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MANUAL MATERIALS HANDLING

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Nearly half the cases of back pain reported by workers each year are work-related. These injuries accounted for more than 543 million lost working days: ~12% of the respondents stopped working or changed jobs due to back pain.[1] This chapter provides an overview of the hazards associated with manual materials handling (MMH); it will focus on muscular strains and sprains, primarily of the lower back. Overuse and overexertion injuries of the upper extremities are covered in Chapter 2. The prevention of these injuries requires sufficient knowledge to both identify workplace hazards and implement changes in the job or process that will reduce or eliminate these hazards.

OCCUPATIONAL SETTING

MMH poses a risk of injury to many workers; injury is more likely to occur when workers perform tasks that exceed their physical capacities. In addition, the physical capacities of individual workers vary substantially. Because MMH hazards are present in many industrial and service operations, workers in a wide variety of industries are potentially at risk. Although the data are not current, the National Occupational Exposure Survey (NOES), conducted by the National Institute for Occupational Safety and Health (NIOSH) in 1982–83, estimated that ~30% of the American workforce is routinely engaged in jobs that expose the worker to the physical hazards associated with manual handling.[2] This figure agrees with the 1988 National Health Interview Survey (NHIS) conducted by the National Center for Health Statistics.[1] In this study, 16% of respondents reported spending 4 h daily in repeated bending, twisting, or reaching. The industries with the greatest estimated total employees exposed to the hazards of lifting were health services, special trade and general building contracting, food and kindred products, and trucking and warehousing.[2]

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The Bureau of Labor Statistics (BLS)[3] also reported that the majority of manual-handling injuries are associated with lifting activities; however, common activities such as bending, pushing, and pulling, and awkward postures, also contribute to overexertion injuries. Nearly 20% of all injuries and illnesses in the workplace and nearly 34% of the annual workers' compensation payments are attributable to occupational low back pain (LBP).[4] A more recent report by the National Safety Council indicated that overexertion was the most common cause of occupational injury, accounting for 31% of all injuries. The back was the body part most frequently injured (i.e. 22% of 1.7 million injuries) and the most costly to the workers' compensation system.[5]

NORMAL ANATOMY AND PHYSIOLOGY OF THE SPINE

The spine is a complex structure made up of bony, muscular and ligamentous components. The spine can be divided into two major subsystems—the anterior and posterior spine. The **anterior spine** is mainly composed of the large bony vertebral bodies. These vertebral bodies rest atop one another and are separated by the cartilaginous invertebral discs, which act as "shock absorbers". The vertebral bodies and discs are held together by two sets of ligaments. The **posterior spine** is made up of the additional bony structures of the vertebral peduncles and laminae, which together form the spinal canal. The facet joints, which join two adjacent vertebrae, and the lateral and posterior spinous processes also form part of the posterior spine. The spinous processes are the attachment points for muscles that move and support the spine.

The spine is dependent on both bony and non-bony support for stability. Bony support is provided by the interdisc and the facet joints. Non-bony support comes from the ligaments and the attached musculature. Because the bony structures and ligaments do not have enough strength to resist the forces generated during movement and lifting, the spine is dependent on the muscles of the back, abdomen, hip and pelvis for stability. This principle explains why muscular fatigue is so important in the pathophysiology of back injury. The parts of the spine with the greatest degrees of movement are at highest risk. Because the thoracic and sacral vertebrae are fixed in place by the ribs and the pelvis, the lumbar vertebrae are the most common sites of injury.

PATHOPHYSIOLOGY OF INJURY AND RISK FACTORS

The interpretation of the research linking work-related musculoskeletal disorders (MSDs) and manual handling is problematic because of the high prevalence of certain disorders in the general population, such as LBP, and their frequent association with non-occupational factors. In addition, the relationship is further obscured by the wide range of disorders, the non-specific nature of the condition, and the general lack of objective data relating different risk factors to overexertion injury. In 1997, the NIOSH published an extensive review of the epidemiologic literature that assessed the strength of the association between specific work factors and certain upper extremity and lower back MSDs. The NIOSH identified more than 2000 studies, examined more than 600 epidemiologic studies, and published a comprehensive review of the epidemiologic studies of back and upper extremity MSDs and occupational exposures.[6] In addition to the NIOSH's work in this field, there have been other extensive reviews that have also critically evaluated the epidemiologic literature[7–13] and demonstrated the relationship between work-related factors and MSDs. These reviews examined the relationships between workplace exposures and outcomes such as symptoms, physical examination findings, specific diagnoses, or disability, and the effect of potential confounders and effect modifiers such as gender, age, injury and medical history. In addition, population surveys and broad government agency reports have been used to assess the prevalence,

incidence and distribution of MSDs across industries and occupations.[1] All of these reviews concluded that there is significant evidence that physical factors are associated with development of MSDs.

It is generally recognized that musculoskeletal injuries are a function of a complex set of variables, including aspects of job design, work environment, and personal factors. Moreover, work-related MSDs may result from direct trauma, a single exertion (overexertion), or multiple exertions (repetitive trauma); typically, it is difficult to determine the specific nature of the causal mechanism. A variety of manual-handling activities increase a worker's risk of developing an MSD, including jobs that involve a significant amount of manual lifting, pushing, pulling, or carrying, and jobs requiring awkward postures, prolonged sitting, or exposure to cyclic loading (whole-body vibration). In addition to these frequent patterns of usage, a variety of personal and environmental factors may affect the risk of developing an MSD. Risk factors increase the probability of occurrence of a disease or disorder, though they are not necessarily causal factors. For the problem of low back injuries involving MMH, three categories of risk factors have been identified by epidemiologic studies—personal, environmental, and job-related.

- **Personal risk factors** are conditions or characteristics of the worker that affect the probability that an overexertion injury may occur. Personal risk factors include attributes such as age, level of physical conditioning, strength, and medical history.
- **Environmental risk factors** are conditions or characteristics of the external surroundings that affect the probability that an overexertion injury may occur. Environmental risk factors include attributes such as temperature, lighting, noise, vibration, and friction at the floor.
- **Job-related risk factors** are conditions or characteristics of the MMH job that affect the probability that an overexertion injury may occur. Job-related risk factors include attributes such as the weight of the load being moved, the location of the load relative to the worker when it is being moved, the size and shape of the object moved, and the frequency of handling.

A summary of significant risk factors is provided in Table 3.1.

Occupationally related MSDs attributed to MMH can result from a direct trauma, a single overexertion, or repetitive loading. The internal tissue response is dependent on tissue strength. It is related to such factors as age, fatigue, and concomitant diseases. Therefore, an injury can occur at different loading levels for different workers. Even for an individual

Table 3.1 Risk factors associated with manual material handling injuries.

Personal factors	Environmental factors	Job-related factors
Gender	Humidity	Location of load relative to the worker
Anthropometry (body weight and height?)	Light	Distance object is moved
Physical fitness and training	Noise	Frequency and duration of handling
Lumbar mobility	Vibration	Bending and twisting
Strength	Foot traction	Weight of object or force required
Medical history		Stability of the load
Years of employment		Postural requirements
Smoking		
Psychosocial factors		
Anatomic abnormality		

worker, a load may be tolerable one day and excessive on another day.[14]

There have been many studies of the multiple factors that contribute to MSDs, some of which have yielded conflicting results. Direct comparisons between epidemiologic studies are often impossible on methodological grounds, and a comparative review is difficult because the variables under study are rarely similar.[15] For example, populations, methods of sampling and data collection, and task and time scales often vary across studies.[16] In addition, studies are confounded by the high prevalence of MSDs in the general population, the wide range of disorders, non-specific symptoms, and frequent association with non-occupational factors. Relationships between MSDs and risk factors would be more apparent if precise and accurate outcome measures were available.[17]

Our knowledge of job-related, environmental and personal risk factors is far from complete. There is a need for long-term, prospective and controlled studies of large samples of workers to identify and quantify workplace factors that contribute to MSDs. Prospective studies should be designed to differentiate factors involved in the development of MSDs from factors that are the result of MSDs.

