2

ERGONOMICS AND UPPER EXTREMITY MUSCULOSKELETAL DISORDERS

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Ergonomics has been defined as the science of fitting the job to the worker,[1] or the art of matching job demands with worker capabilities. Upper extremity (UE) musculoskeletal disorders (MSDs) are soft tissue disorders of the muscles, tendons, ligaments, peripheral nerves, joints, cartilage, or supporting blood vessels in the neck, shoulder, arm, elbow, forearm, hand, or wrist. Examples of specific disorders include tension neck syndrome, rotator cuff tendinitis, epicondylitis, peritendinitis, and carpal tunnel syndrome (CTS). When job demands overwhelm an employee's mental and/or physical capacity, employee health, comfort and productivity can be adversely affected.[2] While comfort and productivity levels are important outcomes to consider, this chapter will focus upon the effect of workplace physical stressors (repetition, force, posture, and vibration) on the musculoskeletal system of the upper extremities. The chapter will not only review the literature, but will also provide practical tools for healthcare providers to (1) assess physical stressors in the workplace, and (2) recognize, treat, and prevent UE MSDs.

OCCUPATIONAL SETTING

Magnitude of the problem

The Bureau of Labor Statistics (BLS) conducts an annual survey of employer-maintained OSHA 200 Logs for about 165 000 private sector establishments in the USA. In 1998, the BLS estimated that nearly 593 000 employees suffered a work-related MSD serious

Physical and Biological Hazards of the Workplace, Second Edition, Edited by Peter H. Wald and Gregg M. Stave
ISBN 0-471-38647-2

enough to result in days away from work (DAW).[3] The median number of DAW was seven, with 120000 cases (20%) missing more than 30 days. Sprains and strains represented the most common diagnosis (81%), followed by carpal tunnel syndrome (5%), soreness/pain (4%), tendinitis (3%), and others (7%).[3] The most common responsible event or exposure was "overexertion" (77%), followed by "bending, climbing, crawling, reaching, twisting" (13%), and "repetitive motion" (10%).[3]

In 1989, Webster and Snook identified 6067 UE MSD workers' compensation claims for policy holders in 45 states with an average (mean) cost of $8070 per claim.[4] They estimated the total direct US workers' compensation costs for UE MSDs to be $563 million in 1989.[4] For this same year, Silverstein et al reported an average Washington State UE MSD claim to range from $7093 to $8250, and estimated the total direct workers' compensation costs for the US to be $6.1 billion.[5] Neither of these estimates include the indirect costs, such as administrative costs for claims processing, lost productivity, and the cost of recruiting and training replacements. It has been suggested that indirect costs are two to three times direct compensation costs.[6]

While these numbers are impressive, they do not take into account those workers who suffer a UE MSD but are never recorded onto the OSHA 200 Log and do not file a claim.[7,8] Rossenman et al reported that in 1996 only 25% of workers with work-related MSD filed for workers' compensation.[9] Factors associated with filing a claim included increased length of employment, lower annual income, dissatisfaction with coworkers, physician restriction on activities, type of physician providing treatment, being off work for at least 7 days, decreased current health status, and increased severity of illness.[9]

Industries at risk

According to the BLS annual survey, the manufacturing and service industries had the most MSDs involving DAW.[3] Looking at a category of illnesses labeled by the BLS as "disorders due to repeated trauma" (DRT), meat-packing plants have had the highest DRT rates since the BLS began collecting industry-specific data in 1984. In 1998, the DRT rate for meat-packing plants was 994 cases per 10000 full-time workers.[3] The motor vehicles/car bodies and the poultry-slaughtering/processing industries have always had some of the highest DRT rates, ranking second and third, respectively, in 1998.[3] Data on CTS from individual state workers' compensation programs and National Health Interview Survey (NHIS) data have identified the same high-risk industries.[5,10–12] Although these industries have higher rates of DRT, the BLS reports substantial numbers of MSD involving lost work days in every industry. This finding is consistent with data from the National Occupational Exposure Survey (NOES), which found physical stressors in most industrial and service operations.[13] The NOES survey 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".[13]

Occupations at risk

Case reports have given rise to a number of disorders named for the patient's occupation

Table 2.1 Work-related MSD named by occupation.

Bricklayer's shoulder
Carpenter's elbow
Golfer's elbow
Tennis elbow
Janitor's elbow
Stitcher's wrist
Cotton twister's hand
Telegraphist's cramp
Writer's cramp
Bowler's thumb
Jeweler's thumb
Cherry pitter's thumb
Gamekeeper's thumb
Carpetlayer's knee

(Table 2.1). This does not mean, however, that these disorders are unique to their occupations. The BLS reported over 100 occupations with large numbers of cases (over 600 cases of MSD involving DAW per occupation).[3] Looking specifically at MSDs involving DAW resulting from repetitive motion, assemblers had the largest number of cases (Table 2.2). The NHIS described cases of self-reported CTS to be highest among mail/message distributors (prevalence 3.2%), health assessment and treatment occupations (2.7%), and construction trades (2.5%).[12] The Wisconsin workers' compensation program reported wrist injury to be highest among dental hygienists, data-entry keyers, and hand grinding and polishing occupations.[11] Although the various occupations have different rates of MSD, the BLS and workers' compensation data point to almost all occupations reporting at least one case of work-related MSD.

Epidemiology

One of the main purposes of epidemiologic studies is to identify factors that are associated (positively or negatively) with the development or recurrence of adverse medical conditions. No single epidemiologic study determines causality. Rather, results from epidemiologic studies can contribute to the evidence of causality. Over the past decade, several publications have reviewed the medical and ergonomic literature to determine whether scientific evidence supports a relationship between workplace physical factors and MSDs. The most comprehensive review was completed by Bernard at the National Institute for Occupational Safety and Health (NIOSH).[14] This review focused on disorders that affected the neck (tension neck syndrome), upper extremities (shoulder tendinitis, epicondylitis, CTS, hand–wrist tendinitis, hand–arm vibration syndrome), and the low back (work-related low back pain). A database search strategy initially identified 2000 studies, but laboratory, biomechanical, clinical treatment and other non-epidemiologic studies were excluded, leaving 600 for systematic review. The review process consisted of three steps.

The first step gave the increased emphasis, or weight, to studies that had high participation rates (> 70%), physical examinations, blinded assessment of health and exposure, and objective exposure assessment. The second step assessed for any other selection bias and any uncontrolled potential confounders. The final step summarized studies with regard to strength of the associations, consistency in the associations, temporal associations, and exposure–response (dose–response) relationships.

