Chapter 2: Worksite Analysis

WORKSITE ANALYSIS OVERVIEW

The key to successful ergonomics programs are organized, orderly, and guided analyses. Work-related musculoskeletal disorders (WMSDs) can be reduced and ultimately prevented with effective surveillance. Regardless of your facility's mission, you should implement worksite analysis using the information presented in this guide. The ergonomics team, an action team, health care providers, management, and employees must join forces to perform this analysis.

Conduct Passive or Active Worksite Surveillance

There are three entry points to passive or active surveillance.

- Health care providers who are treating a worker with a suspected WMSD request analysis of the worksite through the ergonomics team. If a private physician is examining or treating a worker with a supected WMSD, refer to chapter 4 for detailed information on communicating with the Civilian Personnel Advisory Center (CPAC).
- Supervisors who are concerned about possible workplace risk factors or potential WMSDs in their work area request analysis of the worksite through the ergonomics team. Supervisors may also contact the ergonomics team on behalf of workers who have similar concerns.
- The ergonomics team initiates routine work site surveillance, either passive or active. Under either surveillance method—If no evidence of problem areas or WMSDs is found, a routine report is filed.

If there is evidence of a potential problem area, or even one WMSD is found, the ergonomics team forms an action team to conduct a focused (in-depth) assessment of the work environment.

To complete assessment of the work environment and to verify if there is evidence of a problem area or WMSD, the action team conducts a worker survey (e.g., the DoD Job Requirements and Physical Demands (JRPD) Survey) to obtain information on current and past symptoms, including the anatomical location, duration, intensity, and frequency of symptoms.

- A worker's response to a body part discomfort survey may vary over time; however, when worker responses are grouped by work area or job series, the group's responses over time are usually stable.
- These surveys can also identify problem tasks, tools, or work areas, and can be used to assess the effect of ergonomic interventions.
- If no evidence of problem areas or WMSDs is found, a routine report is filed.

If there is evidence of a potential problem area, or even one WMSD is found, the action team should use the results of the JRPD Survey to determine if the problem is limited to one individual case or is area-wide.

Passive surveillance is the systematic analysis of data provided in existing reports and data sources such as routine injury reports, OSHA logs, medical and safety records, workforce reports, and employee suggestions. Active surveillance involves actively seeking information to target and assess problematic work areas, job series, and tasks.

Assess Area-wide Hazards

If the ergonomics problem is area-wide, the action team—

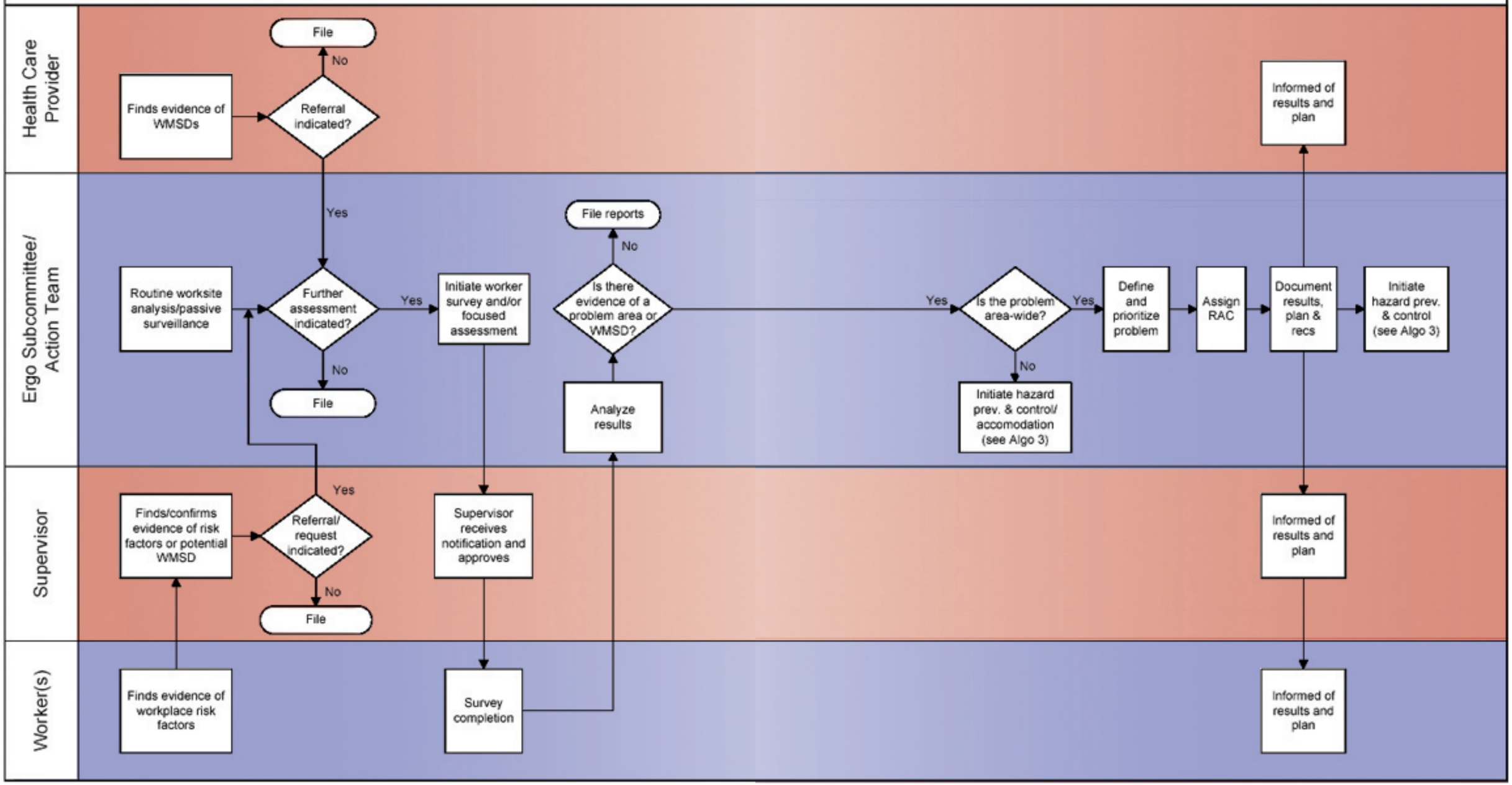
- Defines and prioritizes the problem by its severity or magnitude.
- Assigns a risk assessment code (RAC) to the problem.
  - The RAC describes the level of risk associated with an ergonomic hazard, and combines the hazard severity and mishap probability into a single numeral.
  - The RAC, coupled with the costs associated with any given intervention method, establishes the priority of the problem area.
- Initiates hazard prevention and control. See algorithm 3-1 in chapter 3.
- Initiates education and training, including job-specific training and an overview of interventions being implemented. See algorithm 5-1 in chapter 5.

Assess Individual Case Hazards

If the ergonomics problem is related to one individual case, the action team—

- Focuses on the work task(s) causing the WMSD to determine if the task under normal stressors would cause the WMSD, or if the individual affected by the task has special needs (e.g., obesity, existing handicap, etc.), which the action team will also need to address.
- Defines and prioritizes the immediacy of the problem by asking: "What costs does the WMSD present in terms of compensation, worker error, decreased pro ductivity, and worker morale?"
- Initiates hazard prevention and control. See algorithm 3-1 in chapter 3.
- Initiates education and training, including job-specific training and an overview of interventions being implemented. See algorithm 5-1 in chapter 5.

