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Effects of frequent, active microbreaks during computer operation

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**EFFECTS OF FREQUENT, ACTIVE MICROBREAKS
DURING COMPUTER OPERATION**

A Thesis

Presented to

The Faculty of the Program in Human Factors/Ergonomics

College of Graduate Studies

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Masters of Science

by

Dan Kelso

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ABSTRACT

EFFECTS OF FREQUENT, ACTIVE MICROBREAKS DURING COMPUTER OPERATION

by Dan Kelso

The use of the computer in the office setting has increased significantly in the last two decades. Cumulative trauma injuries have also become a problem in recent years.

Evidence in the field suggests this may be due to a number of ergonomic factors including a lack of stretch breaks during the workday. The present research involved an eight-week study of two groups of workers: one group performed frequent, brief stretch-breaks; the other group followed their customary approach to work breaks.

Measurements of grip strength and endurance, pinch strength and endurance, and self-perception of fatigue and productivity were taken at the beginning and end of the study.

The results revealed that the stretch group had a significant increase in pinch endurance time while the no-stretch group did not show a significant increase in any of the variables measured.

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This work is dedicated to my daughters, Emma and Heather.

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CHAPTER 1

Introduction

In recent years, federal and state governments have been responding to the increasing risk of low level, cumulative type strain related to repetitive work tasks. The Occupational Safety and Health Association realized the potential for serious injury when jobs require repetitive motions, and so they have proposed regulations during the last decade to control exposures associated with musculoskeletal injuries (OSHA, 1999). The National Institute for Occupational Safety and Health (NIOSH), in cooperation with the Center for Disease Control and Prevention (CDC) and the U.S. Department of Health and Human Services, recently published a guidebook for businesses seeking to prevent cumulative trauma related musculoskeletal injuries in their workers (DHHS, 1997). NIOSH contributed heavily to the development of this document through years of research in the area of work related musculoskeletal disorders (WRMDs). This ergonomic program development guide presented a table of “problem” work settings involving heavy repetition and awkward sustained postures, a number of which involved computer operations. The results of NIOSH research and field analysis consistently identified repetitive exertions and awkward or continuous postures as key risk factors for developing musculoskeletal injuries. NIOSH further identified localized fatigue, discomfort or pain, and complaints of undue strain as common symptoms of injury. Within their recommendations section, they proposed a number of work safety engineering and administrative controls, including ergonomic education, workstation modification and improved rest break frequency and duration.

To understand the nature of the physical stresses involved in computer operations, a look at the basic biomechanics of computer use is necessary. Corporate computer operators typically use a standard keyboard and mouse for inputting information, cursor movement, and screen and item selection. Work surface types vary, and may or may not have height adjustability to properly position the monitor, keyboard, and mouse. To control posture and operate these input devices, one generally takes a seated posture which is maintained while the arms and hands operate the keyboard and mouse, and the neck and head are controlled to focus vision on the monitor. Periods of continuous loading of specific arm and shoulder muscles are necessary so precise hand and arm motions can be performed. A series of muscle contractions and muscle movements are required to perform ongoing computer operation. To align the fingers with the keyboard keys, the hands are pronated and the shoulders, arms and hands held in posture or “fixed”. Melhorn (1998) discussed the surprising degree of muscle strain resulting from this form of sustained muscle contraction during computer use. While light muscle contraction may seem to pose less risk of injury than heavier activity, fixing the shoulder area can have a more significant impact when maintained for extended periods of time than one might realize. Melhorn summarized research concluding that the lighter static loading of shoulder and neck muscles in sedentary tasks such as computer operation present a higher likelihood of neck and shoulder injuries than heavy work using the same muscles. He attributed this increased injury risk to the tendency to work longer without breaks during sustained postures as opposed to the common practice of workers feeling

compelled to rest regularly during activity involving moderate to heavy physical effort. Other researchers have found similar results for low-level sustained exertions.

The repetitive key striking required for computer keyboarding and mousing involves repetitive movements of the fingers and sustained postures of the hand and wrist, activities which have been shown to lead to excessive tissue damage due to decreased local tissue blood flow under oxygenation (Rempel, Harrison & Barnhart, 1992; Sjøgaard & Søgaard, 1998). This process of entering and manipulating information through input devices like the keyboard and mouse for extended periods on a regular basis can increase employee risk for developing cumulative trauma disorders (CTDs) (Hales, et al. 1994, Guinter, et al. 1995, Pascarelli & Kella, 1993).

The Human Factors Society, Inc., under the rules and procedures of the American National Standards Institute (ANSI), has established guidelines for designing computer work areas (monitor, keyboard, and seat heights), to assist workers in maintaining optimal work conditions and neutral postures (ANSI/HFS 100-1988). Unfortunately, many company safety programs may assume that modifying workstations in this way is adequate to assure employees are safe from CTDs. While adjusting workstations to support more neutral postures can decrease musculoskeletal loading for computer operations, this does not protect one from musculoskeletal over-stressing and cumulative trauma (Carter & Banister, 1994). Melhorn (1998) suggested that “most current models for musculoskeletal or neuromusculoskeletal injury are incomplete and frequently are based on the loads tissues bear during function compared with tissue tolerance or failure... without consideration for the body’s ability to respond and repair possible micro

musculoskeletal traumas” (p.115). In the 1997 tally from the Environment, Health and Safety Department at Sun Microsystems, over 950 office workers requested ergonomic intervention complaining of physical discomfort and injury related to computer use. These requests have persisted, in spite of the fact this company has had an ergonomics program in place for several years which focuses on modifying computer workstations to help workers minimize musculoskeletal stresses. This suggests other causes of discomfort and injury must be involved.

