Rehabilitation NURSING

Introduction to Ergonomics for Healthcare Workers

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KEY WORDS
back disorders
lifting
patient handling
technology solutions

Healthcare workers who handle and move patients as part of their jobs suffer a disproportionately high number of work-related musculoskeletal disorders (MSDs). The majority of reported work-related MSDs are back pain cases that result in significant numbers of lost work days. It is likely that these lost workdays have a substantial impact on the quality and cost of health care. Patient care ergonomics can reduce the risk of work-related MSDs by helping safety experts design the work so it can be safely performed by most workers. This article provides a general overview of ergonomics—what it is, how it can be used to help design safe work, and why all healthcare workers and administrators should know and understand how excessive work demands can lead to increased risk of work-related MSDs. The article will also explain technological solutions that can be implemented to reduce the risk of work-related MSDs for healthcare workers.

Nurses, nurses aides, and other healthcare workers who are required to perform a wide range of physically demanding manual tasks in their work suffer a disproportionately high number of work-related musculoskeletal disorders (MSDs). In 2006 registered nurses had the fifth highest number of MSDs in the United States, exceeding the number of cases in occupations traditionally associated with labor such as truck driving, construction, and maintenance work (U.S. Department of Labor Bureau of Labor Statistics, 2007). These high rates of work-related MSDs are similar to rates reported for warehouse workers and others who must perform hazardous manual material handling tasks as part of their jobs. Manual handling of patients is more difficult than handling boxes—people are hard to grasp. In addition to facing the physical demands of manual material handling, many healthcare workers also are exposed to cognitively challenging work demands, significant time constraints, and high levels of work stress associated with direct patient care. Physical demands include heavy lifting, pushing, pulling, and working in extreme and stressful body postures to handle patients and equipment and perform tasks on patients who are in less than ideal positions for receiving patient care. The high cognitive demands often result from the considerable responsibility associated with administering complex treatments and drugs and countless other critical healthcare functions. Work stress can also result from long work hours, overtime, and high performance expectations. These stressors have been shown to lead to increased risk of developing work-related MSDs, such as back, shoulder, and hand and arm pain and injury.

Work-related MSDs account for a significant amount of lost work time and high costs to employees and employers alike. Ergonomics can reduce the risk of work-related MSDs by helping safety experts design the work so that it is within the capabilities of most workers. This article provides a general overview of ergonomics—what it is, how it can be used to design safe work, and what all healthcare workers and administrators should know about how excessive work demands can lead to increased risk of work-related MSDs and what can be done to prevent or reduce the risk of these disorders.

