workstation. The health and safety team can perform an ergonomic assessment and risk factor modification to minimize or eliminate identified risks. A worksite intervention may be necessary to determine if other workers are similarly affected.

Passive Surveillance

Safety and occupational health personnel conduct periodic passive surveillance by collecting and analyzing monthly illness and injury reports that identify service members and civilian employees who have experienced a WMSD. Data is analyzed to identify high risk occupations and worksites to target for further evaluation. The ergonomics committee then prioritizes work based on the number and severity of injuries and ergonomic risk factors. Although passive surveillance takes less time than active surveillance, it is not preferred because it focuses on secondary rather than primary prevention. Data regarding military and civilian injuries and illnesses are recorded on OSHA Form 300, Log of Work-Related Injuries and Illnesses, and DA Form 285, the Army Accident Report. Data can also be retrieved from the Office of Workers' Compensation First Report of Injury Log, a workers' compensation state form that the installation injury compensation specialist maintains in the human resource office.

ERGONOMICS RISK FACTOR MANAGEMENT

Currently, there is a debate over the extent to which roles worksite and job design play in the development of WMSDs. Some experts insist personal risk factors are more important than worksite risk factors in determining who will develop an injury. For example, research suggests the heavier a person is, the higher the risk for carpal tunnel syndrome.[12,13] People who are less physically active are also at greater risk for developing carpal tunnel syndrome. Other research shows there is a strong association between WMSDs and the known risk factors of repetition, force, vibration, nonneutral posture, mechanical stress, and environmental factors. The most reasonable approach to risk factor management is to include three critical elements in program management: ergonomics, wellness, and health. Table 15-2 identifies worksite contributions for WMSD prevention. Figure 15-2 illustrates key components to WMSD reduction.

Ergonomics Contributions

Ergonomists maintain worker comfort and enhance productivity by applying knowledge about human capabilities and limitations in worksite design. Effective job or worksite design (or redesign) enables the safety and occupational health team to prevent or reduce exposure to WMSD risks. Based on the hierarchy of controls, the following is a list of ergonomic interventions in order of priority, from most to least successful as defined by DA PAM 40-21:

TABLE 15-2

WORKPLACE CONTRIBUTIONS FOR WORK-RELATED MUSCOSKELETAL DISORDERS PREVENTION

Ergonomics Contribution	Wellness Contribution	Health Contribution
Process elimination	Fitness	Medical case management
Engineering controls	Excessive weight	Job limitations
Substitution	Stress management	Job specification
Administrative controls	Smoking cessation	Work hardening

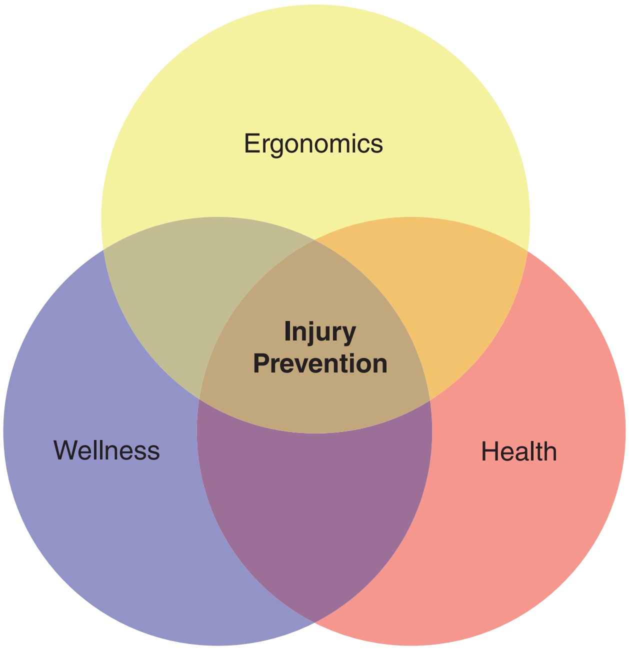

Figure 15-2. The Venn diagram illustrates the key components for injury reduction.

