LABORATORY ERGONOMICS

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1.1 INTRODUCTION TO LABORATORY ERGONOMICS

Biological laboratories such as those found within hospitals, regional laboratories and biotechnology facilities are finding themselves facing the same ergonomic risk factors and problems of Cumulative trauma disorders (CTD) as many other more traditional organizations. Neither the Bureau of Labor Statistics nor the California Department of Industrial Relations in the annual reports of non-fatal occupational injuries and illnesses defines work injury statistics for clinical laboratory workers. As a result, it is difficult to know the extent of CTDs and RMIs in the biotechnology field. From the author's experience, however, it is very prevalent and a cause for significant concern.

The clinical laboratory scientist is not only performing traditional tasks of working with petri dishes, slides, test tubes and biological material under a sterile hood environment using pipettes and performing microscopy in a laboratory environment, but they are also required to perform computerized entry of the collected data. This creates significant risk for additional musculoskeletal fatigue and the onset of CTDs.

Frequency of repetition is the driver in many of these claims. In many laboratories, the work volume is drastically increased above and beyond what a clinical scientist performed when work was primarily manual and not geared towards high volume analysis of test tubes and blood samples. It's not uncommon for a (Kaiser Permanente) regional laboratory to receive samples from over 35 clinics and process over 36,000 samples in a day for a department with limited staffing. A recent NIOSH report (1995) by McGlothlin and Hales, reported that laboratory technicians make approximately 6,000 to 11,750 hand manipulations involving pipettes per shift.

Laboratories are becoming increasingly reliant on computer entry of patient biological samples for easy identification, transfer, storage and testing of results for medical information. The traditional laboratory design of yesterday consisting of fixed height, narrow work counters (36" x 24"-30") with overhead light sources combined with narrow overhead shelves, under counter drawer and cabinet storage remains in the high-tech laboratory of today. These facilities often do not support the computer and analytical systems necessary for medical science's technology and productivity demands.

As a result, ergonomic risk factors are more prevalent today than ever before in the laboratory. The primary risk appears to be excessive repeated movement patterns combined with awkward postures and forceful manual exertions. Much of this is the result of increased work volume, staff cutbacks and inadequate design of today's laboratories facilities and tools created during the dawn of discovery. Often the lab appears more like a chemistry lab from high school and not a high tech/high volume facility reliant on managed care and quick turnover for results.

Laboratory workers tend to work either seated or standing at the counter and varies based on the visual and manual demands presented with the task at hand. For those scientists that work in seated, creating ergonomic solutions in the seated laboratory environment is no easy task. Ergonomic strategies must be applied based on office ergonomic principles, as limited research is available on laboratory ergonomics in the human factors and ergonomics scientific literature. However, for comparison, there is a substantial body of knowledge on the benefits of sit/stand workstations in a computerized office as well as other office ergonomic studies.

With this in mind, the computer, keyboard and mouse are often out of place on the traditional slate counter where laboratory tasks are performed. Furthermore, the postures required to perform the laboratory tasks are distinctly different from those required to perform keyboarding or mousing tasks. In comparing the tasks, reach is substantially different as well as head postures and manual hand techniques. When these tasks are combined and performed simultaneously, the scientist is exposed to frequent or constant repeated movement patterns as well as awkward postures to perform keyboarding as part of the data entry requirement of the testing procedures. In addition, visual demands may far exceed the typical office worker of viewing a monitor up to 6 hours. In many instances, the scientist is not only viewing a monitor but also performing tedious visual inspection of biological samples with the naked eye or through a microscope.

Two tasks that draw significant concern to the laboratory scientist of today involves the use of the traditional biosafety cabinet (sterile hood) used during pipetting, which offers no ergonomic features as well as the use of the microscope which has improved in recent years with some ergonomic redesign. Microscopy is often combined with results analysis and tracking and requires data entry into a computer including monitor viewing independent of itself or as part of multi-tasking.

This discussion will focus primarily on the ergonomic risk factor exposures to Cytogenetics Technologist and the strategies used to reduce risk over an 8-month period of time in a Genetics department. This paper looks at the impact microscopy with its visual and manual demands combined with additional visual requirements of viewing a monitor and counting data manually while seated at a traditional office work surface or laboratory counter impacts a small group of dedicated genetics scientists.

