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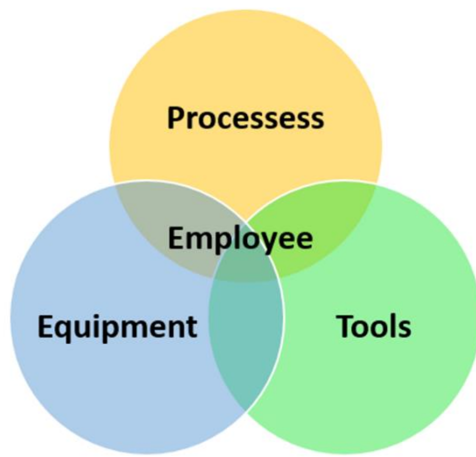
Using Industrial Hygiene Principles to Solve MSD-related Issues in the Workplace

By Emmanuel Winful

Are Ergonomics Issues Present in my Workplace?

Every aspect of daily human activity, including our time at work, home, recreational areas, hospitals, public transportation systems, and all other places in between, is impacted by ergonomics and its applications. The word ergonomics derives its origin from the Greek word "ergon," which means work, and "nomos," which means laws (Middlesworth, 2020; Selki, 2017). Thus, ergonomics is the "laws of work" or "science of work." Different from its Greek origin definition, ergonomics is the science of fitting workplace conditions and job demands to the capabilities of the working population (Bernard et al., 1997; Cohen, 1997). According to the International Ergonomics Association, ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance (Karwowski, 2006) (Figure 1).

Figure 1
Objective of Ergonomics



Another general description of the term is designing the task to fit the worker rather than physically forcing the worker's body to adapt to the task (Karwowski, 2006; Selki, 2017). When an ergonomic mismatch between the individual and their working environment forces them to adapt, it creates musculoskeletal conditions that affect the individual, the company, and the community (Bernard et al., 1997; Eklund, 1995). An excellent ergonomic working environment removes incompatibilities between the work processes, equipment, tools, and the worker, assures high productivity, eliminates illness and injuries, and provides overall employee satisfaction (Andreas & Johanssons, 2018).

This paper focuses on physical ergonomics, specifically, workplace factors that affect the body and its ability to perform physical work, thus, resulting in conditions for developing workplace musculoskeletal disorders (WMSD). The paper presents five industrial hygiene principles (Anticipate, Recognize, Evaluate, Control, and Confirm) to guide safety professionals, engineers, administrators, operation managers, and site supervisors in identifying and developing ergonomic interventions within the workplace.

What are MSDs and their Risk Factors?

According to the CDC, Musculoskeletal disorders (MSD) are injuries or disorders that result from the harsh wear and tear of the muscles, nerves, tendons, joints, cartilage, and spinal discs beyond their ability to recover or self-heal (CDC, 2020). Among workplace injury and disability cases, MSD injuries are the largest category in the United States (Yelin et al., 2016). According to the Bureau of Labor Statistics, MSDs are accountable for over 30% of all workers' compensation costs (U.S. Bureau of Labor Statistics, 2020). While multiple factors complicate the etiology of MSDs, a fundamental understanding of the ergonomic risk factors is essential to their identification within the work environment and to preventing ergonomic-related illnesses.

The primary ergonomic risk factors (Figure 2) known to contribute to the development of WMSDs are:

1. Awkward postures
2. Repetitive motions
3. Forceful exertions
4. Vibration (whole body and segmental)
5. Pressure points or contact stress,
6. Static loading
7. Extreme temperature.
8. Psychosocial

Awkward Postures

Anytime a bodily joint bends or twists significantly outside its natural range of motion, awkward posture results. The deviation from its natural range typically involves repeated or prolonged reaching, twisting, bending, working overhead, kneeling, squatting, and holding fixed positions or pinch grips. Awkward postures may affect various body areas, such as the hands, wrists, arms, shoulders, neck, back, and knees (Jaffar et al., 2011).
Several factors contribute to employees adopting awkward postures. Some of these factors include 1) working at an incorrectly designed or arranged workstation (i.e., workstation too low or high, too far or stretched, limited access or clearance), 2) operating tools and equipment in a poorly illuminated environment, and 3) perform a task that requires extraordinary precision. For example: twisting the neck to view documents while typing for a long time or kneeling in the storage bay of an airplane because of confined space while handling luggage. When an employee puts their body in an awkward position, it impairs blow flow and increases the rate of fatigue (Tang, 2020).