Algorithm 2. Worksite Analysis



GENERAL

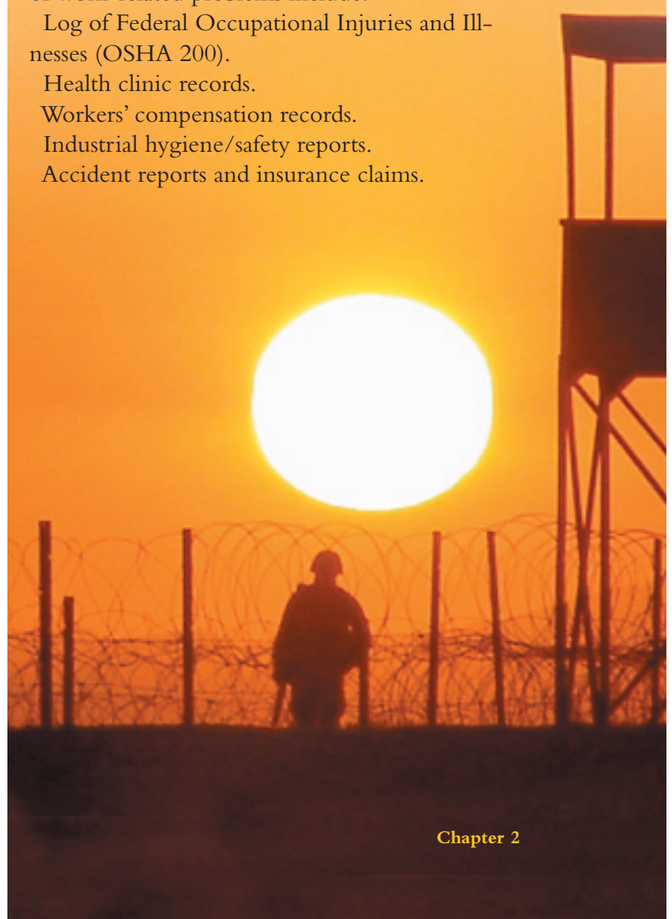
The key to successful ergonomics programs are organized, orderly, and guided analyses. Worksite surveillance is the ongoing systematic collection, analysis, and interpretation of health and exposure data used to identify, record, and track work-related musculoskeletal disorders (WMSDs). Effective surveillance can help reduce and prevent WMSDs if it is used to determine the need for action, and to plan, implement, and evaluate ergonomic interventions and programs.

Worksite analysis includes both passive and active surveillance. These analyses target problem work areas, job series, and tasks for in-depth assessment and intervention.

Passive Surveillance

Passive surveillance is the systematic analysis of data provided in existing reports and data sources such as routine injury reports, logs, summaries of occupational injuries and illnesses, Federal Employees Compensation Act (FECA) claims, medical and safety records, and work force reports and suggestions. The primary purposes of passive surveillance are to establish a baseline level of WMSDs and to identify and target potential problem areas. Both military and civilian workers should be included in the passive surveillance effort. Some of the best sources of data for trend analyses and the identification of work-related problems include:

- Log of Federal Occupational Injuries and Illnesses (OSHA 200).
- Health clinic records.
- Workers' compensation records.
- Industrial hygiene/safety reports.
- Accident reports and insurance claims.



Military Data Sources.

The best source of general military injury and illness data is the Defense Medical Surveillance System (DMSS). This database provides data on hospitalizations and clinic visits that can be segmented by ICD-9 diagnosis, location, MOS, gender, age group, or rank. To register to access this data through the Defense Medical Epidemiologic Database (DMED) Web site, contact http://amsa.army.mil.

Civilian Data Sources.

Workers' compensation records can provide a good source of information for potential problem areas. The DoD Injury Compensation/Unemployment Compensation (ICUC) database is the best source of compensation information. Your local FECA claim coordinator has access to this system.

Injury Codes.

Supervisors, the ergonomics team, health care providers, and trained ergonomics personnel should collect and analyze these data routinely (e.g., quarterly), depending on the risk of injury. Classifying the WMSD according to the current International Classification of Disease (ICD) codes is common and allows comparisons among work areas, job series, and tasks. Table 2-1 lists the ICD-9 codes and Department of Labor (DOL) Nature of Injury (NOI) codes that are typically related to ergonomic design issues.

Table 2-1. ICD-9 and NOI Codes

Body Part	ICD-9 Code	Diagnosis	OWCP Code	OWCP Descriptor	OWCP NOI	NOI Descriptor
Upper Quarter	354	Mononeuritis of Upper Limb and Mononeuritis Multiplex	DB	Occupational Back Strain; Back Sprain	DA	Arthritis, Bursitis
Upper Quarter	355	Mononeuritis of Lower Limb and Unspecified Site	DB	Occupational Back Strain; Back Sprain	DA	Arthritis, Bursitis
Joint, Nonspecific	715	Osteoarthrosis and Allied Disorders	DB	Occupational Back Strain; Back Sprain	DA	Arthritis, Bursitis
Knee/Leg	717	Internal Derange-ment of Knee			D9	Disability, Unclassified
Spine, Nonspecific	721	Spondylosis et al.				
Spine, Nonspecific	722	Intervertebral Disc Disorder				
Spine, Cervical	723	Other Disorders of Cervical Region			D9	Disability, Unclassified
Spine, Nonspecific	724	Back Disorder Not Elsewhere Classifiable and Not Otherwise Specified				
Soft Tissue, Nonspecific	726	Peripheral Enthe-sopathies and Allied Syndromes	DB	Occupational Back Strain; Back Sprain	DA	Arthritis, Bursitis
Soft Tissue, Nonspecific	727	Other Disorders of Synovium, Tendon, and Bursa	DB	Occupational Back Strain; Back Sprain	DA	Arthritis, Bursitis
Wrist/ Hand	728.4	Laxity of Ligament			D9	Disability, Unclassified

Table 2-1. ICD-9 and NOI Codes Continued

Body Part	ICD-9 Code	Diagnosis	OWCP Code	OWCP Descriptor	OWCP NOI	NOI Descriptor
Soft Tissue, Nonspecific	729	Other Disorders of Soft Tissues	DB	Occupational Back Strain; Back Sprain	DA	Arthritis, Bursitis
Shoulder/ Arm	840	Sprains and Strains of Shoulder and Upper Arm			D9	Disability, Unclassified
Elbow/ Forearm	841	Sprains and Strains of Elbow and Forearm			D9	Disability, Unclassified
Wrist/Hand	842	Sprains and Strains of Wrist and Hand			D9	Disability, Unclassified
Hip/Thigh	843	Sprains and Strains of Hip and Thigh			D9	Disability, Unclassified
Knee/Leg	844	Sprains and Strains of Knee and Leg			D9	Disability, Unclassified
Ankle/Foot	845	Sprains and Strains of Ankle and Foot			D9	Disability, Unclassified
Spine, Lumbo-sacral	846	Sprains and Strains of the Sacroiliac Region			D9	Disability, Unclassified
Spine, Nonspecific	847	Sprain of Back Not Elsewhere Classifi-able/Not Otherwise Specified				
Body, Nonspecific	848	Sprain Not Else-where Classifiable	DB	Occupational Back Strain; Back Sprain	DB	Occupational Back Strain; Back Sprain

Rate Calculation.

Incidence, prevalence, and severity rates are based on 100 worker-years per year. The rates should be calculated for all WMSDs. To target specific problem areas or jobs, categorize the rates by body part for each department, job series, work area, or process to target specific problem areas or jobs.