There have been many reports suggesting that there is a significant relationship between psychosocial factors, such as monotonous work, high perceived workload, low job control and low job satisfaction, and risk of MSD.[18] Bongers and de Winters[19] have published a detailed review of the current literature on psychosocial factors and musculoskeletal injuries. They concluded that studies such as those by Linton[20] and Bigos et al[21] support the contention that the role of psychosocial factors may be as important in affecting the risk of injury as the actual physical demands of the job. The data indicate that as the perceived demands of the job increase and the worker's control over those demands decreases, the rate of injury increases. It is believed that psychosocial factors may increase the effect of other physical factors such as muscle tension and poor body mechanics during MMH. Until more data are available to quantify these relationships, however, it is difficult to develop a comprehensive control strategy for psychosocial factors.

MEASUREMENT ISSUES

A variety of measurement tools are available for the ergonomic evaluation of manual-handling tasks, especially manual lifting tasks. These tools range in complexity from simple checklists, which are designed to provide a general indication of the physical stress associated with a particular MMH job, to complicated computer models that provide detailed information about specific risk factors. Although not exhaustive, Table 3.2 summarizes a variety of ergonomic assessment tools and offers a brief description of their advantages and disadvantages. NIOSH researchers reviewed a number of these MMH assessment methods and presented a case study from warehousing for comparison purposes.[22]

These tools provide objective information about the physical demands of manual-handling tasks that will help the user develop an effective prevention strategy. These tools are generally based on scientific studies that relate physical stress to the risk of musculoskeletal injury, particularly when those stressors exceed the physical capacity of the worker.[23–25] Any assessment of physical stress or human capacity is complicated by the influence of a variety of psychosocial factors, including work performance, motivation, expectation, and fatigue tolerance.

Checklists

A checklist is often the first choice for a rapid ergonomic assessment of a particular workplace. Checklists are designed to provide a general evaluation of the extent of a specific

Table 3.2 Ergonomic assessment tools.

Assessment tool	Advantages	Disadvantages
Checklists	• Simple to use • Best suited for use as a preliminary assessment tool • Applicable to a wide range of manual-handling jobs	• Do not provide detailed information about the specific risk factors • Do not quantify the extent of exposure to the risk factors
Biomechanical models	• Provide detailed estimates of mechanical forces on muscoloskeletal components • Can identify specific body structures exposed to high physical stress	• Not applicable for estimating effects of repetitive activities • Difficult to verify accuracy of estimates • Rely on a number of simplifying assumptions
Psychophysical tables	• Provide population estimates of worker capacities that integrate biomechanical and physiologic stressors • Applicable to a wide range of manual-handling activities	• Reflect more about what a worker will accept than is safe • May over- or underestimate demands for infrequent or highly repetitive activities
Physiologic models	• Provide detailed estimates of physiologic demands for repetitive work as a function of duration • Applicable to a wide range of manual-handling activities	• Not applicable for estimating effects of infrequent activities • Lack of strong link between physiologic fatigue and risk of injury
Integrated assessment models	• Simple to use • Use the most appropriate criterion for the specified task	• Require a significant number of assumptions • Limited range of applications
Videotape assessment	• Economic method of measuring postural kinematics • Can be used to analyze a large number of samples	• Labor-intensive analysis required • Limited to two-dimensional analysis
Exposure monitors	• Provide direct measures of posture and kinematics during manual handling • Applicable to a wide range of manual-handling activities	• Require the worker to wear a device on the body • Lack of data linking monitor output and risk of injury (upper extremity)

hazard that may be associated with a manual-handling task or job. A checklist usually consists of a series of questions about physical stressors such as frequent bending, heavy lifting, awkward or constrained postures, poor couplings at the hands or feet, and hazardous environmental conditions. Some checklists use a yes/no format; others use a numerical rating format. Checklists are easy to use, but they lack specificity and they are imprecise. An example of a manual-handling checklist is presented in Figure 3.1. For more information on checklists, see Grandjean,[26] Eastman Kodak,[27] Alexander and Pulat,[28] or National Occupational Health and Safety Commission.[29]

Biomechanical models

Biomechanics involves the systematic application of engineering concepts to the functioning human body to predict the distribution of internal musculoskeletal forces resulting from the application of externally applied forces. Biomechanical modeling provides a method for predicting the pattern and magnitude of these internal forces during manual handling. These predicted forces can then be compared to predetermined tissue tolerance limits to assess the biomechanical stress associated with specific loading conditions. When a

		YES	NO
1. General			
1.1	Does the load handled exceed 50 lbs?	[ ]	[ ]
1.2	Is the object difficult to bring close to the body because of its size, bulk, or shape?	[ ]	[ ]
1.3	Is the load hard to handle because it lacks handles or cutouts for handles, or does it have slippery surfaces or sharp edges?	[ ]	[ ]
1.4	Is the footing unsafe? For example, are the floors slippery, inclined, or uneven?	[ ]	[ ]
1.5	Does the task require fast movement, such as throwing, swinging, or rapid walking?	[ ]	[ ]
1.6	Does the task require stressful body postures, such as stooping to the floor, twisting, reaching overhead, or excessive lateral bending?	[ ]	[ ]
1.7	Is most of the load handled by only one hand, arm, or shoulder?	[ ]	[ ]
1.8	Does the task require working in environmental hazards, such as extreme temperatures, noise, vibration, lighting, or airborne contaminants?	[ ]	[ ]
1.9	Does the task require working in a confined area?	[ ]	[ ]
2. Specific			
2.1	Does lifting frequency exceed 5 lifts per minute?	[ ]	[ ]
2.2	Does the vertical lifting distance exceed 3 feet?	[ ]	[ ]
2.3	Do carries last longer than 1 minute?	[ ]	[ ]
2.4	Do tasks which require large sustained pushing or pulling forces exceed 30 seconds in duration?	[ ]	[ ]
2.5	Do extended reach static holding tasks exceed 1 minute?	[ ]	[ ]

Comment: "Yes" responses are indicative of conditions that pose a risk of developing low back pain. The larger the percentage of "yes" responses, the greater the possible risk.

Figure 3.1 Manual Material-Handling Checklist.

worker is performing a manual lifting task, for example, the internal reaction forces that are needed to provide equilibrium between the body segments and the external forces are supplied by muscle contractions, tendons, and ligaments at the body joints; in effect, the human body acts as a lever system.

Specifically, the external forces at the hands and the body segments create rotational moments or torques at various body joints, especially the lower back. The skeletal muscles exert forces that result in moments about the joints so as to counteract the moments due to external load and body segment weights. Since the moment arms of the muscles (and ligaments) are much smaller than the moment arms of the external forces and body segment weights, small external forces can produce large muscle, tendon, ligament, and joint reaction forces. On the other hand, the muscles can produce large motions with small degrees of shortening. The concept of muscles loading skeletal structures is extremely important in the biomechanics of low back injuries, because handling light loads in certain postures can create large mechanical loads on the lumbar spine structures.

Biomechanical models vary in complexity, depending upon which factors are included in the model. The simplest biomechanical models are based on two-dimensional static analysis and use only one muscle to model the flexor or extensor muscle groups. The complexity of the model may be increased, however, by adding modeling components that consider the effects of dynamic activity, multiple muscles, intra-abdominal pressure (IAP), muscular co-contraction, and posterior ligamentous structures. Although complex models are more difficult to use, they provide insight into the relative importance of the pattern of load distribution (e.g. compression, shear, or torsion).

Static models are simple and easy to use, but they do not consider the inertial effects of the moving body masses and external loads. **Dynamic models**, on the other hand, more closely simulate the loading of a dynamic system, but they are more difficult to use due to the type of data needed to predict the motion parameters. Two-dimensional models are limited to assessing manual-handling activities with movements restricted to one plane. Current research is focusing on the development of biomechanical models that integrate electromyographic data as input to estimate internal loading.[30] Chaffin and Andersson[31] have published a detailed discussion of biomechanical modeling that describes various two- and three-dimensional models.

