Program Development

Ergonomics

Improving safety in the laboratory environment

By Peggy E. Ross

Abstract: *The laboratory environment presents unique ergonomic hazards. Understanding the type of hazards common in a lab can encourage corrective and preventive solutions. This article reviews general ergonomic principles and explains how this knowledge is applied to the laboratory environment.*

LABORATORIES ARE PART of many industries, including manufacturing, healthcare, metallurgy, pharmaceutical, biotechnology, petroleum and fuel, and cosmetics. Critical research—such as stem-cell, enzyme, fuel alternative and medical—is performed in laboratories. Laboratory jobs are varied and may include the use of microscopes, fume hoods, chemicals, pipettes, flasks, glove boxes, automated analyzers, compressed gases, computers and similar equipment. Such an environment presents unique ergonomic hazards.

Ergonomics in the Workplace

Ergonomics—also called human factors engineering—deals with the fit between the worker and the job. "The approach of human factors is the systematic application of relevant information about human capabilities, limitations, characteristics, behavior and motivation to the design of things, and the procedures people use and the environment in which they use them" (Sanders & McCormick, 1993, p. 5). However, workstations have often been designed without consideration of human factors. Improper fit between the worker and the job may cause cumulative trauma disorders (CTDs)—which are also known as repetitive stress injuries, work-related musculoskeletal disorders (MSDs) and overuse disorders (Kroemer, Kroemer & Kroemer-Elbert, 2001, p. 384). CTDs can affect various parts of the body, including the back, neck, shoulders, elbows, hands, wrists and knees (Putz-Anderson, 1988). Onset generally is gradual in nature and results from repeated microtrauma to internal structures: muscles, tendons, ligaments, nerves, bones and cartilage (Ramos Vieira & Kumar, 2004, p. 153).

Poor ergonomic conditions may also "serve as a contributor or exacerbator of an existing health problem or physical limitation" (Putz-Anderson, 1988, p. 4). If a worker has an underlying medical condition, such as a prior fracture, diabetes or circulatory problems, s/he is at greater risk of encountering pain or injury. An individual also may participate in nonwork activities that contribute to the disorder.

When considering an injured worker's eligibility for workers' compensation, many states consider "aggravation of" tantamount to a causal connection. This means that if a job includes ergonomic stressors, the workers' compensation system may cover such an injury as work-related.

Therefore, employers can benefit from incorporating ergonomic solutions. These benefits include the following:

- preventing or reducing the severity of injury or illness;
- reducing absenteeism and associated costs;
- increasing efficiency, productivity and quality;
- promoting comfort and well-being, which improves morale.

Ergonomic Stressors

The first step in integrating ergonomic considerations into the lab environment is to recognize hazards that stress the body and are associated with ergonomic-related injuries. Major ergonomic hazards include repetitive movement, excessive dynamic force (e.g., lifting, pushing, pulling that leads to overexertion); prolonged static force or posture; awkward posture; vibration; direct pressure/contact forces; and exposure to cold (Kroemer, et al., 2001, p. 391).

Several key principles are important when assessing the level of risk associated with ergonomic hazards. The potential risk of injury is influenced by the duration of exposure, force and magnitude of the hazard. Risk level is important for prioritizing ergonomic intervention activities. As part of the ergonomic risk assessment, the level of physical exertion should also be assessed. "Studies have shown that posture, range of motion, force, repetition and time all must be considered in order to categorize the level of physical exertion" (Ramos Vieira & Kumar, 2004, p. 143, 144).

In addition, when force exceeds one-third of a worker's overall static force capability, overexertion leads to an increase in the risk of injury (Kroemer, et al., p. 391). Further, as force increases, potential injury may be more severe in nature.