While the DoD recommends calculating rates monthly, the timeframe for calculating rates at each location is a local decision.

Table 2-2.

Type	Rate (per 100 worker-years per year)	Numerator/ Denominator
New Cases	Incidence	# new cases during the past 12 months x 200,000 hours / # work hours during the past 12 months
All Cases During Period	Prevalence	total # cases in the past 12 months x 200,000 hours / # work hours during the past 12 months*
All Cases Resulting in Lost Workdays	Severity	# lost workdays during the past 12 months x 200,000 hours / # work hours during the past 12 months*

*If the specific number of work hours during the past 12 months is not available, multiply the number of full-time equivalent employees in each area by 2,000 hours to obtain the denominator.

The example to the right illustrates the information presented in table 2-2:

- Work area Y has 30 full-time workers. Over the past 12 months, 4 workers have developed WMSDs, bringing the total number of workers with WMSDs to 7. There were a total of 45 lost workdays over the past year due to WMSD conditions

To calculate the incidence rate:

$$\frac{4 \text{ cases X } 200{,}000 \text{ hours}}{(30) \text{ X } 2{,}000 \text{ hours}} = 13.3 \text{ cases per 100 workers}$$

To calculate the prevalence rate:

$$\frac{7 \text{ cases X } 200{,}000 \text{ hours}}{(30) \text{ X } 2{,}000 \text{ hours}} = 23.3 \text{ cases per 100 workers}$$

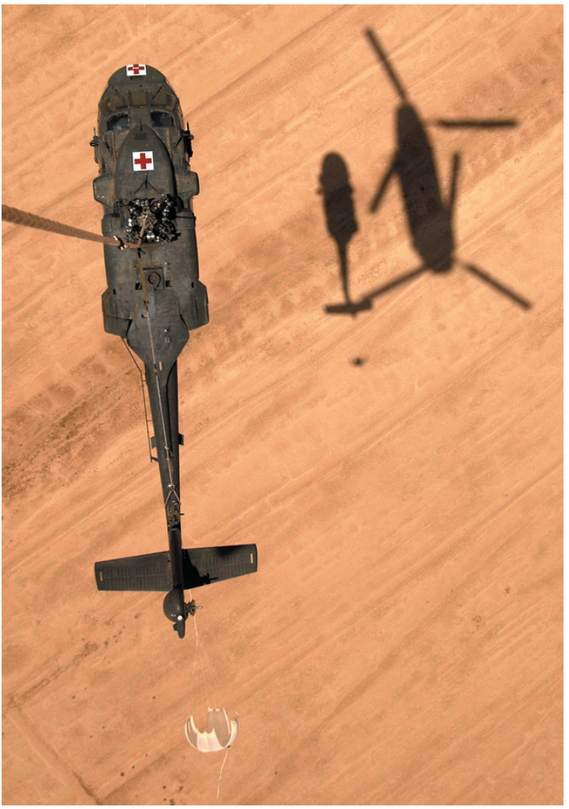
To calculate the severity rate:

$$\frac{45 \text{ lost workdays X } 200{,}000 \text{ hours}}{(30) \text{ X } 2{,}000 \text{ hours per 100 workers}} = 150 \text{ lost workdays per 100 workers}$$

Passive surveillance is limited by the quality of collected data. Data may be incomplete, inaccurate, or inconsistent. Data quality can be affected by maagement's attitudes, peceived or real disincentives to reporing, training provided to the personnel responsible for data input, different coding systems, and differences in medical practitiners' diagnoses. Underreporting of conditions can be a serious problem. Many workers delay seeking medical care and reporting conditions until the condition has become functionally limiting.

Active Surveillance

Active surveillance involves actively seeking information to target and assess problematic work areas, jobs series, and tasks. The advantage this method offers over passive surveillance is a greater degree of sensitivity, which can help identify symptoms that indicate early or developing WMSDs. Early intervention or prevention programs can be more focused and effective with active surveillance.
For example, the action team can use worker surveys to obtain information on current and past symptoms, including the anatomical location, duration, intensity, and frequency of symptoms.



See appendix 2A for a sample of the risk factor/discomfort survey being used by the DoD.

Worker surveys and questionnaires—
- Are generally easy and inexpensive to ad minister.
- Provide a quick way to identify workers' perceptions of discomfort and the sources of discomfort.
- Identify problems that otherwise might go unreported.

Worker surveys should be conducted—
- When passive surveillance indicates an in crease in WMSDs.
- Before and after the initiation of new jobs, tasks, tools, or processes.
- When a worker is hired or transferred in order to establish a baseline.

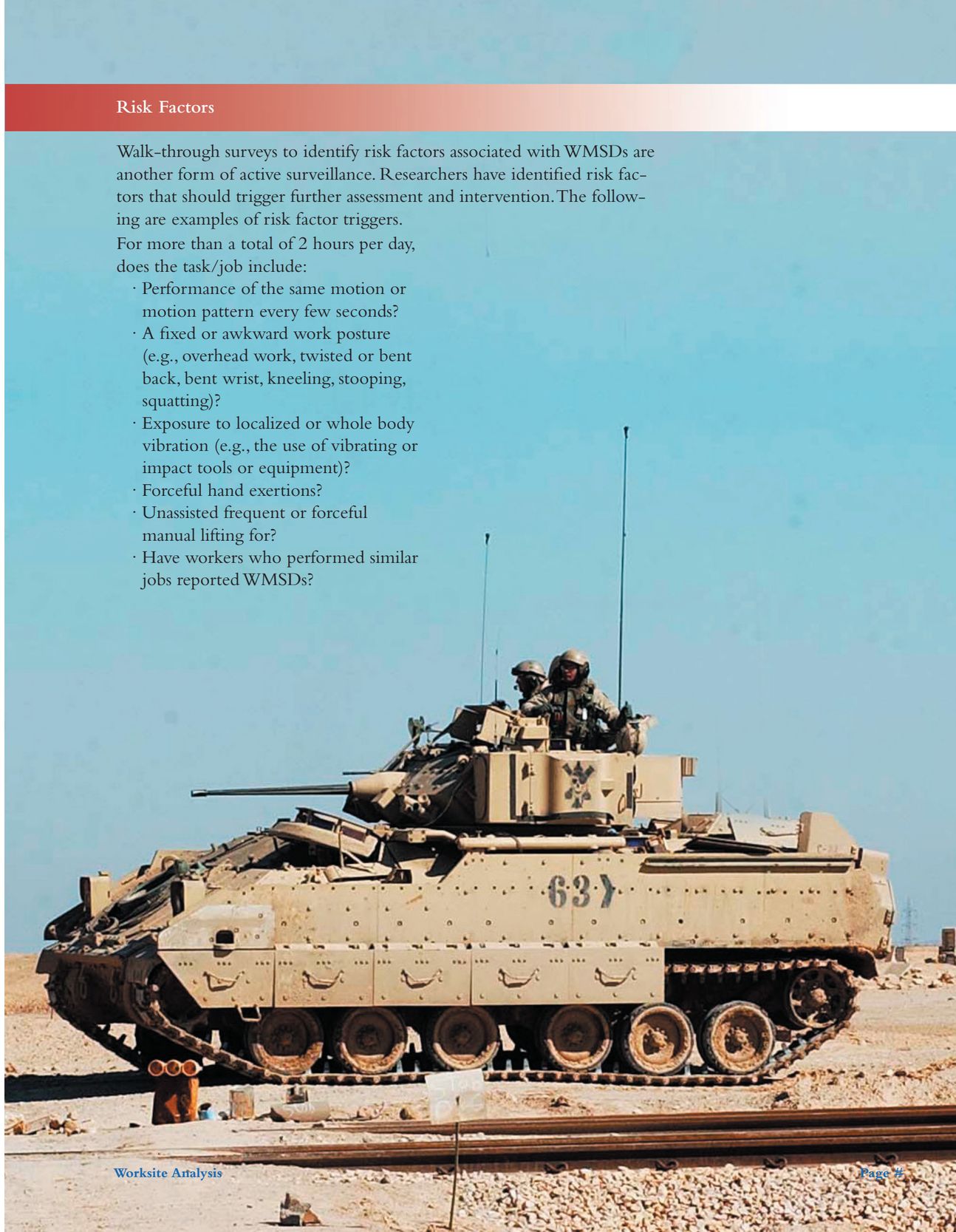
Active surveillance worker surveys are limited by the workers' comprehension of the survey purpose and questions (including language barriers with some non-Englishspeaking workers) and the accuracy of the workers' responses. Researchers have found gender, age, and cultural biases in reporting symptoms in worker surveys.

