

Ergonomic Evaluation at Bill Processing,  
Insurance Services  
*-a detailed office ergonomics case study*

Stephen Bao, Han Kim, Barbara Silverstein, Eddy Rauser  
SHARP Program  
Washington State Department of Labor and Industries  
Olympia, WA

Technical Report Number: 62-2-2009

May 2009

Olympia, Washington



## Summary

An ergonomics evaluation study was conducted for Washington State Department of Labor and Industries' Bill Processing Unit. The objectives of the study were:

- Test effects on physical exposure of the employees when keying activities are extended from the current limit of 5 hours to 6 hours.
- Study the work contents to determine actual activities during the work shifts and compare them with those of 15-18 years ago, when SHARP did similar studies among employees in the Claim Initiation Unit.
- Evaluate physical exposure of the employees in the current work scheduling conditions, and compare them with those of the previous studies.
- Study employees' perception including discomfort and working conditions.
- Apply job evaluation techniques in an office environment and provide recommendations for further improvement.

Among these objectives, the primary objective was the evaluation of extending the currently practiced 5-hour data entry schedule to 6 hours. All other objectives were needed in order to understand the task activities and their impact on the employees, and provide recommendations that were based on objective assessments.

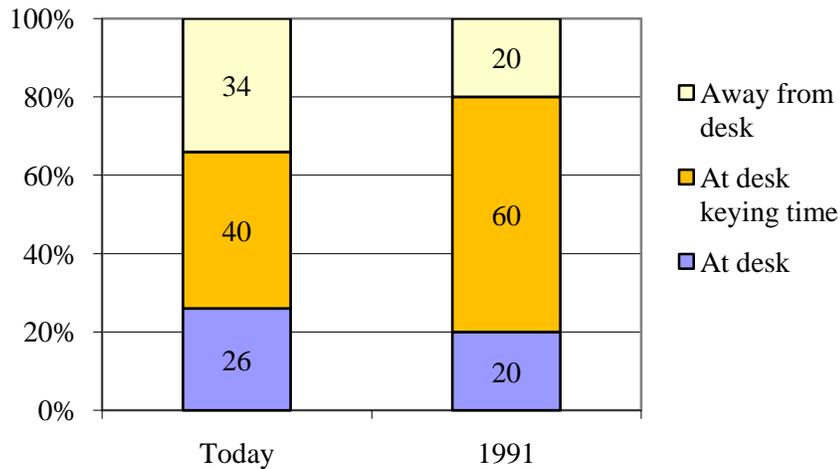
In order to achieve the objectives, a 3-phase study design was developed. There were 5 to 19 participants from the Bill Processing Unit, who volunteered at the different phases of the study. In Phase 1, an all employees' survey was conducted to obtain musculoskeletal health information. The survey was administered online and collected basic demographic information of the subjects, work history information, perceived musculoskeletal problems of different body parts, and psychosocial questions.

Phase 2 was designed to gather task activity information of the current work situation under the 5-hour data entry schedule, and workers' body discomfort perception. This was done by (1) computer use monitoring, using a computer program (RSIGuard) to register various computer use information such as keyboard/mouse use times, times using/not using computer, etc., (2) daily body discomfort survey, which was administered online at the end of a work shift to get information about workers' subjective discomfort rating levels of various body parts and relate them to the task activities they did on that day, and (3) work activity and posture video observation, which was done by using a time-lapse camera to capture images of task performances of workers during a complete work shift to obtain detailed task distribution information.

In Phase 3, physical exposure of extended keying period was evaluated using surface electromyographic (EMG) technique in combination with workers' perceived exertion measurement. EMG technique was used to quantitatively measure muscle activities during work and muscle fatigue status as measured by the shift of median frequency of EMG signals during a work shift. Workers' perceived exertion was the employees' own perception about their fatigue status during a work shift. Detailed time studies of task performance were also performed at the same time muscle activities were recorded so muscle activities could be related to different task activities.

The results showed that workers spent less time on computers and less time on actual keying now compared to 18 years ago. The employees sat at their desk about 66% of the time, while only 40% of the work shift was spent at using their computers compared to 80% and 60% of the work shift, respectively, in the 1991 study.

*Time allocation Current day compared to 1991*



In general, workers spent most of their time (when using their computers) in neutral postures. Workstation configurations and availability of ergonomics-related equipment/devices were greatly improved. The static, median and peak muscle loadings for the four muscles were between 1-4%, 3-8%, and 7-24% of maximum voluntary contraction (MVC) respectively. Corresponding limit values are known as 2%, 10% and 50% MVC, respectively. The muscle loadings were lower when the employees working at their computers compared to performing other desk activities. This might indicate that most ergonomic improvements have been primarily focused on computer work rather than the other parts of daily duties, on which workers still spend a substantial amount of time.

Although muscle loadings were all below the known limits, the static muscle loading of the shoulder muscles (upper trapezius) and forearm extensor muscle (extensor digitorum) could be a concern that may lead to shoulder problems as the activity levels are still considerably high according to some research studies. Static muscle loading is usually resulted from holding the same posture for extended period of time. This was the case when the employees performing typing activities using the keyboards. Although most of the time, the employees might have used the armrests on the chair or wrist rest on the desk, these devices might not be effective enough in supporting the upper arms in performing the typing activity. Alternative support such as forearm support might need to be tested in the future. Typing also created relatively high static loading on the forearm extensor muscle as the employees needed to hold her/his hands in slightly extended hand/wrist posture during typing. Positioning of the keyboard in a negative slope could be a solution to reduce the static forearm extensor loading.

The static shoulder loading might be responsible for the muscle fatigue that occurred early in a work shift. After the first 1.5 hours of continuous work, the median frequency of the right trapezius muscle decreased to 92% of its original value, which is a sign of muscle fatiguing.

The static shoulder loading might also be responsible for the relatively high shoulder complaints. According to the employees' survey, 37% of the employees reported having had pain, itching, stiffness, burning, numbness, or tingling in the shoulder regions in the last 12 months. This was higher compared to the 31% found in the 1991 study. One of the future workplace improvements should probably be focused on lowering the static loading on the shoulder region for the employees.

Although muscle fatigue signs appeared early in a work shift, the muscles were not further fatigued even when the employees continued performing the same data entry activities for 6 hours. Furthermore, there were no differences on the employees' perceived fatigue levels for the shoulder and hand/arm regions between the 5<sup>th</sup> hour and 6<sup>th</sup> hour of a work shift. These results indicate that a 6-hour data entry schedule would not significantly elevate the potential risks of musculoskeletal disorders compared to the currently practiced 5-hour schedule.

According to the employees' survey, in general, most participants in the current study were satisfied with their current job situations, and felt that they had some or much influence over the decisions that affected their jobs. This was similar to what was found in the 1991 study.

Based on the results, it could be concluded:

- Task activities of the employees have changed compared to that in 1991. Workers spent less time on computers and performed less actual keying.
- Self-reported shoulder problems still existed and right shoulder muscle fatigue was observed early in a work shift. These could be caused by relatively high static loadings on the shoulder region. Reducing shoulder static loading should be the focus in future ergonomic improvement efforts.
- Employees were generally satisfied with their current job conditions.
- There were no significant differences of the physical loading effects on the employees between the proposed 6-hour data entry schedule and the currently practiced 5-hour data entry schedule.
- Ergonomic workstation conditions were generally improved compared to that in 1991. Work postures and workstation layout were generally acceptable according to current ergonomics guidelines.
- Further ergonomic improvements may need to go beyond the current office ergonomics guidelines. Proper employee task assignments in order to balance the workload should be practiced. Better hand/arm supports and alternative keyboard use may need to be investigated.

## Introduction

SHARP was approached by the program manager of the Support Services Administration, Insurance Services, Washington State Department of Labor and Industries to conduct an ergonomics evaluation among employees in the Bill Processing Unit. The primary goal of this evaluation was to determine whether the currently practiced 5-hour keying policy was still appropriate given the ergonomic improvements implemented since the original study, which was conducted in early 1990's.

The current 5-hour intensive keying policy was introduced after a series of studies conducted among workers in the Claim Initiation Unit (workers in Bill Processing have similar activities as those in Claim Initiation) in early 1990's by SHARP researchers (SHARP, 1991, 1992, 1993). During the study period, some changes were made in the Claim Initiation Unit such as introduction of new chairs, and practicing alternative work patterns (combination of keying claims and telephoning). Significant drops in the prevalence rates of reported discomfort were found on most body parts from the employees due to these changes. Employees gave positive feedback on alternative work schedules and less keying, new work stations and new building. These studies concluded that limiting keying to less than 5 hours and more frequent altering of medium and low paced keying may help reduce hand/wrist and shoulder musculoskeletal disorders.

More than 15 years has passed since the last ergonomics evaluation study. Technologies of data entry and data management have changed dramatically. Work content and work organization may have changed significantly as well. The agency has been focusing on workstation ergonomics through workers' ergonomics awareness training. Each unit has its own ergo leads who work together with the agency's ergonomics coordinator to improve workstation ergonomics in the unit. It is time to assess whether the 5-hour keying restriction is still valid or whether workers could safely key for up to six hours per day with no adverse health problems. Some employees have also asked to increase the daily keying hours.

The objectives of the present study were:

- Test effects on physical exposure of the employees when keying activities are extended from 5 to 6 hours.
- Study the work content to determine actual activities during the "keying" tasks and compare them with those of 15-18 years ago, when SHARP did similar studies among employees in the Claim Initiation Unit.
- Evaluate physical exposure of the employees in the current work scheduling condition, and compare them with those of previous studies.
- Study employees' perceptions including discomfort and working conditions.
- Apply job evaluation techniques in an office environment.
- Provide recommendations for further improvement.

### **Primary objectives**

- \* How do task activities at Bill Processing affect employees?**
- \* Is a 6-hour keying policy appropriate?**
- \* How can work conditions be further improved?**

## Materials and methods

### *Study Design*

This study consisted of three phases, (1) general employees' survey, (2) physical exposure assessment of the current work situation, and (3) study of extended keying period. Details of methods and procedures in each of the study phases will follow. This study was approved by the Washington State Internal Review Board (IRB) for the compliance with related federal, state, and local regulations.

#### **Study involved three phases:**

- \* A general employees' survey.**
- \* Physical exposure assessment of current work situation with computer use monitoring and video observation.**
- \* Detailed evaluation of extended keying period.**

### *Subjects*

An information session was conducted among Bill Processing employees at the beginning of the project by SHARP researchers to explain the background of the study, objectives, procedures, and answer questions. Positive responses were received from the employees. There seemed to be a willingness and good cooperation for this project from the workers and supervisors in this unit.

Participants were then recruited among the employees in this unit on a voluntary basis. There were about 22 employees in the unit who were performing data entry duties. Volunteers were asked choose to participate in one or more study phases. Signed consents were obtained. Table 1 shows the demographic data of the study participants for each of the three phases.

Table 1. Demographic data of the study participants (mean and range)

| Study phase* | # of subjects (male/female) | Average age (range) | Average height in feet (range) | Average number of years at the job (range) |
|--------------|-----------------------------|---------------------|--------------------------------|--|
| 1            | 19<br>(2/17)                | 42.5<br>(20.3-65.0) | 5.3<br>(5.0-5.9)               | 5.9<br>(0.1-19.8)                          |
| 2a           | 13<br>(1/12)                | 38.3<br>(20.3-63.6) | 5.4<br>(5.1-5.9)               | 6.3<br>(0.1-19.8)                          |
| 2b           | 7<br>(1/6)                  | 34.2<br>(20.3-45.1) | 5.5<br>(5.1-5.9)               | 5.2<br>(0.4-19.8)                          |
| 3            | 5<br>(1/4)                  | 40.0<br>(26.8-55.5) | 5.4<br>(5.1-6.0)               | 6.8<br>(0.5-19.8)                          |

\* Phase 2a included computer use monitoring and daily body discomfort survey, and phase 2b included the work activity and posture observation

### *Methods and procedures*

In **phase 1**, an all employees' survey was conducted to obtain musculoskeletal health information. The survey was administered through an online survey site (<http://www.surveymonkey.com/>) and the link to the survey questionnaires was sent to the employees in the Bill Processing Unit via emails. The survey collected basic

demographic information of the subjects, work history information, perceived musculoskeletal problems of the different body parts, and psychosocial questions. A sample survey questionnaire is attached in Appendix 1. Similar questions that were used in previous studies in the Claim Initiation unit were included in the present survey. Solicitation for participation in the subsequent phases was included at the end of the survey. After the general all employee survey, a list of volunteers for each of the study phases was obtained.

**Phase 2** participants were contacted and scheduled to perform physical exposure assessment. Three methods were used in phase 2: (1) computer use monitoring, (2) daily body discomfort survey, and (3) work activity and posture video observation.

The computer use was monitored by a software (RSIGuard, Remedy Interactive Inc., <http://www.rsiguard.com/index.htm> ) installed on each participant's computer. The program ran in the background and did not interfere with the participant's normal work activities. It registered various computer use information, including keyboard use time, mouse use time, time using computer, time not using computer etc. The program collected the daily computer use information for 10 complete workdays for each of the volunteers.