Bernard concluded that a substantial body of credible epidemiologic research provides strong evidence of an association between MSDs and certain work-related physical factors. This is particularly true when there are high levels of exposure or exposure to more than one physical factor (e.g. repetition and forceful exertion). The strength of the associations for specific physical stressors varies from insufficient to strong (Table 2.3). The consistently positive findings from a large number of cross-sectional studies, strengthened by the available prospective studies, provides strong evidence for an increased risk of work-related MSDs for the neck, elbow, and hand–wrist. This conclusion was supported by another exhaustive review conducted by the National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and the National Research Council.[15]

MEASUREMENT—ASSESSMENT

Physical stressors can be grouped into the following categories: repetition, force, posture, and vibration. They arise from excessive job demands, improperly designed workstations, tools, or equipment, or inappropriate work techniques. Recently, Radwin and Lavender have proposed a different model of "external loading factors".[16] They identified motion, force, vibration and temperature as physical stressors that are modified by the properties of

Table 2.2 MSDs involving days away from work resulting from repetitive motion; occupations with 1% or more of total cases, 1998.

	Repetitive motion		Repetitive typing or key entry		Repetitive use of tools		Repetitive placing, grasping, or moving objects, except tools	
Occupation	Number	%	Number	%	Number	%	Number	%
All occupations	65866	100.0	9784	100.0	9364	100.0	21164	100.0
Assemblers	6683	10.4	65	0.7	1909	20.4	2405	11.4
Miscellaneous machine operators, n.e.c.	3932	6.0	–	–	533	5.7	1735	8.2
Laborers, non-construction	2483	3.8	–	–	284	3.0	988	4.7
Textile sewing machine operators	1782	2.7	–	–	287	3.1	755	3.6
Secretaries	1557	2.4	1111	11.4	–	–	283	1.3
Cashiers	1467	2.2	241	2.5	–	–	602	2.8
Packaging and filling machine operators	1444	2.2	–	–	79	0.8	930	4.4
Electrical and electronic equipment assemblers	1359	2.1	–	–	268	2.9	479	2.3
Data-entry keyers	1279	1.9	1158	11.8	–	–	44	0.2
Truck drivers	1177	1.8	–	–	63	0.7	639	3.0
Hand packers and packagers	1007	1.5	–	–	–	–	619	2.9
Welders and cutters	973	1.5	–	–	309	3.3	315	1.5
Butchers and meat cutters	881	1.3	–	–	412	4.4	196	0.9
Investigators and adjusters, excluding insurance	870	1.3	456	4.7	19	0.2	45	0.2
Book-keepers, accounting, and auditing clerks	859	1.3	399	4.1	203	2.2	–	–
Freight, stock, and material handlers, n.e.c.	835	1.3	–	–	–	–	576	2.7
General office clerks	819	1.2	317	3.2	–	–	137	0.6
Machine operators, not specified	808	1.2	–	–	136	1.5	304	1.4
Production inspectors, checkers, and examiners	802	1.2	–	–	60	0.6	485	2.3
Carpenters	790	1.2	–	–	215	2.3	335	1.6
Supervisors and proprietors, sales occupations	706	1.1	113	1.1	44	0.5	141	0.7
Stock handlers and baggers	701	1.1	64	0.7	–	–	332	1.6
Maids and housemen	678	1.0	–	–	48	0.5	212	1.0

Source: BLS.[3] n.e.c. = not elsewhere classified.

magnitude, repetition, and duration (Table 2.4). Whatever physical stressor model is used, a number of methods are available to measure/estimate these stressors. The method selected should be based on the purpose of the evaluation. The following grouping provides several options.

Survey methods

Employee or supervisor interviews, employee diaries and employee-completed questionnaires are useful because of their low cost, rapid availability, and, for some, the ability to obtain historical data about previous

Table 2.3 Evidence for causal relationship between physical work factors and MSDs.

Body part and risk factor	Strong evidence (+++)	Evidence (++)	Insufficient evidence (+/0)	Evidence of no effect (−)
Neck and neck/shoulder				
Repetition		✓		
Force		✓		
Posture	✓			
Vibration			✓	
Shoulder				
Posture		✓		
Force			✓	
Repetition		✓		
Vibration			✓	
Elbow				
Repetition			✓	
Force		✓		
Posture			✓	
Combination	✓			
Hand/wrist				
Carpal tunnel syndrome				
Repetition		✓		
Force		✓		
Posture			✓	
Vibration		✓		
Combination	✓			
Tendinitis				
Repetition		✓		
Force		✓		
Posture		✓		
Combination	✓			
Hand–arm vibration syndrome				
Vibration	✓			
Back				
Lifting/forceful movement	✓			
Awkward posture		✓		
Heavy physical		✓		
Whole-body vibration		✓		
Static work posture			✓	

Source: Bernard.[14]

exposures.[17–19] One of the most commonly used survey tools is the so-called Borg, or rating of perceived exertion, scale.[20] A 15-point scale (6–20) was created to reflect the linear relationship between physical workload and heart rate divided by 10 (for example, a heart rate of 60 beats/min corresponds to 6 on the scale). The scale is presented to the subject before the start of a job or job task with anchors of "no exertion at all = (6)" to "maximal exertion = (20)". The subject is then asked to rate his or her exertion level

Table 2.4 Relationship between external physical stress factors and their properties.

	Property		
Physical stress	Magnitude	Repetition rate	Duration
Force	Force generated or applied	Frequency with which force is applied	Time for which force is applied
Motion	Joint angle, velocity, acceleration	Frequency of motion	Time to complete motion
Vibration	Acceleration	Frequency with which vibration occurs	Duration of vibration exposure
Cold	Temperature	Frequency of cold exposure	Duration of cold exposure

Source: Adapted from Radwin and Lavender.[16]

after completing the job and/or job task. A 10-point Borg scale was also created (Table 2.5) to account for large muscle group exertion, rather than heart rate or total body exertion.[21,22]

The accuracy of self-assessment surveys has been questioned because of the potential for the worker to either under-report or over-report exposures. For example, highly motivated subjects might underestimate their exertion, while unmotivated subjects might overestimate their exertion. This potential problem has led many to utilize observational checklists (described below).

Table 2.5 Rated perceived exertion scale of Borg.

0	Nothing at all
0.5	Extremely weak (just noticeable)
1	Very weak
2	Weak
3	Moderate
4	Somewhat strong
5	Strong (heavy)
6	
7	Very strong
8	
9	
10	Extremely strong (almost maximal)

Source: Adapted from Borg.[21,22]

Observational methods

Observational methods are commonly employed to objectively assess the workplace for physical stressors. Such observations should arguably follow a checklist to ensure that subtle risk factors are not overlooked.[23] Some checklists can be used by healthcare providers with limited expertise,[24–26] others require some training,[27,28] while others require a considerable amount of experience and training.[29–31] Figures 2.1 to 2.4 provide the reader with four tools for the assessment of workplace physical stressors.