An exploration of the causes of computer work related injuries should begin with the nature of the injuries. A number of conditions such as thoracic outlet syndrome, tendonitis, and carpal tunnel syndrome are often grouped under the title of Cumulative Trauma Disorders (CTDs). Symptoms of a CTD include pain, stiffness, weakness, and numbness or tingling. CTDs are the fastest growing category of occupational injury in the United States workforce. In an on-line source, recent Bureau of Labor Statistics (1999), show the incidence of disorders associated with repeated trauma have increased beyond all other illnesses combined.

The long-term effects of CTDs can be a decrease in musculoskeletal functioning. Pascarelli and Kella (1993) in a clinical study of 53 injured keyboard operators noted decreased range of motion in employees with cumulative trauma injuries. In addition, 40 of the 53 persons examined had wrist flexion impairment. This is believed to be the result of chronic micro trauma and tissue changes that shorten the muscle bundles.

Presenting a description of CTD micro trauma in an on-line source, Randale Sechrest (1997), described the two key activities leading to cumulative trauma, the first of which is repetitive motion.

"Repetitive motions are movement applied to muscles and joints the same way all the time and may contribute to early wear and tear. This is probably because the constant repetitive motion focuses the damage to one area of the body. Basically, the constant force leads to over use. Using muscles and joints after they have become fatigued, or overly tired, increases the likelihood of injury. Overloaded muscles and soft tissue without proper rest have no chance to recover fully. All body tissues are in a constant state of change. Small damages occur continuously, which the body must repair in the normal course of the day. But what happens if the damage is occurring faster than the repair mechanism can keep up with? The damage gets ahead of the body's ability to easily repair the damage quickly. The tissues become weak. They may begin to hurt - to cause symptoms. The weaker the tissues become, the more likely that they will suffer even more damage. A cycle begins that looks like a spiral - constantly downward!" (p. 4)

Dr. Sechrest went on to describe the second key musculoskeletal factor contributing to CTDs: static posture. "The body and its joints are made for movement, and even correct posture held for a long time becomes tiring. Constantly staying in one position causes the muscles to go into a sort of spasm to try and maintain that one position. Constantly changing position allows different muscles to share in the workload

and lets tired muscles rest”. (p. 6) Dr. Sechrest noted that as this spasm like process and soft tissue tension occurs, “blood flow is restricted, depriving muscles and nerves of oxygen and nutrients, and aggravating the symptoms of CTD. Rest and Relaxation can be used to relieve tension and allow recovery.” He encouraged the use of “frequent breaks” to facilitate this recovery. (p. 7)

Regular rest periods are a necessary part of acceptable work conditions. Early in this century, work/rest research in jobs involving moderate to heavy labor by the British Industrial Fatigue Research Board (BIFRB) first demonstrated the value of mid-morning and mid-afternoon rest breaks (reported by Swanson, Sauter, & Chapman, 1989). This proposed schedule of rest breaks by the BIFRB was later adopted as part of the U.S. federal labor laws regulating work/ rest schedules. However, the present widespread challenge of work-related cumulative trauma has arisen in spite of the availability of standard rest break periods. As cited earlier, federal and state government regulations and workplace health program guidelines clearly point to the need for special attention to musculoskeletal rest and recovery when that exertion is at low levels for extended periods, as in computer operations. A Canadian study of computer operators revealed that moderate to severe musculoskeletal symptoms were most likely to be reported by employees who took fewer breaks, and a number of work and personality factors played a part (Polanyi et al. (1997). These results suggest the need for a more effective approach to work/rest scheduling, while pointing the way to key factors in break design.

The frequency, duration, and content of rest breaks for computer operators should not be left to design based on outdated standards. Recent studies have explored optimal

rest break duration and frequency for jobs involving at least regular computer operation. Because “video display terminal” work is characterized by constrained postures and static loads, Swanson et al. (1989), summarized a number of studies to suggest that breaks should be responsive to the 10 to 15 minute fatigue onset in VDT work. Several other studies agree that musculoskeletal recovery can be achieved with short, frequent, rest breaks (Henning, Altrass-Webb, Jacques, Kissel, & Sullivan, A.B. 1993; Genaidy, et al. 1995). In addition, the effects of adequate rest and recovery on worker performance and productivity should not be overlooked. Carter and Banister (1994) summarized early research on work/rest scheduling by stating that regular movement is “essential” to avoid musculoskeletal strain, and frequent breaks are “crucial” to safe and productive work. Bhatia and Murrell (1969) found that frequent, brief rest breaks increased productivity and efficiency in workers performing repetitive manual tasks. Janaro and Bechtold (1985) actually increased subject productivity when frequent rest breaks were used, while Henning et al. (1993) increased productivity even though overall time available for work was decreased by the rest breaks.

