HUMAN FACTORS/ERGONOMICS

1.0 INTRODUCTION

Certain activities may pose various ergonomic hazards to individuals. Human factors/ergonomics is the study of the interaction of the worker and the job in an effort to minimize physical and psychological stress in the workplace. It applies information regarding worker's capacities and capabilities to the design of jobs, products, workplaces, and equipment.

This module presents background information on ergonomics and associated disorders and discusses how to evaluate and control ergonomic hazards. This information can be utilized by personnel in the field and also in the office environment.

Learning Objective(s)
At the end of this module, you will be able to:

- Explain the basic concepts of ergonomics.
- Recognize the fundamental components of human anatomy commonly affected by ergonomic-related disorders.
- Name and characterize typical ergonomic-related disorders.
- Identify the ergonomic risk factors associated with a job task.
- Describe how to evaluate ergonomic risks and identify control measures for avoiding ergonomic-related disorders.

2.0 GENERAL PRINCIPLES OF OCCUPATIONAL ERGONOMICS

The basic concept behind ergonomics is to understand the anatomy, physiology, and psychology of people in order to design the job and the workplace more effectively. For an effective work system, the following ergonomic principles should be considered:

- The role of the worker should be based on physical, cognitive, physiological, and psychological capabilities and limitations (design for humans not machines).
- Equipment should support or compliment the worker in accomplishing a task.
- The environment should provide working conditions that maximize human performance.
- The design should include minimizing the potential for exposures which may result in injury or illness.

Job design should emphasize fitting the job to the person, in order to improve both employee well-being and workplace efficiency. The following factors are considered:

- How much a person can do
- How long a given level of effort can be sustained
- How work can be organized or patterned to reduce the possibility of accumulating fatigue
- How external pressures can influence the worker's perception of job difficulty.

2.1 Work physiology

Work physiology is concerned with evaluating the capacity and limitations of workers for performing physical work as well as determining human tolerances to stresses produced by the physical environment. Generally, a worker's tolerance for physical work is determined by the capacity of his/her circulatory and respiratory systems, as well as muscle strength. For example, physically fit individuals will generally have greater muscle strength and thus a greater tolerance for physical work than those individuals who are not in good shape (e.g, overweight).

2.2 Biomechanics

Biomechanics is concerned with the mechanical properties of human tissue, particularly the response of tissue to mechanical stress. Forces developed by the muscle tendon act on bones at their points of insertion and cause rotation, or torque, around a joint. By understanding the mechanics of a job task, the concepts of biomechanics can beapplied to identify, correct, or avoid injury.

2.3 Anthropometrics

In order to fit the task to the worker, a knowledge of human dimensions and capacities is needed. Anthropometrics is the science of measurements of body size. This information can be used to design workstations, equipment, tools, and personal protective equipment to accommodate the physical dimensions of the user. Typically, equipment and work stations are designed to accommodate the 5th percentile female to the 95th percentile male.

3.0 BASIC HUMAN ANATOMY

The performance of work requires energy. This energy is made possible through a coordinated effort among muscle, nerve, and bone. This section provides the basic structure and function of the components of the musculoskeletal system in order to understand clearly how the human body responds to and adapts to work. The major substructures are:

- Ligaments, tendons, and fascia
- Cartilage
- Bone

- Muscle.

The role of the circulatory and respiratory systems in supplying nutrients and oxygen necessary for muscle contraction and movement is also addressed.

3.1 Functions of Musculoskeletal Components

Bone provides the body's structural support. Joints, which consist of a union of two or more bones, are necessary to allow movement between body segments. Muscles generate movements about the joints. Muscles can contract and shorten, producing movement, or contract without shortening, providing stability. The length of the muscle is important to its ability to produce tension.

Ligaments connect bone to bone and provide stability at the joints, while tendons attach muscles to bone and transmit forces from the muscle. Many joints have discs of fibrocartilage to protect and support them. Cartilage, which covers articular surfaces, provides the joints with sliding surfaces of low frictional resistance.

