7-1-2003

# Employee perceptions of task and work posture frequency in an office environment: The Accuracy of self report

Kevin II Meredith

KATE GLEASON COLLEGE OF ENGINEERING

ROCHESTER INSTITUTE OF TECHNOLOGY

ROCHESTER, NEW YORK

**CERTIFICATE OF APPROVAL**

---

MASTER OF SCIENCE DEGREE THESIS

---

The M. S. Degree Thesis of Kevin Meredith II
has been examined and approved by the thesis committee
as satisfactory for the thesis requirement of the
Master of Science degree.

Dr. Matthew Marshall, Ph.D *Advisor*

Dr. Jacqueline Mozrall, Ph.D.

Permission granted

**Employee Perceptions of Task and Work Posture Frequency in an Office Environment: The Accuracy of Self Report**

I, Kevin Meredith, hereby grant permission to the Wallace Library of the Rochester Institute of Technology to reproduce my thesis in whole or in part. Any reproduction will not be for commercial use or profit.

Signature of Author: ____________________ Date: 7/29/03

# Employee Perceptions of Task and Work Posture Frequency in an Office Environment: The Accuracy of Self Report

**Kevin Innis Meredith II**

Thesis submitted to the faculty of the Rochester Institute of Technology
in partial fulfillment of the requirements for the degree

Master of Science
in
Industrial Engineering

Dr. Matthew Marshall (Chair)
Dr. Jacqueline Mozrall

June 2003
Rochester, New York

Keywords: Office Ergonomics, Perception, Work Sampling

# *Abstract*

The Accuracy of Self Report:
Employee Perceptions of Task and Work Posture Frequency in an Office Environment

By: Kevin Innis Meredith II

Chair: Matthew Marshall

The growth and expansion of the computers in the workplace have changed the way that people do work. In effort to minimize the number of work related musculoskeletal disorders, employee exposure to ergonomic risk factors has been number of assessment methods exist for collecting information regarding exposure to ergonomic risk factors in occupational settings. Establishing the validity of such methods is key to developing a greater understanding of the dose response relationship associated with ergonomic risk factors in the workplace. This research utilized work sampling techniques to determine the accuracy with which workers estimated task and work posture duration in an office environment. Factors believed to influence the accuracy of self report were investigated to determine where the sources of error lie.

In general, self reports were accurate in determining the amount of time spent performing office tasks and the amount of time spent in work postures. Out of nine tasks investigated, only keying ($p = 0.033$) and miscellaneous ($p = 0.016$) indicated a significant difference between self report and actual values. None of the six investigated postures were found to contain significant error. Another finding of this research is that a relationship between the specificity of the measure being investigated and the accuracy of self report may exist. As the specificity of the question being asked increases, the accuracy of the response decreases.

# *Acknowledgements*

My deepest appreciation goes out to Dr. Matthew Marshall for his unfailing support, knowledge and guidance in developing, executing and completing this thesis. Additionally, I would like to thank Dr. Jacqueline Mozrall for her insight and assistance. I also thank Marilyn Houck and the rest of the staff and faculty in the Industrial and Systems Engineering Department at RIT, your help over the last few years is greatly appreciated.

I would like to thank all of the employees, managers and co-workers at Paychex for their help and contributions to this work. The study would not have been the same without you.

Finally, to my family and friends; there is no measure great enough to capture the gratitude in which I have for each and every one of you. Thank you so much for your sacrifices and for keeping me focused on my goals.

## *Table of Contents*

## *Introduction:*

The successful implementation of ergonomic programs has been shown to lower a company's workers' compensation costs (Lewis, Krawiecb, Conferb, Agopsowiczb, Crandallb, 2002), increase product quality (González, Adenso-Díaz, Torre, 2003), and increase worker productivity (Corlett and Bishop, 1976; Riel and Imbeau, 1996). While ergonomics is important to any occupational setting, it is becoming increasingly important in the office environment because the growth and expansion of the computer has fundamentally changed the way people do work. We are now in an "information age" in which computers and the internet have greatly increased the amount of data that are being collected and the speed at which information is transmitted. It is estimated that in the United States, 53% of all employees use a computer at work (Bureau of Labor Statistics (BLS), 2002). Furthermore, approximately 167 million Americans have internet access at home (Nielsen-Netratings, 2002).

Every year in the United States there are 1.8 million reported cases of musculoskeletal disorders by employees (Occupational Safety and Health Association (OSHA), 1999). Musculoskeletal disorders are defined as "injuries or disorders of the muscles, nerves, tendons, joints, cartilage, and spinal discs" (Department of Labor (DOL), 2001). When such injuries can be traced back to an employee's job, the injuries may be categorized as work related musculoskeletal disorders (WRMSD). About one-third of WRMSDs require time off from work and WRMSDs account for one-third of all workers' compensation costs each year (OSHA, 1999). According to information from the National Institute of Occupational Safety and Health (NIOSH) and OSHA, employers pay approximately $20 billion annually in direct workers' compensation costs and another $100 billion in indirect costs (lost productivity, employee turnover, etc.) as a result of WRMSDs in the US (US Department of Health and Human Services, 1997). Furthermore, over 20% of all WRMSD claims are filed by employees who primarily work in an office environment (BLS, 2001). Employees in managerial, professional, technical, sales and administrative support positions are among the types of office jobs that are included in the figure.

Research has shown that increased computer use is correlated to WRMSD symptoms (Travers and Stanton, 2002; Blatter and Bongers, 2002; Punnett and Bergqvist, 1997). However, the relationship between exposure to specific ergonomic risk factors and the development of WRMSD is not well understood. In order to ascertain the relationship between exposure to ergonomic risk factors and the development of WRMSDs, methods are needed to obtain valid, quantitative measurements of these exposures, a need recently identified by the National Occupational Research Agenda for Musculoskeletal Disorders (NORA) (2001). One class of methods commonly employed is self-reported measures in which the worker provides quantitative information on some aspect of his/her job. This information ranges from psychological measurements such as negative affectivity (Heinisch and Jex, 1998) to exposure to ergonomic risk factors such as the amount of force required to complete tasks (Wiktorin, Selin, Ekenvall, Kilbom, and Alfredsson, 1996) or time spent using a computer system (Deane, Podd and Henderson, 1998). While the types of information that may be collected and the motivation for doing so are wide ranging, employee input is often used to obtain information about the frequency or duration with which they perform work activities. One of the problems in utilizing such data is that the accuracy with which workers estimate these activities is not well understood, which consequently brings into question their validity. Developing a better understanding about the validity and accuracy of perceived task frequency would benefit the field of ergonomics because self reported data is among the most inexpensive and easy to obtain. Towards this end, the objective of this research is to utilize work sampling techniques to determine the accuracy with which workers estimate task and work posture duration in an office environment. Factors related to the worker and the tasks will be investigated to determine where the sources of error might exist. Subsequently, the development of methods to increase the reliability of self reports will be explored and possible corrective agents will be prescribed.

## *Background:*

To provide a framework for this research and the variables studied within, a conceptual model was adapted to illustrate how work attributes contribute to the physical demand placed on the worker in an office environment (Figure 1).

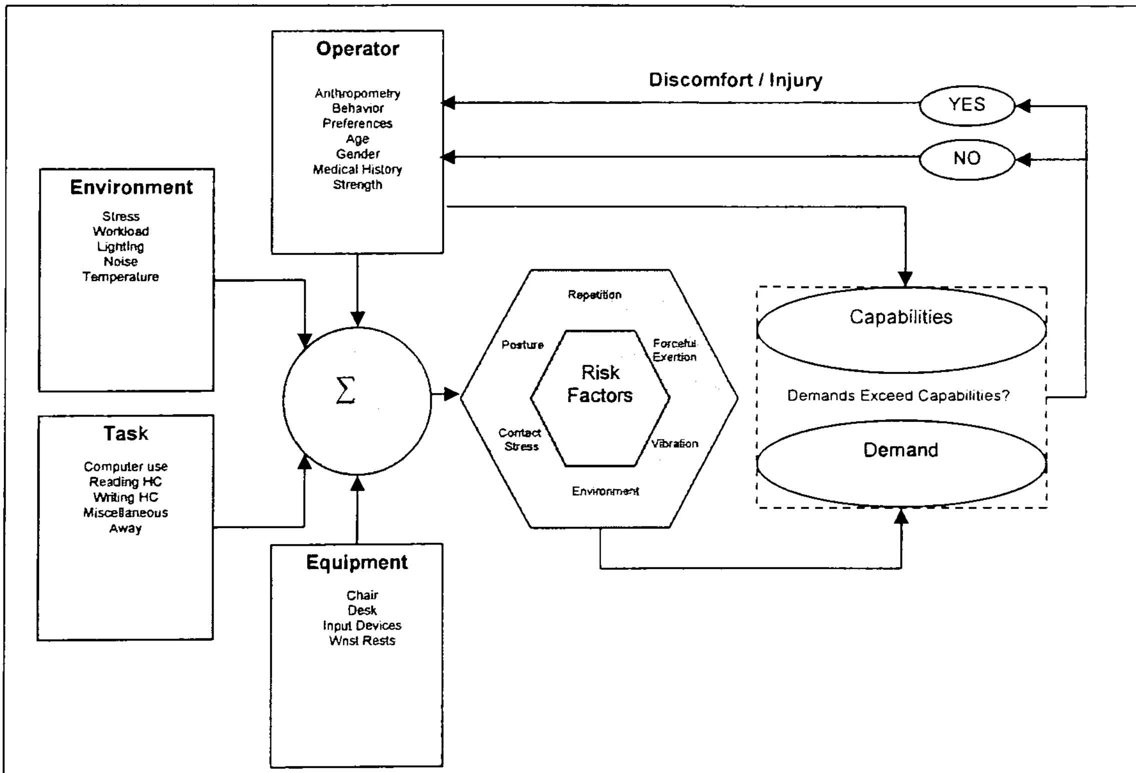



**Figure 1: Research model used to illustrate how work attributes contribute to the physical demand placed on the worker in an office environment.**

Demand on an employee is a summation of factors that arises from the interaction of the employee's physical characteristics and capabilities (strength, anthropometry), the environment they work in (air quality, temperature, culture), the tasks they perform (computer use, filing), and the equipment they utilize (desks, chairs, wrist supports). Within the field of ergonomics there are six major risk factors that are recognized as playing a significant role in the development of WRMSDs.

1. Repetition (repetitive movement and hand activity)
2. Forceful exertion
3. Posture (prolonged static loading and extreme positions of joints)
4. Contact Stress
5. Vibration
6. Environmental exposures (temperature, noise, light, etc.)

The extent to which an employee is exposed to ergonomic risk factors depends on the relationship between the overall physical demand of the work system and the worker's capability and the duration to which the worker is exposed to the work. Thus, in knowing the length of time a worker spends performing a task, one can determine important information regarding the physical risks of the job, provided there is some knowledge of the risk associated with the task. While researchers currently face a difficult challenge in explicitly quantifying the ergonomic risk factors, the duration to which workers are exposed to the tasks they perform is nonetheless an important factor in evaluating the overall physical risk.

**Office Tasks:**

Although there might be a lot of variability in how different workers perform tasks in an office environment, the types of tasks typically found in all office environments are rather limited in scope. Regardless of the service or product a business offers, it is commonplace for office workers to utilize computer input devices, scan the computer monitor, reference hard copy materials for reading and writing, and to use the telephone for verbal communication. Some of the office tasks that are known to have ergonomic risk factors associated with them are described in greater detail below and are summarized in Appendix A.

Keying:

Keying has been associated with several ergonomic risk factors. Punnett and Bergqvist (1997) reviewed the findings associated with ergonomic risk factors of computer use in 56 studies and concluded that use of the computer and keyboard had a direct causal relationship to disorders of the hand and wrist. Keying has been shown to be a highly repetitive task, requiring up to 200,000 key strokes per day (Martin, Armstrong, Foulke, Natarajan, Klinenberg, Serina and Rempel, 1996). Similarly keying has been associated with inadequate work-rest cycles in which the worker sustains extended work periods with no rest (Karlqvist, Wigaeus Tornqvist, Hagberg, Hagman and Toomingas, 2002; Martin et al, 1996). The location and position of the keyboard (Hedge, McCrobie, Land, Morimoto and Rodrigueq, 1995; Hedge and Powers, 1995; Bergqvist, Wolgast, Nilsson and Voss, 1995; Fogleman and Lewis, 2002) have been shown to impact the risk factors associated with keying. Hedge et al (1995) reported that sloping the keyboard away from the user significantly decreased wrist extension while keying ($17.6 \pm 2.6^{\circ}$ vs. $12.1 \pm 1.5^{\circ}$; $p = 0.0249$). Similarly, Hedge and Powers (1995) showed that a negative slope keyboard support significantly reduced wrist extension when keying compared to having the keyboard on the desktop ($-1.2 \pm 2^{\circ}$ vs. $13.0 \pm 2.2^{\circ}$; $p < 0.001$). Fogleman and Lewis

(2002) found that placing the computer keyboard too low was associated with general increased reporting of discomfort in all areas of body except for the lower back and shoulders. Additionally, there was a statistically significant increase in the reporting of head discomfort (Odds Ratio = 2.3, Confidence Interval (CI) (95%) = 1.1 - 4.9). The increased reporting of discomfort was most likely due to the body postures that were maintained while keying at such low levels. When the keyboard is used in a low position, there is strain on the neck and upper back and the wrist is forced into extension because the arms are extended downward. Bergqvist et al (1995) found that high keyboard placement was associated with increased odds of neck/shoulder discomfort (Odds Ratio = 3.1, CI (95%) = 1.3 - 7.2) and neck tension syndrome (Odds Ratio = 4.4, CI (95%) = 1.1 – 17.5). Furthermore, Carter and Banister (1994) found that traditional QWERTY keyboard layouts force the wrists into excessive ulnar deviation and wrist pronation. Other research identify lateral deviation of the hands, extension in the wrists and excessive pronation of the forearms and wrists as non-neutral postures caused by keying (Grandjean, 1984; Sauter, Capman and Knutson, 1984; Rempel, Harrison and Barnhart, 1992). Finally, although it does not require great levels of force to activate the keys of a keyboard, it has been found that people tend to use 4 to 5 times more force than is actually required to depress keys (Feuerstein, Armstrong, Hickey and Lincoln, 1997).

Mousing:

Mousing too has been linked to certain ergonomic risk factors. Aaras Horgen, Bjorset, Ro and Thoresen (1998) used body part discomfort data to find that the use of the mouse is associated with the development of pain in the forearm and the hand. They found that those that used a mouse significantly more than those that did not ($p = 0.006$), had significantly higher intensity ($p = 0.02$) and frequency ($p = 0.03$) of pain. Utilizing odds ratios, Jensen, Finsen, Sogaard and Christensen (2002) found mousing among computer users to be associated with symptoms in the hand/wrist ($p = 0.011$) and shoulder ($p < 0.001$) compared to those that did not use a mouse. Karlqvist, Hagberg, Koster, Wenemark, and Anell (1996) found that the typical prolonged use of the mouse as well as the resulting postural deviations of the shoulder, upper arm, elbow and wrist were risk factors associated with mousing. Cook and Kothiyal (1998) also found that the location of the mouse may play a role in the development of computer use musculoskeletal disorders. In their study, muscle activity was significantly lower in the anterior ($p = 0.01$) and middle ($p = 0.03$) deltoids when the mouse was positioned so that shoulder abduction was minimized. Finally, the magnitude of intra carpal pressure (ICP) has been shown to increase when using a mouse (Keir, Bach, Rempel, 1999). Keir et al (1999) showed that dragging objects (28.8-31.1 mmHg), pointing (18.4-28.8 mmHg) and even resting the hand on the mouse (16.8-18.7 mmHg) significantly increase ($p = 0.003$) normal ICP compared to not having the hand on the mouse (5.3 mmHg).

<u>Telephone Use:</u>

The telephone is one of the most commonly used communication devices in the office environment. Though no research was found that studied the task specifically, telephone use may be linked to musculoskeletal discomfort and WRMSDs because traditional handsets can force the wrists, neck, shoulders and back into awkward and static postures during use. Additionally, cradling the phone increases contact stresses that can cause added compression on the nerves of the neck and shoulder regions (Cornell University, 2002).

Writing Hard Copy Documents:

Though little research exists on the topic, writing hard copy documents can expose workers to potential problems related to posture and force. Writing is a task that is frequently performed on the desktop in many office environments. This can decrease back support because people often lean in toward the desktop when they write. While leaning forward to write, some people support themselves with the forearm and elbow of their writing hand. This may increase the contact stress of the support members. The force associated with gripping the writing utensil can also be a problem. Research has demonstrated that the pinch force maintained while writing is related to the development of "writer's cramp" or other nonspecific discomfort of the hand (Schenk and Mai, 2001; Udo, H., Otani, Udo, A., and Yoshinaga, 2000; Odergren, Iwasaki, Borg, and Forssberg, 1996).