Measuring workers

If the first two methods suggest that physical stressors exist in the workplace, quantitative measurement of those risk factors could be considered. However, quantitative measurement of ergonomic hazards typically utilizes specialized equipment and requires expertise in its use and interpretation of the results. Such measurements should currently be 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 workstation redesign.

Methods used to generate quantitative information on physical stressors include electrogoniometers (dynamic measurements of

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 degrees 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 of 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 s?		
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?		

Figure 2.1 University of Michigan's checklist for Physical Stressors. Adapted from Lifshitz and Armstrong.[24]

posture), accelerometers, and imaging techniques (electronic and laser optical recordings). Two devices that may be useful outside of research settings are spring scales or gauges to estimate force requirements, and simple goniometers to measure static postures. Both of these tools have been used successfully in workplaces, due to their simplicity.

Internal forces can be measured using surface electromyography (EMG), but currently available equipment is expensive, and its use requires expertise that is not widely available. Video and imaging systems as a means to measure posture have been used primarily in the laboratory setting, where the camera's line of sight is perpendicular to the planes of the measured body segments. But given the dynamic nature of most job activities, their use in the workplace seems limited unless multiple cameras can be used from a variety of viewing angles. Goniometer use for measuring static postures is well established, but few jobs require continuous static postures. Electrogoniometers can measure dynamic postures, but their accuracy and associated analytic methods are not well established.

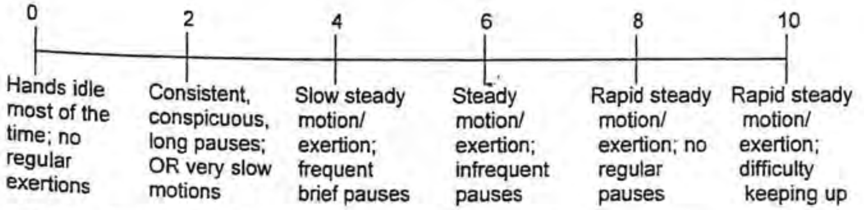

Figure 2.2 Visual-analog scale for rating repetition/hand activity, with verbal anchors.[27]

Body Part	Effort Level	Continuous Effort Time	Efforts/ Min	Priority
Neck/Shoulders	R____	____	____	____
	L____	____	____	____
Back	____	____	____	____
Arms/Elbows	R____	____	____	____
	L____	____	____	____
Wrists/Hands/ Fingers	R____	____	____	____
	L____	____	____	____
Legs/Knees	R____	____	____	____
	L____	____	____	____
Ankles/Feet/Toes	R____	____	____	____
	L____	____	____	____

Effort Categories
1 = Light
2 = Moderate
3 = Heavy

Continuous Effort Time Categories
1 = <6 s
2 = 6-20 s
3 = >20 s

Efforts/Minutes Categories
1 = <1/min
2 = 1-5 min
3 = >5/min

Priority for Change

Moderate = 123, 132, 213, 222, 231, 232, 312

High = 223, 313, 322

Very High = 323, 331, 332

Job Title:____________________

Specific Task:____________________

Job Number:____________________

Department:____________________

Location:____________________

Contact Person(s):____________________

Phone:____________________

Analyst:____________________

Phone:____________________

Date of analysis:____________________

Figure 2.3 Ergonomic job analysis checklist.[28]

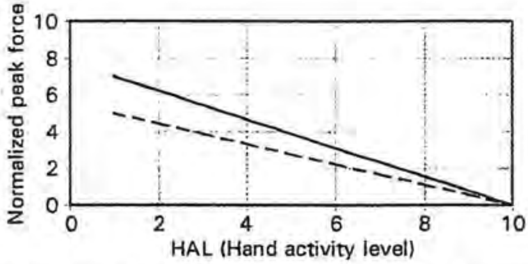

Figure 2.4 The threshold limit value (TLV) for reduction of work-related MDS based on hand activity and force. The top line is the TLV, and the bottom line the action limit. Reprinted with permission from American Conference of Governmental Industrial Hygienist (ACGIH®) TLV® Hand Activity Level Draft Document Copyright 2001.[32]

EXPOSURE GUIDELINES

American Conference of Governmental Industrial Hygienists

In 1999, the American Conference of Governmental Industrial Hygienists (ACGIH) proposed an exposure threshold for UE MSDs based on repetition and peak normal force for mono-task jobs.[32] While MSDs can involve any area of the upper extremity, the focus of the ACGIH threshold limit value (TLV) is the hand, wrist, and forearm. It is based on "mono-task" jobs, defined as jobs that required repeatedly performing a similar set of motions or exertions for four or more hours per day.

Repetition, or average hand activity level (HAL), is determined by a trained observer using the rating scale validated by Latko et al (Figure 2.2),[27] or calculated using information on the frequency of exertion and the work/recovery ratio (Table 2.6).[32] Peak hand force is normalized on a scale of 0–10, where 0 corresponds to no effort and 10 corresponds to 100% maximal effort. Normalized peak hand force is determined for a given task by: (1) determining hand forces and corresponding postures; (2) obtaining strength data for that posture and that worker or work population—in most cases, strength values can be obtained directly or extrapolated from the literature; and (3) calculating normalized peak hand force by dividing required force by strength.

Hand force can be determined by worker ratings, observer ratings, biomechanical analyses, force gauges and EMG. Since the latter three methods require considerable skill and instrumentation, the following discussion will focus on worker and observer ratings. Worker ratings utilize the same Borg scale

Table 2.6 Hand activity level (0–10) is related to exertion, frequency, and duty cycle (% of work cycle where force is greater than 5% of maximum).

Frequency (exertion/s)	Period (s/exertion)	Duty cycle (%)				
		0–20	20–40	40–60	60–80	80–100
0.125	8.0	1	1	–	–	–
0.25	4.0	2	2	3	–	–
0.5	2.0	3	4	5	5	6
1	1.0	4	5	5	6	7
2	0.5	–	5	6	7	8

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described earlier (Table 2.5). Suppose, for example, a male worker rates his job's grip strength requirements as four (somewhat strong). To normalize this force, we measure the worker's grip strength (300 newtons (N)) and compare this to the average male strength (500 N). Therefore, the normalized peak force = 4 × 300 N/ 500 N = 2.4. Observer ratings of force utilize the same Latko et al scale described earlier (Figure 2.2).[27] Factors that the observer should consider include the weight, shape and friction of the work object, posture, glove fit and friction, mechanical assists, torque specification of power tools, quality control, and equipment maintenance. The precision of both the worker and observer ratings are improved by having multiple workers/observers rate the same job.