Although biomechanical models are typically used to help in the design of infrequent, stressful activities requiring high levels of exertion, recent studies have focused on the assessment of repetitive lifting tasks. In studies of spinal compression tolerance, for example, Brinckmann et al[32] showed that repeated compression loading of the spinal motion segments causes them to fail at lower forces than those required in a single loading cycle.

For more information on biomechanical models, see Chaffin and Andersson[31], Kroemer[33], or Garg.[34]

Psychophysical tables

Psychophysics is a branch of psychology that examines the relationship between the perception of human sensations and physical stimuli. The worker's subjective determination is used to assess the synergistic effects of combined physiologic and biomechanical stress created by various manual-handling factors. Stevens[35] and Snook[25] contend that a worker's actual level of physical stress can be assessed by his or her subjective perception of the physical stress.

Although the vast majority of psychophysical research involving MMH activities has emphasized lifting tasks, the use of psychophysical techniques is not restricted to lifting. Psychophysics is also applicable to lowering, pushing, pulling, holding and carrying activities. The use of psychophysical data to assess the physical demands of manual handling is most appropriate for repetitive activities that

are performed more often than once a minute. Databases are available that provide acceptable levels of manual handling for various segments of the population. Acceptable levels of work are typically presented as acceptable weights of lift or carry or acceptable forces of pushing and pulling.[36] A psychophysical table for acceptable weights of carry for industrial workers is shown in Table 3.3. For more information on psychophysical databases, see Snook,[25] Snook and Ciriello,[36] or Ayoub and Mital.[37]

Other psychophysical assessment methods have been developed to assess various MMH activities. For example, self-report measures such as rating of perceived exertion[38] (RPE) and body part discomfort[39] (BPD) have been used to assess a variety of lifting jobs. These assessment measures provide useful information about the worker's perception of the physical demands of the job. Moreover, RPE and BPD compare favorably with measures of physical demand.

Databases containing whole-body and segmental strength measures have also been developed for the design of manual-handling tasks. These include isometric, isokinetic and isoinertial strength databases for whole-body activities, such as lifting, and various databases for the arms, legs, and back. For more information on strength measurement, see Ayoub and Mital[37] and Chaffin and Andersson,[31]

It should be noted that psychophysics relies on self-reports from subjects; consequently, the perceived "acceptable" limit may differ from the actual "safe" limit. In addition, the psychophysical approach may not be valid for all tasks, such as high-frequency lifting.[40]

Physiologic models

One of the goals in designing a manual-handling task is to avoid the accumulation of physical fatigue, which may contribute to an overexertion injury. This fatigue can affect specific muscles or groups of muscles, or it can affect the whole body by reducing the aerobic capacities available to sustain work. Two physiologic factors that affect the suitability of a manual-handling task at the local muscle effort level include the **duration of force exertion** and the **frequency of exertions**. Local muscular fatigue will develop if a heavy effort is sustained for a long period. With heavy loads, the muscles need a substantially longer recovery period to return to their previous state. Small changes in workplace layout or handling heights, however, can often solve a local muscle fatigue problem through a reduction in holding duration. In addition, local muscle fatigue associated with maintaining awkward postures or constant bending can reduce the capacity of the muscles needed for lifting and therefore increase the potential for an overexertion injury to occur.

Table 3.3 Portion of a psychophysical table for maximum acceptable weights of carry.

Height from floor to hands (cm)	Percentage of industrial males	Maximum acceptable weight of carry (kg): 2.1-m carry One carry every:						
		6 s	12 s	1 min	2 min	5 min	30 min	8 h
111	90	10	14	17	17	19	21	25
	75	14	19	23	23	26	29	34
	50	**19**	25	30	30	33	38	44
	25	**23**	30	37	37	41	46	54
	10	**27**	**35**	43	43	48	54	63

Values are available for different heights, distances and sex. Values in bold exceed 8-h physiologic criteria. Adapted from Snook and Ciriello.[36]

Local muscle fatigue may limit the acceptable workloads for manual-handling tasks that are performed for short but intensive periods during a workshift. However, it is the energy expenditure demands of repetitive tasks that have the most profound effect on what a worker is able to do over a longer period of time. Energy expenditure demands are dependent upon the extent of muscular exertion, frequency of activity, and duration of continuous work. A worker's limit for physiologic fatigue is often affected by a combination of discomfort in local muscle groups and more centralized (systemic) fatigue associated with oxygen demand and cardiovascular strain.[27,41]

To assess the cardiovascular demands of manual-handling tasks, physiologic parameters such as heart rate (HR), oxygen consumption and ventilatory rate may be used. In addition, electromyographic (EMG) assessments and blood lactate provide a relative measure of the instantaneous level of physiologic status and muscular fatigue. Assuming that fatigued workers are at a higher risk of overexertion injury, these measures can be used to help prevent overexertion injuries by predicting the limits of fatigue for repetitive handling tasks.

Physiologic models provide a method for estimating the cardiovascular demands associated with a specific manual-handling activity. One such model, developed by Garg,[42] allows the analyst to estimate the energy expenditure demands associated with a complex manual-handling job. The first step is to separate the job into distinct elements or subtasks for which individual energy expenditure values can be predicted, such as standing and bending, walking, carrying, vertical lifting or lowering, and horizontal arm movement. The total energy expenditure requirements for the job are then estimated by summing the incremental expenditures of all of the subtasks.

HR is also useful in predicting physiologic demand, but it is less reliable than direct oxygen consumption measures, due to individual differences in the relationship between HR and energy expenditure. Portable monitors can be used to measure HR and oxygen consumption during manual-handling tasks. For information on assessing physiologic demands, see Astrand and Rodahl[43] or Eastman Kodak.[27]

Integrated assessment models

An integrated assessment model involves a unique approach that considers all three of the primary lifting criteria—biomechanics, physiology, and psychophysics. The integrated approach provides a measure of the relative magnitude of physical demand for a specific manual-handling task which relies on the most appropriate stress measure for that task. The result of the assessment is typically represented as a weight or force limit or as an index of relative severity. An integrated model considers the synergistic effects of the various task factors and uses the most appropriate stress measure to estimate the magnitude of hazard associated with each task factor. Examples of integrated assessment models include Ayoub's Job Severity Index[44] (JSI) and the NIOSH recommended weight limit (RWL) equation.[40] Details on the revised NIOSH lifting equation are presented later in this chapter.

Videotape assessment

Most ergonomic assessments include the use of videotape analysis, where a video camera is used to record the work activity for later analysis. Videotape recordings make it easy to stop or freeze the action so that body posture or workplace layout can be evaluated. Videotape analysis often consists of general observation by the analyst that results in subjective estimates of physical hazards. More detailed video assessment can also be used to quantify the extent of the hazard objectively.

In fact, complex computerized video analysis systems are available that can capture and analyze individual frames from videotape recordings of workers performing manual-handling activities. These video frames can

then be used to make more detailed assessments of spatial or dynamic biomechanical hazards that may not be apparent from the observational approach. These systems may include automatic digitizing capabilities for marking body joint locations and automatic scoring for assessing joint or body segment positions. These systems are generally easy to use, and the output data are presented in a form that is easy to understand and apply. They are limited, however, in their capability to analyze activities that occur outside of the camera focal plane (i.e. the plane parallel to the face of the camera lens). For example, when a body segment or group of segments move outside the camera focal plane, the joint angles and positions measured from the digitized frame are distorted. The amount of distortion depends on the degree of displacement of the joint or segment from the focal plane. Nevertheless, these systems are uniquely suited for certain types of assessments in which large amounts of videotape must be analyzed to determine the extent of the physical hazards.