Reading Hard Copy Documents:

Finally, reading and referencing hard copy documents can force the body into awkward postures. Research has shown, the most prevalent regions of musculoskeletal discomfort associated with reading hard copy documents from the desktop are the neck, shoulders and upper back. Burgess and Neal (1989) found that referencing hard copy documents on the desktop can increase loading on the neck and force the neck into deviated postures compared to using a document holder. Moreover, Bauer and Wittig (1998) showed that the positioning of the document holder may also influence posture and muscle activation in the upper back while reading hard copy documents.

Reading the Monitor:

The location and placement of the computer monitor have also been shown to correlate with WRMSDs. In particular Bauer and Wittig (1998) discussed the linkage between discomfort, postural deviation and muscle activity in the neck and shoulders and the position of the monitor. Muscle activation (13.9% ± 4.4% of average muscle activity) was higher when the monitor was placed in positions that have a higher inclination of vision ($35^{\circ}$ angle connecting line between the eye and midscreen of the monitor). Additionally, they found that angles of inclination of $17.5^{\circ}$ and $0^{\circ}$ do not have a statistically significant influence on head inclination or muscle activation. In support of such claims, Fogleman and Lewis (2002) demonstrated that having the monitor too low was a significant risk factor for subjects reporting discomfort in the shoulders (Odds Ratio = 2.5, CI (95 %) of 1.1 - 5.9) and lower back (Odds Ratio = 2.9, CI (95 %) 1.2 - 7.4). Bergqvist et al (1995) found that high monitor placement was associated with increased odds of neck tension syndrome (Odds Ratio = 7.4, CI (95%) = 0.9 – 60.3).

**Body Support:**

Aside from the tasks themselves, workplace design and equipment can have a significant effect on exposure to risk factors and WRMSD (Punnett and Bergqvist, 1997) and is a significant variable in assessing the work demands. Generally, the workstation should be designed in such a manner as to minimize ergonomic risk factors. One way that this is accomplished in the office environment is to maintain supported neutral postures in the body. Low back pain (Punnett, Fine, Keyserling, Herrin and Chaffin, 1991), fatigue, and soft tissue disorders such as carpal tunnel syndrome and tendonitis (Habes, Carlson and Badger, 1985) have been linked to non-neutral postures. In addition, it has been found that supporting various members of the body can reduce static loading on the muscles used to maintain the postures.

Back and Elbow Support:

A study performed by Andersson and Ortengren (1974) showed that the magnitude of force acting on the back was a function of trunk pressure (pressure between disks L3/L4 of the spine) and body support. Specifically, it was shown that sitting without a backrest increased intra-disk force by about 30% compared to standing. Sitting without a backrest or arm support increased intra-disk force by over 50% compared to standing (Chaffin, Andersson and Martin, 1999). To address these issues, office furniture manufacturers offer a wide array of features intended to offer back and arm support. While this furniture is purchased by employers, the benefit of the support features can only be realized if the employees use them. Failure to utilize these features may increase the physical risk to which the employee is exposed.

Forearm and Wrist Support:

The benefit of supporting the wrists (Damann and Kroemer, 1995) and forearms (Visser, de Korte, van der Kraan and Kuijer, 2000) has also been documented. Damann and Kroemer found that use of a wrist support and correct working height significantly affect the amount of wrist extension ($p = 0.0001$ and $p = 0.0001$), wrist flexion ($p = 0.0138$ and $p = 0.0134$), and radial deviation in the wrist ($p = 0.0359$ and $p = 0.0060$) while mousing. Visser et al (2000) showed that level of activation of the trapezius muscle was lower (mean = 25 % muscle activation, standard deviation (SD) = 15) when the arms were supported with a particular support device compared to no support (mean = 39 % muscle activation, SD = 9). Visser et al (2000) reported similar findings for mouse use. Aaras, Fostervold, Thoresen and Larsen (1995) found the upper trapezius load while keying with the arms supported to have significantly lower mean EMG readings (0.8 % Maximum Voluntary Contraction (MVC)) compared to keying without support (3.6% MVC). Milerod and Ericson (1994) showed arm support significantly reduced static loading on the trapezius descendens ($p = 0.02$), trapezius transverses/supraspinatus ($p = 0.003$) and anterior deltoid ($p = 0.01$) muscles. Furthermore, Bendix and Jessen (1986) found that supporting only the wrist while keying significantly increases ($p = 0.001$) the load on the trapezius muscles (59.9 μV) compared to no support at all (36.2 μV).

**Assessment Tools:**

As alluded to previously, while a set of risk factors has been identified, there is a lack of knowledge within the fields of ergonomics and occupational medicine on the dose-response relationship involved in the development of WRMSDs. There are several reasons for this knowledge gap related to the variability in individuals, but one of the biggest obstacles to understanding the dose-response relationship is the lack of practical and effective tools with which to quantify the risk factors associated with WRMSDs. Ergonomic risk factors and their effects on the human operator can be assessed in a variety of ways. The most commonly used methods are instrumentation, direct observation and self-report (Mortimer, Hjelm, Wiktorin, Pernold, Kilbom, Vingard and MUSIC-Norrtalje Study Group, 1999), each of which are described below.

Instrumentation:

For some physical exposures, it is possible to use instrumentation to directly measure the variable of interest. There are various types of analytical devices to perform direct measurements of ergonomic risk factors such as goniometers and inclinometers to measure joint angels, dynamometers to measure forces and sound and light meters to measure their respective environmental factors. More advanced methods exist, including EMG to measure muscle activation (Bauer and Wittig 1998; Visser et al 2000; Aaras et al 1995; Milerod and Ericson 1994; Bendix and Jessen, 1986), and oxygen uptake to study energy consumption (indirect calorimetry).

Although instrumentation can be used to objectively and quantitatively measure the body's exposure to ergonomic risk, not all variables important to ergonomics can be directly measured. For instance, there is no method to objectively measure the amount of discomfort an individual experiences since discomfort is primarily a subjective response. Even when risk factors can be studied with instrumentation, oversight of the experiment and supervision of the data analysis usually requires specialized knowledge. The cost and expertise associated with instrumentation can be a limiting factor that prevents its use, particularly in studies that utilize a large sample size. Furthermore, ergonomics practitioners in the field typically do not have the resources to use instrumentation on a widespread basis.

Observation:

Direct observation of ergonomic risk factors is applied to many different situations. In some cases observations are objective and in others they are subjective. For example, work sampling can be a very objective observational technique to assess the frequency and distribution of activities performed over a defined envelope of time. In the simplest case, the categorization of work sampling tasks is essentially a binary decision. The observer either records that the subject performs a task or does not perform the task. There is little uncertainty with such a classification. When estimates have more room for interpretation, such as the angular deviation of a particular joint, the observations become more subjective and have lower inter-rater reliability (Keyserling, 1986).

To make the latter group of observational methods at least somewhat objective, anchor points and systematic methods have been used to provide guidance and structure to the analyst. The Ovako Working posture Analyzing System (OWAS) (Karhu, Kansi and Kuorinka, 1977) has been used to determine postural loads on the body (back, arms, legs and head) and to quantify exposure to work-related ergonomic risk factors. A derivative of OWAS is PATH (Posture, Activities, Tools and Handling), which is an ergonomic assessment method that uses work sampling based observation to study manual materials handling (MMH) activities and other exposures for non-repetitive work (Buchholz, Paquet, Punnett, Lee and Moir, 1996). Rapid Upper Limb Assessment (RULA) was designed to investigate the exposure of individual workers to risk factors associated with WRMSDs (McAtamney and Corlett, 1992). RULA is a screening tool that assesses biomechanical and postural loading on the body. The assessment produces a score and suggests follow up actions that may be required. RULA works well for studying sedentary workers such as computer users. Finally, Latko, Armstrong, Foulke, Herrin, Rabourn and Ulin (1997) developed a methodology to rate repetitive hand activity based on observable characteristics of manual work. The method uses a series of 10-cm visual-analog scales with verbal anchors and benchmark examples and was found to have a high correlation ($r^2 = 0.58$) with the amount of recovery time within the job cycle.

Despite their relative popularity and widespread use, issues associated with direct observational methods exist. Some of the assessment techniques require the observer to complete extensive training in order to be used in a reliable fashion. For example, PATH requires a 30 hour training curriculum and manual (Buchholz et al, 1996). In addition, the presence of an observer can cause anxiety to the subject being studied, which may cause the subject to perform in an atypical manner (Rosenthal, 1976). People can get nervous when they know their work is being watched or they may try to conform to anticipated "correct" behaviors to satisfy the observer. It has also been found that the analyst may introduce encoding errors through improper judgment and intentional data distortion (Muckler and Seven, 1992). Lastly, observational methods in themselves can be very subjective; even with rules and guidelines one analyst's perception of what is being observed may differ significantly from the perception of other analysts.

Self Report:

The final class of methods, which is also the focus of this research, is self reported measures. Self reported measures are used to obtain information about an individual's own exposure to risk factors and other work-related variables. Self reports are cost effective in that they are easy to complete and can be administered over large numbers of people (Hartley, Brecht, Pagerey, Weeks, Chapanis and Hoecker, 1977; Mackay and Cox, 1987). The downsides of self report have also been described in the research. Self reports are subjective in nature which may limit the strength of the interpretation of the results found (Fogleman and Lewis, 2002). Self-report can be biased or influenced by psychosocial factors that distort the findings, thereby affecting the accuracy. According to Berry and Houston (1993), the validity of self report hinges on two very important assumptions. The first is that subjects possess significant insight that leads to useful information. Secondly, subjects must be willing to report their personal insights in a truthful manner. Some of the sources of bias that can impact a subject's ability to truthfully transmit self report data are social desirability, dissembling, post hoc rationalization and defense mechanisms (Mackay and Cox, 1987). Another problem with many of the methods that utilize worker perception is that they lack scientific validation necessary to make conclusive decisions about results obtained when using such methods (Mackay and Cox, 1987). This is particularly true for self-report.

A myriad of studies involving the accuracy of worker self report have been performed. Such studies are diverse and cover many relevant topics with one theme in common, an investigation into the accuracy with which subjects provide quantitative information related to a particular work related variable. These studies may be broadly classified into two categories: studies related to ergonomic risk factors (e.g. force, posture) and studies to investigate other work attributes related to the frequency and duration of certain events. Examples of such studies are discussed below.

*Ergonomic Risk Factors:* Self reported measures have commonly been used to study force and exertion related to materials handling. The perceived physical exertion and perceived risks of lifting tasks were found to provide moderate correlation ($r = 0.54$ and 0.53, $p = 0.01$) to the revised NIOSH lifting index for experienced workers (Yeung, Genaidy, Karwowsk, and Leung, 2002). In contrast, the findings of an investigation into the reliability of self report by Van der Beek, Hoozermans, Frings-Dresen and Burdorf (1999) suggests that perceived levels of exerted forces are not accurate enough to be used in epidemiologic studies. Furthermore Wiktorin et al, (1996) used self report to investigate people's ability to predict the weights of loads, to reproduce predetermined levels of force and to estimate the amount of force required to simulate common work tasks. Based on their analysis, three findings were reported. First, it was found that self reports consistently underestimated the weights of the loads being lifted. Secondly, the magnitude of the simulated work forces was reproducible with high precision. Lastly the ability for subjects to quantify the forces associated with common work tasks was poor.

Posture has also been evaluated and much of the literature regarding the duration of time spent working in specific postures concludes that accuracy of self reports is poor (Wiktorin, Karlqvist and Winkel, 1993; Burdorf and Laan, 1991). For example Wiktorin et al (1993) found significant differences between self reports and reference measurements for time spent sitting ($p < 0.01$) and time spent with the head bent forward ($p < 0.01$). Burdorf and Laan (1991) found the percentage of daily work time spent standing ($p < 0.05$) and sitting ($p < 0.05$) as reported through a self administered questionnaire to be significantly different from corresponding observed values. Moreover, Viikari-Juntura, Rauas, Martikainen, Kuosma, Riihimaki, Takala and Saarenmaa (1996) and Wiktorin et al (1996) reported that in general, people overestimate the amount of time spent in strenuous work postures. Andrews, Norman, and Wells (1998) also found poor agreement between self report and observed body postures and loads on the body. Pearson correlation coefficients for the between method comparisons ranged from $r = 0.01$(number of trunk extensions) to $r = 0.51$ (number of moderate trunk flexions $> 15^{\circ}$). Additionally, it was found that self reports overestimated the number of repetitions (number of times a posture was maintained), therefore overestimating their exposure levels. The authors reported that employees found it difficult to estimate the number of times a task was done during an average shift through self report. Interestingly, Mortimer et al (1999) found that self reports about time spent sitting, and working with arms in similar working postures as previous studies were also overestimated but were accurate enough ($r^2 = 0.41 - 0.69$) for studying such postures in future studies.

*Time Related Work Attributes:* Self report has also been used to assess the frequency/duration of work tasks in an office environment. In some cases there is strong agreement between self reports and reference values on specific work tasks being studied.

For example, an investigation into the relationship between self-reported computer system use and system log data, found that only three out of eighteen data points had significant differences ($p < 0.05$). As a result, the study concluded that there were moderate to strong correlations ($r = 0.36 - 0.53$) between self reported duration and frequency of system use and log data (Deane et al, 1998). However, there are studies that contradict the accuracy of self report that Deane et al found. Klemmer and Snyder (1972) used randomized work sampling to evaluate the validity of self report and found that there were noticeable discrepancies in self report estimates of specific communication tasks (talking face-to-face, telephone, reading and writing). Additionally, Homan and Armstrong (2003) compared self report, time lapse video analysis, and electronic activity monitoring to determine the best method for assessing physical workload during computer use. Worker self-reports of daily mousing ($p < 0.01$) and typing time ($p < 0.01$) were significantly higher than that obtained from activity monitoring. Additionally the authors concluded that when workers overestimate the actual time spent mousing and typing they may bias the exposure-response association.

Due to such discrepancies, there have been a number of researchers who have attempted to understand and evaluate the sources of the variability in the accuracy with which subjects self report. It has been suggested that there are two important factors that can influence the accuracy of self report. First, as the detail needing to be recalled increases, the accuracy of self report may decrease. According to Hartley et al (1977), workers are better at identifying the tasks (binary variable) that they performed versus estimating the relative amount of time performing the activities. Secondly, the employee's perception of the tasks being performed can also influence self reports. Two such influences on perception are the importance of the task and the relevance of the task. Burns (1957) reported that workers (managers) usually overestimate the time spent on important activities (production, costs, accounts) and underestimate personal time.

Overall, there does not appear to be a clear pattern in the literature with respect to the reliability of the self reports. In general the apparent lack of agreement associated with research investigating self report demonstrates how unreliable such an assessment method can be. To further investigate this problem, one objective of this research is to utilize work sampling techniques to evaluate the accuracy with which office workers estimate task and work posture duration. Furthermore, this work seeks to investigate whether factors related to the worker and the tasks performed may contribute to the error.

## *Methods:*

To accomplish the stated objectives, an experiment was conducted in which office workers were asked to estimate the amount of time spent performing specific activities in their work environment. The experiment utilized video-based work sampling techniques to monitor the activity of employees at an office complex during normal working conditions. After a typical period of work, participants were interviewed to determine their perception of the frequency with which they performed specific activities. Worker estimates were then compared to the results of the objective work sampling to evaluate the accuracy of the worker perception. Therefore, employee error (actual frequency – perceived frequency) is the independent variable and the tasks and work postures, gender and MSD history are all treated as dependent variables.

### Equipment:

The equipment used for this experiment consisted of a video camera with a time-lapse setting, a computer equipped with video capture hardware/software and a customized software program for work sampling. The video camera was used to record the participants as they tended to their work routine. The time-lapse feature enabled the camera to be used for work sampling. A computer with video capturing and editing capabilities was used to transpose the videos from the video camera to digital media.

**Subjects:**

Fourteen subjects (n = 14) were utilized for this experiment. Nine subjects were female and five were male. Employees involved with this study were consenting and willing participants that were not compensated beyond their normal wages for their participation. All participants work in the human resources department at an office complex and their daily work required the frequent use of a computer and phone. The workstation configuration varied depending on the employee's role. Managers had executive style offices with traditional wooden desks and furniture (n = 2). However, most of the employees (n = 12) worked in cubicles with adjustable work surfaces. All employees used the same type of chair. The participants ranged in age from 20 to 57 years with a mean of 37 years (SD = 16 years). The amount of experience that the participants had working in an office environment ranged from 2 months to 15 years with an average of 11 years (SD = 11 years).

**Procedure:**

The experiment consisted of two phases. The first phase, work sampling, involved using video to sample the work estimates performed by subjects during a typical workday. The second phase, worker interview, involved the assessment of the employee's perception of various work attributes. These included the worker's perception of task frequency, perceived use of body supports and perceived discomfort. Each of these phases is described in further detail below.

