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ERGONOMICS: APPLYING WHAT WE KNOW

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Ergonomics is concerned with the match between job requirements and worker capabilities. It is the science of fitting the job to the worker, designing workplaces, equipment, tools, and work methods that minimize the risk of injury or illness. To a lesser extent, ergonomics may deal with fitting the worker to the job through job selection and, occasionally, worker training, but this approach is generally less effective.

One primary application of ergonomics to construction trades is the prevention of injuries and illnesses that affect the musculoskeletal system. These injuries and illnesses are often referred to collectively as work-related musculoskeletal disorders, or WMD. These sprains, strains, and related problems can be acute or chronic, in the latter case resulting from weeks, months, or years of accumulated microtrauma. The chronic problems are known as cumulative trauma disorders, repetitive strain injuries, or repetitive motion injuries. A distinction is often made between acute musculoskeletal *injuries* and chronic *illnesses*, although the distinction may be more illusory than real. For example, upper extremity cumulative trauma disorders such as carpal tunnel syndrome are usually classified by the Bureau of Labor Statistics as illnesses. However, back disorders are classified by many people as injuries even though they may be preceded by long-term exposure to heavy lifting, repetitive bending, or other ergonomic exposures.⁷ Regardless of the nomenclature, work-related musculoskeletal disorders are becoming

increasingly recognized as widespread and costly problems in construction and other industries.

In the United States, work-related illnesses reported to the Bureau of Labor Statistics for all employment increased nearly two and a half times in 1986-1991.⁵ Most of the new cases in these 6 years were classified as "diseases associated with repeated trauma," which increased from 18% of the total cases in 1981 to 61% in 1991. Additionally, low back injuries are estimated to account for about 16% of all compensable injuries in the workplace and about one third of all workers' compensation costs.³²

In construction, the rate for work-related cumulative trauma in 1991 was 3.1 cases per 10,000 full-time workers, second only to cases of skin disorders among work-related illnesses.⁷ In a study of self-reported work-related complaints over 1 year among 526 unionized construction workers, Cook et al. found the prevalence of musculoskeletal complaints to be 75% in the low back, 41% in both the neck and wrist/hands, 40% in the knees, and 28% in the feet.¹¹ In 1994, Hunting et al. reported on a survey of electricians showing that about half had back or hand/wrist symptoms at least three times in the previous year or one episode lasting longer than 1 week during the previous year.¹⁵ About 82% of the workers had at least one symptom in the past year, while 52% reported 2 or more symptoms.

Work-related medical and compensation costs for WMD in the U.S. are estimated to be between \$20 billion and \$40 billion each year.²⁰ In addition, indirect costs resulting from absenteeism, retraining, lost productivity, and other hidden consequences are estimated to be more than double the direct costs. The effects of these disorders in human suffering and disrupted lives, at home and at work, cannot be measured in monetary terms.

ERGONOMIC RISK FACTORS IN CONSTRUCTION WORK

The physical aspects of a job that increase the risk of WMD in construction are similar to those identified in other industries. These risk factors include *repetition of a same motion*; *manual forces that are excessive or prolonged*, such as heavy lifting or frequent or prolonged grasping; *postures that are awkward or maintained for extended periods*; *pressure from hard surfaces or sharp edges on the body*; *vibration from tools and machinery*; and *environmental factors* such as extremes of temperature and humidity.²⁵

These risk factors are integral parts of many construction jobs as they are currently configured. Lifting and carrying heavy materials, working with the hands overhead or below knee level for extended times, and being exposed to vibration and extreme environmental conditions are common.²³ In one recent study, construction workers identified the most troublesome elements of their jobs as maintaining awkward postures for prolonged times (69% of respondents), working in adverse environmental conditions (67%), having to work "very hard" (44%), and having to reach overhead (43%).¹¹ However, few construction jobs have been studied extensively to document the frequency or intensity of ergonomic risk factors. One exception is a series of studies by Wickström et al. that sought to document the extent of back injuries among workers tying concrete reinforcement rods together.²⁷ The authors reported a larger percentage of concrete-reinforcement workers suffering harmful effects from difficult work postures than any other group. Several investigations of injury data and worker symptoms and complaints are underway to develop trade-specific injury profiles and to provide more detailed assessments of ergonomic risk factors within the construction trades. Although few full-scale epidemiologic

studies have been conducted among construction workers, the high rates of musculoskeletal complaints and the presence of known ergonomic stressors have been documented in the industry.²³ It is therefore appropriate to ask how these problems can be corrected even while further research is carried out.