Guidelines for videotape job analysis, which have been developed by NIOSH researchers, are provided in Table 3.4. For more information on videotape analysis and motion analysis, see Chaffin and Andersson[31] or Eastman Kodak.[27]

Exposure monitors

Monitoring devices have been developed to measure various aspects of physical activity, such as position, velocity, and acceleration of movement. Some monitors can even measure three-dimensional joint angles in real time. These systems consist of mechanical sensors that are attached to various parts of the worker's body, such as the wrist, back, or knees. The mechanical sensors convert angular displacement (rotation) into voltage changes

Table 3.4 Guidelines for recording work activities on videotape.

- If the video camera has the ability to record the time and date on the videotape, use these features to document when each job was observed and filmed. Recording time on videotape can be especially helpful if a detailed motion study will be performed at a later date (time should be recorded in seconds). Make sure that the time and date are set properly before videotaping begins.
- If the video camera cannot record time directly on the film, it may be useful to position a clock or a stopwatch in the field of view.
- At the beginning of each recording session, announce the name and location of the job being filmed so that it is recorded on the film's audio track. Restrict subsequent commentary to facts about the job or workstation.
- For best accuracy, try to remain inobtrusive, i.e. disturb the work process as little as possible while filming. Workers should not alter their work methods because of the videotaping process.
- If the job is repetitive or cyclic in nature, film at least 10–15 cycles of the primary job task. If several workers perform the same job, film at least two or three different workers performing the job to capture differences in work method.
- If necessary, film the worker from several angles or positions to capture all relevant postures and the activity of both hands. Initially, the worker's whole-body posture should be recorded (as well as the work surface or chair on which the worker is standing or sitting). Later, close-up shots of the hands should also be recorded if the work is manually intensive or extremely repetitive.
- If possible, film jobs in the order in which they appear in the process. For example, if several jobs on an assembly line are being evaluated, begin by recording the first job on the line, followed by the second, third, etc.
- Avoid making jerky or fast movements with the camera while recording. Mounting the camera on a tripod may be useful for filming work activities at a fixed workstation where the worker does not move around much.

that can be displayed in real time or saved to a computer for later analysis. The position measures acquired from the sensors can then be differentiated to obtain rotational velocities and acceleration components. These movement characteristics may be used to estimate the extent of risk associated with a particular task and help to identify potential ergonomic solutions. Examples of positional monitoring equipment include potentiometer-based lumbar and wrist motion monitors, such as those developed at The Ohio State University,[45,46] as well as strain gauge-based strip goniometers, such as those developed by Penny and Giles (Santa Monica, CA, USA).

Another device that has been used to assess the extent of exposure to repetitive movement is an accelerometer-based motion-recording system, or activity monitor. An activity monitor consists of one or more accelerometers mounted within a small aluminum case that is connected with a Velcro strap to a worker's wrist, leg, or trunk. The accelerometers are sensitive to the movements of the body. They are capable of counting and recording rapid movements inherent in a specific task or activity. These measures are important because highly dynamic movements that occur over an extended period of time, such as an 8-h workshift, are believed to increase a worker's risk of musculoskeletal injury. The data acquired from the activity monitor are typically plotted as a series of temporal histogram plots showing the extent of dynamic movement as a function or time. The greater the total dynamic activity, the greater the height of the sequential histogram bars and the greater the potential for injury.[47]

It is important to note that the output from exposure monitors alone cannot provide all the information needed to assess the extent of physical demand required by a manual-handling task. It is also important to know the weight of the load and its position, velocity, and acceleration relative to the body during the task. This approach is best suited for repetitive or high-speed manual-handling tasks where the internal forces on the body may be affected more by extreme postures or rapid movements than by the weight or position of the external load.

GUIDELINES AND STANDARDS

Early attempts to prevent overexertion injuries associated with MMH focused on adopting arbitrary weight limits for lifting loads, hiring strong workers, or using training procedures that emphasized correct (but not necessarily safe) lifting techniques. None of these approaches, however, has proven to be effective in significantly reducing overexertion injuries.[48] Recently, industry leaders have started to recognize the risks associated with MMH. To reduce costs and increase productivity, these companies have implemented ergonomic programs or practices aimed at preventing these injuries. In many cases, these ergonomic programs rely on exposure guidelines or standards recommended by the federal government.

California Occupational Safety and Health Administration (CAL/OSHA)

The state of California has several rules that relate to MMH. According to the California Occupational Safety and Health Act of 1973, every employer has a legal obligation to provide and maintain a safe and healthful workplace for the employees. As of 1991, one of the most important worker protection requirements is that every California employer is responsible for establishing, implementing and maintaining a written Injury and Illness Prevention (IIP) Program. A guide to developing the IIP Program with checklists for self-inspection is available at the CAL/OSHA web site (www.dir.ca.gov/DOSH/dosh_publications/iipp.html).

In addition to the IIP, the CAL/OSHA also passed a standard for preventing repetitive motion injuries (RMIs) in 1997. The standard (CAL/OSHA Title 8—Section 5110, Repetitive Motion Injuries) can also be accessed at the

CAL/OSHA web site: (www.dir.ca.gov/Title8/5110.html). The Cal/OSHA rule includes the following requirements.

(a) This section shall apply to a job, process, operation where a repetitive motion injury (RMI) has occurred to more than one employee under the following conditions:

(1) Work related causation. The repetitive motion injuries (RMIs) were predominantly caused (i.e. 50% or more) by a repetitive job, process, or operation;

(2) Relationship between RMIs at the workplace. The employees incurring the RMIs were performing a job process, or operation of identical work activity. Identical work activity means that the employees were performing the same repetitive motion task, such as but not limited to word processing, assembly or, loading;

(3) Medical requirements. The RMIs were musculoskeletal injuries that a licensed physician objectively identified and diagnosed; and

(4) Time requirements. The RMIs were reported by the employees to the employer in the last 12 months but not before July 3, 1997.

(b) Every employer subject to this section shall establish and implement a program designed to minimize RMIs. The program shall include a worksite evaluation, control of exposures which have caused RMIs and training of employees.

(1) Worksite evaluation. Each job, process, or operation of identical work activity covered by this section or a representative number of such jobs, processes, or operation of identical work activities shall be evaluated for exposures which have caused RMIs.

(2) Control of exposures which have caused RMIs. Any exposures that have caused RMIs shall, in a timely manner, be corrected or if not capable of being corrected have the exposures minimized to the extent feasible. The employer shall consider engineering controls, such as work station redesign, adjustable fixtures or tool redesign, and administrative controls, such as job rotation, work pacing or work breaks.

(3) Training. Employees shall be provided training that includes an explanation of:

(A) The employer's program;

(B) The exposures which have been associated with RMIs;

(C) The symptoms and consequences of injuries caused by repetitive motion;

(D) The importance of reporting symptoms and injuries to the employer; and

(E) Methods used by the employer to minimize RMIs.

(c) Satisfaction of an employer's obligation. Measures implemented by an employer under subsection (b)(1), (b)(2), or (b)(3) shall satisfy the employer's obligations under that respective subsection, unless it is shown that a measure known to but not taken by the employer is substantially certain to cause a greater reduction in such injuries and that this alternative measure would not impose additional unreasonable costs.

To assist employees and employers in reducing exposure to the high-risk factors, the CAL/OSHA developed a document entitled "Easy Ergonomics: A Practical Approach for Improving the Workplace". The document provides information about how ergonomics can be used to change jobs and make them safer (www.dir.ca.gov/DOSH/dosh_publications/EasErg2.pdf). The CAL/OSHA indicates that the information in the booklet is intended to provide general guidance, and there may be instances in which workplace issues are more complex than those presented in the booklet. In those cases, they suggest that you may need to seek the advice of an outside expert.