- **Process elimination**. Eliminating a demanding work process essentially eradicates the ergonomic hazard. For example, adopting an automatic bar code scanner would eliminate the ergonomic risk factors associated with a hand-held bar code scanner.
- **Substitution**. Use of poorly designed hand tools can increase the risk of repetitive motion injury. Substituting a new work process or tool (without WMSD hazards) for a work process with identified WMSD hazards can effectively avoid the hazard. For example, hand tools that require awkward wrist positions (extreme wrist flexion, extension, or deviation) can be replaced with tools that allow a neutral wrist posture.
- **Engineering controls**. Ergonomic engineering controls redesign the equipment or worksite to fit the limitations and capabilities of workers. Equipment or worksite redesign typically offers a permanent solution—for example, a computer workstation that can be adjusted to a wide range of anthropometric dimensions.
- **Administrative controls**. Administrative controls help reduce the magnitude, frequency, and duration of exposure to repetitive motion injury risks. Administrative controls change the way jobs are assigned, scheduled, and performed. Workers can be rotated to different jobs or shifts to vary the demands and work routine. Administrative controls include education and training; decisions related to employee rest, break, work schedules; exercise programs; and on-site instruction in lifting techniques. Administrative controls can also include the adoption of policies and procedures to protect the worker like requiring the use of pneumatic hand tools and vibration-damping gloves, and requiring supervisors to enforce the use of protective equipment.
- **Personal protective equipment**. Personal protective equipment (PPE) refers to items that provide a barrier to a hazard and are worn by workers. There is insufficient research to support the efficacy of most PPE advocated for ergonomics application. In the absence of more definitive research, the following is advised:
    - Back belts are not considered PPE and their use is not recommended by the National Institute of Occupation Safety and Health (NIOSH) or the US Army Surgeon General.
    - Knee and elbow pads can protect superficial soft tissues from mechanical insult or contact stress. Although workers may perceive reduced discomfort wearing these devices, research has not substantiated that they are able to reduce pressures inside the knee or elbow joints during weight bearing.
    - Antivibration (AV) gloves must meet ISO 10819:2013 standards. Hand-arm vibration should first be eliminated at the source or reduced to its lowest level that is practicable through the hazard abatement process. AV gloves are to be used as a final resolution.

Wellness Contribution

Fitness

Increased worker conditioning and strength helps prevent injuries and can reduce fatigue. Workers with stronger muscles use a smaller percentage of their strength than a person with weaker muscles. Healthy and fit workers can work longer between recovery breaks because they accumulate lactic acid more slowly than someone who is less fit. Worksite fitness programs designed to reduce employee WMSD risk should exercise the same body parts used to accomplish the work task to ensure the appropriate muscle groups and soft tissues are engaged. For instance, if lifts from the floor frequently take place during the day, then appropriate hamstring muscle stretches and exercises should be a part of the exercise program.[14] Moderate exercise 30 minutes a day, such as walking at a comfortable speed and using light weights for upper body toning, helps condition workers and reduces WMSD risk.

Excessive Weight

Excessive weight can increase the risk of back and lower extremity injury.[15] The extra pounds overweight individuals carry contribute to fatigue because they place additional pressure on the spine and strain on the back muscles. From a biomechanics viewpoint, a large stomach exerts a constant forward pull on the back muscles, which increases the amount of force on the lower back. Excess weight places the back, especially the L4-L5 disc and the L5-S1 disc regions, at risk for an injury. Furthermore, excess weight also stresses the hips, knees, and ankles. A heavier worker will often experience more hip and knee pain when walking compared to a normal weight individual.[16]

Stress Management

Research has indicated that high stress levels associated with working conditions are linked to adverse outcomes such as increased tardiness, absenteeism, and turnover rates.[17] Social factors, both at and away from work, can also cause stress such as workload, deadlines, interpersonal relationships, domestic and financial problems, and personality types (perfectionists, workaholics, etc). Stress can either aggravate local WMSDs, such as carpal tunnel syndrome, or cause diffuse muscle conditions, such as pain, weakness, numbness, tingling, and tissue swelling.[14]

Smoking Cessation

Studies show there is a causative effect between smoking and WMSDs. Smoking is a strong risk factor for back pain and is thought to cause disc disease due to malnutrition of spinal disc cells. Smoking increases the amount of carboxyhemoglobin-induced anoxia and vascular disease that affects the spinal disc cells. Nicotine enters most body fluids and has detrimental effects on a variety of tissues.[18] Smoking causes vasoconstriction that has been linked to other WMSDs.

Health Contribution

Health contribution refers to controls a healthcare provider implements to reduce the worker's injury risk. The controls can be applied proactively before an injury or retroactively after an injury has occurred.

Medical Case Management

Medical case management has several components: injury treatment, worksite evaluation, risk factor elimination, WMSD treatment, and expedited return to work. The case management team focuses on early intervention because literature shows that the longer employees are out of work, the less likely they are to return. The likelihood an employee will return to work after 6 months is 50% and after a year no more than 10%.[17] There are morale and personal benefits as well as reduced medical and workers' compensation disability costs associated with the timely return of an injured employee. Common medical case management practices include self-care and treatment plan oversight, utilization management, and facilitating an injured employee's return to work.

Job Limitations

The medical case management team works with the treating provider to accommodate worksite job limitations. Worksite accommodations facilitate the timely return to work, prevent injury aggravation, and afford rest and healing time. Restricted duty assignments are coordinated among the supervisor, human resources, occupational health, and safety office. In addition, trained ergonomists should evaluate the workstation for hazardous conditions and redesign opportunities.

Job Specification

A job specification details all the elements that form a job description. An ergonomist should review a job description before it is posted to ensure the physical demands can be performed successfully. A task that exceeds an individual's normal capabilities may lead to an injury.

PERSONAL PROTECTIVE EQUIPMENT CONSIDERATIONS

PPE should meet the worker's job requirements and act as a physical barrier between the worker and the hazard. However, PPE may not be the answer to controlling most WMSD hazards; incorrect or ill-fitting equipment may worsen stressors. PPE can cause heat stress, introduce new physical demands because of its weight, and cause worker fatigue, requiring additional rest periods to counteract increased physiological stress. Because PPE is ineffective in preventing non-neutral postures, forceful exertions, and repetitive

Figure 15-3. This is an example of improper back belt use. The worker wears a back belt throughout the course of the work day even though tasks may not involve lifting. Using a back belt in this manner can lead to muscle atrophy.
Photograph courtesy of Christina Graber, Army Public Health Center, Aberdeen Proving Ground, MD. Used with permission.