Work Sampling:

Prior to participating in the study, subjects were briefed on the objectives and the procedure of the experiment. Participants then signed consent forms indicating his/her willingness to be involved with the study. Once consent was obtained, the video camera was set up to capture all activities that the employee performed in their cubicle during the observational period. The time lapse feature on the camera enables work sampling by taking a one second video sample every minute throughout the evaluation period. The information collected on the video was then used to determine the frequency of observed tasks and postures. The percentage of time spent performing a particular activity was then calculated by dividing the number of observations that demonstrated a particular task or posture by the total number of observations. Five hours of data collection produced an accuracy level of ± 4 % that the employee will be in their cube, based on statistics obtained during a pilot study. This calculation is can be found in Appendix B.

Worker Survey:

At the conclusion of the video sampling, the subjects were interviewed to assess their perception of the observation period. Several pieces of information were obtained.

1) *Perception of task frequency.* Employees were asked to indicate the amount of time they perceived to spend performing eight common office tasks during the evaluation period.
2) *Perception of work posture frequency.* Employees were asked to indicate what percentage of the evaluation period they perceived to use specific body part support devices in their office.

Both of these items are described below in detail. All of the forms used to collect the information from the employees in the worker survey (including body part discomfort data) have been included in the Appendix.

*Perception of task frequency:* The perceived frequency with which employees perform common office tasks was obtained through a dictated interview with visual aids and pictures to facilitate data collection. The eight tasks that employees were asked to estimate were keying, mousing, reading on a computer monitor, reading hard copy documents, writing hard copy documents, phone use, miscellaneous office tasks and being away from desk. To maintain a consistent definition of each task, the tasks are described below.

1) *Keying*: Keying occurs only when the digits of the hand physically depress keys on the keyboard (not when fingers rest on the keys).
2) *Mousing*: Mousing occurs when the mouse is moved by motion in the hand and wrist or when the digits of the hand depress the mouse buttons.
3) *Reading off Monitor*: Reading from the monitor occurs when the subject is focusing on the monitor.
4) *Reading Hard Copy Documents*: Reading hard copy documents occurs when the subject references a hard copy document.
5) *Writing Hard Copy Documents*: Writing occurs when subjects mark hard copy documents with a writing utensil.
6) *Phone Use:* Telephone use occurs when the subject is dialing or uses a handset or a headset to communicate with others.

7) *<u>Miscellaneous Tasks</u>*: Any other task that is performed during the evaluation that is not on this list (e.g., stapling, filing, personal time, etc.).

8) *<u>Away From Desk</u>*: When the employee is not in the viewing angle of the camera's lens.

These tasks were selected because they often have ergonomic risks associated with them (See Appendix A) and they exemplify the most typical tasks associated with working in an office environment. The three categories that are included in the study, but are not included in Appendix A (miscellaneous, away and multitasking) are described below. The miscellaneous category is used to capture information about tasks that are performed in an office environment but that are not as common or that are not easily identifiable. Some examples include using a calculator, filing papers or sipping coffee. Away is not included because the study is designed to look at what the participant does inside the cubicle. Although there are tasks that have ergonomic risk factors outside of the cubicle, they are beyond the focus of this study, and therefore not included. It is possible for two or several of these tasks to be performed simultaneously. For this scenario, a "multitasking" category was created. Multitasking is defined as any time that any one of the eight identified office tasks is performed at the same time as any other while the employee is in their cubicle. It is important that multitasking be differentiated from tasks that *require* multiple actions to be performed at the same time. Mousing and keying are used to illustrate this distinction. Using the mouse to interact with the computer cannot effectively be done without simultaneously viewing the monitor. However, with keying information can be entered into the computer without viewing the monitor (e.g., touch typing while referencing a hard copy document). Mousing and viewing information on the monitor would not be considered multitasking, but keying and reading hard copy documents would be. Finally, information was collected on how representative the evaluation period was of a "typical" work day. Employees were asked to indicate on a scale from 1 to 10, with 10 being a perfect representation.

*Perceived frequency of work postures:* The subject's perceived use of support devices to support his/her back, elbows, forearms and wrists is another aspect of the study. In the office environment equipment such as chairs, armrests, wrist rests and even the surface of the desktop are used to support a range of body members. Refer to the Appendix to view the form that was used to collect information about the employee's perceived work posture frequency.

Subjects were asked to indicate the percentage of time that they used their available furnishings to fully support their back and elbows while at their desk. Subjects were shown pictures of what are considered fully supported back and elbow postures and pictures that illustrate a non-fully supported back and elbow postures. They were then asked to indicate the percentage of time in which their back and elbows were fully supported during the evaluation. Subjects were then asked to estimate the percent of time that they fully supported their wrists and forearms while using the computer (keying or mousing). Again, pictures were used to illustrate both supported and unsupported postures. Lastly, subjects were asked to estimate the amount of time they spent "cradling" the phone and mousing with a straight arm. It is widely advised that the elbows should be at an angle of approximately 90° when keying and mousing (Human

Factors and Ergonomics Society, 1998). If the elbow is straight while mousing, added strain on the elbow, neck and shoulders can result. "Cradling" is a term used to describe holding a phone with the head, neck and shoulder without the use of the hands. This posture is usually used when the employee is on the phone for extended periods of time or when the employee needs to use their hands to perform other activities while on the phone. This posture can lead to awkward neck and shoulder positioning and increased muscle tension. Relevant ergonomic risk factors associated with working postures in an office environment are found in Appendix A.

**Analysis:**

After transposing the videotape to digital media, the video was analyzed on a computer. The programs that were used for the analysis were digital video viewing software and a custom made application (Figure 2). This software was used by the analyst at the same time as the viewing software and its purpose is to minimize the amount of time that it takes to fully evaluate and analyze each video session and to improve documentation of the study.

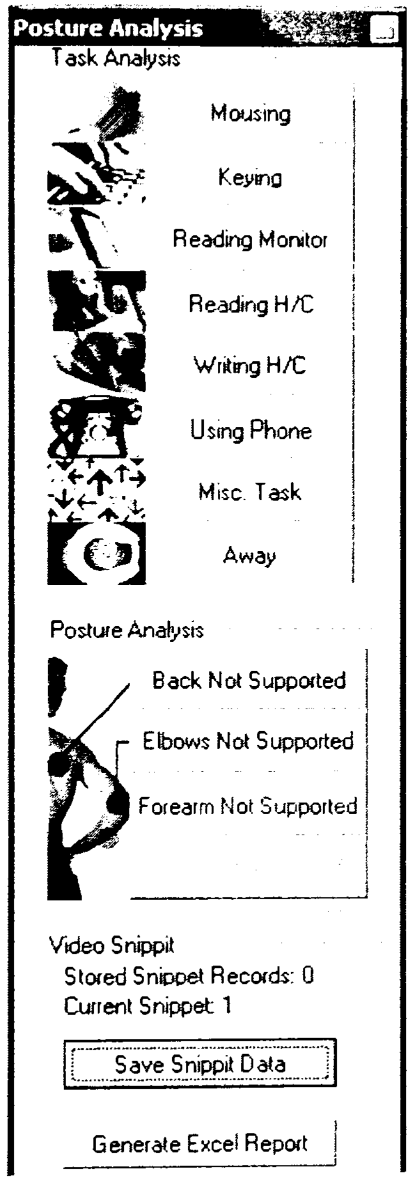



**Figure 2: An illustration of the custom software used to perform the analysis of each employee's video session.**

There were two dimensions of the system that were analyzed (tasks and work postures) and both were executed at the same time. The video was viewed one snippet (one second of video) at a time. Each video contains approximately 300 snippets. For each snippet viewed, a corresponding record was generated by the software that stores information about the employee's actual task frequency and posture. Each of the eight tasks has a corresponding button. For each snippet the analyst presses any and all of the buttons that are represented in the video. After the actual tasks are observed the same snippet is analyzed for work postures. Each unsupported posture is recorded by selecting the appropriate button(s). For the posture analysis the "Forearm Not Supported" and the "Wrist Not Supported" buttons are only used when the use of the mouse or keyboard was selected in the task analysis section. This is necessary because the employee's back and elbows should be supported in every frame analyzed but the same is not necessarily true for the forearms and wrists. After the last snippet has been saved the program generates a report of all the information that was stored in a spreadsheet. Using the data collected in the spreadsheet, the employee's perceived frequency of tasks and work postures were compared to the actual frequencies.

## *Results:*

To provide an overview of the data, scatter plots of perceived frequency vs. actual frequency for each of the tasks (Figures 3) and postures (Figure 4) analyzed in this study were prepared. Ideally, all the data points would fall on the line y = x, indicating perceived and actual values to be the same. The more an employee's perceived frequency deviates from the actual, the further the data are from the line. Qualitatively, these graphs suggest that work postures contain more variability then do tasks, which is exemplified by a greater dispersion of the data.

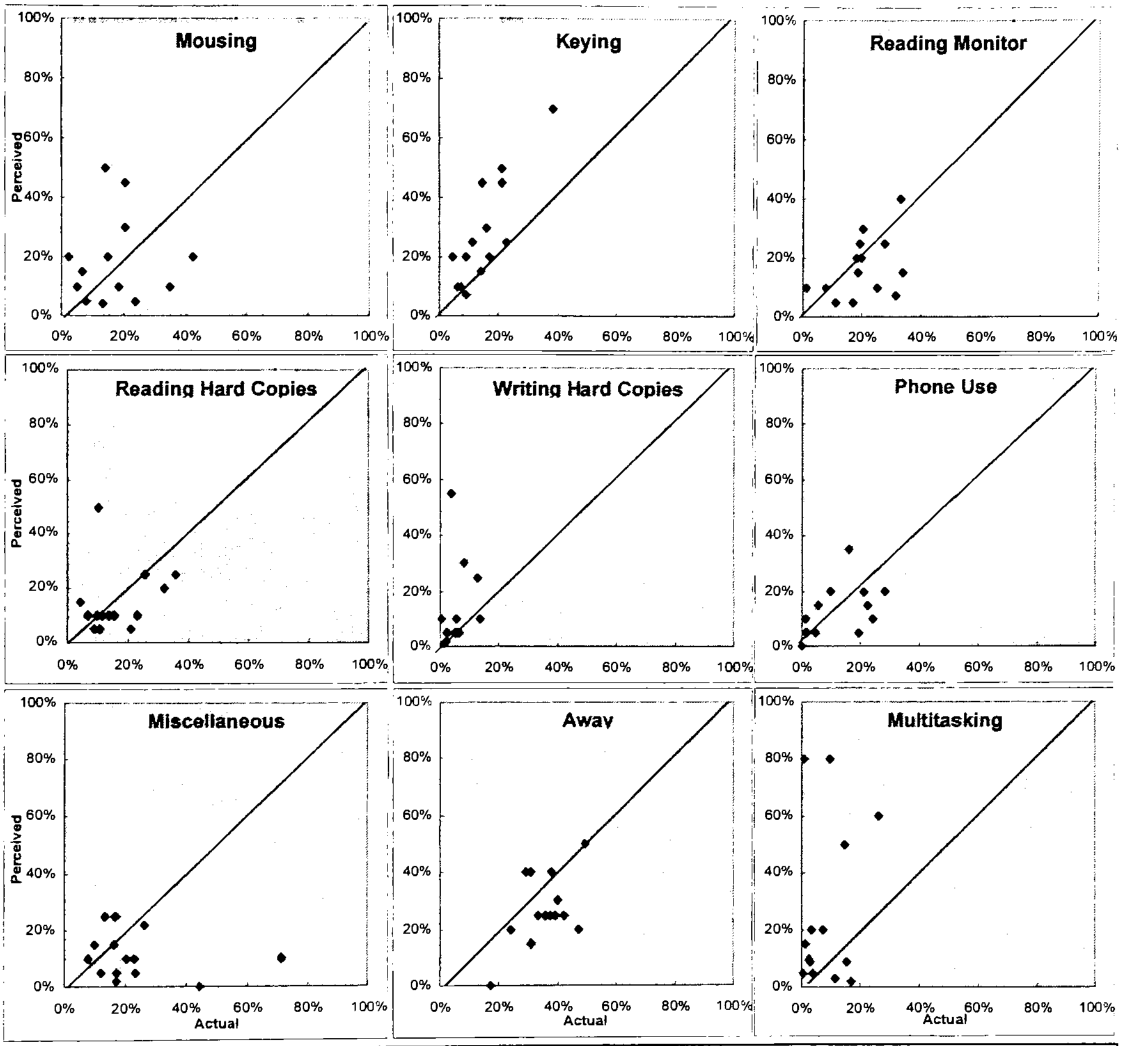



**Figure 3: Perceived vs Actual Task Frequency**
**The further away a data point is from the line (y = x), the greater the error in estimating task frequency.**

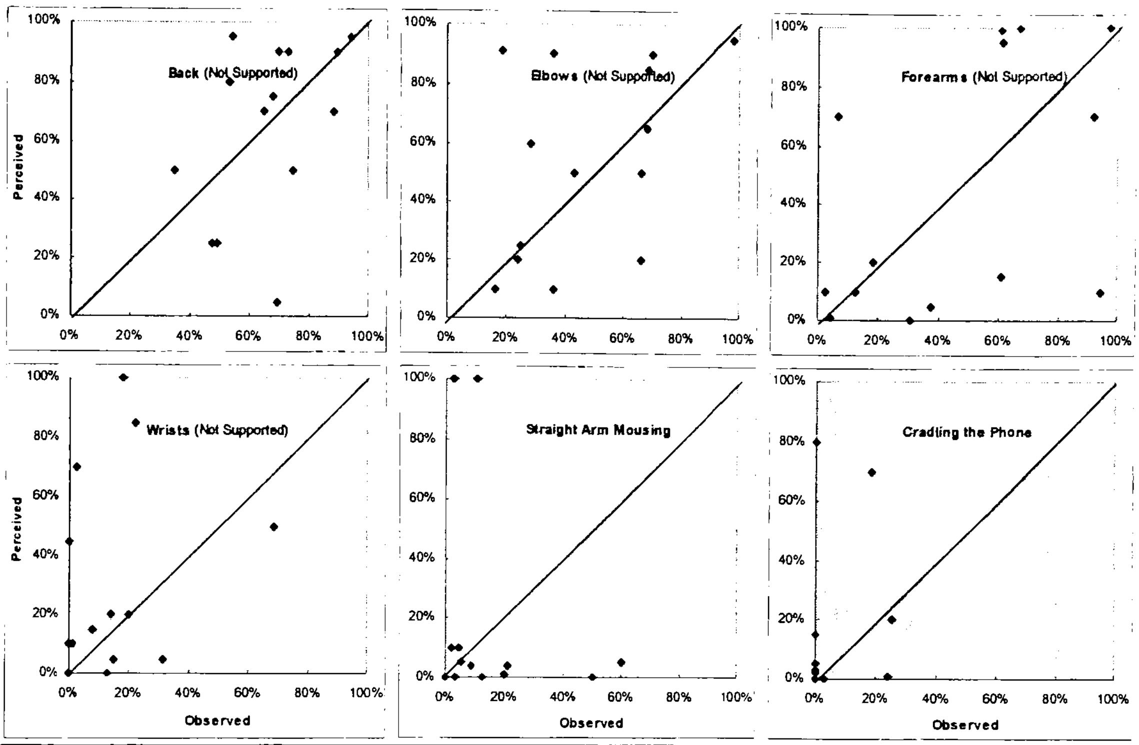



**Figure 4: Perceived vs Actual Work Posture Frequency**
**The diagonal line (y = x) represents complete agreement between self reported work posture frequency and the actual work posture frequency. The further away a data point is from the line, the greater the error in estimating work posture frequency.**

Additionally, Figure 5 provides a visual representation of the mean error between actual frequency and perceived frequency for work tasks (a) and work postures (b). The mean error is accompanied by the upper and lower bounds of the 95% confidence interval. All tasks and work postures that the employee underestimated have a positive mean error value and all tasks and work postures that were overestimated have a negative mean error value.

