Final Report

Evaluation of Best Practices for Alleviating and Preventing Cumulative Trauma Disorder Amongst Healthcare Laboratory Technologist Involved in Pipetting Work

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Executive Summary

This project was designed to evaluate the impact of workstation adaptations on minimizing musculo-skeletal strain by incorporating experimental workstations into the workplace and assessing users after 6 months and 1 year. The research took the form of a comparative study with a test (intervention) group of lab technologists that was given customized workstations and a second (control) group of technologists that continued to work at their existing workstations without any ergonomic modifications. Fifteen laboratory technologists from six different labs were recruited for the study. Evaluation measures consisted of Pain Index Questionnaires, Design Input (Importance and Satisfaction Rating) Questionnaires, and bio-mechanical evaluations at the BCIT Living Lab.

Assessment results, recommendations from the literature and user feedback were used to determine the design for the experimental workstations. Design features of the workstations included powered adjustable height bases, counter top cut outs, and recessed tip discard buckets.

Based on the feedback from lab techs, the adjustable height workstations were a significant improvement over the original workstations. Design input results showed increased satisfaction over all measured domains. The areas of greatest improvement were noted for height of the work counter, adjustability, storage space, task lighting, overall comfort, and overall effectiveness. These features correspond with the features rated as most important in the initial Design Input Questionnaires. Given the limited number of subjects and the confounding factors involved in this type of research Pain Index and Bio-mechanical assessment measures used in the study were not sensitive enough to show differences between the control and intervention groups.

Although the results from this study do not lead to definitive conclusions about the experimental workstations, trends indicate that the new workstations were a significant improvement over the original workstations and led to greater user satisfaction. It was not possible to develop "performance requirements" based on the results of this study, however based on user feedback and design input ratings, it is recommended that new pipette workstation designs include powered adjustable height bases (to accommodate sitting and standing), a C-shaped cut out, a recessed discard bucket, counter top with visual marking of safe reach limits, shelving and storage, accessible display areas for notes and schedules, task and back lighting, turntables, and postings of ergonomic guidelines.

Background

Cumulative trauma disorders (CTDs) are a significant and growing problem amongst lab technologists involved in pipetting work. In the US, CTDs represent 65% of all laboratory injuries reported (1). Given comparable demographics, standards of living, life styles and work place procedures, the assertion can be made that comparable figures exist in Canada. Typical symptoms which can occur as a result of pipetting related injuries include pain in the thumb (DeQuervain's syndrome), forearm, and elbow (tendonitis or tenosynovitis), trigger finger, finger pain (digital nerve injury), and shoulder pain (2),(3). In many cases, the pain is so severe that the subject is no longer able to continue to work or to perform simple everyday tasks.

Research by Bjorksten et. al (4) indicates that an increased risk of hand and shoulder ailments is associated with more than 300 hrs/ year pipetting. A similar study by David and Buckle (5) proposed an increased risk 'dose' to be 220 hrs/year. If one assumes 50 weeks in a working year, these dosages translate to 6hrs/wk and 4.4hrs/wk respectively. A recent WCB document based on the Washington State MSIP model sites 2 hours/day of repetitive motion as being an identifier for musculo-skeletal injury (MSI) risk (6).

The management of the Molecular Genetics lab at the BC Cancer Institute identified injuries resulting from repetitive pipetting work to be a serious problem for their lab staff. At the time the proposal for this project was submitted, 50% of their pipetting team had submitted claims to Workers Compensation for CTDs. The Blood Bank at Burnaby Hospital had complaints of hand pain from repetitive strain from 75% of their full-time laboratory staff involved in pipetting work. Discussion with the lab directors at Vancouver General Hospital and Children's Hospital confirmed the severity of the problem. It has been estimated that there are currently 2600 lab technologists working in B.C. (7). Although attempts were made to acquire definitive statistics on injury rates for BC laboratory technologists, such a statistical breakdown is not readily available.

Injuries and loss of work time from CTDs are a serious concern for lab staff, management, and unions. The problem of alleviating and preventing these types of injuries is complex and involves the design of the pipette, the design of the work place environment, and more specifically, the effect the environment has on the technologist's body and limb orientations relative to the test samples. A review of the literature revealed a number of recommendations for pipetting workstation design (1,2,3,4,5,8,9,10,11,12,13,14,15) however no formal studies were found which evaluated the effectiveness of these strategies.

Project Objectives

The intent of this research was:

1. To provide an ergonomic risk-assessment of existing pipetting procedures and workplace set-ups.
2. To evaluate the impact of an experimental workstation design and workplace changes on alleviating cumulative trauma disorders (CTDs) by incorporating these changes into the workplace and assessing users after 6 months and 1 year
3. To provide a set of performance requirements to control risks associated pipetting work based on the above results.

Research Design

This project was designed to evaluate the impact of workstation adaptations on minimizing musculoskeletal strain by incorporating experimental workstations into the workplace and assessing users after 6 months and 1 year. The research took the form of a comparative study with a test (intervention) group of lab technologists that was given customized workstations and a second (control) group of technologists that continued to work at their existing workstations without any ergonomic modifications.

Fifteen laboratory technologists from six different labs were recruited for the study.
Three questionnaires were developed: Pain Index Questionnaires, Design Input (Importance and Satisfaction Rating) Questionnaires, and Bio-mechanical Evaluations (see Appendix 1).

An ergonomic assessment of existing workstations and pipetting procedures was conducted. Video recordings, task analysis documents, and link diagrams were compiled and reviewed by a multi-disciplinary group. Assessment results, recommendations from the literature and user feedback were used to determine the design criteria for a prototype workstation (see Appendix 2). Using these criteria, an adjustable, experimental workstation was designed (see drawings, Appendix 3).

Lab technologists were asked to trial the workstation at the BCIT Living Lab and provided feedback for a revised design. Based on the feedback, three experimental workstations were built and installed in hospital labs for evaluation.

Evaluation measures consisted of Pain Index Questionnaires, Design Input (Importance and Satisfaction Rating) Questionnaires, and bio-mechanical evaluations at the BCIT Living Lab. Participants were evaluated at three key stages of the study: the beginning (baseline), six months and one year after the experimental workstations were set up in the labs. See Research Design Schedule of Events Appendix 4.

Results were analyzed to determine if the proposed experimental workstation reduced CTDs.

Discussion

Phase I: Pre-intervention Assessments

Design Assessment Tools

Existing questionnaires for upper extremity injuries and lab ergonomics (16,17,18,19,20,21) were reviewed and used as a basis for the development of three assessment tools:

a. Background Questionnaires: These questionnaires solicit demographic information as well as further details about pipetting tasks, other regular work tasks, and leisure activities. It is recognized that workstation adaptations alone are insufficient to address CTDs if subjects are performing other duties that contribute undue musculo-skeletal strain or if subjects participate in off-work activities that may exacerbate the problem. A thorough understanding of the subjects' work activities and lifestyle was considered important to accurately evaluate activities that contribute to the problem.

b. Pain Index Questionnaires: These questionnaires include self report ratings for pain in various body parts, as well as specific hand/wrist pain descriptions and ratings.

c. Design Importance and Satisfaction Rating Questionnaires: The Design Input questionnaires comprise three different parts: importance ratings, satisfaction ratings for original workstations and satisfaction ratings for experimental workstations. Evaluated features include components of the workstation design, the primary work chair, and ambient workstation features. Questions include Likert scale ratings and open-ended questions.

Recruit and Assess Subjects

The recruitment phase of the study proved to be more challenging than initially anticipated. Due to busy lab schedules, management and technologists were reluctant to commit time to the study. As a result, it was necessary to streamline assessment procedures and re-organize the research protocol to minimally impact the schedules of the labs. The usefulness of the grip strength and pinch strength measurements was re-examined. It was concluded that workstation changes were likely to affect bio-mechanical and postural measures, but were unlikely to result in short-term changes in hand function. Given the scheduling issues, it was decided that the range of motion and pinch and grip strength measures be omitted from the assessments. To further reduce inconvenience to the labs, it was decided that questionnaires and lab assessments be completed outside of work hours. Lab technologists were paid an honoraria for their participation.

Phase II: Design and Living Lab Evaluations

Establish Design Criteria And Design Prototype Workstation

Video recordings, task analysis documents, and link diagrams were compiled and reviewed by a multi-disciplinary group including occupational therapists, an ergonomist, an industrial designer, and a mechanical engineer. Assessment results, recommendations from the literature and user feedback were used to determine the design criteria for a prototype workstation (see Appendix 2). Design criteria spanned a range of features including the chair, lab bench/ work surface, equipment and material access, computer access, postural issues, light, noise and temperature.

An objective of the workstation design was to utilize as many commercially available elements as possible in order to make the results of the study easy to implement in laboratories. Another important consideration was to keep modifications at a reasonable cost so that implementing and sustaining workstations at other institutes is both practical and affordable.

Living Lab Assessment #1

The prototype workstation was built and set up at the BCIT Dr. Tong Louie Living Lab for the first Living Lab assessments. A "typical" workstation (based on specifications obtained in the ergonomic analysis) was also set up in the Living Lab.

The Living Lab features a state of the art full scale environmental simulation area (approx 800 sq. ft) with a Data Acquisition Centre that includes s PEAK 3-D Motion Analysis system. The PEAK system was used to monitor the subjects' body positions and timing during pipetting trials. Movement patterns were measured using passive reflective markers attached to upper body landmarks.

Kinematic measurements were obtained via PEAK Performance Technologies' motion capture hardware, software and data collection procedures. It had been anticipated that an upper extremity model would be available from PEAK to do the kinematic calculations. At the time of this research however, the PEAK model was not ready. Consequently a model had to be developed by BCIT. Development of the upper extremity model proved to be more challenging than initially anticipated and the final BCIT version would benefit from further revision.

Prior to collecting data for the biomechanical evaluation, seven digital video cameras were positioned to allow motion capture in the frontal, sagittal and transverse planes.
The system was calibrated using the standard reference frame and protocol provided by Peak Performance Technologies. The detailed trial protocol was piloted with Living Lab staff prior to the assessments to ensure that all equipment was functioning properly and that no details were overlooked.

Six subjects from the intervention group completed the first assessment at the Dr. Tong Louie Living Lab. Subjects were asked to perform a simple pipetting sequence at the "typical workbench" while joint angles, work envelope and timing were monitored using the PEAK motion analysis equipment (see Figure 1). This information was collected as a baseline to later compare with results from the experimental workstation assessment.

Figure 1. Subject participating in Living Lab Bio-mechanical Assessment # 1

After the bio-mechanical evaluation, participants were invited to trial the experimental workstation and provide feedback on various aspects of the design. This was achieved formally through the use of questionnaires, and informally through semi-structured discussions. Obtaining feedback from the laboratory technologists was critical to the project and led to several design changes. Even more importantly, having the lab technologists actively involved in the design revision process led to greater acceptance of the new workstation at future stages of the project.

Phase III: Implementation & On Site Evaluations

Implement Experimental Workstations

Using the feedback from the Living Lab trials, the workstation was redesigned. Specifications were customized for each lab based on user preferences and lab space available. Final design specifications were sent out to the lab techs and managers for review. Meetings were scheduled to discuss details of workstation locations and to ensure that all the appropriate people had been contacted about the installation.

The three workstations were then built and installed in the labs of the intervention group. An ergonomic reminder sheet (see Appendix 5) was posted in a visible location on each workstation. Following installation, each of the technologists in the intervention group was given a personal training session with an occupational therapist. The sessions focused on teaching lab techs how to optimally adjust the workstation height for the tasks they do, how to ergonomically position their equipment within the workstation, and how to properly adjust their chairs (see Postural Consultation reports, Appendix 6).

Lab technologists in the control group continued to work at their existing workstations, without any ergonomic modifications.

Living Lab Assessment #2

The subjects in the intervention group participated in a second bio-mechanical evaluation at the Dr. Tong Louie Living Lab. This time subjects were asked to perform the pipetting sequence at the experimental workstation, set to the height that they typically adjusted it to for pipetting. Work envelope, joint angles, and timing data were collected using the PEAK motion analysis equipment. This information was analyzed and compared to the baseline data collected in Living Lab Assessment # 1. This group also completed a Design Input questionnaire to provide feedback on the experimental workstation.

Also at this time, both groups were asked to fill out Pain Index questionnaires (# 2).
This evaluation was conducted 6 months after the implementation of the experimental workstations.

Final Evaluation (Intervention and Control Groups)

The final evaluation consisted of Pain Index questionnaires (# 3) for both the control and intervention groups, as well as final Design Input questionnaires for the intervention group. The purpose of the final Design Input questionnaire was to see if opinions had changed since the six month evaluation. This evaluation was conducted 1 year after the implementation of the experimental workstations.

Results

Background Questionnaire Results

Fifteen laboratory technologists were recruited for the study. Participating technologists represented 6 different sites, including both hospital labs and privately funded research labs. The group included both males and females, with a height range between 59.4" – 77", and an age range between 24-56 years. Experience levels vary between 2-37 years spent pipetting.

The amount of time spent pipetting varied amongst the labs however on average, lab technologists spent approximately 8.5 hours/week pipetting (estimated as approximately 24% of their time). Tasks performed by the lab technologists associated with pipetting include set-up, labeling, lid/cap removal, vortex mixing, and clean-up. Other tasks typically performed at a pipetting workstation include microscope, computer, and administrative work. Detailed background survey results are summarized in Appendix 7.

Baseline Pain Index Questionnaire Results

Pain questionnaires revealed that all technologists were experiencing some level of pain. Eighty percent of participants reported neck pain, and a similar number reported pain in the right shoulder. Sixty seven percent of participants reported lower back pain, and sixty percent reported upper back pain. Significant levels of pain were defined as any rating of 2 or more (on a 1-10 scale). Highest average pain scores were reported for the lower back (avg =4.2, SD=3.4), right shoulder (avg =3.9, SD= 2.5), and neck (avg =3.6, SD= 1.9).

Questions on hand pain revealed that seventy three percent of participants reported pain in the right wrist and sixty percent of participants reported pain in the right thumb (all participants hold the pipette in their right hand). The most commonly reported areas of pain were the back of the right wrist (N=12, avg pain rating =5.25, SD= 2.1) and back of the right thumb (N= 11, avg pain rating =5.5, SD=2.7). Detailed baseline Pain Index survey results are summarized in Appendix 8.

Workstation Assessment Results:

Amongst the labs involved in the study, two workstation arrangements were noted:

1. Dedicated pipetting workstations: Lab techs rotate workstations, based on a predetermined schedule. In this case, a specific pipetting workstation is shared by a number of lab techs.
2. Personal, multi-task workstations: Each lab tech has his/her own workstation. A variety of laboratory tasks are done at the same bench.

Assessment of existing workstations showed that the majority of labs had spent little time considering ergonomic principals in the setup of their workstations. Workbenches at the test sites did not take into account variations in height of the lab techs. A striking example was noted in one of the labs where a 6'5" lab tech shared a fixed height workstation with a 4'11" lab tech. Another concern was that lab techs often alternate between sitting and standing positions at a fixed height workstation. The variety of tasks conducted at the workbenches was not taken into account at any of the labs. Even at the "dedicated pipetting benches", many set-up, follow up, and administrative procedures involved in pipetting were conducted at the same height of workstation. As a result of the length of pipettes and typical bench height, technologists often work in awkward postures when pipetting. A commonly observed posture was with the lab tech's head and arms in a forward position and the shoulders rounded forward. Typically, the technologists work with arms raised to just below shoulder height and with elbows flexed. Arms are generally not supported. This hunched-forward position is further exaggerated when the feet are placed on the ring-style foot rest common to many lab chairs (see Figures 2 and 3).


Figures 2 and 3 - Laboratory technologists demonstrating typical postures assumed when pipetting

It was noted that most workstations were poorly organized and cluttered with equipment and notes (see Figure 4). In many cases, lighting was found to be inadequate resulting in lab techs leaning in closer to their work than necessary and further accentuating the awkward postures (see Figure 5).


Figure 4 and 5 - Typical workstations illustrating clutter and poor lighting

Due to the high level of concentration required from the job and the time pressures imposed in a busy lab, lab techs were not taking mini-breaks nor stretching.

Major concerns identified in the assessments are summarized in the table below:

General

- Techs often sit for long periods of time
- busy labs, difficult for techs to take stretching breaks
- high level of concentration required
- significant problems with pipettes themselves eg. operational forces and hand positioning
- training and habit-changing challenging for more experienced lab techs

Chair

- awkward sitting postures often adopted
- difficult to fit chair to workstation height
- difficult to adjust chair to different working heights
- chair controls not always self-explanatory
- foot position is a concern (often supported on a stool ring or unsupported)
- inadequate adjustable back support on stools

Lab bench/Worksurface

- fixed height bench used to accommodate standing and sitting
- fixed height bench used to accommodate wide range of heights (4′11″- 6′5″)
- fixed height bench used to accommodate a wide variety of tasks
- chair raised to work at the lab bench results in inadequately supported lower extremities
- widths of some lab benches require significant reach to get the things at the back
- minimal under-counter accessibility
- glossy dark surfaces produce glare
- contact stresses on edges of workbench

Equipment/Material access

- large task and equipment variety among different pipetting functions
- variability throughout week
- clutter on the lab bench
- commonly used items in difficult to reach positions
- placement of waste receptacle varied and awkward (both height and distance from pipetter)
- placement of materials often awkward
- switching between pipettes common in a given task
- different pipette tips required for different pipettes
- many notes, files, and schedules need to be readily accessible to lab techs
- high storage requirement

Postural Issues

- upper arm lifted in front and out to side of the body (upper arm flexion and abduction)
- head held in a forward position with the shoulders rounded forward
- neck flexion
- stabilization of the arm in mid-air
- excessive wrists flexion and extension
- poor awareness of correct posture
- inadequate attention to placement of materials
- feet often unsupported

Lighting

- lack of task lighting
- complaints regarding fluorescent lighting
- fine visual acuity necessary

Design Input Questionnaire (#1) Results

Results from the Design Input Importance and Satisfaction Rating Questionnaires were summarized and graphed below in Figures 6a and 6b. Results closer to the centre of the graph identify features with higher importance/ satisfaction ratings. Ideally, features that rate high in importance (ie. closer to the centre of the graph) should also have high satisfaction ratings (ie. also closer to the centre of the graph). The results below show the greatest discrepancies between satisfaction and importance scores for: height of the primary work counter, adjustability of the work bench, adjustability for seat and back of chair, proper task lighting and overall comfort of workstation.

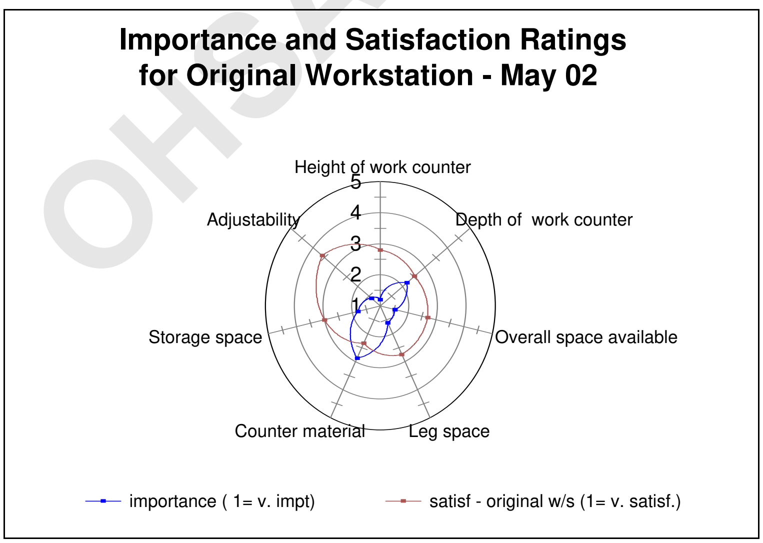

Figure 6a. Micro Features: initial importance and satisfaction ratings. Features rated as most important include height of working counter, adjustability and overall space available. Original workstation features techs were least satisfied with include adjustability, storage space, height of workcounter, overall space available and leg space.

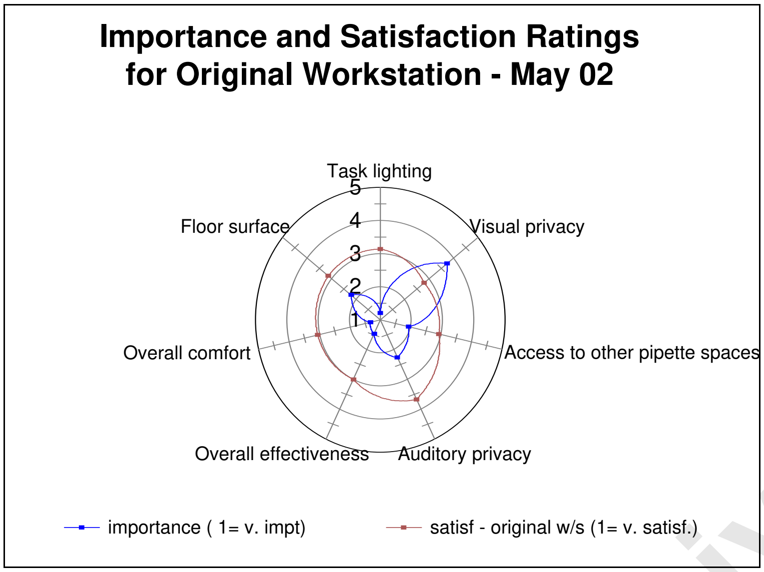

Figure 6b. Macro Features: initial importance and satisfaction ratings. Features rated as most important include task lighting, overall comfort, and overall effectiveness. Original workstation features techs were least satisfied with include auditory privacy, task lighting, and floor surface.