Repetitive Motions

Repetitive motion is when the same body part (muscles, tendons, or joints) repeatedly performs the same movements with little chance for rest or recovery. The risk of injury increases if repetitive movement occurs in the presence of other risk factors like awkward posture or forceful exertion (Jaffar et al., 2011). Organizational factors determining the repetitive motion within a task include the pace of work, the amount of time allotted for rest/recovery, and the variety of tasks performed—for example, an assembly line worker who must package three boxes every minute. The upper torso and limbs of the workers may become fatigued from this repetitive activity. In repetitive motion, the greater the number of repetitions, the greater the risk.

Forceful exertion

Forceful exertion is related to the amount of physical effort/muscle force required to perform a task or maintain control of an object. The applied force may come from gripping, lifting, pushing, pulling, lowering, or carrying (Tang, 2020). Other characteristics that determine the amount of force exerted include the type of grip, the weight and shape of an object, the body posture required, the type of activity, and the duration of continuous force applied to the load (Cohen, 1997; Jaffar et al., 2011; Jones & Kumar, 2001). When an employee's task requires excessive force, it can overload or stress the muscles, tendons, or joints. Prolonged or recurrent forceful exertions can give rise to not only feelings of fatigue but may also lead to musculoskeletal problems when there is inadequate time for rest or recovery (Jones & Kumar, 2001).

Vibration

Vibrational hazards occur when a part of the body (muscles, tendons, joints, organs) becomes exposed to rapid back-and-forth motion about a fixed point. These movements create damage (fatigue, pain, numbness, tingling, increased sensitivity to cold, decreased sensitivity to touch) to the body part or organs due to their resonance or absorption of high energy vibration (Bernard et al., 1997; Cohen, 1997; Jaffar et al., 2011). With the introduction of power tools (such as sanders, grinders, chippers, and drills) in the workplace, this risk is becoming more prevalent, and employees frequently become exposed to hand-arm vibration (HAV) hazards. Frequent exposure to HAV can damage the vascular tissues in the hands/fingers (Raynaud's disease). Another hazard that arises from vibration is Whole-body-vibration (WBV). WBV is associated with vibrations transmitted to the feet while standing on a work surface or legs and hips while sitting on a vibrating surface. WBV can lead to general discomfort and lower back pain (Jaffar et al., 2011; Tang, 2020).

Contact Stress or Pressure Points

Contact stress results from constant impingement of sensitive body tissue, usually on the fingers, palms, wrists, elbows, thighs, or feet against a hard or sharp work surface. These areas of the body where nerves, tendons, and blood vessels are close to the skin and underlying bones are more susceptible to contact stress (Tang, 2020). Prolonged contact stress reduces blood flow, nerve function, and the movement of tendons and muscles. An example of contact stress is having your wrists or forearm against the edge of a desk or work counter (Jaffar et al., 2011).

Static Loading

Static or stationary positions are when a job requires an employee to hold a particular posture for an extended period. The human body is not intended to remain in a fixed position; therefore, when a job requires it, it deprives the muscles of essential oxygen and may cause fatigue and MSDs. For example, a task that requires keeping arms raised overhead for an extended period.

Extreme temperature

These temperatures can be classified as either extremely hot or extremely cold. Cold stress occurs when the body's deep core temperature is lowered. When this happens, it can increase muscle tension and reduce dexterity and sensitivity. Employees exposed to cold temperature events may also grip a tool more tightly, which can restrict blood flow or cause the tissue to become stiff, creating discomfort and pain. In an extremely hot environment, the body's attempt to regulate its temperature may cause less blood to go to the active muscles, brain, and other internal organs, which reduces strength and results in fatigue quickly. The resulting health problem from these physiological changes most commonly is heat stroke and heat exhaustion (Jaffar et al., 2011).