Risk also elevates as the number of ergonomic stressors increases. For example, in the lab environment, a full 5-gallon liquid waste bottle would weigh more than 42 lb. Bottles often are stored on the floor. Changing a bottle exposes a worker to lifting force, com-

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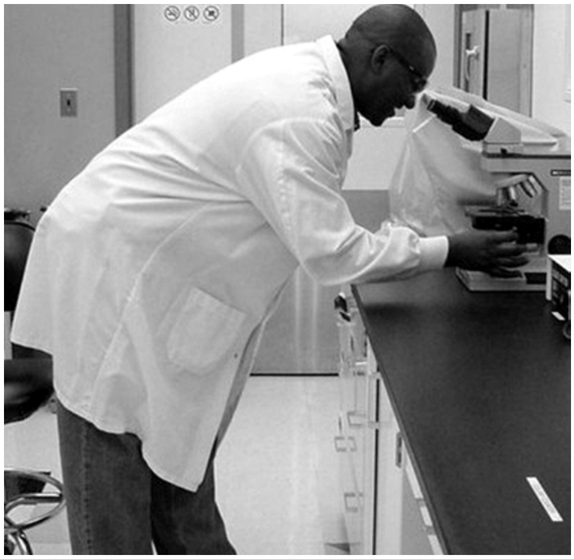


Microscope work requires forward postures of the head and arms. Viewing through a microscope for prolonged periods of time can fatigue the neck and shoulders. Headaches and eye fatigue are common as well.

bined with the awkward posture necessary to lift from floor level.

Posture is another important consideration when evaluating the ergonomic stressors and determining the level of risk. A minor deviation from normal posture may not produce complaints, but an extreme deviation that is maintained for a prolonged time would contribute to greater risk. Physical complaints associated with "inadequate working postures and overloading are more likely to appear among those who are exposed to harmful postures for longer periods of time" (Ramos Vieira & Kumar, 2004, p. 154).

Prolonged static posture is of concern because "during static effort the blood vessels are compressed by internal pressure on the muscle tissue, so that blood no longer flows to the muscle" (Grandjean, 1988, p. 7). In addition, poor overall body posture (e.g., slumping) contributes to ergonomic-related complaints. Risk increases further when force associated with lifting or carrying weight is combined with poor body-segment posture. Repetitive motions using the same muscle groups (especially when combined with force) also heighten overall risk.

Therefore, it is important to identify all ergonomic stressors that influence risk for a particular job. For example, lab employees may use a pinch grip (requiring force between the thumb and index finger) to hold a test tube against a vibratory mixer (vibration) for prolonged periods (static posture). To complicate matters, the shoulder may be elevated and the arm may be held out from the shoulder with the elbow winged out and wrist positioned in an awkward posture (ulnar deviation). In this case, after observing the task and identifying the ergonomic stressors, the evaluator should ask whether the worker has any physical complaints when performing the task.

Ergonomic Considerations in the Laboratory

Neck Posture

Workstation design in the laboratory often leads to awkward neck posture. For example, a worker may be required to tilt his/her head forward to adapt to the work environment (Ramos Vieira & Kumar, 2004, p. 153). This is common when standing and looking down at an electrophoresis test, serology test, petri dish, computer monitor or paperwork. Neck flexion (forward head tilt) requires the small muscles of the neck to hold the weight of the head, linking this posture with musculoskeletal symptoms of the neck and trapezius region. If this posture is observed, one should determine the duration of the static flexion of the neck. If the posture is brief, it may not be an issue; if exposure is prolonged, consider repositioning the work or the worker.

Standing Posture

A worker's overall back posture while standing should also be assessed. Standing posture is common in a lab because it enables a worker to cover a large work area. This is actually ideal from an ergonomics standpoint because movement is beneficial—muscles act as a blood pump when walking, promoting good circulation throughout the body (Grandjean, 1988, p. 7). Movement is so beneficial that "standing in place should be imposed only for a limited period" (Kroemer, et al., 2001, p. 347).

Work should be positioned at approximately elbow height. "Visual displays, including instruments, counters, dials and signals should be placed in front of the body and below eye level so that the line of sight (which aligns the eyes with the visual target) is declined 10° to 40° below the horizontal level" (Plog, Niland & Quinlan, 1996, p. 377).

If visual displays or laboratory charts (such as those on equipment) are placed too high, the body will adjust to see better. Prolonged neck extension or neck flexion leads to postural fatigue and pain (Anshel, 1998, p. 42, 43). Posture should be evaluated for routine and nonroutine activities. Assess force (e.g., lifting) and duration requirements for awkward postures as well. Ensure that items used are within easy reach to prevent bending at the waist for prolonged periods. Many postural issues associated with a lab may be resolved with basic workstation adjustments.