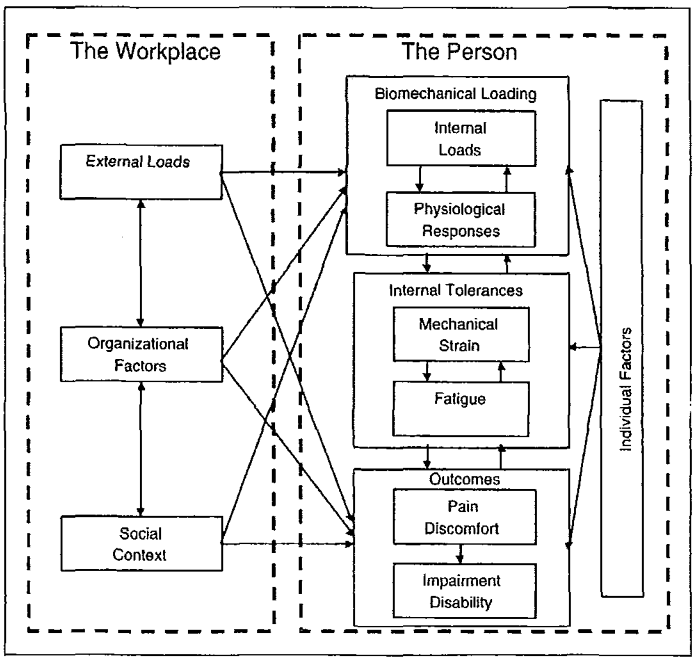
Ergonomics

Ergonomics is the science of fitting or matching workplace conditions and job demands to the capabilities of the working population. A good "fit" decreases the risk of illness and injury to the worker, increases worker productivity, improves the quality of the product or service, and increases satisfaction among the workforce. From a health perspective, ergonomics is the science of preventing work-related MSDs. *Work-related MSDs* are disorders of the muscles, nerves, tendons, ligaments, joints, cartilage, or spinal discs resulting from or made worse by exposure to the work environment or the performance of work. Work-related MSDs typically include disorders of the low back, shoulder, and upper extremity and generally reflect a more gradual or chronic onset but may include injuries due to overexertion, such as those associated with heavy manual lifting, pushing, and pulling. Work-related MSDs do not, however, include disorders that result from instantaneous or acute events, such as a slip, trip, fall, or an accidental event.

The National Research Council (NRC) and National Institute for Occupational Safety and Health (NIOSH) reviewed the extensive scientific literature examining the relationship between work and occurrence of MSDs and concluded that there is a clear relationship between back disorders and physical load (e.g., manual material handling, load moment, frequent bending and twisting, heavy physical wôrk, and vibration), and that repetition, force, and vibration are particularly important work-related factors for disorders of the upper extremities (e.g., hands, wrists, elbow, shoulder, and neck; Bernard, 1997; NRC & Institute of Medicine [IOM], 2001). Both reviews also suggested that work-related psychosocial factors, such as rapid work pace, monotonous work, low job satisfaction, low decision latitude, and job stress were also associated with the development of work-related MSDs. Based on these findings, the NRC and IOM proposed a conceptual model of the roles and influences that the various factors likely play in the development of work-related MSDs (**Figure 1**).

As can be seen in NRC and IOM's conceptual model, the primary pathway of injury starts with external loading resulting from physical work, such as lifting heavy weights, pushing or pulling heavy objects, or working in awkward postures for extended periods of time. These external loads lead to internal biomechanical loading on body tissues and other physiological responses. Although body tissues are specifically designed to withstand certain levels of internal loading, when the loads exceed the limits of the tissue's tölerance or the frequency of exposure is sufficiently high, mechanical strain and tissue fatigue can result, ultimately leading to pain, discomfort, impairment, and even disability. The model indicates other workplace factors affect the development of work-related MSDs, such as psychosocial and organizational factors, social context, and individual factors.

Figure 1. NRC and IOM Conceptual MSD Etiological Model



Because high loads can damage musculoskeletal tissues, it is important to keep the internal loads at a level well below tissue injury tolerance limits. An example of a traditional biomechanical spinal tissue load tolerance model is shown in **Figure 2**. As long as the internal load remains below the tissue injury tolerance limit, harm is not likely to occur. When the internal load exceeds the tolerance limit, however, injury is much more likely. Recent studies have shown that the traditional biomechanical load-tolerance model may be over simplistic. Some have proposed the decreasing load-tolerance model indicated by the dashed line in Figure 2. In this model, the tissue tolerance is not constant; the tolerance of the tissue actually declines because of repetitive loading. The chance of injury increases for the same levels of loading because the tolerance level decreases over time.

Ergonomics science generally relies on several important determinants of worker characteristics and capabilities for the design of safe work. These include worker anthropometry, muscle strength, psychophysical capabilities, tissue tolerance, and physiological limits.

Anthropometry deals with the concepts of body size and mass, reach limits, and other factors associated with the worker's physical characteristics and optimal work design parameters. From the healthcare perspective, anthropometry addresses issues such as appropriate bed height, reach and lifting positions, and other factors associated with the geometric layout of the workplace. Anthropometric tables with gender-based design values have been published for use by ergonomists in determining optimal work station design (Kodak, 2004).