3.2 Functions of Circulatory System

A centrally controlled blood vessel system distributes oxygen to organs and muscles in proportion to their workload. The heart pumps the blood to match the demand for oxygen and venous blood picks up the carbon dioxide waste produced by metabolism.

3.3 Functions of Respiratory System

The respiratory system includes the lungs, airways from the mouth and nose to the lungs, and the muscles of the chest wall and diaphragm. Oxygen is used and carbon dioxide is produced proportionally to the work performed, so the amount of gas exchanged in the alveolar per minute (alveolar ventilation) must reflect this rate. The amount of alveolar ventilation a worker can develop and maintain depends on the individual lung capacity and the amount of effort required to breathe. For instance, the alveolar ventilation rate may be lower for smokers or those with respiratory impairments than for nonsmokers with normal lungs.

4.0 OVEREXERTION PHENOMENONS AND DISORDERS

The following are some common examples of ergonomic-related disorders:

- Localized and whole-body fatigue
- Lower back pain
- Carpal tunnel syndrome
- Tendinitis
- Tenosynovitis
- Bursitis.

4.1 Localized and whole-body fatigue

Localized fatigue occurs only in the affected tissues and can be distinguished from other effects by the fact that it is completely reversible. Altering the work activity will usually provide prompt relief. Whole-body fatigue occurs in many tissues at once when the metabolic demands of working muscles throughout the body exceed the capacity of the respiratory and circulatory systems.

4.2 Lower back pain

Lower back pain typically involves injury to soft tissues such as muscles, tendons, and ligaments. However, more serious injuries may involve structural damage to spinal disks or trauma to nerves. Lower back pain is generally caused by forceful exertions, awkward postures, whole-body vibration, and repetitive exertions or postures. Lower back pain is one of the most commonly encountered and compensated occupational injuries.

4.3 Carpal tunnel syndrome

The carpal tunnel is a canal bordered on the bottom and sides by bone and covered by a fibrous sheath located on the inside of the wrist where the tendons from the forearm pass through the wrist into the hand. Repeated motions associated with grasping, twisting, and flexing can cause the tunnel sheath to become inflamed and swollen. The swelling increases pressure on the tendons and median nerve which pass through the tunnel. The pressure on the nerve can cause impaired function. The symptoms related to carpal tunnel syndrome include inflammation or tingling of the fingers and may progress to loss of feeling and reduction in grip strength. This condition is one of the most severe cumulative trauma disorders (also referred to as repetitive-motion disorders).

4.4 Tendinitis

Excessive motion and force can cause tendinitis, which results in pain, swelling, and tenderness of the tendon. Tendinitis is more commonly found in the hands and wrists, but can also occur in the arms, shoulders, and knees.

4.5 Tenosynovitis

Tenosynovitis, another cumulative trauma disorder typically found in the upper extremities, is caused by pain, swelling, and tenderness of the tendon sheath. When tenosynovitis is associated with the narrowing of the tendon sheath, it can produce a disorder known as trigger finger.

4.6 Bursitis

Bursitis is an inflammatory jointproblem which is commonly found in the elbows and shoulders of workers where repetitive abduction and rotation of the joint is required throughout the work shift.

5.0 RISK FACTORS

Ergonomic risk factors can be categorized into the following classes:

- Forceful exertions
- Awkward postures
- Localized contact stresses
- Vibration
- Temperature extremes
- Repetitive motions.

5.1 Forceful exertions

Forceful exertions such as the lifting or carrying of heavy objects and equipment is generally considered to be a risk factor for lower back pain and other musculoskeletal disorders. Forceful exertions caused by using hand tools can cause upper extremity cumulative trauma disorders (UECTDs) such as inflammation of joints, muscles, and tendons (i.e. carpal tunnel syndrome).

5.2 Awkward postures

Awkward postures can lead to fatigue and discomfort. Awkward posture for prolonged periods, bending, and lifting can lead to musculoskeletal or nerve disorders such as lower back pain and UECTDs.