In general, when performing work such as operating the computer for extended periods, breaks should occur every 30 minutes to an hour. Break duration should not be less than one minute, as this period is usually not adequate to gain recovery, while frequent breaks over 10 minutes, and often even 5 minutes, can be too disruptive to workers and may not allow more recovery than shorter periods of 2-3 minutes (Swanson et al. 1989; Kopardekar & Mital 1994). When considering break content, passive rest breaks are not as effective as active rest at facilitating recovery from musculoskeletal

exertion. Numerous studies have shown a significantly better recovery effect when active rest periods characterized by stretches and related musculoskeletal movement are used rather than passive rest (Melhorn, 1998, Carter et al. 1994, Henning, Sauter, Salvendy, & Krieg, 1989, Swanson et al. 1989, Bhatia, & Murrell, 1969).

When designing a computer operator work/rest schedule, it is important to consider the competitive, high pressure, productivity oriented culture of the modern corporate office environment. A survey conducted at the end of 1999 at Sun Microsystems revealed a number of interesting findings relating to employee work/rest scheduling. Of the 1149 employees responding to the survey, nearly 80% indicated that they felt “tired and sore during a typical day of keyboarding and mouse work”. The regular occurrence of fatigue and pain when performing repetitive activities is considered an early symptom of cumulative trauma injury (Putz-Anderson & Galinsky 1993; Matias, Salvendy, & Kuczek, 1998). A typical day involves 4 hours or more of keyboarding and mousing for 95% of the employees surveyed, and over 8 hours for 35% of the workers. Almost 70% of employees in the survey said they do not take stretch breaks at all. And of those who do stretch, about half stretch only once or twice per day. To accommodate the need for frequent breaks, the way rest schedules are taken will need to be integrated well with the common duties a typical computer operator performs, their attitudes about performance, and reasonable needs by management to effectively run a business (Melhorn, 1998).

Psychosocial factors are commonly cited in research as contributing significantly to employee self-management of recovery periods (Feurstein & Fitzgerald 1992; Melhorn

1998, Hales et al., 1994, Henning et al., 1989). Psychosocial factors relate more to employees' behavior, beliefs and choices rather than actual physical limitations or stressors. Hales et al. (1994) identified a number of psychosocial factors including pressure to be productive and surges in workload. Additional factors identified in the corporate survey reviewed include the tendency to become absorbed in one's work, lack of awareness of musculoskeletal fatigue in the body, and confusion identifying symptoms of cumulative strain. While the general policy for office work at the corporation surveyed allows employees the freedom to take breaks as needed, it appears they do not take advantage of this due to psychosocial reasons.

A more detailed look at Sun Microsystems's internal survey reveals some interesting issues when employee breaks are self-directed. As a part of that survey, employees were invited to write in comments regarding their rest break scheduling practices. The most common responses uncover some of the psychosocial factors affecting employee break schedule management. Employee comments suggest that they do not feel they can stop to take a break due to productivity demands and project deadlines. Workers frequently stated they would forget to take breaks because they were busy with computer tasks. Employees who take breaks often commented they only realized they needed a break when they noticed physical discomfort. Many surveyed remarked they take a short walk for a break but do not stretch their upper body. And finally, a considerable number of employees feel they should take more effective breaks but they either do not know what to do for a proper break, or they feel making copies or doing other manual tasks should be adequate for recovery.

What types of administrative controls can assist the management of rest breaks?

In research on self regulated rest breaks, Hagberg (1981) and Henning et al. (1989), found that study participants did not take adequate breaks for recovery when they appeared influenced by internal conditioning such as competition and need to be highly productive. Henning et al. (1989) conducted a study of the use of discretionary microbreaks in data entry workers. Their results indicated that even when workers were allowed to take rest breaks as long as they wished, keystroke and correction rate data suggested they did not take adequate time to recover from the stresses of keyboarding. It should be noted that neither of these studies involved self-rating systems for discomfort or mood, methods which require participants to periodically attend to their physical state. However, later Henning et al. (1993), followed up with a similar study of self regulated rest breaks and found participants had greater success with rest break frequency and schedule when they self monitored discomfort. When allowed to set microbreaks based on their own perceived level of discomfort, employees were able to consistently decrease their discomfort to a significant degree (Genaidy et al. 1995).

Does worker awareness of subjective discomfort equate to actual physical strain, excess fatigue and cumulative trauma? Melhorn (1998) noted that a growing number of studies suggest, “individuals are capable of reliably estimating their endurance in a physical task and that there is a strong positive correlation between the objective and subjective aspects of a fatigue state” (p. 119). If this is the case, then workers experiencing musculoskeletal stress and fatigue related to computer operations should be

able to become aware of the symptoms. They have the option to take effective action to help their body to recover, decreasing the risk of cumulative trauma injuries.

The main objective of this study was to test the effectiveness of active, self-directed microbreaks at reducing daily-perceived fatigue and increasing forearm and hand flexor strength. Additional objectives of this study were to assess the relationship between strength and fatigue levels perceived by employees and dynamometer readings of flexor strength.

Statement of the Research Problem

The focus of the research was to examine the effects of frequent, short stretch breaks on computer operator hand strength and endurance, and operator perceived productivity and fatigue in the shoulders, arms and hands.

Research Hypothesis

Frequent, short stretch breaks by computer operators will significantly increase hand strength and endurance, and perceived productivity, and decrease perceived fatigue in the hands, arms and shoulders by the end of the experimental period.

Delimitations

Only computer operators working in the call center were used as participants in this study in order to maintain commonality in physical job demands. Participants in the experimental group of this study performed special daily procedures that were not observed or overheard by the control group participants. Therefore, all participants in a particular work group and room shared either control or experimental conditions.

Limitations

This study did not control for other activities that subjects engaged in during the study that might affect maximum strength or endurance for gripping or pinching.