Muscle strength is also important because many tasks are limited by the strength capacity of the exposed workforce. Strength capacity has been measured for both men and women in various postures (Chaffin, Anderson, & Martin, 1999). Generally, men are stronger than women, and strength is highest when postures are in optimal positions. Recently, the Association of periOperative Registered Nurses (AORN; 2007) and the National Association of Orthopaedic Nurses (NAON) developed ergonomic guidelines for patient handling and movement that were based on female arm strength capacity (Sedlak, Doheny, Nelson, & Waters, 2009).

Another measure of work capacity for individuals is their maximum psychophysical capability. Based on comprehensive laboratory research, investigators have developed task-specific, gender-based tables of maximum acceptable weights and forces for work tasks. For example, researchers at the Liberty Mutual Research Center developed tables of maximum acceptable weight of lift and carry, as well as maximum forces for pushing and pulling (Snook & Ciriello, 1991).

Physiological limits have been provided for manual lifting and other physically demanding work. According to Waters and colleagues (1993), NIOSH recommends that *metabolic energy expenditure*, a measure of physiological work demand, should not exceed approximately 33% of a person's maximum aerobic capacity for 2–8 hours of continuous work, 40% for 1–2 hours of continuous work, and only 50% maximum aerobic capacity for a continuous work period of less than 1 hour. A workload that corresponds to approximately 33% of a worker's maximum aerobic capacity would be equivalent to a job in which the worker would be slightly out of breath but not exhausted. The NIOSH recommendation for limiting energy expenditure translates into a working heart rate limit of approximately 110 beats per minute for continuous steady work. Of course, if adequate rest breaks are provided, then higher levels of physiological demand may be acceptable for short periods of time during the work day.

As mentioned previously, tissue tolerance limits provide cutoff points for determining whether a task has sufficiently high risk for work-related MSDs so that a decision can be made about whether an intervention is needed. When lifting, pushing, or pulling objects, the musculoskeletal system must generate very high internal compression and shear forces to balance the externally applied loads (the weight or forces in the hands). Tissue tolerance limits refer to the amount of internal force the musculoskeletal tissues can withstand without becoming damaged. Perhaps the most well-known tissue tolerance limits are for compression of the spinal discs during lifting, pushing, and pulling tasks. NIOSH researchers have recommended spinal disc compression limits of 3,400 Newtons (770 lbs) for manual lifting. More recently, it has been suggested that the spinal shear force limit for the spinal disc would only be approximately 1,000 Newtons (225 lbs; Marras, 2008). These forces should not be confused with the weight of the load lifted or the amount of weight pushed or pulled, as will be explained later in this article.

Findings from epidemiological studies that link work demands to specific health outcomes are important because they can help define acceptable or safe levels of exposure to physical work stressors. These studies are typically used to develop exposure guidelines or recommended exposure limits. As mentioned previously, Bernard (1997) and NRC and IOM (2001) have both reviewed and summarized the epidemiological literature linking work with development of work-related MSDs. In both reviews, authors concluded that there is strong evidence that lifting heavy objects is associated with development of work-related low back pain.

This is especially important for healthcare workers in the rehabilitation setting because these exposure limits can be used to determine when a task exceeds the physical capacity of workers with regard to patient handling and lifting and moving heavy equipment. As shown below, handling patients and equipment and working in extreme postures creates high risk for work-related MSDs.

Why do patient- and equipment-handling and moving (i.e., manual material handling) in extreme postures pose a high risk for work-related MSDs? Manual material handling, such as patient handling, pushing and pulling objects, and working in extreme postures, can create high internal forces on the muscles, ligaments, and joints. A simple spinal model (**Figure 3**) shows how external loading can lead to high internal tissue loading. In this figure, the low back is represented as a simple lever system comprising a lever, fulcrum, and two loads (external and internal), one on each side of the fulcrum. For the model depicted in Figure 3, the arms and trunk act as a combined unit (lever), the fulcrum is represented by the intervertebral disc joining the fifth lumbar and first sacral (L5/S1) spinal joint, and the forces on either side of the fulcrum represent the external forces applied by the arms and the internal back muscle forces that serve to offset the external forces. The distance of each load from the fulcrum is termed the moment arm for its respective load. The mathematical product of each load times its respective moment arm is called the load moment. Although the loads