5.3 Localized contact stresses

Localized mechanical stresses are caused by physical contact between body tissues and objects, equipment, and tools. These stresses are generally associated with job tasks where a body part is in contact with a hard or sharp object.

5.4 Vibration

Whole-body vibration is typically associated with lower back pain. Localized vibration of the upper body, which frequently results from the use of powered tools, may contribute to UECTDs (i.e., hands, wrists). Vibration can also affect knees and ankles. Raynaud's phenomenon, or white finger disease, is also associated with the use of vibrating hand tools. Vibration, in combination with increased cold sensitivity, blanches or whitens the fingers and causes numbness, itching, and tingling.

5.5 Temperature extremes

Working in high temperatures , particularly under high-intensity work conditions, can lead to heat stress, fatigue, or cardiovascular strain. Working in cold temperatures can reduce manual dexterity and gloves may increase the force required to perform the task.

5.6 Repetitive motions

Any job task which involves repeated motion patterns and/or prolonged postures within a work cycle may be considered repetitive. Since exposure is cumulative, the strain increases with prolonged exposure to each of the risk factors described above.

6.0 JOB-TASK/WORKSTATION ANALYSIS

Ergonomic analysis should address both the job task as well as the work environment in which the task is performed. Appendix A summarizes the primary human factors/ergonomic issues which need to be considered.

6.1 Job-Task Analysis

The analysis of tasks for the purpose of ergonomics evaluation addresses the following four characteristics of the task in question:

- Range of motion and reach requirements
- Exertion and strength requirements
- Dexterity and fine motor control requirements
- Frequency and duration.

6.1.1 Range of Motion and Reach Requirements

The range of motion required to perform a task must be compatible with the physical and anthropometric dimensions of the worker. The reach requirements are measured in terms of horizontal and vertical distance from the normal work position and can be compared to established data for working populations. The design criteria are created to establish horizontal and/or vertical reach requirements so that 95 percent of the population from which workers are drawn can comfortably perform the task.

If the task in question requires a reach, or range of motion, that is at or beyond the maximum of the working population, increased effort will be required to perform the task. This may lead to articles being dropped, increased fatigue, or inappropriate task performance.

6.1.2 Exertion and Strength Requirements

The amount of exertion required to perform a task is a limitation that workers recognize easily. However, the amount of weight that can be repeatedly lifted without causing strain or musculoskeletal stress is less well-recognized by workers, and is lower than

might be expected. It should be emphasized that not only is the weight of the object important to assess the biomechanical stress associated with a task, but also the range of motion through which it is moved is a critical determinant of the required exertion level.

The biomechanical characterization of a lifting task or other activity involving physical exertion is a complex and rigorous undertaking. Ergonomic/human factors design should be attempted only by persons familiar with the process, terminology, and execution of such analysis. Remedial action, however, is often more straightforward. Redesign may require lifting assists to reduce the amount of physical work necessary. The overriding principle is that the task should be appropriate to the person doing the work.

6.1.3 Dexterity and Fine Motor Control Requirements

Many field tasks require dexterity and fine motor control. The problems associated with these tasks include tenseness, eye strain, stiffness, and other complaints associated with close attention and relative immobility. The work station and other aspects of the work environment should receive special consideration.

6.1.4 Frequency and Duration

A final critical aspect of task analysis is consideration for the length of the task and the frequency with which it must be performed. The detrimental effects of repetitive activities that require significant physical effort, or close attention, can accumulate over time. Thus, the worker should be given the opportunity to pause and rest when necessary. Since the capabilities and limitations of employees may vary from one person to the next, the frequency of the need for rest should be reviewed by the health and safety officer.

6.2 Work Station Analysis

The work environment includes not only the tools and fixtures with which the work is done, but also considerations of lighting, heat, humidity, indoor air quality, and noise, which are referred to as comfort indices.

6.2.1 Furniture and Fixtures

Furniture should be designed so that occupants can use it with ease and comfort for the duration of the task. For instance, chairs can increase stress on discs in the lower back. Consequently, several styles of unconventional chairs have been developed which are ergonomically correct.

