Chapter

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ERGONOMIC HAZARDS AND UPPER-EXTREMITY MUSCULOSKELETAL DISORDERS

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❑ Ergonomics has been defined as the science of fitting the job to the worker.[1] Given that the abilities of workers vary, ergonomics could be redefined as the art of matching job demands with worker capabilities. When job demands overwhelm an employee's mental or physical capacity, his or her health, comfort, and productivity may be adversely affected.[2] Although it is also important to consider comfort and productivity levels, this chapter will focus on the effect of ergonomic hazards on the musculoskeletal system and the peripheral nervous system of the upper extremities.

Ergonomic hazards are physical stressors and environmental conditions that pose a risk of injury or illness to an individual's musculoskeletal system. Physical stressors can be divided into four main categories: repetition, force, posture, and vibration.[3] These stressors can arise from excessive job demands; improperly designed work stations, tools, or equipment; or inappropriate work techniques. In addition to these physical stressors, ergonomic hazards may arise from potentially deleterious environmental conditions, such as poor job designs, or deleterious work organizational factors.[4] Examples of these factors include excessive work rates, machine- versus self-paced work, shift work, an imbalance in the work-to-rest ratio, demanding incentive-pay or work standards, restriction of operator body movement, and confinement of the worker to a work station without adequate relief periods. Ergonomic hazards have occupational and non-occupational sources; however, only work-related hazards will be addressed in this chapter.

OCCUPATIONAL SETTING

Because ergonomic hazards are present in many industrial and service operations, workers in a wide variety of industries are potentially at risk. The National Occupational Exposure Survey[5] (NOES), conducted by the National Institute for Occupational Safety and Health (NIOSH) in 1982–83, estimated that 4.6 million workers are exposed to "arm transports," 2.8 million workers are exposed to "shoulder transports," 4.9 million workers are exposed to "hand/wrist manipulations," and 3.6 million workers are exposed to "finger manipulations."

The Bureau of Labor Statistics (BLS) conducts an annual survey of OSHA 200 logs for more than 200,000 establishments. The BLS estimates that over 224,000 cases of disorders due to repeated trauma occurred in 1991.[6] From 1984 to 1991, the incidence rate of these disorders increased from 5.1 to 27.0 cases per 10,000 full-time workers (ftw), probably reflecting increased reporting due to raised awareness and an absolute increase in rate (Figure 2-1). During this same time period, red-meat meatpacking plants [Standard Industrial Classification (SIC) code 2011] have always had the highest rates (149 per 1000 ftw in 1991), usually double the rate of the next highest-rated industry. Likewise, poultry processing plants have always been in the top five, ranking second in 1991 (67 per 1000 ftw) (Table 2-1).[6,7] Using data from individual state workers compensation programs, industries and occupations with high rates of occupational carpal tunnel syndrome (OCTS) can be identified (Tables 2-2–2-4).[8,9]

In 1988, questions on various occupational health effects were added to the National Health Interview Survey (NHIS), which is conducted by the National Center for Health Statistics. Approximately 8% of the 127 million active workers reported prolonged hand discomfort (a total of 20 days or more, or seven or more consecutive days within the past month). Approximately

Table 2-1. Top five industries with disorders due to repeated trauma, 1991

SIC	Industry description	Rate per 1000 ftw
2011	Meatpacking	149
2015	Poultry	67
3711	Motor vehicles	56
3354	Knit underwear	51
3632	Refrigerators and freezers	49

Source: Bureau of Labor Statistics Annual Survey.
SIC = Standard Industry Code, ftw = full-time worker.

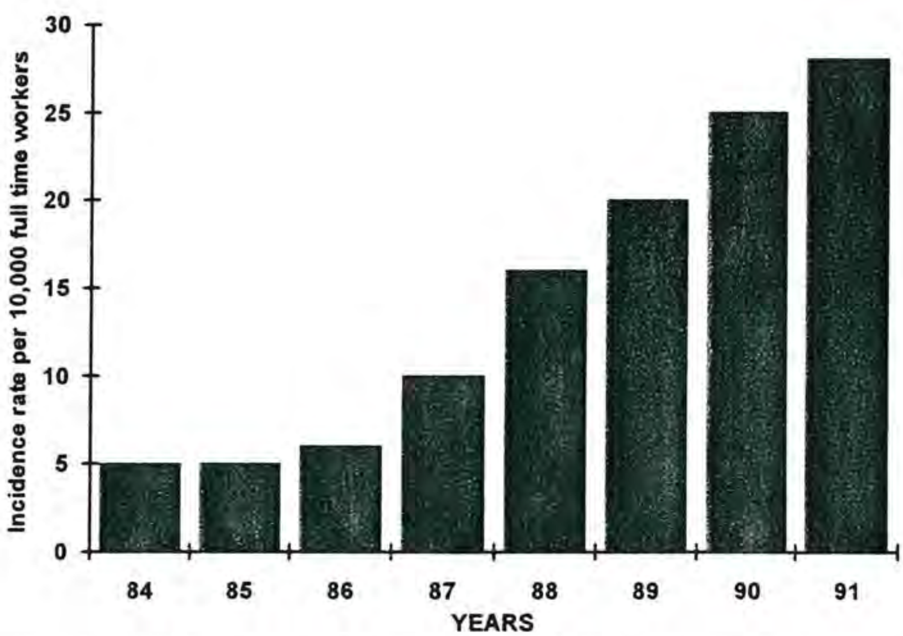

Figure 2-1. Incidence rate of disorders due to repeated trauma in the U.S. private sector, 1984–91. *Source:* Bureau of Labor Standards.

Table 2-2. Top 10 industry rates for occupational carpal tunnel syndrome by Washington Industrial Classification, 1984–88

Industry description	Rate per 1000 ftw	Number of cases
Oyster, crab, clam packing	25.7	50
Meat, poultry dealer	23.9	132
Packing house	18.5	55
Fish canneries processing	18.2	124
Carpentry	11.3	37
Fruit and vegetable canning	10.2	55
Egg production	9.8	30
Box, shook, pallet bin manufacturing	9.3	25
Sawmills, operation and maintenance	9.3	139
Foundries, steel casting	9.0	37

Source: Washington State Workers' Compensation database.
ftw = full-time worker.

Table 2-3. Top 10 industries for wrist injury (potential carpal tunnel syndrome), 1982–86

Industry description	Rate per 1000 ftw	Number of cases
Meatpacking plants	75.1	247
Motor vehicles and car bodies	50.9	373
Electrical equipment—transformers	43.3	103
Metal stamping NEC	28.1	118
Electrical equipment—motors and generators	26.8	83
Machinery—internal combustion engines	21.1	208
Dairy products—cheese making	12.8	74
Miscellaneous plastic products	10.7	85
Grocery stores	5.2	116
Paper mills	4.3	64

Source: Wisconsin Workers' Compensation database.
ftw = full-time worker.