Definition of Terms

Grip Strength. Grip strength is a measure of maximum voluntary effort. In the present study it is defined as the average of three participant maximum hand-grip exertions squeezing the handgrip dynamometer.

Grip Endurance. Grip endurance is the ability to maintain some level of effort over time. In the present study it is defined as the average of three efforts involving the number of seconds participants were able to maintain a maximum exertion squeezing the handgrip dynamometer.

Pinch Strength. Pinch strength is a measure of maximum voluntary effort. In the present study it is defined as the average of three participant maximum pinch-grip exertions squeezing the pinch gauge.

Pinch Endurance. Pinch endurance is the ability to maintain some level of effort over time. In the present study it is defined as the average of three efforts involving the number of seconds participants were able to maintain a maximum exertion squeezing the pinch gauge.

Ratings of Perceived Productivity. Ratings of perceived productivity are the participants ratings from 1 to 10 regarding the level of productivity they felt they were performing at.

Ratings of Perceived Fatigue. Ratings of perceived fatigue are participants' ratings from 1 to 10 regarding level of fatigue they experienced in their hands, arms or shoulders.

No Stretch Group. The no stretch group involved participants' who filled out self-perception questionnaires and gave data on hand and pinch maximum grip strength and endurance but were not tasked with performing stretches.

Stretch Group. The stretch group involved participants who filled out self-perception questionnaires and gave data on hand and pinch maximum grip strength and endurance, and were tasked with performing stretches.

Significance of The Study

For the last several years, based on year end summaries, interviews conducted as a routine part of ergonomic evaluations of office workers at Sun Microsystems, a large, local corporation, suggest that the use of regular, appropriate rest/recovery breaks by office employees is rare. This should raise concerns for several reasons. Most office work at this company is conducted on the computer. Extended periods of computer operation commonly involve excessively repetitive keyboarding and mouse movement and sustained postures that have been found to lead to cumulative trauma injuries (Pascarelli et al., 1993; Hales et al., 1994; Matias et al., 1998). In addition, work performance (productivity) is often negatively affected when performing work involving repetitive motions and sustained postures without adequate recovery periods, due to the functional inhibiting effects of excess fatigue and musculoskeletal strain (Kruizinga, Delleman & Schellekens, 1998; Genaidy et al., 1995; Feurestein et al., 1992).

The gradual over-stressing of the musculoskeletal system due to repetitive motion and postural strain is not simply a local problem. In a study of Canadian computer operators at a newspaper, 20% were found to have persistent, moderate-to-severe upper limb pain (Polanyi et al., 1997). Modern business offices throughout the country increasingly rely on the computer's rapid information processing functions to perform virtually all of the daily tasks. Melhorn (1998) noted the rapid increase in work related computer use represented in Department of Labor statistics, with 25% of the US population using computers at work in 1984, and 45% using computers at work in 1993.

This indicates the trend of increasing computer dependency and the resulting musculoskeletal disorders should continue to rise.

CHAPTER 2

Review of Related Literature

In this review, research in the area of rest and musculoskeletal recovery after periods of physical exertion is explored. The effect of varying rest periods has been studied to some degree over the last few decades within several different disciplines. The physiological effects of rest are considered, along with rest scheduling for cumulative fatigue, the use of active rest, measuring methodologies for strength and fatigue, and worker self-awareness in managing the cumulative stress of work.

Massed verses Distributed Practice

The performance of repetitive tasks was studied in the 1950s, 1960s, and 1970s by motor learning and performance researchers with the goal of identifying optimal physical exercise practice trial/rest periods. A number of studies were grouped in the category of “massed practice versus distributed practice” research. The use of rest breaks in many of these studies was manipulated to investigate the effects of length of rest period on trial performance. The focus of research in massed versus distributed practice was typically the investigation of the effects of rest period duration and frequency on the learning of a task. Little if any attention was given to rest and physical recovery or the effects of repetition on the body. However, some interesting secondary results are relevant to the present study.

In the massed versus distributed research, a recurring finding was superior performance with distributed practice sessions (practice with intertrial rest periods), over massed practice session performance (generally short or absent intertrial rest periods)

(Digman, 1959; Adams & Reynolds, 1954; McBride & Payne, 1979). In these studies, performance was significantly higher in the massed experimental group when rest break duration was increased. Adams and Reynolds (1954) took massed versus distributed practice research a step further, using variable rest periods. They concluded, "The distribution of practice was a performance not a learning variable" (p. 35). Their study revealed that the massed practice group displayed a significant gain in performance when equal rest periods were given both groups, and the massed group actually began to parallel the distributed group. This result appears to suggest a strong influencing effect of recovery time on performance. In addition, as rest period duration was increased further, there was a decrease in performance for both groups. This latter finding is relevant to the present study as it suggests an optimal rest period length, after which the time-off-task appears to adversely affect performance and may not contribute significantly to recovery. It should be kept in mind that these studies assess short-term performance effects, while later studies will address long-term, cumulative over-use effects.

Newell, Antoniou, and Carlton (1988), in their review of the literature in this field, concluded, "there appear to be optimal practice-rest ratios for each task" (p. 310). Their proposal that the research revealed, "task specific influences of massed and distributed practice" (p. 310), supported the view in the present study that modern computer work activities be viewed as a specific, new form of task, with particular rest and recovery demands for optimal worker well being and performance.