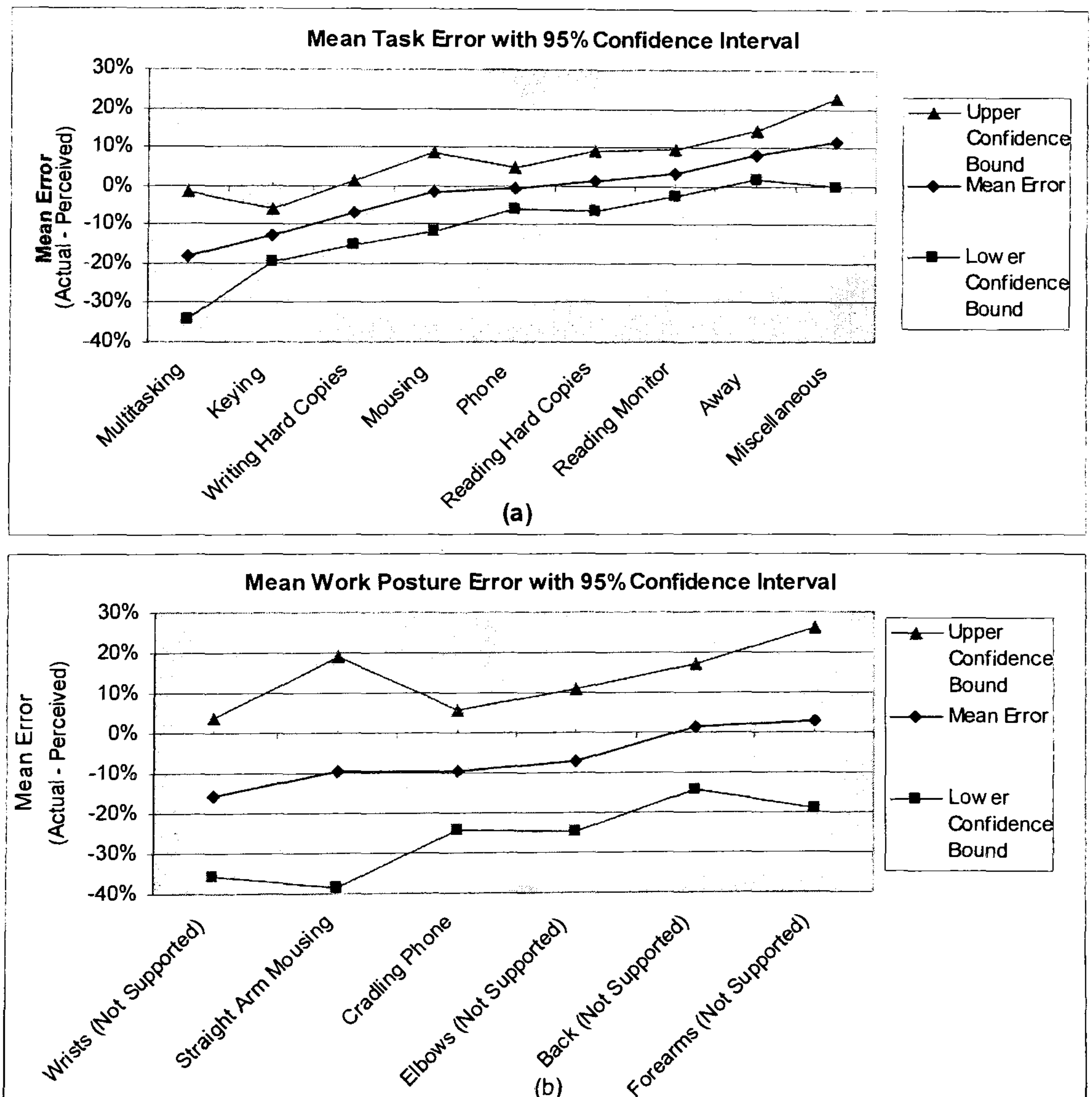



**Figure 5: The mean error surrounded by the 95% confidence interval. The confidence interval represents an upper and lower bound on the range of error that might be expected for each task (a) and for each work posture (b).**

To further investigate such errors in employee perception, a number of statistical analyses were performed. However, the number of viable statistical methods were limited by the small sample size ($n = 14$) of the study, as a small sample size can make normal approximations difficult. To determine if the errors in Figures 3, 4 and 5 were normally distributed Anderson-Darling tests were first performed, and the results are shown in Table 1. According to the Anderson-Darling tests, the errors were normally distributed (alpha = 0.05) for five out of nine task categories. Reading hard copy documents, writing hard copy documents, miscellaneous, and multitasking did not exhibit the properties of being normal. However, the latter two of these tasks are barely non-normal with p-values of 0.035 and 0.034 respectively. It was also found that only three out of six postures were normally distributed (Table 1). Support for the wrists ($p = 0.028$), straight arm mousing ($p = 0.003$) and cradling the phone ($p < 0.001$) were all found to be non-normal. Because nearly half of all the dependent variables failed the Anderson-Darling test for normality, non-parametric statistics were used throughout for analyzing most of the data. These tests are summarized below.

**Anderson-Darling Test for Normality**

| | Measure | A^2 | p-value | Status |
|---|---|---|---|---|
| Tasks | Mousing | 0.207 | 0.833 | Normal |
| | Keying | 0.592 | 0.101 | Normal |
| | Reading Monitor | 0.344 | 0.434 | Normal |
| | Reading Hard Copies | 1.043 | 0.007 | Not Normal |
| | Writing Hard Copies | 1.823 | < .001 | Not Normal |
| | Phone | 0.245 | 0.709 | Normal |
| | Miscellaneous | 0.764 | 0.035 | Not Normal |
| | Away | 0.32 | 0.496 | Normal |
| | Multitasking | 0.773 | 0.034 | Not Normal |
| Work Postures | Back (Not supported) | 0.34 | 0.444 | Normal |
| | Elbows (Not supported) | 0.365 | 0.385 | Normal |
| | Forearms (Not supported) | 0.256 | 0.671 | Normal |
| | Wrists (Not supported) | 0.802 | 0.028 | Not Normal |
| | Fully Extended Mousing | 1.148 | 0.003 | Not Normal |
| | Cradling Phone | 1.858 | < .001 | Not Normal |

**Table 1: The Anderson-Darling test was performed on the difference between observed frequency and perceived frequency for each task and work posture. Displayed are the corresponding A^2 test statistic, the p-value and the status (normal/non-normal) of each measure.**

Effect of Work Task on Error:

To see whether the accuracy for any given task varied significantly from any of the other eight tasks, the Friedman procedure was used. The Friedman procedure is a non-parametric procedure, analogous to a two way ANOVA. The employee's task frequency error and the employee were the response variables ("blocked" by employee). The results of the Friedman test on tasks showed significance ($p < 0.027$), which suggests that there was at least one statistically significant difference among the tasks. Furthermore, Figure 6 shows the mean task error, the lower and upper quartiles, and the groups that were formed as a result of the Friedman procedure. Tasks sharing one or more letter(s) are not significantly different. The perceived frequency of multitasking was generally over estimated and significantly different from mousing, phone use, reading hard copy documents, reading the monitor, away and miscellaneous. Keying differences were significantly different from reading hard copy documents, reading the monitor, away and miscellaneous. Both multitasking and miscellaneous were significantly different from mousing. Miscellaneous was also significantly different from writing hard copy documents. In addition, writing hard copy documents was found to be significantly different from away.

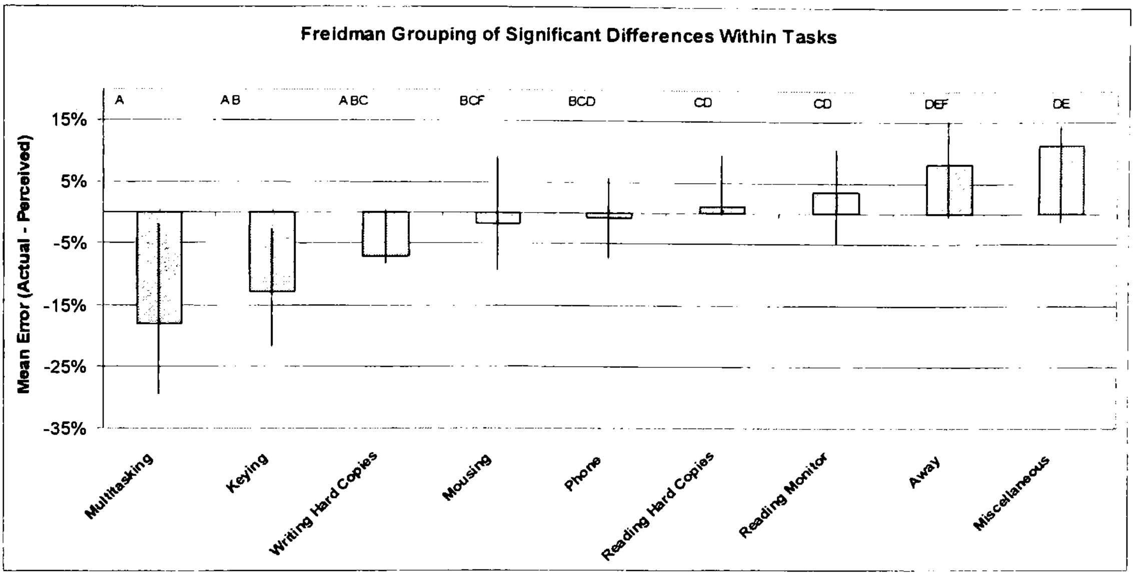



**Figure 6: The graph shows the average error for each task, the associated lower and upper quartiles and the task grouping from the Freidman analysis. A task that shares at least one letter with any other task is not significantly different from that task. If the task does not share at least one letter with another task, than it is significant with that task. For example, multitasking is not significantly different from keying or writing hard copy documents, but it is significantly different from mousing, phone, reading hard copy documents, reading the monitor, away and miscellaneous.**

Effect of Work Posture on Error:

The Friedman procedure was also used to determine whether the accuracy for any given work posture varied significantly from any of the other five work postures. The test found that work postures did not show statistical significance (p = 0.510). Figure 7 presents the mean work posture error, the lower and upper quartiles and the single group formed by the Friedman test.

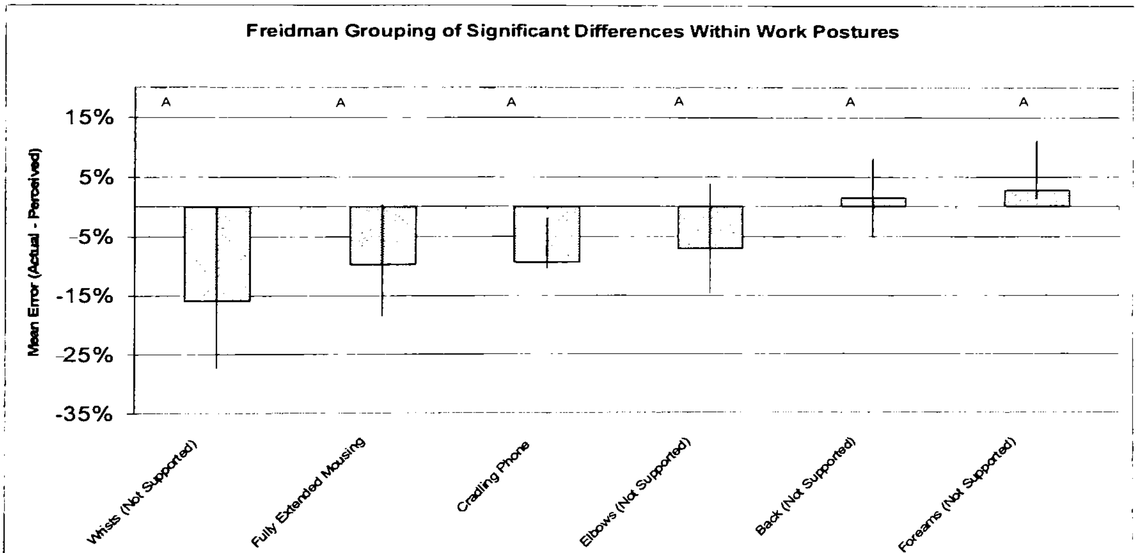



**Figure 7: The graph shows the average error for each work posture, the associated lower and upper quartiles. There were no work postures found to be significantly different from any other.**

Error of Employee Perception:

To determine which tasks and postures exhibited statistically significant differences between the actual and perceived duration (i.e., which errors were significantly different from zero), the Mann-Whitney procedure was used, which is analogous to a paired t-test. The results of the Mann-Whitney procedure are summarized in Table 2.

**Mann-Whitney Rank Sum Test**

| Measure | | W - statistic | p - value | Status |
|---|---|---|---|---|
| Tasks | Mousing | 202 | 0.9816 | Not Significant |
| | Keying | 156 | 0.0325 | Significant |
| | Reading Monitor | 227 | 0.2797 | Not Significant |
| | Reading Hard Copies | 218 | 0.5017 | Not Significant |
| | Writing Hard Copies | 183 | 0.3677 | Not Significant |
| | Phone | 199 | 0.8718 | Not Significant |
| | Miscellaneous | 256 | 0.0155 | Significant |
| | Away | 242 | 0.0759 | Not Significant |
| | Multitasking | 161 | 0.0564 | Not Significant |
| Work Postures | Back (Not supported) | 189 | 0.5344 | Not Significant |
| | Elbows (Not supported) | 196 | 0.7651 | Not Significant |
| | Forearms (Not supported) | 208 | 0.8361 | Not Significant |
| | Wrists (Not supported) | 178.5 | 0.2684 | Not Significant |
| | Fully Extended Mousing | 218 | 0.5037 | Not Significant |
| | Cradling Phone | 173 | 0.1407 | Not Significant |

**Table 2: The Mann-Whitney procedure tests the equality of population medians. The table shows the task, W-statistic, p- value (adjusted for ties) and the status (significant/not significant) of the task. The null hypothesis is that there is no difference between observed and perceived values and alternative hypothesis is that there is a significant difference between the observed and perceived values.**

Keying ($p = 0.033$) and miscellaneous ($p = 0.016$) were the only tasks to show significant differences between the observed and perceived values. However, away ($p = 0.0759$) and multitasking ($p = 0.0564$) were nearly significant. These findings are consistent with the results of the Friedman procedure which identified miscellaneous, multitasking, away, and keying as the tasks with the greatest amount of error. In addition, like the Friedman findings, the Mann-Witney procedure did not detect any significant differences between the observed values and perceived values for any of the investigated work postures.

Adjusted Keying and Mousing:

Despite instructions that explicitly defined keying as "using the digits of the hand to physically depress keys on the keyboard" and mousing as "when the mouse is moved by motion in the hand and wrist or when the digits of the hand depress the mouse buttons," it is possible that subjects incorporated time spent resting their hands on the mouse or keyboard into their perceived estimate of time spent keying or mousing. To investigate this effect, paired t-tests were used to compare the difference in error when using the unadjusted actual data versus using adjusted data (unadjusted actual + resting period) as the "actual" time. The t-tests, which are based in parametric statistics, were selected as the appropriate statistical method for this comparison because the Anderson-Darling normality test showed that errors were normally distributed for keying ($p = 0.101$) and mousing ($p = 0.883$). The difference between the unadjusted actual keying data and the adjusted keying data were significant ($p = 0.003$) at the 95% confidence level which means the unadjusted actual keying data and the adjusted keying data are not equal. In addition, it was found that the adjusted keying data reduced error, as most employees overestimated the amount of time spent keying (Figure 8). To test whether this reduction in error was significant a t-test (alpha = 0.05) was run comparing the adjusted frequency data to the original perceived frequency data. The test showed that there was not a significant difference between the adjusted keying and the original perceived frequency (p = 0.109). This is in contrast to the unadjusted findings, which showed a significant difference between observed and perceived keying frequency (p = 0.033).

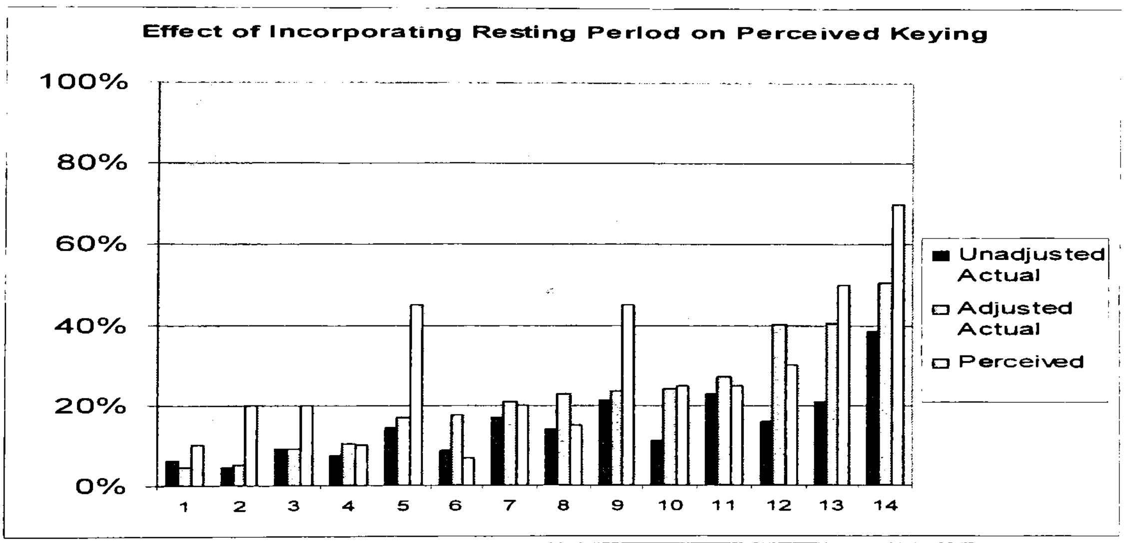



**Figure 8: The unadjusted actual, the adjusted actual (unadjusted actual + time resting hands on keyboard) and the employee's perceived duration of keying. The labels on the x-axis correspond to the ranked order of adjusted actual keying frequency.**

A similar analysis was performed on mousing. The paired t-test investigating the difference between the unadjusted actual data from the video to the adjusted data (unadjusted actual + static resting) is significant at the 95% confidence level for mousing ($p < 0.001$). As with keying, the adjusted actual mousing frequency ($p = 0.068$) did not show significance when compared to the perceived frequency. Figure 9 shows the unadjusted actual mousing, the adjusted actual mousing and the perceived mousing frequency. Although the value is barely non-significant, it appears the adjusted observed mousing frequency has the opposite effect as adjusted keying. Where the accuracy for keying improved when adjusted (because the adjustment moved in the direction of employee's error), the adjusted accuracy for mousing decreased. This occurred because the error in perceptions of mousing frequency were quite low (mean error = -0.017) compared to the adjusted estimates (mean error = 0.110).