Figure 2

Illustration of Ergonomic Risk Factors

Note. From *Elements of ergonomics programs: a primer based on workplace evaluations of musculoskeletal disorders*, by Cohen (1997).

Typically, these physical risk factors alone or in their combinations may be present in one or more of the work/tasks employees perform during a typical workday (Park & Kim, 2020).

Psychosocial

Separate from the physical risk factors, other factors such as psychosocial factors (i.e., work stress/demand, social support, job control, time pressure, and many more) and individual factors (age, gender, smoking, years of experience on the job, pre-existing health conditions) may all be linked to the risk of an employee developing WMSD (Bernard et al., 1997; Jaffar et al., 2011). Hence, the employer needs to recognize those situations where the employee performing the task could be at a higher risk of WMSD and implement targeted strategies to address the ergonomic risk factors (physical, psychosocial, and individual).

How can your organization identify, correct, and prevent costly MSDs?

Different approaches to managing and controlling ergonomic hazards have been emphasized and studied for many years, and their practice has proven successful in many organizations with effective ergonomic programs (Bernard et al., 1997; Cohen, 1997; Hignett et al., 2005). The industrial hygiene principles though traditionally used to monitor and quantify exposures to chemical hazards, can provide an investigatory approach to identifying, correcting, and preventing ergonomic risk. The principles of anticipation, recognition, evaluation, control, and confirmation apply to ergonomic risk factors as they are to chemical hazards.

1. ***Anticipation of Ergonomics Hazards.*** Anticipating hazards is an essential first step and a proactive process that involves identifying potential ergonomic hazards before they occur. This involves identifying tasks that involve repetitive motions, awkward postures, and forceful exertions that could potentially cause MSDs. A job hazard analysis (JHA) is useful for anticipating ergonomic hazards. A JHA is a systematic process involving breaking down a job into its component tasks and identifying the potential hazards associated with each task.

   For example, a JHA of a warehouse worker who loads and unloads boxes from a truck might identify the following potential hazards:
   - Repetitive motions: Reaching, bending, and twisting to load and unload boxes from the truck.
   - Awkward postures: Lifting boxes from the floor, reaching above shoulder height to place boxes on high shelves.
   - Forceful exertions: Lifting heavy boxes.

   Control strategies to minimize or lessen potential risks might be decided upon once potential risks have been identified.

2. ***Recognition of Ergonomic Hazards and Health-Related Issue.*** Recognizing hazards involves identifying when ergonomic hazards are present in the workplace. Though reactive, it involves periodically reviewing cases of MSD injuries among workers and connecting those injuries to the type of work performed. Sources of records to review include your company's OSHA 300 injury and illness logs, worker's compensation records, first aid logs, incident/accident investigation reports, absenteeism reports, and workers' complaints of problems. Case descriptions such as joint stiffness, tingling and numbness, dull, sharp burning pain that does not go away after rest, decreased range of motion, reduced grip strength, and muscle loss indicate ergonomic risk issues in the workplace. In addition to reviewing records, seek employee feedback and watch behaviors in the workplace for signs such as modifying tools, equipment, or workstations, stopping to rotate their shoulders or shaking their arms and hands while executing a task, and wearing back belts or wrist braces while performing a task. These are clues and tips that should provide the employer with an indication of ergonomic problems. While some signs of MSDs are apparent, others may not. Therefore, when reviewing the available records, an effort should be made to categorize the information-by job types or tasks and their associated disorders or symptoms. Once ergonomic hazards have been recognized, steps can be taken to evaluate and control the hazards.