The daily body discomfort survey was conducted at the end of each workday when the computer use monitoring was performed. The survey was again administered online using the online survey engine (<http://www.surveymonkey.com/>), and an email reminder containing the survey page was sent to the participant shortly before the end of the participant's shift. The survey was shortened to one page and asked about discomfort levels of the different body parts (Appendix 2).

The work activity and posture observation was conducted on a separate day. This was done by a time-lapse camera installed at the participant's workstation and capturing still images at one frame per minute during a whole work shift. This observation measurement was done during a single full work day, which was chosen by the participant as a typical work day. Post coding was performed in the laboratory to categorize task activities and body postures of each captured image frame. This coding procedure was performed using a program made by SHARP, which allowed an analyst to view individual picture frames of the recorded task performances and code various task activities, work postures, and equipment use. Distribution (% of time) of task activities and work postures were computed.

In **phase 3**, physical exposure of extended keying period was evaluated using surface electromyographic (EMG) technique in combination with workers' perceived exertion measurement. Surface EMG electrodes were placed on the left and right trapezius muscles on the shoulders as well as the forearm flexor digitorum superficialis and extensor digitorum muscles of the dominant forearm to measure quantitatively the muscle activities of the shoulders and dominant hand (Figure 1). A calibration procedure was performed (Bao, Mathiassen, & Winkel, 1995, Bao, Silverstein, & Cohen, 2001) to obtain the maximal muscle activity level (MVC – maximal voluntary contraction) of each

of the tested muscles. Muscle activities during work were expressed in terms of percentage of the MVC (%MVC), which is a measure of the muscle load relative to the employee's capacity of a particular muscle. Percent of MVC (%MVC) is a relative risk indicator of muscle loading. The EMG distribution was calculated according to the Amplitude Probability Distribution Function (APDF). The static, median and peak muscle load levels were obtained corresponding to the 10<sup>th</sup>(P10), 50<sup>th</sup>(P50) and 90<sup>th</sup>(P90) percentiles of the APDF curve (Jonsson, 1982).

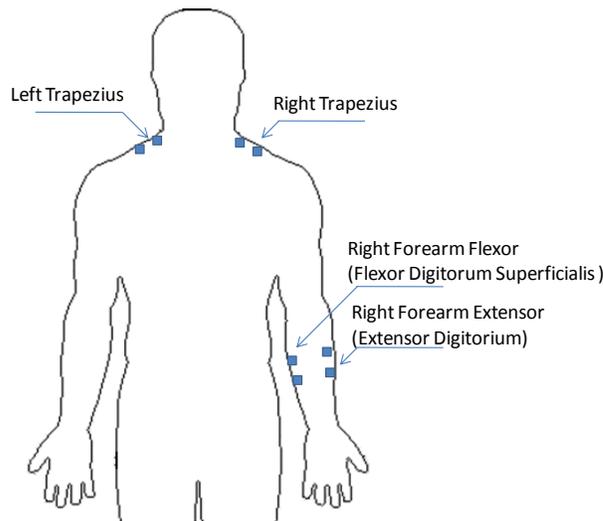


Figure 1. Placement of EMG electrodes (back side view)

Work muscle activities were measured four times (randomly selected between break times) during the work day. Each measurement lasted about 15 minutes. At the same time, the task was also video-taped allowing a detailed time study to be done, so that muscle activities (EMG) could be analyzed in relation to the different task activities. On-site observations were also performed in order to assess workstation conditions according to ergonomics principles (Computer Workstation Checklist, WorkSafeBC, Canada, Appendix 3) and work postures using the Rapid Upper Limb Assessment (RULA) method (McAtamney & Corlett, 1993). The workstation ergonomic condition and work posture assessment results were used to explain the obtained muscle activity results. The RSIGuard software was also installed on the participant's computer on the Phase 3 testing day, in order to ensure that the computer use on the testing day was comparable to the participant's normal work days as measured at Phase 2.

In order to evaluate the proposed 6-hour data entry scheme, muscle fatigue EMG measure and worker's self-reported fatigue level were used as the health indicators for the evaluation. The determination of whether the 6-hour data entry schedule is safe compared to the 5-hour data entry schedule was based on the assumption that when there was an absence of localized shoulder and hand muscle fatigue as measured by EMG and an absence of changes of

**Evaluation of 5- vs. 6-hour keying schedule to determine:**

**\* Any differences between muscle fatigue status as measured by surface EMG between 5 and 6 hours of keying?**

**\* Any differences on employees' perceived fatigue between 5 and 6 hours of keying?**

workers' perceived fatigue of the shoulder and hand regions between the two different schedules.

In order to obtain these indicators, a series muscle test contractions were performed, at the beginning of shift, before and after each of the breaks and at the end of the shift. The test contractions were performed by asking the participant to hold a constant weight of 2 lbs during standardized postures (Hägg & Suurküla, 1988, Bao et al., 2001) while EMG signals were recorded. Frequency analyses were performed on the EMG recordings of these test contractions. The median frequency of EME was calculated and used as an indicator of muscle fatigue (Hägg & Suurküla, 1988). A decreased median frequency indicates a trend of localized muscle fatigue. An index was calculated by comparing the median frequency with an initial median frequency value that was collected at the beginning of the work of the testing day. When the index is <1, it indicates a trend of muscle fatigue.

Before the test contractions, the worker was also asked about his/her perceived fatigue levels of their left and right shoulders and the left and right hand. The Borg CR-10 scale was used (Borg, 1982). The higher the scale is, the higher the perceived fatigue level.

## Results

### *Phase 1 results*

Nineteen data entry operators participated in the survey (participation rate = 86.4%). Eighty four percent (84%) of the participants were right handed. But all of the participants reported use of their right hand or both hands primarily at their jobs. All participants were touch (speed) typist. Most participants (78.9%) considered themselves fast in typing (41 or greater words per minute) and the rest (21.1%) were moderate (21 to 40 words per minute).

Table 1 shows the job characteristics of an average work day as reported by the participants. Data entry was the primary activity among the participants, although some participants might have assigned other primary activities and spent only 5% of their time in data entry.

Table 1: Job characteristics of an average work day

| Job activity               | Number of participants | Mean (Range)     |
|----------------------------|------------------------|------------------|
| % time spent in data entry | 18                     | 61.0 (5.0-100.0) |
| % time spent in keying     | 18                     | 63.9 (5.0-100.0) |
| % time spent on telephone  | 18                     | 2.8 (0.0-20.0)   |

Table 2 shows some of the common equipment that was used by the participants. This was the participants' self-reported equipment use. Some of the participants chose not to answer some of the questions. In general, most participants had the equipment to help them perform their job activities according to current ergonomics guidelines (Computer

### **Key findings of Phase 1**

**\* Most common musculoskeletal complaints were on the neck, followed by the shoulders and low back.**

**\* Employees were generally satisfied with their jobs.**

Workstation Checklist, WorkSafeBC, Canada, Appendix 3). Participants using ergonomic keyboards did not report any related musculoskeletal problems. Most of the participants who reported musculoskeletal problems were related to the use of standard keyboards (80%), and some reported using laptop (10%) and other types of keyboards (10%).

Table 2. Equipment used by participants

| Equipment that participants reported using | # of participants | Percent (%)     |
|--|-------------------|-----------------|
| Standard vs. ergonomic keyboard*           | 13 vs. 3          | 68.4% vs. 15.8% |
| Standard mouse vs. trackball mouse         | 18 vs. 1          | 94.7% vs. 5.3%  |
| Keying from hard copies                    | 7 out of 18       | 38.9%           |
| Two monitors                               | 17 out of 19      | 89.5%           |
| Document holder                            | 11 out of 19      | 57.9%           |
| Wrist rests                                | 11 out of 19      | 57.9%           |
| Arm rest on the chair                      | 9 out of 19       | 47.4%           |
| Footrest                                   | 14 out of 19      | 73.7%           |
| Headset                                    | 5 out of 19       | 26.3%           |

\* The rest of the participants (3 or 15.8%) used other types of keyboards such as laptop keyboard etc.

Table 3 shows prevalence rates of participants that reported having musculoskeletal problems (pain, itching, stiffness, burning, numbness, or tingling) in different body areas in the last 12 months. Neck problems were most frequently reported, followed by shoulder and low back problems. Problems of the elbow/forearm and hand/wrist were relatively low. Although neck problems were most frequently reported, participants reported that low back (42.9%) and shoulder (35.7%) problems were most concerning when they were asked to name the worst problem they had. Most of the neck and shoulder problems were first experienced in the last few years. However, some of the low back problems occurred a long time ago.

Table 3. Prevalence rates of reported musculoskeletal problems in the last 12 months

| Body part     | # of participants reported problem | % participants reported problems | Years that the problem first experienced (mean and range) |
|---------------|------------------------------------|----------------------------------|---|
| Neck          | 8 out of 19                        | 42.1%                            | 2.7 (0.3-7.7)   |
| Shoulder      | 7 out of 19                        | 36.8%                            | 2.9 (0.6-5.3)   |
| Elbow/forearm | 3 out of 19                        | 15.8%                            | 7.5 (7.5-7.5)   |
| Hand/wrist    | 2 out of 19                        | 10.5%                            | 2.5 (2.5-2.5)   |
| Low back      | 7 out of 19                        | 36.8%                            | 13.6 (0.3-27.5)   |

Table 4 shows some of the consequences that the participants had due to the reported musculoskeletal problems. Reported problems on the shoulders, and elbows/forearms usually did not last very long (< 1 day). However, problems affecting the neck, hands/wrists and low back could last more than a day. Many of the participants who experienced musculoskeletal problems also had the problems in the last 7 days. Most people visited a doctor for their problems. Problems with the low back, shoulders and neck have caused workers not being able to come to perform their normal work activities. Fourteen percent (14%) of the workers who had low back problem were assigned to light duty activities. Some workers who had problems reported certain activities could make

their problems worse. The most often reported activities included prolonged sitting (especially in static/awkward postures), and keying in static/awkward posture. Shoulder problems were reported to get worse towards the end of a workday. Prolonged standing was also reported to make low back problems worse.

Table 4. Characteristics and consequences related to the reported musculoskeletal problems (% of participants who had the problem affected)

| Measure                                 | Neck | Shoulders | Elbows/forearms | Hands/wrists | Low back |
|---|------|-----------|-----------------|--------------|----------|
| Problem lasted for $\geq$ 1 months*     | 16.7 | 0.0       | 0.0             | 50.0         | 0.0      |
| Problem lasted for 1 week to 1 month*   | 16.7 | 0.0       | 0.0             | 0.0          | 0.0      |
| Problem lasted for 1 day to 1 week*     | 16.7 | 0.0       | 0.0             | 0.0          | 14.3     |
| Problem lasted for $<$ 1 day*           | 50.0 | 100.0     | 100.0           | 50.0         | 85.7     |
| Still experience problem in last 7 days | 57.1 | 75.0      | 66.7            | 50.0         | 71.4     |
| Activities made the problem worse       | 50.0 | 50.0      | 66.7            | 0.0          | 57.1     |
| Visited doctor for the problem          | 62.5 | 50.0      | 0.0             | 50.0         | 71.4     |
| Missed work due to the problem          | 12.5 | 25.0      | 0.0             | 0.0          | 28.6     |
| Assigned to light duty activity         | 0.0  | 0.0       | 0.0             | 0.0          | 14.3     |

\* Time lasted for each episode.

Table 5. Percent (%) of responses on the psychosocial questions (# of participants: 19)

| Question  | Rarely             | Occasionally        | Sometimes              | Fairly often       | Very often       |
|---|--------------------|---------------------|------------------------|--------------------|------------------|
| How often are you faced with conflicting demands of people you work with?                                 | 55.6               | 11.1                | 33.3                   | -                  | -                |
| How often does your job leave you with too little time to get everything done?                            | 50.0               | 5.6                 | 22.2                   | 16.7               | 5.6              |
| How often is your supervisor willing to listen to your work-related problems?                             | -                  | -                   | 11.8                   | 17.7               | 70.6             |
|   | <i>Very little</i> | <i>Little</i>       | <i>Moderate amount</i> | <i>Much</i>        | <i>Very much</i> |
| How much influence do you have over the amount of work you do?  | 16.7               | 11.1                | 22.2                   | 33.3               | 16.7             |
| How much influence do you have over the availability of materials you need to do your work?               | 27.8               | -                   | 16.7                   | 44.4               | 11.1             |
| How much do you influence the policies and procedures in your work groups?                                | 22.2               | 5.6                 | 22.2                   | 38.9               | 11.1             |
| How much influence do you have over the arrangement of furniture and other equipment at your workstation? | 17.7               | -                   | 17.7                   | 47.1               | 17.7             |
|   | <i>Not at all</i>  | <i>Not too much</i> | <i>Some what</i>       | <i>Quite a bit</i> | <i>Very much</i> |
| How satisfied are you with the amount of influence you have over the decisions that affect your job?      | 11.1               | 11.1                | 27.8                   | 27.8               | 22.2             |
| All in all how satisfied are you with your job?   | 11.1               | 5.6                 | 16.7                   | 11.1               | 55.6             |

Table 5 lists the psychosocial survey results. Overall, most participants were satisfied with their current job situations, and felt that they had some or much influence over the decisions that affect their jobs. However, different opinions did exist as shown in the table. In terms of job stress, most workers rarely or only occasionally felt conflicting demands with co-workers and short of time finishing their work, and very often felt that their supervisors were willing to listen to their work-related problems. Most participants thought that they had much or very much influence on the amount of work they did, availability of materials they needed for their work, work policies and procedures, and arrangement of furniture and work equipment they used. Again, different opinions did exist to these aspects as well.