Washington State Ergonomics Standard

In May 2000, the State of Washington Department of Labor and Industries (WL&I) adopted

an Ergonomics Standard to prevent MSDs in the workplace. The Washington State ergonomics rule (Chapter 296-62 WAC General Occupational Health Standards—Part A-1 Ergonomics) has eight key elements:

1. The rule applies only to employers with "caution zone jobs", those where any employee's typical work includes awkward postures, high hand forces, highly repetitive motion, repeated impact, heavy lifting, frequent lifting, awkward lifting, or moderate to high hand–arm vibration.
2. Employers with caution zone jobs must ensure that employees working in or supervising these jobs receive ergonomics awareness education. These employers must also analyze the caution zone jobs to determine if they have hazards.
3. Employers may choose their own method and criteria for identifying and reducing MSD hazards or may use the criteria specified by WL&I.
4. If jobs have hazards, the employer must reduce exposures below hazardous levels or to the extent technologically and economically feasible.
5. Employers must provide for and encourage employee participation.
6. Implementation is delayed to allow time for all employers to comply.
7. WL&I will assist in implementing the rule by providing educational materials, identifying industry best practices, establishing inspection policies and procedures, and conducting demonstration projects.
8. Employers may continue to use effective methods of reducing MSD hazards that were in place before the rule adoption date as long as the methods, taken as a whole, are as effective as the requirements of the rule.

Illustrations of physical risk factors are listed in Appendix A of the rule, and criteria for analyzing and reducing MSD hazards for employers who choose the Specific Performance Approach are listed in Appendix B. The ergonomics rule and the associated appendices can be accessed on the web at: www.lni.wa.gov/wisha/regs/ergo2000/

For lifting, WL&I developed criteria and a five-step process for reducing heavy, frequent, or awkward lifting that are shown in Figure 3.2. To assist employers in identifying and fixing jobs with musculoskeletal hazards, the WL&I has developed a number of publications and programs, listed in Table 3.5.

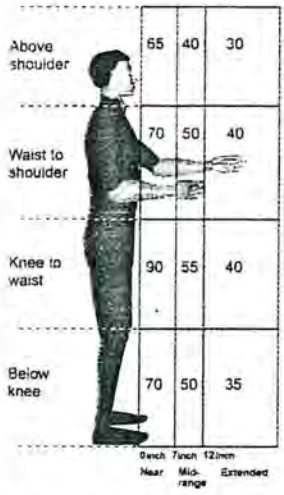
Proposed Occupational Safety and Health Administration Ergonomics Standard (OSHA)

In November 1999, the Occupational Safety and Health Administration (OSHA) also issued a proposed standard to address the significant risk of work-related MSDs confronting employees in various jobs in general industry workplaces.[49] This standard builds on the ergonomics program for "red meat" packing plants issued in 1990.[50] General industry employers covered by the standard would be required to establish an ergonomics program containing some or all of the elements typical of successful ergonomics programs: (1) management leadership and employee participation; (2) job hazard analysis and control; (3) hazard information and reporting; (4) training; (5) MSD management; and (6) program evaluation. The need to establish a program would depend upon the types of jobs in their workplace and whether a MSD covered by the standard has occurred.

The proposed standard would have required all general industry employers whose employees perform manufacturing or manual-handling jobs to implement a basic ergonomics program in those jobs. The basic program included: management leadership, employee participation, and hazard information and reporting. If an employee in a manufacturing or manual-handling job experienced an OSHA-recordable MSD and it was addition-

Step 1 - Find out the actual weight of the objects the employee lifts.
Actual Weight = _____ lbs.

Step 2 - Determine the Unadjusted Weight Limit using the diagram below.
Unadjusted Weight Limit: _____ lbs.



Step 3 - Find the Limit Reduction Modifier from the Table below.

How many lifts per minute?	For how many hours per day?		
	1 hr or less	1 hr to 2 hrs	2 hrs or more
1 lift everry 2–5 mins	1.0	0.95	0.85
1 lift every min	0.95	0.9	0.75
2–3 lifts every min	0.9	0.85	0.65
4–5 lifts every min	0.85	0.7	0.45
6–7 lifts every min	0.75	0.5	0.25
8–9 lifts every min	0.6	0.35	0.15
10+ lifts every min	0.3	0.2	0.0

Limit Reduction Mofifier: _____.

Step 4 - Calculate the Weight Limit.
Start by copying the Unadjusted Weight Limit from Step 2.
Unadjusted Weight Limit: _____ lbs.
If the employee twists more than 45 degrees while lifting, reduce the Unadjusted Weight Limit by multiplying by 0.85. Otherwise, use the Unadjusted Weight Limit
Twisting Adjustment: _____.
Adjusted Weight Limit = _____.
Multiply the Adjusted Weight Limit by the Percentage Modifier from Step 3 to get the Weight Limit.
Weight Limit: = _____ lbs.

Step 5 - **Is this a hazard?** Compare the Weight Limit calculated in Step 4 with the Actual Weight lifted from Step 1. If the Actual Weight lifted is greater than the Weight Limit calculated, then the lifting is a MSD hazard and must be reduced below the hazard level or to the degree technologically and economically feasible.

Note: If the job involves lifts of objects with a number of different weights and/or from a number of different locations, use Steps 1 through 5 above to:
1. Analyze the two worst case lifts—the heaviest object lifted and the lift done in the most awkward posture.
2. Analyze the most commonly performed lift. In Step 3, use the frequency and duration for all of the lifting done in a typical workday.

Figure 3.2 Washington State five-step lifting analysis.

Table 3.5 Resources from Washington State Labor and Industry.

Booklets
Fitting the Job to the Worker: An ergonomics program guideline
Lessons for Lifting and Moving Materials
Office Ergonomics: Practical solutions for a safer workplace
Work Related Musculoskeletal Disorders: Washington State Summary 1992–1994
Cumulative Trauma Disorders and Your Job, Carpal Tunnel Syndrome: A Preventable Disease
Work-Related Disorders of the Back and Upper Extremity in Washington State, 1990–1997 (113 KB PDF file—summary only; please contact SHARP for the entire Technical Report)
Employer Survey of Musculoskeletal Injuries and Illnesses, Risk Factors and Prevention Steps in Washington State Workplaces (42 KB PDF file—summary only; please contact SHARP for the entire Technical Report)
Non-Traumatic Soft Tissue MSDs, 1990–1997 (197 KB PDF file)

WL&I's Safety & Health Assessment & Research for Prevention (SHARP) program has a number of additional research reports on ergonomics and musculoskeletal disorders available, along with a wealth of other safety and health topics

Fact sheets
Commonly Asked Questions about Ergonomics
Quick Tips for Lifting
The Backbelt Fact Sheet
Musculoskeletal Disorders in the Workplace: A Summary of WL&Is' Prevention Efforts 1980s–1999

These publications can be accessed at the L&I web page:
http://www.lni.wa.gov/wisha/ergo/Default.htm

ally determined by the employer to be covered by the proposed standard, the employer would be required to implement the full ergonomics program for that job and all other jobs in the establishment involving the same physical work activities. The full program included, in addition to the elements in the basic program: a hazard analysis of the job; the implementation of engineering, work practice, or administrative controls to eliminate or materially reduce the hazards identified in that job; training the employees in that job and their supervisors; and the provision of MSD management, including, where appropriate, temporary work restrictions and access to a healthcare provider or other professional if a covered MSD occurs. General industry employers whose employees work in jobs other than manual handling or manufacturing and experienced an MSD that was determined by the employer to be covered by the standard would also have been required by the proposed rule to implement an ergonomics program for those jobs. According to OSHA, the proposed standard would affect approximately 1.9 million employers and 27.3 million employees in general industry workplaces.

The proposed ergonomics standard was subsequently overturned by the United States Congress in March 2001, and OSHA is now beginning the process of devloping new ergonomic guidelines or standards.