Figure 15-4. In this example, the back belt rides too high and does not support the back during the lift.
Photograph courtesy of Christina Graber, Army Public Health Center, Aberdeen Proving Ground, MD. Used with permission.

motions, the choices are limited for ergonomic hazards. PPE is good at preventing vibration hazards; protective barriers such as gloves or vibration dampening wraps or seat pads prevent the transfer of energy. A trained ergonomist should be consulted when selecting PPE.

Medical equipment including wrist rests, back belts, and back braces is prescribed by a healthcare provider. The Department of Defense policy and the research literature do not support the blanket use of back belts to prevent back injuries.[16,19,20] In fact, wearing a back belt throughout the workday (as shown in Figure 15-3) causes dependency and muscle atrophy.[21] Figure 15-4 also illustrates improper back belt use and how it can lead to a back injury. The credentialed healthcare provider who prescribes medical equipment, such as the back belt, must educate the worker on proper fit and use, and monitor the worker's wear of the device.

WORKSITE TASK ANALYSES

Once job problems are identified and prioritized, further worksite analysis is important in developing solutions. Many techniques are available for workplace analysis, and they vary greatly in sophistication, time investment, detail, and appropriateness. Generally speaking the ergonomist first identifies the parts of the body at risk. Second, the ergonomist analyzes the tasks and workstation design and how they affect the body. Third, once the analysis is complete the ergonomist can develop potential solutions.

Posture Assessment

Any deviation from neutral posture, regardless of gender, size, or physical condition, puts the worker at risk. Ergonomists should directly observe workers to identify stressful or poor postures and contributing factors. Workstation factors, work location, material orientation, and tool shape, along with job task frequency and duration all contribute to workplace stress and poor posture. A basic postural assessment can be completed using a video or digital camera, tape measure, and either a goniometer or protractor. Engineering controls can reduce workplace stressors and allow work to be performed closer to the body; specifically, the shoulders should be relaxed, the arms hanging at the side, and the arms extended no more than 15 to 20 in. The work surface location should be adjusted to ensure work can be performed in a neutral posture. Hand tools should allow the worker to complete tasks in a neutral hand position, that is, no flexion, extension, ulnar deviation, or radial deviation.

Repetition Assessment

Repetitive motions have been linked to a variety of WMSDs in the upper extremities. Unfortunately, the causes of these disorders are complex and no single causative factor has been identified. Ergonomists must perform task analysis to determine whether machine pacing, high-frequency work, or rapid movements contribute to WMSDs. Ergonomists also assess work pace and advise management to consider the costs and benefits of adopting incentives that allow the worker to dictate work pace. Research has shown that when machines pace the work, WMSD injuries increase.[22] The best way to lower WMSD risk is to reduce repetition through automation and decrease production demands. Two administrative controls that are often employed are worker rotation (rotating workers throughout the day to jobs that do not stress the same body parts) and job enlargement (increasing the scope of a job by adding related tasks and variety).

Duration Assessment

Work duration influences the length of the workday and the body's recovery time before the next work shift starts. Research shows that longer workdays reduce the body's ability to recover; workers fatigue more easily, and muscle soreness is more prevalent.[23] To compensate for longer work shifts, a workload should not exceed the employee's physical capacities. A duration assessment considers the length of the shift and any overtime, break schedule, and the nature of the work (light assembly, heavy manual material handling, monitoring or inspection, etc). The ergonomist looks for ways to control long duration tasks by developing appropriate work, rest, and break schedules.

Forceful Exertion Assessment

Forceful exertions refer to job tasks that produce loads on the joints and soft tissues of the musculoskeletal system. The use of force to lift, carry, or operate a tool is common in many jobs. The amount of muscle force needed to perform a task is dependent on the posture and muscles; less force is needed to complete a task with larger muscle groups and proper posture. The goal of ergonomic work design is to complete the task with the least amount of fatigue in active muscles during the work shift. The ergonomist observes all tasks that require lifting; lowering or other manual material handling; holding or using force to overcome resistance (such as squeezing a hand tool); and measures the force and duration of the activity. The exerted force is measured using a hand dynamometer and pinch gauge to estimate forceful hand exertions, a weight scale to measure weights of objects, and a force gauge with high capacity to record forces.

Forceful exertion is controlled by improved posture and minimized load handling. Ergonomists ensure workers use proper posture and decrease functional load and travel of the handled items. They ensure that all lifted items are stable and can be lifted with two hands kept close to the body. Whenever possible, they design jobs to make use of gravity and employ engineering controls. The ergonomist identifies and selects hand tools that are low in weight and have grip handles that allow the hands to function in a neutral posture, and use hoists or tool balancers to support hand tool weight.