Prototype Workstation Results

Assessment results, recommendations from the literature and user feedback were used to determine the design criteria for a prototype workstation. Design features of the workstation include:

-powered adjustable height base (range to accommodate sitting and standing)
-counter top with a C-shaped cut out to allow greater area in close reach
-Ergo-Rest arm support
-counter top with visual marking of safe reach limits
-custom formed, recessed tip discard bucket
-framing structure and shelves
-task and back lighting
-white board and cork board frame backing for notes
-an adjustable position book holder for notes
-magnetic clips for notes, etc.
-turntables (allow equipment in workstation corners to be rotated into reach)
-mounted buckets and bins for pens and supplies
- jar opener that accommodated different cap sizes
-various height "plinths" to reduce elevation differences with pipetting equipment
-different coloured underlays for contrast against test samples
-adjustable foot stool
-power bars
-posting of ergonomic guidelines

Living Lab Assessment #1 Results

Results from the usability trials are summarized in Appendix 9. In general, feedback for the ergonomic workstation was very positive, and only a few minor changes were suggested. The main changes were and a counter-top shelf that would go up and down with the adjustable height table top and a new discard bin design. It was noted that the original discard bin was too close to the lab techs, and any spill, spray or vapour could potentially be hazardous.

Final Workstations

The final workstation design included a recessed discard bin that was set at the centre of the work area, farther away from the lab tech, but still within the "safe zone" of reach. The adjustable height bases chosen for the workstations were bought from a Canadian company, JoRo Manufacturers. With these bases, height adjustment was fully mechanized and programmable for up to 4 pre-set heights.

The full specifications of the workstation designs for each of the three intervention sites are listed in Appendix 10.

Photos of the completed workstation are shown in Figures 7 and 8.

Figures 7 and 8. Completed workstation

Living Lab Assessment #2

Design Input Questionnaire (#2) Results

Results from the Design Input Ratings for the experimental workstation are graphed below in Figures 9a and 9b . As before, results closer to the centre of the graph illustrate a higher importance/ satisfaction rating. The areas of greatest improvement were noted for height of the work counter, adjustability, storage space, task lighting, overall comfort, and overall effectiveness. All evaluated features were rated higher for the experimental workstation.

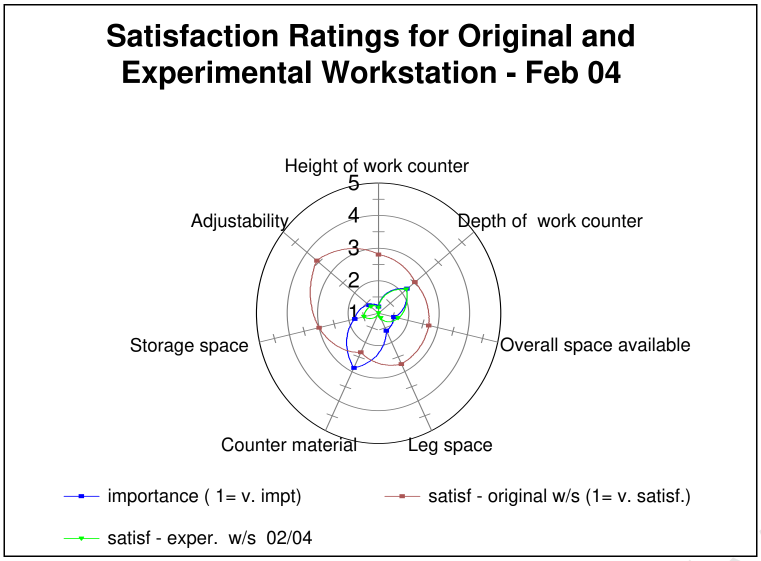

Figure 9a –Micro Features: Design Satisfaction Rating # 2. The areas of greatest improvement were noted for height of the work counter, adjustability and storage space. All evaluated features were rated higher for the experimental workstation.

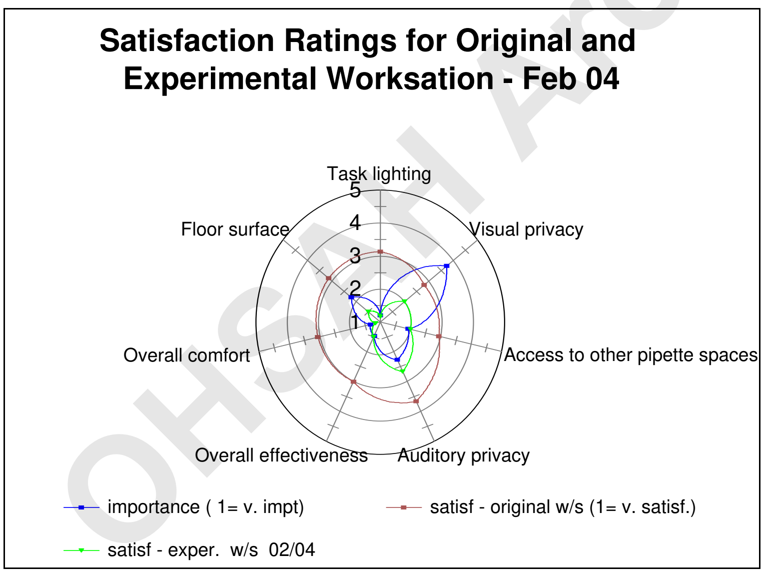

Figure 9b –Micro Features: Design Satisfaction Rating # 2. The areas of greatest improvement were noted for task lighting, overall comfort, and overall effectiveness. All evaluated features were rated higher for the experimental workstation.

Final Assessment Results

I Bio-mechanical Evaluation (#2) Results

a) *Work Envelope Results*

Lateral, vertical and forward reach data was collected and graphed for both the original and experimental workstations (see Appendix 11). It was noted that in most cases reach at the experimental workstation was greater than reach at the original workstation. (An exception was noted with left forward reach; all subjects but one had reduced left forward reach at the experimental workstation.)

Contrary to what was expected, the cut-out led to a more spread out set-up of pipetting equipment. This has been attributed to the fact that having a cut-out results in a greater working surface close to the lab tech, therefore resulting in a larger work envelope within which equipment can be set up. With the exception of two subjects, the differences in reach at the two workstations were less than 10 cm. It should also be noted that reach ranges for both workstations were all under 40cm. These ranges are within the recommended reach zones of 50cm (9,10) .

b) *Joint Angle Results*

Joint angle data graphed included:

- shoulder flexion/ extension
- shoulder abduction/ adduction
- shoulder internal/ external rotation
- elbow flexion/ extension
- L5-S1 flexion/ extension
- neck flexion/ extension
- wrist flexion/ extension
- wrist abduction/ adduction
- wrist internal / external rotation

For each of the joint angles, data from the original and experimental workstation trials was averaged and graphed as a percentage of total pipetting cycle time (see sample Appendix 12). Data was compared to video footage of the lab techs participating in the trials.

The original intent had been to use the Postural and Repetitive Risk-Factors Index (22) to evaluate pipetting risk. The index is based on evaluating the time spent doing the repetitive actions, and scoring time spent in awkward and static postures using a point scale system.

Upon analysis of the biomechanical data, results showed that joint angles measured were inconsistent with the video and too variable to be useful for drawing any conclusions.

This has been attributed to a combination of several factors:

- The upper extremity model is very sensitive to small changes in marker position. Due to the small areas for positioning markers on the hand, a slight difference in marker positioning between the two trials could lead to unjustified differences in measured angles.
- The size of the markers is big relative to the small angles being measured.
- Some of the lab techs showed were inconsistent when pipetting and therefore large variations of joint angles were recorded when the pipetting sequences were repeated.
- The upper extremity model may need further work

c) Timing Data Results

Timing data was collected for the trials at the original and experimental workstations (see Appendix 13). On average, the pipette hand cycle period was quicker at the experimental workstation than the original workstation. Three of the participants showed a slight increase in pipette hand cycle period when pipetting at the experimental workstation, however these increases were less than 7% of the original pipette hand cycle period. Of the four subjects whose cycle period decreased, the decrease was between 5% and 30% of the original cycle period.

II Pain Index Questionnaire (#3) Results

With the help of OHSAH's statistician, data from the Pain Index Questionnaires was analyzed. Average body pain scores were determined by averaging pain scores for all body parts, excluding the hands. A separate analysis was done for the right (pipetting) hand. Results were based on a pain scale of 1-10, with 10 being the highest pain rating.

Detailed Pain Questionnaire results are tabulated in Appendix 14. Average body part pain in the control group was 2.3 for the baseline evaluation and went down to 1.7 for the final evaluation. Average body part pain for the intervention group went down from 2.9 to 2.3 for the final evaluation. Similarly, average pipetting hand pain decreased in both of the groups. Average right hand pain for the control group decreased from 5.2 to 4.1. For the intervention group the average hand pain decreased from 5.3 to 5.2.

As there were a limited number of subjects, and many confounding factors affecting the results, interpretation of the pain index results is difficult. Further study with a greater number of subjects under more controlled conditions would be required to obtain statistically significant results. Further investigation into why pain index results decreased for both groups is recommended.

From the comments in the questionnaires it was noted that lab techs felt pipetting contributed to their pain, however felt that other conditions (such as osteo-arthritis and sciatica) as well as hobbies (such as horseback riding, running, gardening, housework, roofing, and bike riding) might also be contributing to their injuries. In some cases increased levels of work, more time spent pipetting, and more time spent working in the bio-hazard cabinet were reported.

Although shoulder and back pain were reported in the pain ratings, many comments from the questionnaires focused on thumb and hand pain :

> "I believe the problem in the joint at the base of my right thumb is primarily due to squeezing tops of pipettes and unscrewing caps on reagent bottles. I am unable to operate staple gun, open jars due to loss of strength in joint at base of thumb on right hand."

> "Pipetting seems to be the only task which causes discomfort in the thumb. Pipetting has definitely increased and correspondingly, the aching feeling in my right thumb."

> "Physical discomforts are related to specific 'Hamilton' pipettes. Increased level of work and prolonged periods of work increased pain and swelling in hands, especially right thumb."

> " For the past 3 months I have been constantly working +5 days on routine bench and have noticeable pain in both hands. Mainly stiffness, especially joints and knuckle region is tender to touch. Definitely associated with pipetting."

> "Working extra hours I definitely notice the difference of fatigue in hands."

Although there is a possibility that workstation changes may affect hand pain, it is more likely that these injuries are being caused more specifically by the pipettes themselves. Further investigation is recommended.

III Design Input Questionnaire (#3) Results

Results are represented in Figures 10a and 10b. It can be seen that for the most part, results remained consistent with the results from the six month evaluation. The only notable change is a slight decrease in satisfaction rating for the "overall space available". The final rating is still rated as more satisfactory than the original workstation. As before, all evaluated features were rated higher for the experimental workstation.

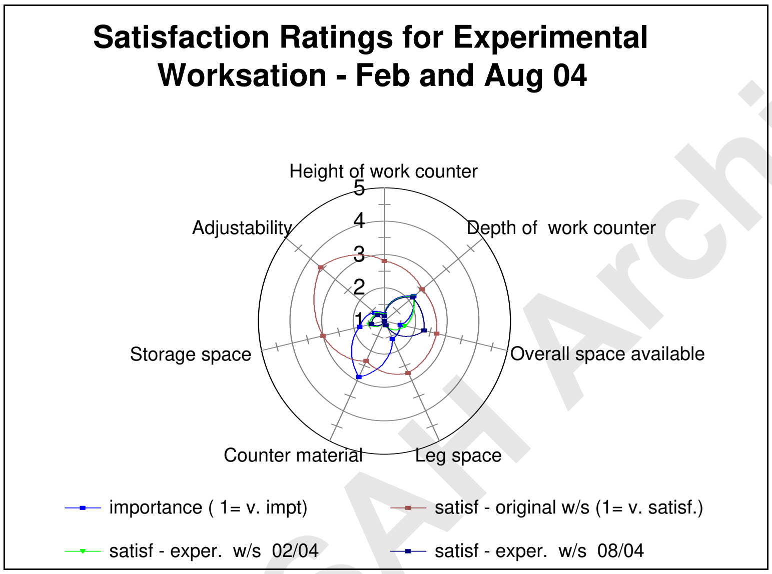

Figure 10a. Micro-Features: Design Input Questionnaire # 3.

Most results remained consistent with those from the six month evaluation. The only notable change is a slight decrease in satisfaction rating for the "overall space available". All evaluated features were still rated higher for the experimental workstation.

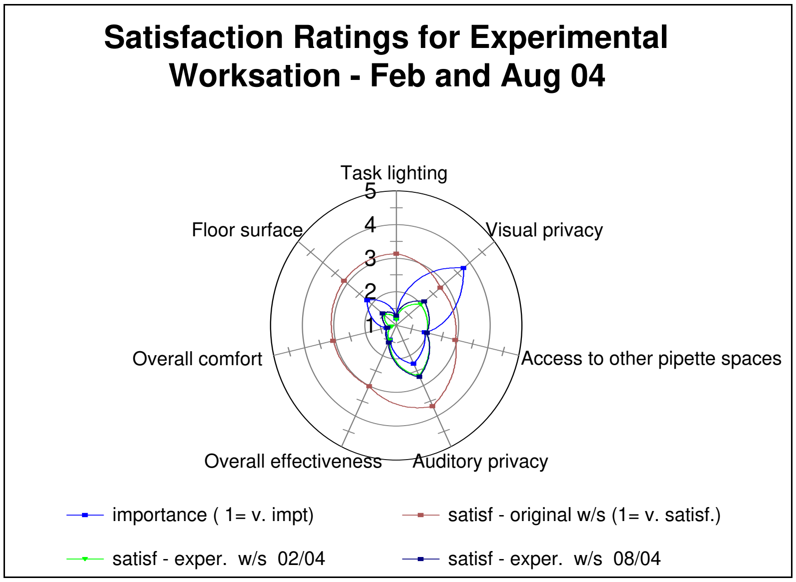

Figure 10b. Macro-Features: Design Input Questionnaire # 3.

Results remained consistent with those from the six month evaluation. All evaluated features were still rated higher for the experimental workstation.

Comments from the six month and final design questionnaires were summarized. In general lab techs were still highly satisfied with their new workstations and had integrated them well into the labs. Features that lab techs were particularly satisfied with included:

- height adjustability
- ability to keep all pipetting materials within reach
- recessed discard bin
- cut out
- increased number of electrical outlets
- clip magnets
- overhead and task lighting (although one person mentioned that the halogen lights got hot)
- portability
- storage
- ease and comfort of moving within the workstation

Although comments for the recessed discard bin were favourable, two lab techs felt that the location of the discard bin was intrusive in their workspace. One lab tech stated she would prefer it to be suspended from the front of the workstation as in the original design. Another suggested it should be placed further back. Unfortunately neither of these suggestions are feasible as putting it in the front leaves lab tech at risk for contamination (as learned from the trial of the original prototype), and moving the bin further back puts it outside the "safe reach" zone.

Comments on the Ergo-rest arm support were not favourable. Lab techs found the arm rest awkward to use, and found that it limited their movements in the vertical plane. Lab techs felt that an arm rest that allowed vertical movement could be helpful. An arm rest called the MASTE-1 was later found on the internet (23), selling for approximately $300. This armrest supports the arm while still allowing movement in 3 planes and may be worthy of investigation. Budget for this project did not allow for the purchase of one of these supports, however labs were made aware of the item and were encouraged to look into purchasing one.

Additional areas for improvement that were commented upon included:

- a document holder that could be mounted centrally
- more shelving
- a counter top made of plain material (one lab tech commented that if the bar code reader was laid on the counter, it attempted to read the speckles)

Conclusions

Results from the background surveys in this study indicate that on average the technologists in this study spend 8.5 hours pipetting per week. Although the time varied considerably amongst labs, these findings indicate that the majority of lab technologists in this study spend more time pipetting than recommended in the literature and are at risk for CTDs.

Pain Index Questionnaire Conclusions

It is not possible to draw statistical conclusions from the Pain Index Questionnaire data, particularly when one considers the small sample size, confounding factors, and limited time frame over which the data was collected. It is also difficult to know if it is possible to reverse the pain that has built up from years of this type of work. Results showed no notable differences between results from the control and intervention groups.

Pain index results and comments indicate that thumb and hand pain are a significant problem. Although there is a possibility that workstation changes may affect hand pain, it is more likely that these injuries are being caused more by the awkward grips and high forces required by the pipettes themselves. Further research into the design of pipettes is recommended.

Design Input Questionnaire Conclusions

All evaluated features were rated higher for the experimental workstation than the original workstation. The areas of greatest improvement were noted for height of the work counter, adjustability, storage space, task lighting, overall comfort, and overall effectiveness. These features correspond with the features rated as most important in the initial Design Input Questionnaires. The new workstations were readily accepted into the hospital labs and feedback was positive.

Biomechanical Evaluation Conclusions

a) Work Envelope

Contrary to what was expected, the experimental workstation resulted in a larger work envelope than the original workstation (although the measured differences were less than 10 cm for most subjects). Reach ranges for both workstations were all under the recommended reach zones from the literature and it is concluded that excessive reach during the pipetting task is likely not a contributing factor to the injuries being sustained from pipetting.

It should be noted that data was collected only for the specific task of pipetting. It is important to remember that other jobs performed by the lab techs (including reaching for equipment) were not analyzed and may result in reach envelope beyond the recommended limits. Lab techs should be coached to set up equipment within safe reach zones. The reach limit markings on the experimental workstation act as a visual reminder.

b) Joint Angles and Posture

Joint angle and postural data were variable and inconsistent with video footage. The upper body model used in conjunction with the PEAK system was shown to be an unreliable means of obtaining kinematic data.

c) Timing

On average, the pipette hand cycle period was quicker at the experimental workstation than the original fixed height workstation. This trend reflects a positive correlation between the experimental workstation and task efficiency.

General Conclusions

Based on the feedback from lab techs, the adjustable height workstations were a significant improvement over the original workstations. Design input results showed increased satisfaction over all measured domains. Given the limited number of subjects and the confounding factors involved in this type of research Pain Index and Bio-mechanical assessment measures used in the study were not sensitive enough to show differences between the control and intervention groups.

Although the results from this study do not lead to definitive conclusions about the experimental workstations, trends indicate that the new workstations were a significant improvement over the original workstations and led to greater user satisfaction. It was not possible to develop "performance requirements" based on the results of this study, however based on user feedback and design input ratings, it is recommended that new pipette workstation designs include :

- powered adjustable height base (range to accommodate sitting and standing)
- counter top with a C-shaped cut out
- recessed tip bucket
- counter top with visual marking of safe reach limits
- shelving and storage
- writing surfaces / holders for notes and schedules
- task and back lighting
- turntables
- posting of ergonomic guidelines

Areas for Future Work

It is hoped that this work will encourage further research to help reduce injuries suffered by lab technologists. Areas recommended for future investigation include investigating new pipette designs, improving pipette design, trialing a 3-dimensional mobile arm support, and further investigation into the work done in the biological safety cabinet. It is also recommended that laboratory science students are educated on ergonomic issues at the start of their careers. A detailed list of areas for future work is outlined in Appendix 15.

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List of Appendices

Appendix 1

Background Questionnaire
Pain Index Questionnaire
Design Importance and Satisfaction Questionnaires

BRITISH COLUMBIA INSTITUTE OF TECHNOLOGY
A POLYTECHNIC INSTITUTION

Questionnaire #1
Ergonomic Evaluation of Pipetting Workstations
Background Questionnaire

Instructions:
These questionnaires are part of a wider study aimed at identifying problems with existing pipetting procedures and developing an ergonomic pipetting workstation. There are three questionnaires. Questionnaire 1 deals with your background as a pipetter. Questionnaire 2 includes a pain index and identifies problems related to pipetting. Questionnaire 3 considers workstation design. Please answer all questions.

This questionnaire should take about 30 minutes to complete.

The information you provide will be seen only by the members of our research team and will be treated in the strictest confidence.

Contact Name:
Johanne Mattie, Neil Squire Foundation / CREATE Lab
Tel.: 604-453-4000; Email: johannem@neilsquire.ca

SUBJECT ID#______________________________
DATE:____________________________________

Every completed questionnaire improves the research findings and thereby increases the potential benefits to the users of pipetting workstations in the future.

Thanks for your help.

Please answer ALL the questions and respond by providing the information requested. Fill in the boxes where appropriate.

PERSONAL DETAILS

1. Name of employer: ____
2. Location of workplace: _____________________________________
3. Job Title: ____
4. Job Description (i.e. main job tasks): ___________________________

____

____

5. Date of birth: ☐☐ (day) ☐☐ (month) ☐☐ (year)
6. Sex: male ☐ female ☐
7. Height: ☐ ft ☐☐ in or ☐☐☐ cm
8. Hand dominance: right hand ☐ left hand ☐ no preference ☐

EMPLOYMENT DETAILS

9. On average, how many hours per week do you work in your present job (including overtime but excluding main meal break)? _______ hours

PIPETTING TASKS

10. How long have you been using pipettes? _____ years ____months
11. Within this working period, have there been any periods of longer than 1 month in the past 5 years when you did not use pipettes? ☐ yes ☐ no
12. If yes, for how long have you been using pipettes since commencing again? _____ months
13. On average, how many days each week, do you use pipettes? _____ days

14. On an average shift, how long are the sessions that you spend continuously doing pipetting work?

_______ hours

15. On average, how many such sessions of continuous pipetting work do you do during the working day?

_____ sessions

16. Please list the time and duration of the rest breaks that you take during the working day.

time of rest break	duration of break (minutes)

17.a. Do you stand or sit when doing pipetting work?

☐ stand ☐ sit ☐ bot h

17.b. If you do both, what percentage of the total time when using pipettes, do you spend standing?

______% standing

18.a. Do you do pipetting work under biological containment cabinets with fume hoods?

☐ yes ☐ no

18.b. If you do, what percentage of your total pipetting time is spent working under such cabinets?

______%

18.c. Could this work be done at an un-contained bench?