Physiological Effects of Work and Rest

In their review of research of the 1960s, Bhatia and Murrell (1969) summarized thinking regarding the hazards of repetitive, light to moderate work. They noted, “Current thinking and practice on fatigue and rest allowances is still largely related to heavy physical work” (p.168). Their review included studies of rest allowances for work involving mild to moderate exertion. Yet they go on to conclude that it is more likely that decrement in output with time in light manual tasks is due to mental causes rather than physical ones. Researchers during this period appear to seriously disregard or at least underestimate the physiological effects of mild exertion related cumulative fatigue and trauma.

In a later ergonomic study of rest schedules under varied light and heavy workloads, Krajewski, Kamon and Avellini (1979), began defining “recovery” in terms of oxygen regulation and changes in heart rate during work and rest. The body’s tendency to either block oxygen flow through certain activities, or increase it, has been a key metric for numerous studies over the years. In the sports medicine field, Andzel (1978) looked at the effects of warm ups and resting on musculoskeletal exertion. The aim here was to study the “oxygen mobilizing” effect of prior exercise during moderate physical exertion. He found that longer rest periods are not always optimal for performance. The exercise groups in Andzel’s study were combined with rest periods varying between 0, 30, 60, 90 and 120 seconds. The results indicated significantly better performance with prior exercise and 30 to 60 second breaks rather than longer rest periods.

Swanson et al. (1989) summarized muscle fatigue studies during the later 1980s related to computer operation work, stating that the research reviewed points toward significant fatigue impact on muscles even at low levels of exertion, and the need for short, frequent breaks from computer work. One such study measured sustained muscle forces at 6 to 20 percent of maximum voluntary contraction (MVC) for computer operators, with fatigue becoming perceivable at 10% of MVC in as little as 10 to 15 minutes. In more recent studies summarized by Tadano (1990), participants who performed extended periods of static muscle contraction, such as those involved in holding arm postures while keyboarding, suffered impaired intramuscular blood and oxygen flow. She explained that the effect of these static contractions on muscle metabolism is to interfere with oxygen and glycogen supply and increase levels of lactic acid, contributing to muscle exhaustion and discomfort. In regards to the repetitive hand and arm exertions involved in computer keyboarding, tendons generate significant sheering forces that, over time, can seriously damage tendon sheaths, synovial membranes and connective tissue. Hagberg (1981) studied muscular endurance during extended period, minimal exertion isometric contraction of the upper arm (working from a 90 degree bend, forearm semipronated, a similar arm posture to that used in computer operations). He found when comparing sustained isometrics with intermittent isometrics that, "the blood flow removal of contraction-inhibiting metabolites is facilitated by intervening rest periods" (p.5). Hagberg went on report, "even rest periods as short as 2 seconds used in the present study enhanced endurance significantly compared with that for sustained isometric exercise" (p.5). As a result of these work physiology oriented

studies, “light” work can be much more physically stressful than previously believed, and rest breaks can be surprisingly effective at countering musculoskeletal fatigue and strain.

Rest Break Frequency and Duration

Research on rest period length and frequency initially appears to present conflicting results. One might think that longer rest periods would allow fuller recovery. Hagberg (1981), found that “even 2 second rest periods enhanced endurance significantly compared with that for sustained isometric exercise”, in subjects performing elbow flexion at 15% to 80% maximum voluntary contraction. Participants in Kopardekar and Mital’s (1994) computer operation study simulated a telephone operator task for 2 hours. Errors made during work were significantly higher for participants taking no breaks, with nearly equal improvement for those taking a 5-minute break every 30 minutes and a 10-minute break every 60 minutes. Although taking more frequent 5 minute breaks made fewer errors, the researchers in this study recommended the 10-minute break every 60 minutes because it would interrupt work less.

In a study of workers performing repetitive manual tasks, Bhatia and Murrell (1969) compared work performance and preferences between workers given a 15-minute break every 90 minutes and a 10-minute break every 60 minutes. While performance showed a similar increase for the two groups, the workers had an interesting subjective response to the two conditions. During an early survey 64% of the workers said they would prefer the 15-minute break schedule to the 10-minute one. After the study, all workers agreed that the 15-minute break duration left them feeling more lethargic, preferring the 10-minute breaks to help them effectively return to work.

Henning et al. (1989) designed a computer operation task with six 40-minute work periods separated by 10-minute breaks, along with self-regulated breaks allowed during the 40-minute work period. While the discretionary breaks during the work period did not improve performance, the 10-minute breaks offset fatigue to maintain productivity. The researchers in this study observed that psychological factors influenced the use of these discretionary “mini-breaks” during the 40-minute session causing subjects to return to work before they were fully rested. Another possibility may be that given the studies workload, 10-minute rest periods every 40 minutes were plenty of time to recover, negating the need for an additional break. It might then have served only as an obstacle to work flow and momentum.

Active Rest Effects on Recovery

While there have been some confusing results, research in the area of active versus passive rest support the use of light activity during breaks to assist in musculoskeletal recovery. In some studies, active breaks can be alternative physical activities other than the one (such as computer keyboarding) being controlled in the experiment. A considerable number of studies use standard stretching routines for active rest periods in order to target and optimize musculoskeletal recovery.