### *Phase 2 results*

On average, participants reported 4.8 (95% confidence interval (95%CI): 4.6–5.0) hours/day using computer while the RSIGuard computer monitoring program registered 3.8 (95%CI: 3.6–4.0) hours/day computer use (computer in use). Participants significantly overestimated their computer use time by about 1.0 (95%CI: 0.8-1.1) more hour/day ( $p < 0.0001$ , paired t-test). There was a moderate correlation between the self-reported computer use time and RSIGuard registered hours (Pearson correlation coefficient: 0.57). Individual differences were significant among participants in registered computer use time ( $p < 0.001$ ), i.e. some workers used computers more than others. Furthermore, day-to-day variations were also significant ( $p = 0.0065$ ), i.e. more computer use on some days than others.

Table 6. RSIGuard registered computer use information (mean and 95%CI)

| Parameter  | Phase 2a<br>(N=10x13)* | Phase 2b<br>(N=5)  | Phase 3<br>(N=5)    |
|--|------------------------|--------------------|---------------------|
| Computer use time (hours)                                  | 3.8 (3.6-4.0)          | 4.1 (2.8-5.5)      | 4.6 (3.5-5.7)       |
| Keyboard use time (hours)                                  | 3.4 (3.2-3.6)          | 3.9 (2.5-5.3)      | 4.5 (3.5-5.6)       |
| Mouse use time (hours)                                     | 3.4 (3.2-3.7)          | 4.0 (2.5-5.5)      | 4.5 (3.4-5.6)       |
| Computer not in use time (hours)                           | 3.6 (3.4-3.8)          | 3.2 (1.6-4.9)      | 2.0 (0.9-3.2)       |
| Total keystrokes per shift (x100)                          | 220 (194-247)          | 271 (42-501)       | 379 (298-461)       |
| Total number of mouse clicks per shift                     | 1067<br>(983-1151)     | 1517<br>(990-2045) | 1145<br>(1017-1272) |
| Keystrokes per minute (times/min)                          | 99 (90-108)            | 112 (36-188)       | 139 (134-145)       |
| Mouse clicks per minute (times/min)                        | 5.5 (5.1-6.0)          | 6.6 (4.4-8.8)      | 4.4 (2.9-5.9)       |
| Frequency switching between keyboard and mouse (times/min) | 4.8 (4.4-5.3)          | 7.1 (3.8-10.4)     | 6.5 (2.4-10.5)      |

\* Phase 2a had 10 days' data on 13 participants.

On average, the total number of hours that the participants were not using their computer (computer not in use) in a shift was 3.6 (95%CI: 3.4-3.8) hours (Table 6). This included lunch, regular breaks as well as away from computer while performing other work-related and non-work-related activities. The ratio of “computer in use” to “computer not in use” was 1.14 (95%CI: 0.99-1.30).

The total number of mouse clicks were 1,067 (95%CI: 982-1151) per shift, and the total number of keystrokes were 22,046 (95%CI: 19401-24691). The continuous keyboard and mouse use hours were defined as the cumulative durations in which two consecutive keystrokes/mouse clicks occur within a 20 second interval. Mouse clicks included not only mouse clicks but also mouse moves and wheel-spins. These corresponded to 3.4 (95%CI: 3.2-3.7) hours of continuous mouse use and 3.4 (95%CI: 3.2-3.6) hours of continuous keyboard use.

Table 7 shows the reported daily discomfort rating for the different body parts. Shoulder (particularly the right shoulder), neck and low back had the highest ratings. Although on average the discomfort ratings were on the lower end (0: lowest discomfort, 10: highest discomfort), some individual participants did report high discomfort in the various body parts. There were significant differences ( $p < 0.05$ , general linear model procedure with subjects, and measurement days in the model) on body discomfort ratings between individual participants for several body parts (neck, shoulders, right wrist and low back), and between measurement days for a few body parts (left shoulder, left elbow and low back).

**Key findings of Phase 2**

**\* On average, each employee actually spent about 3 to 4 hours on the computer each shift.**

**\* Longer computer use was associated with higher shoulder and low back discomfort ratings, although discomfort levels were generally low.**

**\* Longer breaks were associated with lower discomfort ratings.**

**\* Workers had generally acceptable work postures when performing data entry work on the computer.**

Table 7. Daily body discomfort survey results

| Body part      | # of participants and recorded days* | Mean discomfort rating (range) with 0 lowest discomfort and 10 highest discomfort | Had between participant difference | Had between day difference |
|----------------|--------------------------------------|---|------------------------------------|----------------------------|
| Neck           | 13 x 10                              | 0.51 (0-4)  | yes                                | no                         |
| Left shoulder  | 13 x 10                              | 0.49 (0-6)  | yes                                | yes                        |
| Right shoulder | 13 x 10                              | 1.55 (0-10)   | yes                                | no                         |
| Left elbow     | 13 x 10                              | 0.04 (0-4)  | no                                 | yes                        |
| Right elbow    | 13 x 10                              | 0.12 (0-6)  | no                                 | no                         |
| Left wrist     | 13 x 10                              | 0.08 (0-7)  | no                                 | no                         |
| Right wrist    | 13 x 10                              | 0.23 (0-5)  | yes                                | no                         |
| Low back       | 13 x 10                              | 0.43 (0-6)  | yes                                | yes                        |

\* 10 measurement days on 13 participants.

Table 8 shows the correlation analysis results between the computer use parameters and body discomfort ratings. It seems that the number of hours was somewhat correlated to shoulder and low back discomfort ratings. Longer computer use hours were associated with higher discomfort on these body parts. Longer break durations (computer not in use) were associated with lower discomfort ratings in the neck, shoulder and low back region.

Longer keying and mouse uses and more key strokes were related to higher discomfort rating in the right shoulder region.

Table 8. Correlations between body discomfort rating and computer use parameters, Pearson correlation coefficient (p-value) – including all data (n = 10x13).

| Body part        | Hours of computer use | Hours of breaks | # of key strokes | # of mouse clicks | Hours of keying | Key-strokes/ min | Hours of mouse use | Mouse clicks/ min |
|------------------|-----------------------|-----------------|------------------|-------------------|-----------------|------------------|--------------------|-------------------|
| Neck             | 0.14                  | -0.24*          | 0.11             | 0.11              | 0.14            | 0.12             | 0.20*              | -0.06             |
| Left shoulder    | 0.27*                 | -0.27*          | 0.14             | 0.06              | 0.27*           | 0.09             | 0.28*              | -0.19*            |
| Right shoulder   | 0.45*                 | -0.33*          | 0.31*            | -0.06             | 0.46*           | 0.13             | 0.46*              | -0.35*            |
| Left elbow       | 0.12                  | -0.08           | 0.05             | 0.03              | 0.13            | 0.01             | 0.12               | -0.06             |
| Right elbow      | 0.02                  | -0.03           | -0.05            | 0.08              | 0.00            | -0.07            | 0.04               | 0.01              |
| Left hand/wrist  | -0.01                 | -0.02           | -0.11            | 0.04              | -0.16           | -0.07            | 0.01               | 0.02              |
| Right hand/wrist | -0.16                 | 0.08            | -0.21*           | 0.00              | -0.18           | -0.22*           | -0.09              | 0.07              |
| Low back         | 0.31*                 | -0.24*          | 0.12             | 0.19*             | 0.25*           | 0.05             | 0.32*              | -0.11             |

\* Significant at  $p < 0.05$ .

Video observations, on average, collected 485 (range: 468-501) pictures on each of 6 completed participants during a work shift, which was about 8.1 hours (including break times). Work activities and work postures were categorized picture by picture. Table 9 shows the distribution of task activities, keyboard/mouse use, as well various work postures. Employees spent about 40% of the shift time (including all break times) using computers, which corresponded to about 3.2 hours computer use.

During computer work, the right hand was on the keyboard 54% of the time compared to 41% of the time on the mouse (Table 9). Most of the time, the employees had their postures in neutral positions. Upper arms were often supported on the chair's armrests (about 85% of the time). On average, the low back was supported by the chair's backrest 76% of the time. The operators sat upright most of the time (68% of the time). However, they did spend some time leaning forward (13%) and sitting in a reclined posture (19%).

Table 9. Distribution of task activities, keyboard/mouse use, and work postures based on video observations (% of the shift, mean and range)

| Parameter  | Distribution (% of shift) |
|--|---------------------------|
| <i>Task activity (N = 6)</i>                               |                           |
| Computer work  | 40.3 (13.9-65.6)          |
| Away from computer and workstation (including break times) | 33.9 (8.5-59.5)           |
| Conversation with co-workers                               | 3.5 (1.1-7.0)             |
| Organizing documents                                       | 4.0 (0.6-11.4)            |
| Micro breaks   | 4.2 (1.0-8.2)             |
| Using the phone  | 1.3 (0.2-2.5)             |
| Reading at desk  | 6.0 (1.0-10.6)            |
| Writing at desk  | 3.5 (1.6-6.0)             |
| Other  | 3.9 (1.5-7.9)             |

Table 9. continues

| <i>Computer work and work postures (N = 6)</i> |   |
|--|---|
| Keyboard/mouse use (left hand)                 | Keyboard: 79.6 (62.2-97.5); mouse: 0.0 (0.0-0.0)  |
| Keyboard/mouse use (right hand)                | Keyboard: 53.6 (19.1-77.6); mouse: 41.0 (19.4-68.3)   |
| Upper arm flexion (left)                       | neutral: 99.0 (97.0-100.0); 20°-45°: 0.6 (0.0-3.0);<br>45°-90°: 0.4 (0.0-2.1); >90°: 0.0 (0.0-0.0)                                      |
| Upper arm flexion (right)                      | neutral: 96.1.0 (82.0-100.0); 20°-45°: 3.8 (0.0-18.0);<br>45°-90°: 0.1 (0.0-0.7); >90°: 0.0 (0.0-0.0)                                   |
| Upper arm rotation (left)                      | neutral: 75.4 (44.3-97.5); inward rotation: 23.9 (2.5-55.7);<br>outward rotation: 0.7 (0.0-2.1)   |
| Upper arm rotation (right)                     | neutral: 86.2 (70.1-96.1); inward rotation: 10.1 (2.5-27.8);<br>outward rotation: 3.7 (0.4-13.4)  |
| Wrist flexion/extension (left)                 | neutral: 94.3 (90.7-99.7); extension>15°: 5.1 (0.0-8.4);<br>flexion>15°: 0.6 (0.0-1.0)  |
| Wrist flexion/extension (right)                | neutral: 97.4 (94.8-100.0); extension>15°: 2.0 (0.0-5.2);<br>flexion>15°: 0.1 (0.0-0.4)   |
| Wrist ulnar/radial deviation (left)            | neutral: 81.4 (31.3-100.0); ulnar deviation>15°: 18.3 (0.0-<br>68.7); radial deviation>5°: 0.2 (0.0-1.0)                                |
| Wrist ulnar/radial deviation (right)           | neutral: 88.2 (52.5-100.0); ulnar deviation>15°: 11.5 (0.0-<br>47.5); radial deviation>5°: 0.2 (1.0-1.5)                                |
| Neck flexion/extension                         | Neutral: 82.1 (66.0-97.1); flexion>20°: 15.6 (2.9-33.0);<br>extension>5°: 2.4 (0.0-6.0)   |
| Neck rotation                                  | Neutral: 75.2 (59.7-87.0); rotation to left>15°: 0.9 (0.0-1.7);<br>rotation to right>15°: 23.9 (11.3-39.8)                              |
| Trunk flexion/extension                        | Neutral: 94.1 (82.1-99.5); extension>5°: 5.9 (0.5-17.9)   |
| Arm supported (left)                           | 87.5 (68.7-100.0)   |
| Arm supported (right)                          | 86.7 (53.5-98.0)  |
| Back supported                                 | 75.8 (5.2-98.5)   |
| Overall posture                                | Leaning forward: 12.7 (0.5-34.3);<br>Sitting upright: 68.0 (1.5-97.7);<br>Sitting reclined: 18.7 (0.0-98.0);<br>Standing: 0.6 (0.0-3.0) |

### *Phase 3 results*

The average EMG recording work sample was 15.6 (range: 15.0-20.3) minutes. According to detailed time study of the video recordings of these work samples, the participants spent most of their time on keying (73.8%), followed by mousing (13.9%) as shown in Table 10. Continuous typing duration was 13.5 seconds compared to only 3.0 seconds for mousing (Table 10).

#### **Key findings of Phase 3**

**\* Static loading on forearm extensor and shoulder muscles were the main concerns.**

**\* Static muscle loading was related to computer work characteristics.**

**\* There was no difference of fatigue indicators between 5-hour vs. 6-hour data entry schedule.**

**\* Muscle fatigue signs appeared early in a work day.**

The RSIGuard registered computer use time was 4.6 (95%CI: 3.5-5.7) hours (Table 6). The computer not in use time was 2.0 (95%CI: 0.9-3.2) hours. Keyboard use and mouse use times were 4.5 (95%CI: 3.5-5.6) hours and 4.5 (95%CI: 3.4-5.6) hours respectively.