The National Institute for Occupational Safety and Health (NIOSH)

The NIOSH has not recommended formal exposure limits for general MMH activities. In 1981, however, the NIOSH published its *Work practices guide for manual lifting* (WPG).[51] The 1981 WPG contained an equation for assessing certain manual lifting tasks. The 1981 NIOSH lifting equation (NLE) provided a unique method for determining

weight limits for selected two-handed manual lifts, but it was limited in its scope of application. It only applied to lifting tasks that occurred directly in front of the body (sagittal plane lifts) and had optimal hand-to-object couplings (i.e. handles). Responding to the need for a guideline with a brooder application and more flexibility, the NIOSH revised the lifting equation. In addition to the four risk factors addressed by the 1981 equation (i.e. horizontal location, vertical height, vertical distance traveled, and frequency), the Revised NLE includes weight reduction factors for the assessment of asymmetric or non-sagittal plane lifts that begin or end to the side of the body, and for lifting objects with less than optimal hand-to-object couplings (i.e. no handles). The original 1981 NLE was based on the concept that the overall physical stress for a specific lifting task is a function of the various task-related factors that define the lift, such as task geometry, load weight, and lifting frequency. This concept also forms the basis for the recently revised NLE, which provides a practical method for determining the overall physical stress attributable to the various task-related factors. The revised NIOSH equation yields a unique set of evaluation parameters that include (1) intermediate task-related multipliers that define the extent of the physical stress associated with individual task factors; (2) the NIOSH RWL, a task-specific value that defines the load weight that is considered safe for nearly all healthy workers; and (3) the NIOSH Lifting Index (LI), which provides a relative estimate of the overall physical stress associated with a specific manual lifting task.

The RWL is defined by the following equation:

$$\text{RWL} = \text{LC} \times \text{HM} \times \text{VM} \times \text{DM} \times \text{AM} \times \text{CM} \times \text{FM}$$

where the load constant (LC) is equal to 51 lb and the terms HM, VM, DM, AM, CM and FM are the task-specific multipliers within the equation that serve to reduce the recommended weight limit according to the specific task factor to which each multiplier applies. The magnitude of each multiplier will range in value between zero and one, depending on the value of the task factor to which the multiplier applies. The multipliers are defined as follows.

Component	Metric	US Customary
HM (horizontal multiplier)	$25/H$	$10/H$
VM (vertical multiplier)	$1 - (0.003\lvert V - 75\rvert)$	$1 - (0.0075\lvert V - 30\rvert)$
DM (distance multiplier)	$0.82 + (4.5/D)$	$0.82 + (1.8/D)$
AM (asymmetric multiplier)	$1 - (0.0032A)$	$1 - (0.0032A)$
FM (frequency multiplier)	(Determined from Table 3.6)	
CM (coupling multiplier)	(Determined from Table 3.7)	

In order to use the revised NIOSH lifting equation, you need to make the following measurements:

L = Weight of the load being lifted (lb or kg)

H = Horizontal location of the hands from mid-point between the ankles. Measure at the origin and the destination of the lift (cm or in).

V = Vertical location of the hands above the floor. Measure at the origin and destination of the lift (cm or in).

D = Vertical travel distance between the origin and the destination of the lift (cm or in).

A = Angle of asymmetry, defined as the angular displacement of the load from the sagittal plane when lifts are made to the side of the body. Measure at the origin and destination of the lift (degrees).

F = Average frequency rate of lifting measured in lifts/min. Duration is defined as < 1 hour, 1–2 hours, or 2–8 hours. Specific recovery allowances are required for each duration category.

The LI provides a relative estimate of the level of physical stress associated with a particular manual lifting task. The estimate of the level of physical stress is defined by the

Table 3.6 Frequency multiplier (FM).

	Work duration					
	≤1 hour		≤2 hours		≤8 hours	
Frequency lifts/min	$V < 75$	$V \geq 75$	$V < 75$	$V \geq 75$	$V < 75$	$V \geq 75$
0.2	1.00	1.00	0.95	0.95	0.85	0.85
0.5	0.97	0.97	0.92	0.92	0.81	0.81
1	0.94	0.94	0.88	0.88	0.75	0.75
2	0.91	0.91	0.84	0.84	0.65	0.65
3	0.88	0.88	0.79	0.79	0.55	0.55
4	0.84	0.84	0.72	0.72	0.45	0.45
5	0.80	0.80	0.60	0.60	0.35	0.35
6	0.75	0.75	0.50	0.50	0.27	0.27
7	0.70	0.70	0.42	0.42	0.22	0.22
8	0.60	0.60	0.35	0.35	0.18	0.18
9	0.52	0.52	0.30	0.30	0.00	0.15
10	0.45	0.45	0.26	0.26	0.00	0.13
11	0.41	0.41	0.00	0.23	0.00	0.00
12	0.37	0.37	0.00	0.21	0.00	0.00
13	0.00	0.34	0.00	0.00	0.00	0.00
14	0.00	0.31	0.00	0.00	0.00	0.00
15	0.00	0.28	0.00	0.00	0.00	0.00
>15	0.00	0.00	0.00	0.00	0.00	0.00

Values of V are in cm: 75 cm = 30 in.

Table 3.7 Coupling multiplier (CM).

	Coupling multipliers	
Couplings	$V < 75$ cm (30 in)	$V \geq 75$ cm (30 in)
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

relationship of the weight of the load lifted to the recommended weight limit. The LI is defined by the following equation:

$$LI = \frac{\text{Load Weight}}{\text{Recommended Weight Limit}} = \frac{L}{RWL}$$

A detailed explanation of the use of the revised NIOSH lifting equation, including definitions of terms and procedures, is available in an applications manual for the revised NIOSH lifting equation.[52] The document can be downloaded from the NIOSH web site (www.cdc.gov/niosh/94-110.html).

The developers of the Revised NLE indicated that studies were needed to determine the effectiveness of the NLE in identifying jobs with increased risk of lifting-related LBP for workers. Recently, NIOSH researchers published the results of a cross-sectional epidemiologic study designed to evaluate the effectiveness of the equation in identifying jobs with elevated risk of causing LBP.[53] In the NIOSH study, 50 jobs were evaluated using the Revised NLE. The LI values of the jobs were compared to information obtained about the LBP symptoms in people who worked in those jobs. Using logistic regression modeling, the odds ratio (OR) for LBP was determined for various categories of LI values compared to the unexposed control group. LBP was assessed with a symptom and occupational history questionnaire that was

administered to 204 workers employed in lifting jobs and 80 workers employed in non-lifting jobs. Participation was 89–95% among the exposed workers and 82–100% among unexposed workers at four facilities. The authors found that as the LI increased from 1.0 to 3.0, the odds of LBP increased, with a peak and statistically significant OR occurring in the two to three LI category (unadjusted OR = 2.45; CI 1.29–4.85). For jobs with an LI higher than 3.0, however, the OR was lower (1.63; CI 0.66–3.95). The decrease in the OR for these highly exposed jobs is likely to result from a combination of worker selection and a survivor effect. This study also examined several confounding variables such as age, gender, body mass index and psychosocial factors which were included in the multiple logistic models. The highest OR was in the two to three LI category (2.2; CI 1.01–4.96).

DIAGNOSIS AND TREATMENT

The primary objectives of the diagnosis and treatment of occupationally related musculoskeletal injuries are to: (1) assist the recovery of workers and allow for a rapid return to work; (2) ensure that proper diagnostic tools are used so that an accurate assessment is made of the magnitude of the injury; and (3) provide appropriate cost-effective treatments that avoid unnecessary surgery. The system should be based on an organized approach to evaluation, diagnosis, and treatment, which is essential for an early return to work and reduction in costs and lost work time. For example, a standardized diagnostic and treatment protocol has been shown to be effective in significantly and continuously reducing the number of incidents, days lost from work, low back surgery cases, and financial costs of LBP.[54]

Although a variety of MSDs result from MMH, the single most costly medical condition is work-related LBP, which affects millions of Americans. Experts have indicated that there is significant variation in assessment and treatment of LBP that results in inappropriate or at least less than optimal care for many patients with low back disorders. This issue was addressed in 1994 with the publication of the Clinical Practice Guideline for Acute Low Back Pain in Adults by the Agency for Health Care Policy and Research (AHCPR). These guidelines focused on returning the patient to normal activity, and are now in widespread use.[55] Copies of the guidelines are available on the Agency's (now renamed the Agency for Healthcare Research and Quality) web site at www.ahcpr.com

Complicating the diagnosis and treatment of occupationally related LBP are the legal issues of disability and compensation and how they relate to pain and impairment. Pain and impairment, which are direct measures of the extent of injury, primarily depend on the severity of the injury. Disability and compensation, however, may depend more on the nature of the compensation system and laws than on the severity of the injury.[56] Unfortunately, there is often an incentive to magnify pain symptoms to remain off work as well as to increase the size of an eventual disability settlement. However, clinical experience indicates that only ~5% of workers misuse their workers' compensation benefits for secondary gain.