The HAL and the normalized force estimates can now be plotted and compared to the TLV (Figure 2.4). Employees performing job tasks above the solid top line will be at significant risk of acquiring a UE MSD, and specific control measures should be utilized so that the force for a given level of hand activity is below this line. The dotted lower line represents an "action limit", the point at which general controls, including surveillance (discussed below), are recommended. Although professional judgment is used to account for awkward or extreme postures, contact stresses, low temperatures, and vibration, the TLV does not specifically account for these potential stressors. If these stressors are present on jobs, the TLV and the action limit will be lower.

Others

Since ACGIH TLV does not account for all potential physical stressors, the reader is encouraged to review other proposed UE exposure guidelines, such as the strain index proposed by Moore and Garg,[29,33] and the Rapid Upper Limb Assessment (RULA) proposed by McAtamney and Corlett.[30]

Posture is an important potential physical stressor. 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 non-neutral) and normal ranges of motion have been developed by the American Academy of Orthopedic Surgeons.[34] 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.

Kodak has proposed the following posture guidelines:[35]

- Keep the work surface height low enough to permit employees to work with their elbows at their sides, and wrists near their neutral position.
- Keep reaches within 20 inches in front of the work surface so that 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 more than 90° of rotation around the wrist.
- Avoid gripping requirements in repetitive operations that spread the fingers and thumb apart more than 2.5 inches. Cylindrical grips should not exceed 2 inches in diameter, with 1.5 inches being the preferable size.

Federal Ergonomics Standard

Over the past decade the Occupational Safety and Health Administration (OSHA) worked to develop an ergonomics standard. On November 14, 2000 a final Ergonomics Program Standard was issued to take effect January 16, 2001. In March 2001, under the Congressional Review Act, Congress passed and President Bush signed a resolution of disapproval. Accordingly, OSHA removed the standard form the Code of Federal Regulations on April 23, 2001. In its place the Bush Administration pledged to find solutions to ergonomic-related problems affecting the nation's workforce. In addition, OSHA will continue to conduct ergonomic investigations, and, if appropriate, cite and fine companies with ergonomic problems under the authority of the General Duty Clause. The repealed standard is still available from OSHA's web site.[36]

California Ergonomics Standard

In 1993, the California State Legislature required its Occupational Safety and Health Standards Board to develop an ergonomics standard on or before January 1, 1995. Subsequent legal challenges shaped its content and start date. The current standard, adopted in 1999, applies to a job, process, or operation where a repetitive motion injury (RMI) has occurred to more than one employee under the following conditions:

1. A licensed physician objectively identified and diagnosed the RMI; and
2. The RMI was work-related (>50% caused by a repetitive job, process, or operation); and
3. The employees with RMIs were performing a job process, or operation of identical work activity (performing same repetitive motion task); and
4. The employee reported the RMI to the employer in the last 12 months.

If the above conditions are met, the employer is required to develop an ergonomics program with the following three components: worksite evaluation, control of workplace exposures, and employee training. The worksite evaluation requires that each job, process, or operation of identical work activities be evaluated for exposures causing RMIs. If these exposures are found, they must be corrected in a timely manner, or, if not capable of being corrected, have the exposures minimized to the extent feasible. In addition, employees must receive training on:

- The employer's ergonomic program;
- The exposures which have been associated with RMIs;
- The symptoms and consequences of injuries caused by repetitive motion;
- The importance of reporting symptoms and injuries to the employer; and
- Methods used by the employer to minimize RMIs.

Finally, the employer is obligated to make an alternative intervention if the alternative has proven to reduce RMI and would not impose unreasonable employer costs.[37]

Washington Ergonomics Standard

In May 2000, the State of Washington issued its ergonomics rule. The rule is exposure based, and does not include requirements for handling of insurance claims, or for medical management. Employers are covered by the rule if their workplace contains "caution zone jobs" which may be hazardous and require further evaluation. The rule defines caution zone jobs as exposure to physical risk factors (awkward posture, high hand force, highly repetitive motion, repeated impact, heavy/frequent/awkward lifting, and moderate/high hard-arm vibration) for a significant duration, typically for more than two hours per day. Jobs that meet this definition must be analyzed for work-related MSD hazards and, if found, those exposure must be reduced below the hazardous level or to the extent technologically and economically feasible. The rule also requires employees working or supervising in caution zone jobs to receive ergonomics awareness education, and be given the opportunity to participate in the analysis for work-related MSD hazards and selecting measures to reduce these hazards. Compliance with the rule will be phased-in by type of industry and size of the workforce.[38]

NORMAL PHYSIOLOGY AND ANATOMY

Muscles

Muscle consists of muscle fibers (muscle cells), nerve elements (motor neurons, afferent neurons, receptors of different types), connective tissue, and blood vessels. Muscle fibers are classified into two types: type I fibers, also known as slow-twitch or red muscle fibers, and type II fibers, also known as fast-twitch or white muscle fibers. In muscle fibers, the smallest morphologic contractile unit is the sarcomere, built of actin and myosin filaments. The smallest functional unit is the motor unit, which consists of a motor neuron cell and the muscle fibers that its branches supply. The muscles of the body are the generators of internal force that convert chemically stored energy into mechanical work. A muscle contracts its thread-like fibers, which shortens the length of the muscle, thereby generating a contractile force.

Myalgia is the medical term for the symptom of muscle pain. The most common type of myalgia, delayed-onset muscle soreness (DOMS), is a contraction-induced injury after vigorous or unaccustomed exercise. DOMS is a self-limiting condition that typically appears within the first 24 hours after exercise, peaks at 48–72 hours, and resolves within 1 week. Histologic and chemical changes are found in affected muscles, but these changes are not permanent and lead to a conditioning effect when they take place in a graduated manner.[39–41]

Armstrong proposed the following theory for the pathogenesis of DOMS:[39–41]

- High mechanical forces, particularly those associated with eccentric exertions, cause structural damage of the muscle fibers and associated connective tissue structures.
- This structural damage alters the sarcolemma's permeability, producing a net influx of calcium into the cell. This calcium inhibits mitochondrial production of ATP, and activates proteolytic enzymes that degrade Z-discs, troponin, and tropomyosin.
- The progressive degeneration of the sarcolemma is accompanied by diffusion of intracellular products into the interstitium and plasma; this attracts inflammatory cells that release lysosomal proteases, which further degrade the muscle proteins.
- Active phagocytosis and cellular necrosis lead to accumulation of histamine, kinin, and potassium, which stimulate regional nociceptors, resulting in the sensation of DOMS.