☐ yes ☐ no

19.a. Do you do pipetting work under sterile conditions?

☐ yes ☐ no

19.b. If you do, what percentage of your total pipetting time is spent working under sterile conditions?

______%

19.c. Could this work be done under non-sterile conditions? ☐ yes ☐ no

20. Please provide a brief description of the pipetting tasks that you do in the course of your work: ____

____

____

____

____

____

____

____

21. For the following pipetting tasks, do you use your right hand, left hand or either hand? Select the hand you use most of the time. Select either hand only if you have a 50/50 split between right and left handed task performance.

	right hand	**left hand**	**either hand**
volume adjustment			
application of pipette tip			
aspiration			
	right hand	**left hand**	**either hand**
dispensing			
tip ejection			

22.a. Do you wear protective gloves when using pipettes? ☐ yes ☐ no

22.b. If you do, please provide details of the type and material.

____

____

____

23. What is the maximum number of plunger "depression-release" repetitions that you do per minute? ________ reps

24. Which type(s) of pipette do you use?

manufacturer	**type**	**manual/electronic**	**volume**

25. Of your total time spent doing pipetting work, please estimate the percentage that you use a single channel as opposed to a multi-channel pipette.

Multichannel ________ % Single channel __________ %

26. If you operate multi-channel pipettes, how many channels do you employ?

_______ # of channels ☐ N/A

27. Please describe any features of plunger-operated pipettes that make them uncomfortable to use. ____

____
____
____
____

28. Do you have any suggestions for improving the design of the pipettes that you use? ____

____
____
____
____

29. Do you have any support for your pipetting arm/hand?

☐ yes ☐ no

30. Please describe any features of the following that make pipetting tasks more difficult:

a. equipment:____

____
____

b. workplace layout:____
____
____

c. work organisation:____
____
____

d. working environment:____
____

OTHER REGULAR WORK TASKS

31. Please estimate the percentage of your total working time that you spend doing pipetting and other regular work tasks, for example:

a. microscopy ____________________ %

b. administrative, clerical ______________ %

c. computer work __________________ %

d. other laboratory (specify)____________ %

______________________________%

______________________________%

other (specify)____________________ %

______________________________%

______________________________%

32. Please indicate the other tasks that you perform at your pipetting workstation.

	yes	no
a. microscopy	☐	☐
b. administrative, clerical	☐	☐
c. computer work	☐	☐

d. other laboratory (please specify):

____

____

____

____

____

e. other (please specify):

____

____

____

____

Labelling

32. Do you label vials (id. label, date, etc.)? ☐ yes ☐ no

33. How do you label?________________________________

____

34. Do you label both the vial and the cap? ☐ cap only ☐ vial only ☐ both

35. In a typical pipetting session (see question #14), how many labels would you write? _______ labels

36. a. Do you experience problems labelling? ☐ yes ☐ no

b. If yes, what is the nature of those problems?____________________

____

____

____

Lid/cap application and removal

37. In a typical pipetting session (see question #14), how many caps/lids would you apply or remove? ______ caps/lids

38. a. Do you experience problems with this activity? ☐ yes ☐ no

    b. If yes, what is the nature of those problems?____________________

    ____
    ____
    ____

39. a. Do you use a cap removal tool? ☐ yes ☐ no

    b. If yes, do you experience problems using the cap removal tool? ☐ yes ☐ no

    c. If yes, what is the nature of those problems?____________________

    ____
    ____
    ____

ACTIVITIES OUTSIDE OF WORK

5. Please specify frequency with which you participate.

Recreational Activity	**No. of hours/week**
Sport (specify):	
Housework:	
Childcare:	
Home use of computers:	
Video games:	
Crafts (specify):	
Shop activities (specify): (e.g. woodworking):	
Gardening:	
Other (specify):	

Many thanks for your help!

Questionnaire #2
Ergonomic Evaluation of Pipetting Workstations
Pain Index Questionnaire

Instructions:
These questionnaires are part of a wider study aimed at identifying problems with existing pipetting procedures and developing an ergonomic pipetting workstation. There are three Questionnaires. Questionnaire 1 deals with your background as a pipetter. Questionnaire 2 includes a pain index and identifies problems related to pipetting. Questionnaire 3 deals with workstation design. Please answer all questions.

This questionnaire should each take about 30 minutes to complete.

The information you provide will be seen only by the members of our research team and will be treated in the strictest confidence.

Contact Name:
Johanne Mattie, Neil Squire Foundation / CREATE Lab
Tel.: 604-453-4000; Email: johannem@neilsquire.ca

SUBJECT ID#_______________________________
DATE:_____________________________________

Every completed questionnaire improves the research findings and thereby increases the potential benefits to the users of pipetting workstations in the future.

Thanks for your help.

FATIGUE / ENDURANCE

1. Do you get headaches during or after a pipetting session

☐	☐	☐	☐	☐
never	rarely	more than one quarter of the time	more than half the time	almost always

2. Compared with your level of fatigue after doing other laboratory tasks (eg. microscopy, clerical etc.), on a scale of 1 to 10, how would you rate your level of fatigue after a session of pipetting?

1 2 3 4 5 6 7 8 9 10

I have much more energy ………………………………………………………… I am much more tired

3. On a scale of 1 to 10, how would you rate your level of fatigue just before you take a break during a pipetting session?

1 2 3 4 5 6 7 8 9 10

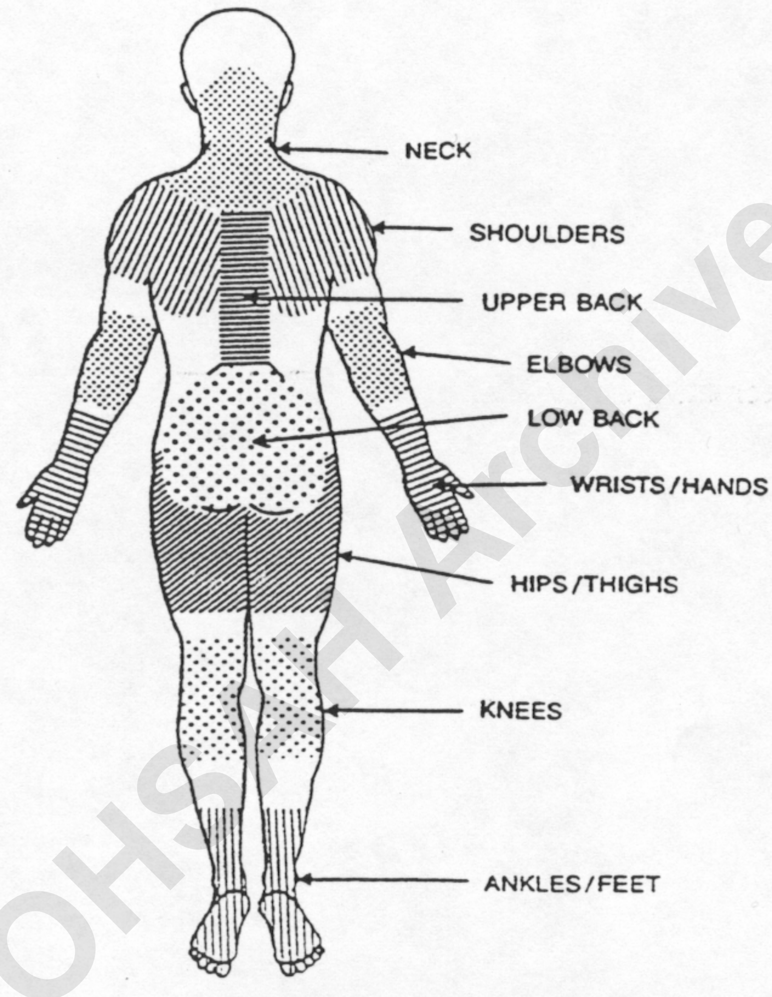
I feel like I could keep pipetting for a long time ……………………………………………………… I have to stop because I am no longer able to pipette

4. On a scale of 1 to 10, how would you rate your level of fatigue at the end of a pipetting session?

1 2 3 4 5 6 7 8 9 10

I feel like I could keep pipetting for a long time ……………………………………………………… I have to stop because I am no longer able to pipette

We are interested in mild and severe problems affecting the muscles, ligaments, nerves, tendons, joints and bones suffered both at work and away from work. This could mean sprains, strains, inflammations, irritations and dislocations, which have resulted in aches, pains, numbness, swelling, tingling, stiffness or loss of function.



This picture shows how the body has been divided. Please answer the questions shown opposite for each body area. Body sections are not sharply defined and certain parts overlap. You should decide for yourself which part (if any) is or has been affected.

MUSCULOSKELETAL DISORDERS

Please answer all questions by using tick boxes – one tick for each question. Please note that this part of the questionnaire should be answered, even if you have never had trouble in any part of your body.

During the last 12 months, on a scale of 1-10, how severe was the pain in the following joints?	Please describe the TYPE of pain (e.g. aching, stabbing, burning, numbness, swelling, tingling, pins & needles, stiffness, or loss of function…):	During the last 12 months, have you been prevented from carrying out normal activities (e.g. job, hobbies, housework) because of this trouble:
NECK: None ……………………….unbearable 1 2 3 4 5 6 7 8 9 10	NECK:	NECK: ☐ No ☐ Yes
RIGHT SHOULDER: None ……………………….unbearable 1 2 3 4 5 6 7 8 9 10 LEFT SHOULDER: None ……………………….unbearable 1 2 3 4 5 6 7 8 9 10	RIGHT SHOULDER: LEFT SHOULDER:	RIGHT SHOULDER: ☐ No ☐ Yes LEFT SHOULDER: ☐ No ☐ Yes
RIGHT ELBOW: None ……………………….unbearable 1 2 3 4 5 6 7 8 9 10 LEFT ELBOW: None ……………………….unbearable 1 2 3 4 5 6 7 8 9 10	RIGHT ELBOW: LEFT ELBOW:	RIGHT ELBOW: ☐ No ☐ Yes LEFT ELBOW: ☐ No ☐ Yes
UPPER BACK: None ……………………….unbearable 1 2 3 4 5 6 7 8 9 10	UPPER BACK:	UPPER BACK: ☐ No ☐ Yes
LOWER BACK: None ……………………….unbearable 1 2 3 4 5 6 7 8 9 10	LOWER BACK:	LOWER BACK: ☐ No ☐ Yes
RIGHT HIP/THIGH/BUTTOCK: None ……………………….unbearable 1 2 3 4 5 6 7 8 9 10 LEFT HIP/THIGH/BUTTOCK: None ……………………….unbearable 1 2 3 4 5 6 7 8 9 10	RIGHT HIP/THIGH/BUTTOCK: LEFT HIP/THIGH/BUTTOCK	RIGHT HIP/THIGH/BUTTOCK: ☐ No ☐ Yes LEFT HIP/THIGH/BUTTOCK ☐ No ☐ Yes

HAND AND WRIST DISCOMFORT

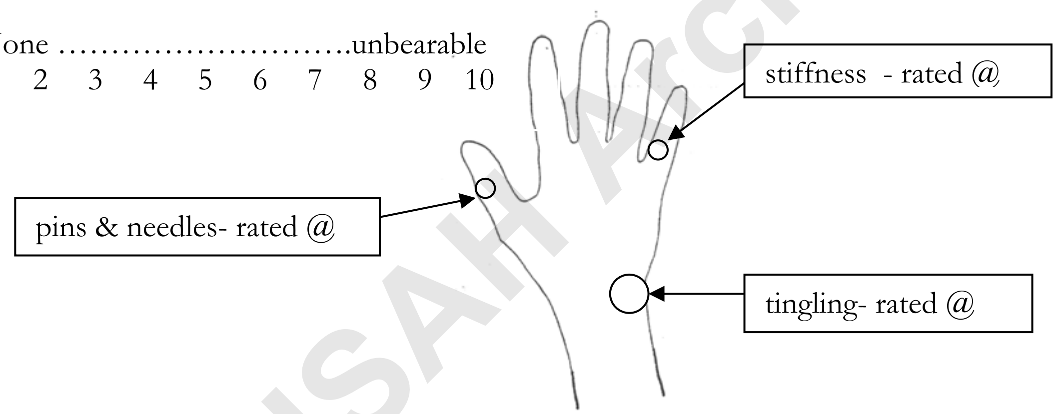
Instructions:

1. Please describe any pain (aching, stabbing, burning, pins & needles), numbness, swelling, tingling, stiffness, injuries to the hand and/or weakness of grip that you have experienced

2. On the diagrams below, mark the area(s) of the hands which are affected. Please indicate the location(s) that are affected, the type(s) of physical discomfort you feel, and a pain intensity rating from 1 to 10 (as before).

For example:

None ……………………….unbearable
1 2 3 4 5 6 7 8 9 10

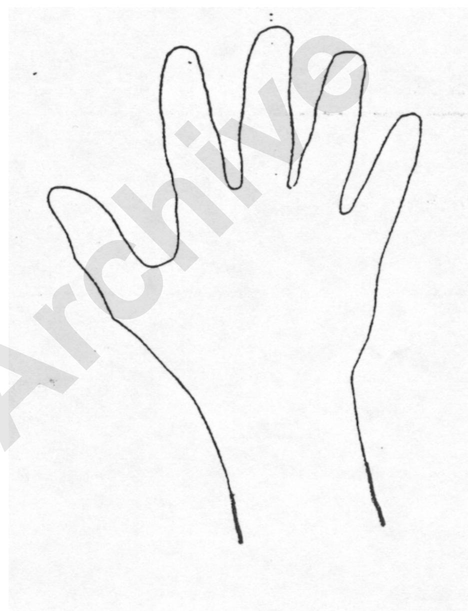


PAIN SCALE:

none ……………………………………unbearable
1 2 3 4 5 6 7 8 9 10

Back Of Hand

LEFT



RIGHT

Additional Information:

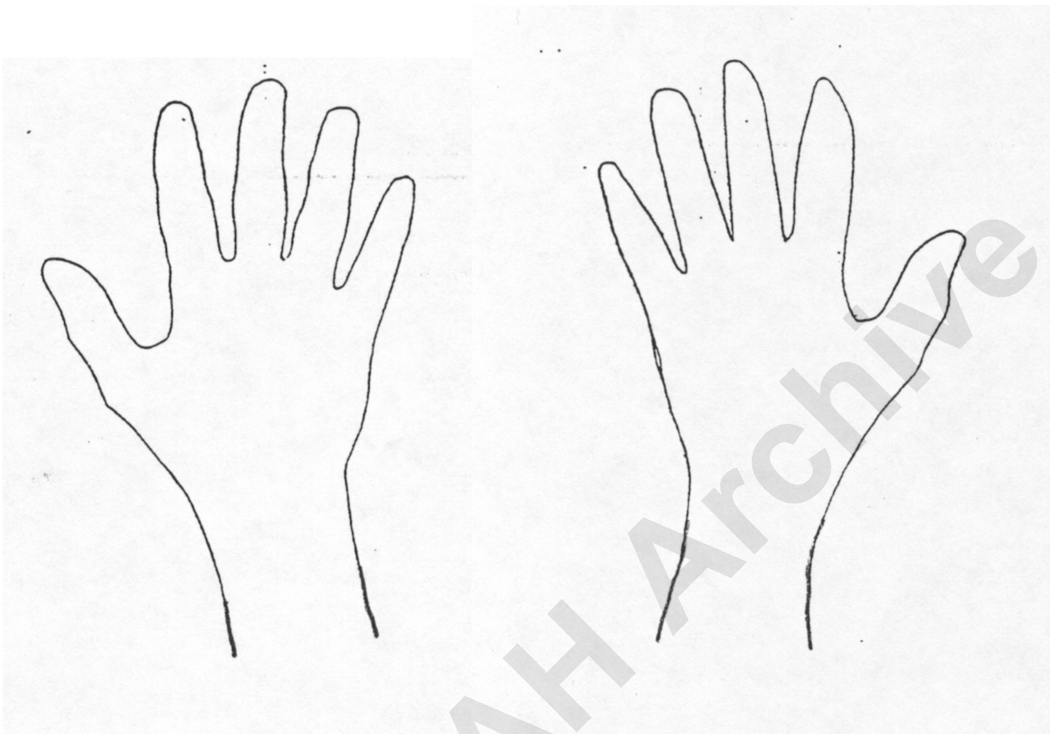
____
____
____
____
____

PAIN SCALE:

none ………………………………….unbearable

1 2 3 4 5 6 7 8 9 10

Palm Of Hand



LEFT **RIGHT**

Additional Information:

A LL M USC ULO SKELETA L DISO RDERS

5. Did the onset of any physical discomfort(s) that you have reported above, begin before you started to work with pipettes? ☐ yes ☐ no

If yes, which physical discomfort(s)?______________________________

____

____

6. Was the onset of any physical discomfort(s), that you have reported above, associated with:

   a. the performance of any specific work-related task(s)? ☐ yes ☐ no

   If yes, please provide details. ____________________________________

   ____

   ____

   b. an increase in the level of work activity? ☐ yes ☐ no

   If yes, please provide details. ____________________________________

   ____

   ____

   d. prolonged period(s) of work? ☐ yes ☐ no

   If yes, please provide details. ____________________________________

   ____

   ____

e. the performance of any specific home or recreational activities? ☐ yes ☐ no

If yes, please provide details. ____________________________________

____

____

7. In response to any of the above, have you had to change jobs or duties because of any physical discomforts that you have reported above? ☐ yes ☐ no

   If yes, please provide details. ____________________________________

   ____

   ____

   ____

   ____

8. Are there any other causes or factors (either related to work or un-related to work) which you feel could have initiated the physical discomforts? ☐ yes ☐ no

   If yes, please provide details. ____________________________________

   ____

   ____

   ____

   ____

Many thanks for your help!

BRITISH COLUMBIA
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Questionnaire #3
Pipetting Workstation Design Input Questionnaire
Part A :PIPETTE WORKSTATIONS IN GENERAL

Instructions:
These questionnaires are part of a wider study aimed at identifying problems with existing pipetting procedures and developing an ergonomic pipetting workstation. There are three questionnaires. Questionnaire 1 deals with your background as a pipetter. Questionnaire 2 includes a pain index and identifies problems related to pipetting. Questionnaire 3 considers workstation design. Please answer all questions.

This questionnaire should take about 10 minutes to complete.

The information you provide will be seen only by the members of our research team and will be treated in the strictest confidence.

Contact Name:
Johanne Mattie, Neil Squire Foundation / CREATE Lab
Tel.: 604-453-4000; Email: johannem@neilsquire.ca

SUBJECT ID#______________________________
DATE:____________________________________

Every completed questionnaire improves the research findings and thereby increases the potential benefits to the users of pipetting workstations in the future.

Thanks for your help.

PART A

Please answer the following questions about PIPETTE WORKSTATIONS IN GENERAL

Please rate how IMPORTANT each of the particular design/workstation features are to you based on the following scale:

1=Very Important
2=Quite Important
3=Neutral
4=Quite Unimportant
5=Very Unimportant

1. PRIMARY WORK BENCH	very important	quite important	neutral	quite unimportant	very unimportant
	1	2	3	4	5
a) Height of the primary work counter					
b) Depth of the primary work counter					
c) Overall space available to conduct pipette tasks on primary work counter					
d) Leg (thigh,knee, and feet) space under primary work counter					
e) Material primary work counter is made of					
f) Space for storing pipette work-related items					
g) Adjustability					

2. PRIMARY WORK CHAIR / STOOL (if applicable)	very important	quite important	neutral	quite unimportant	very unimportant
	1	2	3	4	5
h) Size (width & depth) of the seat					
i) Firmness of the seat					
j) Size (width & height) of back					
k) Firmness of the back					
l) Height (from floor to seat)					
m) Contains arm rests					
n) Has "adjustability" for seat & back					
o) Has rollers or casters					
p) Type of material (upholstery) on the chair					
q) Adjustability for height					

3. MACRO or AMBIENT WORKSTATION FEATURES	very important	quite important	neutral	quite unimportant	very unimportant
	1	2	3	4	5
r) Proper task lighting					
s) Visual privacy (from other workers/workstations)					
t) Easy access to other pipette related work spaces (other than primary work counter)					
u) Auditory privacy (noise from any sources)					
v) Overall effectiveness of workstation					
w) Overall comfort of workstation					
x) Floor surface					

4. Please describe any additional features of pipetting workstations that you feel are particularly IMPORTANT.

Thanks for your help!

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Questionnaire #3
Pipetting Workstation Design Input Questionnaire
Part B: CURRENT PRIMARY PIPETTE WORKSTATION

Instructions:
These questionnaires are part of a wider study aimed at identifying problems with existing pipetting procedures and developing an ergonomic pipetting workstation. There are three questionnaires. Questionnaire 1 deals with your background as a pipetter. Questionnaire 2 includes a pain index and identifies problems related to pipetting. Questionnaire 3 considers workstation design. Please answer all questions.

This questionnaire should take about 10 minutes to complete.

The information you provide will be seen only by the members of our research team and will be treated in the strictest confidence.

Contact Name:
Johanne Mattie, Neil Squire Foundation / CREATE Lab
Tel.: 604-453-4000; Email: johannem@neilsquire.ca

SUBJECT ID#______________________________
DATE:___________________________________

Every completed questionnaire improves the research findings and thereby increases the potential benefits to the users of pipetting workstations in the future.

Thanks for your help.

PART B

Please answer the following questions about your CURRENT PRIMARY PIPETIE WORKSTATION.