Questions have been raised about the effect of repeatedly using the same questionnaire for the same worker population; however, no controlled study addressing these questions has been conducted.

An individual worker's response to a body part discomfort survey may vary over time; however, when worker responses are grouped by work area or job series, the group's responses stabilize over time. These surveys can identify problem tasks, tools, or work areas and can be used to assess the effect of ergonomic interventions.

Risk Factors

Walk-through surveys to identify risk factors associated with WMSDs are another form of active surveillance. Researchers have identified risk factors that should trigger further assessment and intervention. The following are examples of risk factor triggers.
For more than a total of 2 hours per day, does the task/job include:
- Performance of the same motion or motion pattern every few seconds?
- A fixed or awkward work posture (e.g., overhead work, twisted or bent back, bent wrist, kneeling, stooping, squatting)?
- Exposure to localized or whole body vibration (e.g., the use of vibrating or impact tools or equipment)?
- Forceful hand exertions?
- Unassisted frequent or forceful manual lifting for?
- Have workers who performed similar jobs reported WMSDs?



Getting Started

Effective surveillance can help reduce and prevent WMSDs if it is used to determine the need for action, and to plan, implement, and evaluate ergonomic interventions and programs. Table 2-2 presents a snapshot of "what, who, how, and when" for each surveillance or analysis method.

2-2. Analysis Process Factors

Variable	What	Who	How	When
Passive Surveillance	Existing data analysis	• Ergonomics team • Action team • Health care providers • Management • Employees	Data analysis • Incidence rates • Prevalence rates • Severity rates • OSHA 200 log • Compensation cases • IH/Safety reports • DMED	Local decision, e.g.: • Quarterly
Active Surveillance	Worker surveys and questionnaires	• Ergonomics team • Action team • Management • Employees	Worker group targeted by job series, area, task	Local decision, e.g.: • One WMSD, so survey to define the extent of the problem • Potential problem identified through complaint, supervisor report, or walk-through inspection • After training • Newly assigned personel • Change in job, task, tools, or processes
	Identified workplace risk factor(s)	• Ergonomics team • Action team • Supervisor • Worker groups	• Direct observation • Checklist	Local decision, e.g.: • Periodically • With change of new process, equipment, or task

2-2. Analysis Process Factors

Variable	What	Who	How	When
Identified workplace risk factor(s)	• Prioritization of ergonomics concern for indepth analysis and intervention • Determination of area/job series-wide problem vs. individual	WMSD case • Ergonomics team • Action team • Health care providers • Management	• Supervisor Local criteria, e.g.: • Cost • Number of workers affected • Severity	• RACs Local decision, e.g.: • Within 1 week of problem determination
High-Risk Targeting (if needed)	Identification of high-risk components of complex jobs or work areas	• Ergonomics team • Action team • Supervisor • Worker (focus) groups	• Review of documents (job descriptions, safety reports) • Focus group dicussions	Local decision, e.g.: • Based on prioritization, but not more than 2 weeks after prioritization
Assessment Method Determination and Investigation	Decision on method of assessment • Checklist • Risk factor assessment • In-depth survey	• Ergonomics team • Action team • Management • Supervisor	Local decision based on criteria, e.g.: • Complexity • Criticality of problem	Local decision, e.g.: • Based on prioritization, but not more than 2 days after high-risk targeting

Setting Priorities

The presence of any risk factor(s) or even one WMSD requires further investigation, a detailed job analysis, and intervention. When prioritizing jobs or work areas for indepth assessment and intervention, consider—

- The number of workers affected.
- High incidence or prevalence rates.
- Case severity.
- Exposure time of risk factors.
- Reported/unreported symptoms.

Jobs undergoing major changes in process or products, or where the interventions can be easily accomplished, should also receive priority consideration.

If the work area poses no risk to the "typical" worker (e.g., someone who is not bothered by the normal physiological stress found in the work area), then the action team should manage the problem as a single WMSD case.

The team should provide special accommodations for a worker whose tolerance capacity is below the level necessary for a specific work area (e.g., due to a previous injury, medical condition, or extreme anthropometric limitations).

Symptoms of WMSDs are best measured by conducting a JR/PD survey. Appendix 2A is a sample DoD JR/PD survey that the action team can use to assess workers' job requirements and physical demands.

Basic Work Area Information

An action team should be formed, or areas of responsibility should be identified (e.g., who is responsible for office/industrial areas), to investigate potential problem areas. The action team should initially collect descriptive work area information, including the demographics of the workers, the tasks performed in the work area, the products produced in the work area, and the specifics of the workstation.

Demographics.

Demographic information should include:

- Number of workers assigned to the area or job series.
- Age and gender distribution of the workers.
- Length of the workday and daily break schedule.
- Any special administrative arrangements such as job rotation plans or flex schedules.
- Length of time at a particular task or job.

Tasks.

Task-related information should include:

- Description of the task.
- Task objective.
- Percentage of the day spent performing the task.
- Task pacing (e.g., continuous or intermittent, machine-paced, or self-paced).

Products.

If a specific product is produced, the action team should identify:

- Weight and dimensions.
- Cost of producing a unit.
- Production rate and quotas.
- Error rate and any error penalties for the workers.

Targeted Assessments

The action team should conduct an in-depth assessment of the work environment once problem areas or job series have been identified and prioritized. The four basic components of the work environment—the workstation and physical environment; specific tasks; tools, equipment, and containers used in performing the tasks; and employee characteristics—are outlined in table 2-3.

Table 2-3. Basic Components of the Work Environment

Workstation and Physical Environment Features	Task Features	Tools, Equipment, and Containers Features	Employee Characteristics
Benches Chairs Checkout stand Controls and displays Lighting Mats Noise level Shelves Stools Storage bins Tables Temperature Vehicle cab	Job content (simple, routine, or complex, variable) Level or amount of autonomy Pacing Training Work scheduling	Assembly parts Boxes Components Hand tools Keyboards Machines Power tools	Anthropometric dimensions Endurance Range of motion Strength Sensory status (visual, tactile, perception)

Many methods are available for assessing the work environment. If the worker performs only a few distinct tasks daily, the assessment can be easily focused on these tasks. If the job is variable (i.e., there are a variety of tasks that may be performed by the worker), the action team must go through a high-risk task focusing process.

High-Risk Task Focusing.