Table 10. Task activity performance characteristics based on detailed video observation analysis (mean and 95%CI, # of subjects: 4, # of work samples/subject: 4)

| Parameter                                 | Typing              | Mousing             | Desk work           | Away from desk      | Other seated activities |
|---|---------------------|---------------------|---------------------|---------------------|-------------------------|
| % time                                    | 73.8<br>(68.6-79.0) | 13.9<br>(10.4-17.4) | 6.2<br>(2.7-9.6)    | 2.2<br>(0.6-3.8)    | 3.9<br>(2.1-5.6)        |
| Continuous duration (sec)                 | 13.5<br>(10.8-16.2) | 3.0<br>(2.0-4.1)    | 6.5<br>(3.3-9.7)    | 17.5<br>(5.8-29.2)  | 7.3<br>(4.6-10.1)       |
| Number of activity changes (times/minute) | 3.74<br>(2.96-4.52) | 3.20<br>(2.40-4.00) | 0.63<br>(0.23-1.04) | 0.04<br>(0.01-0.06) | 0.37<br>(0.11-0.63)     |

Table 11 shows muscle activities during the work sample periods. Three different muscle activity levels of the amplitude probability distribution function (APDF) analysis are shown in this table representing (1) static loading (10<sup>th</sup> percentile level or P10), (2) median loading (50<sup>th</sup> percentile level or P50), and (3) peak loading (90<sup>th</sup> percentile level or P90).

Table 11. Forearm and shoulder muscle activities (%MVC) recorded during the work samples, mean and standard deviation (missing subject: 1)

| Muscle                         | # of subjects and # work samples | Static level (P10) | Median level (P50) | Peak level (P90) |
|--------------------------------|----------------------------------|--------------------|--------------------|------------------|
| Extensor digitorum             | 4x4                              | 3.95 (1.30)        | 7.67 (1.46)        | 13.99 (1.80)     |
| flexor digitorum superficialis | 4x4                              | 1.92 (0.77)        | 4.22 (1.37)        | 24.38 (22.01)    |
| Left trapezius                 | 4x4                              | 1.39 (0.72)        | 3.12 (1.70)        | 7.03 (4.34)      |
| Right trapezius                | 4x4                              | 2.06 (1.61)        | 5.08 (3.12)        | 11.07 (6.09)     |

Muscle activities were very different when performing different task activities (Figure 2). Forearm extensor muscle had the highest static loading while performing mousing, typing and desk work, compared to the other activities ( $p < 0.05$ ). However, mousing and typing activities had lower shoulder muscle static loading compared to desk work and other seated work activities ( $p < 0.05$ ).

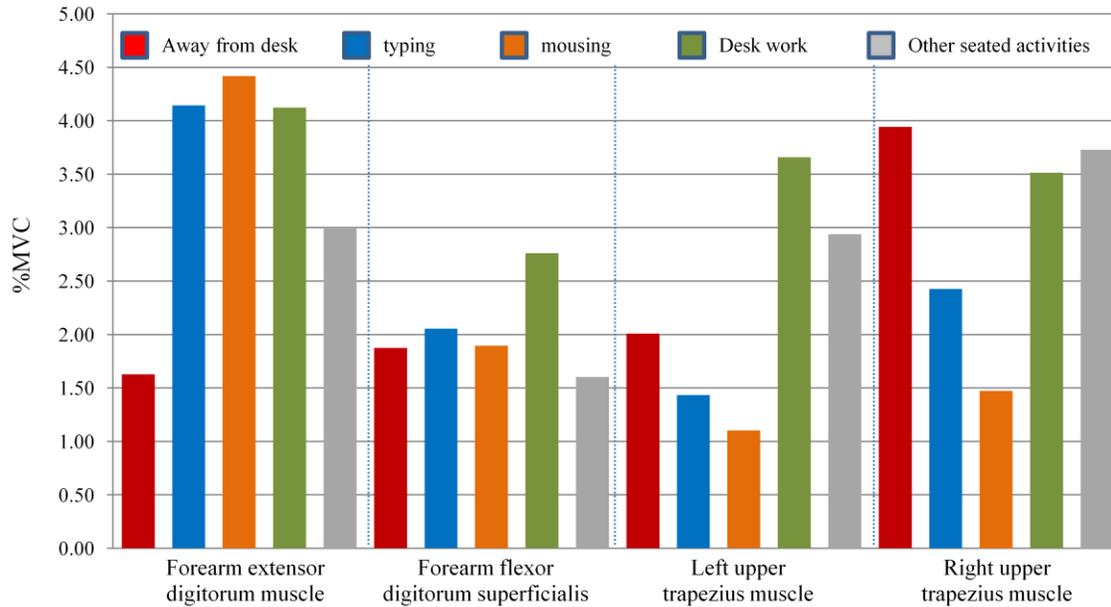


Figure 2. Mean static muscle activities (%MVC) when performing different activities (# of subjects = 4, # of work samples per subject: 4)

Table 12 shows the correlations between the total percent of time spent on the different activities and the static muscle activities. Longer percent of time spent on typing resulted in higher forearm extensor static loading (Figure 3a), but longer percent of time and longer continuous time spent on mousing resulted in lower forearm extensor and flexor muscle static loadings (Figure 3b). Frequently changing activities (e.g., between typing to mousing or other activities) had different effects on static muscle loadings of the left and right shoulders Figure 4a and 4b). The more frequently activities were changed, the higher static loading on the left shoulder (Figure 4a), but lower static loading on the right shoulder (Figure 4b).

Table 12. Pearson’s correlation coefficient between task activity characteristics and the static muscle loading (# of subject = 4 and # of work sample = 4)

| Activity          | Task study parameter                   | Forearm extensor digitorum | Forearm flexor digitorun superficialis | Left upper trapezius | Right upper trapezius |
|-------------------|--|----------------------------|--|----------------------|-----------------------|
| Typing            | % time                                 | 0.66*                      | -0.03                                  | -0.17                | -0.32                 |
| Mousing           |  | -0.70*                     | -0.51*                                 | 0.24                 | -0.15                 |
| Desk work         |  | -0.48                      | 0.20                                   | 0.18                 | 0.51*                 |
| Typing            | Continuous duration (sec)              | 0.32                       | 0.69*                                  | -0.56*               | 0.33                  |
| Mousing           |  | -0.51*                     | 0.24                                   | -0.20                | 0.30                  |
| Desk work         |  | 0.22                       | 0.28                                   | -0.17                | -0.19                 |
| To/from typing    | Number of activity changes (times/min) | -0.23                      | -0.87*                                 | 0.55*                | -0.51*                |
| To/from mousing   |  | -0.13                      | -0.90*                                 | 0.46                 | -0.60*                |
| To/from desk work |  | -0.45                      | 0.18                                   | 0.09                 | 0.62*                 |

\* significant at  $p < 0.05$ .

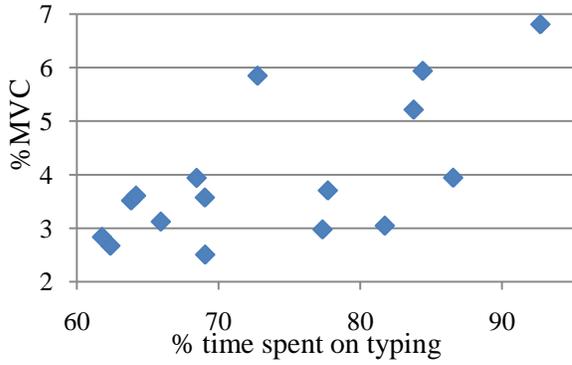


Figure 3a. Static forearm extensor loading and total % time spent on typing

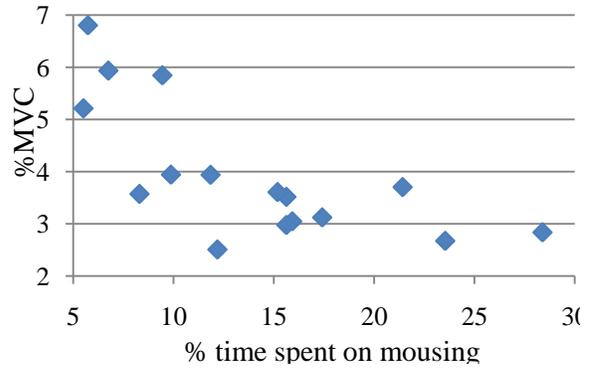


Figure 3b. Static forearm extensor loading and total % time spent on mousing

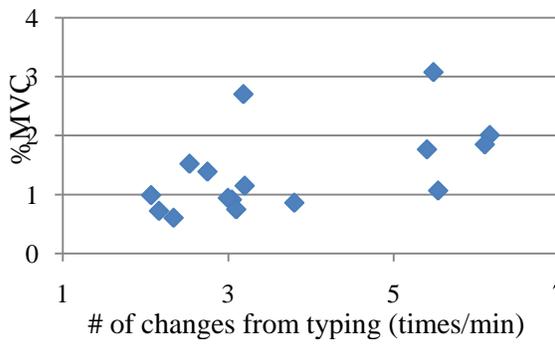


Figure 4a. # of changes from typing (times/min) and static left shoulder muscle loading

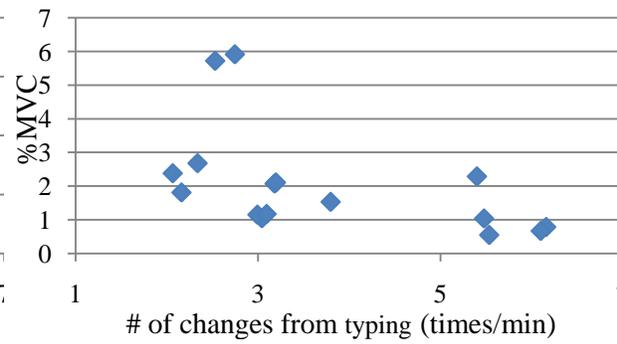


Figure 4b. # of changes from typing (times/min) and static right shoulder muscle loading

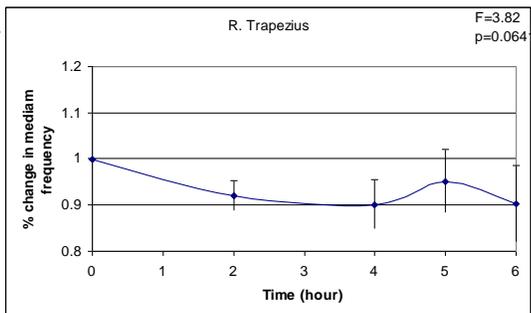
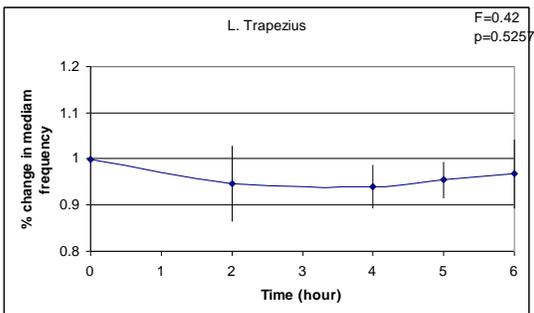
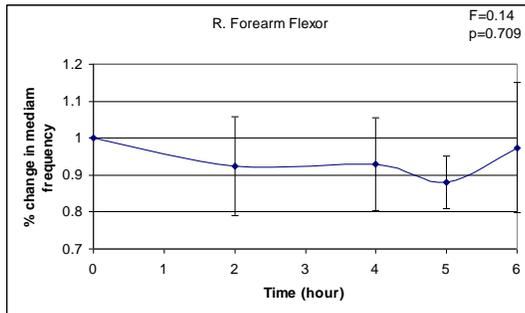
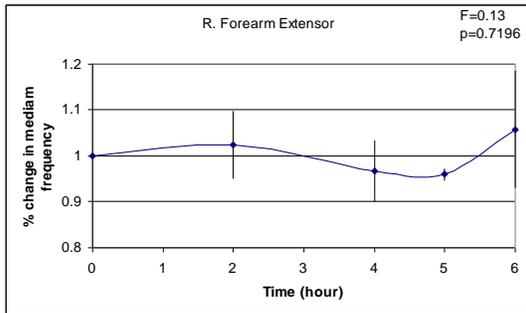


Figure 5. Median EMG frequency changes of four different muscles during a work shift (# of subjects = 5)

There were statistically significant differences ( $p < 0.05$ ) between employees with regards to the median EMG frequency changes on all four measured muscles. This indicated that the fatigue effects were different between individuals. There were significant differences ( $p < 0.05$ ) with regards to the right trapezius muscle (shoulder) median frequency changes between different times during a work shift, though no such differences were found to be statistically significant ( $p > 0.05$ ) for the other three muscles.

In general, the shoulder muscles (trapezius muscles) and forearm flexor muscle demonstrated a trend of fatigue at work compared to before work (Figure 5). This trend seemed to occur just after a couple of hours from the start of a work shift. Due to the large individual differences, such a trend was only statistically significant on the right shoulder muscle ( $p < 0.05$ ). At the first break time, on average, the median frequency of the right trapezius was decreased to 92% of the initial values.