1.2 HISTORY OF GENETICS DEPARTMENT

Kaiser Permanente (KP) is the largest provider of healthcare services in California and performs internal procedures for its hospital facilities through a regional system of departments designated for very specific tasks. The downsizing and specialization which is viewed as a common practice with other industries is practiced within the KP hospital system of managed care to control costs and improve overall quality and quantity of medical testing and accuracy. Intensive productivity demands are required of each department, which no longer is shared throughout all the KP hospital system. As a result, these departments are often plagued with high rates of work injuries and illnesses most commonly related to disorders due to repeated trauma or CTDs and RMIs.

Management's concerns prompted the desire to begin a more aggressive ergonomics program in the Genetics Department consisting of worksite analysis, hazard prevention and control measures and a comprehensive training program. Twelve (12) hours of analysis were performed assessing the Cytogenetic Technologist's (CT) position and other laboratory areas of concern. The CT is one of the primary job titles within the Genetics Department that has been plagued by the onset of RMIs. In the department undergoing analysis, of 29 employees, 8 had filed RMI claims within 1998 or 28% of the employees.

The essential job tasks required of this group are divided into seated and standing tasks. Over a typical 8-hour day the tasks include:

Seated: Microscopy- Perform microscopic analysis and photography of chromosome metaphase. View up to 20 slides/day or approximately 5 cases/day. Manually count chromosomes through microscope or on monitor.

Standing: Harvesting –Select and harvest in-vitro cells from cultures and prepare slides. Perform chromosome banding and staining within small petri dishes. Up to 60 dishes in a ½ day.

Time allocation to the tasks include:

- Microscope viewing: > 4 hours total cumulative time/day (includes simultaneous monitor viewing and counting)
- Manual counting and documenting chromosomes >4 hours

- Slide preparation: 2 hours
- Prepping petri dishes: <. 5 hours
- Aspirating cells: 2 hours
- Keyboarding and data entry: .5 hours

1.3 PRELIMINARY SITE SURVEY RESULTS

Prior to beginning the ergonomic analysis, employees were surveyed regarding the four or five work tasks that involve forceful exertions, awkward postures, repetitious movements, vibration or contact stresses. Employees were also asked to provide solutions to resolve the identified concerns. Participatory surveys such as this help the ergonomist to identify the most critical tasks that may be driving the work injury claims at the site. In addition, it provides the employees the opportunity to identify their concerns and be part of the problem solving process.

Of the 15 surveys received, 12 identified solutions as well. The breakdown of concerns is listed below.

Table 1.1 Ergonomic risk factors and associated tasks for Cytogenetics Technologists from a participatory survey. N=15.

Ergonomic Risk Factor (#responses)	Identified Task
♦ Contact Stress (1)	Leaning forearm on counter
♦ Repetitive Motion (12)	Scope focusing Mousing (karyotyping) Pipetting Slide mounting
♦ Static Postures (11)	Microscopy Monitor work (counting)
♦ Forceful Exertions (5)	Harvesting Air drying of slides Frozen tissue removal
♦ Awkward Postures (6)	Reach into drying chamber Reach into cryochamber Chair height to counter Monitor reach Cleaning incubators.

Employees were then asked to provide solutions to the identified risk factors. The following were provided:

- ♦ Flexible schedules including task rotation, task interruption, stretch breaks and exercises.

- Chairs that provide better support to arms, back and legs with more adjustable height range. Include chair education
- Lower drying chamber to reduce awkward reach
- Reading glasses instead of bi-focals
- Upper extremity support during microscopy
- Alter scope angle or height
- Alter monitor angle – drop down
- Provide for stage arm manipulation

1.4 ADDITIONAL RISK FOR GENETIC SCIENTISTS

Additional analysis of risk revealed a variety of other concerns surrounding the workstations, tool use, personal factors and common work practices. The following are included as risk factors and meet the criteria of exposure for 4 or more hours or as a personal factor.

Table 1.2 Risk factor exposure analyses for Cytogenetic Technologist.