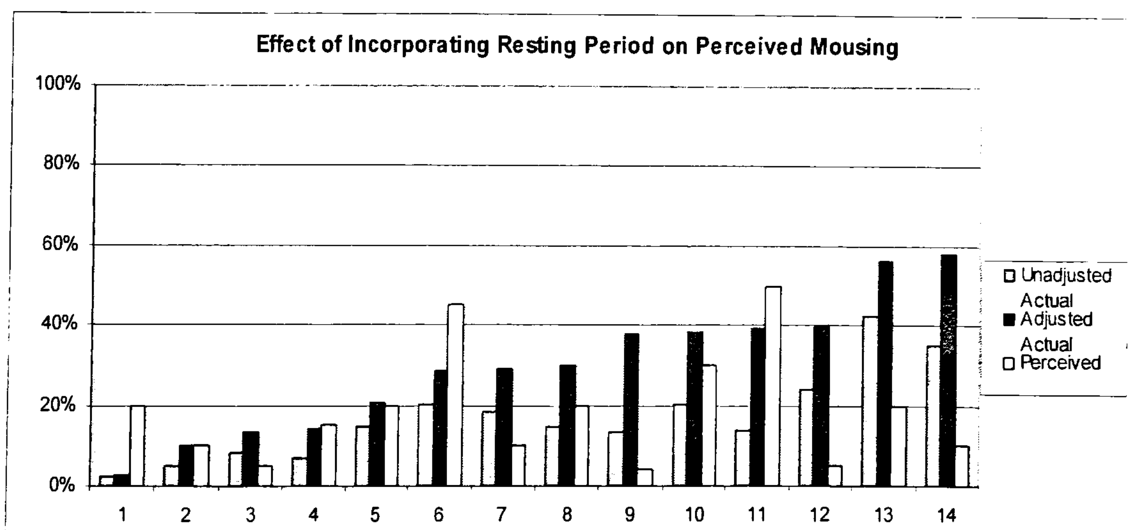



**Figure 9: The unadjusted actual, the adjusted actual (unadjusted actual + time resting hands on mouse) and the employee's perceived duration of mousing. The labels on the x-axis correspond to the ranked order of adjusted actual mousing frequency.**

Musculoskeletal Disorder History:

The presence of musculoskeletal discomfort has been investigated in previous research dealing with the validity of self report. Using the Mann-Whitney procedure ($p = 0.289$), there was not a significant difference in the accuracy of those with a history of an MSD ($n = 2$) and those without such histories ($n = 12$) for task accuracy. Similarly, there did not appear to be a significant relationship between MSD history and the accuracy of work posture frequency ($p = .963$). The small sample size and the uneven distribution of subjects in the classification scheme (MSD history vs. not) may have influenced these results.

Question Specificity:

As mentioned previously, there is research that supports the notion that the accuracy of self report is dependent on the level of accuracy contained with the measure being queried. Figure 10 illustrates the relationship between question specificity and accuracy. As the detail of the question being investigated increases (becomes more specific), the magnitude of error also increases. The self reported measures with the lowest level of error are general tasks and those with the largest magnitudes of error are specific work postures.

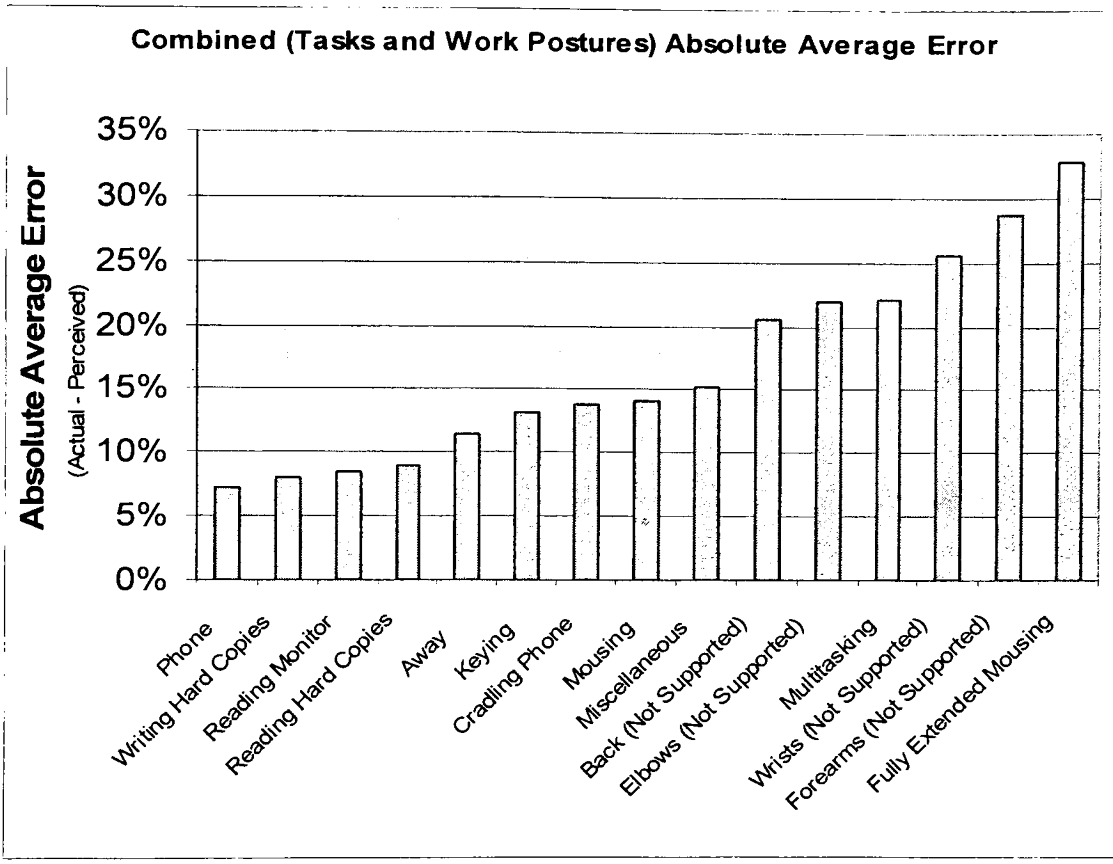



**Figure 10: The absolute average error for all tasks and work postures follow a pattern of increasing error with increased question specificity.**

## *Discussion:*

Overall, the accuracy of self reported measures was relatively good, with six of fifteen measures having less than 5% average error, eleven of fifteen measures having less than 10% error and all measures having less than 20% error. Homan and Armstrong (2003) found a twofold relationship between self report and work sampling. In that study, self report values were on average two times higher than those for work sampling. Although the current study found self reports to be overestimated, the level of error was found to be slightly lower, at 1.5 times higher. The findings of this study are consistent with those of previous research involved with self report but the small sample size of the study may limit the strength of their interpretation. Having a small number of subjects makes statistical analysis more difficult and often times limits the expansion of the results to other applications. Having a larger number of subjects may have decreased the variability and increased the power of the study.

### Comparison of Findings:

Tasks:

There were similarities and challenges to the findings investigated in previous research associated with specific office tasks. Kelmmer and Snyder (1972) found that reading (8%) and writing (8%) are generally overestimated with self report. The current study found agreement with employees overestimating time spent writing hard copies (7% overestimation), but in contrast, employees were quite accurate at estimating the amount of time spent reading hard copy documents. The average error for reading hard copies was 1%, indicating it was only slightly underestimated.

Burns (1957) found that workers usually overestimate the time spent on important activities and underestimated personal time. Such findings loosely correspond to the findings of this study. Employees in the current study overestimated the time spent performing important activities such as writing hard copy documents (8%) and keying (13%), but underestimated the amount of time spent on personal activities like being away from the desk (8%) and miscellaneous tasks (11%). Although away and miscellaneous are not exclusively composed of personal activities, they are the only classification of tasks that address personal needs.

Hartley et al (1977) and Klemmer and Snyder (1972) found that workers overestimate the time spent on the phone. Even though employee estimation of phone use was quite accurate, it was found that phone use was overestimated by about 1% in the current study as well as Klemmer and Snyder (1972). The time spent using the computer and thus the tasks associated with using the computer seem to correspond quite well to the findings of Deane et al (1998), Hartley et al (1977), and Homan and Armstrong (2003), all of which found a general overestimation in the amount of time spent using the computer. As with Deane et al (1998) this study found that workers overestimated the time spent on the computer (average error of keying, mousing and reading the monitor). Hartley et al (1977) and Homan and Armstrong (2003) found keying to be overestimated. Specifically, Homan and Armstrong (2003) found self reported estimates for keying to be significantly higher ($p = 0.01$) than representative values obtained using work sampling. Keying was also found to be significantly overestimated ($p = 0.033$) in the current study. According to Homan and Armstrong (2003) the amount of time spent mousing was also significantly higher for self report. The current study did not find a significant difference between self reported duration of mousing time to that of work sampling, but mousing was generally overestimated by 2%.

The inclusion of non-keying and non-mousing time into employee estimates of actual time spent keying and mousing is an important finding. Homan and Armstrong (2003) found that 25% of keying time was not spent keying but rather "statically exerted" or resting on the keyboard. Similarly, it was found in the current study that 32% of time spent interacting with the keyboard included time resting the hands on the keyboard. It was also found that 42% of the employee's mousing estimate included time spent resting the hand on the mouse with no activity. Finding a significant difference between keying estimates and adjusted keying (original actual + static resting) suggests that the employees in this study incorporated non-keying time (resting the hands on the keyboard without activating the keys) in their estimates for the amount of keying performed during the evaluation period. Such a finding may indicate employees inherently associate the total time they spend at the keyboard in their estimates for actual keying frequency. It was a particularly important finding in the current study because unadjusted keying was found to have a significant level of error ($p = 0.033$) but adjusted keying was not significant ($p = 0.062$).

It is recommended that those who use self report to obtain keying duration should be aware of the potential ambiguities associated with such estimates. Although the gross postures are relatively similar when keying or resting the hands on the keys, there are a number of significant differences between them. Where static loading may be a dominant risk factor when resting the hands on the keys, similar postures are often maintained while keying. Additionally, the act of keying can involve repetitive movements and a greater number of awkward movements and postures which are not present when resting the hands statically. Thus, when employees incorporate resting time into their actual keying time, they are overestimating their exposure to more ergonomic risk factors, than if resting were not included. Such a finding may have implications on self reported measures in epidemiologic studies that attempt to quantify the exposure levels associated with keying. This problem is further compounded by the fact that the duration of self reported keying time has been found to be overestimated as demonstrated in this study and others (Homan and Armstrong, 2003; Hartley et al, 1978).

Postures:

It was difficult to compare the findings associated with work postures to those of other studies because of the classifications of work postures used. There are no direct comparisons for working postures to the level of detail used in this study. The current study uses a set of categories that fall between two large bodies of literature. Some studies (Mortimer et al, 1999; Wiktorin et al 1996) use broad classifications like sitting or standing or working with hands above shoulder level but such categories were not believed to be informative enough for target applications of the current study. Other studies investigated posture with much more detail (Keyserling, 1986; Armstrong, Foulke, Joseph and Goldstein, 1982; Nordin, Ortengren and Andersson, 1982), focusing on joint angles. Such categories were not feasible in this study because the experimental set-up (single camera work sampling) could not provide the degree of accuracy needed to perform such an assessment. The classifications used in this study were selected because it was assumed that most of the employee's work would be performed while sitting in a chair at their desk. Additionally, the categories represent a way to investigate the use of support mechanisms, an area of research that appears lacking.

Hierarchy of Specificity and Accuracy:

Another finding that emerged from this research is the relationship between the specificity of the self reported measure and the accuracy of the employee. There appears to be a link between the question specificity involved with self reported variables and accuracy. Supporting the findings of Hartley et al (1977) and Klemmer and Snyder (1972), there was a general trend in the findings that accuracy may suffer with increasing detail (precision of the measure). Hartley et al (1977) found that workers were not as good at indicating the amount of time spent performing an activity as they were at identifying the tasks that they performed. Klemmer and Snyder (1972) found that self report was more accurate for broad categories (i.e. communicating) than they were at identifying specific tasks (talking face-to-face, telephone, reading and writing) within the category. It appears as though the accuracy of self report was generally inversely related to a hierarchy corresponding to the level of specificity in the question being investigated.

Figure 10 depicts a relationship between question specificity and accuracy quite well. As the detail of the question being asked increases (becomes more specific), the magnitude of the error increases. Figure 11 shows that the most general questions were related to the amount of time spent performing typical office tasks. The next level of detail looked at the frequency of specific tasks and the frequency of work postures. The most detailed level looked at specific types of postures.

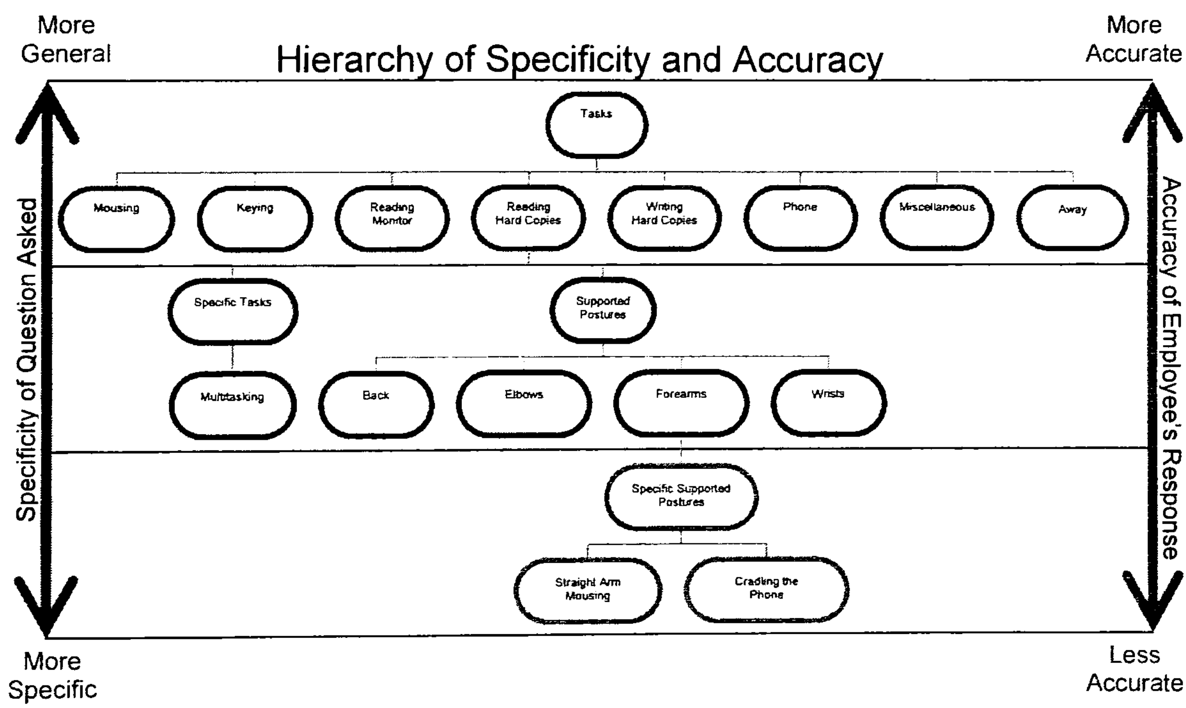



**Figure 11: The model suggests a relationship between question specificity and the accuracy of self report. As the question being asked becomes more specific, the accuracy of self report will decrease.**

The smallest error was found in top level of the hierarchy, with the average error for all general tasks being 11 %. The group of specific tasks and general work postures had an average error of 24 %. The final category did not have twice the error of the middle group, but it does contain the single measure with the greatest level of inaccuracy overall.