Mechanical Compression Assessment

Any outside object that comes in contact with the body creates mechanical compression. The fingers and hands are a common target for mechanical compression; hands are constantly in contact with tools, parts, or equipment. The hand is sometimes used as a hammer when a worker pounds an object in place with a closed fist. Prolonged exposure to mechanical compression of the hands can cause soft tissue damage to the fingers, palm, and wrist.[24] Other body parts are also at risk if they are exposed to hard surfaces, sharp edges, or heavy weights (for example, carrying a heavy item on the shoulder). Mechanical compression is assessed by: (*a*) identifying contact points between the body, work objects, and work surfaces; (*b*) determining the contact force; (*c*) establishing the contact location, either qualitatively (ie, sharp edge or hard surface) or quantitatively (square inches, linear feet, etc); and (*d*) determining contact duration and frequency.

Good tool design can minimize the impact mechanical compression has on the hands. When considering a hand tool, it is important to select handles that:

- extend past the palm,
- are made of a soft, compressible material, and
- are rounded and have no finger grooves.

Workers are advised to avoid using the hand as a tool when performing tasks.[25] Mechanical compression for other body parts is minimized by spreading force requirements over a larger surface area. For instance, carrying a bag that has a 2-inch shoulder strap will place half as much force on the shoulder as a bag with a 1-inch shoulder strap.

Vibration Assessment

Vibration in the workplace is a common occurrence for individuals who work with powered hand tools or drive heavy vehicles or equipment. Energy is transmitted from a vibrating source to the body through the hands, seat, or feet. Prolonged exposure to vibration can cause permanent tissue damage similar to that seen in Raynaud syndrome.

Segmental Vibration

The use of vibrating hand tools can lead to small blood vessel spasms of the hand, wrist, and arm. This impaired circulation can directly affect muscle function, and continued work can lead to permanent vibration injury or WMSD. For over 20 years it has been demonstrated that replacing worn out pneumatic power tools with new tools that employ vibration-dampening technology increases worker productivity and lowers vibration risk.[25] Vibration equipment is available that allows the ergonomist to conduct segmental vibration surveys. These surveys also involve worker observation and determine exposure frequency. Whenever possible, the ergonomist should compare exposure duration and intensity with known standards such as the American Conference of Governmental Industrial Hygienists threshold limit value for vibration exposure.[26] Segmental vibration exposure is best controlled by eliminating the vibration source. Well-maintained tools, dampening gloves, and tool handles coated with vibration-dampening material also help control vibration exposure.

Whole-Body Vibration

Whole-body vibration is transmitted to the body through vehicle or machinery seats and affects the vertebrae, intervertebral discs, and supporting back muscles. Soldiers sitting in an armored vehicle driving over an unpaved road experience vibration transmitted to the feet from the floor boards and to the buttocks through the seat. Whole-body vibration in combination with other WMSD risk factors such as long-duration tasks in nonneutral postures increases the risk of a back disorder. Whole-body vibration analysis involves observing the worker; determining exposure frequency, intensity, and duration; and comparing these measures with known standards. Whole-body vibration exposure is best controlled by eliminating the vibration source or decreasing the exposure time.

Cold Temperature Assessment

Working in cold temperatures has been linked to repetitive motion injuries of the hands and can reduce manual dexterity. Duration studies in cold environments are conducted with a stopwatch and thermometer. During a cold temperature assessment, the ergonomist measures temperatures to determine if they fall within a certain range and checks with workers to ensure they have adequate clothing and equipment. Workers should have well-fitting gloves to increase finger temperature, clothing that maintains core body temperature on the torso, and hand tools that do not conduct cold.

MANUAL MATERIAL HANDLING

Background

On average, approximately 30% of all workplace injuries are attributed to manual material handling (lifting, lowering, carrying, pulling, or pushing) activities; the majority of injuries are to the back.[27] In workers under age 45, back injuries are the most prevalent cause of disability and the diagnosis with the highest cost in the 30 to 50 age group. Approximately 1% of the US population is chronically disabled and 1% is temporarily disabled due to back injury.[28] From a search using the Defense Medical Epidemiologic Database (DMED), the US Army is approaching 500,000 ambulatory visits a year due to back injuries.[29] These ambulatory visits now exceed 300 cases per 1,000 soldiers annually, and in many instances the case rate exceeds 400 cases per 1,000 soldiers annually.[30] Figures 15-5 and 15-6 contain detailed information on ambulatory back injury cases and case rates. Unfortunately, the DMED does not contain costs associated with ambulatory visits; however, lost work time and disability payments can be three times as much as medical costs.[31] Other common injuries include pinched or trapped hands and fingers, crushed feet and toes, and trauma resulting from a slip, trip, or fall.