6.2.2 Comfort Indices

The amount and nature of the light provided can significantly affect the ease with which work can be accomplished. Proper lighting" is a relative term since lighting that is good for one task may be inappropriate for another. The amount of glare, the provision of too

much or too little light, and the effects of fluorescent versus incandescent bulbs are all important considerations.

The temperature of a work environment may be of particular importance if persons working in the area are in poor physical condition and/or must use chemical protective clothing. Since protective garments tend to accumulate body heat, persons wearing them will become uncomfortable more quickly in warm environments. In addition, the use of a respirator may contribute further by adding to heat retention and raising the anxiety level of the user.

Indoor air quality (IAQ) takes into account factors such as the supply and distribution of fresh air, the level of airborne contaminants (i.e., carbon dioxide, carbon monoxide, etc.) microbiological contamination and related environmental comfort issues.

Noise can vary considerably depending on the type of equipment present. Noise can be distracting, annoying, and, if loud enough and of sufficient duration, can affect a person's hearing.

7.0 CONTROL METHODOLOGY

Following the identification of ergonomic hazards, control measures must be designed and implemented to eliminate or minimize the hazards. Control measures may include engineering controls and/or administrative controls.

Engineering controls should be the first consideration when addressing ergonomic hazards, since they fit the job to the person, instead of the person fit to the job. Engineering controls include designing or modifying work stations, work methods, tools to eliminate awkward postures, repetitive motions, and excessive forces. Engineering controls may include the following:

- Use of adjustable furniture/fixtures
- Provision of ergonomically designed tools
- Suspension of heavy tools
- Use of material handling equipment and devices
- Provision of additional task lighting
- Redesign of controls/displays
- Job automation.

Where engineering controls are not feasible or do not fully correct the problem, administrative controls should also be implemented. Administrative controls may include the following:

- Instructing personnel in the proper work techniques and use of ergonomically designed tools and workstations
- Decreasing production rates and limiting overtime

- Restructuring jobs to allow for selfpacing and for sufficient rest pauses
- Increasing the number of workers performing a task
- Allowing for job rotation
- Adjusting the size or weight of the product handled
- Instituting a preventive maintenance program for tools and equipment to reduce ergonomic stress.

7.1 Learning and Skill Acquisition Training Programs

Learning and skill acquisition training programs can be used to instruct personnel in the proper use of appropriate equipment and safe lifting/carrying techniques. The use of these control methodologies can increase productivity, as well as workers' physical and mental well-being.

The time it takes for a worker to become fully skilled in a job task depends on the:

- Task
- Worker's capabilities and capacities
- Environment.

Training can be accomplished through the use of lectures, simulation, videotapes, demonstration, on-the-job training, and other learning aids in the workplace.

7.1.1 Proper Use of Appropriate Equipment

Using ergonomically designed tools can help avoid UECTDs:

- Use tools with handles of appropriate size and shape, with all edges and sharp corners (with which the workers might come into contact) rounded off. Avoid narrow tool handles that concentrate large forces onto small areas of the hand or handles with preformed grips that do not fit the individual.
- Minimize vibration of powered hand tools.
- Avoid repetitive or sustained exertions, especially if they are accompanied by deviations from a straight wrist or forceful exertions.
- Keep the elbow at the side of the body, the forearm semi-pronated, and the wrist straight. Hands are stronger and less vulnerable to injury when the wrists are kept straight.

7.1.2 Safe Lifting/Carrying Techniques

Whenever possible, use material handling equipment and devices, such as forklifts, hand trucks, two-wheel dollies, etc. If manual handling is necessary, always practice safe lifting/carrying techniques. Always size up the load before attempting to lift/carry it on your own. Size up the load to determine the approximate dimension, weight, and if material handling devices or the aid of another worker will be needed. Although there are varying techniques for safe lifting/carrying that are taught which are dependant on the

specific application, the following general guidelines for lifting and carrying should be followed:

- Two-handed
- In front of the body
- No twisting
- Good handhold
- Balanced load
- Good footing and unobstructed walkways
- Unrestricted posture
- Lift and carry load as close to the body as possible
- Maintain the back in the natural posture as much as possible when lifting and carrying (natural "S" curve).