Please rate how SATISFIED you are with each of the particular design/workstation features on the following scale:
1=Very Satisfied
2=Quite Satisfied
3=Neutral
4=Quite Unsatisfied
5=Very Unsatisfied

1. PRIMARY WORK BENCH	very satisfied	quite satisfied	neutral	quite unsatisfied	very unsatisfied
	1	2	3	4	5
a) Height of the primary work counter					
b) Depth of the primary work counter					
c) Overall space available to conduct pipette tasks on primary work counter					
d) Leg (thigh,knee, and feet) space under primary work counter					
e) Material primary work counter is made of					
f) Space for storing pipette work-related items					
g) Adjustability					

2. **PRIMARY WORK CHAIR / STOOL (if applicable)**	very satisfied	quite satisfied	neutral	quite unsatisfied	very unsatisfied
	1	2	3	4	5
h) Size (width & depth) of the seat					
i) Firmness of the seat					
j) Size (width & height) of back					
k) Firmness of the back					
l) Height (from floor to seat)					
m) Arm rests (if applicable)					
n) "Adjustability" of seat & back					
o) Rollers or casters (if applicable)					
p) Material (upholstery) on the chair					
q) Adjustability for height					

3. **MACRO or AMBIENT WORKSTATION FEATURES**	very satisfied	quite satisfied	neutral	quite unsatisfied	very unsatisfied
	1	2	3	4	5
r) Task lighting					
s) Visual privacy (from other workers/workstations)					
t) Access to other pipette related work spaces (other than primary work counter)					
u) Auditory privacy (noise from any sources)					
v) Overall effectiveness of your workstation					
w) Overall comfort of your workstation					
x) Overall design of your workstation					

4. Please describe any additional features of the experimental workstation that you are particularly SATISFIED with.

5. Please describe any additional features of the experimental workstation that you are particularly UNSATISFIED with.

6. Have you any suggestions for improvements to the experimental pipetting workstation design?

Thanks for your help!

BCIT® BRITISH COLUMBIA INSTITUTE OF TECHNOLOGY
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Questionnaire #3
Pipetting Workstation Design Input Questionnaire
Part C: EXPERIMENTAL PIPETIE WORKSTATION

Instructions:
These questionnaires are part of a wider study aimed at identifying problems with existing pipetting procedures and developing an ergonomic pipetting workstation. There are three questionnaires. Questionnaire 1 deals with your background as a pipetter. Questionnaire 2 includes a pain index and identifies problems related to pipetting. Questionnaire 3 considers workstation design. Please answer all questions.

This questionnaire should take about 10 minutes to complete.

The information you provide will be seen only by the members of our research team and will be treated in the strictest confidence.

Contact Name:
Johanne Mattie, Neil Squire Foundation / CREATE Lab
Tel.: 604-453-4000; Email: johannem@neilsquire.ca

SUBJECT ID#______________________________
DATE:____________________________________

Every completed questionnaire improves the research findings and thereby increases the potential benefits to the users of pipetting workstations in the future.

Thanks for your help.

PART C

Please answer the following questions about the EXPERIMENTAL PIPETTE WORKSTATION YOU WERE EXPOSED TO IN THE LIVING LABORATORY.

Please rate how SATISFIED you are with each of the particular design/workstation features on the following scale:
1=Very Satisfied
2=Quite Satisfied
3=Neutral
4=Quite Unsatisfied
5=Very Unsatisfied

1. PRIMARY WORK BENCH	very satisfied	quite satisfied	neutral	quite unsatisfied	very unsatisfied
	1	2	3	4	5
a) Height of the primary work counter					
b) Depth of the primary work counter					
c) Overall space available to conduct pipette tasks on primary work counter					
d) Leg (thigh,knee, and feet) space under primary work counter					
e) Material primary work counter is made of					
f) Space for storing pipette work-related items					
g) Space for storing items used for tasks other than pipetting					
g) Adjustability					

2. PRIMARY WORK CHAIR / STOOL (if applicable)	very satisfied	quite satisfied	neutral	quite unsatisfie	very unsatisfie

	1	2	3	4	5
h) Size (width & depth) of the seat					
i) Firmness of the seat					
j) Size (width & height) of back					
k) Firmness of the back					
l) Height (from floor to seat)					
m) Arm rests (if applicable)					
n) "Adjustability" of seat & back					
o) Rollers or casters (if applicable)					
p) Material (upholstery) on the chair					
q) Adjustablility for height					

3. MACRO or AMBIENT WORKSTATION FEATURES	very satisfied	quite satisfied	neutral	quite unsatisfied	very unsatisfied
	1	2	3	4	5
r) Task lighting					
s) Visual privacy (from other workers/workstations)					
t) Access to other pipette related work spaces (other than primary work counter)					
u) Auditory privacy (noise from any sources)					
v) Overall effectiveness of this workstation					
w) Overall comfort of this workstation					
x) Overall design of this workstation					

4. Please describe any additional features of your existing workstation that you are particularly SATISFIED with.

5. Please describe any additional features of your existing workstation that you are particularly UNSATISFIED with.

6. Have you any suggestions for an ergonomic pipetting workstation?

Thanks for your help!

Appendix 2 - Design Criteria

Pipette Study-Design Criteria

Wednesday, 04 September 2002

Areas of Concern:

- sitting for long periods of time on a task stool (feet supported on ring)
- lifting upper arm in from of the body (upper arm flexion)
- head and arms held in a forward position with the shoulders rounded forward
- abduction of arm out to side of body
- neck flexion
- stabilization of the arm in mid-air
- excessive pronation and supination
- contact stress
- the task of pipetting
- REACH AND VISUAL ACCESS

Concerns	Design Criteria	Would be nice
<u>Chair</u> • awkward postures are adopted • neutral postures are difficult to maintain • difficult to fit to workstation height • difficult to adjust chair to different working heights • chair controls may not be self-explanatory • foot position is a concern • inadequate adjustable back support • non-adjustability of arm supports	<u>Chair</u> • use of adjustable chairs or ergonomically designed stools with height, back and seat pan adjustments • must have castors; lockable • chair must have 5 legs • the leg span on the chair must be a minimum of 15 inches. • seat height must be adjustable from 19 inches to 30 inches from the seat reference pan (SRP) • full seat depth must be 15 inches - 17 inches • width of the seat pan must be greater than or equal to 18 inches • seat pan angle should be adjustable from -5 degrees to +15 degrees • front edge of the seat must be rounded ("waterfall edge"). • backrest must be adjustable in height from 7-10" from SRP to the peak of the lumbar support • backrest must be 15-21" in height above the SRP. • backrest should adjust horizontally from 15- 17" from the front of the seatpan and it should be possible to lock it in place	<u>Chair</u> • all adjustments (seat height, backrest height, seat angle, & backrest angular movement) must be easily performed from a seated position • adjustment levers should be differentiated from one another by shape or texture • seat pan and backrest should be covered with cushioning that compresses to between 0.5 inches and 1 inch • seat pan must be covered with 1 inch of compressed padding • cushioning must have minimal contours. • tilt tension with lock control should be available on the back • provide recommendations for a specific chair or stool for this type of work • instructions on how to adjust the chair must be afixed to each chair • staff inservices on adjusting chairs • sit back in chair to keep back supported • regular stretch breaks

	• backrest must be 12 inches to 19 inches in width • backrest must curve horizontally and vertically to give a lumbar support with a maximum indentation of 1.5 inches.	• add industrial height footstool to the work area if a stool is used •
<u>Lab bench/Worksurface</u> • fixed height bench used to accommodate standing and sitting • fixed height bench used to accommodate wide range of heights (4'11"- 6'5") • chair is raised to work at the lab bench resulting in inadequately support lower extremities • different widths of lab benches (some require significant reach to get the things at the back) • minimal undercounter accessibility • glossy dark surfaces • contact stresses on edges of workbench	<u>Lab bench/Worksurface</u> • modular workstations on lockable castors that can be adapted to different layouts/ tasks • height adjustable: electric or crank (electric would be preferred) • high-gloss worksurface should be avoided • rounded edges on worksurface to avoid contact stress • several power sources required • focus on frequency of use placement of materials • clear space under the worksurface for knees • worksurface height should be adjustable between 34 –38" (ideal range 21-48.5") • worksurface depth should be a minimum of 30 inches	<u>Lab bench/Worksurface</u> • change in design – crescent shaped, cut-out or U-shaped placing everything within reach • width adjustable – a work area that can be slid forward and angled? • increase the amount of workspace • provide articulating or cantilevered shelves • try different colour overlays for worksurface in Living Lab? dark gray? • possibly have different coloured vinyl(?) surfaces to be used as backdrop for different tasks • pipetting plinth? or have pipetting surface lower?
<u>Equipment/Material access</u> • large task and equipment variety among different pipetting functions • variability throughout week • too many things on the lab bench • too many things in difficult to reach positions • placement of waste receptacle varied (some high and some low) • placement of materials often seemed awkward • switching between pipettes common in a given task • different pipette tips required for different pipettes • many notes, files, and schedules which need to be readily accessible to lab techs	<u>Equipment/Material access</u> • copy holder/paper clip for holding worksheets/protocols (gooseneck?) • shelving should be at a maximum height of 39 inches above the SRP • depth of shelving should be no more than12 to 15 inches	<u>Equipment/Material access</u> • focus on frequency of use placement of materials – articulating shelves, cantilevered trays • placement of items within easy reach • built in waste receptacle (consider left and right handed users) • left/right sequencing addressed by convertible recesses that could be used for tips or waste depending on left or r. handed user • also include recess for vortex mixer? • review of heights of objects • try and maintain access to equipment at a constant height • lazy susans • carousel for pipettes • carousels for trays and tubes?? • provide angled tube racks to allow easier access – these would have to maintain tubes in vertical position?? • have adjustable position for timer(s) (gooseneck?)

• timer critical for a lot of tests • access to water and sink required		• alternative signal for timer to alert tech to different tasks? visual? auditory?
Computer access • poor computer workstations • holding pen or other objects when keyboarding • awkward positions when keyboarding • scanning of samples required in some labs	Computer access • make sure user has room for legs under the computer • build computer access into workstation as it plays an important role for most labs • monitor should be on a monitor support stand above the workstation at eye height, 28 to 30 inches above SRP • keyboard should be built into the workstation and be able to be pulled out as required • if computer work is done as a separate task it should be done at a standard computer workstation	Computer access • principles of office computer ergonomics apply • do not keyboard with something in the hands • maintain neutral posture • adjustable monitor support so monitor can be higher /out of the way when being used infrequently and to eye height when required • movable computer keyboard that can be tucked away (under cut-out?) when not in use • consider layout for scanning tasks
Storage access • high storage requirement		Storage access • review work tasks to determine appropriate storage • sliding/pull out shelves • roll-away under counter shelving (for knee space when required) • have lowest bench-top shelf adustable with table height interchangeable modular units with or without shelves
Postural Issues • shoulders hunched • head bent forward • arms elevated; "winged" elbows • wrists bent • fine visual accuity necessary • poor awareness of correct posture • inadequate attention to placement of materials	Postural Issues • provide footstool for standing… or open bottom shelf?	Postural Issues • postural training • focus on neck, back and shoulder alignment • focus on frequency of use placement of materials – articulating shelves • anti-fatigue mats may be a problem for rolling chair – consider anti-fatigue soles for shoes • knee and toe space (10") required
Lighting • lack of task lighting • complaints regarding fluorescent lighting	Lighting • provide adequate dedicated task lighting	Lighting • full spectrum lighting preferred (esp. with colour rendering) • parabolic louvre for task lighting to direct light and reduce glare • provide opportunities for day light

Noise • complaints of noise from freezers, centrifuges and other work areas		Noise • consideration should be paid to noise level and type of noise
Temperature • complaints of cold temperatures and fluctuation in temperatures		Temperature • maintain consistent temperature conducive to work that is carried out
Workplace layout • difficulty with too many things going on in an areas • lack of space • old equipment		Workplace layout • dedicated task areas • create functional space for the tasks to be carried out – review annually • purchase updated equipment
Other • training and habit-changing will be a big challenge		Other • frequently change task • avoid overtime • avoid compressed work weeks • staff education regarding other home and personal activities that may cause or exacerbate the problems • consider providing training to student lab techs at BCIT
Pipetting • significant problems observed with the pipetting task		Pipetting • pipette suspended holder??

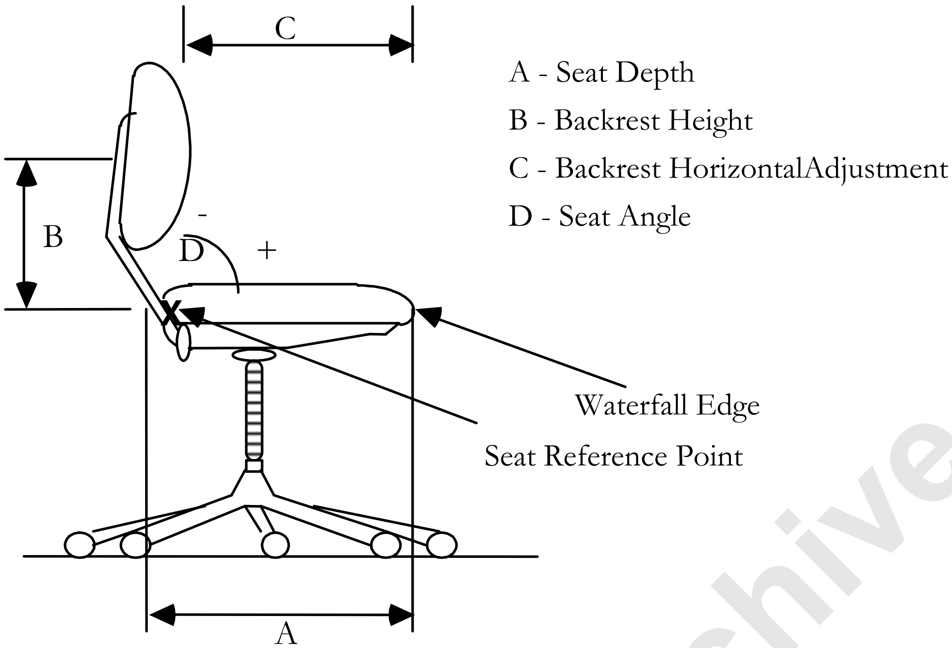
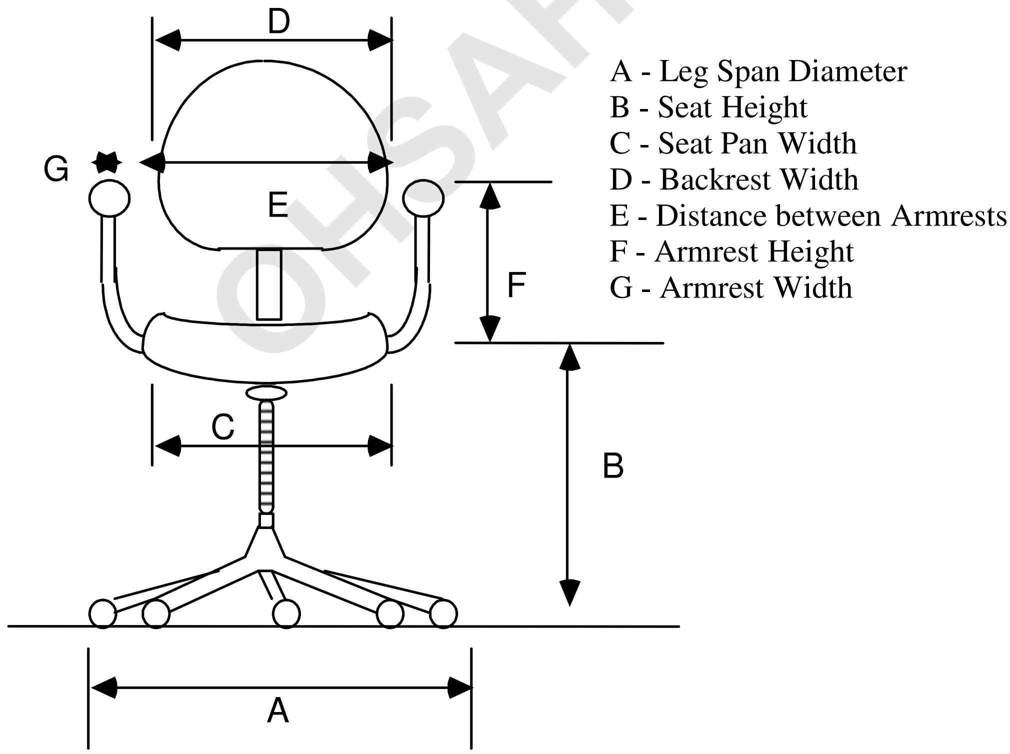
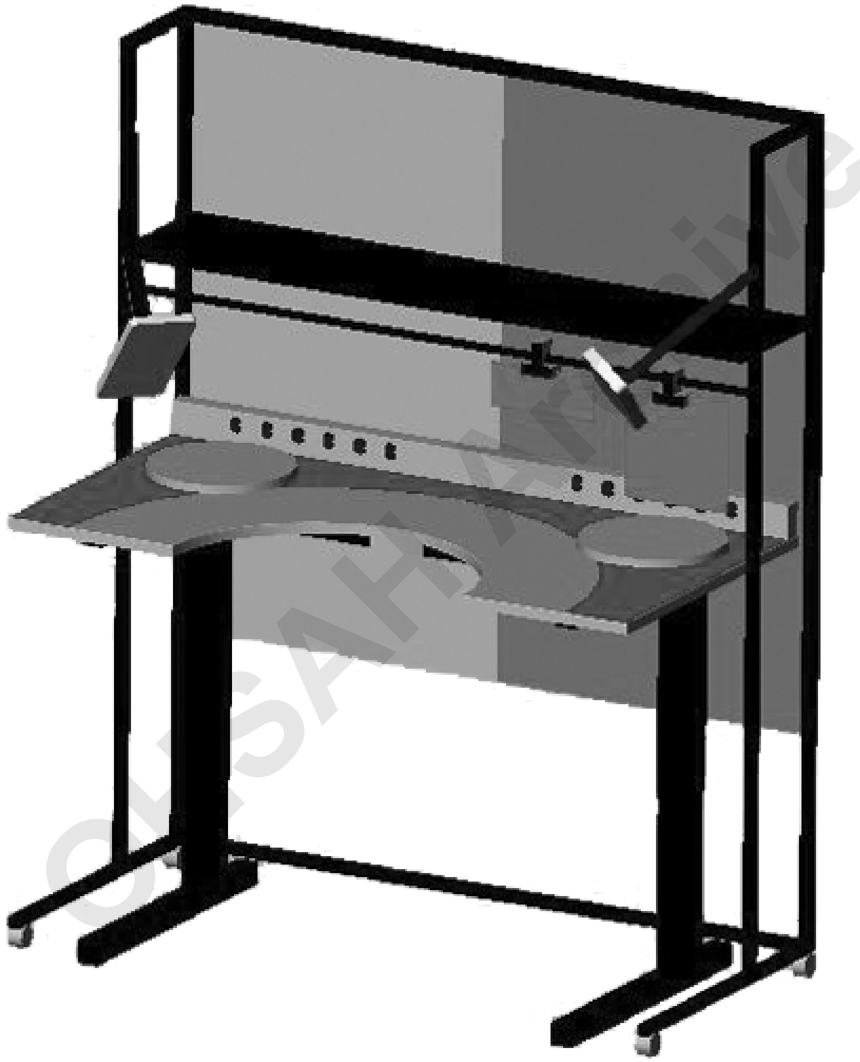


Figure 1: Side View of Chair



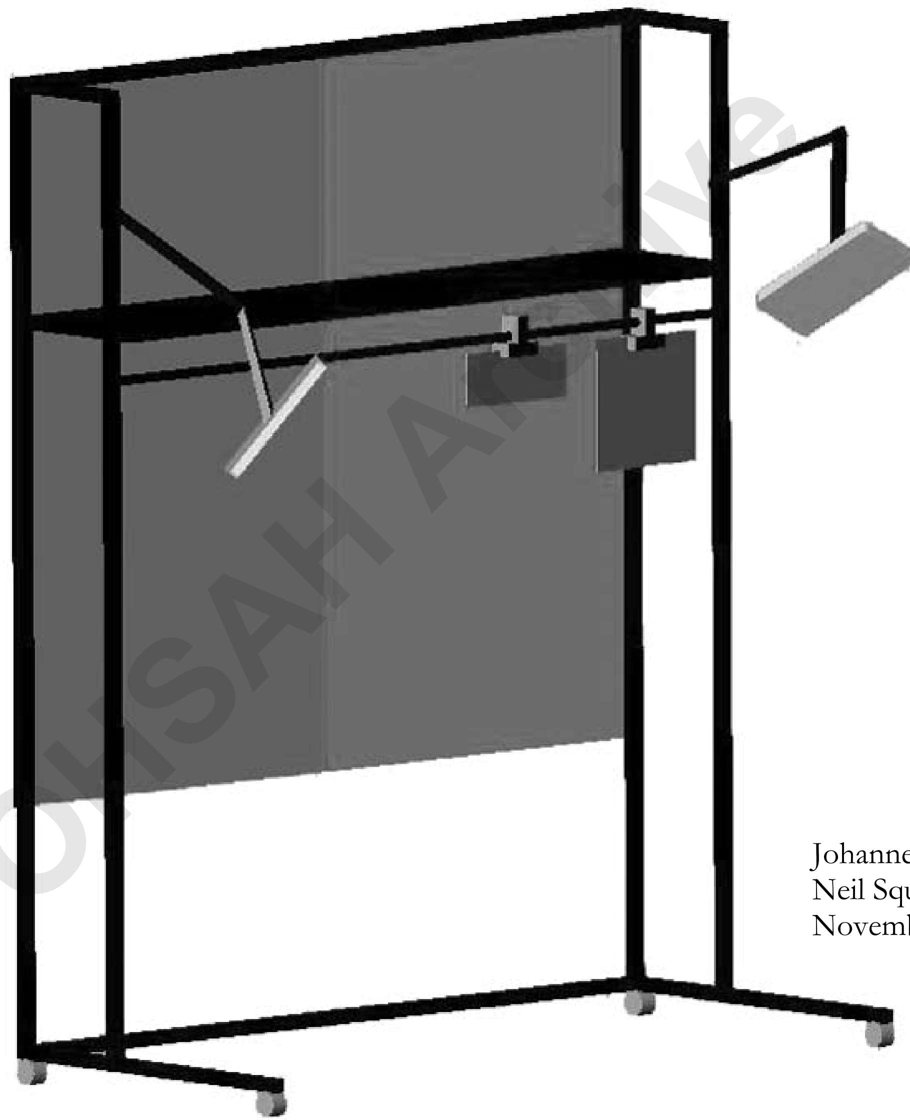
Appendix 3 - Experimental Workstation Drawings