Diagnosis

More than 90% of all episodes of back pain are probably attributable to mechanical causes, but it is rarely possible to precisely identify the specific cause of the pain.[57] Thus, the early diagnostic evaluation of back pain is designed to rule out systemic disease, grossly identify neurologic or anatomic abnormalities that may eventually require surgery such as fracture, tumor, infection, or cauda equina syndrome, and identify characteristic indicators of injury that influence the selection of treatment.

The first step in diagnosing LBP, and perhaps the most important, is the medical history. The medical history should include

an assessment of current symptoms, individual history of injury, functional status, and injury documentation.[58–61] Based on the medical history, the clinician should be able to make a differential diagnosis, identify likely problems that may be encountered during the physical examination, and make a preliminary determination of the potential for disability.

The second step in the diagnostic process is a complete physical examination. At minimum, this examination would include a check of the deep tendon reflexes at the Achilles and quadriceps tendons, bilateral straight-leg raising, palpation of the paraspinal muscles for spasm, and a screening motor and sensory neurologic examination. The neurologic examination should give special attention to the L5 and S1 nerve roots, since the vast majority of disc herniations occur at either the L4–L5 or L5–S1 interspaces. It has been suggested that a system should be developed to ensure that all parts of the examination are completed.[60]

Current clinical tests and imaging procedures usually offer few clues to the precise source of pain, except in the minority of cases where a herniated disc is clearly causing nerve root irritation. Experts have concluded that plain radiography is of limited value in distinguishing mechanical causes of pain, because X-ray findings are poorly correlated with symptoms. Nevertheless, radiographs may be necessary to rule out other pathologic conditions, such as infections or tumours, or for making the diagnosis of spinal stenosis, spondylolisthesis, or fracture.[54]

Imaging may be needed (e.g. myelography, computed tomography, or magnetic resonance imaging) to identify an abnormality corresponding to a neurologic deficit from a herniated disc.[62] However, these sophisticated imaging tests should not be ordered too early in the course of back pain, especially when there is an absence of clinical findings that suggest a need for surgical intervention. In general, these tests should be limited to workers who have continued neurologic findings after 4–6 weeks of conservative therapy. It is also important to remember that an abnormal imaging study and back pain are not necessarily related. The clinical course of each worker must be considered before this causal link is made and surgery is considered.

Treatment

Epidemiologic data suggest that the vast majority of low back injuries are not serious and that most workers return to work after a short time with only conservative therapy. In general, only a minority of all affected persons have back pain > 2 weeks in duration. By contrast, 90% of patients return to work within 6 weeks of onset of the back pain.[60,63] Conservative therapy typically consists of some combination of ice, bed rest (for up to 2 days if there are no neurologic findings), drug therapy (generally non-steroidal anti-inflammatory drugs), and mild exercise. There is little evidence, however, to indicate which treatment is most appropriate.[60,62,63] Treatment with electric stimulation (TENS) is controversial and unproven, but some workers have shown very good results.

If conservative therapy fails and 4–6 weeks have passed, further diagnostic tests should be scheduled. These cases generally fall into one of the following four categories, by location of the patient's predominant complaints: (1) LBP, which is typically diagnosed as back sprain; (2) leg pain radiating below the knee, which is commonly referred to as sciatica; (3) posterior thigh pain; and (4) anterior thigh pain. Each of these conditions warrants a unique treatment regimen.[54] It may also be appropriate to thoroughly investigate and address psychological and psychosocial issues at this time. Failure to deal with a significant psychological or psychosocial issue will delay the patient's return to work and may ultimately result in treatment failure and total disability.

A few back patients have symptoms suggesting sciatica, which is usually the first clue to a herniated disc. It is estimated that only 5–10% of patients with persistent sciatica require surgery. In general, only patients diag-

nosed with cauda equina compression (CEC) or a similar mechanoanatomic problem require immediate surgical intervention. Other indications for referral include severe or progressive neurologic deficits, or persistent neurologic finding after 4–6 weeks of conservative therapy. In the overwhelming number of cases of LBP, the appropriate treatment includes a course of conservative therapy.[54,62]

There is general agreement among clinicians that treatment for LBP must be given according to a strict timetable so that patients do not develop a dependence that would prolong symptoms and functional limitations. Also, patient reassurance and education is an important aspect of therapy. The clinician must avoid labeling the patient. The patient should be reassured that the natural history of their condition is favorable and that he or she should be able to return to work in a short time.[62]

MEDICAL SURVEILLANCE

Medical surveillance for MMH is similar to what was discussed for upper extremity MSDs. Active and passive surveillance of the workplace are necessary to establish a database of potential exposures in each workplace. Medical management of injuries and early reporting should be incorporated within the general medical treatment program at each work site. Since there is usually a short latency period between exposure and the onset of symptoms, medical surveillance per se is not helpful in eliminating MMH injuries. It may be useful to screen employees in order to match their physical abilities to the job. However, this is more of an exercise in prevention of injuries, and is thus covered in the next section on prevention.

PREVENTION

Attempts at ergonomic control of MMH problems have included both worker-directed and workplace-directed programs.

Workplace-directed approaches are based on changes in the design of the work to eliminate or minimize the problem; they rely on substitution and engineering controls. Consequently, these approaches are more generalized and less dependent on knowing the detailed capacity of the worker performing the task or job. Workplace-directed approaches include elimination of manual handling from the process through automation, reduction of the amount of physical exertion required to perform the MMH activity by using mechanical aids to assist the worker, or modification of the layout of the workplace to eliminate the MMH problem. In comparison, **worker-directed-approaches** primarily deal with attempts to maintain a balance between the worker's capacity and the demands of the job. This is usually attempted through worker screening, increases in the worker's physical capacity, or protection of the worker from the physical hazard. These controls are based on personal protection and administrative controls. Consequently, they require individualization on a worker-to-worker and job-to-job basis. More important, this approach requires detailed information about the capacity of each worker, as well as the demands of the job. Remember, however, that worker-directed approaches fail to directly reduce the extent of the physical hazard associated with the task or job.

Substitution

Automation Workplace automation should be a top priority when the job has high physical demands, is highly repetitive, or is performed in a hazardous environment. Automation may consist of one or more machines or machine systems such as conveyors, automated handling lines, automated storage and retrieval systems, or robots. This approach is best suited for the design of new work processes or activities or for the redesign of highly stressful tasks. Because automation

often requires large capital expenditures, this approach may be prohibitive for small companies with only a few workers.

Mechanical aids In cases where the physical demands are high and automation is not practical, mechanical aids can be used to ameliorate the extent of those demands. Mechanical handling aids include machines or simple devices that provide a mechanical advantage during the MMH task, such as hand trucks, cranes, hoists, lift tables, powered mobile equipment and lift trucks, overhead handling and lifting equipment, and vacuum lift devices. As mentioned earlier in this chapter, the State of California OSHA has developed a document entitled "Easy Ergonomics" that includes a number of mechanical aids that would be useful in reducing exposure to MMH.

Engineering controls

Engineering controls of MMH hazards are preferred to other methods, such as worker selection and testing, training in safe Work practices, or the use of personal protective equipment, which are less reliable and often less effective. The engineering procedure involves modifying tasks and tools using ergonomic principles to reduce the effects of biomechanical stress. For MMH jobs, ergonomic design/redesign may be accomplished by modifying the job layout and procedures to reduce bending, twisting, horizontal extensions, heavy lifting, forceful exertions, and repetitive motions. The ergonomic approach is largely based on the assumption that work activities involving less weight, repetition, awkward postures and applied force are less likely to cause injuries and disorders. The ergonomic approach is desirable because it seeks to eliminate potential sources of problems. Ergonomics also seeks to make safe work practices a natural result of the tool and worksite design.