Many jobs require high-risk task focusing. For example, mechanics generally have a high rate of back injuries. However, assessing mechanics' jobs is problematic due to the random order of the wide variety of tasks they perform. These tasks are based on the repair needs of the vehicles or machinery and the variety of work techniques used among the workers. The task-focusing process uses information from the workers' job descriptions, injury report data, and the input of the workers. The process involves classifying and sub-classifying workers to a level where most of the workers in the group are exposed to the same risk factors.

Data can be gathered by questionnaire for larger groups, but smaller focus groups are more effective when identifying high-risk tasks. Once the action team establishes similar exposure groups, a select number of "experts" from that group are chosen to identify the high-risk tasks. The size of the group depends on the size of the work force and the expertise of the workers.

The workers should be asked to identify major problem areas, physically demanding high-risk tasks, workstation design problems, and tool and equipment concerns. Focus the discussion by asking about specific elements of the job description (e.g., the requirement to occasionally lift 75 pounds) and injury histories. The workers' familiarity with the job is critical. The entire exposure group of workers should then receive training in the risk factors for WMSDs and typical workstation problems, concerns, and solutions.

Site Analysis

Once a small number of high-risk tasks, workstation design problems, or tool and equipment concerns have been identified, the assessment process becomes straightforward. All of the ergonomic assessment methods focus on the basic risk factors of awkward posture, repetition, mechanical compression, vibration, force, temperature extremes, and duration/recovery time. The risk for developing a WMSD increases as exposure to a single risk factor or a combination of risk factors increases.

Checklist Assessments

There are a variety of checklist assessments available for the action team. Checklists can be used in regular, periodic surveys, or to initially assess high-risk work areas and tasks. Most of these checklists address the basic recognized risk factors and have a scoring mechanism to quantify risk. Checklists are quick, easy-to-use assessments and require a minimum of training. However, checklists are limited by a narrow focus on common risk factors and do not cover the entire spectrum of risk factors that may be present at a specific worksite. Some of the checklists focus on a specific element of the work environment, such as a particular tool or the chair. Other checklists examine posture, repetition, and duration factors

See appendix 2B for sample checklists. See chapter 5 for more information on training requirements under the ergonomics program.

Detailed Assessments

The action team should have several tools available for the detailed assessment, including a—

- Video camera to record workers' postures and movements during specific tasks.
- Tape measure to capture workstation dimensions and reach distances.
- Timer or stopwatch to measure the duration of a specific task, subtask, or break from the task.
- Force gauge or spring scale to measure push or pull forces or the weight of tools, products, or objects.

The videotape is an essential tool in the assessment process. The tapes provide a permanent record of the activity and allow the ergonomist to assess motions and postures in slow motion. Videotapes also serve to enhance ergonomic training and demonstrations.
Conduct the following actions during the pre-survey:

- Check equipment.
- Obtain approvals and schedule taping.
- Verify presence of electrical outlets, if needed.
- Verify lighting conditions and bring lighting equipment, if needed.
- Use a tripod to support the camera, if needed.

The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) has developed an inclusive survey form for use during detailed assessments. This form is available from the Ergonomics Program Web site: http://chppmwww. apgea.army.mil/ergopgm/Tools/checklist.pdf

Conduct the following actions during the survey:

- Identify the video segment on a piece of paper, and film this piece of paper for 3 seconds at the beginning of the video.
- Activate the time/date indicator if the camera has this feature.
- Select views that will maximize description of movement.
- Initially, record the worker's whole body posture and entire work area.
- Select views 90° from each other.
- Film at least 10 cycles if the job is repetitive.
- If several people perform the job, film two to three employees doing the same job.
- Focus on overexertion or fatigue conditions.
- Frame each view with common reference points.
- If multiple tasks are involved in a process, tape the tasks in order.

Team Preparation

Thorough planning before the site survey is critical. Action team members should be assigned specific tasks, including:

- Taking workplace measurements.
- Interviewing supervisors and workers.
- Sketching and note taking. Make sure to note the locations of equipment, fixtures, etc., on the sketch, and identify:
  - Dimensions of surfaces.
  - Reach distances.
  - Clearances.
  - Travel distances.
- Videotaping.
- Identifying and measuring risk factors.

Schedule the survey when the tasks of interest are being performed and subjects are available. Every effort must be made to minimize disruption to the workplace and record a representative "picture" of the tasks.

Sampling Strategies

The action team determines the most appropriate sampling strategy for the tasks of interest. Sampling strategies may be classified as:

- Random interval sampling, or observing/evaluating the worker(s) at randomly selected time intervals (e.g., 15-, 22-, and 61-minute intervals).
- Fixed interval sampling, or observing/evaluating the worker(s) at specific time intervals (e.g., every 30 minutes).
- Selected interval sampling, or observing/evaluating the worker(s) at a specific time during the day or during a specific task/subtask.
- Continuous sampling, or observing/evaluating entire work processes.

The type of work performed, the variability of subtasks, the objectives of the assessment, and methodological constraints determine the choice of sampling strategies. Continuous sampling is the most involved approach and requires sophisticated instrumentation and computer assistance. However, this approach provides the most accurate and meaningful data, including an estimate of the percentage of time the worker spends in an awkward posture, in a repetitive activity, applying force, exposed to vibration, or using a particular tool or piece of equipment. In most instances, fixed or selected interval sampling of target high-risk tasks will provide sufficient information for the worksite assessment.

Special Task Features

The action team should assess the special features of the task, including the use of hand tools, gloves, prolonged standing, prolonged sitting, and materials handling. Each is discussed below. These special features also include exposure to vibration and poor lighting conditions, which are discussed later as biomechanical/environmental risk factors.

Hand Tools.

Hand tools are used in numerous jobs. Poorly designed tools that require the employee to assume awkward postures, apply excessive force, or perform the same motion repeatedly can be particularly problematic. These tools can stress the entire upper extremity and contribute to WMSDs.

Gloves.

Gloves are required in certain work areas to protect the hands from physical hazards including chemicals, temperatures, abrasives, and biological contaminants.
Management should review each work area's personal protective equipment (PPE) hazard assessment document, which is an OSHA requirement established in 29 CFR 1910.132(d), to determine if gloves are required, and if so, what type.

Gloves reduce dexterity and tactile feedback, causing the worker to increase his or her grip force. Working with tight-fitting gloves or bulky gloves also increases the force applied. Proper fitting gloves in good repair that provide the required protection are critical. The action team should assess the function, condition, type, and fit of work gloves.

Other specifications that the team should use when assessing a worker's chair are located in the "Chair Evaluation Checklist" found in appendix 2B. General information on chair controls and computer workstation measurements can be found in the DoD information guide, Creating the Ideal Computer Workstation.

Prolonged Standing.

Prolonged standing, especially on a hard surface, increases lower extremity and back discomfort. If prolonged standing is required, assess the standing surface, shoes, and activity. Antifatigue matting should be at least ½-inch thick and made of a firm, resilient material. There are a wide variety of mats available to accommodate specific workplace requirements (e.g., water drainage, antistatic, or chemical resistance). If standing and moving is required, assess the workers' shoes for cushioning. Task requirements during standing should be noted, especially any requirement to operate foot pedals. Using foot pedals while standing causes extreme and awkward hip and back postures. The team should also note if a sit-stand stool would be feasible given the work situation and task requirements.

Prolonged Sitting.