Tools/Materials	**Workstation**	**Personal Factors**	**Work Practice Actions**
Glove use	Fixed height work surface	Pre-existing conditions: work injuries	Sustained or prolong static postures: sitting, grasping, pinching, forward bending at trunk and neck
Tweezers/forceps	Standing on hard surface	Multiple employees <5th percentile height	Repetitive movement patterns (1x15s.)
Pipette	Hard edge		Forceful grip
Scalpel	Fixed keyboard height		Leaning on hard edge
Microscope	Fixed monitor height		Awkward postures of neck, shoulders, wrist, hands and back.
Slides			Unsupported arms above waist
			Minimal changes in posture or pace
			Work cycle time >30 seconds repeated or sustained

1.5 SUMMARY OF WORKSTATION ANALYSIS

Aside from assessing risk, a site analysis of the workstations where most tasking occurs was performed. This included an assessment of the most critical areas of concern including chairs, monitors, document holders, work surfaces including supports and microscopes.

Figure 1.1 A Cytogenetic Technologist demonstrates typical work postures at the lab counter using the microscope and counting chromosomes on the monitor. Right upper extremity overuse is related to sustained elevation above the work surface to count cells on the monitor. This awkward forward reach for the monitor creates additional wrist extension. The employee uses the obsolete "Workrite" document support for elbow support as well as documents.

1.51 Ergonomic Chairs

The Harter Anthro Accord Task Chair and Stool are utilized in the Microscopy room by a majority of the workstations. The Task Stool is modified in its pedestal height adjustment from 17 to 24 inches, while the Task Chairs offer a pedestal height of 15 to 21 inches. The Harter Task Stools along with three of the task chairs offer armrest support while 4 offer no armrest support. Those chairs with armrests adjust in height and width limited to about 1' from the seat pan. Armrest length is limited as is cushion depth. All chairs provide forward seat pan tilt and seat back tilt for slight recline. They also offer 2" adjustable lumbar support. No tilt tension is found on these units. They meet minimal ANSI 100 ergonomic criteria. For the purpose of performing microscopy, these chairs may not be considered as comfortable as some higher end models, especially for the prolonged posture that occurs within these chairs while performing microscopy.

Figure 1.2 Another technologist at work in the Microscopy room. She is using the microscope to count instead of the monitor and documenting her results. Microscopy often fosters forward head posture. The Harter chair armrest does not provide adequate arm support for upper extremities despite offering height and depth adjustment. The stage control has been modified and dropped closer to the surface to reduce forward reach. The binder acts as a document support while the forearm rests on the hard surface edge.

In a survey of approximately 8 users, 5 rated the chair as comfortable, while 3 found the chair to be barely comfortable and also noted symptoms while using the chair. Of the employees surveyed, most were fully aware of the ergonomic features and adjustability that the chair offered. Not all, however, maximized the features of the ergonomic chair. Some employees find the forward tilt position not as comfortable as neutral and therefore do not use it as much during microscopy.

1.52 Monitors

Monitor size may vary within the Microscopy room. There are both computer monitors and small televisions screens used to view chromosomes and to perform counting tasks. No glare screens are provided and each screen size is either 11,12 or 13 inches across the diagonal. Most of these are positioned below eye level with a few angled up on small 2 x 1 inch angular platforms. Other monitors are located directly on the work surface. Employees must write or count on the screens the selected chromosomes in each sample. The monitors must be kept within an arm's length or closer to forearms distance so that the employee can actively write on the screen. Counting on the screen is awkward (Fig. 1.1) and requires shoulder flexion forward, forearm pronation combined with wrist extension and a sustained pinch of the pen.

1.53 Document Support

Traditional document holders are not viewed in the work area. Some employees utilize a clipboard on the work surface or a 1-2" binder to support documents. One obsolete "Workrite" document holder (Fig. 1.1) was observed in another location outside of the Microscopy room. Documents are viewed and written on throughout the workday. Especially counting sheets, which must remain in close proximity between the microscope and monitor.

1.54 Work Surfaces

The Microscopy room offers wall mounted fixed height work surfaces, 30 inches high by 30 inches deep, approximately 57 inches across for each segregated work area. Some are cornered and therefore provide a somewhat wider work area. There are binder bins/shelves over the top and surrounding each work area for storage. There is lighting directly below each binder bin illuminating the back half of the work surface. A few alternative work areas for microscopy are found at lab counters set at 36". The current work surface design is not effective in meeting employee needs for simultaneous microscopy and cell counting on monitors. The postures required to perform these tasks are static and awkward creating fatigue to the neck, upper back and upper extremities.