Table 2-4. Top 10 occupations for wrist injury (potential carpal tunnel syndrome), 1982–86

Occupation	Odds ratio[a]	Number of cases
Dental hygienists	16.9	14
Dataentry keyers	11.0	25
Hand grinding and polishing occupations	7.0	16
Miscellaneous hand working occupations	6.3	79
Typists	6.2	21
Textile sewing machine operators	6.2	69
Hand cutting and trimming occupations	5.8	29
Hand packers and packagers	3.9	7
Shoe machine operators	3.7	23
Butchers and meat cutters	3.5	169

Source: Wisconsin Workers' Compensation database.
[a]Odds ratio using the incidence rate for all Wisconsin workers as the referent.

0.5% reported both prolonged hand discomfort and medically diagnosed carpal tunnel syndrome (CTS). Individuals who reported repetitive bending or twisting of the hand and wrists at work were 3.7 times more likely to report CTS, and individuals who used vibrating tools were 1.8 times more likely to report CTS.[10]

MEASUREMENT ISSUES

There is no universally accepted method for assessing ergonomic hazards in the workplace. The following list, however, suggests some of the options:

- **Survey** workers about the job tasks they perform.
- **Observe** workers as they perform their job tasks.
- **Measure** the physical attributes of the workplace and the physiological responses of workers to their job tasks.

Whatever methods are finally adopted, each method should ascertain information on the four known ergonomic hazards: **force, repetition, posture,** and **vibration.**

Employee Surveys, Questionnaires, and Checklists

Employee surveys, questionnaires, and checklists are useful because they are low in cost and easily available. In addition, they allow for the collection of historical data about previous exposures.[11–13] Although the information obtained from these sources will be similar to that obtained during a medical interview, questionnaires provide a more efficient means of collecting ergonomic information from employees.

Observing Workers

Observing workers as they perform their job tasks is another useful way to assess the ergonomic hazards of a workplace. The observer can use checklists or videotape to verify information on the four main physical risk factors. Specific checklists for trained observers have been developed[14–20] (Appendix 2-I). In addition to checklists, video-

APPENDIX 2-I. MICHIGAN'S CHECKLIST FOR UPPER-EXTREMITY CUMULATIVE TRAUMA DISORDERS

Risk Factors	No	Yes
1. Physical Stress:		
1.1 Can the job be done without hand/wrist contact with sharp edges?	☐	☐
1.2 Is the tool operating without vibration?	☐	☐
1.3 Are the worker's hands exposed to temperature >70° F	☐	☐
1.4 Can the job be done without using gloves?	☐	☐
2. Force:		
2.1 Does the job require exerting less than 10 lb of force?	☐	☐
2.2 Can the job be done without using finger-pinch grip?	☐	☐
3. Posture:		
3.1 Can the job be done without flexion or extension of the wrist?	☐	☐
3.2 Can the tool be used without flexion or extension of the wrist?	☐	☐
3.3 Can the job be done without deviating the wrist side to side?	☐	☐
3.4 Can the tool be used without deviating the wrist side to side?	☐	☐
3.5 Can the worker be seated while performing the job?	☐	☐
3.6 Can the job be done without "clothes-wringing" motion?	☐	☐
4. Workstation Hardware:		
4.1 Can the orientation of the work surface be adjusted?	☐	☐
4.2 Can the height of the work surface be adjusted?	☐	☐
4.3 Can the location of the tool be adjusted?	☐	☐
5. Repetitiveness:		
5.1 Is the cycle time longer than 30 secs?	☐	☐
6. Tool Design:		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	☐	☐
6.2 Is the span of the tool's handle between 5 and 7 cm?	☐	☐
6.3 Is the handle of the tool made from material other than metal?	☐	☐
6.4 Is the weight of the tool below 4 kg (note exceptions to rule)?	☐	☐
6.5 Is the tool suspended?	☐	☐

Source: Adapted from Lifshitz Y, Armstrong T. A design checklist for control and prediction of cumulative trauma disorders in hand intensive manual jobs. Proceedings of the 30th Annual Meeting of Human Factors Society, 1986:837–841, Santa Monica: Human Factors Society.

recorders can tape employees performing their work. These tapes can be reviewed in slow motion so that a more precise count can be made of subtle movements, exertions, and postures. This videotape analysis is used to calculate the repetition rate for each joint area involved in the work activity. In addition, the work duration/recovery cycle should be described.

Measuring Workers

If the first two methods (i.e., surveys and observation) suggest that ergonomic hazards exist in the workplace, quantitative measurement of those risk factors could be considered. However, such measurement typically requires specialized equipment, and a certain expertise is needed first to use the equipment and then to interpret the data. Therefore, these measurements are currently reserved for research settings in which the goal is to evaluate the link between an exposure and a disease outcome, or to demonstrate that ergonomic hazards have been reduced or eliminated through job or work station redesign.

Equipment used to generate quantitative information on ergonomic hazards include electrogoniometers (dynamic measurements of posture), accelerometers, and imaging techniques (electronic and laser optical recordings). Some devices can be used by nonexperts to measure static postures. Because of their simplicity, both spring scales or gauges to estimate force requirements and simple goniometers have been used successfully in field studies. These simple tools are often helpful at the survey stage to roughly determine forces involved in repetitive tasks.

Internal forces can be measured using surface electromyography (EMG), but the currently available equipment is expensive and its use requires special expertise. Video and imaging systems have been used to measure posture primarily in the laboratory setting, where the camera's line of sight is perpendicular to the planes of the measured body segments. Given the dynamic nature of most job activities, their application to workplace measurement seems limited unless several cameras can be set up to allow for a variety of viewing angles. The use of a goniometer—a tool that measures the angles at joints—for measuring static postures is well established, but few jobs require continuous static postures. Electrogoniometers can measure dynamic postures, but their accuracy and associated analytical methods are not well established.

EXPOSURE GUIDELINES

There is no consensus on a single method to quantitatively assess ergonomic hazards, with the exception of vibration (see Chapter 4).[21] This has resulted in a wide variety of methods to assess the workplace, which has made it difficult to compare results across ergonomic studies. In addition, some upper extremity (UE) musculoskeletal disorders lack objective signs of injury—resulting in a wide variety of diagnostic criteria across studies. These two factors (lack of ergonomic exposure and musculoskeletal disease consensus criteria) have prohibited the establishment of exposure limit values based upon scientific studies.

However, our inability to establish a numerical exposure limit should not be construed as a lack of association between the biomechanical hazards and UE musculoskeletal disorders. It is merely a reflection of the state of the art in measurement techniques; until specific guidelines can be developed, it is reasonable to ensure that ergonomic hazards are reduced to the lowest extent feasible. Therefore, we would like to offer some general guidelines for assessing acceptable exposures to the physical hazards of repetition, force, and posture.