There were no statistically significant signs showing the muscles were getting further fatigued over the entire testing day for any muscles ( $p > 0.05$ ). There were no statistically significant shifts of the median frequency of any muscles at the 5-hour and 6-hour measurement times ( $p > 0.05$ ). This indicated that data entry did cause shoulder muscle fatigue particularly during the initial period of a shift, however, evidence did not show a significant difference between the 5-hour and 6-hour data entry schedules.

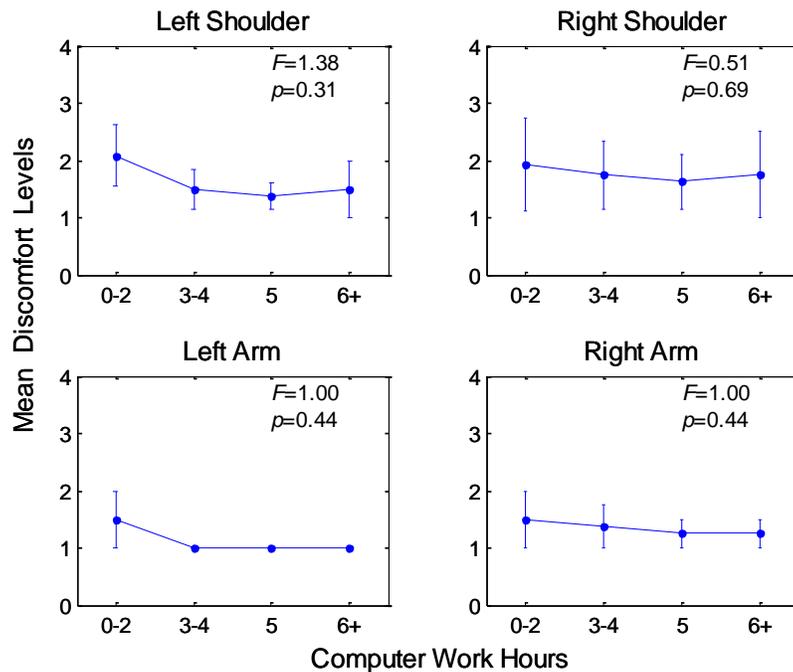


Figure 6. Changes of workers' self-reported fatigue levels during a work day (# of subject=5); Computer work hours = Total work hours – Rest hours (regular and lunch breaks)

There were statistically significant differences between subjects with regards to the employees' self-reported discomfort levels of both shoulders and the right hand ( $p < 0.05$ ). However, there was no significant difference between the subjects on the self-reported

left hand discomfort level ( $p>0.05$ ). No significant differences on the self-reported discomfort levels of all four body parts between different times of the work shift ( $p>0.05$ ). On average, the employees' self-reported discomfort levels were 1.6 (95% CI: 1.3-1.9), 1.8 (95% CI: 1.4-2.2), 1.2 (95% CI: 0.9-1.4) and 1.3 (95% CI: 1.1-1.6) on a 0 to 10 scale for the left, right shoulders and left and right hands respectively. The corresponding verbal anchors on the Borg scales (Borg, 1982) were between “very, very light” to “very light”.

According to workers' self reported fatigue levels of the different body parts, no statistically significant changes ( $p>0.05$ ) were found between hour 5 and 6 (Figure 6).

In terms of the general quality of workstation layout based on current office ergonomics guidelines, the observational evaluations showed that the workstations of the five participants were in compliance with these ergonomics guidelines. Some minor issues were observed and listed in Table 13.

Three out of the five participants had a final rapid upper limb assessment (RULA) score of 1, indicating that posture was acceptable if it was not maintained or repeated for long periods. Two of the five participants received a RULA score of 3, indicating that further investigation was needed and changes might be required. The moderate RULA score was mainly contributed by occasional forearm reaching activities.

Table 13: Ergonomic workstation quality issues based on observational evaluation (including observation results of both phase 2 and 3)

| # of work-stations affected (phase 2 + 3) | Issue description   |
|---|---|
| 2+1                                       | Keyboard was slightly too high causing forearms to be at a $<90^\circ$ angle.   |
| 2+1                                       | Low back was not supported by the curved part of the chair backrest.  |
| 4+3                                       | Most footrests do not have the possibility to adjust the angle of $10^\circ$ - $20^\circ$ .   |
| 1+2                                       | Some chair's backrests could not be raised or lowered.  |
| 1   | The angle of backrest could not be adjusted.  |
| 2+1                                       | Worker was not able to place her chair at a comfortable typing or viewing distance from the screen due to chair's armrests.                         |
| 0+1                                       | It was not possible to tilt the chair's seat.   |
| 4+1                                       | No document holder was used.  |
| 0+1                                       | Awkward posture was maintained when using the phone.  |
| 0+1                                       | Not enough space beneath the work surface to move legs.   |
| 1+1                                       | Worker did not consider the elements of job to determine if they could be improved by re-organizing, alternating, modifying, or expanding the tasks |
| 0+3                                       | A few workers did not stretch and move their muscles regularly.   |

## Discussion and conclusions

### *Work activities*

In the 1991 study, it was found that employees sat approximately 80% of the work shift and 60% of the work shift was spent on actual keying. The present study showed that the employees sat at their desk about 66% of the time, while only 40% of the work shift was spent at using their computers according to the results of the video observations (Table 9). Absence from the work area was minimal in the 1991 study, compared to about 34% in the present study (Table 9). There seemed to be a significant reduction of computer work and increase in doing other activities away from computer and workstation in the present study. This indicated larger activity variability in the current jobs compared to those in 1991. These could be attributed to many factors including computer technology advances, actual work content changes and work organization changes.

**Workers spent less time on computers and less time on actual keying now compared to 18 years ago.**

The 40% of time spent on computers corresponded to 3.2 hours computer use per work shift according to the phase 2 video recording analysis. This figure was comparable or probably slightly greater than the usual conditions. This is because that the computer use time of phase 2b (when operators were video filmed during the work shift) was about 1.08 times greater than phase 2a (when no video cameras were used and 10-day average data were collected) according to the RSIGuard monitoring program (Table 6). The knowledge of being video filmed during a workday might have modified employees' work behavior slightly. This might be confirmed by the computer use data registered by the RSIGuard program at Phase 3 when the employees were monitored by on-site researchers. The registered computer use time at Phase 3 was 1.21 times of that during the 10-day monitoring period. Employees spent more time at their computer when they were aware of being observed.

The actual numbers (between 3.8 to 4.6) of hours of computer use registered by the RSIGuard program (Table 6) somewhat overestimated the actual computer use time as the video observation showed only 3.2 hours computer use. This discrepancy was due to the design of the RSIGuard program. It only started to register the change when the computer was idle for more than 20 seconds. For example, if an employee was away from the computer to fetch some document and returned within 20 seconds, the RSIGuard program would consider the computer was used continuously during the period, while the video observation would pick up the absence. This also caused the errors in the keyboard and mouse use times. The RSIGuard program registered almost equal keyboard and mouse use times (Table 6), while the video observation showed keyboard use of the right hand was 1.3 times more than the mouse use (Table 9) and detailed time study at Phase 3 showed typing on a keyboard was 5.5 times more often than using a mouse (Table 10). The short continuous durations (Table 10) of keyboard use (13.5 seconds) and mouse use (3.0 seconds) were shorter than the 20 second lag time

of the RSIGuard program, resulting in the RSIGuard program over-registered the keyboard and mouse use times.

### *Physical exposures*

In general, workers spent most of their time (when using their computers) in neutral postures (Table 9). This probably explained the low RULA scores obtained through the observations at Phase 3. This indicated that the employees had relatively low postural loading (i.e., had good work postures in general) when performing their computer work.

The measured muscle loadings at the median and peak levels (Table 11) seemed to be not a health concern according to current knowledge on vocational EMG measurement. According to Jonsson (1982), a median EMG load level at or below 10%MVC and a peak level at or below 50%MVC should be considered safe. The median and peak EMG levels of the employees in Phase 3 were much lower than the recommended limits (Table 11). In addition, the employees also reported relatively low perceived discomfort levels (between very, very light to very light) when performing the data entry activities (Phase 3 results).

With regards to the static EMG levels during when the muscles had to hold for a longer period of time such as to maintain a posture, the current limit standard was 2 to 8%MVC (Jonsson, 1982, Westgaard & Winkel, 1996). However, some researchers even suggested a lower acceptable limit of 1%MVC (Aarås, 1987). In that case, the static muscle loading of the current study could be a potential concern as they were near the lower bound of the suggested limit (Table 11).

**Although physical loading was generally acceptable according to current guidelines, static muscle loading that resulted from maintaining a work posture was a potential concern.**

High static muscle loading can usually cause muscle fatigue, which is believed to be linked to the development of musculoskeletal disorders (Armstrong, 1993). The relatively high right shoulder static muscle loading of 2%MVC in the current study (Table 11) was likely to be responsible for the development of right shoulder muscle fatigue early in a work shift (Figure 5).

As mentioned earlier, static muscle loading is related to maintaining a posture for a long period of time. This was reflected in the results in Table 12. Longer % time in typing was correlated to higher forearm extensor muscle loading as typing requires an operator to hold his/her hand posture steady, while frequent changing between typing to mousing/desk work was correlated to lower right upper trapezius and forearm extensor muscle loadings, as the postures are changed between the activity changes. An interesting finding on the relationships between the frequency of changes from typing to other activities and the left and right upper trapezius static muscle loading (Table 12) should be noted. With the frequency of activity changes increased, the left upper trapezius static loading increased, while the right upper trapezius static loading decreased. As explained, the decrease of the right trapezius static loading was due to the posture changes. While

the right hand moved between the keyboard and mouse, the left hand still held in the typing position. This required the left trapezius muscle to be activated to stabilize the left upper extremities in position, thus resulted in increased static muscle loading.

Another interesting result in the current study is the relationship between % time in mousing and static forearm muscle loading (Table 12). Opposite to the effect between % time in typing and static forearm extensor muscle loading, the longer % time or longer continuous duration in mousing actually related lower static loading of the forearm muscles (Table 12). This could be explained by the fact that longer % time in mousing required the operator rest his/her hand on the mouse pad, which provided a support to the right upper extremity, thus resulted in lowered static muscle loading.

#### *Workers' perceptions and self-reported musculoskeletal symptoms*

In general, most participants in the current study were satisfied with their current job situations, and felt that they had some or substantial influences over the decisions that affected their jobs (Table 5). Similar results were found in the 1991 study when employees reported a relatively high level of job satisfaction. They were somewhat less satisfied with the amount of influence they had over job decisions than they were with the overall job in 1991. This was the case in the current study as well (Table 5). In 1991, most employees indicated that they rarely or only occasionally faced conflicting demands or did not have enough time to get everything done. Supervisory support in listening to work-related problems was fairly to very high. This was similar in the current study that most employees (56% and 50%) reported that they rarely faced conflicting demands or had not enough time to get everything done, respectively (Table 5). The majority of employees (71%) in the current study reported their supervisors were willing to listen to their work-related problems (Table 5).

**Self-reported shoulder problems were still the major concern as compared to the 1991 study. This could be due to the relatively high static shoulder muscle loading.**

The prevalence rates of reported musculoskeletal problems in the last 12 months for the elbow/forearm and hand/wrist were drastically decreased in the current study (Table 3) compared to that obtained in 1991 (Figure 7). The prevalence rates of the neck and low back were also somewhat decreased. However, the shoulder problems remained the same (Figure 7).

The shoulder problems might still be due to the relatively high static shoulder muscle loadings as discussed previously. The static shoulder muscle loading during work should be addressed in order to reduce the shoulder problems. Some suggestions will be discussed later. Some of the self-reported musculoskeletal problems might not be related to the current work conditions as some of them were first experienced many years ago (Table 3).

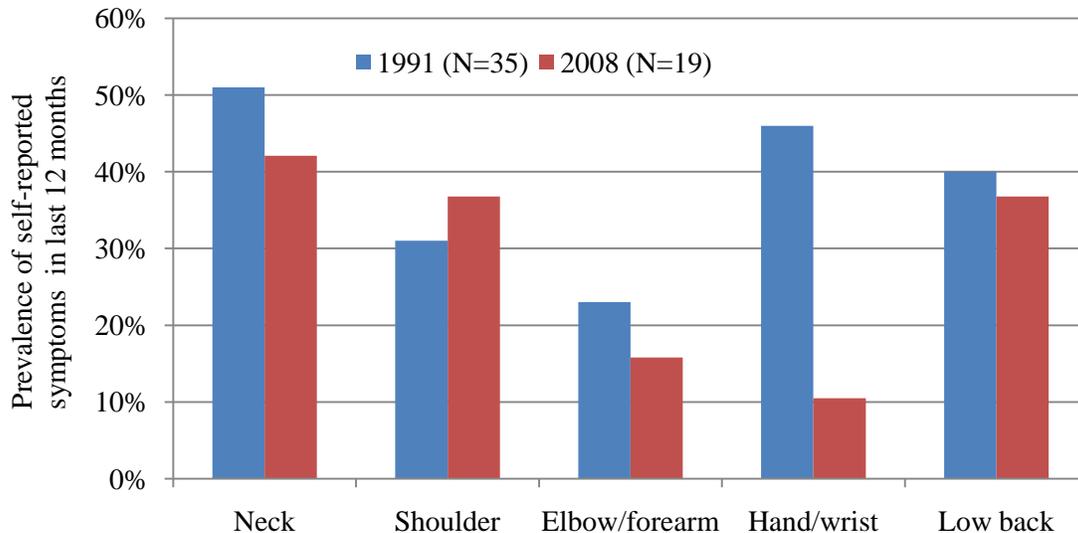


Figure 7. 12-month prevalence rates of self-reported musculoskeletal problems in 1991 and 2008 studies.