There are at least four advantages to adopting an ergonomic design/redesign strategy. First, an ergonomic approach does not depend on specific worker capabilities or learned behaviors, such as training. Second, human biological factors and their variations are accounted for in ergonomic approaches, using design data that accommodate large segments of the populations. Third, ergonomic intervention is relatively permanent, since the workplace hazard is eliminated. Fourth, to the extent that sources of biomechanical stress at the work-site are eliminated or significantly reduced, the difficult issues involving potential worker discrimination, lifestyle modifications or attempts at changing behavioral patterns of workers will be of lesser practical significance. Many MMH jobs entail a variety of specialized tasks with overlapping sources of physical stress. Each MMH task may contribute in some unknown manner to the onset of an overexertion injury. Often, numerous adjustments may be required for each activity to minimize the hazard of overexertion injury.

Training and education

The term training has been used to describe two distinctly different approaches to injury prevention and control—**instructional training** in safe materials handling, and **fitness training** (e.g. conditioning, strengthening, or work hardening).

The basic premise of instructional training in MMH is that people can more safely handle greater loads when they perform the task correctly than if they perform the task incorrectly. Although this approach is fundamentally sound, there are some potential problems in its application.

First, it is difficult to clearly distinguish between correct and incorrect materials-handling practices. For example, in manual lifting, there is little agreement on what constitutes a safe lifting style.[48] Perhaps one of the most important things to understand about lifting is that there is no single, correct way to lift. For example, the old adage of lifting with a straight back and bent legs may be inappropriate in many instances. For this reason, the

NIOSH does not recommend a correct lifting style; instead, it suggests that a free-style lift is appropriate in most instances.[51]

Second, the instructional approach relies on the worker's ability to comply with a set of recommended practices, which may be forgotten or changed from time to time. Regardless of the potential associated with MMH training, all workers who perform MMH activities should receive basic instructional training in the recognition of hazardous tasks and should have a thorough knowledge of what to do when a hazardous task is identified. Furthermore, the instructional training should provide information to the worker on how he or she can become involved in the process of preventing and controlling injuries on the job.

Unlike instructional training, the basic premise of **fitness training** is that a worker's risk of injury would decrease if his or her strength or fitness increased. Although this seems intuitive, it is not clear whether an individual's strength may affect his or her risk of injury. Certainly, a worker's capacity to perform heavy work might be increased, but there is some controversy about the relationship between worker strength and risk of injury.[64] Moreover, it is not known how the soft tissues of the body respond to increased loads associated with stronger muscles, especially if the worker performs tasks requiring greater strength demands.

Although both types of training programs have been used to prevent MMH injuries, the effectiveness of training in preventing or controlling injuries is unclear at the present time. Therefore, training programs should be used as a supplement to workplace-directed approaches. Additional information on training programs is provided by Ayoub and Mital[37] and Eastman Kodak.[27]

Employee screening

Some ergonomic experts advocate the use of screening methodologies, which rely on the assessment of one or more physical characteristics of the worker, to select specific workers for certain MMH jobs. In general, screening approaches are designed to identify workers with a high-risk of overexertion injury, or screen workers according to some preselected set of strength or endurance criteria in an attempt to match the capacity of the worker to the demands of the job.

Risk assessment screening Attempts to identify workers with a high risk of overexertion injury have included such activities as spinal radiographs, psychological testing, and medical examinations, which are designed to provide an objective basis for excluding certain individuals from stressful MMH jobs. None of these methodologies, however, have been shown to be reliable in predicting an individual's risk of overexertion injury. It is now widely accepted that the medical risks from radiation associated with radiography far outweigh any potential benefit derived from routine spinal X-ray screening.[51] Although no psychological tests have been found to quantify a worker's risk of overexertion injury, psychological testing can provide an indication of how a worker might respond to a severe injury. Similarly, medical examinations have also failed to reliably identify workers who may have an above-average risk of overexertion injury.

Physical capacity screening Another type of screening approach that has been used to select workers for MMH tasks includes individual testing of physical characteristics, such as strength, aerobic capacity, or functional capability. The underlying basis for using tests such as these to screen workers for MMH jobs is the belief that the risk of injury is dependent on the relationship between the capacity of the worker and the demands of the job. When the physical demands of the job exceed the capacity of the worker, the worker is at risk for developing an MSD. Thus, the idea of this approach is that workers should be matched to jobs according to the demands of the work.

A number of studies have been conducted to develop databases of maximum strength capacities (i.e. population averages) that could be used to design manual-handling tasks and workstations. These studies, however, disagree as to which of the three principal testing methods—isometric, isokinetic, or isoinertial—is most useful for determining strength capacity guidelines. Some researchers argue that traditional isometric lifting strength measurements, by which thousands of workers have been tested, are limited in assessing what workers can do under dynamic task conditions. These researchers suggest that dynamic strength testing is more appropriate than static strength testing for determining strength capacity.[65] This assertion is based on how well the test replicates the job requirements. Other researchers, however, claim that isokinetic lifting strength measurements probably have no greater inferential power to predict risk injury or job performance than any other form of testing.[66] Kroemer[67] claims that isoinertial strength testing is the most appropriate lifting strength testing method because it matches actual lifting conditions. Isoinertial methods, however, have not been generally validated in terms of their ability to predict risk of injury.[68]

Maximum isometric lifting strength (MILS) has been studied and reported extensively. It has a well-established testing procedure[69] and has been reported in field tests to predict risk of injury.[23,70] Extensive measures of MILS have been made for various work postures and activities. One study, for example, measured the isometric strength of 1239 workers in rubber, aluminum and electronic component industries.[71] In another study that measured the standardized isometric strengths (i.e. arm lift, torso lift, and leg lift) of 2178 aircraft manufacturing workers,[64] the employees were followed for >4 years to document back-pain complaints. The investigators found that worker height, weight, age and gender are poor predictors of standardized isometric strength, a finding that agrees with other studies.[71] The investigators also found, however, that standardized isometric strength is a poor predictor of reported back pain, a finding that conflicts with the results of some other studies.[72]

Marras et al[73] published an ergonomics guide for assessing dynamic measures of low back performance. This guide provides information on elements of dynamic performance, techniques to assess dynamic performance, and relationships between testing techniques and internal forces.

Personal protective equipment

Personal protective equipment (PPE) is defined as a device or item used by the worker as protection from recognized hazards, such as heat, cold, vibration, and other physical hazards. Ergonomic stressors should be considered when selecting PPE, and the use of the protective device should not contribute to extreme postures or excessive force. Some devices that have been advertised as PPE, such as braces, splints, back belts, and other similar devices, are not PPE according to the OSHA.[50] There is little evidence that these devices provide any realistic protection from injury for healthy workers performing MMH activities.[74] In fact, there is some evidence that prolonged use of back belts by healthy workers may actually increase the risk of low back injury.[75]

Finally, in an attempt to protect workers from the ergonomic stressors associated with manual handling, certain devices have been developed and marketed that force workers to use good body mechanics. For example, a back inclinometer alarm, which sounds an alarm when the worker's back exceeds a certain flexion angle, was developed to prevent excessive back flexion. These devices, however, have not been shown to reduce the incidence or severity of manual-handling injuries and cannot replace sound ergonomic job design.

In summary, MMH activities, such as excessive lifting, pushing, pulling, and carrying, represent a serious hazard for MSD for

many workers. There are analytic tools to identify ergonomic hazards that may result in overexertion injury, and prevention tools that are effective in reducing the potential for risk of work-related overexertion injury. Successful ergonomic programs require the full cooperation of management, labor organizations, government, and the workers themselves. The solution requires a team effort with a commitment to identify and eliminate hazardous material-handling tasks from the workplace.

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PHYSICAL AND BIOLOGICAL HAZARDS OF THE WORKPLACE

Second Edition

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