Repetition refers to the number of movements or exertions in a specific joint per unit time (typically 1 min). Acceptable levels of repetition are related to the intensity of effort (i.e., force as a percentage of strength) and the duration of that effort. In other words, job tasks that require little effort can be repeated more frequently than job tasks that require great effort. This fact prevents the simple listing of ranges for acceptable repetition rates and underscores the interrelationship between a job's repetition and force.

Rodgers has developed an ergonomic job analysis technique to prioritize jobs for ergonomic

APPENDIX 2-II. RODGER'S ERGONOMIC JOB ANALYSIS FORM FOR PHYSICAL EFFORT ERGONOMIC JOB ANALYSIS

Body part	Effort Level	Continuous effort time	Efforts/ min	Priority	Effort categories
Neck/shoulders	____	____	____	____	1 = Light 2 = Moderate 3 = Heavy
Back	____	____	____	____	**Continuous effort time categories** 1 = <6 sec 2 = 6–20 sec 3 = >20 sec
Arms/elbows	____	____	____	____	**Efforts/min categories** 1 = <1/min 2 = 1–5 min 3 = >5/min
Wrists/hands/fingers	____	____	____	____	
Legs/knees	____	____	____	____	
Ankles/feet/toes	____	____	____	____	

Priority for change

Moderate =	1	2	3
	1	3	2
	2	1	3
	2	2	2
	2	3	1
	2	3	2
	3	1	2
High =	2	2	3
	3	1	3
	3	2	1
	3	2	2
Very high =	3	2	3
	3	3	1
	3	3	2

Job title: ____________________

Specific task: ____________________

Job number: ____________________

Department: ____________________

Location: ____________________

Contact person(s): ____________________

Phone: ____________________

Analyst: ____________________

Phone: ____________________

Date of analysis: ____________________

Source: Rodgers S. Job evaluation in worker fitness determination. Occupational Medicine, State of the Art Reviews. 1988; 3:219–420. Philadelphia: Handley & Belfus. Reprinted with Permission.

intervention based upon the job's repetitiveness and force requirements (Appendix 2-II).[22] Other investigators have utilized cycle time to describe repetitiveness. Cycle time (the time required to complete a job task) is relatively easy to calculate for assembly-line jobs, where repetitiveness is arbitrarily defined as a cycle time of <30 sec. Cycle times <30 sec have been associated with UE musculoskeletal disorders.[23]

Force can be defined as the mechanical effort to accomplish a specific movement or exertion. Population norms by gender have been developed for upper-extremity muscle groups.[24] Just as acceptable repetition levels are related to effort (force), the acceptable levels of force are related to employee posture. For example, grip strength of the hand decreases as the wrist is deviated from the neutral posture.[24]

Posture can be defined as the position of a part of the body relative to an adjacent part, as measured by the angle of the connecting joint. Standard posture definitions (neutral and nonneutral) and normal ranges of motion have been developed by the American Academy of Orthopedic Surgeons.[25] Postural stress develops as a joint reaches its maximal deviation; therefore, postures should be maintained as close to neutral as possible. In addition to postures at the extreme end of a joint's range, tasks that require finger-pinching postures have been associated with UE musculoskeletal disorders.

The Eastman Kodak Company has proposed the following posture guidelines[26]:

- Keep the work surface height low enough to permit employees to work with their elbows at their sides and their wrists near their neutral position.
- Keep reaches within 20 in. in front of the work surface so the elbow is not fully extended when forces are applied.
- Keep motions within 20–30° of the wrist's neutral point.
- Avoid operations that require >90° of rotation around the wrist.
- Avoid gripping requirements in repetitive operations that spread the fingers and thumb apart >2.5 in. Cylindrical grips should not exceed 2 in. in diameter; 1.5 in. is the preferred size.

EPIDEMIOLOGY, PATHOGENESIS, AND PATHOPHYSIOLOGY OF INJURY

UE musculoskeletal disorders involve damage to the body's bones, joints, and muscle-tendon units of the neck, shoulder, elbow, wrist, and hand. Peripheral nervous system and neurovascular disorders will also be included within the category of UE musculoskeletal disorders. These disorders can be caused or aggravated by exposure to ergonomic hazards and can occur in the back and lower extremities in addition to the UE. All these disorders should be considered to be multifactorial in etiology.

General terms such as *chronic trauma disorders, repetitive strain injuries, repetitive motion injuries, repetitive trauma disorders, cumulative trauma disorders*, and *overuse syndrome* have been used to describe these disorders. Although these terms may be useful for surveillance purposes, health care providers evaluating individual patients should make a specific diagnosis using the International Classification of Diseases Ninth Revision (ICD-9) codes (Table 2-5). In some individual cases, a work-related etiology can be established with reasonable certainty. In other cases, the specific ergonomic stress and the mechanism of injury may not be apparent. These cases require a thorough search for both occupational and nonoccupational causes.

Much of the scientific literature supports a relationship between physical stressors and musculoskeletal disorders; however, some critics remain unconvinced.[27] For the most part, controversy stems from disagreement about studies of carpal tunnel syndrome (CTS). Some studies suggest that no relationship exists between CTS and the physical stressors[28–30] and instead emphasize the importance of psychosocial factors.[31] Other studies, however, have found a positive relationship.[32–41] Varying degrees of methodologic limitations existing in these studies provide fodder for this debate.[42–45] We will now provide a brief review of the literature that addresses the relationship between physical stressors and musculoskeletal disorders by anatomical structure.

Peripheral Nerve Entrapment Disorders

Carpal tunnel syndrome (CTS), the most well-known peripheral nerve entrapment disorder, has many non–work-related factors[46,47] (Table 2-6). One report claims that 5% of CTS cases are due to work,[48] whereas three others suggest that

Table 2-5. Specific ICD-9 diagnoses referred to as cumulative trauma disorders (CTD) by ICD-9 codes