Who's Responsible For Ergonomics

Regardless of whether they understand the term *ergonomics*, a wide range of people make decisions affecting the number and severity of ergonomic risk factors to which construction workers are exposed. Architects, designers, and project owners determine the materials, methods, and procedures that will be needed to complete a project. Their choices influence the postures, repetitions, forces, and other factors to which workers will be exposed. Contractors and subcontractors clearly have a major impact on how project plans are translated into a final product. Through their decisions about the flow of materials, the sequencing and coordination of tasks, scheduling, and other factors, contractors can directly influence the ergonomic risk factors on a job site.²⁴

Suppliers of materials, tools, and machinery also influence risk factors for WMD through the design, packaging, and delivery methods they adopt. Such factors include the weight of a load to be lifted or the time and effort required to find a particular item in a bundle of parts.

Construction workers use their bodies at work in ways that affect the likelihood of illness and injury. For reasons discussed below, it can be argued that they may be victims of unfortunate circumstances; nevertheless, workers have a major contribution to make in reducing WMD because they alone know all the constraints involved in completing a job.

Regulators also make, or fail to make, decisions that affect ergonomic risk factors in construction.

Organizational and Psychosocial Factors

In construction, change does not come easily and occurs in the context of certain psychosocial and economic realities. The ever-changing mix of employees and employers (contractors) tends to fragment accountability and incentives for controlling ergonomic risk factors in the workplace. Contractors who may never see or be held responsible for the long-term effects of their workers' exposure to ergonomic risk factors have little incentive to modify work practices or purchase new tools or equipment to reduce hazards.

For instance, whole-body vibration puts operators of construction equipment at high risk for back problems. Solutions exist. Vibration-dampened ergonomically designed cabs produce much lower stress on the musculoskeletal system.¹ But, because these are cumulative injuries from chronic exposure and workers change jobs frequently, contractors have little incentive to retrofit or replace old cabs or pay extra for better cab designs. Unless workers are experiencing WMD problems, contractors do not recognize the need. Here the fluid nature of the construction industry and the chronic nature of WMD collide to produce inaction.

In addition to the ergonomic risk factors that contribute to WMD, injury and illness rates are influenced by economic factors.¹³ During recessions or when unemployment is high in a particular area, workers may be more likely to risk injury, not to report injuries and illnesses, and to work while injured. They may need the work, fear losing their jobs, or may be concerned about not being hired on a future job. Even in good economic times, some construction jobs, such as drywall installation,

may be compensated on a piece-rate basis, which often encourages workers to perform faster and for longer hours than can be sustained without risk of injury or illness. Paradoxically, safety incentive programs, in which employees are rewarded for working a certain number of days without a lost-time accident, may encourage workers to underreport illnesses and injuries and to continue working with pain and discomfort until their conditions are more severe and even disabling.¹⁷

Proposed changes to reduce WMD must also deal with psychosocial factors. Construction work is considered to occur in a "rough and tumble" culture that encourages workers to get the job done at any physical cost. Such a climate tends to foster overexertion, when workers feel pressure from peers and supervisors to push beyond reasonable limits. Scheduling and production pressures may tend to speed up the work, and workers may cut safety corners to complete the work faster. Supervisors and contractors may not recognize or be willing to accept the possibility that workers may be more productive over the long-term by working more slowly but steadily. Furthermore, limited opportunities to participate in decisions about one's own work process are believed by some to increase workers' physiologic susceptibility to the effects of physical stressors.⁵

Another economic and psychosocial factor, the transient nature of construction employment, impedes efforts to pinpoint and control the causes of injuries and illnesses or to assess the efficacy of ergonomic interventions. With many different subcontractors moving on and off a site, there is rarely a central authority for safety and health as there is in many larger industrial settings. One contractor may create hazards for another's employees. Most often there is no responsible person on a work site who knows about ergonomic risk factors and is authorized to correct situations before they result in injury or illness.