Sitting Posture

Laboratory seating can present challenges associated with achieving optimum table and desk height. Chairs should be adjustable and should provide lumbar support. Seat pans should have a waterfall front and "be short enough that the front edge does not press into the sensitive tissues near the knee" (Kroemer, et al., 2001, p. 433).

It is also important to provide clearance for the worker's knees and thighs (Kroemer, et al., 2001, p. 348). The author has observed workers sitting in laboratories twisted to the side or with both legs inside an open chemical cabinet door because there was no room for their knees and thighs. A twisted body posture is considered ergonomically unsuitable (Kroemer, et al., p. 346). Furthermore, placement of legs and feet inside a cabinet that contains chemicals presents additional safety issues.

If the feet do not rest comfortably on the floor—as is often the case with high chairs found in laboratories—a footrest that promotes thigh position horizontal to the floor should be provided (Kroemer, et al., 2001, p. 433). In addition, chairs should have five casters for stability and the wheels should have a coefficient of friction suitable for the floor composition.

Chemical Handling

Flasks and beakers are often stored over, behind or under a workbench. Large waste containers may be located at floor level. As a result, a worker may have to overreach, bend or stoop when handling chemicals. Several solutions can ease these concerns.

For example, evaluate container size and weight, and toxicity of contents when selecting chemical storage containers. If postures are awkward because large bottles of chemicals are stored overhead, move them to a lower shelf that is below shoulder height. Store only empty glassware and solid chemicals overhead. Use lower shelves for heavy, toxic or infrequently used items. Avoid storing frequently used or heavy items below knee height. Consider providing a stool for items placed high above. If possible, place waste containers on a wheeled cart that can be pushed to the waste area.

Microscopes

Microscope work requires forward postures of the head and arms. Viewing through a microscope for prolonged periods can fatigue the neck and shoulders. Headaches and eye fatigue are common as well.

To provide relief, consider tilting the microscope to reduce neck flexion. A headrest attached to the microscope provides support for the neck and head, while armrests provide support for the forearms. Additionally, some microscopes feature extending eyepieces, adjustable binocular tubes and adjustable bases that improve posture (Humantech Inc., 1996, p. 48, 49). Teaching employees to take a brief break and look up and away for 20 seconds every 20 minutes may reduce discomfort as well (J. Anshel, personal communication, April 19, 2007). Postural stretching exercises for the neck and upper back also may be beneficial.

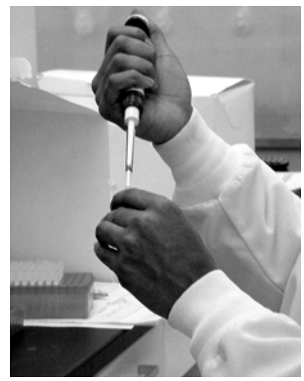
Pipettes

Lab workers commonly use pipettes to measure liquids. When pipetting, a worker's shoulders are raised, elbows generally wing out and forearms rotate, and wrists, hands and thumbs are often held in awkward postures. Some research has found that "work involving pipetting is associated with elevated rates of MSDs of the hand and wrist" (Asundi, Bach & Rempel, 2005, p. 67).

A joint Duke University/NIOSH study reported that "the relationship between pipetting and MSD development remains largely unknown" (Lu & Sudhakaran, 2005). A survey of pipette users performing continuous pipetting for more than 60 minutes found that 90% of the users reported hand complaints (David & Buckle, 1997).

So, although causal connection between CTDs and pipette use is under debate, lab workers who pipette for extended periods report difficulties concerning the muscle force/tension requirements of the thumb during plunger operation and tip ejection. Wrist and hand postures are often awkward with traditional plunger pipettes as well. In addition, static thumb muscle load is elevated further when the task requires precision (Asundi, et al., 2005).

Various modified ergonomic pipettes have been designed. Lu and Sudhakaran (2005) reported that postural stresses associated with pipette use "include awkward and static shoulder elevation, forearm rotation, elbow flexion and wrist deviation." They concluded that "the redesigned, low-force pipette showed a significant reduction in the most important MSD risk factors for pipetting, as compared to two other traditional axial-design pipettes" (Lu & Sudhakaran). This author provided the low-force pipette to two symptomatic laboratory workers in 2006.