Lifting

Although back injury prevention training has existed since the 1950s, there has been no appreciable decrease in back injury rates.[32] Preventing lift-related back injuries is difficult because factors that increase the risk are many and often present at the same time. Figure 15-7 contains a diagram of all the risk factors present when a lift takes place. Back injury prevention or lifting

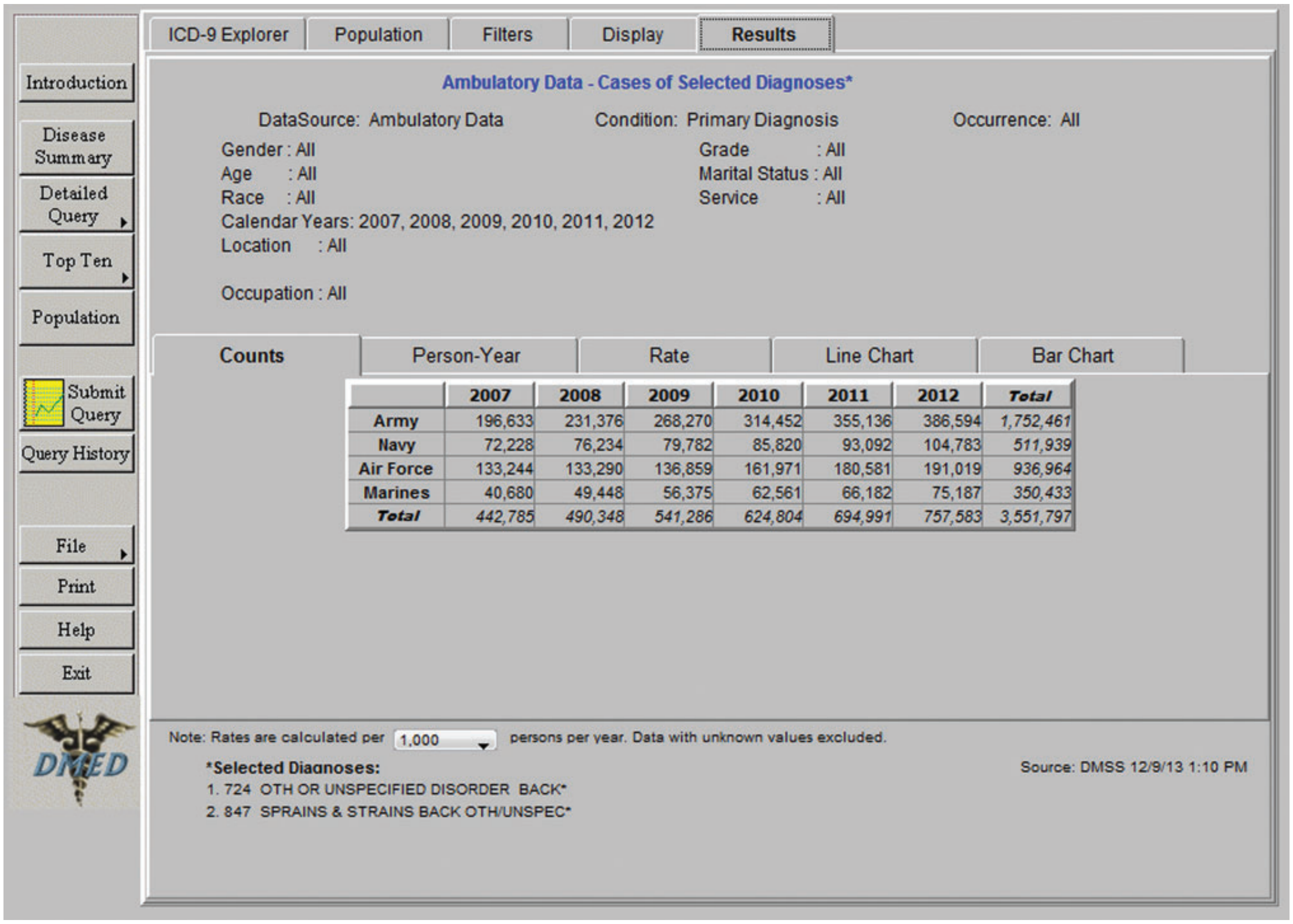

Figure 15-5. Department of Defense Ambulatory data for back injury cases from 2007 to 2012.
Reproduced from Defense Medical Epidemiology Database, Armed Forces Health Surveillance Branch of the Defense Health Agency.

technique training conveys valuable information; however, the best way to prevent a back injury is to reengineer the job to eliminate or reduce physical demands. While lifting technique training can improve body posture, it is not a replacement for task redesign. In order for training to be meaningful, it must target the worker's activities, be continually reinforced, and take place in a work environment that will not exceed work capacities and physical limitations.

Case Study 1: Engineering Control

This case study demonstrates how engineering controls can minimize WMSD risk factors, improve worker safety, increase productivity, and lower injury risk. Two employees had to lift a trash barrel approximately 4 ft to dump a barrel of waste. Figure 15-8 shows how waste was removed at an office building, before the ergonomic intervention. WMSD risk factors present were forceful exertions from lifting the barrel of waste; poor upper extremity postures from lifting the barrel; and mechanical compression from the barrel. Workers risked back and shoulder strain while tipping the barrel over to empty it. A number of ergonomic interventions, such as the use of a specialized dolly, as pictured in Figure 15-9, can improve a job. Now the job can be performed in half the time with only one worker and all risk factors are eliminated.