Most comments from the employees in the current study were related to prolonged sitting/standing. But in the 1991 study, significant concerns were raised about poor workstations. There seemed to have been extensive changes in terms of ergonomic improvements of workstations.

#### *5-hour vs. 6-hour keying schedule*

There were no indications of more increased muscle fatigue at 6-hour data entry schedule compared to 5-hour schedule according to the EMG frequency analysis (Figure 5). At the same time, the employees did not report changes in perceived fatigue between the 5-hour and 6-hour data entry schedules (Figure 6).

In addition, it seemed that an employee in a 6-hour data entry schedule in the current work situation might actually only have to spend about 5.3 hours working at the computer (87.7% time spent on keying and mousing x 6 hours of computer work = 5.3 hours actual data entry) considering the observed time spent on computer from Phase 3 measurement (Table 10). The actual keying time was just a little higher than that under a 5-hour data entry schedule in the 1991 work situation, when the actual data entry at the computer would be about 5.1 hours under the 5-hour keying schedule in an 8 hour work shift (60% time spent on actual computer work x 8.5 of work and breaks = 5.1 hours actual computer work (SHARP, 1991). Therefore, it may be fair to conclude that changing the 5-hour data entry schedule to a 6-hour one should not make significant exposure changes on the data entry employees under the current work situations.

**\* 6-hour data entry schedule should make no difference compared to the currently practiced 5-hour schedule.**

**\* Static muscle loadings still impose a potential risk to the employees.**

**\* Balancing workload among employees should be considered to avoid putting some employees under higher risk.**

Nevertheless, it should still be noted that the right shoulder muscle did show the signs of fatigue early in a work shift (Figure 5). The recorded static muscle loading on the forearm extensor and trapezius muscles were still relatively high. Further actions should be taken to lower the static muscle conditions. Frequent short breaks in combination with stretching should be able to improve the static shoulder muscle loading conditions.

In addition to relatively high average static loadings on some muscles, it should also be noted that there was an individual variation in terms of percent times actually spent on data entry activities (Table 10). For instance, an operator who spent 79% time in typing and 17.4% time in mousing (96.4% total on data entry – the upper 95% percentile) would actually spend 5.8 hours on data entry in a 6-hour data entry schedule compared to another operator who spent 68.6% time in typing and 10.4% time in mousing (79.0% total on data entry – the lower 95% percentile) would actually spend only 4.7% on data entry. The 1st operator would have much higher exposure compared to the 2<sup>nd</sup> one. Therefore, carefully balancing the workload among employees should be considered in order to avoid overloading some employees.

### *Workstations*

Generally speaking, the workstations in the current study were, to a large extent, in compliance with the currently accepted general office ergonomics guidelines (Appendix 3) as shown in the Phase 3 results. This was quite different in the 1991 study when a substantial number of chairs were found to be broken (SHARP, 1991). Employees used backrest support more than 75% of the time compared to only 69% of the time found in the 1991 study (SHARP, 1991). All these ergonomic workstation improvements and better employees' ergonomics awareness training offered by the agency probably explained the generally good work postures as estimated by the RULA method (Phase 3 results).

However, there is still room for further improvement. As noted from the checklist results (Table 13), some poor ergonomics issues were identified among a few employees. Many of the issues were related to individual employee's choices, rather than the equipment availabilities. Ergonomics awareness refresher training may be necessary to remind employees of better workstation ergonomics.

Much of the ergonomics workstation improvements and employee ergonomics awareness training were probably focused on the use of computers. This may make sense as employees spent most of their time in a work shift in computer use (40%, Table 9). As shown that the static loadings of the upper trapezius (shoulder) muscles were lower when performing typing and mousing compared to other seated activities (Figure 2). The static shoulder muscle loading is directly related to the work postures which are influenced by the workstation situations. A too high work surface will

**\* Workstations were generally in compliance of current ergonomics computer workstation guidelines.**

**\* Further improvements beyond the guidelines may be needed to reduce static loadings and lower shoulder complaints.**

cause an operator to shrug his/her shoulders or elevate his/her upper arms. Both will result in high static shoulder muscle loading. The workstation ergonomic conditions for desk work and other seated activities may be an area to be addressed by future ergonomic improvement, although the impact of such improvement may be limited as the total duration of these activities may not be very high (about 10% of the actual working hours as shown in Table 10, or about 19% of the total shift time as shown in Table 9).

Some further improvement of the computer workstations may be more important in order to reduce the static shoulder muscle loading. Although the static shoulder muscle loading was lower or near the lower bound of the suggested limits, some researchers still consider that 2%MVC is probably too high (Aarås, 1987). Also we saw relatively high self-reported shoulder complaints in our phase 1 survey (Table 3). These may suggest further ergonomic improvements are needed.

Although we observed that employees had their hand/arm supported more than 85% of time, often they supported at the elbow or hand/wrist regions. While they perform typing/mousing activities, they may still need to put out significant muscular efforts in order to maintain their upper body postures. Visser et al. (2000) conducted a study comparing arm or wrist supports and found the lower levels of trapezius muscle activations with the use of arm supports and no reduction with the use of wrist supports. One of the further ergonomic improvements may be to provide the employees with means to support their forearms when performing typing/mousing activities.

During the computer work, we also found relatively high static loading on the forearm extensor muscle (Table 11). The reason for that is probably the hand/wrist postures when using the keyboard. Most workers had their keyboard in a conventional slope position (i.e., the further side of the keyboard is slightly higher than the closer side of the keyboard, or positive slope). This keyboard position requires the hand/wrist assumes a slightly extended posture, which would result in higher static extensor muscle loading. Simoneau et al. (2003) studied the effort of different keyboard positions on the arm muscle activities and found that a slightly negative slope of keyboard placement could improve the hand/wrist extension posture and reduce forearm extensor muscle loading. Therefore using a negative slope keyboard placement might be an option for employees who want to reduce their forearm static loading.

It was noted that 16% of the employees used the so-called ergonomics keyboard or split fixed angle keyboard (Table 2) among the 19 participants in study phase 1. It was also noticed that none of the employees who used ergonomics keyboards had reported musculoskeletal problems. Although the small sample size may not have statistical power to prove the association, other studies have shown that split fixed angle keyboard could place the hand/wrist closer to a neutral posture (Baker & Cidboy, 2006, Marklin, Simoneau, & Monroe, 1999). Therefore, offering employees ergonomic keyboards might be a solution to hand/wrist concerns.

Introducing ergonomics keyboards may encounter resistance from employees who may have the perception that the alternative keyboard may reduce typing productivity.

However, a recent study (Anderson, Mirka, Joines, & Kaber, 2009) showed that productivity can be quickly regained.

### *Conclusions*

- Task activities of the employees have changed compared to that in 1991. Workers spent less time on computers and performed less actual keying.
- Self-reported shoulder problems still existed and right shoulder muscle fatigue was observed early in a work shift. These could be caused by relatively high static loadings on the shoulder region. Reducing shoulder static loading should be the focus in future ergonomic improvement efforts.
- Employees were generally satisfied with their current job conditions.
- There were no significant differences of the physical loading effects on the employees between the proposed 6-hour data entry schedule and the currently practiced 5-hour data entry schedule.
- Ergonomic workstation conditions were generally improved compared to that in 1991. Work postures and workstation layout were generally acceptable according to current ergonomics guidelines.
- Further ergonomic improvements may need to go beyond the current office ergonomics guidelines. Proper employee task assignments in order to balance the workload should be practiced. Better hand/arm supports and alternative keyboard use may need to be investigated.

### Acknowledgment

We appreciate the cooperation of the employees and management in Bill Processing Unit during the conducting of this project. Randy Clark reviewed the manuscript.

## References

- Aarås, A. (1987). Postural load and the development of musculo-skeletal illness. *Scand J Rehab Med, Supplement No 18*.
- Anderson, A. M., Mirka, G. A., Joines, S. M. B., & Kaber, D. B. (2009). Analysis of alternative keyboards using learning curves. *Human Factors, 51*, 34-45.
- Armstrong. (1993). A conceptual model for work-related neck and upper-limb musculoskeletal disorders. *Scand J Work Environ Health, 19*, 73-84.
- Baker, N. A., & Cidboy, E. L. (2006). The effect of three alternative keyboard designs on forearm pronation, wrist extension, and ulnar deviation: a meta-analysis. *Am J Occup Ther, 60*(1), 40-49.
- Bao, S., Mathiassen, S. E., & Winkel, J. (1995). Normalizing upper trapezius EMG amplitude: comparison of different procedures. *5*, 251-257.
- Bao, S., Silverstein, B., & Cohen, M. (2001). An electromyography study in three high risk poultry processing jobs. *International journal of industrial ergonomics, 27*, 375-385.
- Borg, G. A. V. (1982). Psychophysical bases of perceived exertion. *Med Sc Spt Exer, 14*(5), 377-381.
- Hägg, G., & Suurkula, J. (1988). Relations between electromyographic signs of fatigue during work and occupational myalgia in the shoulder region. In (pp. 321-324): Elsevier Science Publisher.
- Jonsson, B. (1982). Measurement and evaluation of local muscular strain on the shoulder during constrained work. *Journal of Human Ergology, 11*, 73-88.
- Marklin, R. W., Simoneau, G. G., & Monroe, J. F. (1999). Wrist and forearm posture from typing on split and vertically inclined computer keyboards. *Hum Factors, 41*(4), 559-569.
- McAtamney, L., & Corlett, E. N. (1993). RULA: a survey method for the investigation of work-related upper limb disorders. *Applied Ergonomics, 24*, 91-99.
- SHARP. (1991). *Cumulative trauma disorders in claims initiation, baseline findings* (No. 16-1-1991). Olympia, Washington: SHARP, Washington State Department of Labor & Industries.
- SHARP. (1992). *Cumulative trauma disorders in claims initiation follow-up preliminary report* (No. 16-3-1992). Olympia, Washington: SHARP, Washington State Department of Labor & Industries.
- SHARP. (1993). *Cumulative trauma disorders in claims follow-up study* (No. TR 16-5-1993). Olympia, Washington: SHARP, Washington State Department of Labor & Industries.
- Simoneau, G. G., Marklin, R. W., & Berman, J. E. (2003). Effect of computer keyboard slope on wrist position and forearm electromyography of typists without musculoskeletal disorders. *Phys Ther, 83*(9), 816-830.
- Visser, B., de Korte, E., van der Kraan, I., & Kuijer, P. (2000). The effect of arm and wrist supports on the load of the upper extremity during VDU work. *Clin Biomech (Bristol, Avon), 15 Suppl 1*, S34-38.
- Westgaard, R. H., & Winkel, J. (1996). Guidelines for occupational musculoskeletal load as a basis for intervention: a critical review. *Appl Ergon, 27*(2), 79-88

## Appendix 1. The general all employees' survey (used in Phase 1)

### 1. SHARP Work and Health Survey Questionnaires

This survey is for research purpose only. Your answer will help us to understand your job stress and identify potential problems. The results will help us to make recommendations for work condition improvement. Ony summary results will be shared with your employer. Only SHARP researchers can access your individual responses. We wish you can participate in this study, although your participation is voluntary.

#### 1. Do you want to participate in this study?

Yes

No

#### 2. Today's date:

MM DD YYYY  
MM/DD/YYYY  /  /

Next

## 2. Personal Identification

### 3. Your name:

(last)

(first)

### 4. Date of birth

mm/dd/yyyy    MM    DD    YYYY  
 /  /

### 5. Gender

Male

Female

### 6. Height:

feet

inches

### 7. Are you right or left handed?

Right

Left

### 8. Which hand do you use most at work?

Right

Left

Both equally

### 3. Work History (1)

9. When did you begin working in the Claims Initiation group at L&I?

MM DD YYYY  
MM/DD/YYYY  /  /

10. What is your job title history in the Support Services of the Insurance Services?

|                 | Work Group           | Job title            | No. of years at the job |
|-----------------|----------------------|----------------------|-------------------------|
| Current job:    | <input type="text"/> | <input type="text"/> | <input type="text"/>    |
| Previous job 1: | <input type="text"/> | <input type="text"/> | <input type="text"/>    |
| Previous job 2: | <input type="text"/> | <input type="text"/> | <input type="text"/>    |
| Previous job 3: | <input type="text"/> | <input type="text"/> | <input type="text"/>    |

11. What are the major tasks you do at your current job (please list)

1:

2:

3:

4:

12. What are the major tasks you did at your previous job 1 (please list)

1:

2:

3:

4:

13. What are the major tasks you did at your previous job 2 (please list)

1:

2:

3:

4:

14. What are the major tasks you did at your previous job 3 (please list)

1:

2:

3:

4:

#### 4. Work History (2)

15. In most jobs, the workload varies from day to day. In your job, what percent of your days are heavy workload days (in %)?