Ergonomic Pipetting Workstation



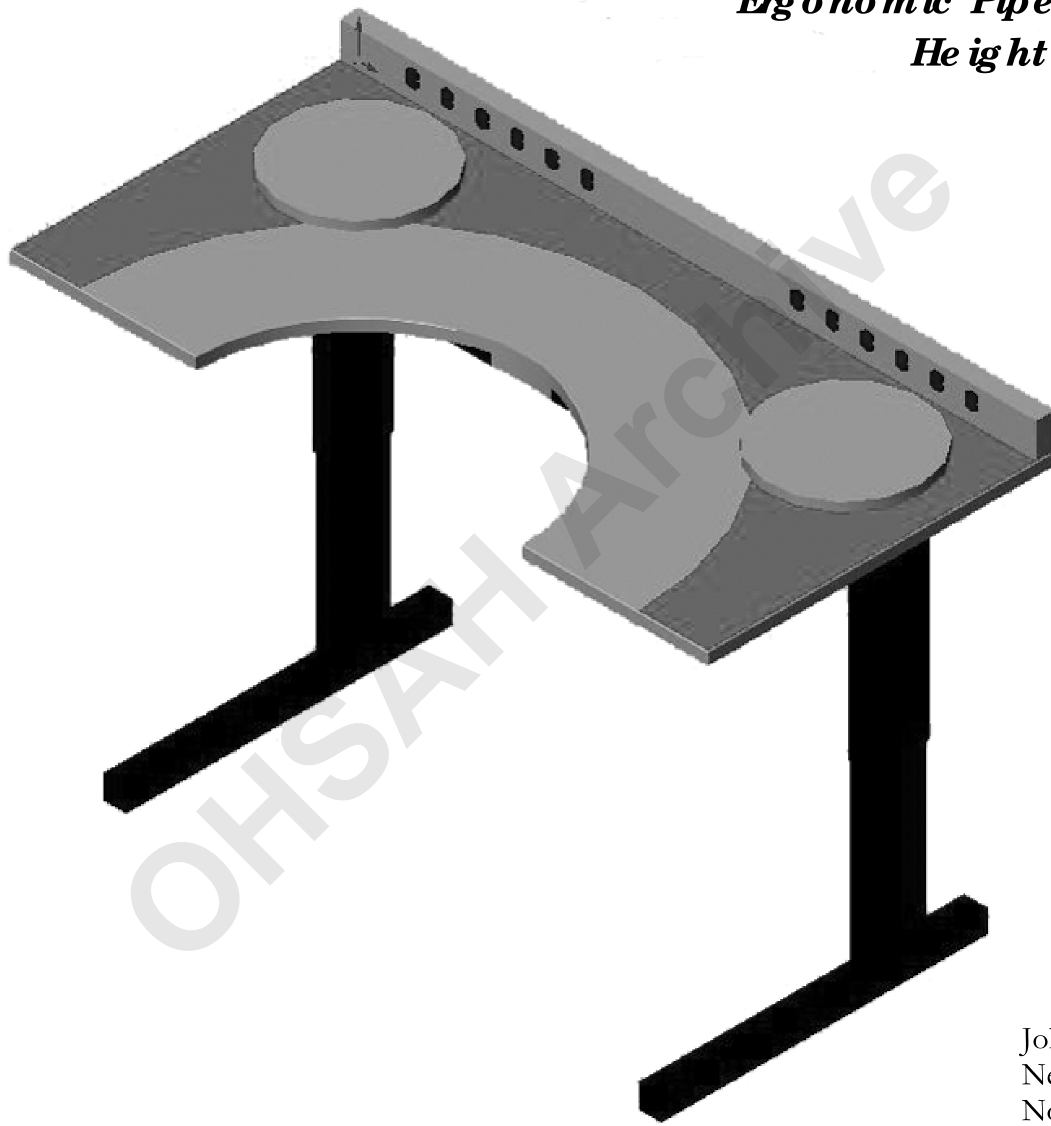
Johanne Mattie
Neil Squire Foundation/CREATE
November 28, 2002

Ergonomic Pipetting Workstation - Frame



Johanne Mattie
Neil Squire Foundation/CREATE
November 28, 2002

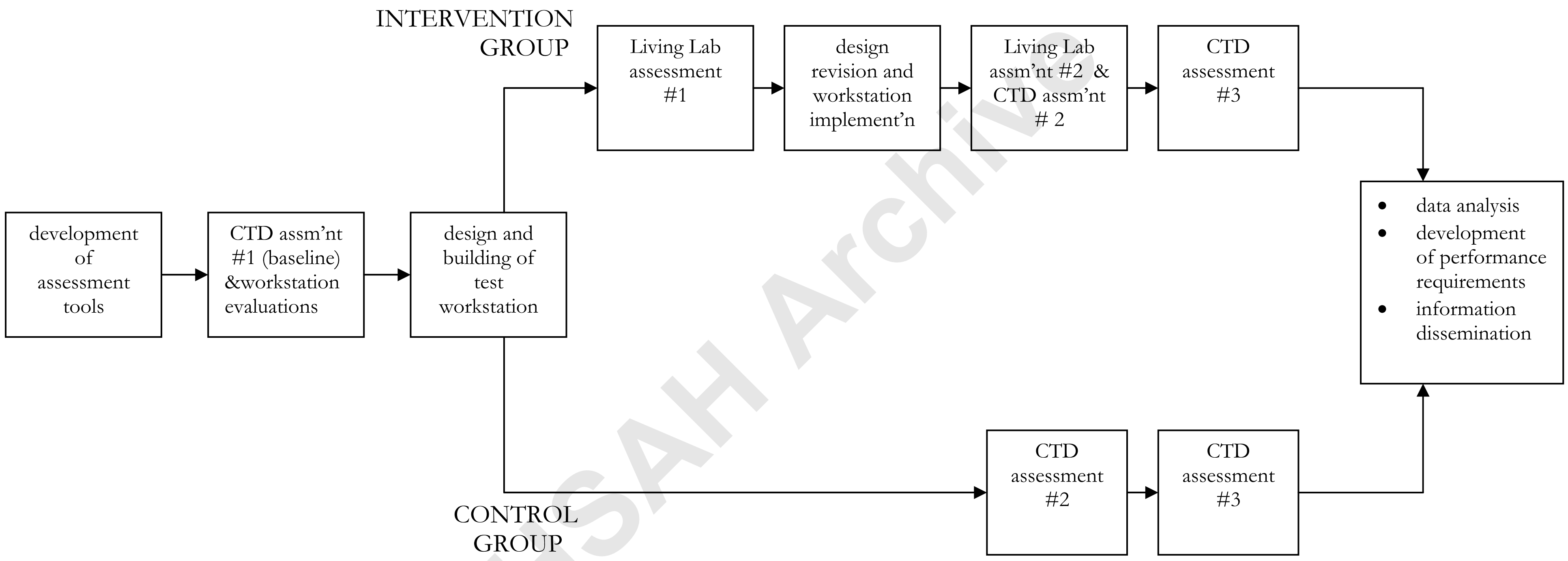
Ergonomic Pipetting Workstation
Height Adjustable Table



Johanne Mattie
Neil Squire Foundation/CREATE
November 28, 2002

Appendix 4 - Research Design Schedule of Events

PIPETIE RESEAR CH SHEDULE O F EV ENTS



Appendix 5 - Ergonomic Reminder Sheet

Getting your workspace set-up!

September 2003
Lab Workstation Project

Reminders

1 Take time to set-up properly.

2 Adjust your chair/stool to fit you comfortably.

3 Adjust the workstation height to the task you are carrying out.

4 Use the swivel in your chair to reduce body twisting.

5 Change working positions frequently.

6 Always face the object of work.

7 Keep your body close to your work

8 Keep trays and other supplies that you use frequently in close reach.

9 Adjust the workstation or your chair to avoid working with your arms elevated.

10 Take regular breaks

Neil Squire Foundation
Suite 220 – 2250 Boundary Road
Burnaby, BC V5M 3Z3
Tel: 604-473-9363

The adjustable lab workstation your are now using is designed to let the worker sit and carry out their duties in comfort while allowing for voluntary changes in their working position.

There are three contact areas in the workspace that affect the worker's posture: the seat, the work surface (the lab benchtop) and the floor. To ensure the most comfortable posture possible, two of these factors have to be adjustable.

Adjusting Your Chair/Stool

Always assume a proper sitting or standing neutral posture. When sitting, use only an adjustable stool or chair with built-in foot and arm rests to insure you have lower back, thigh, and feet support. If leg clearance is not available, workbench must not be used for work requiring use of a stool. Otherwise, create legroom under the bench by removing drawers

This is not a good seated posture!

Hopefully you have **a fully adjustable chair or stool.** This project is providing you with the other, and perhaps the most preferable option, a fully adjustable lab workstation.

A basic rule of ergonomics is that there is no such thing as an "average" person. To facilitate differences, fully adjustable chairs/stools are provided that can accommodate a maximum range of people.

Options that should be available on your chair/stool:

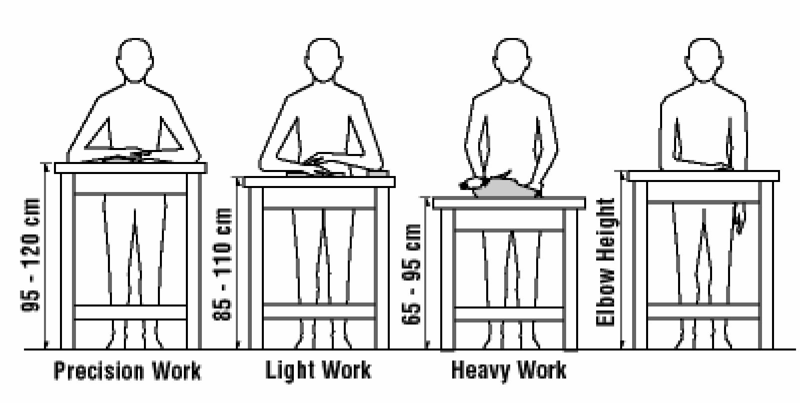
- The controls can be operated from a seated position.
- Adjustments can be made in height and tilt.
- There are ways to avoid pressure at the back of the thighs or knees.
- The backrest should support the lower back.
- A stable five-point base should be a feature.
- Wheels or casters are necessary.
- The swivel mechanism should be working.
- A foot ring should be available with a stool.

The chair/stool should be adjusted to **have the seat height approximately 25** – 35 cm (about 10 – 14 in.) below the work surface.

Adjusting Your Workstation

The workstation you are using is height adjustable (the height can be easily changed). This enables you to match the workstation to your individual body size and to the particular task you are carrying out

Setting workstation heights



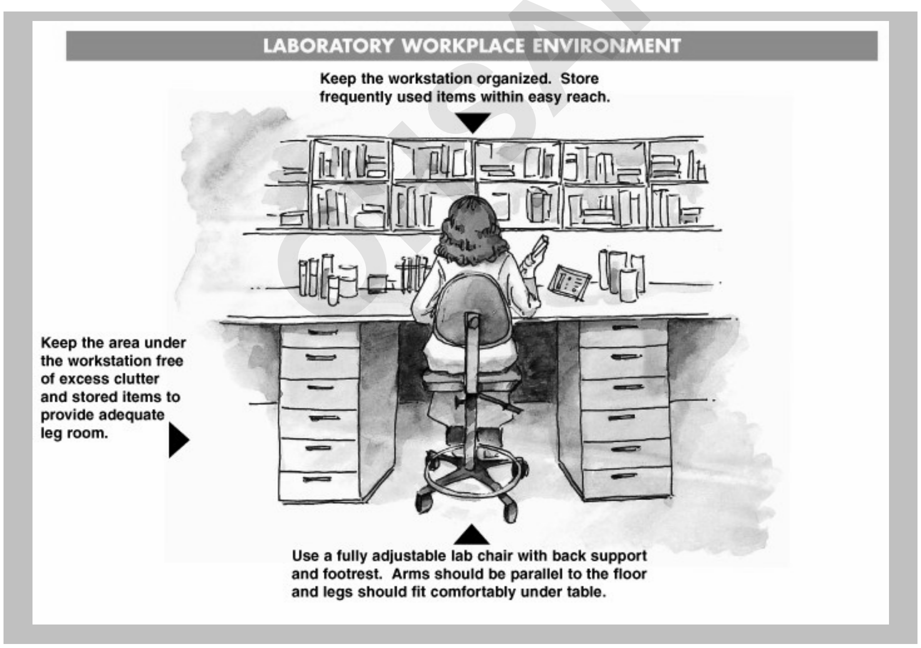
Different tasks require different work surface heights:

- Precision work should be approximately 5 cm (2") above elbow height 95 – 120 cm from floor (37" – 47")
- Light work – approximately 5 – 10 cm. Below elbow height 85 – 110 cm (33" – 43")
- Heavy work – from 20 – 40 cm. below elbow height 65 – 95 cm. (26" – 37")

Pre-setting working heights on the lab workstation

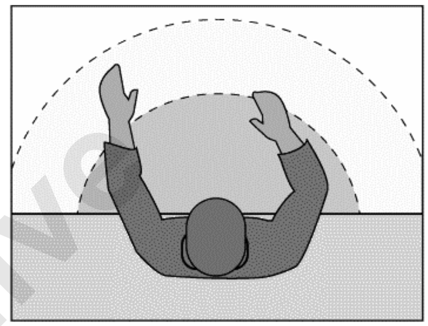
Working heights can be pre-set for certain tasks such as: pipetting, paper work, other lab work and set-up/clean up. You need to determine a maximum of four working heights.

Instructions for programming the workstation have been demonstrated and can be reviewed by reading the attached information



Pre-setting working heights on the lab workstation

Organization of the workspace is very important. Think about the frequency of use concept – keep the items you use most frequently within your reach envelope. Keep samples and instruments within easy reach.



Forearm support - use the forearm support to support and reduce static load on the upper limbs. This is particularly helpful if the arms must be elevated for lengthy periods.

Turntable - Place items that you need, but use less frequently on the turntables. This will allow you to access items readily when you need them.

Items located on the Shelving – place items on the shelving area that are only used occasionally. Avoid reaching.

Thank you for taking time to particpate in this project.

If you have questions please contact:

Johanne Mattie – 604-453-4000
Katrina Tilley – 604-473-9363

Appendix 6 - Postural Consultation Reports

Neil SQUIRE FOUNDATION

EDUCATION, TECHNOLOGY AND CAREER DEVELOPMENT FOR PEOPLE WITH PHYSICAL DISABILITIES.

Ergonomic/Postural Consultations for the Lab Workstation Project

Adjustable height customized lab workstations were installed at the following sites in August 2003:

- Burnaby General Hospital – Blood Bank
- BC Cancer Institute – Molecular Genetics Lab
- St. Paul's Hospital – Immunology Department

Arrangements were made for Katrina Tilley, Occupational Therapist with the Neil Squire Foundation, to visit each participant site and to carry out a brief ergonomic/postural consultation of the lab workstation.

A handout was prepared outlining the steps to consider when getting set-up at the lab workstation to carry out tasks. Topics covered in the consultation included:

- Setting the work area up
- Correctly adjusting the chair/stool to support the individual carrying out the task
- Correctly adjusting the height of the work surface depending on the task being carried out
- An overview of ergonomic and postural considerations related to reaching, repetitive tasks, computer related tasks, etc.
- An overview of using the ergonomic items provided with the lab workstation such as: Ergorest arm supports, footrest, book holder, task lighting, etc.

Ergonomic/Postural Consultations for the Lab Workstation

The following information was collected at each site:

Burnaby General Hospital – Blood Bank

Visited on September 5, 2003

Ergonomic/Postural Consultation with Lynne Vanderkooy

Situation:

- Single user set-up
- Lab technician prefers to stand to work
- Anti-fatigue mat in place
- Ardent office chair available to for sitting
- Chair adjustment demonstrated

Burnaby General Hospital – Blood Bank	
Concerns	**Solutions**
Placement of the book stand (interfered with people walking by).	This was re-positioned to the right side of the work area. Numerous positions were tried and the far right set-up worked well.
Positioning of the Ergorest Arm Support (where to put it and how to use it). Lab technician was instructed on how to set the Ergorest up for specific tasks. One support was used.	Lab technician was recommended to set-up the Ergorest for suitable tasks and remove it when not required.

Burnaby General Hospital – Blood Bank	
Concerns	**Solutions**
The level of light output provided by the under mount light and the halogen side lamps was not adequate.	Provide this information to the R&D team. It may be necessary to review the type of light used and the positioning of light to avoid shadow creation.
Having a solid area to write without blocking the visual contact with others in the lab.	Recommended using a clipboard to support the paper work on the shelf hanger or using the bookstand for clipping and writing.
Not sure about the use of the footstool. Criteria for using the footstool were outlined. Use of the footstool was demonstrated from a standing position alternating placing left and right foot on the stool.	Recommended to use personal comfort judgment with the use of the footstool. Not necessary for some people depending on the seated position.

BC Cancer Institute – Molecular Genetics Lab
Visited on September 5, 2003
Ergonomic/Postural Consultation with Michelle Anderson

Situation:

- Multi-user set-up
- Lab technicians prefers to sit to work
- Ardent office chair available to for sitting
- Chair adjustment demonstrated

BC Cancer Institute – Molecular Genetics Lab	
Concerns	**Solutions**
Placement of the book stand (interfered with people walking by).	Attempts were made to re-position this so that the clamp was closer to the wall (to avoid bumping into it). This did not allow for adequate adjustment and placement of the book holder. It may be beneficial to have a smaller piece of plexiglass. Provide this information to the R&D team.
Positioning of the Ergorest Arm Support (where to put it and how to use it). Lab technician demonstrated using the Ergorest with her right forearm, however she preferred to place her elbow in the forearm pad and use it as a pivot.	Lab technician was requested not to use the Ergorest as a pivot from the elbow due to concerns of damage to the nerves at the elbow joint. Agreed to provide this information to the R&D team. It may be necessary to customize the Ergorest to allow for the forearm elevation movement.
The level of light output provided by the under mount light and the halogen side lamps was not adequate.	Provide this information to the R&D team. It may be necessary to review the type of light used and the positioning of light to avoid shadow creation.
Not sure about the use of the footstool. Criteria for using the footstool were outlined. Use of the footstool was demonstrated from a standing position alternating placing left and right foot on the stool.	Recommended to use personal comfort judgment with the use of the footstool. Not necessary for some people depending on the seated position.
Limited space for setting up all that needs to be done.	Agreed that more time needed to be provided to trying the workstation to determine if work tasks can be set-up differently within the space provided.

St. Paul's Hospital – Immunology Department
Visited on September 9, 2003
Ergonomic/Postural Consultation with Alison Reid

Situation:

- Multi-user set-up
- Lab technicians prefer to stand and/or stand to work
- Office chair available to for sitting
- Chair adjustment demonstrated

St. Paul's Hospital – Immunology Department	
Concerns	**Solutions**
Positioning of the Ergorest Arm Support (where to put it and how to use it). A Lab technician demonstrated using the Ergorest with his right forearm. He also preferred to place his elbow in the forearm pad and use it as a pivot.	The lab technicians were requested not to use the Ergorest as a pivot from the elbow due to concerns of damage to the nerves at the elbow joint. Agreed to provide this information to the R&D team. It may be necessary to customize the Ergorest to allow for the forearm elevation movement.
The level of light output provided by the under mount light and the halogen side lamps was not adequate.	Agreed to provide this information to the R&D team. It may be necessary to review the type of light used and the positioning of light to avoid shadow creation.
Not sure about the use of the footstool. Criteria for using the footstool were outlined. Use of the footstool was demonstrated from a standing position alternating placing left and right foot on the stool.	Recommended to use personal comfort judgment with the use of the footstool. Not necessary for some people depending on the seated position.
Limited space for setting up all that needs to be done.	Agreed that more time needed to be provided to trying the workstation to determine if work tasks can be set-up differently within the space provided.

Appendix 7 - Background Survey Results

Summary Of Results From Background Questionnaires

User Profile

1. Number of participants: 15
   11 female, 4 males

2. Height:
   range: 59.4" – 77"
   avg height: 65.6"

3. Age:
   range: 24-56 years
   avg age: 43.6"

4. Number of years of pipetting experience:
   range: 2-37 years
   avg: 19.8 years

5. Minutes/week spent pipetting:
   range: 22.5 –1500 min.
   avg 511 min.

6. Percentage of time spent pipetting:
   average: 24%, range 3-67%

7. Other tasks done at pipetting workbench:
   microscope: 40% of participants
   admin: 67% of participants
   computer: 46.7% of participants

8. Percentage of time spent doing other tasks:
   microscope : avg. 14% , range 0-50%
   admin: avg: 16% , range 0-25%
   computer: avg 22%, range 5-40%

9. All lab techs in study right handed

10. Working position: 6 sit , 8 stand and sit, 1 stands

11. Labelling:
    93% hand label, 67% label only by hand
    73% label vials, 27% label caps and vials
    27% reported problems labelling
    Number of labels/session: avg 29, range 10-75

12. Cap removal
    Percentage reporting difficulties with cap removal: 53%
    Number of caps/session: avg. 26, range 10-50
    Percentage who use a cap removal tool: 33%

Appendix 8 - Baseline Pain Index Questionnaire Results

Summary of Results From Pain Questionnaires #1– Baseline Assessment

1. Most common areas of pain labelled on hands:

Back of hand :

73% reported wrist pain
60% reported thumb pain
33% reported knuckle pain

Palm of hand:

33% reported thumb pain
33% reported wrist pain

Table 1. Average right hand pain for control and intervention groups

Group	At baseline
Control	
N	7
Mean ± SD	5.2762 ± 1.73223
Median	5.0000
Intervention	
N	8
Mean ± SD	5.2500 ± 2.17124
Median	5.5000

Table 2. Right hand pain at baseline for control and intervention groups

	N	Mean	SD	Median
hand back thumb	4	5.50	3.697	6.00
	7	5.43	1.813	6.00
hand back wrist	6	5.50	1.517	5.50
	6	5.00	2.828	5.00
hand back knuckles	4	6.25	1.708	6.50
	3	5.67	0.577	6.00
hand front thumb	4	5.50	1.915	6.00
	2	5.50	4.950	5.50
hand front wrist	3	5.00	2.646	4.00
	4	5.75	3.202	5.50
hand front knuckles	2	5.00	2.828	5.00
	0			

SD = standard deviation. First line indicates control group; second line indicates intervention group.