Case Study 2: Administrative Control

Figure 15-10 shows a smoke ejector fan stored approximately 7 ft off the ground on top of a fire truck before the ergonomic intervention. Three firefighters had to lift and lower the 86-lb smoke ejector fan and were exposed to several WMSD risk factors: forceful

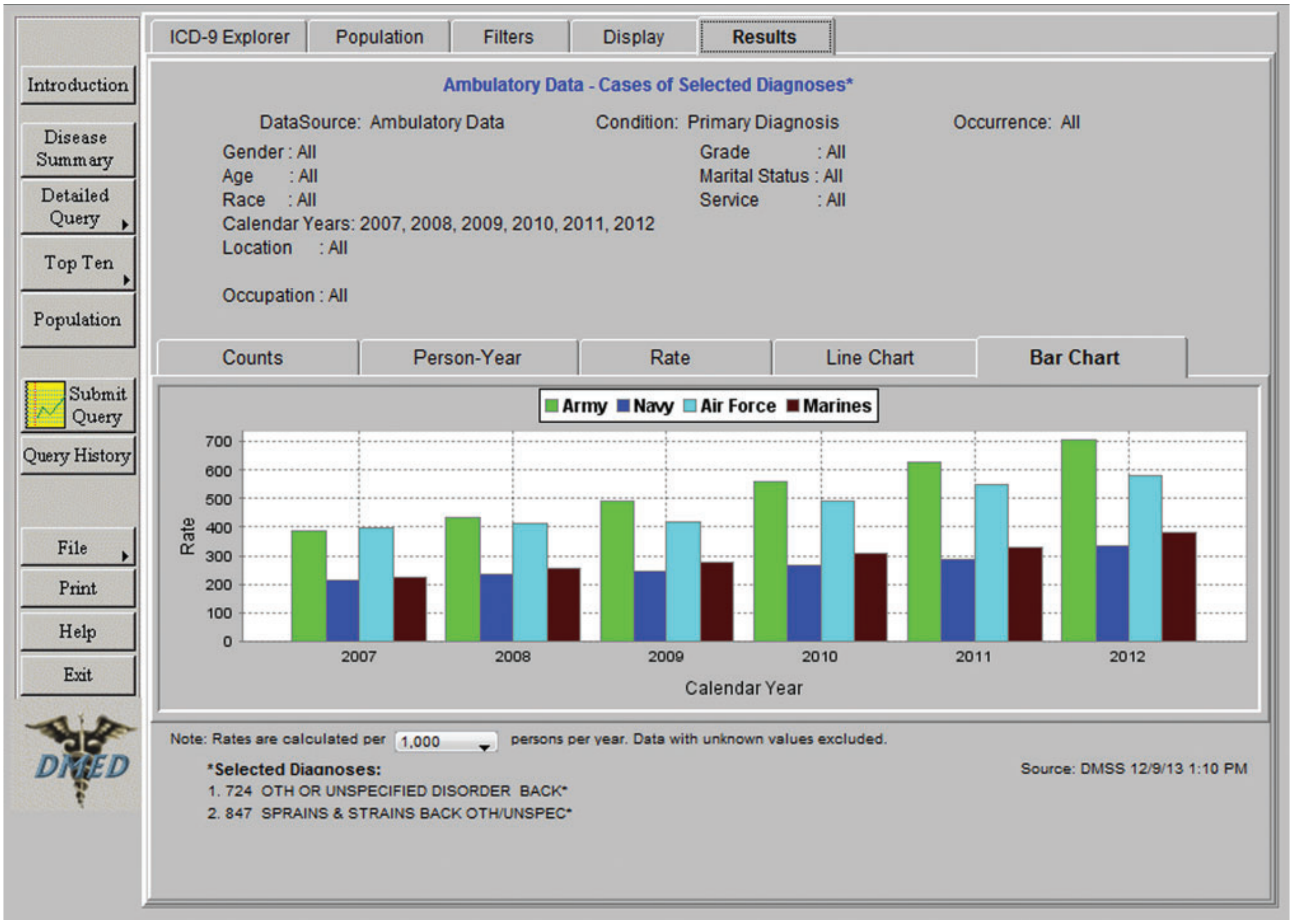

Figure 15-6. Department of Defense Ambulatory data for back injury case rates from 2007 to 2012.
Reproduced from Defense Medical Epidemiology Database, Armed Forces Health Surveillance Branch of the Defense Health Agency.

exertion from lifting or lowering the smoke ejector fan; poor posture from lifting with the hands above the shoulders; and mechanical compression of the hands and torso from contact with the fan and fire truck. Workers risked back and shoulder strain as well as trauma to the body if the fan fell on a body part or if they fell off the truck during the manual material-handling procedure.

Figure 15-11 illustrates how an administrative ergonomics intervention can improve a job through a decision to store the heavy object in a lower location. Although the weight of the fan has not decreased, lifting and lowering the fan to its new storage spot is easier. This ergonomic intervention allows only two workers to lift and lower the fan (more people can assist if needed) approximately 2 ft off the ground. Relocation of the fan has reduced the forceful exertion and improved worker posture as well as decreased manpower and time.