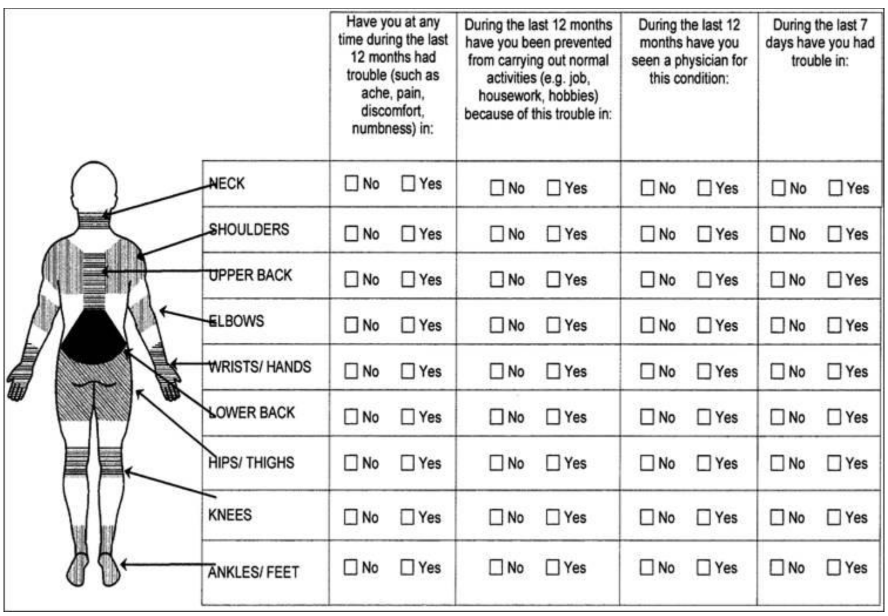
3. ***Evaluation of Exposure.*** In industrial hygiene, evaluation requires measuring or monitoring an individual or a population of workers' exposure level to a specific physical, biological, or chemical agent during their work activities at a particular time (Schneider & Wahl, 1998). The industrial hygienist then determines if the measured exposure(s) are safely below or over an acceptable occupational limit. Similarly, evaluating ergonomic hazards involves assessing the risk associated with an employee's exposure to ergonomic risk

factors within the task performed or work environment. Various tools and techniques are available for assessing the magnitude of the risk factors against an acceptable risk index. The methods for observing and measuring ergonomic risk factors are divided into questionnaires, observational, and direct measurements.

a. **Questionnaires** are the easiest and less time-consuming method. It requires asking the employee several questions to determine the task performed, gauge their understanding of MSD injuries, and knowledge of risk factors. Several surveys or checklists are used to assess the prevalence of ergonomic risk or MSD symptoms. The common questionnaires used include the OSHA Screening tool, job content questionnaire, standardized Nordic and Dutch Musculoskeletal Questionnaires, etc. The standardized Nordic Questionnaire (Figure 2) helps to identify which of the nine body regions (neck, shoulder, upper back, elbow, low back, wrist/hands, hip/thighs, knees, and ankles/feet) show symptoms of MSDs. It also comes with a body map to indicate areas affected and identify the causes of those injuries.

Figure 2

Illustration of a section of the Nordic Questionnaire



	Have you at any time during the last 12 months had trouble (such as ache, pain, discomfort, numbness) in:	During the last 12 months have you been prevented from carrying out normal activities (e.g. job, housework, hobbies) because of this trouble in:	During the last 12 months have you seen a physician for this condition:	During the last 7 days have you had trouble in:
NECK	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
SHOULDERS	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
UPPER BACK	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
ELBOWS	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
WRISTS/ HANDS	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
LOWER BACK	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
HIPS/ THIGHS	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
KNEES	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
ANKLES/ FEET	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes

Note. From *The Healthy LifeWorks Project,* by Curwin, 2013.

b. **Observational method** requires watching, taking photos, or videotaping the employee's task. This process requires observing the employee while performing the tasks rather than simulating them, as there could be variability in the exposed risk factor. For example, the position and angle of an employee's wrist may be different when they hold a power drill versus using it to remove a screw or drill a hole. Currently, many different observational tools (Figure 3) allow for qualitatively or semi-quantitatively assess ergonomic risk factors and estimating MSD risk thresholds (Andreas & Johanssons, 2018; Ramaganesh et al., 2021). Each tool has its purpose, risk factors and body regions assessed, types of tasks they are suitable for, and limitations. The employer or professional should select the appropriate tool(s) for the risk factors or job application looking to assess. Additional tools may be needed to score an observed ergonomic risk factor during observation. Some of the tools include:

1) scale or force gauges to quantify weights or forces
2) tape measures to determine distance and height
3) stopwatch to measure repetition, time spent in awkward postures and recovery
4) protractor to measure deviations from neutral posture
5) Thermometer and a light meter to measure environmental factors

Figure 3

A Comparison of the Commonly Used Ergonomic Assessment Tools

Whole Body Screening Tools (Qualitative Tools)
OSHA Screening Tool
Washington State's Caution Zone
Washington State's Hazard Zone

Whole Body Assessment Tools (Semi-Quantitative)
PLIBEL
Quick Ergonomic Checklist (QEC)
Rapid Entire Body Assessment (REBA)
Rodgers Muscle Fatigue Assessment

Office Work Assessment Tools
OSHA Computer Workstation Checklist
Rapid Office Strain Assessment (ROSA)

Upper Limb Assessment Tool (Semi-Quantitative)
Distal Upper Extremity Tool (DUET)
Occupational Repetitive Action Index (OCRA)
Rapid Upper Limb Assessment (RULA)

Upper Limb Assessment Tools (Quantitative)
ACGIH® TLV® for Hand Activity Level
ACGIH® TLV® for Hand-Arm Vibration
Revised Strain Index
The Shoulder Tool

Lifting Assessments (Qualitative)
ACGIH® TLV® for Lifting

Lifting Assessments (Semi-Quantitative)
Liberty Mutual Manual Material Handling Equations/
Washington State (WISHA) Lifting Calculator

Lifting Assessments (Quantitative)
BWC/OSU Lifting Guidelines
BWC/OSU One-Handed Lifting and Lowering Guidelines
LiFFT (Lifting Fatigue Failure Tool)
Revised NIOSH Lifting Equation (1991)
The Shoulder Tool
Utah Back Compressive Force Model

Push/Pull Assessments
BWC/OSU Push/Pull Guidelines
Liberty Mutual Manual Material Handling Equations
The Shoulder Tool

Note. Adapted from AIHA Ergonomic Assessment Toolkit, page 8 by Kotowski and Gibson (2023)

c. **Direct measurement** provides accurate risk estimation using wearable sensors placed on the body segments affected. Examples of direct measurement instruments can include:
   i. Electronic goniometer and inclinometers to measure work postures
   ii. Pressure mapping insoles, instrument force shoes and gloves, electromyography to estimate magnitude of force exerted from muscle activity.
   iii. Heart rate monitor to measure fatigue and cardiovascular activity.

Regardless of the method chosen to assess an employee's job, additional information such as 1) tools, equipment, and materials used to perform the job, 2) the workstation layout and physical environment, 3) the task demand and the climate in which the work is performed is vital in making a decision (Cohen, 1997). The information collected and the scores from the analysis will lay the groundwork for developing ways to reduce or eliminate ergonomic risk factors.

4. ***Control of Exposure and Confirmation of Control Measures:*** Following the evaluation, an objective plan is needed to control or reduce the ergonomic risk with ratings (moderate, high, or extreme levels of ergonomic risk factors) that exceed the MSD risk threshold. Employers can use several methods to control ergonomic hazards, including:

a. **Engineering Controls** is the most effective and preferred approach to prevent and control ergonomic hazards because it may reduce or eliminate the underlying reasons for MSDs. The engineering control intervention typically results in physically rearranging, modifying, and redesigning the job or the work area layout and using different tools and equipment. When developing engineering controls, consideration also needs to be given to the capabilities and limitations of the employee to eliminate/reduce the hazard on the job (Tompa et al., 2010). Examples of engineering control strategies can include:

i. Changing the way materials, parts, and products are transported or lifted with the help of mechanical assisting devices, vacuum assist devices, manipulators, adjustable carts, or conveyors to reduce force, repetition, and awkward postures in lifting or handling tasks.
ii. Eliminate reaching, bending, or other awkward postures by providing workstations with height-adjustable workbenches, material bins, or cutout work surfaces.
iii. Provide adjustable tables and chairs that workers can use with various sizes and shapes, allowing neutral postures.
iv. Design or change storage containers to ones with handles or cutouts for easy gripping or access to reduce repetitive reaching, bending, twisting, and forceful exertions.