Figure 2. Tissue Tolerance Models

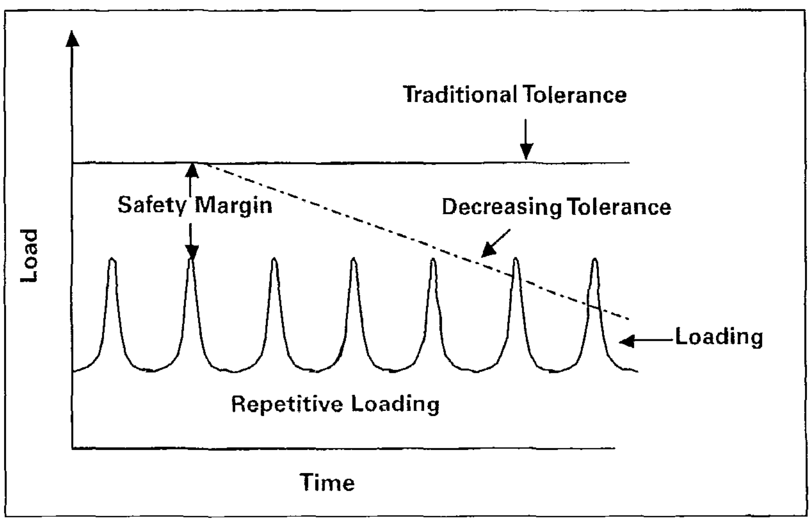
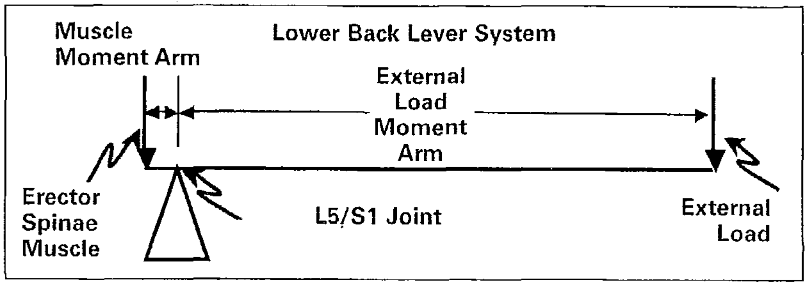


Figure 3. Spinal Biomechanical Model



can be different magnitudes and different distances from the fulcrum, the moment on each side of the fulcrum must be equal to be balanced. The load being applied through the hands and arms of the person can be visualized as one side of the lever system, and the loading provided by the muscles in the back can be thought of as the balancing load on the other side of the lever system. In Figure 3, the length of the two moment arms is very different. The moment arm for the external load applied at the hands can be a great distance from the fulcrum (up to 63.5 cm or 25 in. at full forward arm extension for a tall man), whereas the moment arm for the internal back muscles is very close to the fulcrum (about 6.5 cm or 2.6 in.). This means that even a small external load applied in the hands will require a very large muscle force to maintain mechanical equilibrium and balance both sides of the lever system. It is the combined downward force of the muscles, the body mass of the upper torso, and the load being handled that create large compression forces on the fulcrum of the lever system. In this illustration, it is the spinal discs that carry most of the load created by the external and internal moments. The total force on the fulcrum (i.e., spinal discs) can be many times greater than the actual magnitude of the external load. As shown previously, when the magnitude of the internal forces on the spinal discs exceed their ability to withstand those loads (injury tissue tolerance), the discs can be irreparably damaged, preventing them from functioning properly and resulting in severe injury and pain.