Henning et al. (1989) found that passive microbreaks did not improve fatigue, mood, or productivity in participants performing heavy computer operations. However the researchers did suggest that the unexpected results might have occurred because subjects were not willing to take adequate recovery time during discretionary breaks. In their review of early research, Swanson et al. (1989) pointed out that many early studies

concluded when active rest break was used worker productivity increased. The use of exercise stretches during a NIOSH study of micro break effectiveness for data entry operators (Swanson et al. 1989) resulted in no differences in mood and comfort between passive and active rest break groups. However keystroke production for the active rest break group in their study was significantly less declined than for the passive break group. Henning et al. (1993) found somewhat mixed results with manipulation of breaks and exercise for computer operators. In their field study of two work sites, computer workers at one site showed increased productivity and comfort scores with microbreaks over standard breaks, with highest scores occurring in the microbreaks with stretching condition. At the second worksite these effects were reversed. Further investigation of the computer work performed at the second site suggested that scheduled breaks for these workers tended to disrupt their task flow, decreasing productivity and feelings of calm and comfort. Henning et al. suggested the need for a more sophisticated “task specific” approach to rest break design, sometimes using an automated break system and in other situations a worker-managed one.

A number of studies (Genaidy et al. 1995; Takashi & Miyamoto 1998; Seradge, Jia, & Owens 1995) reviewed found that recovery could occur quite rapidly when active breaks are taken. Takashi and Miyamoto (1998) concluded in their study of exercise and recovery that light post-exercise physical activity facilitates the venous return from muscles, shortening recovery time. Seradge et al. (1995) found that after increasing carpal tunnel pressure in the wrist through hand intensive tasks, a 1-minute break involving hand and wrist movement significantly decreased carpal tunnel pressure and

maintained it so at least 15 minutes. Genaidy et al. (1995) found that microbreaks (2 minutes in length), with stretches for the upper extremities controlled meatpacking worker perceived discomfort significantly better than passive rest.

Henning et al. (1993) conducted a field study attempting to validate a recent National Institute of Occupational Safety and Health (NIOSH) lab study involving scheduled microbreaks of 30 seconds to 3 minutes with and without stretching exercises. Henning et al. found no significant change in worker mood but highest comfort scores and productivity rates when active rest breaks were used. These researchers agreed with earlier conclusions regarding short, frequent, active rest breaks by noting that they appear to capitalize on the rapid rate of recovery that occurs early in a rest break period, helping prevent the accumulation of fatigue over the work spell.

Worker preference for active over passive rest breaks was consistently noted in the research reviewed by Sundelin and Hagberg (1989). These researchers used electromyography readings during active rest breaks to measure the muscle load effects during work and rest. Unfortunately, the electrical activity in the muscle tissue during active rest breaks obscured readings of changes in muscle load making these results inconclusive. However, they did note that computer workers were found to prefer active rest breaks to passive ones. Subjective factor of preference related to rest break should not be dismissed, as there is evidence that individuals can accurately perceive their level of fatigue (Melhorn, 1998).

One issue that arises with discretionary rest-break scheduling is the integration of such routines with the modern computer operator's approach to work. Henning ./ al.

(1989) attempted to explore the use of discretionary-length “microbreaks” as an effective method for controlling fatigue in data entry workers. The results of his study indicate that when workers took a scheduled 10-minute break away from the data entry task between sessions, performance improved and perceived fatigue decreased. However when participants controlled their own microbreaks, averaging approximately 30 seconds, they tended to return to task too quickly, resulting in decreased performance scores and less recovery from fatigue. These researchers saw the data entry workers' perceived loss of “efficiency” or momentum as the key factor motivating premature termination of microbreaks. Their point is a good one, as psychosocial factors should be taken into account when designing realistic break schedules that were accepted by workers.

Measurement of Musculoskeletal Fatigue and Recovery

Various metrics have been used to measure physical capacities as well as the cumulative effects of overwork on the worker. Some approaches involve measurement of keystroke performance scores in the lab setting (keystroke monitoring) and comparisons of worker productivity records (Henning et al. 1989) . A number of recent studies comparing work-rest schedules make use of self-perception surveys (Henning et al. 1993 Kopardekar & Mitar 1994, Swanson & Sauter 1993). The design of these self survey tools typically involves a series of questions, or “polar” terms (such as weak---strong) and a 5 to 10 point rating scale, for documenting participant self perceived mental, emotional or physical state. The common use of these tools and the consistency in results

support it as a valuable device for measuring subjective factors such as fatigue and productivity.

In the medical field, sports medicine, and human factors research, the use of isometric strength testing devices has served as a simple and effective tool for assessing the effects of fatigue, strength levels, and general physical performance. In a study of fatigue curves, Kroll (1966) used a device called a “tensiometer” to measure muscle strength/fatigue over time. The tensiometer works under the same isometric muscle contraction principles as the modern handgrip dynamometer, but is fitted to the wrist and hand. Jackson, Laughery, & Osburn (1984) used isometric strength testing devices, including grip strength testing equipment, to quantify strength levels and predict performance in physically demanding tasks. Biomechanical studies at the Mayo Clinic involved the use of a hand held dynamometer to measure fatigue rates (Motzkin et al. 1991). In their study of upper extremity strength with varied microbreak schedules, Genaidy et al. (1995), used grip strength testing to compare sub-groups in a meat-cutter rest break study. Jones (1989), in a review of techniques for hand assessment, notes two forms of grip assessment for muscle and joint function, power and precision. While power grips relate more to something like gripping a suitcase, the precision grip is used when performing lighter finger manipulation like screwing in a bolt.