Additional training on safe lifting and carrying techniques may be warranted depending on your job duties.

8.0 SUMMARY

The use of ergonomics can help reduce both physical and mental stress in the workplace by:

- Designing the job for human capabilities and capacities
- Understanding ergonomic risk factors
- Using ergonomically-designed tools, equipment, and workstations
- Practicing ergonomic control methodologies.

Accounting for the human factors of workers can help:

- Reduce injuries, turnover, and absenteeism
- Improve productivity
- Improve morale and satisfactions.

Key concepts presented in this module are:

- General ergonomic principles, including work physiology, biomechanics, and anthropometrics
- Symptoms of common ergonomic-related disorders
- Risk factors associated with ergonomic-related disorders
- Basic considerations in job task/workstation analysis
- Methodologies for controlling ergonomic risk factors.

Measures you should take to prevent physical and mental stress:

- Know your limitations. Do not attempt to perform work beyond your physical capabilities.
- Be aware of your work environment. Take steps to counteract any associated stresses:
  - For example, if excessive noise is part of your work environment, hearing protection may
    be warranted (if noise is not controlled through other means)
  - If your work environment is too dim, provide additional lighting.
- Be familiar with the signs and symptoms of ergonomic-related disorders. Inform your supervisor or your facility's medical center if symptoms persist.
- Understand the components of job-task and workstation analysis
  - Range of motion and reach requirements
  - Exertion and strength requirements
  - Dexterity and fine motor control requirements
  - Frequency and duration
  - Furniture and fixtures
  - Comfort indices (noise, illumination, temperature, etc.).
- Use ergonomically-designed tools, if possible.
- When using hand tools, always keep the elbow at the side of the body, the forearm semi-pronated, and the wrist straight.
- Always size up a load before attempting to lift/carry it.
- Practice safe lifting/carrying techniques.

EXERCISE

Read the following questions and circle the appropriate response.

1. Ergonomics takes into account workers' physical and psychological capa-bilities. T F

2. The amount of oxygen used and carbon dioxide produced by the body is a constant, fixed rate dependent on the size and fitness of the individual. T F

3. Carpal tunnel syndrome is an ergonomic-related disorder caused by localized contact stresses. T F

4. Ergonomic risk factors include forceful exertions, repetitive motions, and awkward postures. T F

5. The time it takes for a worker to become fully skilled in a job task depends on the task, worker’s capabilities and capacities, and environment. T F

6. When using hand tools, avoid narrow loop handles that concentrate large forces onto small areas of the hand, or handles with preformed grips that do not fit the individual. T F

7. Recommendations for avoiding UECTDs include keeping the wrist slightly bent, since hands are stronger and less vulnerable to injury in this position. T F

8. If at all possible, always use material handling equipment and devices. T F

9. Safe lifting/carrying techniques should be taught to workers and practiced periodically, emphasizing good footing, unrestricted posture, and two-handed lifts in front of the body without twisting. T F

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APPENDIX A: SUMMARY OF HUMAN FACTORS/ ERGONOMIC ISSUES

A. Work Station
   - Lighting
   - Range of motion requirements
   - Furniture design
   - Convenience of raw materials and waste disposal

B. Tools and Instrumentation
   - Ease of control
   - Location and visibility of displays
   - Level of physical effort required

C. Environmental Considerations
   - Temperature
   - Relative humidity
   - Noise levels
   - Lighting
   - Indoor air quality

D. Personal Protective Equipment
   - Mobility
   - Claustrophobia and other psychological issues
   - Heat buildup
   - Visibility
   - Dexterity and tactile sensitivity

E. Emergency Equipment
   - Availability
   - Location
   - Ease of donning
   - Appropriateness to hazard

F. Lifting and Manual Handling of Materials
   - Weight
   - Location
   - Frequency
   - Duration