Key Elements of an Effective Ergonomics Program

NIOSH developed a list of key elements for an effective ergonomics program that is shown in Figure 4 (1997). These key elements provide an effective pathway for controlling work-related MSDs. Specifically, the key elements include the following:

Step 1. Look for Signs of MSDs

This step includes an assessment for signs and symptoms of MSDs. It might include tools such as worker surveys, questionnaires, or discomfort diagrams.

Step 2. Set the Stage for Action

This element focuses on the need for management commitment and employee involvement in the process. Studies have shown that ergonomics programs are likely to fail if there is not adequate recognition from management that a program is needed and demonstration of a strong commitment to implementing a program. Most successful programs include a high level of employee involvement in the development of the process, such that there is buy in from both management and employees.

Step 3. Train—Build In-House Expertise

The goal of this element is to ensure adequate training of in-house experts so that jobs can be properly evaluated and effective solutions can be identified.

Step 4. Gather and Examine Evidence of MSDs

This step involves collecting and examining health and risk factor data. Reviewing health data such as injury and illness records, lost work days, restricted work day information, and workers' compensation costs can help target those specific jobs associated with the highest incidence of work-related MSDs. Risk factors must also be assessed for jobs to identify those that have the highest risk and determine which jobs need to be changed to reduce risk to acceptable levels.

Step 5. Develop Controls

To control the risk of work-related MSDs, some job changes are typically required. These may include simple solutions, such as assigning more than one caregiver to perform a specific task, or they may require more complex solutions, such as the use of assistive handling technology, powered patient lifting, or transferring devices or equipment movers. The best solution for a potentially high-risk job is often defined by the magnitude of the risk and the availability of a specific solution. For work in the rehabilitation setting, the most effective solutions include using equipment and technology to help with patient handling and moving equipment, such as powered patient lifts, equipment movers, and carts for moving rehabilitation equipment. More information about controls for the rehabilitation setting is provided later in this article.

Step 6. Establish Healthcare Management

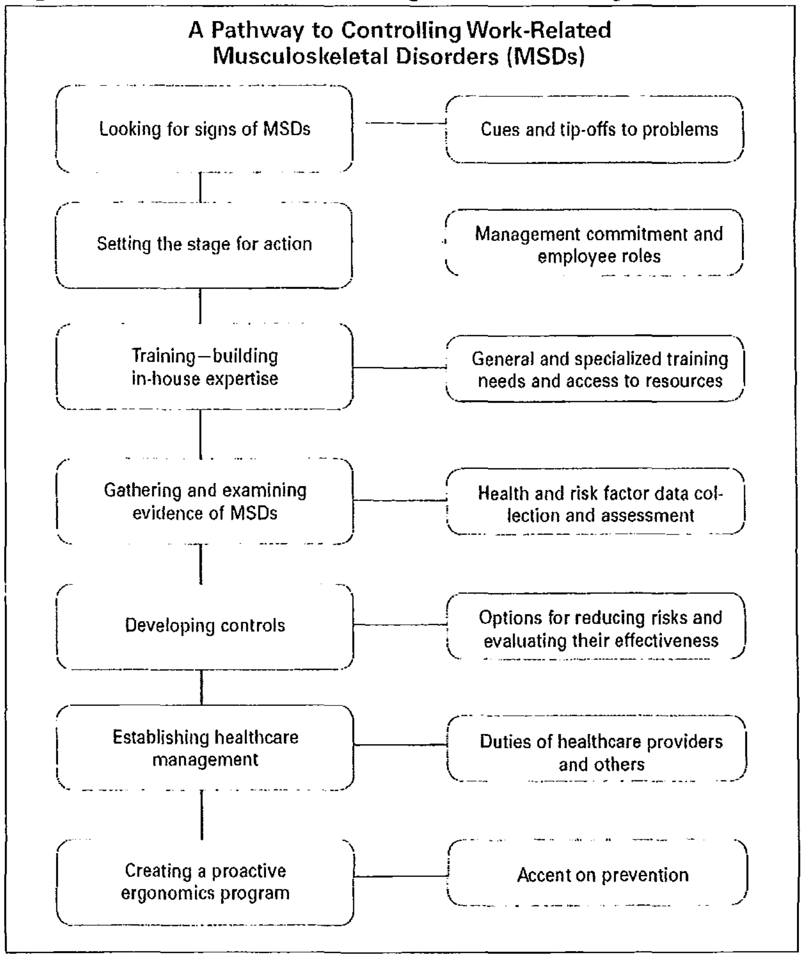
An essential part of any ergonomics program is establishing a healthcare management program for injured workers. This provides early detection of symptoms of work-related MSDs and treatment and return-to-work options for injured workers. Healthcare management should be integrated with exposure assessment and control for optimum effectiveness.