Although the average error is not twice as great for the most precise category, it was made its own category because each of the specific tasks (straight arm mousing and cradling the phone) had twice the error of tasks that they correspond to. Cradling the phone had a much lower error rate than straight arm mousing, but the ratio of error between the specific and general tasks is consistent. The relatively low error rates of cradling the phone may correspond to the high accuracy of phone use. Although cradling the phone is a very specific activity related to posture, it is directly related to the accuracy of phone use. Using the phone was the most accurately estimated task. The error for cradling the phone (error = 14%) was twice as great as the error for phone use (error = 7%). A similar relationship was found between straight arm mousing (error = 33%) and mousing (error = 14%).

**Application of Results:**

Correction Factors:

One of the stated objectives of this work was to recommend an effective way to compensate for inaccuracies associated with self reported measures. Figure 5 illustrates one method of accomplishing that goal. The mean error is accompanied by the 95% confidence interval for estimation error of tasks and work postures. The goal in using the confidence interval around the error is to provide a guideline for the range of errors that may be expected when these results are applied to other jobs with a similar task breakdown in the field. Similarly, Table 3 can be used as a guide to help "correct" an employee's perceived task and work posture frequency. The table shows the correction factor and the 95% confidence interval for each task and work posture studied. The correction factor can be thought of as a point estimate for the most likely value of an employee's perceived task or work posture frequency. A negative sign on the corrective factor for a task indicates that employees have tendency to overestimate the actual frequency in which that task/work posture is performed. A positive correction factor suggests that the task or work posture is typically underestimated. The 95% confidence interval can help provide a certain degree of assurance that the likelihood of a given estimate is within a known range. For example, if an employee perceives to spend 23% of the day mousing, the corrected mousing value would be 21% (23% - 2%), with a lower confidence limit of 9% (21% - 12%) and an upper confidence limit of 29% (21% + 8%). Similarly, an employee estimating to spend 23% of the day reading the monitor would have a corrected value of 27% (23% + 4%), a lower confidence limit of 24% (27% - 3%) and an upper confidence limit of 37% (27% + 10%).

| | Measure | Correction Factor | Lower Confidence Bound | Upper Confidence Bound |
|---|---|---|---|---|
| Task | Away | 8 % | 2% | 14% |
| | Keying | -13% | -20% | -6% |
| | Miscellaneous | 11% | 0% | 23% |
| | Mousing | -2% | -12% | 8% |
| | Multitasking | -18% | -34% | -2% |
| | Phone | -1% | -6% | 5% |
| | Reading Hard Copies | 1% | -7% | 9% |
| | Reading Monitor | 4% | -3% | 10% |
| | Writing Hard Copies | -7% | -15% | 1% |
| Work Posture | Back (Not Supported) | 2% | -14% | 17% |
| | Cradling Phone | -9% | -24% | 6% |
| | Elbows (Not Supported) | -7% | -25% | 11% |
| | Forearms (Not Supported) | 3% | -19% | 26% |
| | Straight Arm Mousing | -10% | -38% | 19% |
| | Wrists (Not Supported) | -16% | -36% | 4% |

**Table 3: Correction factors and 95% confidence intervals for office tasks and postures studied.**

This study evaluated self report using point estimation, which is essentially a continuous scale. In many cases a coarser categorical scale may be used, such as a five point scale (e.g. RULA., PATH). The accuracy of the employee's self report was driven by a discrete and very specific estimate of the amount of time spent performing work tasks or maintaining supported postures. If the employees were asked to indicate their estimates using a five point anchored scale, similar to those used in standardized observational methods, it is likely that the accuracy levels would go up. One way in which anchored scales could be used in this work is by asking employees to indicate which single category (0-20%, 21-40%, 41-60%, 61-80%, 81-100%) best represents the amount of time that they spent performing a given task, rather than an absolute point estimate (e.g. 23%). Because they are not asked to provide a single point estimate, but rather a range of estimates that compose a category, they would likely have greater accuracy. One reason why the use of a five point anchored scale may be preferred over that of a single estimate is related to the ambiguities of dose-response relationship in ergonomics. At this time, there is no way to determine the length of time required to develop an MSD or discomfort based upon a specific exposure. For example, there is really no way to know whether there is a significant difference between keying for 44 minutes or an hour as it relates to the physical effect on the worker. Thus a courser scale (five point) may be warranted.

Based on the widths of the confidence intervals formed by the lower and upper 95% confidence levels in Table 3, the accuracy of self report on a five point scale can be investigated. In general, the width of the 95% confidence interval for each measure can be thought of as a sliding bar that moves over a fixed five point scale depending on the employee's perception. As the employee selects a category further to the right (e.g. 61-80%), the confidence interval slides to the center of that category. All categories that are covered by the width of the confidence interval are likely to correspond to the actual duration. For example, the width of the 95% confidence bound on the error of phone use was shown to be 11% in Table 3. If an employee were to indicate that 0-20% of the day was spent on the phone, one can be quite certain that the actual value is in that category or at worst in the adjacent 21-40% category. There is little doubt that the actual value will fall within 0-40% and will not fall in the 41-100% range. When a measure with a larger 95% confidence interval range is selected, there is less certainty that the category selected by the employee is the actual categorization. An example of this can be found when cradling the phone is considered. Cradling the phone has a 95% confidence bound width of 30%. If the same individual used in the example above were to indicate that they spent 0-20% cradling the phone, there are now three categories in which it is likely for the actual duration to fall. Due to the large size of the confidence range for cradling the phone, the actual percentage could fall in the 0-20%, 21-40% or 41-60% categories but it is unlikely that it would be in the 61-80% or 81-100% categories. As demonstrated above, the application of this work to existing ergonomic assessment procedures can help better understand the accuracy of employee self report.

With respect to the use of self report scales, it is important to mention that the selection of the type of scale and level of detail depends on the particular application. The potential for the findings of this work to be prescribed to five point fixed scales brings us once again to findings of Hartley et al (1977) and the hierarchy of specificity and accuracy

(Figure 11). Asking an employee to indicate a single point estimate of task/work posture frequency is undoubtedly more specific a question than asking an employee to indicate a range of estimates provided by the categorical bounds of a five point scale. In effect, by using anchored categories of task and posture frequency, the accuracy would be likely to increase without losing or distorting the relationship between dose and response and without establishing a level of acceptance for the required level of accuracy.

Field Validity:

There is no reason to believe that the work performed within this human resources department would be substantially different than those of other companies, but variations in the work performed in office environments do exist. Because such differences can be significant, the findings presented in this work should be applied to work environments in which tasks are distributed in a manner similar to those in the current study. For example, a medical transcriptionist spends substantially more time keying than a human resource worker from this study. Performing one task disproportionately more than all others could bias an employee's ability to identify the duration of time spent performing that or any other task in question. Specifically, the more equally distributed an employee's work activities are, the greater the potential error will be. If an employee is quite sure they spent 90% of the day keying, there would only be 10% of the day left to assign to the eight other selected tasks. Provided that the original 90% estimate is reasonably accurate, the accuracy would surely be quite high for all other tasks as well. In contrast, it was found in this study that keying had the second highest level of error out of all tasks (mean error = 12.8%), but was performed a relatively short duration of time

(15% of the evaluation time). Thus on average, there was 85% of the evaluation time left to distribute between the eight other tasks, leaving significant room for error. As a result, the findings of this work should only be applied to situations in which work tasks are distributed in a similar manner as those found here.

**Effects of Training:**

Interestingly, the effect of training on perception has been demonstrated as a means of increasing the accuracy of self reports (Marshall, 2002; Deeb, 1999). Marshall (2002), found that subjects with no training had significantly higher average error ($p = 0.001$) than those who were trained when simulating the force required to perform a series of work tasks. Deeb (1999) had similar results for subject's ability to estimate the weights of objects and found that after two training sessions the impact of training on accuracy decreased. One reason that training may increase the accuracy of self report may be due to the nature of perception. Perception is the process of organizing and interpreting sensory information, thus allowing one to recognize meaningful objects and events. Perception is not an independent function of the body, but rather a link that helps integrate the peripheral (sensing) and central nervous systems (memory). Due to the notion of selective attention, it has been suggested that one can focus attention on only a limited aspect of all that is capable of being experienced. This may be a fundamental source of error of self reports because issues associated with selective attention may influence the peripheral nervous system component of perception.

In this study employees may have been focusing their attention on the daily tasks that they were performing and, therefore, may not have been specifically thinking about the amount of time they spent performing a specific task or maintaining a specific work posture. In other words, the subjects may have been filtering or using selective attention to focus on sensory and motor information that was directly related to completing the days work. Through training however, it may be possible for such an issue to be addressed. A key component of perceiving information is memory retrieval, which is the central nervous system component of perception. It seems as if this process can be made more efficient and accurate through learning or in this case training. The goal of training is essentially to provide a means of producing a relatively permanent change in an individual's behavior due to experience. In the works of Marshall (2002) and Peed (1999) it was found that once a benchmark value has been learned or committed to memory, there is an increased likelihood that it can be accurately recalled when demanded by future events. In the office environment, training can be easily implemented through activity monitoring. Software programs that track keyboard and mouse usage are readily available. Such programs would allow office workers to train themselves by comparing the "actual" keying or mousing time to their perceived time. Although the influence of training on the accuracy of self report was not investigated in this study, further research on the topic does seem warranted.

**Limitations:**

In the current study, employees were asked to indicate their task and work posture frequency as a percentage of the total observation time (ratio). As a result, it may have been harder for employees to estimate perceived frequency as a proportion. Homan and Armstrong (2003) had employees indicate task duration to the nearest half hour after the results of their pilot study suggested that such a categorization was easier for employees to understand and accurately respond to. However, Hartley et al (1977) suggest that responses to questions as a proportion or time estimate are both examples of ratio classifications and therefore have the same level of accuracy.

It is conceivable that expanding the length of the work sampling or observing over multiple days could have lead to different results. Using the results of the pilot study, great care was taken to ensure the duration of time for each work sampling session would produce a sufficient level of certainty (95% CI) that the subject would be in the cubicle performing tasks during the evaluation (Appendix B). This however did not help in calculating the number of work sampling sessions that were performed. It is possible that using data from only a single day could be biased for an atypical workday. Although this issue was anticipated and addressed by asking employees to indicate the degree to which the work performed during the evaluation was similar to work performed during an average workday, the accuracy of such a question inherently relies on the reliability of self report (the basis of this thesis). The hierarchy of question specificity and accuracy (Figure 11) may provide some confidence in an employee's ability to accurately compare the work performed during the valuation with that of a typical day. Comparing the general work of one work period to another would be categorized as a broad question and may therefore contain enough accuracy. This specific comparison however, was not tested in the current study.

As mentioned throughout this work, the small sample size may be a limiting factor of the experiment. Even though there were significant findings between the accuracy of self reports and work sampling for some office tasks, there might have been more tasks and work postures deemed to have significant differences with a larger sample size. Along with summary statistics, Appendices F and G provide an overview of the actual, perceived and error values for all tasks and work postures observed. Furthermore, a post hoc analysis of the sample size demonstrated that the study's power varied substantially (keying = 0.98, back (not supported) = 0.04). Although the low power of some of the comparisons cannot be overlooked, there is reason to believe that the significant findings of this study are truly significant. If such differences were detected using a level of significance of 0.05 with a small sample size, then the opportunity of finding a greater number of significant results using more subjects seems quite likely. It may be possible for further researchers to build upon the findings of this study utilizing a larger sample size. In doing so, one may be able to expand upon the general understanding regarding the feasibility of utilizing self reported measures to study ergonomics in the office environment.

## *Conclusion:*

In conclusion, the findings of this study demonstrate self report is a relatively accurate method for obtaining information regarding task and work posture frequency in the office environment. This is exemplified through a lack of significant differences between the actual and the perceived values of all the measures that were studied. The self reports for just two out of sixteen tasks and work postures were found to differ significantly from values obtained through work sampling. One very interesting finding of this study is that the accuracy of self report appears to be influenced by the level of specificity of the measure being reported on. As the level of specificity of the question increases, so too does the error. This inevitably decreases the accuracy of the response and therefore the reliability of self report. Lastly, based upon research outside of the office environment, training may be used to increase the accuracy of self reports. When applied to the office environment, the use of activity monitoring to help train workers on their "actual" task frequency should be further investigated.

*Appendices*

## Appendix A:

| Task | Task Description | Ergonomic Risk Factors | Relevant Research |
|---|---|---|---|
| Keying | Most computer users use a keyboard as the primary input device to transmit text to the computer. Keying occurs when the digits of the hand physically depress keys on the keyboard. Simply having one's hands on the keyboard is not considered keying. | **Postures:** Keying can place the hands, wrists and elbows in awkward postures for prolonged durations.<br>**Repetition:** The soft tissues from the hand to the shoulder can undergo trauma from overuse associated with the repetitive nature of keying.<br>**Contact Stress:** Interfacing the bottom of the wrist and the forearms with a physical surface (especially a sharp edge) can decrease circulation. | Hedge et al, 1995; Hedge and Powers, 1995; Bergqvist et al, 1995; Fogleman and Lewis, 2002; Fagasanu and Kumar, 2003; Aaras et al, 1995; Punnett and Bergqvist, 1997; Martin et al, 1996; Karlqvist et al, 2002; Carter and Banister, 1994; Grandjean, 1984; Sauter et al, 1984; Rempel et al, 1992; Feuerstein et al, 1997; Bendix and Jessen, 1986; Fagasanu and Kumar, 2003 |
| Mousing | The mouse is the primary input device that is used to interact with the computer. Mousing occurs when the mouse is moved by motion in the hand and wrist or when the digits of the hand depress the mouse buttons. Resting the hand on the mouse is not considered mousing. | **Postures:** Mousing can place the hands, wrists, elbows and shoulders in awkward postures for prolonged durations.<br>**Repetition:** The soft tissues in the digits of the hands, the wrists, elbows and shoulders can undergo trauma from overuse associated with the repetitive movements used to operate a mouse.<br>**Contact Stress:** Interfacing the bottom of the wrist and the forearms with a physical surface can decrease circulation and increase ICP. | Aaras, 1998; Keir et al, 1999; (Johnson et al, 1993; Karlqvist et al, 1994;are both from keir et al 1999) Karlquist et al, 1998; Damann and Kroemer, 1995; Visser et al, 2000; Jensen et al, 2002; Fogelman and Brogmus, 1995; Cook and Kothiayal 1998; Hamilton, 1996; Cooper and Straker, 1996; Fagasanu and Kumar, 2003 |
| Reading Monitor | The computer's monitor is the primary output device for almost all computer systems. Reading from the monitor occurs when the subject is focusing on the monitor. | **Postures:** Awkward and maintained postures can result from inappropriately positioned monitors and viewing detailed information. This can impact the back, neck and shoulders.<br>**Repetition:** Switching between reading information from the monitor and other tasks can cause repetitive twisting in the neck. Additionally the eyes are forced into repeated motions that can increase the likelihood of eyestrain. | Bauer and Wittag, 1998; Fogleman and Lewis, 2002; Bergqvist et al, 1995 |
| Reading Hard Copy Documents | Hard copy documents are any media in which the employee can physically hold, alter and view without the use of a computer. Reading HC documents occurs when the subject is focusing on a hard copy document. | **Postures:** Reading can place the hands, wrists, elbows and shoulders in awkward postures for prolonged durations in an attempt to more easily view the information that the document contains.<br>**Contact Stress:** Placing the elbows on surfaces to hold hard copy documents fro extended durations can decrease circulation. | Burgess and Neal (1989) |
| Writing Hard Copy Documents | Writing on hard copy documents occurs in the office environment on a daily basis. Writing occurs when subjects mark hard copy documents with a writing utensil. | **Postures:** Writing can place the hands, wrists, elbows, neck and back in awkward, unsupported postures. The wrists and hands are at risk because of the forces required to hold a writing utensil (pinch grip). The neck and back are at risk because people often lean over and minimize support while writing.<br>**Repetition:** The soft tissues in the digits of the hands, the wrists, elbows and shoulders can undergo trauma from overuse associated with the repetitive movements used when writing hard copy documents. Movements in the fingers, wrist and elbow produce the greatest risk.<br>**Contact Stress:** Interfacing the hands, the bottom of the wrists, the forearms and the elbows with a physical surface can decrease circulation while writing. | Schenk and Mai, 2001, Odergren et al, 1996; Udo et al, 2000; Hynak et al, 2001; Johsson et al, 1988 |
| Telephone Use | The telephone is the primary device used for verbal communication across long distances. Telephone use occurs when the subject dials or uses a handset or a headset to communicate to others. | **Postures:** Using the telephone can place the hands, wrists, elbows, shoulders neck and back in awkward postures. The greatest concern associated with phone use is "cradling" the phone because it forces the body into awkward postures that are usually maintained for prolonged durations. Dialing the phone can also cause reaching and decreased back support.<br>**Repetition:** Frequently dialing the phone is the major repetitive risk factor associated with phone use. The areas of the body most often affected are the digits of the hands, the wrists and the shoulders.<br>**Contact Stress:** Cradling the phone can increase pressure on the soft tissues in the neck, shoulder and ear. | Cornell, 2002; |

**Appendix A: Task Selection and Associated Ergonomic Risk Factors. The table describes selected office tasks and the recognized ergonomic risk factors that have been associated with them in scientific research.**

## Appendix B: Calculation of Work Sample Duration

In order to determine the percentage of time spent performing specific tasks by work sampling the following statistical formula was used. More specifically it was used to determine the number of observations needed providing a 95% confidence level and the results of a pilot study.