ICD-9 Code			Diagnosis
353			**Nerve root and plexus disorders**
	353.0		Brachial plexus lesions (cervical rib syndrome, costoclavicular syndrome, scalenus anticus syndrome, thoracic outlet syndrome)
	353.9		Unspecified nerve root and plexus disorder
354			**Mononeuritis of upper limb and mononeuritis multiplex**
	354.0		Carpal tunnel syndrom (median nerve entrapment)
	354.2		Lesions of the ulnar nerve (cubital tunnel syndrome, tardy ulnar nerve palsy)
	354.3		Lesions of the radial nerve
	354.9		Mononeuritis of upper limbs, unspecified
443			**Other peripheral vascular disease**
	443.0		Raynaud's syndrome
			Raynaud's phenomenon (hand-arm vibration syndrome)
444			**Arterial embolism and thrombosis**
	444.2		Arteries of the extremities (ulnar artery thrombosis)
723			**Other disorders of cervical region**
	723.3		Cervicobrachial syndrome (diffuse)
	723.9		Unspecified musculoskeletal disorders and symptoms referable to neck (cervical disorder, NOS)
726			**Peripheral enthesopathies and allied syndromes**
			(Enthesopathies are disorders of peripheral ligamentous or muscular attachments)
	726.1		Disorders of bursae and tendons in the shoulder region (rotator cuff syndrome, supraspinatus syndrome, bicipital tenosynovitis)
	726.3		Enthesopathy of elbow region (medical and lateral epicondylitis)
727			**Other disorders of synovium, tendon, and bursa**
	727.0		Synovitis and tenosynovitis
		727.03	Trigger finger (acquired)
		727.04	Radial styloid tenosynovitis (deQuervain's)
		727.05	Other tenosynovitis of hand and wrist
	727.2		Specific bursitides, often of occupational origin
	727.9		Unspecified disorder of synovium, tendon, and bursa
728			**Disorders of muscle, ligament, and fascia**
	728.9		Unspecified disorder of muscle, ligament, and fascia
729			**Other disorders of soft tissues**
	729.1		Myalgia and myositis, unspecified (fibromyositis)
	729.8		Other musculoskeletal symptoms referable to limbs (swelling, cramping)
	729.9		Other and unspecified disorders of soft tissue

~50% of CTS cases are work-related.[49–51] Clearly, the percentage of work-related CTS cases seen in a practice is dependent on the industry mix that the practice serves. Industries and occupations with increased incidence for CTS have been identified by case studies[52,53] and workers' compensation claims (Tables 2-2–2-4).[8,9]

Most epidemiologic studies support the relationship between CTS and the biomechanical risk factors of high force, high repetition, extreme

Table 2-6. Conditions associated with carpal tunnel syndrome

Endocrine conditions	Diabetes mellitus, pregnancy, use of estrogens or oral contraceptives, acromegaly, myxedema
Rheumatic disorders	Rheumatoid arthritis, systemic lupus erythematosus, scleroderma, polymyalgia rheumatica, eosinophilic fascitis, gout, osteoarthritis
Cardiac disorders	Congestive heart failure, vascular shunts
Blood disorders	Amyloidosis, hemophilia
Renal disorders	Renal insufficiency
Infectious disorders	Tuberculosis
Trauma	Previous fracture of the carpal bones
Tumors:	
Benign	Gangliomas, lipomas
Malignant	Multiple myeloma

Source: Adapted from Leach[46], and Spinner.[47]
Leach RE, Odom JA Jr: Systemic causes of carpal tunnel syndrome. *Postgrad Med J* 44:127–31, 1968
Spinner RJ, Bachman JW, Amadio PC: The many faces of carpal tunnel syndrome. *Mayo Clin Proc* 64:829–36, 1989

Table 2-7. Epidemiologic studies addressing risk factors for carpal tunnel syndrome

Study	Design	Exposure ascertainment	Disease ascertainment	Risk factor	OR/RR
1981 Cannon[34]	Case-referent	Job category	Clinical assessment	Vibration Repetition (Rep)	7.0* 2.1*
1985 Punnett[35]	Cross-sectional	Questionnaire & videotape	Questionnaire	Repetition	3.0*
1987 Silverstein[36]	Cross-sectional	Electromyelograph & videotape	Questionnaire & physical exam	LoForce-LoRep HiForce-LoRep LoForce-HiRep HiForce-HiRep	1.0 1.8 1.9 15.5*
1989 Wieslander[37]	Case-referent	Questionnaire	Clinical assessment & nerve conduction	Vibration Repetition Force Obesity	6.1* 4.5* 2.7* 3.4*
1990 deKrom[38]	Case-referent	Questionnaire	Clinical assessment & nerve conduction	Flexed wrist Extended wrist	8.7* 5.4*
1990 Chiang[39]	Cross-sectional	Observation	Clinical assessment & nerve conduction	LoRep-NotCold HiRep-NotCold HiRep-VeryCold	1.0 2.2 9.4*

(continued)

Table 2-7. Epidemiologic studies addressing risk factors for carpal tunnel syndrome *(continued)*

Study	Design	Exposure ascertainment	Disease ascertainment	Risk factor	OR/RR
1991 Barnhart[40]	Cross-sectional	Observation	Physical exam & nerve conduction	Repetition	1.9*
1991 Scottland[29]	Cross-sectional	Current vs. pre-employment	Nerve conduction	2/16 measures of median nerve conduction different between groups	
1988 Nathan[28]	Cross-sectional	Observation	Nerve conduction	VLightForce-LoRep	1.0
				LightForce-ModRep	1.0
				ModForce-HiModRep	1.7*
				HeavyForce-HiRep	1.4
				VHeavyForce-VHiRep	2.2*
1992 Nathan[30]	Prospective cohort	Observation	Nerve conduction	Body mass index	0.6%*
				Age	3.3%*
				Wrist dimension	2.1%*
				Hand dominance	1.0%*
				Exercise level	0.6%*
				Weight	0.4%*

OR = odds ratio, RR = relative risk.
*Statistically significant at $p \leq 0.05$.

postures, and vibrating tools (Table 2-7). It is important to point out that many of these are cross-sectional studies, which should be regarded as hypothesis-generating rather than definitive evidence of a causal relationship. In addition, all the studies listed in Table 2-7 suffer from the absence of a validated exposure assessment tool and the lack of a specific clinical test to determine work-relatedness. Nevertheless, these studies generally support the association between CTS and biomechanical stressors. However, the need for definitive evidence for a causal relationship remains.

Two proposed mechanisms of action dominate the current debate regarding the pathophysiology of CTS: mechanical compression and microvascular insufficiency.[54–56] Proponents of the microvascular insufficiency theory cite evidence of CTS symptoms and nerve conduction slowing associated with median nerve ischemia, both clinically and experimentally.[57–59] Advocates of the mechanical compression theory refer to studies suggesting that mechanical compression causes a reduction in the median nerve diameter or a thinning of the nerve's myelin sheath, resulting in nerve conduction slowing.[57,60–62]

Other peripheral nerve entrapment disorders [median nerve compression at the shoulder or elbow, radial nerve compression at the elbow (posterior interosseus syndrome and radial tunnel syndrome), ulnar nerve compression at the elbow, or digital nerve compression in the hand] have not been reported with work activities. On the other hand, external trauma to the ulnar nerve at the wrist while performing work activities has been reported to cause entrapments.[63] Shea estimated that ~24% of all ulnar nerve entrapments at the wrist are due to occupational causes.[64] The determination of risk factors for the aggravation of thoracic outlet syndrome has been hampered by the inability to reach consensus on its diagnostic criteria. However, in the absence of a cervical rib, the diagnosis is questionable.