Prolonged sitting can lead to back and lower extremity problems, especially when the chair does not properly fit the worker or the type of work. Most chairs are designed for people weighing no more than 275 pounds. If the worker weighs more than 275 pounds, he or she will need a chair designed to support their additional weight. Hard, unpadded, and flat seat pans are uncomfortable for periods over 1 hour. Soft, deeply padded seat pans cause the worker to sink too far into the seat, transferring the weight load from the buttocks to the surrounding tissues. Over extended periods of time, this causes tension in the hip muscles.

Materials Handling.

Materials handling problems can be assessed in a variety of ways. Generally, a combination of these methods provides a more complete picture of the problem. These methods include checklists and standardized assessments of the task and workstation. The critical factors in any assessment of a
materials handling task include:

- Distance of the load from the spine and distance of the load from the floor. As the load moves away from the spine and above or below the critical "strike zone" between the thighs and shoulders, the biomechanical stress on the worker increases greatly,also increasing the risk of injury.
- Twisting involved in the task. Any twisting decreases the stability of the spine, increasing the probability of injury.
- Frequency and duration of the task. As the frequency and duration of the task increase, there is less time for the tissues to recover from the physiologic stress, again increasing the probability of injury.

Energy Expenditure

The action team should assess the energy requirements of the work and determine if recommended energy levels are exceeded, requiring increased rest periods to recover from the physiologic stress. Recommended eergy expenditure limits are based on the daily workload. This workload should not exceed 35 percent of a person's maximum aerobic power over an 8-hour day. This represents approximately 5 kilocalories (kcal)/min for men and 3.35 kcal/min for women. The heart rate should not exceed 115 beats/min for aerobic exercise, 112 beats/min for leg work, and 99 beats/min for arm work.

Table 2-4 presents approximate energy expenditure rates for various types of work. The table estimates are based on an average-size worker and should be adjusted for the individual worker's weight. For every 10 pounds the worker is overweight or underweight, 0.1 kcal/min should be added/subtracted. The actual energy expenditure of the worker depends on his/her health, experience, conditioning, and age.

See appendix 2C for a discussion of the NIOSH Lift Equation and the Lift Index.

Table 2-4. Energy Expenditure Rates for Various Types of Work

Type of Work	Typical Task	Energy Expenditure (kcal/min)
Light hand work, sitting	Writing	1.6
Moderate hand work, sitting	Soldering	2.2
Moderate arm work, sitting	Hammering	3.0
Moderate body work, walking	Pushing wheelbarrow	5.0
Heavy arm work, standing	Sawing wood	6.8
Heavy body work, walking	Pushing manual lawnmower	7.7
Very heavy body work, standing	Chopping tree with ax	8.0
Very heavy arm work, standing	Shoveling continuously	8.5

Source: Sanders and McCormick, 1992.

Task Analysis

Task analysis includes many assessment methods that observe human behavior in a task and record task elements and demands. These elements and demands are compared to human capabilities to determine if modification, redesign, controls, or automation are required. Task analysis methods include:

- Motion analysis, which identifies excessive repetitions and awkward and static postures.
- Timed activity analysis.
- Time and motion analysis. (kcal/min)

Task analyses break tasks down into component elements and may subdivide the elements to the motion or micro-motion level. There are five types of information used in task analyses:

- Sequence of activities.
- Duration of activities.
- Frequency of activities.
- Fraction of time (of a person, machine, or work unit) exposed to specific workplace risk factors or activities.
- Spatial movements.

One of the most useful approaches to ergonomic assessment combines the task analysis methodology with the approach that researchers recommend for ergonomic job analysis. The task analysis records the job, task, work cycle time, and specific component steps in the task. These component steps are then examined for workplace risk factors by affected body part. Other questions the action team may ask during a task analysis include:

- What is the task's name?
- What is the task's objective or end result?
- How many workers perform this task?
- How much of the day is spent performing the task?
- Is the task continuous or intermittent?

Risk Factor Considerations

Considering risk factors as part of the overall ergonomics assessment requires some qualitative expert judgment as well as comparing observations to specific criteria (e.g., joint angles—elbows, wrists, etc.). The frequency and duration of exposure to risk factors may also affect how you assess or correct ergonomics problems. However, no specific guidelines exist on duration, though a number of scientifically validated thresholds and many expert opinions are available. Therefore, use your best professional judgment and remember:

- Duration is the amount of time a worker is exposed to the risk factor.
- Frequency is the number of times a task occurs or is performed.
- Prolonged exposure increases local and generalized fatigue and tissue stress.
- As the frequency and duration of exposure increases, the required recovery period increases proportionally.

Workplace risk factors, as well as some environmental factors like temperature extremes and lighting conditions, are presented below.

Repetition. Repeated motions or tasks increase fatigue and muscle-tendon strain. Highly repetitive tasks often prevent adequate tissue recovery from the effects of awkward postures and force. The level of risk from repetition varies by body part.

Force. Forceful exertions increase the physiologic stress to muscles, tendons, and joints. Muscles fatigue faster as the force exerted increases. Force increases with—

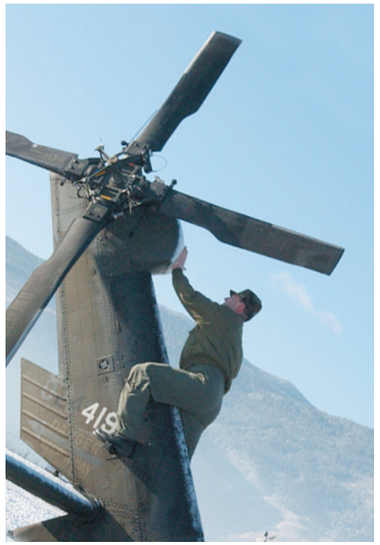
- Object weight.
- Load distribution characteristics (shifting or bulky loads require more force exertion).
- Friction (slippery objects or surfaces require more force).
- Awkward postures.
- Vibration (localized hand tool vibration increases grip forces).
- The type of grip (a pinch grip places three to four times more force on tendons than a power grip).

Mechanical Compression or Contact Stress. Mechanical compression, such as grasping a tool or using a pinch grip, creates pressure over a small area. Mechanical compression can be caused by hard or sharp objects, the sharp edge of the desk, and small diameter handles. This compression interferes with blood flow and nerve function.

Posture.
Awkward postures require increased muscle force; contribute to muscle fatigue, tendon fatigue, and joint soreness; and increase forces on the spine. Figure 2-2 identifies the optimal position and angle of various body parts during work activities. It also presents the angles at which body parts will experience minimum, moderate, and severe stress.

Figure 2-2. Posture Positions and Angles

Joint and Position	Optimal	Minimal Stress	Moderate Stress	Severe Stress
Neck				
Forward flexion	0-10o	11-15o	16-20o	21-30o
Extension	0-5o	6-10o	11-15o	16-20o
Rotation	0-15o	16-25o	26-35o	36-45o
Side bend (Lateral)	0o	1-5o	6-10o	11-15o
Back				
Twist	0o	1-5o	6-10o	11-15o
Forward bend	0o	1-10o	11-20o	over 20o
Shoulders				
Side reach	0-5o	6-15o	16-25o	over 26o
Forward reach	0-25o	26-45o	46-90o	over 91o
Across body reach	0-10o	11-15o	16-20o	over 21o
Elbow flexion	60-90o	91-105o	106-120o	121-135o
Forearm rotation—pronation/supination	0o	1-20o	21-35o	36-50o
Wrist				
Extension	0o	1-20o	21-35o	over 36o
Flexion	0o	1-15o	16-35o	over 36o
Deviation	0o	1-10o	11-15o	over 16o
Hips				
Standing	0o	1-5o	6-10o	11-15o
Sitting	90o	91-100o	101-110o	over 110o
Knees				
Standing	0-95o	96-110o	111-130o	over 130o
Sitting	0-95o	96-110o	111-130o	over 130o
Ankles				
Upward flexion	90o	89-85o	84-80o	79-75o
Downward flexion	90-105o	106-115o	116-125o	126-135o



Vibration. Force and acceleration play an important role in ergonomics. Occupational vibration sources include motor vehicles (e.g., heavy equipment, buses) and various hand-held power tools that may contribute to worker discomfort and ultimately lead to worker injury. For practical purposes, just the presence of vibration in the workplace should be noted as a potential risk factor. Remember to consider the frequency and duration of exposure to the vibration in your observation.