CONTROLS FOR ERGONOMIC RISK FACTORS

Once the ergonomic risk factors associated with particular work tasks are identified and understood, the approaches to controlling or modifying the risk factors are engineering controls, administrative controls, and the use of personal protective equipment.²⁰

Engineering Controls. Engineering controls are measures that are taken to physically modify the forcefulness, repetitiveness, awkwardness, vibration levels, physical pressures, or environmental extremes associated with performing a job. Examples of engineering controls include modifications of materials, tools, machinery, and work surfaces. Engineering controls are usually the most effective long-term approach to reducing risks for WMD. However, in a highly dynamic work environment such as a construction site, finding feasible engineering controls may be difficult.

Administrative Controls. Administrative controls, such as rest breaks, changing work organization, or worker training, are an important part of any program intended to reduce WMD among construction workers.

Personal Protective Equipment. The third approach, the use of personal protective equipment, is considered much less reliable than administrative or engineering controls for preventing WMD. The ergonomic value of backbelts, wrist splints, and vibration-absorbing gloves is largely unproved.²¹

THE ERGONOMICS PROCESS AND THE TEAM APPROACH

Experience in industrial settings over the last 10–15 years has shown that the most successful strategy for making ergonomic improvements is to use a team approach

and develop a process for identifying and solving problems.³¹ This approach is analogous to several highly successful management methods, such as total quality management. Using TQM to reduce WMD in the construction industry may be more difficult but more necessary than it is in industrial settings.

The ergonomics process is an ongoing cycle of identifying high-risk tasks, analyzing the tasks for ergonomic risk factors, proposing a solution for reducing the risk factors, implementing the intervention, and evaluating the solution. The cyclical nature of the process is important for two reasons. First, the process is rarely perfect the first time, and one or more repetitions are almost always necessary to fine-tune the details of the proposed improvement. At times, a proposed solution may be tried and abandoned entirely in favor of an alternative. Second, the process must be cyclical and continuous because of ongoing changes in designs, materials, tools, machinery, and work methods. These changes are especially prevalent in construction, where a job site may change dramatically in a short time.

Who should be involved in this ergonomics process? Experience in industry and common sense indicate that everybody who can influence or be influenced by proposed ergonomic interventions should have input in the decision making if it is to have the highest probability of success.³¹ Too many times, impressive engineering solutions to ergonomic problems have gone unused due to failure to consult workers or supervisors. In addition to workers and contractors, the team could include suppliers, manufacturers, owners, and others, depending on the problem to be addressed.

Examples of Ergonomic Interventions in Construction

Ergonomic interventions to control WMD can range from the very simple to the more elaborate. Modifications can be costly, but in many cases they cost little or nothing. Many ergonomic improvements actually save time and money. There are lessons to be learned from successful and unsuccessful ergonomic interventions.

Stresses related to **drywall installation** have been reduced using a number of job modifications.²⁶ Simple handles have been developed for carrying one or two sheets of drywall to reduce stress on the hands and shoulders. Dollies for moving drywall have been developed that are narrow, for getting through small doorways, but that can be tipped sideways to create a table for cutting the drywall and will allow for picking it up at waist height. Mechanical lifts exist to raise and hold drywall overhead to reduce shoulder stress.

One study found that workers fastening drywall became fatigued and significantly slowed their work pace late in the workshift.¹⁴ Experiments with frequent 10- to 15-second breaks, or micropauses, indicated that workers could maintain their productivity throughout the day and ultimately be more productive.

In some regions, drywall dimensions have been reduced from 4 feet wide (120 cm) to 3 feet wide (90 cm) to reduce the weight of the board, making it easier to carry and lift.⁴ This intervention will need to be closely evaluated because this change could also result both in increased repetitions and dust exposure for drywall fasteners and tapers.

A tool has been developed to allow **concrete reinforcement** workers to tie rods from a standing height.¹² This technique is widely used in Europe and is intended to reduce the load on the back that results from working in a bent posture and the stress on the wrist from repeated twisting of the wires. However, the Swedish-developed tool weighs 15–18 pounds, and U.S. workers complain it is too heavy. The tool is so different from current practice in the U.S. that many workers initially reject it as no improvement to their current technique. Because the tool requires the use of different

muscle groups than do current work methods, there is a need for an acclimation period of 2-3 weeks before workers can decide whether the tool provides an improved work method for them. This tool is apparently most useful for bridge decks, which must be tied at every junction for long runs.