Step 7. Create a Proactive Ergonomics Program

Ergonomics works best when the program is proactive rather than reactive. When signs and symptoms of MSDs are addressed early in the injury development process, the overall severity of the injury is reduced for the worker, and the impact on the workplace is minimized. The most effective ergonomic program is one in which ergonomic considerations are part of the early facility design and construction process. It has been shown that incorporating ergonomic controls in the design and construction phase can cost about one-fortieth as much as retrofitting workplaces with ergonomic solutions (Alexander, 2004).

From the perspective of a healthcare organization, it is important to determine how best to implement these elements into a successful program. For example, who within the organization is responsible for each of the critical elements? What are the first steps that are needed, and how do you actually begin to implement the process? How long should it take to fully implement the plan? After the organization has made a commitment to implement a plan, it will require a team effort. Most successful programs begin with the organization of a strong ergonomics team. An effective ergonomics team would typically include a number of individuals from management, labor, worker groups, health and safety experts, and any others who would be responsible for implementing the full ergonomics plan. Before this step usually takes place, however, there has to be some recognition by upper-level management of the need to implement a program and a strong commitment to follow through with the recommendations of the ergonomics team is necessary.

Figure 4. Elements of an Ergonomics Program



Exposure Assessment Methods

As noted in Step 4, a task-specific ergonomic exposure assessment is needed to identify those tasks with increased risk for work-related MSDs and those in need of controls. Exposure assessment methods can consist of simple checklists for screening purposes or complex task-specific analyses for assessing tasks such as lifting, pushing, pulling, and carrying objects. There are also extensive ergonomic assessment tools for evaluating highly repetitive or strength-demanding upper extremity tasks, such as using pipettes, retractors, scissors, and other hand- or arm-intensive work. Some examples of ergonomic exposure assessment methods for reviewing tasks with high risk for back disorders include the Revised NIOSH Lifting Equation (Waters et al., 1993; Waters, Putz-Anderson, Garg, & Fine, 1994), the University of Michigan 3D Static Strength Prediction Method (Chaffin et al., 1999), the Ohio State University Lumbar Motion Monitor (Marras et al., 1993), and the Liberty Mutual Psychophysical tables (Snook & Ciriello, 1991). Most of these methods provide quantitative information about the relative physical demand of the job of interest and the percentage of individuals who would have the capacity to safely perform the task. A description of these tools has been previously published (Waters, Baron, & Putz-Anderson, 1998). After a task has been evaluated using one of the ergonomic exposure assessment methods, the analyst likely will know how physically demanding the task is and whether a simple or more complex technologically based control would be needed to make the job safer. For example, the Revised NIOSH Lifting Equation was recently used to determine that no caregiver should lift more than 35 lbs of a patient's body weight under ideal conditions, and that the recommended weight limit would be even less when conditions were less than ideal, such as lifting with arms extended or with the back in extreme flexion (Waters, 2007). Previously, researchers have assessed manual patient lifting tasks and have shown them to be very high risk for work-related MSDs (Garg & Owen, 1992; Marras, Davis, Kirking, & Bertsche, 1999).