Eccentric contractions (muscle activation while the muscle is stretched), rather than isometric contractions, are felt to lead to DOMS.[42] Eccentric contractions can occur when muscles are exposed to either a single rapid stretch or a series of repetitive contractions.[41] Both models are consistent with DOMS requiring a temporary reduction in physical loading because of pain or discomfort. This is followed by a gradual increase in physical loading to stimulate healing and subsequent tissue-remodeling processes.

Muscle also undergoes a number of age-related changes, such as a 20% decrease in muscle mass, a 20% reduction in maximal isometric force, and a 35% decrease in the maximal rate of developing force and power.[43] This latter reduction is not due to differences in muscle recruitment strategies, but rather due to a change in the contractility of the muscle itself.[44] This translates into a marked decrease in the ability to sustain power over repeated contractions in older individuals. In addition, animal experiments have also demonstrated that older muscle damages more easily and heals more slowly.[45,46] These effects may help explain why older athletes seem to require greater rest intervals between training sessions, and why workers in physically demanding jobs tend to change to less demanding jobs with age.[47]

Tendons

As a general rule, tendons transmit the contractile force generated by muscles to bone. Tendons are composed of collagen fibrils grouped into fibers that are collected together into fiber bundles that are united into fascicles.[48] A large number of fascicles form the tendon. The fiber bundles and fascicles are enclosed in thin films of loose connective tissue called the *endotenon*. This connective tissue contains blood vessels, lymphatic vessels, nerves, and elastic fibers, and allows the fascicles to slide relative to one another. The whole tendon is wrapped in connective tissue called the *epitenon*. In some tendons, a further sheath, the *paratenon*, surrounds the tendon. The paratenon is merely a specialization of the areolar connective tissue through which many tendons run. A number of structures associated with tendons control and facilitate their movement. Where tendons wrap around bony pulleys or pass over joints, they are held in place by retaining ligaments (retinaculae, or fibrous sheaths that prevent bowstringing). Tendons glide beneath these retaining structures due to the lubrication provided by the synovial sheath.[49] In some regions, tendons are prevented from rubbing against adjacent structures by bursae. Although tendons generally have a good blood and nerve supply, regions of tendon subjected to friction, compression or torsion are hypovascular or avascular. The general structure of tendons is modified in two regions: the sites where they attach to bone (enthesis) and the region where they are compressed against neighboring structures (around bony pulleys).[50] Fibrocartilage formation at the site of this compression loading is considered a normal/adaptive response. In summary, tendons have the capacity to change their structure and composition in response to mechanical stimulation. In most cases, this mechanical stress is beneficial and adaptive for maintaining cell activity and tissue function.

Peripheral nerves

Peripheral nerves carry signals to and from the central nervous system. A nerve fiber (neuron) consists of the nerve body, which is located in the anterior horn of the spinal cord (motor neuron) or in the dorsal root ganglia (sensory neuron), and a process extending into the periphery—the axon.[51] The axon is surrounded by Schwann cells. In myelinated fibers, a Schwann cell is wrapped around only one axon, in contrast to non-myelinated fibers, where the Schwann cell wraps around several axons. Myelinated and non-myelinated nerve fibers are organized in bundles, called *fascicles*, which are bound by supportive connective tissue, the *perineurium*. The bundles are usually organized in groups, held together by loose connective tissue called the *epineurium*. In between the nerve fibers and their basal membrane is located intrafascicular connective tissue—the *endoneurium*. The amount of connective tissue components varies between nerves, and between various levels along the same nerve. The myelin insulation divides the axon into short, uninsulated regions (nodes of Ranvier) and longer, insulated regions (internodes). Conduction of nerve impulses proceeds by sequential activation of successive nodes without depolarization of the intervening internode (saltatory conduction).

PATHOPHYSIOLOGY AND PATHOGENESIS

Muscles

Myopathy is the medical term for measurable pathologic changes in a muscle, with or without symptoms. Myopathies can be due to a variety of congenital (e.g. muscular dystrophy) or acquired (e.g. inflammatory, metabolic, endocrine, or toxic) disorders. These diseases are not typically work-related and will not be discussed further.

Muscle pain syndromes of unknown etiology can be classified into two categories: general and regional. General muscle pain involving all four quadrants of the body is called primary fibromyalgia. Primary fibromyalgia is not work-related because, by definition, trauma-induced myalgia is excluded by the specific diagnostic criterial set by the American College of Rheumatology.[52] Regional muscle pain syndromes, not involving the whole body, often fall under the term myofascial syndrome. This has been defined as a painful condition of skeletal muscle characterized by the presence of one or more discrete areas (trigger points) that are tender when pressure is applied.[53] These muscle-related syndromes, a common example of which is tension neck syndrome, could be associated with work exposures. A variety of mechanisms have been proposed to account for this syndrome. A few are listed below.

Work and Eccentric Contractions DOMS is a result of eccentric contractions that could occur on or off the job. DOMS has objective histologic and chemical changes, but these changes are part of the normal physiologic response. The pain or discomfort associated with DOMS, however, typically results in a temporary reduction in physical loading due to pain or discomfort. This is followed by a gradual increase in physical loading to stimulate healing and subsequent tissue remodeling. But if workers with physically demanding jobs have little control over the magnitude and duration of loading, the work can aggravate and hinder the healing process, thereby increasing the risk of developing a more chronic condition. Work-hardening programs are specifically designed to minimize this risk by prescribing graduated physical training regimens

Work and gamma motor neurons This theory starts with evidence that muscle pain, inflammation, ischemia or sustained static muscle contractions are known to lead to the release of potassium chloride, lactic acid, arachidonic acid, bradykinin, serotonin and histamine in the affected muscle.[54] These substances, in turn, are known to excite chemosensitive group II and IV afferents, which have a potent effect on gamma-muscle spindle systems and heighten the response of those spindles to stretch. Increased activity in the primary muscle spindle afferents may cause muscle stiffness, leading to further production of metabolites, more stiffness, and repetition of the cycle.

Work and the overload of type I fibers Another hypothesis for the pathogenesis of tension neck syndrome is that prolonged static contractions of the trapezius muscle result in an overload of type I muscle fibers. Type I muscle fibers are used for low static contractions. Support for this hypothesis comes from findings on biopsy. When compared to healthy controls, type I fibers in patients with chronic trapezius muscle pain: (1) were larger, (2) had a lower capillary-to-fiber ratio, (3) had a more "ragged" appearance, and (4) had reduced ATD and ADP levels.[55–57] Whether these findings are due to inadequate muscle recruitment[58] or inadequate tissue oxygenation is unknown.[59]

Work and muscle fatigue Finally, much work has been done on the mechanisms of fatigue relating to muscle disorders. A complete review of these mechanisms can be found in Gandevai et al.[60]

Tendons

Physicians in sports medicine have suggested that tendon disorders fall into four main categories: paratendonitis, paratendonitis with tendinosis, tendinosis, and tendinitis.[61] These categories are based on clinical and histologic findings. It can be difficult to distinguish between these specific conditions on clinical evaluation alone. Because most conditions can be treated conservatively, histologic changes have been documented in only a subset of patients whose cases proceeded to surgery. Thus, many cases are defined simply as "tendinitis" based on history, examination, and impaired function.