Summary

In summary, this review of literature in the area of musculoskeletal recovery reveals a progression toward parameters for designing optimal rest period schedules. Research in massed versus distributed practice revealed an increase in performance with

periodic work pauses. More physiologically oriented studies defined the impact of exertion and recovery on soft tissue. Studies in human factors and other disciplines indicated significant physical risk from extended periods of light to moderate exertion, and focused on outlining rest break frequency, duration and content. Optimal musculoskeletal recovery benefits appear to come from short, frequent, active breaks.

While many factors can contribute to discomfort, fatigue and injury in those performing computer-oriented office work, the present study focused on the use of frequent, active micro breaks as a method to improve recovery from fatigue and to increase general hand strength in computer operators.

CHAPTER 3

Methods

The focus of this research is to examine the effects of frequent, short stretch breaks on hand and finger strength and endurance, as well as perceived degree of fatigue in the shoulders, arms and hands of computer operators. In this methods chapter, the participants, apparatus and instrumentation, experimental design and experimental procedures are described. The Institutional Review Board, Human Subjects Committee approved this study; the approval letter is attached in Appendix I.

Participants

Participants were 36 employees 18 or more years old from a local business office. They were employed in call center positions that involve continuous phone activity and relatively continuous keyboard work, with some mouse activity. Participation in this study by employees was completely voluntary and solicited through the use of an “ Agreement to Participate in Research” form (Appendix A).

Volunteer participants were kept together with coworkers in their work area and assigned as a group to either the stretch break or the no stretch condition. This coworker grouping was done to avoid exposing participants to the conditions and directions of both the stretch break group and no stretch group, as some employees in the same work group share an office area.

Participant Demographics

Participant information gathered at the start of the study included name, age, number of hours on the computer per day, and percentage of keyboarding or mouse use per day.

Apparatus and Instrumentation

A Jamar hand dynamometer with an analog dial was used to assess grip strength involving muscles and tendons of the hand and forearm. A B&L pinch gauge was used to assess pinch strength involving muscles and tendons of the fingers and hand. The validity and reliability of these devices for accurately measuring hand strength have been measured in earlier studies. Mathiowetz et al. (1985) selected the Jamar dynamometer and the B&L pinch gauge for their normative study of handgrip and pinch strength, noting that early research found these devices to be the most accurate measure of strength with “the highest calibration accuracy” of devices tested (p. 69). In a study by Bohannon (1998), Jamar handgrip dynamometer measurements correlated significantly with manual muscle test scores, supporting the construct validity of handgrip dynamometry for characterizing upper extremity strength changes. Nitschke, McMeeken, Burry and Matyas (1999), in their study of clinically meaningful interpretations of grip strength measurements, concluded that the use of the Jamar handgrip dynamometer had high test-retest reliability for assessing maximum grip strength.

A self-survey data collection form was another measure used by participants in the study. The Self Perception Record was used for recording data on perceived fatigue, strength, and productivity (Appendix B).

By permission (Appendix C), two stretching procedure sheets designed by Bob and Joan Anderson of Stretch Incorporated (Appendix D) with a series of standard stretches were combined and modified for use by the stretch break group. Instructions for performing the stretches were attached to the stretch sheet. A “Tally Sheet” was maintained by participants in the stretch break group to help them keep track of breaks and maintain a regular schedule (Appendix E). Each stretch break group participant was given a standard minute/second timer to measure time between and during stretch breaks. The supervisor in the stretch group was asked to encourage participants to follow test protocol and take regular breaks.

Experimental Design

To examine the effects of active microbreaks on handgrip strength and endurance, pinch strength, and ratings of perceived discomfort, work periods with or without microbreaks were manipulated over an 8-week period. In similar research by Garfinkel, Singhal, Katz, Allan, Reshetar and Schumacher (1998), significant improvements in grip strength and wrist discomfort were noted in participants performing yoga stretches over an 8 week period. The dependent variables measured for the present study were ratings of maximum grip strength, grip endurance, maximum pinch strength, pinch endurance, ratings of perceived productivity, and ratings of perceived fatigue.

Experimental Procedures

Participant orientation occurred at 9:00 am on the first day of the study, from 9:30 am to approximately 11:00 am all other data were gathered. On the final day of the study, all data were gathered between 9:30 am and approximately 11:00 am.

Once work groups had been identified and management permission granted, individual employees were asked to participate in this study. Those employees agreeing to participate were given a copy of the “Participant Instructions” sheet (Appendix F) to read and the experimenter clarified any part of the instructions as needed. There was a brief interview to generate a list of participant names and document participant demographic information: time and date of the interview, the participant number, age, number of hours spent working on the computer per day, percentage of time on the mouse and keyboard, and participant’s initial mean maximum strength and endurance hand grip and pinch scores. This information was documented on the Participant Information Form that is attached in Appendix G. Three maximum and three endurance hand and pinch grip measurements were taken from participants in the stretch break and no stretch breaks group prior to the beginning of the study and at the end of week 8. During handgrip measurement, the experimenter demonstrated to the stretch break group participants how to hold the dynamometer. The dynamometer was set at the third level grip position for all participants as done by Nitschke et al. (1999) to best accommodate a wide range of hand sizes. The participants' dominant arm was relaxed at their side positioned with the elbow bent at a 90-degree angle and hand in a thumb-up vertical position. Participants were told “I want you to squeeze the handle as hard as possible, ready, begin....squeeze hard, ...harder....good”. The same arm/hand preparations were used for the handgrip endurance test. Participants were asked to squeeze the dynamometer handle as hard as possible and hold it as long as they can. Participants were told, “squeeze the handle as hard as possible and hold it, then say ‘done’ when you