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Selecting an Ergonomics Risk Assessment Tool

By David Brodie

When assessing ergonomic stressors, the use of quantitative or semiquantitative evaluation tools provides the evaluator with numeric output with which s/he may evaluate the risk for the development of MSDs for a given job. This output may also allow the evaluator to compare relative risk of multiple jobs or tasks, thereby identifying jobs or tasks that pose the greatest risk. This may help set priorities for ergonomics efforts.

These tools may also provide the evaluator or designer with recommended limits to the stressors present in a job, task or job design. These limits may be used to help reduce the risk to safe levels. Furthermore, the results may be used to compare the same job or task before and after an intervention is implemented.

Given the large number of ergonomics risk assessment tools available in books, peer-reviewed literature and from various other sources, one should consider these three recommendations when selecting a tool.

1) Read original articles and/or documentation to understand the design, use and intent of the ergonomics tool.

One common error is using the tool incorrectly and for the wrong purpose. When an ergonomics tool is developed, it is often for a specific purpose, such as evaluating a specific type of activity (e.g., lifting, posture, hand activity) or a specific work environment. The validity of the tool may be compromised if used outside of these conditions, so it is important to know these boundaries.

One challenge is that there is insufficient information to determine the exact way in which the tool should be implemented. Also, it is often impossible to determine what to do when attempting to apply the tool in suboptimal conditions (what do you do when a novel situation develops?). Furthermore, the peer-reviewed articles on a given tool often focus primarily on the theory and design of the tool, not its practical application. This leads to the second recommendation.

2) Establish assumptions and decision criteria for the tool.

To consistently and effectively apply an ergonomics tool, it is important to interpret the design and approach of the tool and develop appropriate strategies to implement it consistently and accurately. Once the tool's boundaries are understood, it is necessary to develop decision criteria to ensure that the tool is always used within these boundaries—and that users of the tool will achieve consistent outcomes (i.e., reliability).

If a tool is used consistently, then the output of the tool can be used to measure such conditions as baseline exposure, differences in exposure and changes in exposure. With this level of consistency, it is unnecessary to have a tool that has external validity (i.e., correlation with injury causation). Instead, the tool simply provides a means of accurately measuring changes in exposure, which is of value in itself. If the tool has been validated through research such that it has external validity, then the value of the measures is even greater.

3) Provide sufficient time for training and practice.

One critical factor in achieving accurate, consistent output from an ergonomics risk assessment tool is practice. Once an individual is trained on the tool's design and boundaries, and on the process and decision criteria for its implementation, then it is necessary to practice, practice and practice again.

An analyst should be able to explain the theory of a tool, discuss the measures and methods that are used to apply the tool, describe its output and interpret that output before applying it in real-world situations. This does not mean that a person cannot use a tool without this absolute level of knowledge; instead, this means that a person should practice and learn about the tool in a work setting, but refrain from using the outputs until positive that the process used is accurate. In this interim stage, it is helpful to discuss the implementation of the tool with a mentor or long-time user. Ergonomics community e-mail lists are one way to contact experienced ergonomists. In addition, the Board of Certification in Professional Ergonomics' website (www.bcpe.org) provides a listing of professional ergonomists who may be willing to provide mentorship in this process.

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All symptoms were resolved within 2 weeks and have not, to date, recurred.

Clearly, ergonomic implications should be considered when purchasing pipettes. Obtain sample pipettes and have workers conduct a comfort and accuracy trial before making a final purchasing decision. Then, periodically revisit the literature to learn about innovative new designs.

Glassware: Flasks, Beakers & Test Tubes

When deciding what type of flasks and beakers to use or purchase, first consider the container's liquid contents. For example, plastic beakers weigh less than glass but would be inappropriate for acids. Grasping a traditional beaker requires force between the thumb and palm/fingertips. Because the hand is open, force is required for grasping, combined with forearm rotation to a palm-down position, associated with pouring. A single-handle beaker would allow for a preferred power grasp. NIOSH recommends a handle diameter of 1.25 to 2 in. for power tasks (NIOSH & Cal/OSHA, 2004, p. 5). While forearm rotation would still be necessary for pouring, force requirements would be reduced thanks to improved coupling (grip). For large volume and/or frequently handled liquids, dispensers with a spigot help eliminate awkward pouring postures.