Painting overhead can place strain on the arms and shoulders from pressing a long pole with a roller on it against the ceiling. The worker must maintain a tight grip on the pole to support it and press upward to apply the paint. One successful and inexpensive intervention in Sweden has been the use of a "painter's disk," a simple plastic flange that screws onto the pole just above the handle. The weight of the pole and roller can then be supported by the flange, reducing the required grip force.⁹ Neck stress, another ergonomic problem associated with painting overhead, has been addressed with an inflatable neck pillow that is worn behind the neck and attached by suspenders to the pants.²²

Laying of masonry blocks is known to cause back injuries. The weight of the blocks and awkward postures used to handle them are obvious risk factors. In Germany, masonry blocks are manufactured with handholds to make them easier to lift, and a limit has been set on the weight of blocks that one person is allowed to lift.¹⁶ Blocks heavier than 25 kg (55 lb) must be lifted by a hoist. Blocks weighing 7.5-25 kg (16.5-55 lb) must be lifted using two hands; only blocks weighing less than 7.5 kg (16.5 lb) may be lifted one-handed. Even stricter standards exist in Sweden, where one-handed lifts may be used only for blocks weighing up to 3 kg (6.6 lb); two-handed lifts are required for blocks weighing 3-12 kg (6.6-26.4 lb).² Blocks weighing 12-20 kg (26.4-44 lb) may be lifted only between knee and shoulder heights (0.5-1.5 m), and blocks heavier than 20 kg must be lifted mechanically.

In general, **materials handling** is a major risk factor for ergonomic injuries on job sites. Better coordination of materials shipments and storage has been suggested as a way to reduce injury rates.²³ For example, materials should be stored as close as possible to where they will be used. In Germany, a just-in-time delivery system for bricks has been developed and implemented with the cooperation of the brick manufacturers, contractors, and unions.¹⁹ This modification requires much more coordination between the trades. Better planning must be evaluated for possible negative consequences such as speeding up the pace of the work.

Proper physical conditioning has been shown to help prevent injuries. In Sweden, an exercise program was introduced to allow workers 10 minutes of paid time to limber up before beginning work.¹⁰ Workers who participate in this program say they feel better and healthier and have fewer aches and pains than those who don't. The program gives workers time to socialize and plan their day, which has a beneficial psychological impact. Similar exercise programs have been instituted by several construction companies in the U.S. in the past few years.

Training is a common administrative control strategy for reducing WMD. Training in "proper lifting" techniques has been a main emphasis of many worker training programs, but few data support this approach as an effective method for back injury prevention.²³ In fact, the method of lifting most widely taught (with the knees, keeping the back straight) may be more dangerous in some situations. However, training that helps workers develop strategies for recognizing and avoiding dangerous working conditions may have much broader benefits. Workers can benefit from understanding what causes WMD and what factors in the workplace put them at higher risk for injury and illness.

Introducing New Technologies in Construction

Technology can have a dramatic impact on people's jobs—positive and negative. Construction practices have changed considerably in the past 20 years. For example, the number of poured concrete structures is increasing. Walls are almost entirely drywall construction. Hot asphalt roofing is often replaced with single-ply roofing. Sheet-metal duct work is mostly built off-site using computer-aided design and plasma-arc cutters. Some housing sections are made on assembly lines and bolted together on site.

Although none of these changes were made with any thought toward their ergonomic impact on workers, current technologic capacity includes the ability to design tools and equipment specifically with ergonomic factors in mind. The situation is analogous to car manufacturers who emphasize design-for-assembly as an important aspect of the overall production process. Workers should be involved in the design, testing, and implementation of any new technology. Workers know the intricacies of their jobs and the potential problems best. They are often the best source for ideas on how to redesign equipment to meet their needs. Worker involvement in redesign will lead to greater acceptance later.³⁰

Workers are often skeptical of new technology and may have good reason.³ It is not unusual for ergonomic improvements to be "sold" to employers as a way to reduce injuries and increase productivity. This can pose a dilemma for workers. Increases in productivity can lead to a need for fewer workers. In an economic climate in which as many as 50% of construction workers may already be unemployed, workers may not be receptive to technological innovations that increase productivity and reduce the amount of needed labor. However, even if the number of workers required for a job declines, if a company becomes more competitive and obtains more work as a result, employment by the company might remain constant. Workers may reject or resist change unless they see benefits, such as fewer accidents, a longer work life, reduced pain and suffering, or increased productivity that can maintain employment levels.