Proposed mechanisms for work-related tendon disorders include:[62] (1) ischemia in hypovascular tissues; (2) microinjuries incurred at a rate that exceeds repair potential; (3) thermal denaturation; (4) dysregulation of paratenon–tendon function; and (5) inflammatory processes secondary to some, or all, of these other factors.

Shoulder disorders provide evidence for the ischemic theory. Work above one's head can have two effects: compression (impingement) and reduced local bloodflow. Impingement comes from the narrow space between the humeral head and the tight coracoacromial arch. As the arm is raised in abduction, the rotator cuff tendons and the insertions on the greater tuberosity are forced under the coracoacromial arch.[63] Reduced local bloodflow occurs when the supraspinatus muscle is statically contracted, increasing the intramuscular pressure higher than the arterial pressure of the vessel traversing the supraspinatus muscle belly and supplying it with oxygen.[64] These work factors, in combination with the fact that the entheses of the three tendons comprising the rotator cuff are hypovascular, lead to tendon degeneration manifested by microruptures and calcium deposits. Once the tendons are degenerated, exertion may trigger an inflammatory response resulting in active tendinitis.[65]

The pathogenesis and pathophysiology of lateral epicondylitis is less worked out. Histologic evaluation of tennis elbow tendinosis identifies a non-inflammatory response in the tendon. This histopathology reveals disorganized immature collagen formation in association with immature fibroblastic and vascular elements. This has been named angiofibroblastic tendinosis and is thought to be the result of an avascular degenerative process.[66] This pathology is located at the enthesis of the extensor carpi radialis brevis (ECRB) tendon. Factors associated with its development include age, systemic factors, direct trauma, and repetitive overuse from sports, occupation, and performing arts. It is theorized that multiple repetitive eccentric loading of the ECRB results in tension loading, microruptures of the peritendon and secondary anoxia and degenerative consequences.

Tendon sheaths

Tendons can become trapped in their synovial sheaths due to a narrowing of their fibroosseous canal. Tendons passing through stenotic canals frequently have a nodular or fusiform swelling and can be covered with granulation tissue.[67] Whether these tendon changes are a cause or an effect of the narrowing is unclear. If the narrowing occurs in the first dorsal compartment, the disorder is known as De Quervain's tenosynovitis.[67] If it occurs in the flexor digits or thumb (A-1 pulley), it is known as trigger finger or trigger thumb.[68]

While the term tenosynovitis implies inflammation of the tendon sheath, inflammatory cells are rarely found on histology. The lack of inflammatory cells could represent a sampling bias, since typically only chronic severe cases are biopsied, when the inflammatory process could have already run its course.[69] The fundamental pathologic change is hypertrophy and/or fibrocartilaginous metaplasia; however, recent studies suggest that the fibrocartilaginous metaplasia represents an adaptive response to compressive forces.[50]

The pathogenesis of tendon entrapment disorders involves static compression, repeated compression, and acute trauma. The static compression model is based on clinicians' observations that De Quervain's tenosynovitis is related to repeated, prolonged, or unaccustomed, exertions that involve the thumb in combination with non-neutral wrist or thumb postures. Tensile loading of the abductor pollicis longus or extensor pollicis brevis, in combination with their turning a corner at the extensor retinaculum, creates a compressive force. The retinaculum responds with functional hypertrophy or fibrocartilaginous metaplasia. The duration of compression is more important than the number (repetition) of compressions. The repeated compression theory relies on the same biomechanical argument, except that the number of episodes of loading (repetition) is more critical than the accumulated duration of loading.

Peripheral nerves

Although a number of peripheral nerve entrapment disorders exist, CTS is the most common, most studied, and will be the only nerve entrapment disorder discussed in this chapter.

CTS is the entrapment of the median nerve within the carpal canal at the wrist. Rempel[70] has summarized three possible mechanisms:

(1) friction associated with repetitive tendon motions, leading to flexor tendon sheath irritation and swelling; (2) repeated direct mechanical trauma to the median nerve by structures within the carpal tunnel; and (3) prolonged elevated pressure within the carpal tunnel, leading to ischemia, tissue swelling, and epineural fibrosis. The last mechanism is supported by the following: (1) carpal tunnel pressure (CTP) is almost always higher in patients with CTS than in normal subjects;[71] (2) surgical decompression (carpal tunnel release surgery) seems to be effective at reducing the elevated CTP and improving symptoms;[72] (3) histologic studies of the flexor tendon sheaths biopsied during carpal tunnel release show edema and vascular changes consistent with long-standing ischemia;[73] (4) animal models of acute and chronic nerve compression show physiologic and histologic findings consistent with nerve ischemia;[71] (5) in human studies, acute elevation of CTP results in acute nerve dysfunction, with the critical threshold varying according to the subject's diastolic blood pressure;[74] and (6) human studies have found a dose–response relationship between CTP and wrist posture,[75] fingertip loading,[76] and repetitive hand activity.[77] These findings are consistent with the static and dynamic biomechanical models of CTS.[78]

Psychosocial

Numerous studies have documented the association between psychological stress and health complaints. However, controversy exists as to whether these health complaints represent an actual increase in disease, an increase in reporting, or somatization. Although several studies have linked psychological stress and medical diseases,[79–89] few have reported a relationship between psychosocial stress and objective signs of UE musculoskeletal disorders.[90–93] The mechanism for this effect is unclear, but some authors have postulated that psychosocial stress can lead to muscle tension, thereby overloading some specific muscle fibers.[94,95] Bongers et al[96] and Moon and Sauter[97] have provided excellent reviews on the subject.

DIAGNOSIS AND TREATMENT

The successful treatment of UE MSDs relies on prompt evaluation, specific diagnosis, and appropriate intervention.

Clinical evaluation

Like all conditions with a potential occupational etiology, the occupational health history is a fundamental component of the evaluation.[98–101] The history should (1) characterize the symptoms, (2) provide an employee description of work activities, and (3) identify predisposing conditions or factors. This information should be documented in the employee's medical record. Figure 2.5 contains a form to assist with the collection of this information. If the employee description of work activities is unclear, or if further information is needed to understand employee job tasks and workplace conditions, this can be ascertained by visiting the workplace or viewing jobs tasks recorded on videotape. Simple reviewing a written description of job tasks may not provide an adequate understanding of the ergonomic stresses involved in the job.