16. On average, how many hours do you work each week (in hours)?

17. In the last year, how many weeks did you work more than 5 days or more than 40 hours (in weeks)?

18. Do you usually work in the office all day?

Yes

No

19. If Yes, on average, how many times do you get up from your work station in a day?

# of times

20. Do you use a computer terminal on your job?

Yes

No

Prev

Next

## 5. Work History (3)

**21. Assign a percentage value (10 = 10%), the total should add up to 100.**

|                  |                      |
|------------------|----------------------|
| Data entry       | <input type="text"/> |
| Interactive work | <input type="text"/> |
| Work processing  | <input type="text"/> |
| Programming      | <input type="text"/> |
| Other activity   | <input type="text"/> |

**22. Please specify the other activity you do at the computer:**

**23. Do you primarily key from hard copy?**

Yes

No

**24. What percent of your time do you spend keying?**

% time:

Prev

Next

## 6. Work History (4)

25. How many hours/day do you usually spend keying?

Number of hours

26. How fast do you type?

Slow (less than 20 words per minute)     Moderate (21 to 40 words per minute)     Fast (41 or greater words per minute)

27. Do you consider yourself a

touch (speed) typist     "hunt & peck" typist

28. Which keyboard do you currently use the most?

Keyboard #1     Keyboard #2     Keyboard #3     Keyboard #4



1. Standard Keyboard



2 Ergo Keyboard



3. Laptop Keyboard



4. Other Specialized Keyboard

29. How long have you used this keyboard?

Years (.5 = 1/2 a year)

30. Have you used a different keyboard in the past year?

Yes     No

Prev

Next

## 7. Work History (5)

**31. If Yes, why did you change?**

- Equipment upgrade    Changed workstations    Requested change    Other

**32. If other, please specify:**

**33. How long did you use this other keyboard?**

Years

Months

**34. What kind of monitor do you use?**

|                   | Type                 |
|-------------------|----------------------|
| Monitor 1 primary | <input type="text"/> |
| Monitor 2         | <input type="text"/> |

**35. When was the last time you had your eyes examined?**

Month

Year

**36. Do you wear contact lenses?**

- Yes    No

**37. Do you wear bifocals?**

- Yes    No

**38. Do you wear glasses specifically for computer work?**

- Yes  
 No

## 8. Work History (6)

**39. Which of the following equipment do you use on your job (please check)?**

- |  |   |  |
|--|---|--|
| <input type="checkbox"/> Keyboard        | <input type="checkbox"/> Ajustable Work table | <input type="checkbox"/> Footrest            |
| <input type="checkbox"/> 10 key          | <input type="checkbox"/> Headset              | <input type="checkbox"/> Chair height        |
| <input type="checkbox"/> Standard Mouse  | <input type="checkbox"/> Telephone            | <input type="checkbox"/> Chair backrest      |
| <input type="checkbox"/> Trackball mouse | <input type="checkbox"/> Document holder      | <input type="checkbox"/> Chair seat pan tilt |
| <input type="checkbox"/> Computer Screen | <input type="checkbox"/> Wrist rest           | <input type="checkbox"/> Task lighting       |
| <input type="checkbox"/> Glare screen    | <input type="checkbox"/> Arm rest             |  |

**40. what percent of your time do you spend on the telephone?**

%

**41. What type of telephone do you use at work? (check one answer)**

- |  |   |
|--|---|
| <input type="radio"/> Hand - held receiver | <input type="radio"/> Use both                  |
| <input type="radio"/> Headset              | <input type="radio"/> Don't use a phone at work |

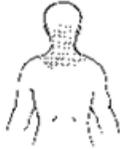
**42. If you use a headset at work, how long have you been using it?**

Years

Months

## 9. Neck (1)

### The Neck



43. In the past year, have you had pain, itching, stiffness, burning, numbness, or tingling in the area shown on this diagram more than three times or lasting more than one week?

- Yes  
 No

44. How long does each episode of NECK problem usually last?

- less than 1 hour       25 hours to 1 week       1 month to 6 months  
 1 hour to 24 hours       one week to 1 month       more than 6 months

45. How many separate episodes of this NECK problem have you had in the past year?

- constant       once a week       every 2-3 months  
 daily       once a month       every 6 months

46. Have you had this NECK problem in the past 7 days?

- Yes       No

47. Have you ever had an accident or sudden injury to your NECK such as whiplash, a fracture, or sudden "slipped disc"?

- Yes       No

[Prev](#) [Next](#)

10. Neck (2)

48. Do specific activities make this NECK problem worse?

Yes

No

49. Specify which activities

50. When did you first notice this NECK problem?

MM DD YYYY  
MM/DD/YYYY  /  /

51. What job did you have when you first noticed this NECK problem?

Current job

Other job

52. Specify other job

53. Have you seen a doctor or other health care provider for this NECK problem?

Yes

No

54. If yes, how many times in the past year?

# of times

55. Have you missed any workdays because of this NECK problem?

Yes

No

56. If yes, how many days in the past year?

days

57. Have you spent any days doing light or restricted work because of this NECK problem?

Yes

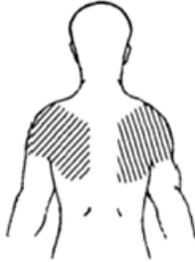
No

58. If yes, how many days in the last year?

days

## 11. Shoulders (1)

### Shoulders



**59. In the past year, have you had pain, itching, stiffness, burning, numbness, or tingling in the area shown on this diagram more than three times or lasting more than one week?**

- Yes  
 No

**60. How long does each episode of SHOULDER problem usually last?**

- less than 1 hour  
 1 hour to 24 hours  
 25 hours to 1 week  
 1 week to 1 month  
 1 month to 6 months  
 more than 6 months

**61. How many separate episodes of this SHOULDER problem have you had in the past year?**

- constant  
 daily  
 once a week  
 once a month  
 every 2 - 3 months  
 longer than every 3 months

**62. Have you had this SHOULDER problem in the past 7 days?**

- Yes  
 No

[Prev](#) [Next](#)

## 12. Shoulders(2)

63. Have you ever had an accident or sudden injury to your SHOULDER such as dislocation, fracture, or tendon tear?

Yes  No

64. Do specific activities make this SHOULDER problem worse?

Yes  No

65. Specify which activities

66. When did you first notice this shoulder problem?

MM DD YYYY  
Time (Month and Year)  /  /

67. What job did you have when you first noticed this SHOULDER problem?

Current job  Other job

68. Specify "other job"

69. Have you seen a doctor or other health care provider for this SHOULDER problem?

Yes  No

70. If yes, how many times in the the past year?

# of times

71. Have you missed any workdays because of this SHOULDER problem?

Yes  No

72. If yes, how many days in the past year?

# of days

73. Have you spent any days doing light or restricted work because of this SHOULDER problem?

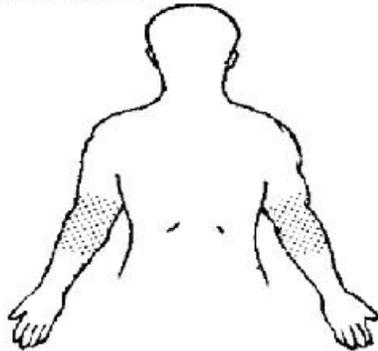
Yes  No

74. If yes, how many days in the past year?

# of days

### 13. Elbow/Forearm (1)

#### Elbow/Forearm



75. In the past year, have you had pain, itching, stiffness, burning, numbness or tingling in the area shown on this diagram more than three times or lasting more than one week?

Yes

No

76. How long does' each episode of ELBOW/FOREARM problem usually last?

less than 1 hour

25 hours to 1 week

1 month to 6 months

1 hour to 24 hours

one week to 1 month

More than 6 months

77. How many separate episodes of this ELBOW/FOREARM problem have you had in the past year?

Constant

once a week

every 2-3 months

Daily

once a month

once more than3 months

78. Have you had this ELBOW/FOREARM problem in the past 7 days?

Yes

No

Prev

Next

## 14. Elbow/Forearm (2)

79. Have you ever had an accident or sudden injury to your ELBOW/FOREARM such as dislocation, fracture, or tendon tear?

Yes  No

80. Do specific activities make this ELBOW/FOREARM problem worse?

Yes  No

81. Specify which activities:

82. When did you first notice this ELBOW/FOREARM problem?

MM DD YYYY  
Month and Year  /  /

83. What job did you have when you first noticed this ELBOW/FOREARM problem?

Current job  Other job

84. Specify "other job":

85. Have you seen a doctor or other health care provider for this ELBOW/FOREARM problem?

Yes  No

86. If yes, how many times in the past year?

# of times:

87. Have you missed any workdays because of this ELBOW/FOREARM problem?

Yes  No

88. If yes, how many days in the past year?

# of days:

89. Have you spent any days doing light or restricted work because of this ELBOW/FOREARM problem?

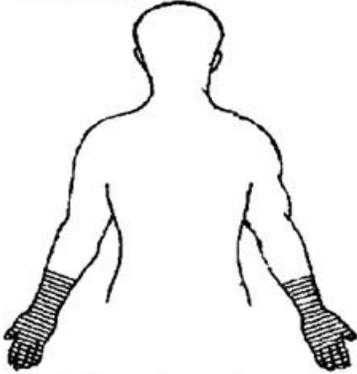
Yes  No

90. If yes, how many days in the past year?

# of days:

## 15. Hand/Wrist(1)

Hand/Wrist



91. In the past year, have you had pain, itching, stiffness, burning, numbness or tingling in the area shown on this diagram more than three times or lasting more than one week?

- Yes  
 No

92. How long does each episode of HAND/WRIST problem usually last?

- less than 1 hour       25 hours to 1 week       1 month to 6 months  
 1 hour to 24 hours       1 week to 1 month       more than 6 months

93. How many separate episodes of this HAND/WRIST problem have you had in the past year?

- constant       once a week       every 2 - 3 months  
 daily       once a month       once more than 3 months

94. Have you had this HAND/WRIST problem in the past 7 days?

- Yes       No

95. Have you ever had an accident or sudden injury to your HAND/WRIST such as dislocation, fracture, or tendon tear?

- Yes  
 No

[Prev](#) [Next](#)

16. Hand/Wrist (2)

96. Do specific activities make this HAND/WRIST problem worse?

Yes  No

97. Specify which activities:

98. When did you first notice this HAND/WRIST problem?

MM DD YYYY  
Month and  /  /   
Year:

99. What job did you have when you first noticed this HAND/WRIST problem?

Current job  Other job

100. Specify "other job":

101. Have you seen a doctor or other health care provider for this HAND/WRIST problem?

Yes  No

102. If yes, how many times in the past year?

# of times:

103. Have you missed any workdays because of this HAND/WRIST problem?

Yes  No

104. If yes, how many days in the past year?

# of days:

105. Have you spent any days doing light or restricted work because of this HAND/WRIST problem?

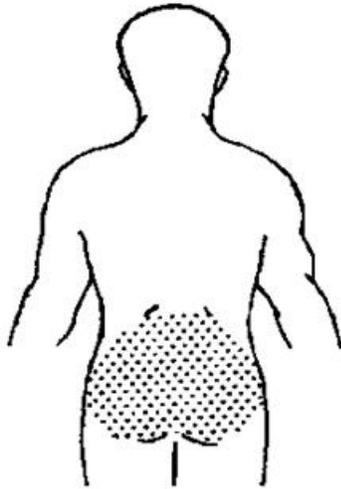
Yes  No

106. If yes, how many days in the past year?

# of days:

17. Back (1)

Back



107. In the past year, have you had pain, itching, stiffness, burning, numbness or tingling in the area shown on this diagram more than three times or lasting more than one week?

- Yes
- No

108. How long does each episode of BACK problems usually last?

- less than 1 hour
- 1 hour to 24 hours
- 25 hours to 1 week
- one week to 1 month
- one month to 6 months
- more than 6 months

109. How many separate episodes of this BACK problem have you had in the past year?

- constant
- daily
- once a week
- once a month
- every 2 - 3 months
- once more than 6 months

110. Have you had this BACK problem in the past 7 days?

- Yes
- No

[Prev](#) [Next](#)

18. Back (2)

111. Have you ever had an accident or sudden injury to your BACK such as dislocation or fracture?

Yes  No

112. Do specific activities make this BACK problem worse?

Yes  No

113. Specify which activities:

114. When did you first notice this BACK problem?

MM DD YYYY  
Month and  /  /   
Year:

115. What job did you have when you first noticed this BACK problem?

current job  other job

116. Specify "other job":

117. Have you seen a doctor or other health care provider for this BACK problem?

Yes  No

118. If yes, how many times in the past year?

# of times:

119. Have you missed any workdays because of this BACK problem?

Yes  No

120. If yes, how many days in the past year?

# of days:

121. Have you spent any days doing light or restricted work because of this BACK problem?

Yes  No

122. If yes, how many days in the past year?

# of days:

123. Of the problems you have just described, which do you consider to be the most serious or troublesome?

- Shoulder     Elbow/forearm     Hand/wrist     Back

124. For the problem that bothers you the most, how would you describe the pain or discomfort it has caused you during the past 7 days?