Ergonomic Interventions for Controlling Exposures

Perhaps the most crucial element of an ergonomics program is the implementation of ergonomic interventions or controls for reducing risk of work-related MSDs for those jobs deemed to have high risk. When a job is identified as having high risk, some form of intervention is needed to reduce the risk for the worker who must perform that job. According to standard industrial hygiene hierarchy of control practices, the first choice for controlling risk factors for work-related MSDs is engineering controls. Engineering controls include the use of powered and nonpowered assistive handling equipment such as battery-powered motorized hoists, lateral transfer devices, and push/pull assist devices, such as those shown in **Figures 5a–d**. Engineering controls are preferred as the first choice because they reduce a worker's exposure to physical stressors. Because the equipment or device removes the physical demands of the work, the caregiver is allowed to focus more on patients and their safety during the handling procedure. Studies have shown that using equipment for patient handling is effective in reducing patient handling injuries (Collins et al., 2004) and the equipment can pay for itself in less than 3 years after purchase (NIOSH, 2006). Using equipment for safe patient handling and movement can also increase the quality of patient care (Garg 1999; Nelson, Collins, Siddharthan, Matz, & Waters, 2008) and reduce staff turnover rates, especially in long-term care facilities (J. Joliff, personal communication, June 20, 2005). The Veterans Health Administration (VHA, 2006) has published a series of charts or algorithms (i.e., task-specific decision logic trees) for choosing the most appropriate equipment for specific patient handling tasks.

If engineering controls are not feasible to reduce the risk for a specific work task, administrative controls may be effective. Administrative controls include assigning more workers to do the task, training the workers to perform the task, or rotating workers between jobs so that exposure time is reduced. Administrative controls are generally considered to be less effective than engineering controls because they do not actually reduce the physical demands of the work and they rely on workers performing the task in a specific way, which is not always possible.

As a last resort, if engineering and administrative controls are not feasible, then personal protective approaches are often considered. Unfortunately, there is little in the way of personal protective equipment for preventing work-related MSDs. Back belts, which are often thought of as personal protective equipment, have not been shown to be effective in reducing risk for uninjured workers engaged in heavy lifting, and, in fact, may increase the noninjured worker's risk of developing a lifting-related MSD (NIOSH, 1994).

Psychosocial Stressors and Impact Risk of Work-Related MSDs

In addition to specific individual factors that can modify how a person responds to physical loading, such as age, gender, strength, and physical conditioning, there are a variety of other nonphysical factors that can affect the risk of work-related MSDs, such as the psychosocial and organizational context of the job (Figure 1). Psychosocial factors typically include perceived heavy workload and lack of control over work as contained in the classic demand and control model (Karasek & Theorell, 1990), work stress, job dissatisfaction, supervisor support, and a variety of other work organization factors. Some notable work organization factors include work hours, shift work, overtime, mandatory overtime, and other administrative factors. In selecting ergonomic solutions to prevent work-related MSDs in a particular workplace, all of the potential risk factors should be considered to determine what solutions or controls would be most effective.

Summary

Ergonomics is the study of how to design safe and productive workplaces so the demands of the job "fit" the capabilities of the workers who must do the work. From this point of view, it is necessary to know both the job demands and the work capacity of the workforce to design jobs that are safe, efficient, and productive and that minimize risk of work-related MSDs. NIOSH outlines the steps for implementing an ergonomics program (1997), and one of the most important elements of an ergonomics program is the intervention or control implementation phase. In the healthcare industry, patient handling and movement have been identified as frequently occurring jobs with high risk for work-related MSDs. Fortunately, a wide range of patient-handling equipment is available as a solution for this high risk task.

Acknowledgment

The findings and conclusions in this article are those of the author and do not necessarily represent the views of NIOSH.

Figure 5. Examples of Patient Handling Ergonomic Technology Solutions

a. Ceiling-mounted full-body lift b. Sit-to-stand lift c. Floor-based full-body lift d. Powered device for moving equipment and wheelchairs

Note. Photos courtesy of Arjo Huntleigh

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