After the history is taken and information obtained about workplace conditions and job tasks, the neck and UE should be examined.[102–104] A comprehensive examination would include inspection, palpation, assessment of the ranges of motion, evaluation of sensory and motor function, and applicable provocative maneuvers. Employees with underlying systemic disease (e.g. diabetes mellitus) may require a more complete examination involving other organ systems. Results of the examination findings, both positive and negative, should be documented in the employee's medical record. Figure 2.6 contains

Date: ____________
Name: ____________________ Age: ______years Gender: female male
Company: _______________ Dept: _______________ Job Title:_____________

Symptom Characterization
Onset:
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
Exacerbating/Relieving Activities:

Prior treatment modalities:

Description of Work Activities
Characterize the required job tasks (particularly with respect to physical stressors [force, repetition, posture, vibration]):
____
____
____

Changes in work patterns: longer hours overtime other
Changes in frequency of tasks: no yes
Changes in duration of tasks: no yes
Unaccustomed work: no yes
Changes in work equipment: no yes
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: ______________________

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: ______________________
____

Figure 2.5 Musculoskeletal occupational health history.

a form to assist with the collection of this information.

Clinical diagnosis

Using the information from the clinical evaluation, an assessment or diagnosis should be made. Diagnoses should be consistent with the International Classification of Diseases, Ninth Revision (ICD-9) (Table 2.7). Terms such as repetitive motion disorder (RMD), repetitive strain injury (RSI), overuse syndrome, and cumulative trauma disorder (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 a diagnosis is made, an opinion is usually rendered regarding whether occupational factors caused, aggravated or contributed to the condition. This tends to be the most difficult portion of the assessment. Unlike the classic occupational diseases, such as asbestosis or silicosis, most occupational MSDs do not have a pathognomonic finding or test specific to the exposure. Therefore, the impor-

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 neurologic 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	______	______
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	______	______
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	______	______

Figure 2.6 Physical examination recording form for the neck and upper extremity.

tance of a thorough exposure assessment cannot be overemphasized.[105] In 1979, NIOSH published a guide for state agencies and physicians on the process of determining work-relatedness of disease.[106] The process outlined in this guide, modified for MSD, are still relevant today:

- Has a disease condition been established by accepted clinical criteria?
- Does the literature support that the disease can result from the suspected agent?
- Has exposure to the agent been demonstrated?
- Has the exposure been of sufficient degree and duration to result in the diseased condition?
- Have non-occupational factors been considered?

Table 2.7 Specific ICD-9 diagnosis 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 syndrome (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 (rotar cuffs 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 (acquire)
	727.04 Radial styloid enosynovitis (de Quervain's)
	727.05 Other tenosynovitis of hand and wrist
	727.2 Specified 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 tissue
	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

Nos = Not otherwise specified.

- Have other special circumstances been considered?

Clinical interventions

Clinical interventions should be tailored to the specific diagnosis. However, because soft tissue disorders represent the overwhelming majority of work-related musculoskeletal conditions,[107] resting the symptomatic area and reduction of soft tissue inflammation are the mainstays of conservative treatment.[108–114] 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.

Resting the symptomatic area Reducing or eliminating employee exposure to musculoskeletal risk factors by changing the job conditions (forceful exertions, repetitive activities, extreme or prolonged static postures, vibration, direct trauma) is the most effective way to rest the symptomatic area. This allows employees to remain productive members of the workforce and is best accomplished by engineering and work practice controls in the workplace (see Prevention section).

Until effective controls are installed, employee exposure to biomechanical stressors can be reduced through restricted duty and/or temporary job transfer. The principle of restricted duty and temporary job transfer is to reduce or eliminate the total amount of time spent exposed to the same or similar musculoskeletal risk factors.[115,116] A variety of factors (e.g. symptom type, duration, and severity; response to treatment; and biomechanical stressors associated with work) must be considered when determining the length of time for which an employee is assigned to restricted duty. When trying to determine the length of time assigned to restricted work, the following principle applies: the degree of restriction should be proportional to symptom severity and intensity of the job's biomechanical stressors. In addition, caution must be used in deciding which jobs are suitable for job transfer, because different jobs may pose similar biomechanical demands on the same muscles and tendons.[117]

Complete removal from the work environment should be reserved for severe disorders, workplaces where the only available jobs involve significant biomechanical stressors for the symptomatic area, or workplaces where significant modifications to the current or available jobs are not feasible. For purposes of removal from the work environment, severe disorders can be defined as those that negatively affect that employee's activities of daily living (e.g. difficulty in buttoning clothes, opening jars, brushing hair, etc.)

Immobilization devices, such as splints or supports, can help rest the symptomatic area.[109–114,118] These devices are especially effective off the job, particularly during sleep. Wrist splints, typically worn by patients with possible CTS, should not be worn at work unless the employee's job tasks do not require wrist deviation or bending.[119] Employees who struggle to perform a task requiring wrist deviation with a splint designed to prevent wrist deviation can exacerbate symptoms in the wrist due to the increased force needed to attempt to overcome the splint. This effect may also cause other joint areas (elbows or shoulders) to become symptomatic as work technique is altered.[119,120] 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).[120,121] These recommendations do not preclude the use of immobilization devices for patients with special needs due to underlying medical conditions.

Finally, employees with MSDs should be advised about the potential risk posed by hobbies, recreational activities, and other personal habits that involve certain biomechanical stressors.[112–114] Employees should modify their behaviors to reduce such stress.

Treatment for soft tissue/tendon disorders Most clinicians consider cold therapy on the affected area useful to reduce the swelling and inflammation associated with acute tendon-related disorders.[112–114,122] The effectiveness of cold therapy in chronic disorders is not well established, despite several articles discussing its mechanism.[123–126] 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.[127]

Oral anti-inflammatory agents (aspirin or other non-steroidal anti-inflammatory agents) are considered useful to reduce the severity of symptoms, through either their analgesic or anti-inflammatory properties.[109–114,128] 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.[128]

Physical and occupational therapy is a valuable adjunct for treatment of MSDs. Useful modalities may include (1) stretching and strengthening programs, (2) individualized training on proper body mechanics, and (3) teaching of appropriate self-care.[112–114,121,129]

Many, if not most, work-related MSDs improve with the above conservative measures. Symptomatic employees should be followed to document symptom improvement. Employees who do not improve within the expected time frames should be re-evaluated, or a second opinion should be obtained.

For some disorders resistant to conservative treatment, local injection of a corticosteroid may be indicated.[109–114,130] 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. While some symptoms may indicate the need for immediate surgical intervention, these situations are rare. Surgical options should be reserved for severe, chronic cases that, after an adequate trial of conservative therapy (described above), prevent 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.