- None     Little     Moderate     Bad     Very bad     Almost unbearable

125. How would you describe the pain or discomfort this problem has caused you during your worst episode?

- None     Little     Moderate     Bad     Very bad     Almost unbearable

126. Were you using a keyboard at the time this problem first developed?

- Yes     No

## 19. Symptom

127. What keyboard were you using when you first experienced your problem?

(Please note: if you were using more than one keyboard regularly, please list them in a descending order, i.e. the most frequent one on the first row, followed by the 2nd most frequent one).

Most frequently used keyboard:

2nd most frequently used keyboard:

3rd frequently used keyboard:



1. Standard Keyboard



2. Ergo Keyboard



3. Laptop Keyboard



4. Other Specialized Keyboard

## 20. Psychosocial (1)

This series of questions asks you to describe your job in terms of specific qualities.

**128. In order to gain a better understanding of your work environment, we want to know how you feel about your job situation. We would like you to think about the type of work you do in your job. Circle the number that best describes your feelings.**

|   | Rarely                | Occasionally          | Sometimes             | Fairly often          | Very often            |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Conflicts can occur in any job. How often are you faced with conflicting demands of people you work with? | <input type="radio"/> |
| How often does your job leave you with too little time to get everything done?                            | <input type="radio"/> |
| How often is your supervisor willing to listen to your work-related problems?                             | <input type="radio"/> |

[Prev](#) [Next](#)

## 21. Psychosocial (2)

129. The next series of questions asks how much influence you now have in each of several areas of work. By influence we mean the degree to which you determine what is done by others and have freedom to determine what you do yourself.

|   | very little           | little                | moderate amount       | much                  | very much             |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| How much influence do you have over the amount of work you do?  | <input type="radio"/> |
| How much influence do you have over the availability of materials you need to do your work?               | <input type="radio"/> |
| How much do you influence the policies and procedures in your work groups?                                | <input type="radio"/> |
| How much influence do you have over the arrangement of furniture and other equipment at your workstation? | <input type="radio"/> |

[Prev](#) [Next](#)

## 22. Psychosocial (3)

**130. The next series deals with how satisfied you are with your work situation.**

|  | not at all            | not too               | some what             | quite a bit           | very much             |
|--|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| How satisfied are you with the amount of influence you have over the decisions that affect your job? | <input type="radio"/> |
| All in all how satisfied are you with your job?  | <input type="radio"/> |

**131. Is there anything else you would like to add?**

**132. Please comment on what you think would improve or relieve your symptoms.**

[Prev](#) [Next](#)

## 23. Final Page

Thank you for taking the time to complete this questionnaire.

**133. Are you willing to participate in the exposure assesemnt of the current situation - part 1, by letting us to install a program on your computer to register your keyboarding and mousing use?**

Yes

No

**134. Do you have a copy of RSiGuard installed on your computer?**

Yes

No

I do not know.

**135. Are you willing to participate in the exposure assessment of the current situation - part 2, by allowing us to video record you using a time-lapse camera while you perform your normal task activities?**

Yes

No

**136. Are you willing to participate in the exposure assessment of extended keying period when we are going to use electromyography and video recording to measure the exposures?**

Yes

No

Prev

Done

## Appendix 2. Bodily discomfort survey (used in Phase 2)

### LNI Discomfort Survey

[Exit this survey](#)

This is a survey about your discomfort level (0 - lowest discomfort, 10 - highest discomfort). Please complete this at the end of your shift on each day during the study. Thanks for your cooperation. If you have any questions, please call Stephen Bao at 902-5676.

Today's date is:

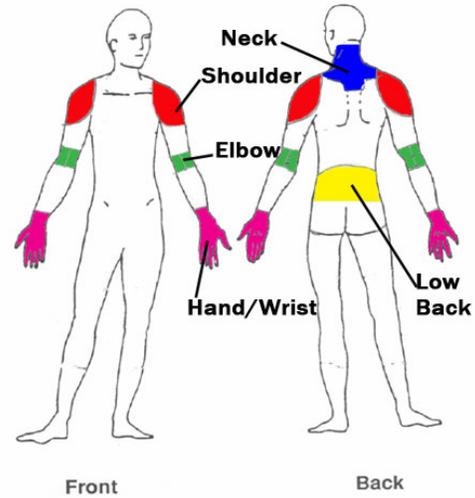
MM DD YYYY  
MM/DD/YYYY  /  /

Your log-on id:

How many hours do you think you spent on your computer today (in hours)? Note: You only need to give a rough estimate.

Please rate your discomfort level for each of the body parts:

|                        | Neck                     | Left shoulder            | Right shoulder           | Left elbow               | Right elbow              | Left hand/wrist          | Right hand/wrist         | Low back                 |
|------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 10 Maximum discomfort  | <input type="checkbox"/> |
| 9 Very, very high      | <input type="checkbox"/> |
| 8 Very high            | <input type="checkbox"/> |
| 7 High                 | <input type="checkbox"/> |
| 6                      | <input type="checkbox"/> |
| 5 Somewhat high        | <input type="checkbox"/> |
| 4 Moderately high      | <input type="checkbox"/> |
| 3                      | <input type="checkbox"/> |
| 2 light                | <input type="checkbox"/> |
| 1 Very light           | <input type="checkbox"/> |
| 0.5 very, very light   | <input type="checkbox"/> |
| 0 No discomfort at all | <input type="checkbox"/> |



Done

## Checklist and exercises

| Computer Workstation Checklist   |                          |   |
|--|--------------------------|---|
| <p>Use this checklist to help assess your posture, workstation layout, lighting, and work organization. The checklist summarizes information from both the text and drawings in this guide. If you answer “no” to any of the questions, review the relevant sections in the booklet.</p> |                          |   |
| Yes  | No                       | 1. Check your posture (pages 5–6)   |
| <input type="checkbox"/>   | <input type="checkbox"/> | When using your keyboard or mouse, are your forearms horizontal at about a 90-degree angle at the elbow, with shoulders and upper arms relaxed? |
| <input type="checkbox"/>   | <input type="checkbox"/> | Are your wrists in a straight position when using your keyboard or mouse?   |
| <input type="checkbox"/>   | <input type="checkbox"/> | When you look at the screen, is your head upright (that is, not bent forward or backward)?  |
| <input type="checkbox"/>   | <input type="checkbox"/> | Is your lower back supported by the curved part of the chair backrest?  |
| <input type="checkbox"/>   | <input type="checkbox"/> | When you are seated, are your thighs resting horizontally with a 90- to 110-degree angle at the hips?   |
| <input type="checkbox"/>   | <input type="checkbox"/> | Are you able to sit without feeling pressure from the chair seat on the back of your thighs or knees?   |
| <input type="checkbox"/>   | <input type="checkbox"/> | Are your feet fully supported by the floor or a footrest?   |
| Yes  | No                       | 2. Adjust your chair (pages 7–9)  |
| <input type="checkbox"/>   | <input type="checkbox"/> | Can you adjust your chair when you're sitting on it?  |
| <input type="checkbox"/>   | <input type="checkbox"/> | Can you adjust the height of your chair between 38–51 cm (15–20 in.) to achieve a straight wrist posture?                                       |
| <input type="checkbox"/>   | <input type="checkbox"/> | If you use a footrest, does it have a non-slip surface?   |

| Yes                      | No                       | <b>2. Adjust your chair (pages 7–9) continued</b>   |
|--------------------------|--------------------------|---|
| <input type="checkbox"/> | <input type="checkbox"/> | Does the footrest support both your feet when your heels are 12 cm (5 in.) apart?   |
| <input type="checkbox"/> | <input type="checkbox"/> | Can you adjust the footrest between an angle of 10–20 degrees?  |
| <input type="checkbox"/> | <input type="checkbox"/> | Is the footrest stable when your feet are resting on it?  |
| <input type="checkbox"/> | <input type="checkbox"/> | Can you raise or lower your chair's backrest?   |
| <input type="checkbox"/> | <input type="checkbox"/> | Can you adjust the angle of the backrest?   |
| <input type="checkbox"/> | <input type="checkbox"/> | If your chair has armrests, can you place your chair at a comfortable typing or viewing distance from the screen?                         |
| <input type="checkbox"/> | <input type="checkbox"/> | Does your chair have five legs with castors?  |
| <input type="checkbox"/> | <input type="checkbox"/> | Is the upholstery on your chair made of a breathable fabric?  |
| <input type="checkbox"/> | <input type="checkbox"/> | Does your chair seat have a rounded front edge?   |
| <input type="checkbox"/> | <input type="checkbox"/> | Can you tilt the seat of your chair?  |
| Yes                      | No                       | <b>3. Make your computer workstation layout fit you (pages 10–18)</b>   |
| <input type="checkbox"/> | <input type="checkbox"/> | Is the top line of text on your screen (not the top of the monitor) at eye level?   |
| <input type="checkbox"/> | <input type="checkbox"/> | Does your screen tilt?  |
| <input type="checkbox"/> | <input type="checkbox"/> | Is the distance between your eyes and the screen 33–70 cm (13–28 in.)? Most people find a viewing distance of 50 cm (20 in.) comfortable. |
| <input type="checkbox"/> | <input type="checkbox"/> | Does the angle of the keyboard allow you to work with your wrists straight?   |
| <input type="checkbox"/> | <input type="checkbox"/> | Are your mouse and keyboard on the same level?  |
| <input type="checkbox"/> | <input type="checkbox"/> | Are your mouse and keyboard close to one another?   |

| Yes                      | No                       | <b>3. Make your computer workstation layout fit you (pages 10–18) continued</b>   |
|--------------------------|--------------------------|---|
| <input type="checkbox"/> | <input type="checkbox"/> | Can you reach your mouse comfortably without stretching or reaching?  |
| <input type="checkbox"/> | <input type="checkbox"/> | Do you know how to adjust your monitor, keyboard support, and work surfaces?  |
| <input type="checkbox"/> | <input type="checkbox"/> | Is your document holder at the same height and viewing distance as your monitor so that you move your head very little when you look from document to screen? |
| <input type="checkbox"/> | <input type="checkbox"/> | When you are editing on screen, is the monitor directly in front of you?  |
| <input type="checkbox"/> | <input type="checkbox"/> | When you are inputting data, are your source documents placed on a document holder directly in front of you?  |
| <input type="checkbox"/> | <input type="checkbox"/> | Is your document holder able to hold binders, books, computer paper, or other documents that you work with?   |
| <input type="checkbox"/> | <input type="checkbox"/> | Are the items you use frequently within easy reach (0–30 cm or 0–12 in.)?   |
| <input type="checkbox"/> | <input type="checkbox"/> | Are the items you use occasionally within arm’s reach (30–50 cm or 12–20 in.)?  |
| <input type="checkbox"/> | <input type="checkbox"/> | Can you maintain a comfortable, upright head posture when using the phone?  |
| <input type="checkbox"/> | <input type="checkbox"/> | Are the items you seldom use stored more than 50 cm (20 in.) from you or off the desk surface?  |
| <input type="checkbox"/> | <input type="checkbox"/> | Are large reference materials located near waist level?   |
| <input type="checkbox"/> | <input type="checkbox"/> | Do you have enough space beneath your work surface to move your legs?   |

| Yes                      | No                       | 4. Check for lighting problems (pages 19–22)  |
|--------------------------|--------------------------|---|
| <input type="checkbox"/> | <input type="checkbox"/> | Does the level of light make it easy for you to see the screen without squinting or straining?  |
| <input type="checkbox"/> | <input type="checkbox"/> | Is your screen free of reflected glare?   |
| <input type="checkbox"/> | <input type="checkbox"/> | Is your monitor positioned so that your line of sight is parallel to the window?  |
| <input type="checkbox"/> | <input type="checkbox"/> | Have you adjusted the brightness and contrast controls on your monitor to make it easier to see the screen?   |
| <input type="checkbox"/> | <input type="checkbox"/> | Are walls, floors, and work surfaces a matte (dull) finish and free of distracting images or lights?  |
| <input type="checkbox"/> | <input type="checkbox"/> | Is the task lighting on your writing surface to your left, if you are right-handed, (or to your right if you are left-handed) to avoid shadows on your documents and reflected glare? |
| <input type="checkbox"/> | <input type="checkbox"/> | When working at your computer, do you have enough light to read your hard copy easily?  |
| Yes                      | No                       | 5. Organize your work and improve job design (pages 23–24)  |
| <input type="checkbox"/> | <input type="checkbox"/> | Have you considered the elements of your job to determine if they can be improved by re-organizing, alternating, modifying, or expanding the tasks you perform?                       |
| <input type="checkbox"/> | <input type="checkbox"/> | Do you take regular breaks away from the computer throughout the day?   |
| <input type="checkbox"/> | <input type="checkbox"/> | Do you take micro pauses when working on your computer?   |
| <input type="checkbox"/> | <input type="checkbox"/> | Do you vary your work activities regularly so that you change your posture and use other muscles?   |
| <input type="checkbox"/> | <input type="checkbox"/> | Do you pace your work activities over the entire shift?   |
| <input type="checkbox"/> | <input type="checkbox"/> | Do you stretch and move your muscles regularly?   |