Individual Risk Factors

Individual risk factors change over time. A 55-year-old worker does not have the same capabilities as a 25-year-old worker because capacity declines as people age.[33] A worker who is physically fit can better meet the job's physical demands and is at less risk for injury than a less fit coworker.[34] Gender and body build differences also contribute to individual risk factors. On average, women have approximately two-thirds the lifting strength of men.[35] Women also work closer to their aerobic capacities than men when performing the same task and therefore, are at a greater risk for injury.[34] Taller people are weaker in lifting strength and are more susceptible to back pain because they lean forward more and have to reach farther.[36,37] Lastly, the literature suggests that the ability to handle weight or exert force is limited by a worker's muscle strength.[38,39] Weaker workers who perform lifting activities are more likely to suffer lower back pain.[40]

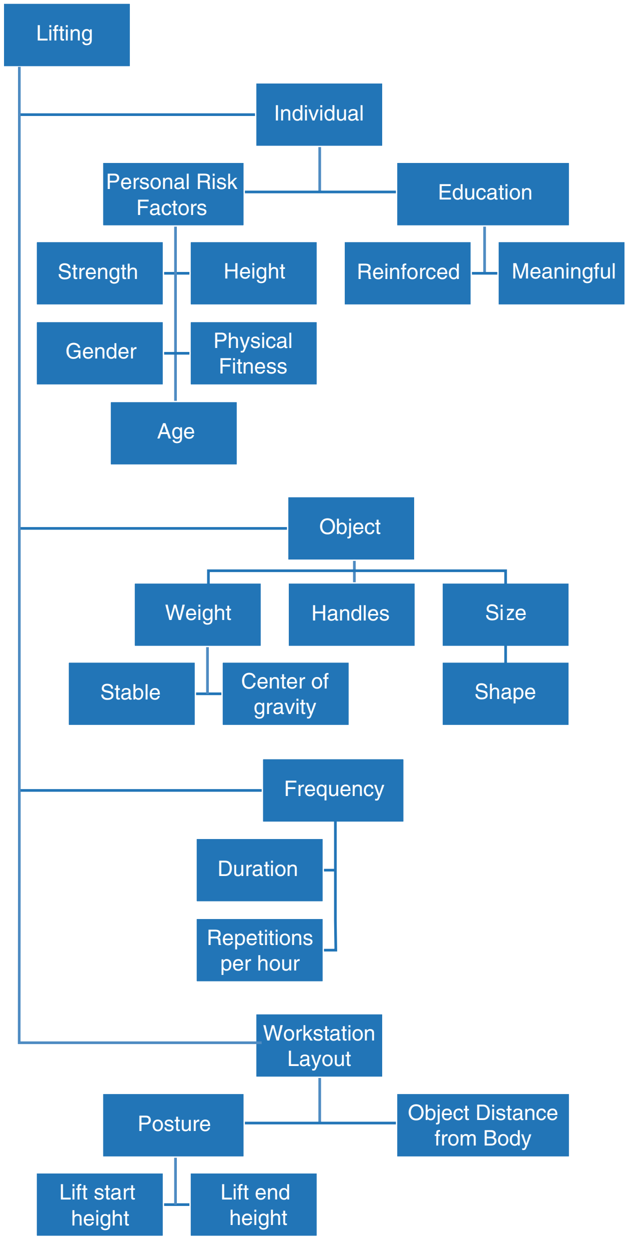

Figure 15-7. There are multiple risk factors to consider when a lift takes place to ensure a worker will benefit from ergonomic interventions.

Objects and Weight Distribution

Although an object's weight is a good predictor of low back stress, it is not an absolute measure. Frequency, duration, and posture should be considered when determining a safe lifting weight. The National Institute for Occupational Safety and Health indicates that people should not lift more than 51 lb under ideal conditions.[41] From a biomechanical perspective, objects that weigh the same do not place the same amount of

Figure 15-8. Waste removal process before ergonomic intervention.
Photograph courtesy of Christina Graber, Army Public Health Center, Aberdeen Proving Ground, MD. Used with permission.

Figure 15-9. Waste removal process after an ergonomic intervention. Notice how the use of an engineering control reduces the risk of worker injury.
Photograph courtesy of Dump Dolly LLC (San Angelo, TX). Used with permission.

Figure 15-10. Lowering of a smoke ejector fan before ergonomic intervention. Notice the firefighters' poor postures and force requirements as they reach to move the fan.
Photograph courtesy of Christina Graber, US Army Public Health Center, Aberdeen Proving Ground, MD. Used with permission.

stress on the back. Unevenly distributed loads cause handling problems, and workers experience back stress when they react to unexpected weight shifts. Slowed reaction times may lead to strained back ligaments and injured intervertebral discs. Objects whose center of gravity is farther from the spine place more stress on the back.[42,43]

The size and shape of an object contribute to the lifting stress. Any item that cannot fit between the knees is too large to lift safely. Collapsible containers such as bags cause problems when lifted, so the shape should be as small as possible. Good handles or couplings are essential to provide load and postural stability during lifting.[44] Research has shown that containers with handles can increase lifting capacity[45] and containers without handles decrease lifting capacity.[46,47]

A 25-lb object held 25 in from the body requires more force to lift than a 50-lb object held 10 in away. Biomechanical studies demonstrate that holding objects farther from the spine decreases the maximum amount of weight individuals can safely lift.[48,49] Studies have also shown that lifting items on or close to floor level greatly increases lumbar back stress.[50,51] A properly designed ergonomic workstation ensures that all lifts begin and end between mid-thigh and mid-chest, and ideally occur at knuckle height.