Tendon Disorders (Peritendinitis, Tenosynovitis)

Although CTS may be a more familiar diagnosis, muscle-tendon disorders such as peritendinitis and tenosynovitis are far more common. Investigations in which the type of musculoskeletal conditions was specified found the ratio of muscle-tendon disorders to CTS ranged from 62:0 to 2:1 (Table 2-8). Like CTS, tendon disorders have many nonoccupational causes, particularly athletic activities.[78–80] No studies have been conducted to determine the incidence or prevalence rates of tendon disorders in the general population. Likewise, no studies have been done to establish the ratio of work- to non–work-related tendon disorders. Finally, the wide variation in the ratio of tendon disorders to CTS in the same or similar industries (Table 2-8), underscores the lack of consistent clinical and epidemiologic case definitions.

With the exception of vibration, the risk factors for work-related tendon disorders are similar to those for the non–work-related conditions—awkward postures, high forces, and repetitiveness (Table 2-9). Work activities involving these stressors are associated with statistically significant increases in tendon disorders of the shoulder and hand-wrist. Tendon disorders of the elbow region are associated with high forces and awkward postures; however, these associations are not statistically significant (Table 2-9). It is important to note that studies identifying these risk factors suffer from the same limitations found in the CTS investigations: Most studies are cross-sectional; they lack a validated method to measure biomechanical factors; and there is no specific clinical test to establish the diagnosis or determine work-relatedness.

Moore has concisely summarized tendon structure, function, and biomechanical properties.[94] Two kinds of ergonomic stresses affect the tendon— tensile forces, and contact and shearing forces (Table 2-10). The tendon responds to these two forces with elastic and viscous deformation, which reduces tendon blood flow and nutrient perfusion. Evidence for this theory is supported by shoulder studies.[95-97]

Table 2-8. Ratio of muscle-tendon: CTS disorders

Study	Industry	Ratio
1966 Hymovich[65]	Electrical	62:0
1971 Ferguson[66]	Electrical	20:1
1979 Kuorinka[67]	Scissors manufacturing	17:0
1979 Luopajarvi[68]	Food processing	20:1
1982 Armstrong[69]	Poultry	15:1
1983 Viikari-Juntura[70]	Slaughterhouse	5:1
1986 Silverstein[71]	Industrial factories	2:1
1989 NIOSH[72]	Meatpacking	
	High exposure	7:1
	Lower exposure	10:1
1990 NIOSH[73]	Poultry	
	High exposure	28:1
	Lower exposure	41:1
1990 Amadio[74]	Musicians	3:1
1991 Moore[75]	Pork processing	4:1
1992 NIOSH[76]	VDT operators	40:1
1993 Liss[77]	All industries	2:1

CTS = carpal tunnel syndrome.

Table 2-9. Epidemiologic studies addressing risk factors for tendon disorders

Study	Study design	Exposure ascertainment	Disease ascertainment	Risk factor	OR/RR
1979 Belle[81]	Case-referent	Interview & observation	Clinical evaluation	Posture (work above shoulders)	11*
1981 Herberts[82]	Cross-sectional	Observation and electromyelo-graph	Clinical evaluation	Posture (work above shoulders)	13*
1984 Herberts[83]	Cross-sectional	Observation	Clinical evaluation	Posture & force	9*
1983 Wells[84]	Cross-sectional	Weight	Questionnaire	Load (force)	4*
1987 Hagberg[85]	Cross-sectional	Observation	Questionnaire & physical exam	Posture (work above shoulders)	11*
1990 NIOSH[86]	Cross-sectional	Observation & videotape	Questionnaire & physical exam	Lack of suffi-cient rest	4*
Elbow					
1984 Roto[87]	Cross-sectional	Observation	Clinical evaluation	HiForce and posture	7
1991 Kurppa[88]	Cohort	Observation	Clinical evaluation	HiForce	6
1991 Viikari-Juntura[89]	Cross-sectional	Observation	Clincial evaluation	HiForce	1
Hand-wrist					
1979 Kuorinka[90]	Cross-sectional	Job analysis	Clinical evaluation	Repetition and posture	1
1979 Luopajarvi[91]	Cross-sectional	Questionnaire & videotape	Clinical evluation	Repetition and posture	8*
1987 Armstrong[92]	Cross-sectional	Electromyelo-graph & videotape	Questionnaire & physical exam	LoForce-LoRep HiForce-LoRep LoForce-HiRep HiForce-HiRep	1.0 2.0 2.0 29.0*
1990 McCormack[93]	Cross-sectional	Job category	Clinical evaluation	Repetition	4*
1991 Kurppa[94]	Cohort	Observation	Clinical evaluation	Force	24*

OR = odds ratio, RR = relative risk.
*Statistically significant at $p \leq 0.05$.

Table 2-10. Variables causing ergonomic stresses to tendons

Tensile forces	Contact and shearing forces
• Magnitude of applied tensile force	• Magnitude of applied tensile force
• Duration of applied force	• Radius of curvature of the surface around which tendon bends (proportional to the degree of postural deviation)
• Duration of recovery interval between force applications	• Length of arc of contact between tendon and supporting surface
• Strain rate	• Coefficient of friction between tendon and adjacent structures
• Number of cycles of repeated loading	

Source: Adapted from Moore.[94]
Moore JS: Function, structure, and responses of components of the muscle-tendon unit. In Moore JS, Garg A (eds) *Occupational Medicine, State of the Art Reviews: Ergonomics: Low-back pain, Carpal Tunnel Syndrome, and Upper Extremity Disorders in the Workplace*, pp 713–740. Philadelphia, Handley & Belfus, Inc., 1992

The pathogenesis and pathophysiology of lateral epicondylitis (i.e., pain at the lateral aspect of the elbow) is less clear. The predominant theory is that repetitive, forceful exertions cause microruptures of the peritendon as it inserts onto the bone's periosteum.[98–100] These microruptures cause inflammation and granular tissue.[101] Other theories embrace a friction model in which repetitive movements cause friction against adjacent structures, resulting in tendon inflammation. This theory is supported by animal models in which rabbit muscles were repeatedly stimulated electrically, causing repetitive contractions of the muscle-tendon unit. Examination of these tendons revealed signs of inflammation.[102]

Muscle Disorders (Delayed Onset Muscle Soreness)

Delayed-onset muscle soreness (DOMS) is skeletal muscle pain or discomfort following unaccustomed physical activity. Everyone has probably experienced this condition, particularly following sporting activities. The biomechanical risk factors of high force, static postures, and repetition have been associated with a type of DOMS known as *tension neck syndrome* (Table 2-11). As with the CTS and tendon studies, definitive statements about the causes of tension neck syndrome must be tempered by such study limitations as cross-sectional study design, lack of a validated method to measure biomechanical factors, and lack of a specific clinical test to establish the diagnosis or determine work-relatedness.