SURVEILLANCE

Surveillance is "the ongoing systematic collection, analysis, and interpretation of health and exposure data in the process of describing and monitoring a health event".[131] The goal of both hazard and health surveillance systems is the identification of hazardous exposures. Once hazardous exposures are recognized, intervention efforts can be targeted at those exposures with the purpose of preventing future health problems in (as yet) unaffected individuals.

Surveillance should not be confused with screening. Screening is the application of a clinical test to asymptomatic individual at increased risk for a particular disease.[132] The goal of screening tests is the identification of individuals who need further medical evaluation or other intervention. Although clinical tests can identify individuals with MSDs early in their development, there are currently no known screening tests to predict which asymptomatic individuals will develop symptoms and disease. Exposure and health surveillance can be divided into two types: passive and active.

Passive surveillance

Passive health surveillance systems utilize existing databases to identify high-risk jobs. Examples of these databases in occupational medicine include the OSHA 200 Logs, workers' compensation records, medical department logs, clinical laboratory data, hospital discharge records, and accident reports. These databases can be used to identify industries, occupations, jobs or tasks that are associated with disease or injury.

Figure 2.7 illustrates how data can be transcribed onto a spreadsheet and used to calculate disease incidence rates. These incidence rates, usually expressed as cases per 100 full-time workers (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

Department or job (a)	Hours worked (b)	Injuries and illness (c)	Incidence rate (e)	Incidence rate in previous year (e)	% change (f)

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

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

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

Figure 2.7 Disease incident rate calculations.

musculoskeletal injury rate can be targeted for further ergonomic and/or medical evaluation. In addition, jobs or departments can be followed over time, to monitor trends in these rates.

Although attractive because of their low cost, passive surveillance databases are sometimes developed for purposes other than surveillance and may have significant limitations.[132,133] These limitations include under-reporting, disease misclassification, and exposure misclassification. For example, under-reporting in the OSHA 200 Logs can occur for any of the following reasons: symptomatic employees not seeking medical care ("macho" attitude, ignorance that the condition could be work-related, or fear of employer retaliation); restricted or no access to employee health facilities; or misunderstanding about when a case is to be recorded on the OSHA 200 Log. Disease misclassification occurs, for example, when a disorder is recorded as an injury rather than a "disorder due to repeated trauma". Exposure misclassification can occur when employees use a general term to describe their job title; for example, an employee in the poultry industry may report his or her job title as "cutter" in a plant with five distinct cutting positions. Each one of these cutting jobs may be associated with a different ergonomic hazard, and the identification of high-risk jobs requires specific knowledge of the employees' cutting position.

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,[134] and have been developed for both pulmonary[135] and musculoskeletal disorders.[136] Symptom surveys collect more accurate information, and can serve a triage function if performed in a confidential manner.[137] Active surveillance systems can also collect information on exposures. This information is typically established by plant personnel or non-medical consultants; however, healthcare providers may be called upon to participate in a comprehensive ergonomics program. If exposure surveillance is a component of that program, the survey instruments in Table 2.5 and Figures 2.1–2.4 could be used to establish an exposure surveillance database.

PREVENTION

The control of identified ergonomic hazards is the most effective means of preventing work-related UE MSDs, and is the primary focus of any ergonomics program. Intervention strateɡies should follow a three-tiered approach: ɪngineering controls, administrative controls, ɪnd medical treatment.

:ngineering controls

Numerous studies have shown that engineerɪg interventions can reduce ergonomic azards.[138–146] In addition, several studies ave shown this reduced exposure to result ı a reduction in the rates of MSDs.[147–161] In ɔme situations, these ergonomic solutions are bvious and consistent with common sense. n the other hand, work sites frequently :quire a more comprehensive approach to ɔntrol of ergonomic hazards. This compreɜnsive approach should address the following sk factors: repetition, force, posture, and bration.

To reduce repetitiveness, the following terventions could be used: (1) enlarged ork content; (2) automation of some job sks; (3) uniform spreading of work across e workshift; (4) job restructuring. To reduce rce or mechanical stressors, the following terventions should be considered: (1) creasing the weight of tools, containers, d parts; (2) optimizing the size, shape and ction of handles; and (3) using torque ntrol devices. Reduction of awkward or treme postures could be achieved by (1) :ating the work more appropriately, and (2) ecting tool design and location based upon rkstation characteristics. Engineering ntrols for the reduction of vibration are iewed in Chapter 4.

In some instances, however, engineering ntrols are not currently available. Until ɡineering controls become available, other ects of an ergonomics program—adminisive and medical treatment controls—can be plemented.

ministrative

ninistrative controls can be defined as work :tices or training used to reduce employee osure to ergonomic stressors. Examples of k practice controls include: (1) more frequent and longer rest breaks;[162,163] (2) limiting overtime; (3) varying work tasks, or broadening job responsibilities; and (4) periodic rotation of workers between stressful 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 technique has been associated with the development of UE MSDs.[164,165]

Medical treatment

The goal of medical treatment as a component of an ergonomics program is to provide prompt evaluation and treatment to limit the severity, disability and costs associated with these disorders. It should also serve to initiate a re-evaluation of the ergonomic stresses associated with the affected worker's job and institution of appropriate control measures. Medical treatment in this sense is a secondary and tertiary prevention mechanism. Medical management programs are an important component of any successful ergonomic programs.[156,166–168] They should always be used with engineering and administrative controls during the implementation of a complete ergonomics program.[169]

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Title	Physical and biological hazards of the workplace
Authors	Wald, Peter H., 1955-;Stave, Gregg M.
Call Number	RC963 .P57 2002
Subjects	Medicine, Industrial.;Industrial hygiene.;Occupational diseases.;Hazardous substances.;Industrial safety.
Collation	xx, 680 p. : ill., maps;26 cm.
Publisher	New York : Wiley-Interscience, c2002.
Edition	2nd ed.
Catalog Notes	Includes bibliographical references and index.
Catalog Number	175343
ISBN	0471386472 (alk. paper)

Requested From
Pitt 7-8-03

Rec'd 1994 Edition on 7-15-03.

PHYSICAL AND BIOLOGICAL HAZARDS OF THE WORKPLACE

Second Edition

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Published simultaneously in Canada.

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Library of Congress Cataloging-in-Publication Data:

Physical and biological hazards of the workplace / edited by Peter H. Wald and Gregg M. Stave.-- 2nd ed.
p. cm.
Includes index.
ISBN 0-471-38647-2 (cloth)
1. Medicine, industrial. 2. Industrial hygiene. 3. Occupational diseases. I. Wald, Peter H., 1955-II. Stave, Gregg M.

RC963 .P48 2001
616.9'803--dc21 2001046816

Printed in the United States in America.

10 9 8 7 6 5 4 3 2