If a detailed analysis is necessary, it should include force and tri-axial acceleration measurements to evaluate the occupational vibration components. When evaluating hand-arm vibration, surveyors should use the American National Standards Institute (ANSI) S3.34-1986 and the hand-arm vibration threshold limit values (TLVs®) of the American Conference of Governmental Industrial Hygienists (ACGIH). When evaluating whole-body vibration, surveyors should follow procedures in ANSI 3.18-1979 and the ACGIH TLVs for whole body vibrations.

Temperature. In their booklet on TLVs, the ACGIH (2001) recommends temperature limits for bare skin exposure by type of activity. Exposure to temperatures below these levels may—

- Reduce the dexterity and sensitivity of the hand.
- Increase grip force.
- Exacerbate the effects of localized vibration.

Prolonged contact between the bare hand and metal surfaces below 59°F (15°C) may impair dexterity, and contact with metal surfaces below 44.6°F (7°C) may induce numbness. Table 2-4 presents additional guidance on temperature exposure limits by activity.

Table 2-4.

Activity	Temperature Limits for Bare Skin Exposure
Sedentary work	60oF (15.5oC)
Light work	40oF (4.4oC)
Moderate work (fine manual dexterity not required)	20oF (-7.0oC)

Lighting. Inadequate lighting or direct or indirect glare can force the worker to assume awkward and fixed postures. Inadequate lighting during inspection tasks or video display terminal (VDT) work often leads to eye strain.

The lighting levels described in table 2-5 represent the minimum level for each activity. These levels do not indicate the level for maximum worker productivity. The amount of light needed for maximum visual efficiency varies with the worker's age (e.g., older workers require more light).

Table 2-5.

Type of Work	Examples	Recommended Light Level (lux)*
General	Storeroom	80-170
Moderately precise	Packing, simple assembly	200-250
Video display terminal	Data entry	500-600
Fine work	Reading, writing, book-keeping, fine work on machines	500-700
Very fine to precise	Technical drawing, watch making, testing electrical equipment	1,000-2,000

*1 lux = 0.929 footcandle.

Risk Factor and Body Part Analysis

The task components responsible for identified risk factor exposures are recorded by affected body part in an analysis table. For example, a mechanic's task of removing a tire requires the subtask of removing the lug nuts. This subtask involves the use of a pneumatic drill to remove the nuts. The subtask exposes the hand to vibration, the hand and arm to forceful exertions, the hand to mechanical compression (depending on the shape of the handle), and the hand, arm, and shoulder to awkward postures. These exposures are recorded in the analysis table by subtask number for each risk factor identified and body part affected.

This analysis process allows the team to identify the subtasks responsible for high exposures to the risk factors and the body parts most frequently exposed to these risk factors. Often intervention strategies are easily identified after this focusing analysis is completed.

Figure 2-3a shows a sample task description and, in combination with figure 2-3b, often helps the action team identify strategies more easily.

Figure 2-3b presents a sample risk factor analysis and task description.

Figure 2-3c presents a sample survey summary table for the ergonomics subcommittee to use when summarizing the risks associated with specific tasks for upper management.

Risk Assessment Codes and Ergonomics

The bottom line for all preventive medicine programs is to reduce or avoid the costs of clinic visits, hospitalization, lost time, disability, rehabilitation, and death. The ergonomics program is no exception. Therefore, a model for estimating costs of ergonomics hazards was developed. This model quantifies the costs that prevention avoids. Risk assessment codes (RACs), in conjunction with the cost effectiveness index, are used to establish a priority listing of abatement projects.

If an area-wide ergonomics problem is discovered, the action team appointed to the surveillance of the area assigns a RAC to the problem to define its severity or magnitude. The RAC—

- Describes the level of risk associated with an ergonomics problem, and combines the hazard severity and accident probability into a single numeral.
- Coupled with the costs associated with any given intervention method, establishes the priority of the problem area.

One model for assigning RACs to ergonomics hazards is presented in appendix D. This model should support the action team and the ergonomics subcommittee in quantifying the risk of ergonomics hazards, improving the understanding of a stated ergonomics risk, and assisting management in making intervention decisions. Limitations of the Model. Since no clear thresholds exist for ergonomic hazards, the model and its components are presented as a starting point. The action team must use professional judgment in evaluating the hazard severity in terms of hazard intensity and exposure time.

Use the information in chapter 3 as your guide for prescribing appropriate interventions.

Mechanic's Task

The mechanic's task of removing a tire* requires the following subtasks:

1. Stabilize car (e.g., wheel blocks, hand brake).
2. Position car jack.
3. Remove hubcap (if present).
4. Loosen tire nuts with pneumatic wrench (not completely removed).
5. Raise car jack.
6. Remove nuts with pneumatic wrench.
7. Remove tire.

Once the task is broken down, the action team can analyze each subtask separately. By using the table in figure 2-3b, and applying the number of the subtask to the affected body part and the encountered workplace risk factor, the action team can create a summary of the most stressful or highest risk portions of the overall task.

*Replacing the tire also needs to be considered in exposure to risk factors. It is similar to the task of lifting.

Figure 2-3b. Sample Risk Factor and Body Part Analysis

Body Part	Workplace Risk Factors				
	Position	Force	Repetition	Mechanical Stress	Vibration
Neck					
Back	7	7			
Shoulder	4, 6, 7	4, 6, 7			4, 6
Arm	4, 6, 7	4, 6, 7		4, 6	4, 6
Hand/Wrist	6	7		4, 6	4, 6
Legs	7	7			
Feet					

By applying the number of each subtask outlined in figure 2-3a to the table above, the action team can determine which body part is affected by which workplace risk factor during which subtask.

To summarize this example, the most stressful/highest risk portions of the mechanic's task of removing a tire are the nut loosening and removing and the tire removal. The body parts primarily affected by these subtasks are the back and upper extremities.

Possible solutions to controlling or eliminating the workplace risk factors associated with changing a tire might be to add a—

- Mobile counterbalance to the pneumatic wrench.
- Second worker to assist the mechanic, especially during the most stressful, high-risk portions of the task.
- Support device or hand lift to support the weight of the tire and assist in removal.

Figure 2-3c. Sample Survey Results Summary

Body Part	Workplace Risk Factors					
	Position	Force	Repetition	Mechanical Stress	Vibration	Risk Assesment
Neck	Low	Low		Low	Low	Low
Back	High	High		Low	Low	High
Shoulder	High	High		Low	Medium	High
Arm	High	High		Medium	Medium	High
Hand/Wrist	High	High		High	High	High
Legs	Medium	Medium		Low	Low	Medium
Feet	Low	Low		Low	Low	Low

When the action team completes their survey, and reports the results to the ergonomics subcommittee, the subcommittee must present the results to upper management.