Muscle responses to ergonomic stressors have mechanical and physiological components. Mechanical responses to eccentric contractions or prolonged static contractions include muscle fiber Z-line rupture, ragged type-1 muscle fibers, decreased intracellular adenosine triphosphate (ATP) levels, and reduced local blood flow.[107–111] Evidence for muscle damage from the mechanical stress includes increases in serum creatine kinase.[112,113] These changes are typical findings of DOMS; they are considered reversible with rest. After some days or weeks of rest, the muscle should not only recover but also increase its capacity due to a conditioning effect. However, some researchers argue that if the ergonomic stressors occur daily, the muscles will not repair themselves adequately, resulting in prolonged muscular damage.[114]

Psychosocial Factors

Numerous studies have documented the association between psychological stress and health complaints. However, there is some debate as to whether these health complaints represent an actual increase in disease, an increase in report-

Table 2-11. Epidemiologic studies addressing risk factors for neck-shoulder disorders

Study	Design	Exposure ascertainment	Disease ascertainment	Result	OR/RR
1976 Onishi[103]	Cross-sectional	Job title, observation, electromyelography	Physical exam	Repetitive movements	4*
1979 Kuorinka[67]	Cross-sectional	Job analysis	Clinical evaluation	Repetition, posture, force	4*
1981 Hunting[104]	Cross-sectional	Job title, observation	Physical exam	Repetition	7*
1983 Kukkonen[105]	Cross-sectional	Job title	Physical exam	Repetition	2*
1988 Amano[106]	Cross-sectional	Job title, videotape	Physical exam	Repetition	7*

OR = odds ratio, RR = relative risk.
*Statistically significant at $p \leq 0.05$.

ing, or somatization. Although several studies have linked psychological stress and medical diseases,[115–125] only three studies have reported a relationship between psychosocial stress and objective signs of UE musculoskeletal disorders.[126–128] The mechanism for this effect is unclear, but some authors have postulated that psychosocial stress can lead to muscle tension, overloading some specific muscle fibers.[129,130]

MEDICAL SURVEILLANCE

The OSHA Ergonomic Program Management Guidelines for meatpacking plants recommends worksite and medical surveillance. These guidelines, which are reviewed in Chapter 3, will probably be used as the framework for any future OSHA Ergonomic standard. In this chapter, the medical surveillance section precedes the medical diagnosis and treatment section, to be consistent with the OSHA guidelines.

Surveillance has been defined as "the ongoing systematic collection, analysis, and interpretation of health and exposure data in the process of describing and monitoring a health event."[131] Surveillance should not be confused with screening. **Screening** is the application of a clinical test to asymptomatic individuals at increased risk for a particular disease.[132] The purpose of screening tests is to identify individuals who need further medical evaluation or other intervention. Although clinical tests can identify individuals with musculoskeletal disorders early in their development, there are currently no known screening tests to predict which asymptomatic individuals will develop symptoms and disease.

Passive Surveillance

Figure 2-2 illustrates how passive data sources (such as OSHA 200 logs, workers compensation records, and medical department logs) can be transcribed onto a spreadsheet and used to calculate disease incidence rates. These incidence rates, usually expressed as cases per 100 ftw per year, can then be compared to the incidence rates for different industries, plants, departments, or jobs. Those jobs or departments found to have an increased musculoskeletal injury rate can be targeted for further ergonomic or medical evaluation. In addition, jobs or departments can be followed over time to monitor trends in these rates.

Department or job (a)	Hr worked (b)	Injuries & illnesses (c)	Incidence rate (d)	IR previous yr (e)	% change (f)

(c) Injuries or illnesses of the upper extremity not caused by accidents.

$$\text{Incidence Rate (d)} = \frac{\text{Number of Injuries + Illnesses (c)} \times 200{,}000}{\text{Hours Worked (b)}}$$

$$\text{\% Change (f)} = \frac{\text{Current (d)–Previous (e)}}{\text{Previous (e)}}$$

Figure 2-2. Disease incidence rate calculations.

Passive surveillance databases are attractive due to their low cost. However, they are often developed for purposes other than surveillance and may have significant limitations, including underreporting, disease misclassification, and exposure misclassification.[7,133,134] There are currently only two national databases with potential for passive hazard surveillance—the NIOSH NOES database and the OSHA Integrated Management Information System (IMIS) database.[135] Unfortunately, these systems were designed to prioritize national resources rather than provide data on individual plants; therefore, their usefulness is limited.

Active Surveillance

Active surveillance systems generate more accurate databases to identify high-risk positions. Direct symptom surveys are good examples of active disease surveillance tools in occupational medicine.[136] They have been developed for both pulmonary[137] and musculoskeletal disorders.[138] Symptom surveys collect more accurate information and can serve a triage function if performed in a confidential manner.[139] Active surveillance systems can also gather information on exposures. This information is usually collected by plant personnel or nonmedical consultants; however, health care providers are sometimes asked to participate in more comprehensive ergonomics programs. If exposure surveillance is a component of the program, consultants may want to use the checklist shown in Table 2-12 to establish a preliminary database.[140]

DIAGNOSIS AND TREATMENT

The successful treatment of upper-extremity musculoskeletal disorders relies on prompt **evaluation,** specific **diagnosis,** and appropriate **intervention.**

Clinical Evaluation

As with all other conditions that have a potential occupational etiology, the occupational health history is a fundamental component of the evaluation.[141–144] The history should character-

Table 2-12. Ergonomic hazard identification checklist

	Never	Sometimes (<3 times/day)	Usually (≥3 times/day)	If USUALLY, list jobs
1. Do workers perform tasks that are externally paced?				
2. Are workers required to exert force with their hands (e.g., gripping, pulling, pinching)?				
3. Do workers use hand tools or handle parts or objects?				
4. Do workers stand continuously for periods of more than 30 min?				
5. Do workers sit for periods of more than 30 min without the opportunity to stand or move around freely?				
6. Do workers use electronic input devices (e.g., keyboards, mice, joysticks, track balls) for continuous periods of more than 30 min?				
7. Do workers perform activities with hands raised above shoulder height?				
8. Are workers exposed to vibration?				

ize the symptoms, provide an employee description of work activities, and identify predisposing conditions or factors, including psychological and nonoccupational factors. This information should be documented in the employee's medical record. A form to assist with the collection of this information is included in Appendix 2-III. If the employee description of work activities is unclear, or if further information is needed to understand employee job tasks and workplace conditions, the investigator should visit the workplace or review the job tasks as recorded on videotape. Simply reviewing a written description of job tasks may not be enough to understand the ergonomic stresses actually involved in the job.