When evaluating ergonomic implications for glassware in the laboratory, consider test tube handling. Again, the frequency and type of use is important. For frequent use, a pump-activated, definitive-measure dispenser can reduce awkward wrist postures and forearm rotation associated with filling test tubes. Squeeze bottles may be used for some tasks (Humantech Inc., 2000, pp. 3-12). Automated loaders decrease the frequency and duration of manually handling individual tubes, thereby eliminating ergonomic risk. In addition, automated washers may help decrease the awkward motions involved in manually cleaning laboratory equipment with a brush and with rotating the forearm to place the tubes on a drying rack.

Fume Hoods

Fume hood use often presents several ergonomic hazards. First, the worker must be positioned as close to the work as possible to eliminate unnecessary reaching. Providing sufficient toe space under the cabinet allows the employee to get closer to the work without bending forward. Often, a worker will reach under a glass door to measure, reach up to place a pipette into a chemical jug or perform other work activities. Once it is determined that the hood provides sufficient air velocity, move the work as close to the worker as is safely possible.

Another concern is the placement of test tube racks, chemicals and equipment within the fume hood. "Work objects should be located close to the front edge of the work surface so that the worker does not have to bend over and lean across the surface to grasp items" (Plog, et al., 1996, p. 377). "When possible, choose fume hoods that have full horizontal opening capabilities so the researcher does not have to twist, bend and reach into them. If large depths are not necessary, vertical-opening hood faces are adequate" (Humantech Inc., 1996, p. 50). Angled glass surfaces promote improved visualization inside the hood as well (Humantech Inc.).

Another common complaint among lab workers involves raising and lowering the fume hood doors. Preventive maintenance and lubricating tracks helps reduce associated force requirements. Powered assists can also help reduce the force requirements for opening heavy hood doors.

Isolators/Gloveboxes

Isolators and gloveboxes present their own particular ergonomic hazards. According to Dean Roderique, CSP, CIH, corporate director of industrial hygiene at Baxter International Inc., the main ergonomic challenge arises from the design of gloveboxes and isolators, which are intended to "fit the ventilation, not the people" (D. Roderique, personal communication, April 26, 2007). Postural issues are prevalent since workers must reach into a slot that may be too high or too low for them. While some units may feature levelers, adjustability is limited. Adding steps and ladders presents additional safety hazards.

Another major ergonomic challenge involves gloves and coupling. Heavy-duty gloves are provided with the unit because of the chemicals being handled. The worker must double-glove (for self-protection). S/he puts on gloves, then inserts his/her hands into the second pair of gloves attached to the unit. This creates a poor coupling issue due in part to wearing two pairs of gloves; it gets worse because most gloveboxes are fitted with extra-large gloves, even though many lab workers do not have extra-large hands. Roderique recommends glove size 6 to 8 rather than the more common 10 to 12.

When coupling is poor, force requirements increase for tasks such as removing the cap from a bottle. Additionally, consider placing chemicals and objects at optimal reach distances to reduce shoulder and arm fatigue. Keep work as close to the worker as possible. Tools or slides with handles may help the employee bring items within easier working range. "Reduce reach distance and wrist undulations" (Roderique). Evaluate the size and weight of containers and consider easy-open containers. Lighting also should be evaluated, and providing an angle to the glass may help as well. Finally, assess the worker's foot positioning to ensure that s/he has a stable base that allows feet to be positioned shoulder-width apart. Floor mats may be beneficial when a worker stands at a glovebox for extended periods. If possible, consider ergonomics in the design phase and engineer controls to promote adjustability.