$Sp=2\sqrt{(p(1-p))/N}$

Where S = desired relative accuracy = 95% confidence = ± 5% (.05) accuracy
p = percentage occurrence of an activity as a percentage of the total number of observations = .88
(p was determined from the results of a pilot study to be .88 (88% of all the frames showed the employee in their cubicle)
N = total number of random observations (sample size)

$Sp=2\sqrt{(p(1-p))/N}$

Or

$N=(4p(1-p))/(s^2p^2)$

$N=((4)(.88)(.12))/((.05^2)(.88^2))$

$N=.4224/.001936$

$N=218$

This is means that if we want to use the data from the pilot study and assume a 95% confidence level with ± 5% accuracy that we need to take at least 218 observations. The length of the observation period in hours is found (by dividing 218 observations by 60 observations per hour) to be 3.63 hours or 3 hours and 39 minutes.

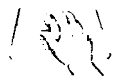
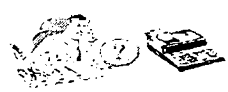
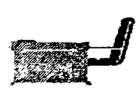
When using the above formula in the opposite fashion we can determine the level of accuracy that can be expected from a five-hour evaluation period or 300 observations. When this is done the accuracy is ± 4 %.

## Appendix C: Worker Survey for Task Perception

# Employee Perceived Frequency of Tasks

**Name:** **Date:**

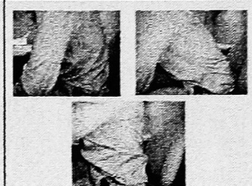
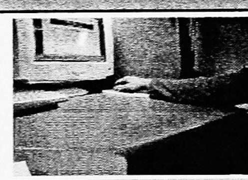
What percentage of the evaluation period did you spend doing each of the tasks below?

| | Percentage for Evaluation Period |
|---|---|
| Keying  | |
| Mousing  | |
| Reading Information On Monitor  | |
| Reading Hard Copy Documents  | |
| Writing Hard Copy Documents  | |
| Using the Phone  | |
| Miscellaneous Office Tasks  | |
| Away From Desk  | |
| Multi-tasking  What percent of the evaluation did you perform any of the above tasks in conjunction with any other? | |
| On a scale from 1 - 10 (10 being a perfect representation), how similar was the work that you performed during the evaluation period to that of your "typical" work day? | |

# Appendix D: Worker Survey for Work Posture Perception

## Employee Perception of Supported Postures

**Name:** ____________________ **Date:** ____________

| | | | | | | |
|---|---|---|---|---|---|---|
| What percentage of the time that you were in your chair during the evaluation were your back and elbows supported? | | | | | | |
| **Back** | Fully Supported (Using chair back or back rest) |  | ____% | Not Supported |  | ____% |
| **Elbows** | Fully Supported |  | % | Not supported |  | % |
| What percent of the time that you used the mouse and keyboard during the evaluation were your wrists and forearms supported? | | | | | | |
| **Fore Arms** | Supported |  | ____% | Not Supported |  | ____% |
| **Wrists** | Supported |  | ____% | Not Supported |  | ____% |
| **Specific Posture Related Questions** | | | | | | |
| What percent of the mousing perfomed during the evaluation was done with your arm fully extended ? | | | | |  | ____ |
| What percent of your phone use during the evaluation was spent "cradling" the phone? | | | | |  | ____ |

# Appendix E: Body Part Discomfort Data Form

Please legibly print the following contact information on the lines below.

Employee Name:__________________ Age:______ Date:__/__/02

How long have you been working in an office environment?: _____How long have you worked for your current employer?:______ Have you ever been diagnosed with a Cumulative Trauma Disorder (CTD)?:_____ If yes, please explain:____________________________________

**Use this scale to rate How Often you experience discomfort**

0 Never
1 Rarely (a few times a month)
2 Frequently (a few times a week)
3 Almost Constantly (nearly every day)
4 Constantly (every day)

**Use this scale to rate How Intense your discomfort is. 10 is the worst you have ever experienced**

0 Nothing at all
0.5 Just noticeable discomfort
1 Very light discomfort
2 Light discomfort
3 Moderate discomfort
4 Somewhat uncomfortable
5 Uncomfortable
6
7 Very uncomfortable
8
9
10 Very very uncomfortable

**1. Do you experience any visual discomfort when you are working at a computer?**

| How Often? Never | | | | Constant | | How Intense? Nothing | | | | | | | | | | | Very, Very Uncomfortable |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | | 0 | .5 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | | | | | Tired Eyes | | | | | | | | | | | | |
| | | | | | Pain Behind Eyes | | | | | | | | | | | | |
| | | | | | Itchy Eyes | | | | | | | | | | | | |
| | | | | | Watery Eyes | | | | | | | | | | | | |
| | | | | | Blurred Vision | | | | | | | | | | | | |
| | | | | | Double Vision | | | | | | | | | | | | |
| | | | | | Difficult to See Far | | | | | | | | | | | | |
| | | | | | Difficult to See Near | | | | | | | | | | | | |
| | | | | | Headaches | | | | | | | | | | | | |

**2. Do you experience any postural discomfort when you work at your computer?**

| How Often? Never | | | | Constant | | How Intense Nothing | | | | | | | | | | | Very, very Uncomfortable |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | | 0 | .5 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | | | | | Neck | | | | | | | | | | | | |
| | | | | | Shoulder | | | | | | | | | | | | |
| | | | | | Upper Back | | | | | | | | | | | | |
| | | | | | Lower Back | | | | | | | | | | | | |
| | | | | | Upper Arm | | | | | | | | | | | | |
| | | | | | Fore Arm | | | | | | | | | | | | |
| | | | | | Elbow | | | | | | | | | | | | |
| | | | | | Wrist | | | | | | | | | | | | |
| | | | | | Hand | | | | | | | | | | | | |
| | | | | | Buttocks | | | | | | | | | | | | |
| | | | | | Thighs | | | | | | | | | | | | |
| | | | | | Lower Legs | | | | | | | | | | | | |
| | | | | | Feet | | | | | | | | | | | | |

# Appendix F: Summary of Raw Task Differences

| Employee | Mousing | | | Keying | | | Reading Monitor | | | Reading Hard Copies | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Observed | Perceived | Difference | Observed | Perceived | Difference | Observed | Perceived | Difference | Observed | Perceived | Difference |
| 1 | 0.081 | 0.050 | 0.031 | 0.144 | 0.450 | -0.306 | 0.112 | 0.050 | 0.062 | 0.211 | 0.050 | 0.161 |
| 2 | 0.203 | 0.450 | -0.247 | 0.213 | 0.450 | -0.237 | 0.184 | 0.200 | -0.016 | 0.097 | 0.100 | -0.003 |
| 3 | 0.133 | 0.040 | 0.093 | 0.090 | 0.070 | 0.020 | 0.315 | 0.070 | 0.245 | 0.151 | 0.100 | 0.051 |
| 4 | 0.238 | 0.050 | 0.186 | 0.228 | 0.250 | -0.022 | 0.199 | 0.200 | -0.001 | 0.044 | 0.150 | -0.106 |
| 5 | 0.024 | 0.200 | -0.176 | 0.090 | 0.200 | -0.110 | 0.014 | 0.100 | -0.086 | 0.100 | 0.500 | -0.400 |
| 6 | 0.053 | 0.100 | -0.047 | 0.074 | 0.100 | -0.026 | 0.079 | 0.100 | -0.021 | 0.137 | 0.100 | 0.037 |
| 7 | 0.350 | 0.100 | 0.250 | 0.112 | 0.250 | -0.138 | 0.254 | 0.100 | 0.154 | 0.108 | 0.050 | 0.058 |
| 8 | 0.424 | 0.200 | 0.224 | 0.169 | 0.200 | -0.031 | 0.186 | 0.150 | 0.038 | 0.068 | 0.100 | -0.032 |
| 9 | 0.139 | 0.500 | -0.361 | 0.160 | 0.300 | -0.140 | 0.279 | 0.250 | 0.029 | 0.254 | 0.250 | 0.004 |
| 10 | 0.149 | 0.200 | -0.051 | 0.385 | 0.700 | -0.315 | 0.169 | 0.050 | 0.119 | 0.086 | 0.050 | 0.038 |
| 11 | 0.186 | 0.100 | 0.086 | 0.210 | 0.500 | -0.290 | 0.195 | 0.250 | -0.055 | 0.114 | 0.100 | 0.014 |
| 12 | 0.068 | 0.150 | -0.082 | 0.141 | 0.150 | -0.009 | 0.340 | 0.150 | 0.190 | 0.320 | 0.200 | 0.120 |
| 13 | 0.150 | 0.200 | -0.050 | 0.061 | 0.100 | -0.039 | 0.332 | 0.400 | -0.068 | 0.229 | 0.100 | 0.129 |
| 14 | 0.203 | 0.300 | -0.097 | 0.044 | 0.200 | -0.156 | 0.203 | 0.300 | -0.097 | 0.359 | 0.250 | 0.109 |
| Average | 0.171 | 0.189 | -0.017 | 0.151 | 0.280 | -0.129 | 0.204 | 0.169 | 0.035 | 0.163 | 0.150 | 0.013 |
| Standard Deviation | 0.111 | 0.142 | 0.177 | 0.089 | 0.182 | 0.118 | 0.095 | 0.103 | 0.107 | 0.097 | 0.121 | 0.138 |

| Employee | Writing Hard Copies | | | Phone | | | Miscellaneous | | | Away | | | Multitasking | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Observed | Perceived | Difference | Observed | Perceived | Difference | Observed | Perceived | Difference | Observed | Perceived | Difference | Observed | Perceived | Difference |
| 1 | 0.133 | 0.100 | 0.033 | 0.239 | 0.100 | 0.139 | 0.228 | 0.100 | 0.128 | 0.307 | 0.150 | 0.157 | 0.151 | 0.090 | 0.061 |
| 2 | 0.039 | 0.550 | -0.511 | 0.159 | 0.350 | -0.191 | 0.203 | 0.100 | 0.103 | 0.359 | 0.250 | 0.109 | 0.097 | 0.800 | -0.703 |
| 3 | 0.056 | 0.100 | -0.044 | 0.000 | 0.000 | 0.000 | 0.262 | 0.220 | 0.042 | 0.306 | 0.400 | -0.094 | 0.006 | 0.050 | -0.044 |
| 4 | 0.005 | 0.100 | -0.095 | 0.053 | 0.150 | -0.097 | 0.233 | 0.050 | 0.183 | 0.380 | 0.400 | -0.020 | 0.034 | 0.200 | -0.166 |
| 5 | 0.024 | 0.050 | -0.026 | 0.048 | 0.050 | -0.002 | 0.714 | 0.100 | 0.614 | 0.293 | 0.400 | -0.107 | 0.014 | 0.150 | -0.136 |
| 6 | 0.079 | 0.300 | -0.221 | 0.211 | 0.200 | 0.011 | 0.442 | 0.000 | 0.442 | 0.493 | 0.500 | -0.007 | 0.074 | 0.200 | -0.126 |
| 7 | 0.065 | 0.050 | 0.015 | 0.015 | 0.050 | -0.035 | 0.100 | 0.150 | -0.050 | 0.376 | 0.250 | 0.126 | 0.008 | 0.800 | -0.792 |
| 8 | 0.021 | 0.050 | -0.029 | 0.284 | 0.200 | 0.084 | 0.161 | 0.150 | 0.011 | 0.241 | 0.200 | 0.041 | 0.263 | 0.800 | -0.337 |
| 9 | 0.053 | 0.050 | 0.003 | 0.098 | 0.200 | -0.102 | 0.164 | 0.250 | -0.086 | 0.332 | 0.250 | 0.082 | 0.148 | 0.500 | -0.352 |
| 10 | 0.014 | 0.010 | 0.004 | 0.196 | 0.050 | 0.146 | 0.169 | 0.020 | 0.149 | 0.471 | 0.200 | 0.271 | 0.169 | 0.020 | 0.149 |
| 11 | 0.052 | 0.050 | 0.002 | 0.224 | 0.150 | 0.074 | 0.119 | 0.050 | 0.069 | 0.402 | 0.300 | 0.102 | 0.114 | 0.030 | 0.084 |
| 12 | 0.019 | 0.020 | -0.001 | 0.000 | 0.000 | 0.000 | 0.131 | 0.250 | -0.119 | 0.391 | 0.250 | 0.141 | 0.024 | 0.100 | -0.076 |
| 13 | 0.051 | 0.050 | 0.001 | 0.014 | 0.100 | -0.086 | 0.166 | 0.050 | 0.118 | 0.422 | 0.250 | 0.172 | 0.037 | 0.050 | -0.013 |
| 14 | 0.127 | 0.250 | -0.123 | 0.013 | 0.050 | -0.037 | 0.079 | 0.100 | -0.021 | 0.173 | 0.001 | 0.172 | 0.029 | 0.090 | -0.061 |
| Average | 0.053 | 0.124 | -0.071 | 0.111 | 0.118 | -0.007 | 0.227 | 0.114 | 0.113 | 0.353 | 0.272 | 0.082 | 0.083 | 0.263 | -0.180 |
| Standard Deviation | 0.039 | 0.149 | 0.144 | 0.103 | 0.097 | 0.095 | 0.166 | 0.081 | 0.200 | 0.086 | 0.125 | 0.108 | 0.077 | 0.285 | 0.280 |

# Appendix G: Summary of Raw Work Posture Differences

| Employee | Back (Not Supported) | | | Elbows (Not Supported) | | | Foreams (Not Supported) | | | Wrists (Not Supported) | | | Fully Extended Mousing | | | Cradling Phone | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Observed | Perceived | Difference | Observed | Perceived | Difference | Observed | Perceived | Difference | Observed | Perceived | Difference | Observed | Perceived | Difference | Observed | Perceived | Difference |
| 1 | 0.730 | 0.900 | -0.170 | 0.361 | 0.900 | -0.539 | 0.609 | 0.150 | 0.459 | 0.078 | 0.150 | -0.072 | 0.087 | 0.040 | 0.047 | 0.000 | 0.020 | -0.020 |
| 2 | 0.531 | 0.800 | -0.269 | 0.662 | 0.500 | 0.162 | 0.942 | 0.100 | 0.842 | 0.314 | 0.050 | 0.264 | 0.000 | 0.000 | 0.000 | 0.030 | 0.000 | 0.030 |
| 3 | 0.542 | 0.950 | -0.408 | 0.184 | 0.910 | -0.726 | 0.042 | 0.010 | 0.032 | 0.000 | 0.000 | 0.000 | 0.209 | 0.040 | 0.169 | 0.000 | 0.000 | 0.000 |
| 4 | 0.660 | 0.750 | -0.070 | 0.248 | 0.250 | -0.002 | 0.667 | 1.000 | -0.333 | 0.219 | 0.850 | -0.631 | 0.102 | 1.000 | -0.898 | 0.182 | 0.700 | -0.518 |
| 5 | 0.348 | 0.500 | -0.152 | 0.162 | 0.100 | 0.062 | 0.125 | 0.100 | 0.025 | 0.000 | 0.100 | -0.100 | 0.600 | 0.050 | 0.550 | 0.000 | 0.000 | 0.000 |
| 6 | 0.700 | 0.900 | -0.200 | 0.684 | 0.850 | -0.166 | 0.917 | 0.700 | 0.217 | 0.000 | 0.450 | -0.450 | 0.200 | 0.010 | 0.190 | 0.000 | 0.800 | -0.800 |
| 7 | 0.696 | 0.050 | 0.646 | 0.358 | 0.100 | 0.258 | 0.183 | 0.200 | -0.017 | 0.150 | 0.050 | 0.100 | 0.055 | 0.050 | 0.005 | 0.000 | 0.050 | -0.050 |
| 8 | 0.492 | 0.250 | 0.242 | 0.428 | 0.500 | -0.072 | 0.607 | 0.950 | -0.343 | 0.688 | 0.500 | 0.186 | 0.020 | 0.100 | -0.080 | 0.000 | 0.030 | -0.030 |
| 9 | 0.475 | 0.250 | 0.225 | 0.980 | 0.950 | 0.030 | 0.973 | 1.000 | -0.027 | 0.178 | 1.000 | -0.822 | 0.029 | 1.000 | -0.971 | 0.000 | 0.000 | 0.000 |
| 10 | 0.885 | 0.700 | 0.185 | 0.662 | 0.200 | 0.462 | 0.304 | 0.000 | 0.304 | 0.127 | 0.000 | 0.127 | 0.045 | 0.100 | -0.055 | 0.241 | 0.010 | 0.231 |
| 11 | 0.895 | 0.900 | -0.005 | 0.238 | 0.200 | 0.038 | 0.024 | 0.100 | -0.076 | 0.012 | 0.100 | -0.088 | 0.026 | 1.000 | -0.974 | 0.000 | 0.150 | -0.150 |
| 12 | 0.942 | 0.950 | -0.008 | 0.699 | 0.900 | -0.201 | 0.605 | 0.990 | -0.385 | 0.140 | 0.200 | -0.060 | 0.500 | 0.000 | 0.500 | 0.000 | 0.000 | 0.000 |
| 13 | 0.748 | 0.500 | 0.248 | 0.682 | 0.650 | 0.032 | 0.378 | 0.050 | 0.328 | 0.200 | 0.200 | 0.000 | 0.031 | 0.000 | 0.031 | 0.000 | 0.050 | -0.050 |
| 14 | 0.648 | 0.700 | -0.052 | 0.283 | 0.600 | -0.317 | 0.064 | 0.700 | -0.636 | 0.026 | 0.700 | -0.674 | 0.125 | 0.000 | 0.125 | 0.250 | 0.200 | 0.050 |
| **Average** | 0.665 | 0.650 | 0.015 | 0.474 | 0.544 | -0.070 | 0.460 | 0.432 | 0.028 | 0.152 | 0.311 | -0.159 | 0.145 | 0.242 | -0.097 | 0.050 | 0.144 | -0.093 |
| **Standard Deviation** | 0.174 | 0.295 | 0.271 | 0.251 | 0.326 | 0.308 | 0.346 | 0.425 | 0.387 | 0.182 | 0.333 | 0.344 | 0.184 | 0.412 | 0.497 | 0.096 | 0.265 | 0.259 |

## *References*

Aaras, A., Fostervold, K.I., Thoresen, M., and Larsen, S. (1995). Postural load at VDU work a comparison between different workplace design. In M. Kumashiro (Ed.), The Paths to Productive Aging, London (pp. 151-156). Bristol, PA: Taylor & Francis.