After the history is taken and information is obtained about workplace conditions and job tasks, the neck and upper extremities should be examined. A comprehensive examination would include inspection, palpation, assessment of the ranges of motion, evaluation of sensory and motor function, and applicable provocative maneuvers. Classical maneuvers such as Tinel's and Phalen's tests may be helpful, but they are not diagnostic in themselves. Employees with

APPENDIX 2-III. MUSCULOSKELETAL OCCUPATIONAL HEALTH HISTORY

Name: ______________________

Age: ______ years Gender: ☐female ☐male

Symptom Characterization

Onset: ☐month ☐day ☐year

Quality: (let employee describe; check all that apply)
☐pain ☐tenderness ☐weakness ☐soreness ☐numbness
☐tingling ☐burning ☐swelling ☐cramping ☐throbbing

Location: (R = right, L = left) ______ neck ______ shoulder ______ upper arm
______ elbow ______ lower arm ______ hand/wrist

Radiation: (R = right, L = left) ______ neck ______ shoulder ______ upper arm
______ elbow ______ lower arm ______ hand/wrist

Evolution of symptoms quality: ______________________
Evolution of symptoms location: ______________________
Evolution of symptoms severity: ______________________
Exacerbating activities: ______________________
Relieving activities: ______________________
Prior treatment modalities: ______________________

Description of Work Activities

Characterize the required job tasks (particularly with respect to ergonomic hazards):
____
____
____
____

Work patterns: ______________________
Changes in work patterns: ☐longer hours ☐overtime ☐other
Frequency of tasks: ______________________
Changes in frequency of tasks: ☐no ☐yes
If yes, list change: ______________________
Duration of tasks: ______________________
Changes in duration of tasks: ☐no ☐yes
If yes, list change: ______________________
Unaccustomed work: ☐no ☐yes
Changes in work equipment: ☐no ☐yes
If yes, list change: ______________________
Length of time at various job tasks: ______________________
Frequency and duration of rest breaks: ______________________
Nature of work: ☐salary ☐hourly ☐piecework
Job rotation program: ☐no ☐yes
If yes, list rotation schedule: ______________________

(continued)

APPENDIX 2-III. MUSCULOSKELETAL OCCUPATIONAL HEALTH HISTORY *(continued)*

Predisposing Conditions or Factors for CTD

Prior trauma to the symptomatic area: ☐no ☐yes

Prior musculoskeletal symptoms or diagnoses: ☐no ☐yes

If yes, were these successfully treated? ☐no ☐yes

Length of time until complete recovery: ____________________

List hobbies: ____________________

____

List recreational activities: ____________________

____

List underlying diseases: ____________________

____

Other Comments: ____________________

____

____

underlying systemic disease (e.g., diabetes mellitus) may require a more complete examination, including the examination of other extremities or other organ systems. Results of the examinations findings, both positive and negative, should be documented in the employee's medical record. A form to assist with the collection of this information is included in Appendix 2-IV. In workers where there is an increased suspicion of nerve entrapment, further evaluation, including electromyography (EMG) and nerve conduction velocities (NCV), may be appropriate.

Diagnosis

Diagnoses should be consistent with the International Classification of Diseases, Ninth Revision (ICD-9) (Table 2-5). Terms such as *repetitive motion disorders* (RMD), *repetitive strain injury* (RSI), *overuse syndrome*, and *cumulative trauma disorders* (CTD) may be useful for surveillance purposes or epidemiologic investigations, but they are not ICD-9 diagnoses and should not be used as individual medical diagnoses.

Once the diagnosis is established, a determination must be made as to whether occupational factors contributed to the condition. This tends to be the most difficult portion of the assessment. Unlike such classic occupational diseases as asbestosis or silicosis, most occupational musculoskeletal disorders do not have a pathognomonic finding or test specific to the exposure. In addition, we are still unable to quantify when an exposure has sufficient intensity, frequency, and severity required to be contributory to the disease process. Therefore, the importance of a thorough exposure assessment cannot be overemphasized.[51]

Clinical Interventions

Clinical interventions should be tailored to the specific diagnosis. However, because soft-tissue disorders comprise the overwhelming majority of work-related musculoskeletal conditions,[145] resting the symptomatic area and reducing the soft-tissue inflammation are the mainstays of conservative treatment.[94,146–151] The expected duration of treatment, dates for follow-up evaluations, and time frames for improvement or resolution of symptoms should be specified at the initial evaluation and whenever any change in the employee's condition is noted. Psychosocial issues should be addressed concurrently with medical issues.

APPENDIX 2-IV. PHYSICAL EXAMINATION RECORDING FORM FOR THE NECK AND UPPER EXTREMITY

Name: ______________________ Current job: ______________

Examiner: ______________________ Date: _____/_____/_____

Discomfort scale: 0 = no discomfort, 1 = minimal, 2 = mild, 3 = moderate, 4 = severe, 5 = worst ever

Note: This form does not provide space for extensive neurological assessment.

Neck

Inspection: Inflammation (red, swollen, warm)	______ yes	______ no
Palpation:	*Right*	*Left*
Trapezius trigger point	______	______
Trapezius spasm	______	______
Maneuvers:		
Resisted flexion	______	______
Resisted extension	______	______
Resisted rotation	______	______

Shoulder

Inspection: Acromium inflammation?	______ yes (R or L)	______ no
Maneuvers:	*Right*	*Left*
Passive abduction	______	______
Active abduction	______	______
Resisted abduction	______	______
Deltoid palpation	______	______

Elbow

Inspection: Olecranon inflammation:	______ yes (R or L)	______ no
Palpation:	*Right*	*Left*
Medial epicondyle	______	______
Lateral epicondyle	______	______

Forearm

Inspection: Forearm inflammation?	______ yes (R or L)	______ no
Maneuvers:	*Right*	*Left*
Passive wrist flexion	______	______
Passive wrist extension	______	______
Resisted wrist flexion	______	______
Resisted wrist extension	______	______
Resisted finger flexion	______	______
Resisted finger extension	______	______
3rd Digit resisted extension	______	______

(continued)

Resting the Symptomatic Area

The most effective way to rest the symptomatic area is to reduce or eliminate employee exposure to musculoskeletal risk factors by changing the nature of the job itself (i.e., forceful exertions, repetitive activities, extreme or prolonged static postures, vibration, direct trauma). This allows the employee to remain a productive member of the workforce; it is best accomplished by engineering and work practice controls in the workplace.