Contact edges are rounded but hard and there is padding to lean the forearms on in most areas. Employees use vinyl covered padding, wrist rests and egg crate foam to pad edges for forearm cushioning during microscopy and writing/counting tasks. Prototype "Workrite" armrests are used in the facility (Fig. 1.3). These non-articulating, adjustable height and angled cushioned supports are attached to the front edge of the work surface. It provides support to the forearms of the scientist during microscopy. Employees had varying results with the supports based on survey results. For the most part, microscope users benefit with forearm support when properly set to reduce postural fatigue to the neck, back, shoulders and upper extremities. Ease of adjustability of these supports is most critical when attached to the work surface.

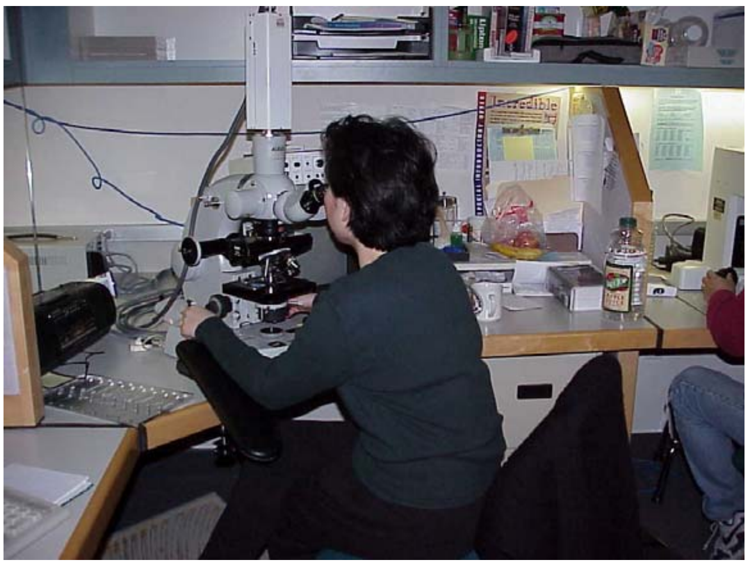

Fig 1.3 This employee is demonstrating poor sitting technique with a rounded unsupported spine, cervical extension and legs crossed. She is using the prototype "Workrite" forearm support to support the left and right sides. Elbow remains extended from the trunk despite the support facilitating forward slouched postures. The supports appear to be set too wide for the user.

1.55 Microscopes

Employee assessments (McGlothlin and Hales) of psychosocial factors of laboratory scientists reveal substantial concern with the sedentary, monotonous, repetitive nature of the jobs combined with few opportunities for advancement. Microscopy is one of those jobs as it is considered sedentary, monotonous, repetitive and static with manual exertions. The extreme visual demands may even exceed those required for monitor viewing during computing on a typical day. The scientist's posture during microscopy is one of exactness holding sustained head and neck postures for extended periods of time while viewing through the ocular piece. The fixed angle of the ocular adds to the awkward forward head posture assumed to view samples under the scope's lenses. In some microscopes, the ocular is now adjustable in angle and distance between them offering the user more flexibility in eye, head and neck posture. Ideally, the scientist should be looking through the center of the ocular lenses for best pupil comfort (Anshel, 1998). Nonetheless, the scientist is likely to experience significant eye and muscle fatigue along with muscle spasms to the neck and shoulder musculature as a result of the postural requirements. This often leads to referred pain to the wrist and hands. In this study, claims to the neck, upper extremity and hands were the most common related to microscopy.

Another critical aspect of microscopy is the relationship between the user and the scope's contact points. Vision and reach determine ones posture; with microscopy, the user must be able to reach the magnifying controls, the stage controls and the ocular piece for viewing simultaneously. These are repeated and sustained efforts often exceeding 2-hour time frames. The variable height of the scopes measured from ocular to control knobs to work surface used reflects the relationship required for a good fit to the end user. Ideally, the end user desires elbows in close proximity to the trunk for near reach and the head in line with the shoulders with eyes slightly down. If the ocular is set close to the scope at a fixed horizontal angle and the control knobs elevated above the surface > 1", the end user must begin to assume awkward postures from neutral. The higher the control and stage adjustment knobs and the greater the angle of the ocular, the more awkward the posture becomes and the more difficult to sustain. End-users usually sit in these postures for extended periods of time as well adding to the cumulative effect of the exposures.