2. Percentage of participants rating pain>1 in listed body parts:
   (most commonly used descriptors in brackets)
   right shoulder (aching) : 80%
   neck (aching, stiffness) : 80%
   lower back (stiffness) : 67%
   upper back (aching ,stiffness):60%
   right elbow (aching): 33%
   l.hip/thigh/buttock: 27%
   r. hip/thigh/buttock: 20%
   left elbow:7%

Table 3. Body part pain at baseline for control and intervention groups

	N	Mean	SD	Median
neck	7	2.14	1.215	2.00
	8	4.50	2.619	4.00
right shoulder	7	3.14	2.268	2.00
	8	4.63	2.774	4.00
left shoulder	7	2.29	2.215	1.00
	8	1.75	0.886	1.50
right elbow	7	1.29	0.756	1.00
	8	3.63	3.335	2.00
left elbow	7	1.43	1.134	1.00
	8	1.00	0.000	1.00
upper back	7	3.14	2.545	2.00
	8	3.75	2.315	5.00
lower back	7	4.57	3.309	4.00
	8	3.88	3.441	2.50
right hip	7	1.57	1.512	1.00
	8	2.00	2.449	1.00
left hip	7	1.57	1.512	1.00
	8	2.50	2.507	1.00

SD = standard deviation. First line indicates control group; second line indicates intervention group.

Table 4. Average body part pain for control and intervention groups

Group	At baseline
Control	
N	7
Mean ± SD	2.3492 ± 1.10448
Median	1.7778
Intervention	
N	8
Mean ± SD	3.0694 ± 1.54182
Median	2.9444

3. 4 participants had some of injury before working with pipettes

4. 12 participants reported some of injury related to work-related tasks

5. 11 participants reported injury as a result of increase in level of work activity

6. Injuries which prevented participants from carrying out regular activities (number of participants in brackets):

r. shoulder (3)
r. elbow (3)
up. back (1)
lower back (4)

Appendix 9 - Usability Trial Results

Summary of Living Lab Usability Trials

Wednesday, 04 June 2003

Six subjects from the intervention group participated in the Living Lab Usability Trials. After the bio-mechanical data was collected from the "typical" workstation, participants were asked to asked to try the ergonomic workstation and provide feedback on the various features presented. The following summarises the comments made by the participants:

Adjustable Height Base

All subjects thought the adjustability was a great feature, and liked the fact that they could stand and sit comfortably at the workstation.

Switch location

All subjects liked the location of the switch, although one stated a preference of having the switch inside the cut-out area.

Framing Structure/ Shelves

It was suggested that having a low shelf move with the tabletop might be better than a fixed shelf. A higher (adjustable) shelf fixed to the frame was still desired for less frequently used items.

Task Lights

Subjects liked the extra lighting, and were pleased with how easily the positioning could be adjusted. One subject expressed concern that the halogen light might be too warm, but then figured he would likely not bring it close enough for it to be a problem.

Back Lighting For Shelves

All subjects liked the extra back lighting

Book Holder

Most subjects liked the book holder and the fact that it could be removed and re-positioned so easily. It was suggested that a smaller size (to fit 8 ½ " x 11") would be better for St. Paul's Hospital, as they usually deal with sheets of paper instead of binders. One subject said she preferred using clips to post her notes.

Jar Opener

Most subjects thought the jar opener was good, although very few thought they would use it. They were reluctant to have more equipment on their bench, and figured it would slow them down. They also seemed to think that the jar opener would only work on a limited number of containers.

Various Height Plinths

There were mixed reviews about the plinths. Suggestions were made about putting a ledge on the plinth so samples could not slide off. After considering the changes to the discard bucket (see below) it was decided to not pursue the plinth idea as plinths would make the recessed discard harder to access.

Red Vinyl "Reach Zone"

All subjects liked the visual reminder, however it was determined that the zone would have to marked in a permanent way on the tabletop. Cleaning agents used by the labs need to be considered.

White/Black Vinyl Underlays

While subjects thought the underlays provided good contrast for visual tasks, it was determined that disposable sheets of paper would be better for hygienic reasons. A concave mirror was also suggested as a way of improving visuals without having to hold samples up to the light.

Clips For Notes Etc.

All subjects liked having lots of clips for notes.

Mounting For Buckets and Bins

Subjects liked the buckets and bins, although some wondered whether buckets and bins placed on the lower shelf might interfere with countertop space. It was decided that bins could easily be moved to the higher shelf if required.

White Board/ Cork Board

Subjects from 2 of the labs liked the white board and cork board, however one subject suggested that an enclosed backboard would prevent her communicating with her co-workers and preferred the back to be open.

Foot Stool

All subjects liked the foot stool.

Power Bars

All subjects thought that the 2 power bars provided adequate power, and that the location of the power bars was fine.

Posting of Ergonomic Guidelines

Subjects agreed that having the ergonomic guidelines posted on the workstation would be a good reminder for proper posture and table/chair height adjustment.

Turntables

All subjects liked the turntables.

Ergo-rest Arm rest

Feedback on the arm rest was mixed. One participant did not like it and thought it would get in his way and hinder movement. Two subjects liked the idea (one subject suggested putting a strap on the arm rest to prevent the arm from slipping off). Three subjects weren't sure about it but were willing to give it a try. An ergo-rest with an extension pole will be used in the intervention workstations as it will provide more height adjustability.

Discard Bucket

One subject expressed concern about aerosols from the discard bucket being potentially hazardous to the lab techs if the discard bucket were so close. It was decided that a recessed discard hole (centrally located, within the "safe" zone) would be a better option.

In general comments were very positive and lab techs seemed keen to try the ergonomic workstation in their labs.

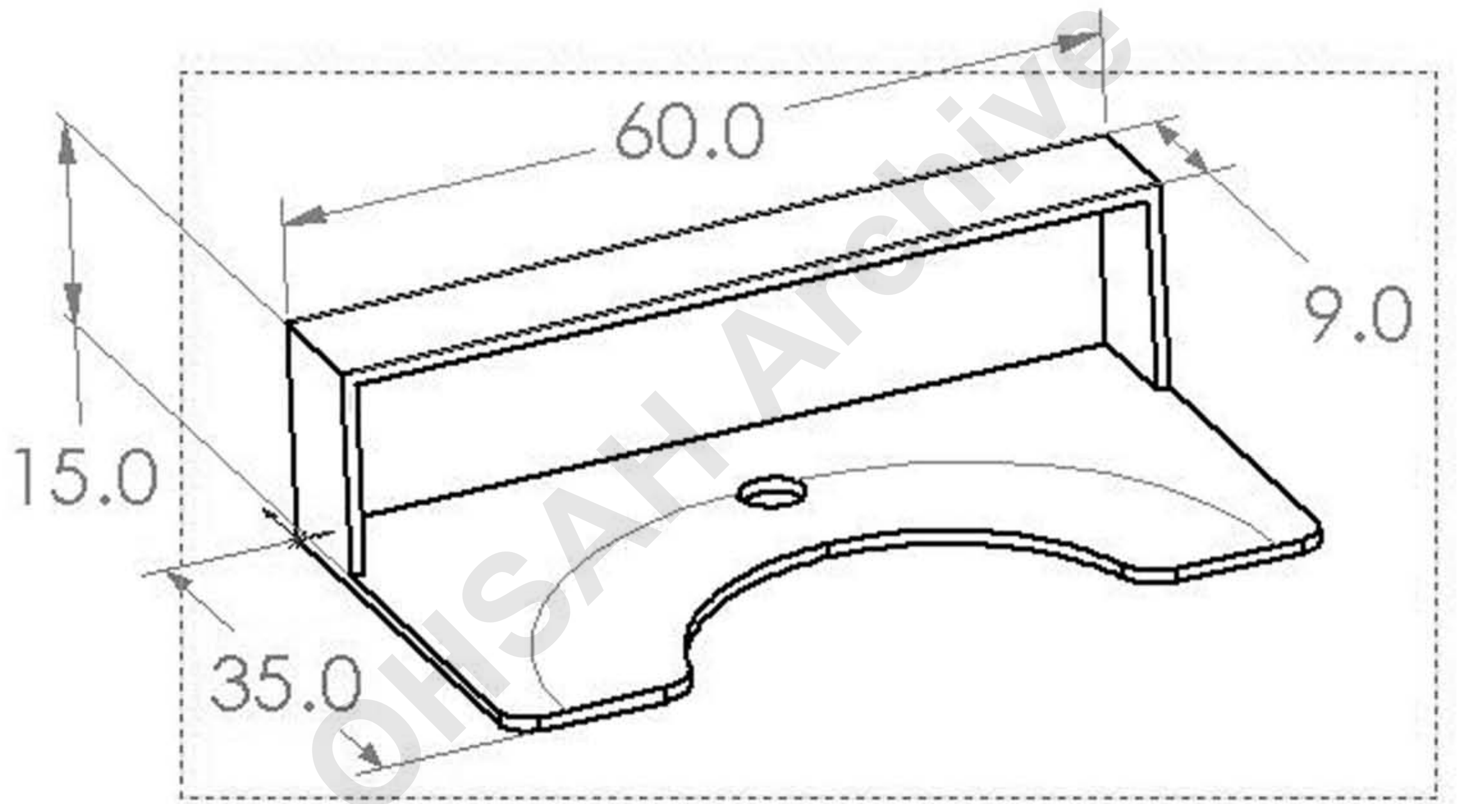
Appendix 10 - Specifications for Intervention Site Workstations

Implementation Phase Workstations Components: BC Cancer

Neil Squire Foundation / BCIT Health Technology Research Group
Thursday, 22 May 2003

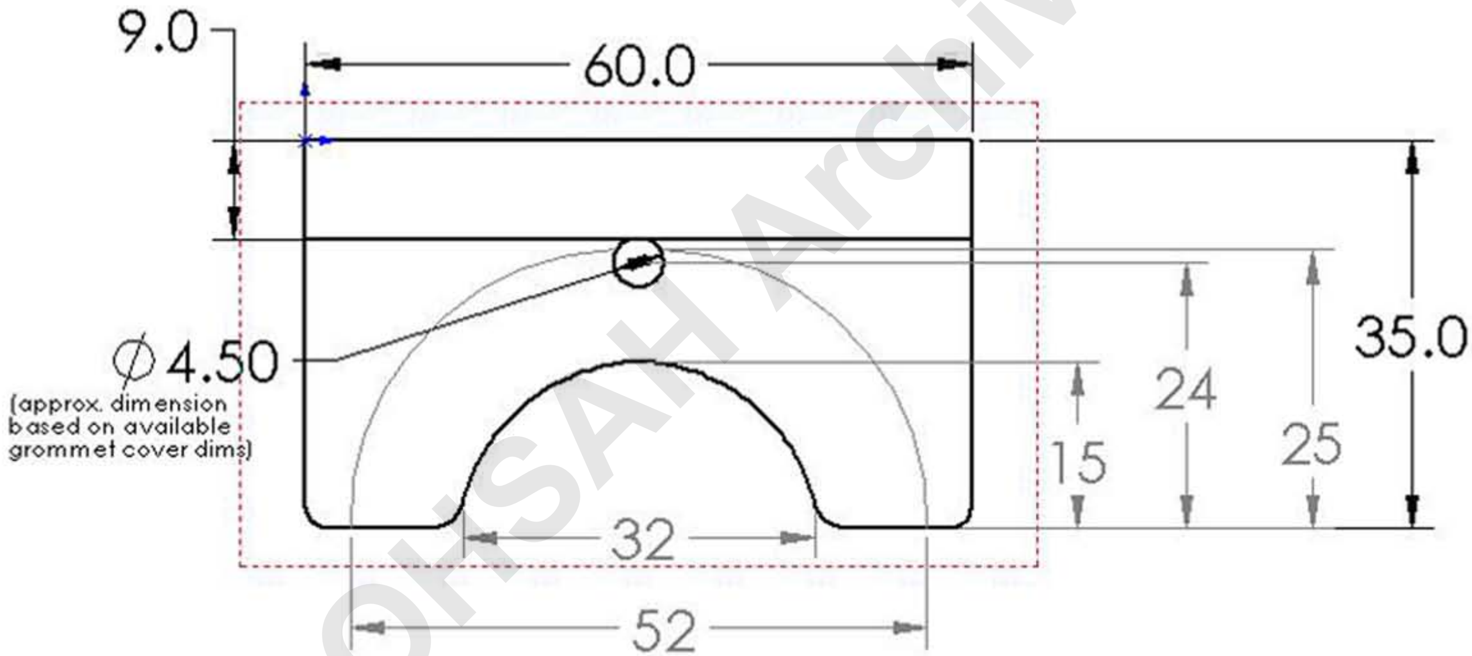
1. adjustable height bases
   - -minimum height 27 ½",
   - -16" of height adjustability (to 43 ½")
   - -on lockable casters
   - -must accommodate cut-out on countertop
2. countertop
   - - 36" x 60"
   - - recessed discard + cover (approx. 4.5" diameter, centred at 10" from cut-out)
   - -"c" shaped cut-out 14" radius, centered
   - - mottled grey laminate
   - - Painted red line 10" outside cut out (24" radius)
   - - able to withstand cleaning with 10% bleach sol'n, 70% ethanol, and alcanox
3. countertop shelf
   - - 15" high hutch (approx. 9" wide)
   - - steel strip for magnets and clips
4. framing structure
   - -72" high, 60" + wide (to inside), approx. 10" deep
   - - adj. ht shelf at approx 66" from floor
   - - with steel strip for magnets and clips
   - - cork and whiteboard at back
   - - on lockable casters
5. 2 adjustable arm halogen task lights
6. warm fluorescent back light under countertop shelf
7. 2 lazy susans, painted black
   - -overlayed with non-slip surface
8. discard bucket with lip to fit in countertop recess
   - -must fit existing discard bags
9. various height plinths
   - -with ridge around edges
10. white/black paper underlays
11. storage buckets and hooks
12. clips and magnets for notes etc.
13. foot rest
14. book holder
15. arm rest
16. power bars (2) upright at back of counter
17. posting of ergonomic guidelines

Neil Squire Foundation
BC Cancer Pipetting Workstation
Johanne Mattie
June 5, 2003



Size: A
Scale: 1:16
Dimensions are inches

Neil Squire Foundation
BC Cancer Pipetting Workstation
Johanne Mattie
June 5, 2003



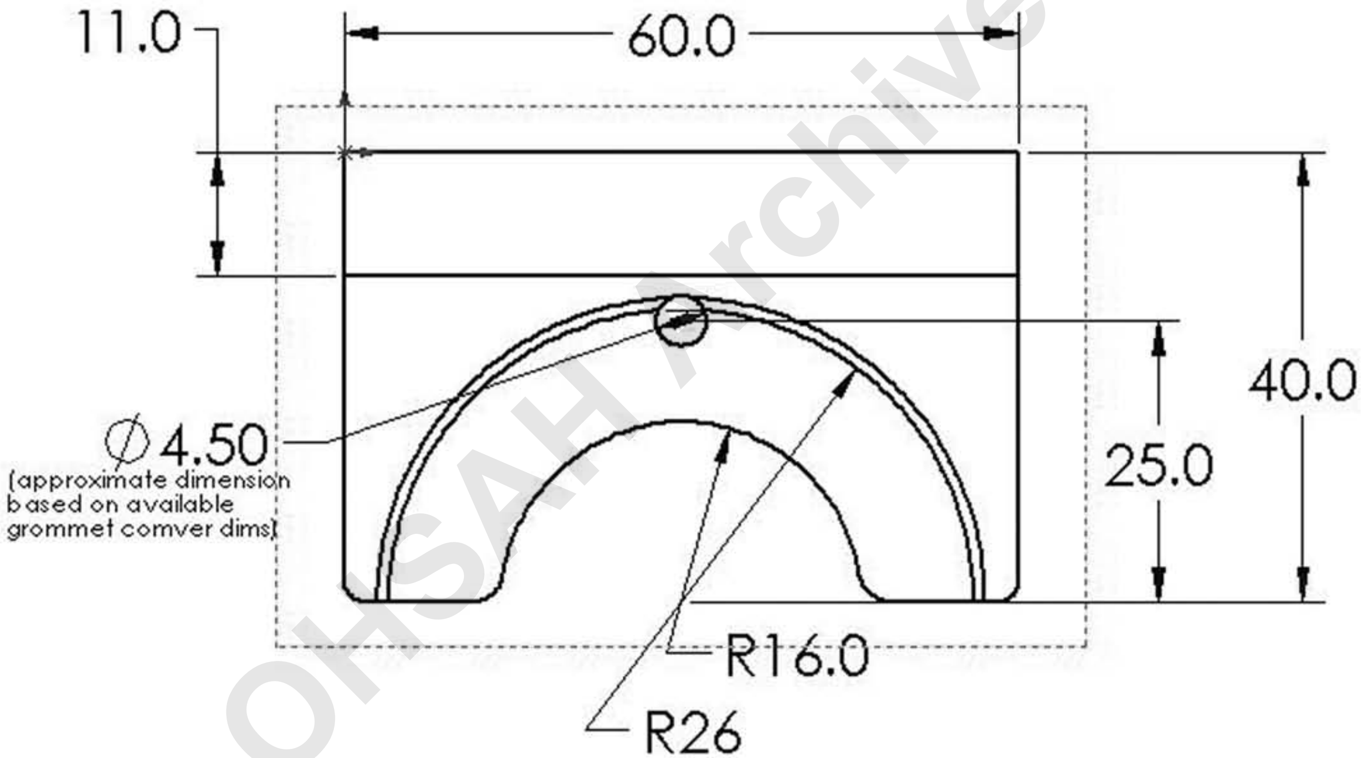
Size: A
Scale: 1:16
Dimensions are inches

Implementation Phase Workstations Components: Burnaby Hospital

Neil Squire Foundation / BCIT Health Technology Research Group
Thursday, 22 May 2003

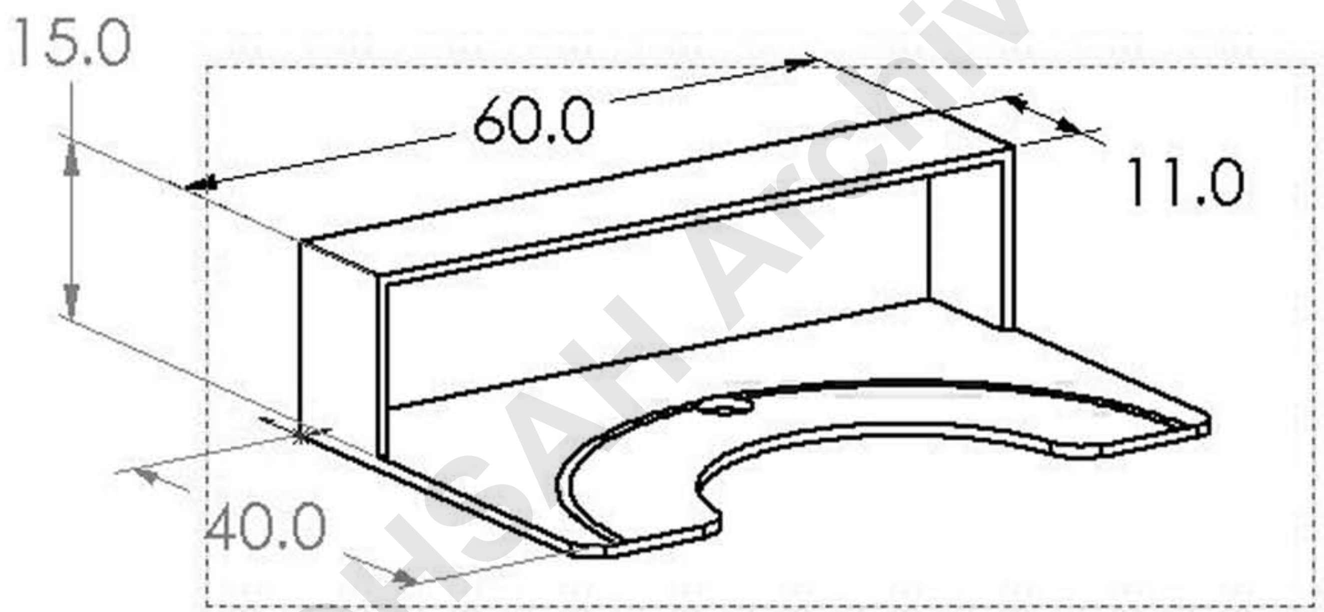
1. adjustable height bases
   - -minimum height 27 ½",
   - -16" of height adjustability (to 43 ½")
   - -on lockable casters
   - -must accommodate cut-out on countertop
2. countertop
   - 36" x 60"
   - recessed discard + cover (approx. 4.5" diameter, centred at 10" from cut-out)
   - "c" shaped cut-out 14" radius, centered
   - mottled grey laminate
   - Painted red line 10" outside cut out (24" radius)
   - able to withstand cleaning with 10% bleach sol'n, 70% ethanol, and alcanox
3. countertop shelf
   - 15" high hutch (approx. 9" wide)
   - steel strip for magnets and clips
4. framing structure
   - 72" high, 60" + wide (to inside), approx. 10" deep
   - adj. ht shelf at approx 66" from floor
   - with steel strip for magnets and clips
   - cork and whiteboard at back
   - on lockable casters
5. 2 adjustable arm halogen task lights
6. warm fluorescent back light under countertop shelf
7. 2 lazy susans, painted black
   - -overlayed with non-slip surface
8. discard bucket with lip to fit in countertop recess
   - -must fit existing discard bags
9. various height plinths
   - -with ridge around edges
10. white/black paper underlays
11. storage buckets and hooks
12. clips and magnets for notes etc.
13. foot rest
14. book holder
15. arm rest
16. power bars (2) upright at back of counter
17. posting of ergonomic guidelines
18. anti-fatigue matting that allows chairs to roll