Mixers

Test tubes are typically held against vortex mixers using a pinch grip. This task poses several ergonomic hazards including vibration (which exceeds 9 m/s^2), repetition, awkward postures and high force requirements necessary for activation (G. LaPorte, BureauVeritas, senior manager, ergonomics, personal communication, April 12, 2007). This is important because American Conference of Governmental Industrial Hygienists recommends limiting exposure greater than 8 m/s^2 and up to 12 m/s^2 to less than 1 hour (Janicak, 2004, p. 37). Because vibration is combined with other ergonomic stressors (force and awkward posture), the potential for ergonomic injury increases.

Therefore, it is important to consider the frequency and duration of mixer use. If frequency and duration are brief, vibration and force requirements for use of the mixer would be less critical. If work use is extended, the implications are apparent. LaPorte advises consideration of ergonomics when reviewing equipment specifications and selecting mixers. However, since purchasing staff may lack ergonomic knowledge, comparative trials can help facilitate employee satisfaction (LaPorte).

Automated Analyzers

Automated analyzers have progressed dramatically in recent years. Manual sample feeding largely has been replaced with automated feed mechanisms, which has improved ergonomic conditions. Still, calibration and equipment maintenance often are conducted at heights below waist level or behind equipment in tight quarters, which necessitates awkward postures. Equipment designers should consider nonroutine activities, such as maintenance and calibration, in the design process. In addition, purchasers should compare equipment and consider all aspects of equipment operation, both routine and nonroutine.

Hot Water Baths

Reaching into a hot water bath to insert or retrieve samples often requires elevated shoulders and awkward wrist postures. Evaluate the height of the work-

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er's shoulders when using the bath. Baths may be appropriately placed on a lower shelf to reduce shoulder stress. To reduce awkward wrist posture, consider baskets with handles or curved ergonomic tools that reduce ulnar deviation of the wrist.

Lifting

Lifting hazards in the laboratory include moving compressed gas cylinders; moving equipment; removing large bottles of chemicals from cabinets or shelves; changing waste containers; and receiving new samples or equipment. Thus, each laboratory should be assessed for lifting hazards. If gas cylinders are moved manually, consider placing them on a wheeled cart. Based on the frequency and weight of lifts, consider whether mechanical lifting devices are appropriate. When manual lifting is required, ensure that workers are trained in proper lifting techniques and reinforce these behaviors. Identify coupling issues from lifting while wearing poor-fitting gloves. If this is an issue, identify chemically compatible gloves that fit properly and facilitate a good grip.

Computers

Computers are common in labs. Keyboards should be placed so the worker's elbows are at approximately a 90º angle. Monitors should be placed directly in front of the worker with the top of the monitor just below eye level to promote neutral neck posture. Avoid placing the computer in a position where glare from the window reflects on the monitor screen or in the worker's eyes (Anshel, 2006, p. 21). The mouse should also be within easy reach. If computer use is of short duration, standing posture is acceptable. A floor mat can promote comfort and reduce fatigue. For prolonged use, a sitting workstation is recommended.

Avoiding Ergonomic Injury in the Lab

Implementing a solid ergonomic program in the lab requires time, resources and management commitment. This commitment will strengthen the lab's safety culture—employees will recognize the importance of their well-being to management and the business.

Involve employees in the hazard recognition process. Identify priority actions based on potential risk of injury, worker complaints and the potential severity of injury. Review OSHA logs and first-aid reports to assess trends in worker complaints. Encourage early symptom reporting and provide prompt medical management as well as ergonomic intervention when required.

Another positive step is the development of a written ergonomic program that defines scope and responsibility. A written action plan that establishes timelines and assigns responsibility for each project is also important. When making decisions and developing the action plan, evaluate options, prioritize and select the best corrective or preventive action for the individual laboratory operation.

Conclusion

Laboratory ergonomics is based on the same human factors/ergonomic principles found in any work environment. A detailed search for data on ergonomic-related injuries associated with the laboratory environment yielded no results. Research associated with laboratory ergonomics was limited to the NIOSH/Duke University pipette study.

In the author's experience, symptoms have been reduced or abated when the ergonomic risk reduction strategies described in this article have been implemented. Understanding the concepts of general ergonomics and how they translate to the lab environment provides the foundation for a solid ergonomic program. A strong ergonomic program will protect lab workers and benefit the company. This area also presents an opportunity for further research to validate control methods specific to the laboratory environment. ■

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