APPENDIX 2-IV. PHYSICAL EXAMINATION RECORDING FORM FOR THE NECK AND UPPER EXTREMITY *(continued)*

Wrist		
Inspection: Inflammation	______ yes (R or L) ______ no	
Extensor ganglion cyst	______ yes (R or L) ______ no	
Flexor ganglion cyst	______ yes (R or L) ______ no	
Maneuvers:	*Right*	*Left*
Guyon Tinel's	______	______
Carpal Tinel's	______	______
Phalen's	______	______
Hands and Fingers		
Inspection: Inflammation	______ yes (R or L) ______ no	
Maneuvers:	*Right*	*Left*
Trigger finger	______	______
Finkelstein's	______	______

Until effective controls can be installed, employee exposure to biomechanical stressors should be reduced through restricted duty or a temporary job transfer. These measures should serve to reduce the total amount of employee exposure to musculoskeletal risk factors.[152,153] A variety of factors (e.g., symptom type, duration, and severity; response to treatment; biomechanical stressors associated with work) must be considered when determining how long an employee will spend on restricted duty. To determine the length of the assignment to restricted work, the following principle should be applied: The degree of restriction should be proportional to the severity of the symptom and the intensity of the job's biomechanical stressors. In addition, caution must be used in deciding which jobs are most suitable for the temporary transfer, because different jobs may nevertheless make similar biomechanical demands on the same muscles and tendons.[154]

Total removal from the work environment should be reserved for severe disorders, workplaces where the only available jobs entail significant biomechanical stressors for the symptomatic area, or workplaces where significant modifications to the employee's current job or any of the other available jobs are not feasible. For purposes of removal from the work environment, *severe disorders* can be defined as those that have a negative effect on the employee's daily activities (e.g., those that cause difficulty in buttoning clothes, opening jars, brushing hair, etc.).

Immobilization devices, such as splints or supports, can help rest the symptomatic area.[146–151,155] These devices are especially effective off the job, particularly during sleep. Wrist splints, typically worn by patients with possible carpal tunnel syndrome, should not be worn at work unless the employee's job tasks do not require wrist deviation or bending.[3,156] Employees who struggle to perform a task requiring wrist deviation while wearing a splint designed to prevent such deviation can exacerbate symptoms in the wrist due to the increased force needed to overcome the splint. The device may also cause other joint areas (elbows or shoulders) to become symptomatic as the work technique is altered.[139,156] Recommended periods of immobilization vary from several weeks to months, depending on the nature and severity of the disorder. Immobilization should be prescribed judiciously and monitored carefully to prevent iatrogenic complications (e.g., disuse muscle atrophy).[151,157] These recommendations do not preclude the use of immobilization devices for patients who have special needs due to underlying medical conditions.

Finally, employees with musculoskeletal disorders should be advised about the potential risks posed by hobbies, recreational activities, and other personal habits that involve certain biomechanical stressors.[149–151] They also need to modify their behaviors outside the workplace to reduce stress on the symptomatic area.

Treatment for Soft-Tissue/Tendon Disorders

Most clinicians consider cold therapy on the affected area helpful in reducing the swelling and inflammation associated with acute tendon-related disorders.[149–151,158] The effectiveness of cold therapy in chronic disorders has not been established, despite several articles discussing its mechanism.[159–162] Cold therapy is inappropriate for employees with neurovascular conditions such as hand-arm vibration syndrome, thoracic outlet syndrome, and CTS. In addition, prolonged direct contact with chemical cold packs or ice baths should be avoided to prevent frostbite-type injuries.[163]

Oral antiinflammatory agents (i.e., aspirin or other nonsteroidal antiinflammatory agents) can also help to reduce the severity of symptoms either through their analgesic or antiinflammatory properties.[146–151,164] Their gastrointestinal and renal side effects, however, make their chronic prophylactic use among asymptomatic employees inappropriate and may limit their usefulness among employees with chronic symptoms.[164]

Physical and occupational therapy is a valuable adjunct in the treatment of musculoskeletal disorders. Useful modalities include stretching and strengthening programs, individualized training on proper body mechanics, and teaching of appropriate self-care.[149–151,157,165]

Many, if not most, work-related musculoskeletal disorders improve when these conservative measures are adopted. Symptomatic employees should be followed to document such improvement. Employees who do not improve within the expected time frames should be reevaluated, or a second opinion should be obtained.

For disorders that prove resistant to conservative treatment, local injection of a corticosteroid may be indicated.[146–151,166] The addition of a local anesthetic agent to the injection can provide valuable diagnostic information. For example, to confirm a case of CTS, many clinicians look for rapid symptom improvement following the injection of anesthetic agents into the carpal canal. Although some symptoms may indicate the need for immediate surgical intervention, these situations are rare. Surgical options should be reserved for severe, chronic cases that, even after an adequate trial of conservative therapy, preclude the employee's return to work or show objective signs of disease progression. The length of time needed for an adequate trial of conservative therapy depends on many variables, including an employee's ability to remain productive without jeopardizing his or her long-term health.

PREVENTION

The control of identified ergonomic hazards is the most effective means of preventing work-related UE musculoskeletal disorders and should be the primary focus of any ergonomics program. Intervention strategies should follow a three-pronged approach, including engineering controls, administrative controls, and medical treatment. Psychosocial factors, if present, must also be addressed, since failure to do so may limit the effectiveness of other ergonomic interventions.

Engineering Controls

Numerous studies have shown that **engineering controls** can reduce ergonomic hazards.[167–175] In addition, several studies have shown that reduced exposure results in a reduction in the rates of musculoskeletal disorders.[152,176–183] In some situations, these ergonomic solutions are obvious and consistent with common sense. On the other hand, worksites may require a more comprehensive approach to the control of ergonomic hazards. This comprehensive approach should address the risk factors of repetition, force, posture, and vibration.[184]

To reduce repetitiveness, the following interventions can be used: mechanical aids, enlarged work content, automation of some job tasks, uniform distribution of work tasks across the workshift, and job restructuring. To reduce force or mechanical stressors, the following interventions should be considered: decreasing the weight of tools, containers, and parts; optimizing the size, shape, and friction of handles; and using torque control devices. Amelioration of awkward or extreme postures could be achieved by locating the work in a mechanically advantageous position, and selecting tool design and its location based upon work station characteristics. Engineering controls for the reduction of vibration are reviewed in Chapter 4.

In some instances, however, engineering controls are not currently available. Until they are, other aspects of an ergonomics program—administrative and medical treatment controls—can be implemented.

Administrative Controls

Administrative controls can be defined as work practices or training used to reduce employee exposure to ergonomic stressors. Examples of work practice controls include more frequent and longer rest breaks,[185] limiting overtime, varying work tasks or broadening job responsibilities, and periodic rotation of workers between more and less stressful jobs. Since job rotation exposes more workers to the more stressful job, it is suitable only where short-term performance of the stressful job poses no appreciable ergonomic hazard. Otherwise, other control methods must be utilized. Training programs range from fundamental instruction on the proper use of tools and materials to instruction on the use of protective devices. Improper work techniques have been associated with the development of UE musculoskeletal disorders.[186–187]

Medical Treatment

The goal of **medical treatment** as a component of an ergonomics program is to provide prompt evaluation and treatment that will limit the severity of the condition. It should also lead to a reevaluation of the ergonomic stresses associated with the affected worker's job and the institution of appropriate control measures. Medical treatment in this sense is a secondary and tertiary prevention mechanism. It should always be combined with engineering and administrative controls during the implementation of a complete ergonomics program.

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