Frequency

Frequency is the most critical task element that determines an individual's capacity to perform manual material handling.[34] Manual material handling activities that are frequent or repetitious need to be redesigned. Two ways to decrease the frequency material is handled is either to increase the weight limits of objects or increase the task duration. OSHA recognizes task duration as one of the key criteria when designing weight limits for lifting tasks. Furthermore, there is a positive linear relationship between duration and the body's metabolic demands. When given a choice, workers will decrease the amount of weight they handle and take more time to complete the task.[34]

Figure 15-11. Firefighters relocate a smoke ejector fan after an ergonomic intervention. Notice how relocating the fan from the top of the fire truck to the rear bumper allows for easier access.
Photograph courtesy of Christina Graber, Army Public Health Center, Aberdeen Proving Ground, MD. Used with permission.

SUMMARY

The need for ergonomics will not disappear as technology and equipment improvements allow soldiers to serve more efficiently and civilian employees to work faster than ever. History has shown that technological advances need to be matched by improved workstation design and worker training. The US Army's ergonomics initiatives are an essential element in meeting goals to maximize troop readiness and reduce civilian employee lost work time and injury costs. The goal of an ergonomics program is to prevent WMSDs through active and passive surveillance. Industrial hygienists, safety officers, and other stakeholders determine if WMSD risk factors exist. Physical therapists, occupational therapists, and occupational health nurses treat symptomatic workers for injuries and rehabilitate them. Command and management support changes in work practices and workstation design to minimize or eliminate identified WMSD risk factors. If any link in the ergonomics chain is weak, soldiers and civilian workers will not receive the support and resources they need to maximize productivity.

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ATTACHMENT: BASIC ERGONOMICS ASSESSMENT SURVEY FORM

Basic Ergonomic Assessment

Instructions: Respond to the screening question for each of the five risk factors. Complete a more detailed exposure assessment for each "yes" answer. Record responses on the answer form.

Installation: ___________________________________ Building number: _______________

1. Frequent repetitions
   a. Does the task include performance of the same motion or motion pattern every few seconds for more than a total of 2 hours per day? ___________
   b. Process name: ____
   c. Task name: ____
   d. Number of people performing task: _______________________________________

Definition: Frequent repetitions occur when the same movement is performed over and over again with little variation (eg, typing). The repetitious movement may be a "pattern" of several motions which are repeated (eg, parts assembly).

2. Awkward postures/Fixed postures
   a. Does the task include a fixed or awkward work posture (eg, overhead work, twisted or bent back, bent wrist, kneeling, stooping, or squatting) for more than a total of 2 hours per day?___________
   b. Process name: ____
   c. Task name: ____
   d. Number of people performing task: _______________________________________

Definition: Awkward postures require joints to deviate from anatomically neutral positions. Examples include the postures that the body assumes during twisting, crouching, kneeling, squatting, and stooping.

Definition: Fixed postures require prolonged muscle contraction without movement. Examples include, but are not limited to, maintaining an unsupported posture (eg, sitting on a stool that has no back support) or prolonged gripping of a tool.

3. Forceful hand exertions
   a. Does the task include forceful hand exertions for more than a total of 2 hours per day?___________
   b. Process name: ____
   c. Task name: ____
   d. Number of people performing task: _______________________________________

Definition: The force required to hold, move, manipulate or use a tool or object. Examples of forceful hand exertions include: gripping, pinching, squeezing, lifting, or manipulating a tool or object. Squeezing manual wire crimpers is an example of a forceful hand exertion.

4. Frequent/Forceful manual handling
   a. Does the task include unassisted frequent or forceful manual handling for more than a total of 2 hours per day?___________
   b. Process name: ____
   c. Task name: ____
   d. Number of people performing task: _______________________________________

Definition: Unassisted frequent or forceful manual handling. Examples include: lifting, lowering, carrying, handling or pushing/pulling heavy objects, equipment, tools, animals or people without assistance from mechanical devices.

5. Vibration
   a. Does the task include exposure to localized or whole body vibration?___________
   b. Process name: ____
   c. Task name: ____
   d. Number of people performing task: _______________________________________

Definition: Vibration is the oscillatory motion of a physical body. Hand-arm vibration is produced by contact with powered tools or equipment or by contact with vibrating structures. Whole body vibration exposure occurs while standing or sitting in vibrating environments or objects including: trucks and heavy machinery, or while using heavy equipment such as jackhammers.

Adapted from: Goddard DE, Neufeld KL. *Basic Ergonomics Assessment Survey Form*. Aberdeen Proving Ground, MD: US Army Proponency Office for Preventive Medicine; 2003.