b. **Administrative Controls** aim to establish efficient work practices and policies that change how work is done to reduce or prevent employees' exposure to ergonomic risk factors. Examples of administrative or work practice strategies include:

i. Provide more breaks or reduce the amount of overtime to allow for rest and recovery in physically tasking jobs.
ii. Training workers to understand ergonomic risk factors and to learn techniques that can be applied to the task to reduce stress and strain while executing their work activities. For jobs that require repetitive motion, modify the work pace to relieve the repetitive burden and allow the worker more control of the process.
iii. Require that two people only lift heavy loads to limit force exertion.
iv. Encourage exercises that gradually increase physical exertion through a warm-up, gentle stretches, and strengthening.

c. **Personal Protective Equipment** equires using protection devices to reduce exposure to ergonomics-related risk factors. As in industrial hygiene and occupational safety, PPE provides a barrier between the worker and the hazard. However, using PPE as an ergonomic intervention is controversial since it is hard to establish whether they effectively protect against ergonomic risk factors (CDC, 2020; Cohen, 1997). For example, in the case of vibration attenuation devices, they may reduce the effect of vibration on the hand but has the potential to increase awkward hand placement and grip due to loss of dexterity.

PPE should be carefully considered as a solution to an ergonomic risk factor to ensure it addresses the problem without introducing another. Some PPE that can help address ergonomic problems includes:

i. Knee pads for kneeling tasks.
ii. Shoulder pads to cushion loads carried on the shoulder
iii. Wrist supports to reduce the risk of MSD associated with typing

Ergonomic hazards are often more complex and multifactorial than traditional industrial hygiene and safety hazards, hence, a combination of these control strategies must be applied to achieve a solution that works for the near and long term (Bernard et al., 1997; Cohen, 1997; Eklund, 1995; Schneider & Wahl, 1998; Tompa et al., 2010). For a successful ergonomics improvement strategy, it is not only helpful to anticipate, recognize, evaluate, and seek to implement ergonomic interventions in the workplace, but efforts should be made early on in the process to:

a. Seek management commitment and employee participation. This step is crucial and perhaps the controlling factor in determining the intervention's success, like any safety and health program.
b. Ensure worker involvement and seek a participatory approach to intervention identification and implementation. A participatory approach is vital since it allows all affected parties to share ideas for controls (Hignett et al., 2005); most of the time, some employees might have already come up with a solution.
c. Have a systematic way to implement controls which may consist of 1) trials or tests of the selected solutions, 2) evaluation of trial or test control effectiveness, 3) modifications or revisions to control, and 4) full-scale implementation.

After implementing control, a post-implementation evaluation using the same assessment tools is required. The post-assessment ensures that the controls reduce or eliminate ergonomic risk factors while introducing no new ones. The evaluation should occur within a week to a month of the implementation. Separate from the post-assessment, data should be gathered to evaluate the intervention's overall effectiveness and return on investment. Key indicators to look for include 1) a reduction in MSD incidence rates, 2) a reduction in the severity of MSDs for those with symptoms, 3) an increase in productivity and quality of work, and 4) a reduction in job turnover or absenteeism. Other observational factors that can be indicators of control effectiveness include how employees apply ergonomic principles in their work following training or administrative changes. Additionally, following confirmation of effectiveness of interventions, employers should seek to continually improve their process and identify any process or human factor changes that can make the interventions ineffective.

In conclusion, ergonomic hazards are common occupational hazards faced by workers in various industries. However, by using the principles of anticipate, recognize, evaluate, control, and confirm employers can systematically reduce or eliminate these hazards in the workplace.

About the Author

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