Aaras, A., Horgen, G., Bjorset, H., Ro, O., and Thoresen, M. (1998). Musculoskeletal, visual, and psychosocial stress in VDU operators before and after multidisciplinary ergonomic interventions. Applied Ergonomics, 29(5), 35-354.

Andersson, B.J.G., and Ortengren, R. (1974). Lumbar disc pressure and myoelectric back muscle activity during sitting; II: Studies on an office chair. Scandinavian Journal of Rehabilitation Medicine, 6, 115-121.

Andrews, D.M., Norman, R.W., and Wells, R.P. (1998). Comparison of self-report and observer methods for repetitive posture and load assessment. Occupational Ergonomics, 1, 211-222.

Armstrong, T.J., Foulke, J.A., and Martin, B.J. (1994). Investigation of applied forces in alphanumeric keyboard work. American Industrial Hygiene Association Journal, 55, 30-35.

Baron, S., Hales, T., and Hurrell, J. (1996). Evaluation of symptom surveys for occupational musculoskeletal disorders. American Journal of Industrial Medicine 29, 609-617.

Bauer, W., and Wittig, T. (1998). Influence of screen and copy holder positions on head posture, muscle activity and user judgment. Applied Ergonomics, Volume 29(3), 185-192.

Bendix, T., and Jessen, F. (1986). Wrist support during typing – A controlled, electromyographic study. Applied Ergonomics, 17(3), 162-168.

Bergqvist, U., Wolgast, E., Nilsson, B., and Voss, M. (1995). Musculoskeletal disorders among visual display terminal workers: Individual, ergonomic, and work organizational factors. Ergonomics, 38(4), 763-776.

Berry, L.M., and Houston, J.P. (1993). Psychology at work: An introduction to industrial and organizational psychology. Madison, W.I.: Brown & Benchmark

Blatter, B.M. and Bongers, P.M. (2002). Duration of computer use and mouse use in relation to musculoskeletal disorders of neck and upper limbs. International Journal of Industrial Ergonomics, 30(2), 295-306.

Buchholz, B., Paquet, V., Punnett, L., Lee, D., and Moir, S. (1996). PATH: A work sampling-based approach to ergonomic job analysis for construction and other non-repetitive work. Applied Ergonomics, 27, 177-187.

Burdorf, A., and Laan, J. (1991). Comparison of methods for the assessment of postural load on the back. Scandinavian Journal of Work, Environment and Health, 17, 425-459.

Bureau of Labor Statistics, U. S. Department of Labor. (2001). Number of nonfatal occupational injuries and illnesses involving days away from work involving musculoskeletal disorders by selected worker and case characteristics 1999 (Table 11). Retrieved June, 2002, from Bureau of Labor Statistics Web site: http://www.bls.gov/iif/oshwc/osh/case/ostb0911.pdf

Bureau of Labor Statistics. (2002). Computer and internet use at work in 2001-2002. Retrieved October, 2002, from Bureau of Labor Statistics Web site: http://www.bls.gov/news.release/ciuaw.nr0.htm

Burgess, R. and Neal, R.J. (1989). Document holder usage when reading and writing. Clinical Biomechanics, 4, 151-154.

Burns, T. (1957). Management in action. Operational Research Quarterly, 8(2), 45-60.

Carter, J.B., and Banister, E.W. (1994). Musculoskeletal problems in VDT work: A review. Ergonomics, 37(10), 1623-1648.

Chaffin, D.B.J., Andersson, G. B. J., and Martin, B.J. (1999). Occupational Biomechanics (3rd ed.). Wiley.

Cook, C. J., and Kothiyal, K. (1998). Influence of mouse position on muscular activity in the neck, shoulder and arm in computer users. Applied Ergonomics, 29(6), 439-443.

Corlett, E.N., and Bishop, R.P. (1976). A technique for assessing postural discomfort. Ergonomics, 19(2), 175-182.

Cornell University, 2002. Retrieved September, 2002, from CUErgo: Cornell University Ergonomics Web site: www.ergoweb.com

Damann, E.A., Kroemer, K.H.E. (1995). Wrist posture during computer mouse usage, In Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting (pp. 625-629). Santa Monica, CA: Human Factors Society.

Deane, F.P., Podd, J., and Henderson, R.D. (1998). Relationship between self-report and log data estimates of information system usage. Computers in Human Behavior 14, 621-636.

Deeb, J.M. (1999). Muscular fatigue and its effects on weight perception. International Journal of Industrial Ergonomics, 24, 223-233.

Feuerstein, M., Armstrong, T., Hickey, P., and Lincoln, A. (1997). Computer keyboard force and upper extremity symptoms. Journal of Occupational and Environmental Medicine, 398, 1144-1153.

Fogleman, M., and Lewis, R. J. (2002). Factors associated with self-reported musculoskeletal discomfort in video display terminal (VDT) users. International Journal of Industrial Ergonomics, 29, 311-318.

González, B.A., Adenso-Díaz, D., and Torre, P.G. (2003). Ergonomic performance and quality relationship: An empirical evidence case. International Journal of Industrial Ergonomics, 31, 33-40.

Grandjean, E. (1984). Postures and the design of VDT workstations, Behavior and Information Technology, 3, 301-311.

Habes, D., Carlson, W., and Badger, D. (1985). Muscle fatigue associated with repetitive arm lifts: Effects of height, weight and reach. Ergonomics, 28(2), 471-488.

Hartley, C., Brecht, M., Pagerey, P., Weeks, G., Chapanis, A., and Hoecker, D. (1977). Subjective time estimates of work tasks by office workers, Journal of Occupational Psychology, 50, 23-36.

Hedge, A., McCrobie, Land, B., Morimoto, S., and Rodrigueq, S. (1995). Healthy keyboarding: Effects of wrist rests, keyboard trays, and a preset tiltdown system on wrist posture, seated posture, and musculoskeletal discomfort. In Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting (pp. 630-634). Santa Monica, CA: Human Factors Society.

Hedge, A., and Powers, J.R. (1995). Wrist postures while keyboarding: Effects of a negative slope keyboard system and full motion forearm supports. Ergonomics, 38(3), 508-517.

Heinisch, D.A., and Jex, S.M. (1998). Measurement of negative affectivity: A comparison of self-reports and observer ratings. Work and Stress 12(2), 145-160.

Homan, M., and Armstrong, T. (2003). Evaluation of three methods for assessing work activity during computer use. American Industrial Hygiene Association Journal, 64, 48-55.

Human Factors and Ergonomics Society. (1998). American national standard for human factors engineering of visual display workstations (ANSI/HFS 100-1988). Santa Monica, CA: Author.

Jensen, C., Finsen, L., Sogaard, K., and Christensen, H. (2002). Musculoskeletal symptoms and duration of computer and mouse use. International Journal of Industrial Ergonomics, 30, 265-275.

Karhu, O., Kansi, P., and Kuorinka, I. (1977). Correcting working postures in industry. A practical method for analysis. Applied Ergonomics, 8, 199-201.

Karlqvist, L., Hagberg, M., Koster, M., Wenemark, M., and Anell, R. (1996). Musculoskeletal symptoms among computer assisted design (CAD) operators and evaluation of a self-assessment questionnaire International Journal of Occupational Environment and Health, 2, 185-194.

Karlqvist, L., Wigaeus Tornqvist, E., Hagberg, M., Hagman, M., and Toomingas, A. (2002). Self-reported working conditions of VDU operators and associations with musculoskeletal symptoms: a cross-sectional study focusing on gender differences. International Journal of Industrial Ergonomics, 30, 227-294.

Keir, P., Bach, J., and Rempel, D. (1999). Effects of computer mouse design and task on carpal tunnel pressure. Ergonomics, 42(10), 1350-1360.

Keyserling, M. (1986). Postural analysis of the trunk and shoulders in simulated real time. Ergonomics, 29, 569-583.

Klemmer, E.T., and Snyder, F.W. (1972). Measurement of the time spent communicating. Journal of Communication, 22, 142-158.

Latko, W., Armstrong, T., Foulke, J.A., Herrin, G.D., Rabourn, R.A., and Ulin, S.S. (1997). Development and evaluation of an observational method for assessing repetition in hand tasks. American Industrial Hygiene Association Journal, 58, 78-285.

Lewis, R.J., Krawiecb, M, Conferb, E., Agopsowiczb, D., and Crandallb, E. (2002). Musculoskeletal disorder worker compensation costs and injuries before and after an office ergonomics program. International Journal of Industrial Ergonomics, 29(2), 95-99.

Mackay, C., Cox, T., (1987). Self-report Techniques. Psychophysiology and the electronic workplace. Wiley & Sons Ltd.

Marshall, M. (2002). Development of Models and Procedures for Evaluating Hand Exertions During Manual Work. Unpublished doctoral dissertation, University of Michigan, Ann Arbor, MI.

Martin, B.J., Armstrong, T.J., Foulke, J.A., Natarajan, S., Klinenberg, E., Serina, E., and Rempel, D. (1996). Keyboard reaction force and finger flexor electromyograms during computer keyboard work. Human Factors, 38(4), 654-664.

McAtamney, L., and Corlett, N. (1992). RULA: A survey method for the investigation of work-related upper limb disorders. Applied Ergonomics, 24, 91-99.

Milerod, E., and Ericson, M.O. (1994). Effects of precision and force demands, grip diameter, and arm support during manual work: An electromyographic study. Ergonomics, 37, 255-264.

Mortimer, M., Hjelm, E.W., Wiktorin, C., Pernold, G., Kilbom, A., Vingard, E., and MUSIC-Norrtalje Study Group, (1999). Validity of self reported duration of work postures obtained by interview. Applied Ergonomics, 30, 477-486.

Muckler, F.A., and Seven, S.A. (1992). Selecting performance measures: "Objective" versus "subjective" measurement. Human Factors, 34, 441-455.

National Institute for Occupational Safety and Health. (2001). National Occupational Research Agenda for Musculoskeletal Disorders. Cincinnati, OH: NIOSH.

Neilson Netratings, (2002), Retrieved November, 2002, from Neilson Netratings Web site: http://pm.netratings.com/nnpm/owa/NRPublicReports.Usages:

Nordin, M., Ortengren, Rlk and Andersson, G. B. J. (1982), Measurement of trunk movements during work. (Goteborg, Sweden: Department of Orthopedic Surgery, University of Goteborg).

Occupational Safety and Health Administration, U.S. Department of Labor. (1999). Ergonomics proposal to prevent 300,000 injuries; Save $9 billion a year. Retrieved June, 2002, from Occupational Safety and Health Administration Web site: http://www.osha.gov/media/oshnews/nov99/national-11221999.html

Occupational Safety and Health Administration, U.S. Department of Labor. (2001). Regulations (Standards - 29 CFR) • Part Number: 1904, Part Title: Recording and Reporting Occupational Injuries and Illness, Subpart: C, Subpart Title: Recordkeeping Forms and Recording Criteria, Standard Number: 1904.12. Washington, DC: Author.

Odergren, T., Iwasaki, N., Borg, J., and Forssberg, H. (1996). Impaired sensory-motor integration during grasping in writer's cramp. Brain, 119( Pt 2), 569-83.

Punnett, L., and Bergqvist, U. (1997). Visual display unit work and upper extremity musculoskeletal disorders: A review of epidemiological findings. Arbetslivsinstitutet National Institute for Working Life

Punnett, L., Fine, L.J., Keyserling, W.M., Herrin, G.D., and Chaffin, D.B. (1991). Back disorders and non-neutral trunk postures of automobile assembly workers. Scandinavian Journal of Work Environment and Health, 17, 337-346.

Rempel, D.M., Harrison, R.J., and Barnhart, S. (1992). Work-related cumulative trauma disorders of the upper extremity. Journal of the American Medical Association, 267, 838-842.

Riel, P.F. and Imbeau, D. (1996). Justifiying investments in industrial ergonomics. International Journal of Industrial Ergonomics, 18, 349-361.

Rosenthal, R. (1976). Experimenter Effects in Behavioral Research. (Enlarged Ed.). New York: Irvington.

Sauter, S.L., Capman, L.J., and Knutson, S.J. (1984). Improving VDT work: Causes and control of health concerns in VDT use, Report prepared for the Department of Administration, State of Wisconsin (Report Store).

Schenk, T., and Mai, N. (2001). Is writer's cramp caused by a deficit of sensorimotor integration? Experimental Brain Research, 136(3), 321-30.

Travers, P.H. and Stanton, B. (2002). Office workers and video display terminals; Physical, psychological and ergonomic factors, Official Journal of the American Association of Occupational Health Nurses, 50(11), 489-493.

Udo, H., Otani, T., Udo, A., and Yoshinaga, F. (2000). An electromyographic study of two different types of ballpoint pens--investigation of a one hour writing operation. Industrial Health, 38(1), 47-56.

U.S. Department of Health and Human Services. (1997). HHS Press Release: Prevention of job-related musculoskeletal disorders draws national audience at conference hosted by NIOSH, OSHA. Retrieved June, 2002, from Occupational Safety and Health Administration Web site: http://www.cdc.gov/niosh/ergprs.html

Van der Beek, A., Hoozermans, M.J.M., Frings-Dresen, M.H.W., and Burdorf, A. (1999). Assessment of exposure to pushing and pulling in epidemiological field studies: An overview of methods, exposure measures, and measurement strategies. International Journal of Industrial Ergonomics, 24, 417-429.

Viikari-Junta, E., Rauas, S., Martikainen, R., Kuosma, E., Riihimaki, H., Takala, E.P., and Saarenmaa, K. (1996). Validity of self-reported physical work load in epidemiologic studies on musculoskeletal disorders. Scandinavian Journal of Work, Environment and Health, 22, 251-259.

Visser, B., de Korte, E., van der Kraan, I., and Kuijer, P. (2000). The effect of arm and wrist supports on the load of the upper extremity during VDU work. Clinical Biomechanics, 5(Supplement No. 1), S34-S38.

Wiktorin, C., Karlqvist, L., and Winkel, J. (1993). Validity of self-reported exposures to work postures and manual material handling. Applied Ergonomics, 19, 208-214.

Wiktorin, C., Selin, K., Ekenvall, L., Kilbom, A., and Alfredsson, L. (1996). Evaluation of perceived and self-reported manual forces exerted in occupational materials handling. Applied Ergonomics, 27, 231-239.

Yeung, S.S., Genaidy, A.M., Karwowsk, W., and Leung, P.C. (2002). Reliability and validity of self-reported assessment of exposure and outcome variables for manual lifting tasks: A preliminary investigation. Applied Ergonomics, 33, 463-469.