Hand controls require micro-movements for fine focus and exact positioning of the slide under the viewing circle. Focus and refocus as well as repositioning of the slide on the stage to find the specific cells and inspect them are repeated continuously during microscopy. Repetitive pinch of the control knobs combined with force to rotate the knobs is common and causes manual fatigue often leading to carpal tunnel syndrome and other repetitive motion disorders of the wrist and hand.

Consideration to improving seated microscopy postures should be given to altering the seat pan angle from neutral to forward tilt. Changing seat pan angle will change the thigh-torso angle placing the hips higher than the knees. In turn, the spine assumes greater lumbar extension relative to the anterior pelvic tilt. Head and neck angles change as a result to a downward flexion and viewing angle of the eyes. This allows the end-user to be in an "up and over" posture to look down into the ocular. The forward tilt provides a naturally balanced sitting posture. This differs from the typical neutral seat pan posture where the end user assumes a slouching posture facilitating the cervical spine into forward head or axial extension to look into the ocular leading to postural fatigue throughout the spine.

Table 1.3 A comparison of the 3 microscopes used and their features.

MICROSCOPE	Nikon Eclipse E800	Zeiss Axiophoto	Zeiss Photomicroscope
HEIGHT TO OCULAR FROM SURFACE	17 1/2" to 20 1/2" Adjustable	18 3/4"	16 1/2"
BASE	7"	9 1/2"	9 1/4"
DEPTH	16"	12 1/2"	12"
STAGE HEIGHT FROM SURFACE	8"	N/A	N/A
CONTROL KNOB CIRCUMFERENCE	4"	4" (largest) 3 1/2" (smallest)	Built-up 6 1/2" (largest) 4" (smallest)
CONTROL KNOB HEIGHT ABOVE WORK SURFACE/ HORIZONTAL DISTANCE FROM EDGE	3 3/4"/ 6-8" (variable)	4-5"/ 4-6" (variable)	5-6"/ 5-7" (variable)
OCULAR ANGLE	90 degrees Adjustable angle	30 degrees Fixed angle	30 degrees Fixed angle
FLOOR TO CONTROL KNOB	32"	35"	35"

1.6 SUMMARY OF RECOMMENDATIONS

Due to the nature of the work performed in the Genetics Lab, seated work is the most essential posture. As a result, the chair is likely the most important tool in the workplace. Employers who select chairs as a strategic ergonomic tool often see substantial improvement in morale and productivity along with reduction of injuries almost immediately upon implementation. The work injuries to date are the result of employees working at fixed height surfaces with a typical office ergonomic chair primarily used for office tasking for extended periods of time in awkward postures. The recommendations encourage the investigation of alternative ergonomic chairs designed for highly static jobs that offer more postural variation, support and ease of control. The addition of adjustable height surfaces to allow for sit/stand options is also advantageous for positive benefits.

Work practice strategies are the most powerful and promising self-care solution for this environment in that it is within every employees' and managers' control. Work rotation, or primarily, task rotation is essential for highly repetitive jobs. The more static and repetitive work, the more frequent the task interruption is suggested.

Balci and Aghazadeh (1998) report that for every 30 minutes of repetitive work, 3-5 minutes of interruption being stretching, postural change, or alternative task is strongly suggested and supported in the literature. For a 60-minute task, 10 minutes is suggested. Previous NIOSHstudies have shown that lab technicians encouraged to take more frequent but shorter work breaks throughout the day and perform more frequent task changes aid in reducing the risk of CTDs. Stretching education and cues, use of the Theracane ™ self-massager and/or other in-house exercise tools should be promoted and supported by management/supervisors throughout the workday.

Numerous recommendations were made as a result of this study to the department manager. Not all were implemented. Below is a list of the most successful strategies used over the last year since the study took place.