Another important aspect of new technology in construction is also related to employment levels: the skill level required to use the technology. The easier it is to use, the faster it will be accepted. A danger exists that new technology, in reducing the skill level required to do a job, may lessen job security of highly trained, more experienced workers. Ideally, new technology should give workers more skills.

If a new technology is substantially different from current work methods or requires markedly different skills, workers will need training and time to acclimate to the new methods. If the new technology helps workers and allows them to work in a manner similar to what they are accustomed to, it will be accepted more easily. Workers often must be convinced of the hazards of doing the work in the traditional way. For example, battery-powered screwdrivers are similar to the electric screwdrivers commonly used in the industry, but they weigh less and are more portable and, thus, preferable ergonomically. Once manufacturers began making models with smaller and more durable, longer-life batteries, they were widely accepted in construction.

Construction workers often buy their own hand tools. The payback time often needs to be short, because individual workers may not be able or willing to make long-term investments for uncertain benefits. The same economic concerns are faced by contractors who may be asked to make large investments in new equipment.

There is a lack of information about which new technologies or tools to use. Despite the marketing efforts of many tool manufacturers, there is no such thing as an "ergonomic tool" that is good for every task. Tools must be assessed in the context of the work for which they will be used. Their efficacy depends on their appropriate use. A bent-handle hammer, for instance, has been suggested as an ergonomic intervention for carpenters.²⁹ However, although it might not help with nailing concrete forms, it might be useful for nailing roofing materials.

IMPLEMENTING WHAT WE KNOW

Once effective ergonomic control measures are identified, three levels of implementation can be used: education, regulation, and engineering.

Education about how risks of WMD can be reduced is important at all levels. Suppliers, owners, contractors, supervisors, and workers all need to know how the work site can be improved to reduce WMD. Given the financial and personal costs associated with WMD, individuals at each level should have ample motivation for implementing ergonomic improvements. Ergonomic improvements to prevent WMD also can help make jobs more accessible to already-injured workers. In the U.S., the Americans with Disabilities Act, which requires reasonable accommodation for injured workers, could have a significant impact on construction work sites in the future.

However, experience has shown that regulation is often necessary to assure widespread adoption of safer and less risky work practices. Both OSHA and the American National Standards Institute are developing standards intended to reduce ergonomic risk factors and their consequences. The construction industry knows the importance of conducting job hazard analyses as part of project planning; perhaps ergonomic impact will someday be incorporated into these analyses.

A national strategy to prevent WMD in construction must be multifaceted. It must focus on the development of engineering controls and interventions and their dissemination in the workplace. Secondly, it must lead to implementation of effective administrative strategies. Third, a national strategy must promote a research effort focused primarily on identification of common ergonomic problems and effective solutions. NIOSH has a control technologies branch that has developed many control technologies, such as for woodworking machinery, and it could be useful in devising interventions for construction.¹³

Fourth, an essential part of an effective national strategy to reduce WMD must be information dissemination. Databases like the Solutions database from the Canadian Center for Occupational Safety and Health can provide information about solutions that have been devised for occupational safety and health problems.⁸ Use of the news media, including articles in union and contractor publications, presentations at conferences, and television programs, can play an important role in raising awareness of ergonomic issues and possible solutions. Innovative mechanisms are needed for information dissemination such as "construction extension services" similar to those that exist for agriculture. Construction technology centers need to be developed similar to those being established for manufacturing industries by the National Institute for Standards and Technology. Economic incentives such as tax credits or low-interest loans could be used to stimulate the adoption of new technology.

Innovations that cannot be implemented site-by-site, such as redesigned concrete blocks or ergonomically better rotary tower crane cabins, will need to involve manufacturers, materials engineers, owners, contractors, workers, and, in some instances, regulatory agencies.

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