Neil Squire Foundation
Burnaby Workstation
Johanne Mattie
June 2, 2003



Size: A
Scale: 1:16
Dimensions are inches

Neil Squire Foundation
Burnaby Workstation
Johanne Mattie
June 2, 2003



Size: A
Scale: 1:16
Dimensions are inches

Implementation Phase Workstations Components: St. Paul's Hospital

Neil Squire Foundation / BCIT Health Technology Research Group
Thursday, 22 May 2003

1. adjustable height bases
   - -minimum height 27 ½",
   - -16" of height adjustability (to 43 ½")
   - -on lockable casters
   - -must accommodate cut-out on countertop
2. countertop
   - - 36" x 60"
   - - recessed discard + cover (approx. 4.5" diameter, centred at 10" from cut-out)
   - -"c" shaped cut-out 14" radius, centered
   - - mottled grey laminate
   - - Painted red line 10" outside cut out (24" radius)
   - - able to withstand cleaning with 10% bleach sol'n, 70% ethanol, and alcanox
3. countertop shelf
   - - 15" high hutch (approx. 9" wide)
   - - steel strip for magnets and clips
4. framing structure
   - -72" high, 60" + wide (to inside), approx. 10" deep
   - - adj. ht shelf at approx 66" from floor
   - - with steel strip for magnets and clips
   - - cork and whiteboard at back
   - - on lockable casters
5. 2 adjustable arm halogen task lights
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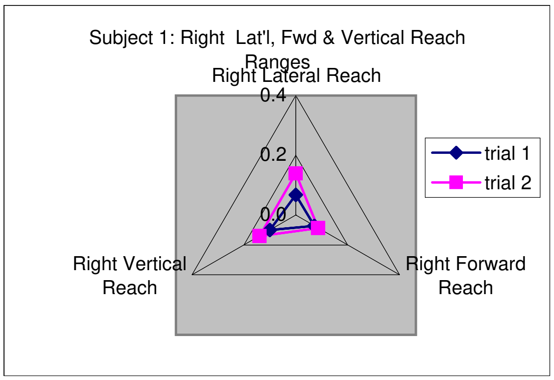
8. discard bucket with lip to fit in countertop recess
   - -must fit existing discard bags
9. various height plinths
   - -with ridge around edges
10. white/black paper underlays
11. storage buckets and hooks
12. clips and magnets for notes etc.
13. foot rest
14. book holder
15. arm rest
16. power bars (2) upright at back of counter
17. posting of ergonomic guidelines

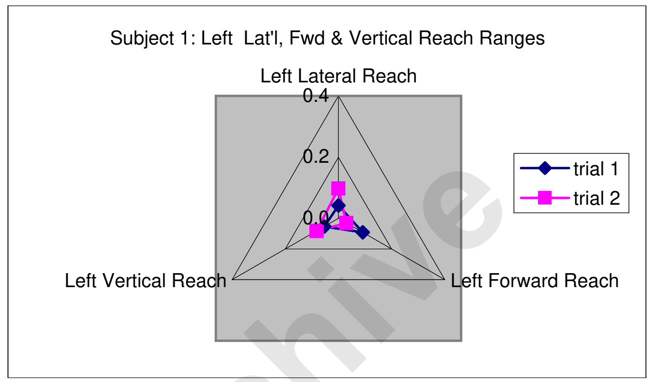
Appendix 11 - Reach Data

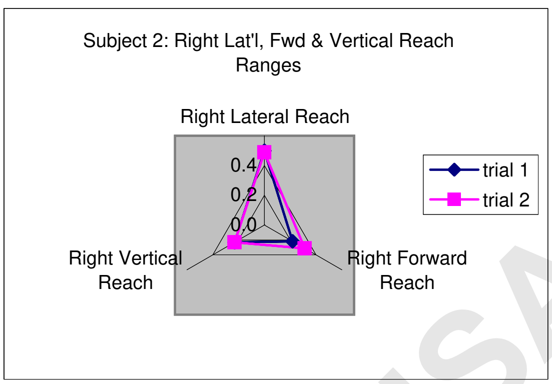
PIPETIE STUDY MAXIMUM REACH GRAPHS

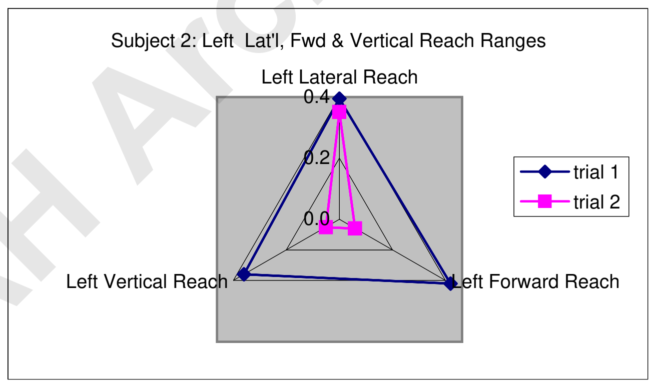
Trial 1: orginial workstation, Feb 2004
Trial 2: experimental workstation, Aug 2004

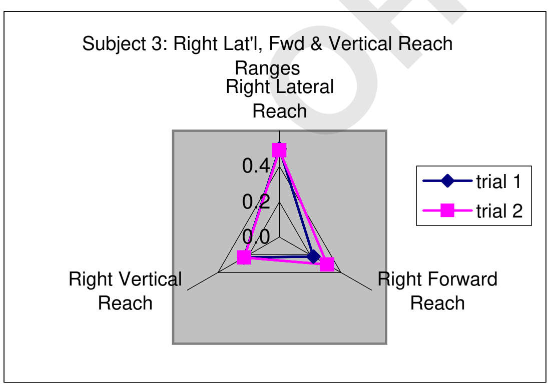
(All measurements are in meters; data represents difference between maximum and minimum reach values)

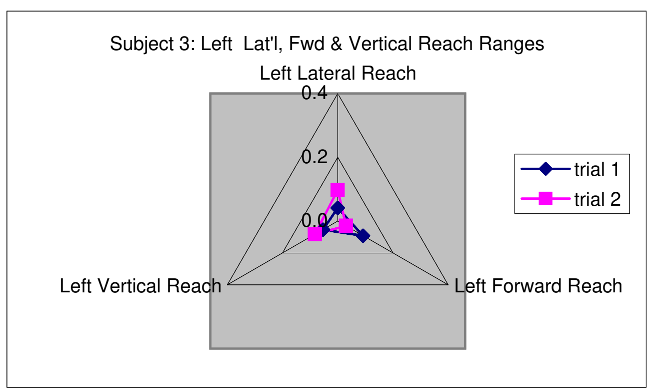








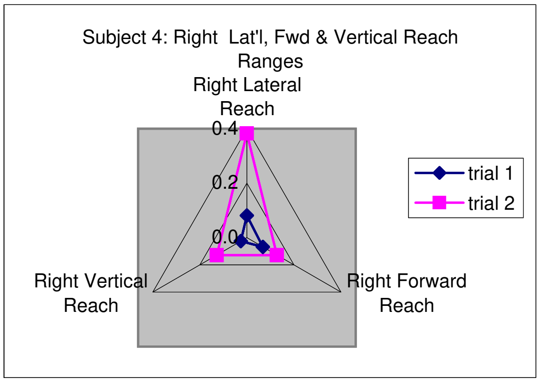


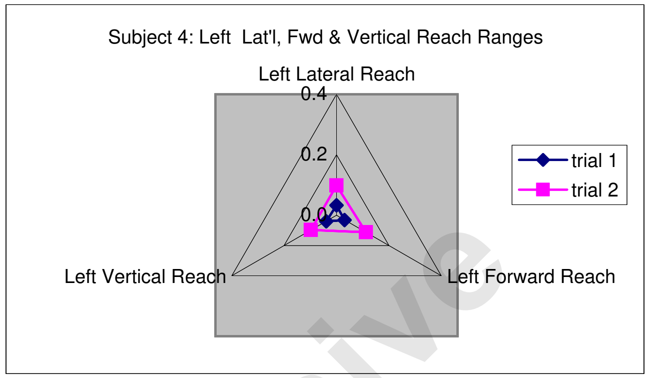


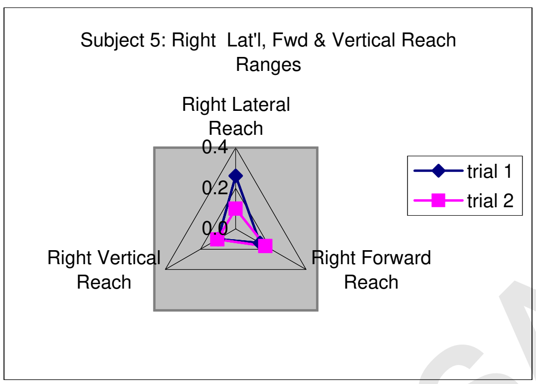
PIPETTE STUDY MAXIMUM REACH GRAPHS

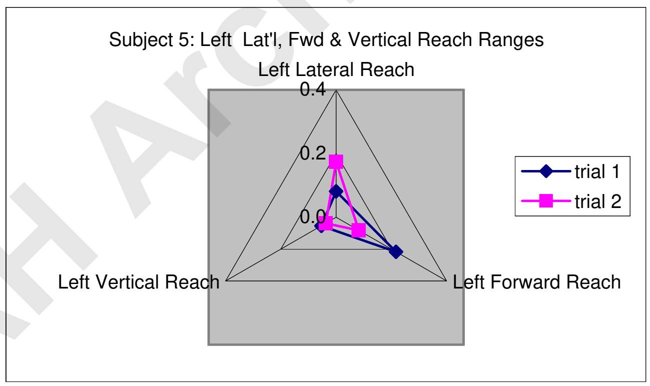
Trial 1: orginial workstation, Feb 2004
Trial 2: experimental workstation, Aug 2004

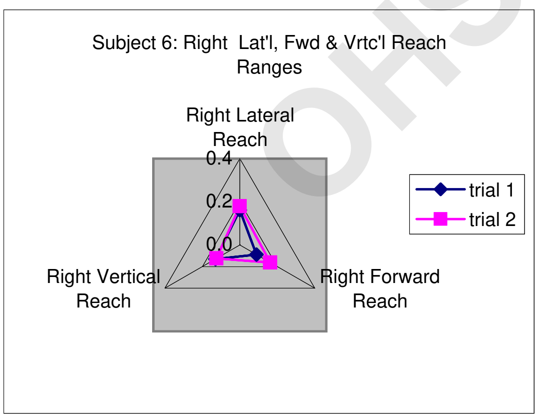
(All measurements are in meters; data represents difference between maximum and minimum reach values)

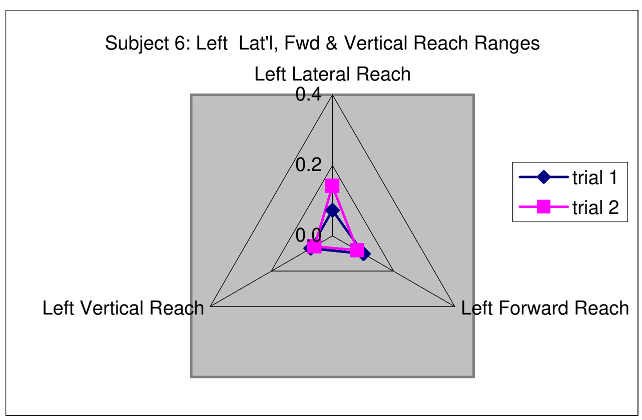








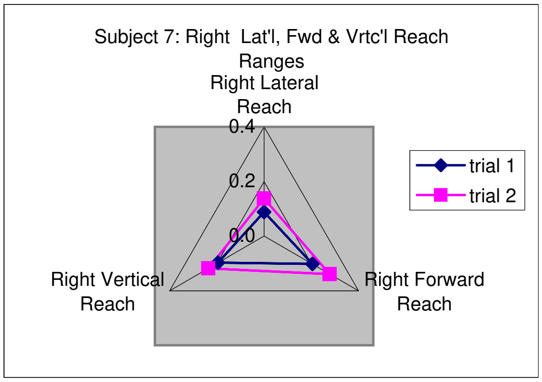


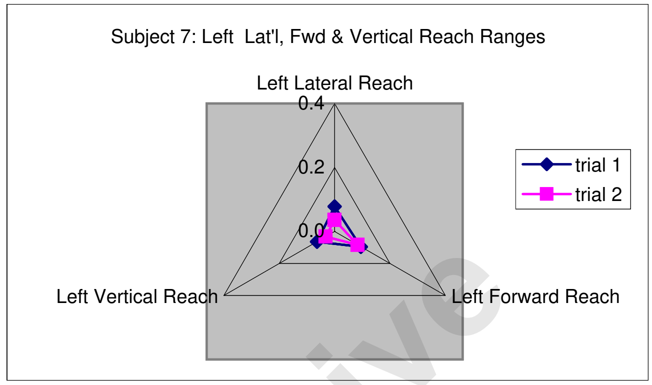


PIPETTE STUDY MAXIMUM REACH GRAPHS

Trial 1: orginial workstation, Feb 2004
Trial 2: experimental workstation, Aug 2004

(All measurements are in meters)



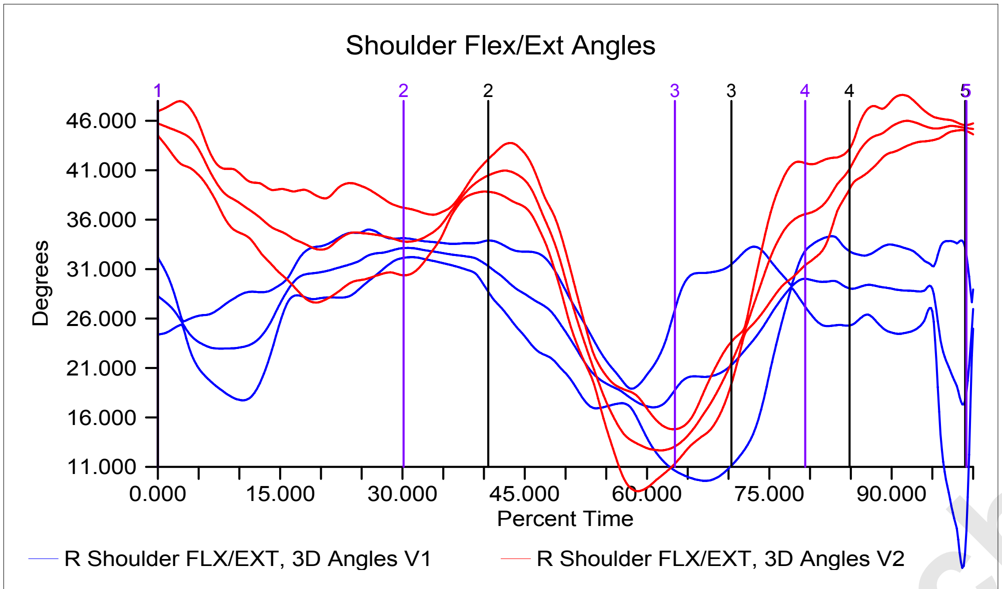


Appendix 12 - Sample of Joint Angle Data

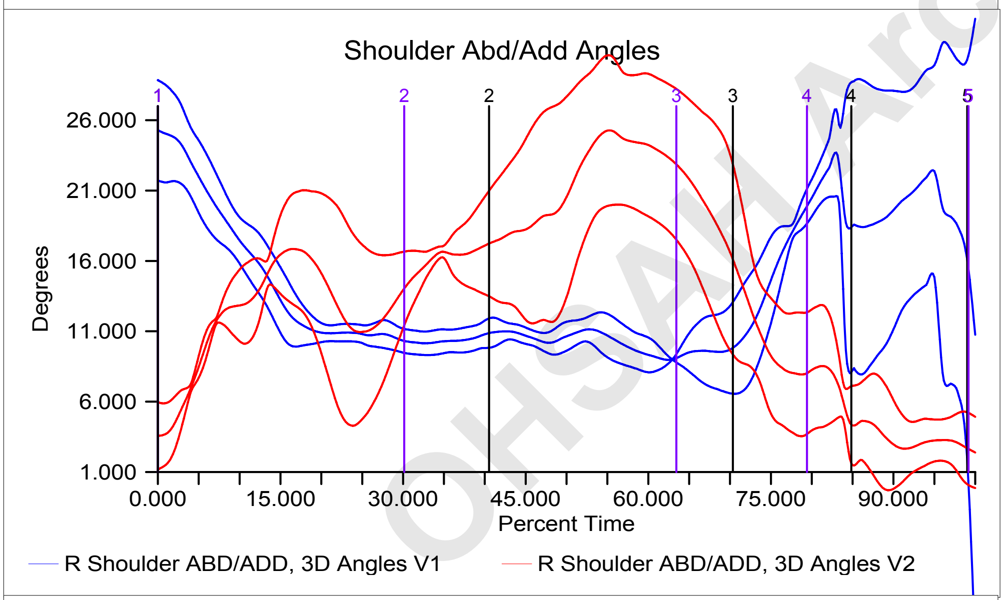
Pipette Project Shoulder Kinematics

Trial name: PIP0201(ave_ave)
Date: 9/8/2004
Description: Pipette study
Comments: Participant 2

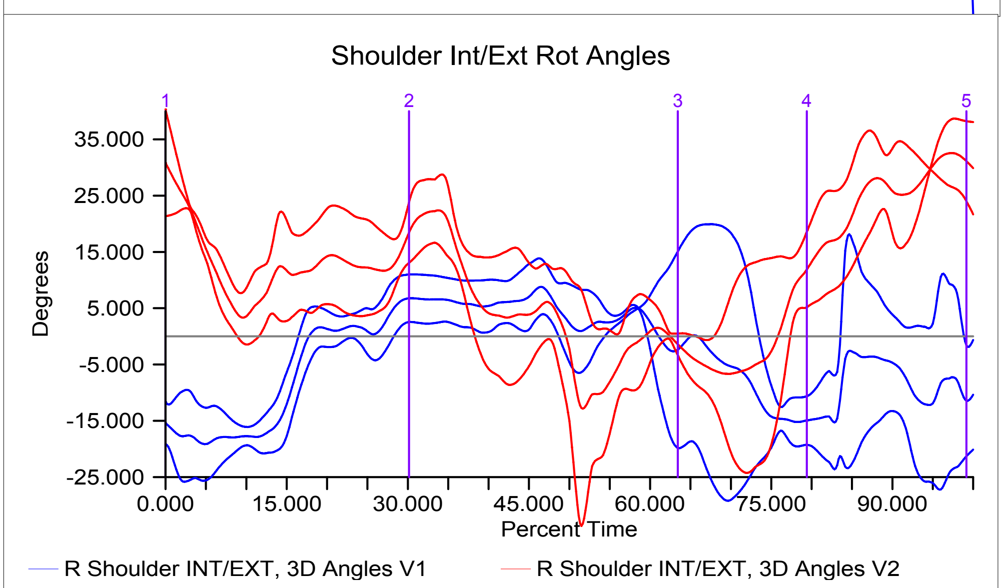
Trial name: PIP0202(ave_ave)
Date: 9/8/2004
Description: Pipette study
Comments: Participant 2



	Minimum	Maximum	Range
R Shldr FLX/EXT V1	17.018	33.141	16.123
R Shldr FLX/EXT V2	12.669	45.988	33.319



	Minimum	Maximum	Range
R Shldr ABD/ADD V1	8.970	25.280	16.310
R Shldr ABD/ADD V2	2.392	25.276	22.884

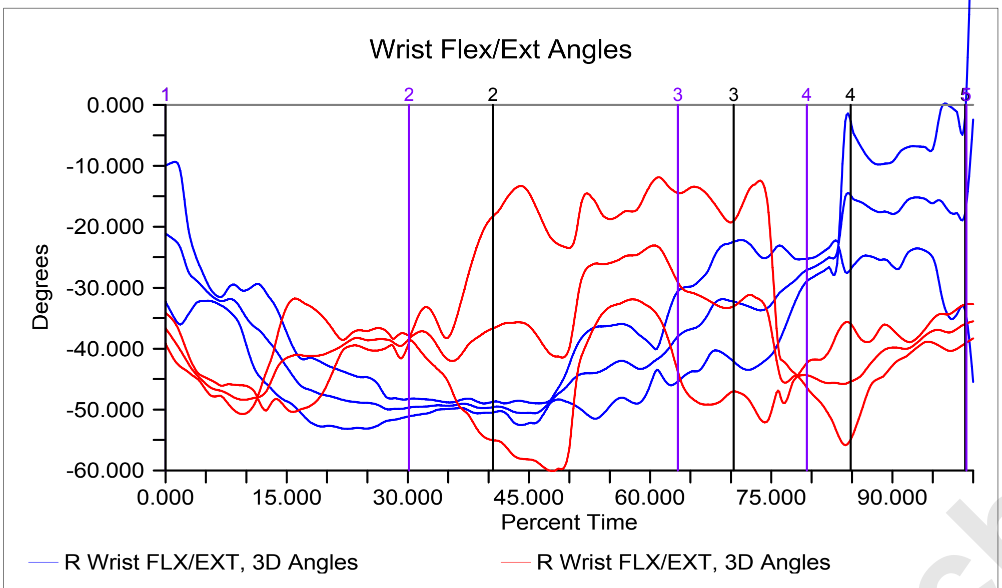


	Minimum	Maximum	Range
R Shldr INT/EXT V1	-19.135	8.798	27.933
R Shldr INT/EXT V2	-12.835	32.566	45.401