I. Administrative Suggestions for Employer/Supervisor

a. Develop specific work rotation schedule for microscopy and other alternative tasks specific to essential functions. 30 minutes maximum static posture limit for microscopy without interruption. Have employee participate in scheduling of work task rotation.
b. Task interruption for stretching or Theracane ™ (3-5 minutes).
c. Consider minimizing the use of the monitor screen for counting of chromosomes as this is a cause of awkward postures during microscopy. Encourage employees to count through scope. Only use monitors for more difficult counting situations, ie. Bone marrow.

II. Departmental Purchases:

a. Quickstick padding for tool, utensil build-up (handles) and control knobs.
b. Alternative Ergonomic chairs with more support and adjustability.
c. Pistol safety blowgun for air-drying slides.
d. Adjustable height tables.
e. Theracane ™ self-massager with video and booklet.
f. Arm supports of varying kinds.
g. Industrial and office footrests.
h. Microscopes with adjusting ocular angle as well as extended, drop down stage control knob
i. Alternative cordless mouse
j. Monitor height supports.

III. Training and Work Practice Suggestions:

a. Custom laboratory ergonomics training - site specific. Include safe work practice training for all areas as well as Self-care of the neck and back, Theracane TM instruction and all ergonomic equipment use.

Engineering recommendations were made regarding customized microscopy tables that allowed for height adjustability for the microscope and the monitor on independent platforms. The designs never left the drawing board per say and were rejected by management based on poor vendor support in developing the prototype.

1.7 FOLLOW-UP RESULTS AFTER IMPLEMENTATION OF RECOMMENDATIONS

Results were collected 5 months after completion of the training and again at 1 year following the training. The 6-month follow-up study was extremely favorable in regards to employee benefits. 17 employees completed the survey.

Table 1.4 Results of the 6-month follow-up survey with sample feedback.

Question	Yes	No	Blank	Feedback
Did the ergonomics study and training directly impact you?	12	4	1	Increased task awareness; increased posture awareness; set-up work area to meet my needs; bring items closer
Did you receive any new ergonomic equipment in your work area as a result of the project?	11	6	0	Bench cushions for arms; footrest; arm supports and padding; Theracane; table edge padding
Have you modified your own work practices since the laboratory ergonomics training?	15	1	1	I look to the opposite direction; I change tasks or take breaks more often; more frequent rest breaks; adjust my equipment; task rotation; exercise and stretch; better posture, Theracane use; fit station to my needs.
Overall do you feel better since your employer introduced ergonomics and the training?	10	3	4 not sure	
Do you feel your employer is doing all they can do to help you work more comfortably?	10	6	1 undecided	Order more appropriate chairs, provide individual workstations

In addition, the employees were asked to rate their employer's overall effort in improving workplace ergonomics as well as their own efforts. Using a scale from 1 to 5 with 1 as poor and 5 as excellent, the employees rated the employer a 3.23 and themselves a 3.41 indicating a score of slightly better than satisfactory in overall performance.

At the one-year point, no surveys were taken, however the staffing levels increased to 31. Workers' compensation claims experienced a reduction in overall reporting in 1999 by 87%. The department noted 1 recordable CTD in 1999. This resulted in injury rates reduced by 850% in one year.

Management was noted as saying that the most effective part of the study was the training session. In the training, safe work practices were emphasized with many examples. Employee awareness regarding their work activities such as sitting properly and rotating tasks has been the most helpful thus far. Equipment use varies at times but is not used as much as earlier in the study. Much of the products purchased have been moved to cabinet shelves.

1.8 CONCLUSION

Ergonomic studies are few and far between regarding the overall impact the Laboratory has on scientists. The best comparison comes from the well-defined field of office ergonomics. This study demonstrates the significant productivity standards and ergonomic risk factor exposure on today's laboratory (genetic) scientist. Microscopy as an essential job task comes with significant postural risk to the end user and is further aggravated by high repetition and the use of a computer monitor for additional visual demands leading to CTDs.

This study justifies the benefits of training employees in the importance of safe work practices including task rotation and interruption, the use of adjustable equipment and the importance of posture awareness. These findings are supported in Dainoff's (1998) recent study regarding productivity in the modern office. In the study, two criteria for efficient work are defined as: getting into an optimum (ergonomically correct) posture, and being able to move during the workday.

Further study is required on the visual and postural demands of microscopy as well as the use of customized chairs and work surfaces that can better accommodate the needs of this highly specialized seated work force.

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