Different formats are available for reporting survey results to upper management. One of the most effective formats is a table, like the sample above, which gives an at-a-glance summary of the amount of risk associated with a mechanic's task of changing a tire. To create a summary table, the ergonomics subcommittee refers to the risk factor and body part analysis survey results (like the ones presented in figure 2-3b), and uses symbols to indicate the amount of exposure (e.g., high, medium, low) associated with the task.

Often a summary table like this one is very helpful to workers and upper management in understanding the problem and deciding on a future course of action.

APPENDIX 2A
RISK FACTOR/DISCOMFORT SURVEYS

Workplace risk factors contribute to WMSDs. Exposure to these risk factors can result in decreased blood flow to muscles, nerves, and joints; nerve compression; tendonitis; muscle strain; and joint damage. Prolonged exposure to the risk factors can lead to permanent damage and a debilitating condition.

Supervisors and workers need to be aware of the workplace risk factors and should report their presence to the ergonomics subcommittee. Action team members can use table 2A-1 to help supervisors and employees understand the workplace risk factors.

To facilitate a complete analysis, this appendix also includes:

- A guide for action team members to use to administer the survey.
- A Job Requirements and Physical Demands (JR/PD) survey to assess workers' job requirements and physical demands. The JR/PD survey was traditionally scored by hand. This method is time consuming and requires the evaluator to have basic knowledge of the Microsoft Excel application. In order to reduce time and improve accuracy during survey correction, the USACHPPM Ergonomics Program developed the JR/PD survey on mark sense forms. Individuals answer survey questions by filling in the appropriate "bubble" directly on the survey sheet. The completed surveys can be mailed back to the USACHPPM Ergonomics Program for quick scoring and report generation, or installations may request a copy of the scanner program and scan the surveys locally.

The JR/PD survey (hand-scored version only) and a macro that will help you score the survey and summarize the results are available electronically at http://sgwww.satx.disa.mil/~hscoemo/index.htm. At this site, look under "publications."

The DoD Ergonomics Working Group also maintains a Web site on the Internet. For more information, access the working group home page at http://chppmwww.apgea.army.mil/ergowg/, or contact the working group chair at DSN 584-3928 or commercial 410-436-3928.

Obtaining Forms JR/PD survey forms are available from USACHPPM, Attn: MCHB-DC-OER, Stark Road, Bldg. E-1570, APG, MD 21010-5403; DSN 584-3928, commercial 410-436-3928.

Table 2A-1. Understanding Workplace Risk Factors

Workplace Risk Factor	Definition/Description/Effect	Method of Assessment
Repetition	Repeated motions or tasks increase fatigue and muscle-tendon strain. Highly repetitive tasks often prevent adequate tissue recovery from the effects of awkward postures and force.	· Observation · Comparison to standards
Force	Forceful exertions increase the physiologic stress to muscles, tendons, and joints. Muscles fatigue faster as the force exerted increases.	· NIOSH Lift Equation (see appendix C of this chapter) · Force gauge (comparisons to push/pull, lift/carry, etc.)
Posture	Awkward postures require increased muscle force; contribute to muscle fatigue, tendon fatigue and joint soreness; and increase forces on the spine.	· Observation · Comparison to standards · Joint angle table (see figure 2 of this chapter)
Mechanical compression or contract stress	Mechanical compression creates pressure over a small area. Mechanical compression can be caused by hard or sharp objects, the sharp edge of a desk, and small diameter handles. This compression interferes with blood flow and nerve function.	· Observation · Task modeling (psychophysical)
Vibration	Localized vibration occurs when a part of the body contacts a vibrating object. Whole body vibration occurs when the entire body is in contact with a vibrating/moving body (e.g., when driving a forklift).	· Observation · ACGIH standards · ISO and ANSI standards
Temperature	Prolonged contact between the bare hand and metal surfaces below 59oF (15oC) may impair dexterity and contact with metal surfaces below 44.6oF (7oC) may induce numbness.	· Observation and measurement · ACGIH standards
Lighting	Inadequate lighting or direct or indirect glare can force the worker to assume awkward and fixed postures.	· Observation · Recommended light levels (see discussion in this chapter)

Job Requirements and Physical Demands Survey
Administrative Script

IH, safety, and health care personnel and technicians can administer this survey.

Welcome and Introduction

Welcome and thank you for taking the time to complete this occupational health survey. The survey will assess your job requirements and physical demands.
The purpose of the survey is to enable the ergonomics subcommittee to better understand and identify opportunities for improving work in shops and offices throughout the installation.
After you complete the survey, we will:
Analyze the results for the entire work area.
Determine a PRIORITY SCORE for the work area.
Provide information to the ergonomics subcommittee.
We will then decide on priorities for follow-up and work area improvement.
This is an anonymous survey. You will notice that we do not ask you to provide your name and there is no coding system. The survey is also voluntary. You are not required to take the survey; however, your participation is appreciated.
We are using the survey to get an overall assessment of the experiences in your work area as a whole. We are not looking specifically at you or your individual responses.
However, if you wish to request a follow-up visit by the ergonomics subcommittee, you may do so.

Overview of the Survey
The survey is divided into several parts.
I will give you a quick overview of each section, so follow along with me as I go through the form.
Page 1 asks for general information about yourself. Please fill out all of the information on this page with the exception of the "workplace identifier" section.

Turn to page 2.
Pages 2 and 3 ask for information about your work location and job classification. NOTE: A local decision on work location identification is required; for example, "only answer questions 13 (building) and 14 (room)."
Please fill out questions 15 and 16 with your job series code and pay plan information.

Turn to page 4.
A. Description of Work (Questions 1-38)
For this section, please provide a response to all questions.
This section allows you to describe certain job factors related to your work that occur on an approximately daily basis.
In Part F of this survey, you will have a chance to tell us about the work that you do less often, like sea-

sonal work.

Turn to page 8.
B. Organizational Factors (Questions 39-44)
These questions ask about aspects of your job that may be sources of stress for you.
C. Physical Effort (Question 45)
This question asks about the physical effort required to do your job.

Turn to page 9.
D. Discomfort Factors (Questions 46-50)
This section enables you to identify how your body responds to demands of the job. For example, describing whether you are comfortable or experience fatigue or discomfort is one of the purposes of this part of the survey.
Again, we will make conclusions about the entire work area based on how all of you respond to the survey questions. We do not intend to focus on any one individual.

Turn to page 10.
E. General Questions (Questions 51-55)
These questions ask about medical care, medical conditions, and persistent pain and discomfort.

Turn to page 11.
F. Work Content
This section allows you to list the tasks you perform in your work and how often you do them. You now have the opportunity to tell us about the types of tasks you do and approximately how often you do the tasks over a given period of time.
We will use this information to determine:
What the typical/routine tasks are for your work area.
The variety of tasks that are done by your work area, even if they are not done very often.

Turn to page 12.
G. Process Improvement Opportunities
The purpose of this section is to identify the tasks that you think put the greatest demands on your body. For this section, consider your routine, nonroutine, and seasonal tasks, and describe the tasks that you think are a problem.
We will need to know this information in order to help the ergonomics subcommittee decide which tasks may be good candidates for improvement.

Turn back to page 1 and begin.
We expect that it will take you about 15-20 minutes to complete the survey.
When you are finished with the entire survey, please turn it in to me.
Thank you again for your participation.

INSERT JR/PD SURVEY