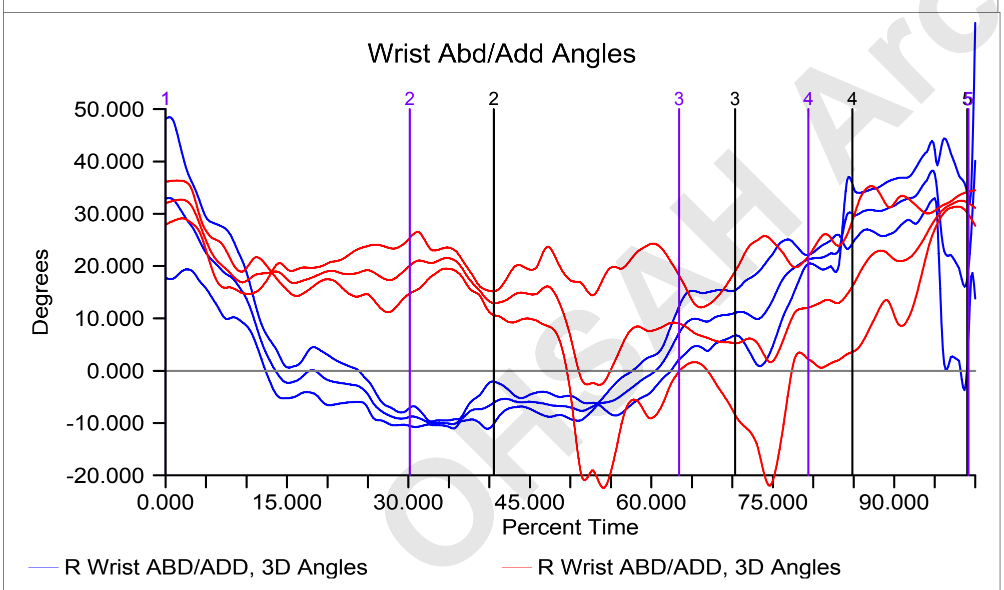
Pipette Project Wrist Kinematics

Trial name: PIP0201(ave_ave)
Date: 9/8/2004
Description: Pipette study
Comments: Participant 2

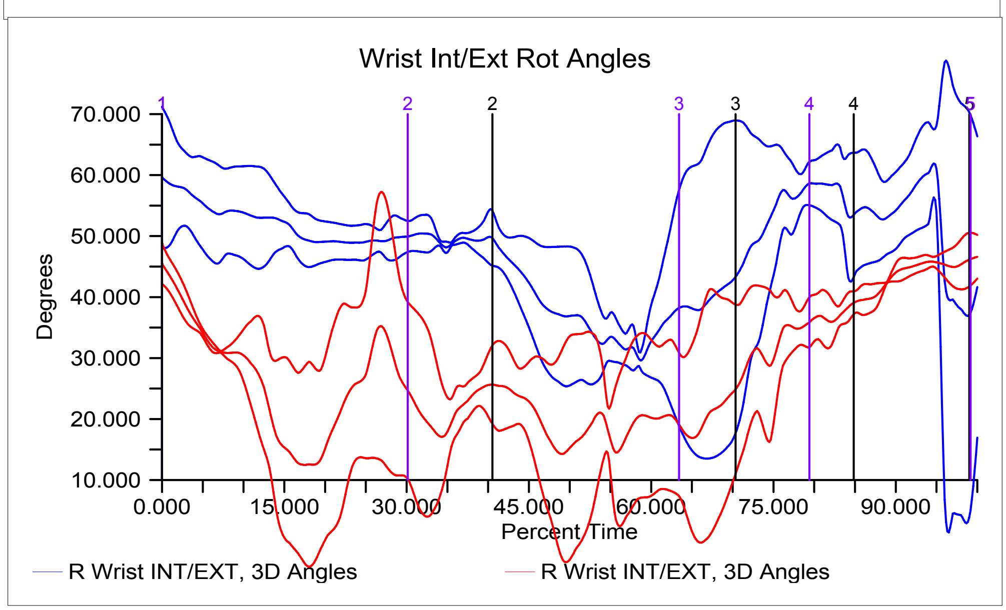
Trial name: PIP0202(ave_ave)
Date: 9/8/2004
Description: Pipette study
Comments: Participant 2



	Minimum	Maximum	Range
R Wrist FLX/EXT V1	-50.613	-2.414	48.199
R Wrist FLX/EXT V2	-48.386	-23.076	25.310



	Minimum	Maximum	Range
R Wrist ABD/ADD V1	-10.186	40.129	50.315
R Wrist ABD/ADD V2	-2.695	32.711	35.406

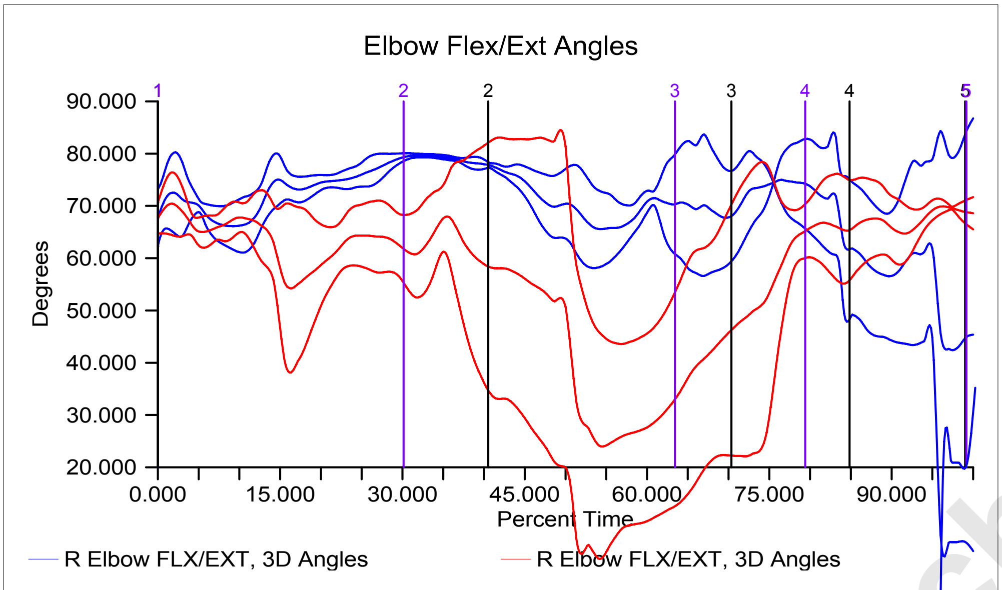


	Minimum	Maximum	Range
R Wrist INT/EXT V1	29.616	61.904	32.288
R Wrist INT/EXT V2	12.477	46.607	34.131

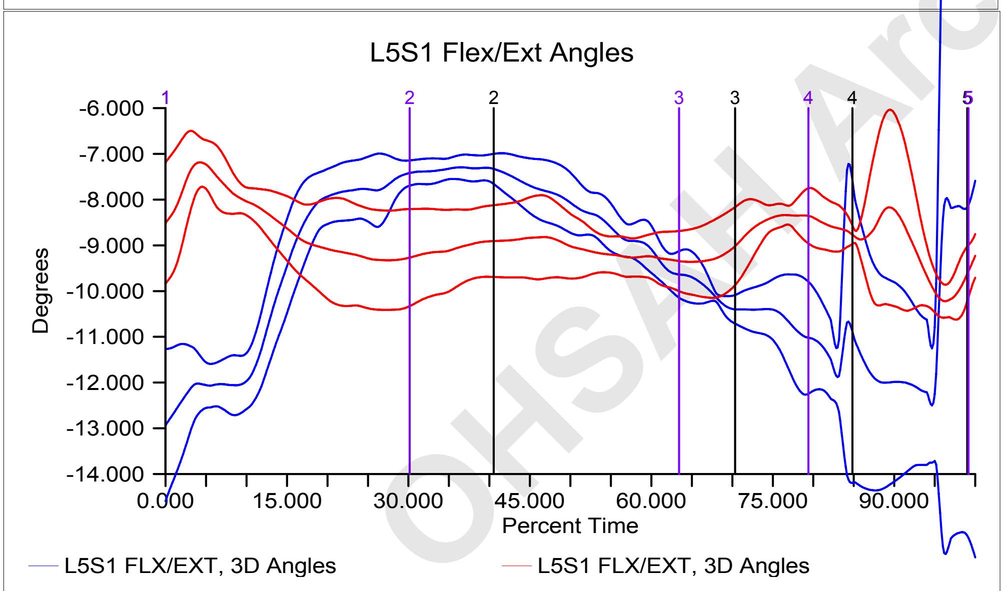
Pipette Project Kinematics

Trial name: PIP0201(ave_ave)
Date: 9/8/2004
Description: Pipette study
Comments: Participant 2

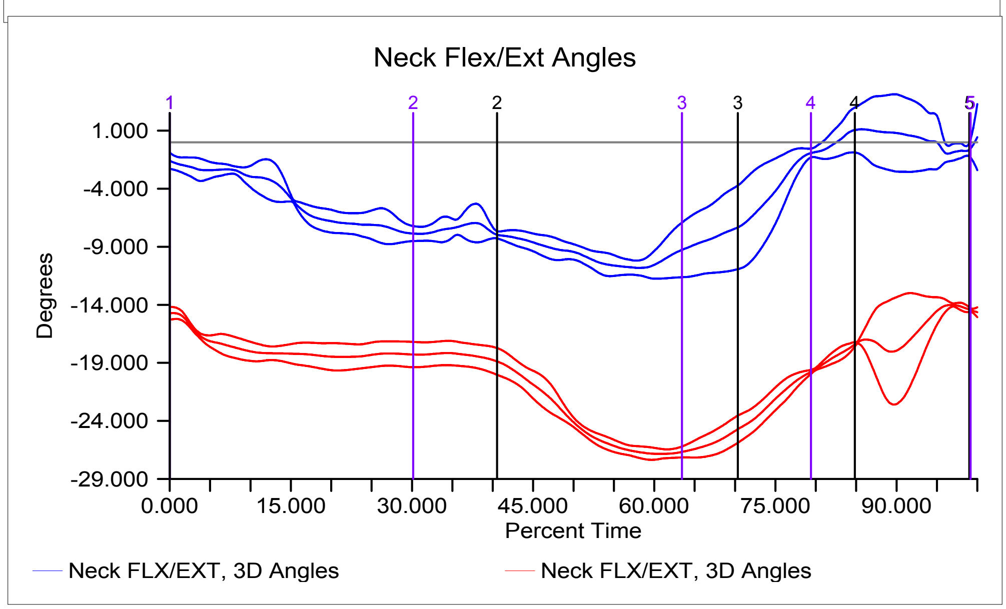
Trial name: PIP0202(ave_ave)
Date: 9/8/2004
Description: Pipette study
Comments: Participant 2



	Minimum	Maximum	Range
R Elbow FLX/EXT V1	42.415	79.644	37.229
R Elbow FLX/EXT V2	23.975	70.429	46.454



	Minimum	Maximum	Range
L5S1 FLX/EXT V1	-12.929	-7.293	5.636
L5S1 FLX/EXT V2	-10.221	-7.186	3.035



	Minimum	Maximum	Range
Neck FLX/EXT V1	-10.822	1.119	11.941
Neck FLX/EXT V2	-26.839	-14.013	12.825

Appendix 13 - Timing Data

Pipette Timing Data
Pipette Hand Cycle Period for Original and Experimental Workstations

subject		original workstation period (sec.)	experimental w/s period (sec.)	percentage decrease of cycle period
1		6.00	6.24	-4.00
2		10.16	7.29	28.25
3		4.93	4.95	-0.41
4		5.49	5.87	-6.92
5		6.42	5.23	18.54
6		6.35	5.83	8.19
7		10.86	10.35	4.70
	Average	7.17	6.54	6.91
	st. dev.	2.35	1.84	12.65

(a negative number for the percentage decrease of cycle period indicates an increase in cycle period)

Appendix 14 - Final Pain Index Questionnaire Results

Table 1. Comparison of characteristics at baseline between control and intervention groups

Variable	Control (n = 7)	Intervention (n = 8)	p-value *
Age at baseline	42.9 ± 14.2	44.3 ± 8.2	0.862
Years in pipeting	19.2 ± 14.2	20.3 ± 10.9	0.999
Pipeting hours (min/wk)	457.5 ± 453.1	491.1 ± 350.8	0.416
Level of fatigue after a session of pipetting compared to other laboratory tasks +	7.3 ± 2.4	4.8 ± 2.3	0.052
Level of fatigue just before you take a break during a pipetting session +	6.3 ± 1.6	4.4 ± 1.9	0.067
Level of fatigue at the end of a pipetting session +	6.9 ± 1.7	4.9 ± 2.4	0.057
Average body pain +	2.3 ± 1.1	3.1 ± 1.5	0.417
Average right hand pain +	5.3 ± 1.7	5.3 ± 2.2	0.954

*, p-value was calculated by Mann-Whitney U test.

+, Fatigue level ranged from 1 to 10, with 1 being able to pipet for a long time and 10 being no longer able to pipet; average body pain and average right hand pain ranged from 1 to 10, with 1 being none and 10 being unbearable.

Table 2. Comparison of changes from baseline to follow up for average body part pain and average right hand pain between control and intervention groups

	Average body part pain		
Group	**At baseline**	**At 22-month follow-up**	**At 28-month follow-up**
Control			
N	7	6	5
Mean ± SD	2.3492 ± 1.10448	1.7593 ± 0.49400	1.7333 ± 0.86638
Median	1.7778	1.7222	1.4444
Intervention			
N	8	7	7
Mean ± SD	3.0694 ± 1.54182	2.8413 ± 1.53002	2.3968 ± 1.07316
Median	2.9444	2.1111	2.3333
p-value *		p = 0.519	p = 0.254

	Average right hand pain		
	At baseline	**At 22-month follow-up**	**At 28-month follow-up**
Control			
N	7	5	5
Mean ± SD	5.2762 ± 1.73223	4.8600 ± 2.34478	4.1200 ± 2.25211
Median	5.0000	5.5000	4.6000
Intervention			
N	8	5	4
Mean ± SD	5.2500 ± 2.17124	5.3667 ± 1.38644	5.1875 ± 1.62500
Median	5.5000	6.0000	5.5000
p-value *		p = 0.465	p = 0.624

*, The p-value for comparison of changes between intervention and control groups was calculated by Mann-Whitney U test.

Table 3. Comparison of changes from baseline to follow-up for body part pain between control and intervention groups

measurement	Body Part Pain											
	At baseline				At 22-month follow-up				At 28-month follow-up			
	N	Mean	SD	Median	N	Mean	SD	Median	N	Mean	SD	Median
neck	7	2.14	1.215	2.00	6	3.17	2.401	2.50	5	2.40	1.673	2.00
	8	4.50	2.619	4.00	7	3.43	2.637	2.00	7	4.00	2.309	4.00
r.shoulder	7	3.14	2.268	2.00	6	1.17	0.408	1.00	5	1.60	1.342	1.00
	8	4.63	2.774	4.00	7	4.00	3.317	3.00	7	3.57	2.370	4.00
l.shoulder	7	2.29	2.215	1.00	6	1.67	1.033	1.00	5	2.00	1.732	1.00
	8	1.75	0.886	1.50	7	2.14	2.268	1.00	7	1.00	0.000	1.00
r.elbow	7	1.29	0.756	1.00	6	1.00	0.000	1.00	5	1.00	0.000	1.00
	8	3.63	3.335	2.00	7	1.86	2.268	1.00	7	1.57	1.512	1.00
l.elbow	7	1.43	1.134	1.00	6	1.00	0.000	1.00	5	1.00	0.000	1.00
	8	1.00	0.000	1.00	7	1.00	0.000	1.00	7	1.00	0.000	1.00
upr back	7	3.14	2.545	2.00	6	2.50	2.811	1.00	5	2.00	1.414	1.00
	8	3.75	2.315	5.00	7	3.00	2.236	3.00	7	2.57	2.299	1.00
lowr back	7	4.57	3.309	4.00	6	2.83	1.722	3.00	5	2.80	2.490	1.00
	8	3.88	3.441	2.50	7	5.00	3.416	6.00	7	4.14	2.854	3.00
r.hip	7	1.57	1.512	1.00	6	1.00	0.000	1.00	5	1.40	0.894	1.00
	8	2.00	2.449	1.00	7	2.14	2.610	1.00	7	1.71	1.496	1.00
l.hip	7	1.57	1.512	1.00	6	1.50	1.225	1.00	5	1.40	0.894	1.00
	8	2.50	2.507	1.00	7	3.00	2.236	3.00	7	2.00	2.236	1.00

SD = standard deviation.
First line indicates control group; second line indicates intervention group.

Table 4. Comparison of changes from baseline to follow-up for right hand pain between control and intervention groups

measurement	Right Hand Pain											
	At baseline				At 22-month follow-up				At 28-month follow-up			
	N	Mean	SD	Median	N	Mean	SD	Median	N	Mean	SD	Median
hd bk thumb	4	5.50	3.697	6.00	4	5.25	2.754	5.50	4	5.75	2.217	6.00
	7	5.43	1.813	6.00	3	6.00	2.000	6.00	3	5.00	2.646	4.00
hd bk wrist	6	5.50	1.517	5.50	2	4.50	3.536	4.50	1	3.00		3.00
	6	5.00	2.828	5.00	2	5.50	3.536	5.50	2	6.00	0.000	6.00
hd bk knuckles	4	6.25	1.708	6.50	2	4.50	3.536	4.50	3	4.33	3.055	5.00
	3	5.67	0.577	6.00	1	5.00		5.00	2	4.50	0.707	4.50
hd frnt thumb	4	5.50	1.915	6.00	3	3.33	3.215	2.00	4	4.75	2.363	4.00
	2	5.50	4.950	5.50	2	4.00	1.414	4.00	2	6.50	4.950	6.50
hd frnt wrist	3	5.00	2.646	4.00	2	1.50	0.707	1.50	2	2.00	1.414	2.00
	4	5.75	3.202	5.50	2	7.00	1.414	7.00	1	6.00		6.00
hd frnt knuckles	2	5.00	2.828	5.00	4	3.25	2.630	2.50	2	3.00	0.000	3.00
	0				0				0			

SD = standard deviation.
First line indicates control group; second line indicates intervention group.

Appendix 15 - Areas for Future Work

AREAS FOR FUTURE WORK:

It is hoped that this work will encourage further research to help reduce injuries suffered by lab technologists. Areas recommended for future investigation include:

Improving Pipette Design:
The main suggestions for improving pipette design are focused on reducing the forces for the tip pick-up and ejection mechanisms. Other suggestions include smoother plunger movements for aspirating and dispensing fluids and grips that fit better to the shape of the hand. While many of the newer, electronic pipettes address some of these concerns, the price range is beyond what many labs can afford.

Investigating Newer Pipette Designs:
Vista Labs has recently introduced the Ovation Bio Natural pipette (http://www.vistalab.com/index.asp). Lab techs in this research were shown a mock up of this design and responded positively to the new style. Further investigation of this product would be worthwhile.

Trialing a 3-dimensional Mobile Arm Support
The MASTE-1 mobile arm support from Jaeco Orthopedic allows motion in the vertical plane. As limitation to motion in the vertical plane was noted as a primary concern for the arm support used in this study, it is suggested that the 3-dimensional support device be trialed.

Further Investigation into the Biological Safety Cabinet
Depending on the lab, many lab techs spend considerable time working in a biological safety cabinet (BSC). Due to the fixed height and physical access barriers of these cabinets, the ergonomic concerns for lab techs are significant. It is recommended that further work be done to consider the issues of these cabinets.

Further Investigation of other lab issues
Results from the questionnaires pointed to other factors in the lab that may be contributing to injuries. It is recommended that further work consider:
-the repetitive task of removing lids from reagent bottles and jars
-the awkward postures used for microscope work (particularly older microscopes with limited adjustment features)

Upper Extremity modelling
It is recommended that further work be done on the upper extremity model.

Education of new lab techs
As it is difficult for lab techs who have been pipetting for many years to change their work habits, it is recommended that BCIT and other training centres instruct Laboratory Science students on the importance of ergonomics, workstation set-up, and taking stretching breaks.

Further study with more subjects

As the number of lab techs participating in this research was limited, further study with a greater number of subjects is recommended. Attempts should be made to control for confounding factors wherever possible.

ABOUT THIS DOCUMENT

The Occupational Health and Safety Agency for Healthcare (OHSAH), which operated from 1998-2010, was a precursor to SWITCH BC. Conceived through the Public Sector Accord on Occupational Health and Safety as a response to high rates of workplace injury, illness, and time loss in the health sector, OHSAH was built on the values of bipartite collaboration, evidence-based decision making, and integrated approaches.

This archival research material was created by OHSAH, shared here as archival reference materials, to support ongoing research and development of best practices, and as a thanks to the organization's members who completed the work.

If you have any questions about the materials, please email hello@switchbc.ca or visit www.switchbc.ca