can't hold it any longer and have let go ...ready, begin..... squeeze hard and hold it as long as you can .....hold it". Pinch gauge testing used an opposing finger-grip similar to that used when gripping a computer mouse. Participants started in the same arm position as that used for the handgrip measurement, with the index and middle fingers opposing the thumb below them. Directions for performing the maximum and endurance pinch-grips were the same described for the handgrips above. The mean of three trials for each of the four measurements was used for analysis of grip and pinch strength effects as recommended by Jones (1989) and Nitschke et al. (1999). A recovery period of 20 seconds was allowed between all trials as was used by Nitschke et al. (1999).

All participants were given dated copies of the Self Perception Record to complete at the end of each day of the study and were instructed in how to complete it during the orientation session. Participants in the stretch break group were also given the Break Tally form and instructed to keep it near their computer in a high-visibility location. Stretch break instructions directed participants in the stretch break group to take a 3-minute break every 30 minutes during the workday and mark an "X" on the tally sheet under that days' date when they have done so. They were to continue working during the stretches by continuing only phone type activity on their headset.

Participants in the no stretch group were given the same instructions for the completion of the Self Perception Survey. The no stretch group participants were assessed for maximum and endurance hand and pinch grip as described earlier in this section.

Participant confidentiality was maintained throughout the study. Participant identification numbers were assigned to a list of participant names. Participant names were not used on any other document in this study. All Self Perception Records, Participants Information forms, and Tally sheets only had the participant identification numbers on them. The participant names list was secured in a locked file separate from all participant data sheets. At the end of the study the participant names list was destroyed.

CHAPTER 4

Results

Statement of the Research Problem

The focus of the research was to examine the effects of frequent, short stretch breaks on computer operator hand strength and endurance, and individual perceived productivity and fatigue in their shoulders, arms and hands. Supervisor feedback suggests the stretch group participants were able to maintain continuous work on the headphones while performing the 3 minutes of stretches every 30 minutes. Presented in the following chapter are supplementary findings along with the analysis of data.

Supplementary Findings

A number of key factors changed during the study, including the way the study was designed and conducted. While the original number of participants selected was a total of 36, high attrition due to employees quitting the company reduced the number of participants to 13. Of this, seven individuals were in the no-stretch group and six individuals were in the stretch group. Also, the stretch group was set up to use timers to identify when 30 minutes had passed and when they should begin their stretch routine. During the first week of the study the stretch group work supervisor discarded the timers and told employees every 30 minutes, "It is time to do your stretches". She stated that she felt they would be more consistent, however there was no evidence that the participants were not being consistent to that point. The supervisor noted that the stretch group participants were consistently responsive to her request to break, and performed 3

minutes of a variety of stretches at each break as instructed during first day orientation with the experimenter.

Analysis of Data

Eight, two way ANOVAs with repeated measures were conducted to analyze maximum grip strength, grip endurance, maximum pinch strength, pinch endurance, rating perceived fatigue in the hands, shoulders and arms, and perceived productivity dependent variables.

The first analysis was to study the difference between stretch break and no stretch groups at pre and posttest maximum handgrip strength. The second analysis was to study the difference between stretch break and no stretch groups at pre and posttest handgrip endurance. The third analysis was to study the difference between stretch break and no stretch groups at pre and posttest maximum pinch strength. The fourth analysis was to study the difference between stretch break and no stretch groups at pre and posttest pinch endurance. The fifth analysis was to study the difference between stretch break and no stretch groups at pre and posttest rating of perceived fatigue in the hands. The sixth analysis was to study the difference between stretch break and no stretch groups at pre and posttest rating of perceived fatigue in the arms. The seventh analysis was to study the difference between stretch break and no stretch groups at pre and posttest rating of perceived fatigue in the shoulders. The eighth analysis was to study the difference between stretch break and no stretch groups at pre and posttest rating of perceived productivity level.

Presented below in Table 1 are the descriptive statistics from the analysis of the self-perception record, grip and pinch strength scores, and grip and pinch endurance scores. Only those participants finishing the study were included in the analysis. In both Tables 1 and 2, the descriptive data scores for fatigue and productivity represent ratings, strength scores represent foot pounds registering on the dynamometer and pinch gauge, and scores for endurance represent the number of seconds maximum device compression lasted. In Table 1, the experimental group is represented by an "E" in parenthesis and the control group by a "C" in parenthesis. Raw data are presented in Appendix H.

Table 1

Descriptive Statistics of Participant Scores by Group

<u>Self Perception Record Rating</u>	<u>Pre</u>		<u>Post</u>	
	<u>M</u>	<u>S</u>	<u>M</u>	<u>S</u>
Fatigue Hand (E)	4.83	1.33	6.00	1.55
Fatigue Hand (C)	5.57	1.51	5.29	1.70
Fatigue Arm (E)	6.00	1.55	4.67	1.37
Fatigue Arm (C)	5.29	1.70	4.00	1.96
Fatigue Shoulder (E)	4.83	0.98	4.00	2.10
Fatigue Shoulder (C)	5.38	1.94	4.00	1.96
Productivity (E)	4.17	1.33	4.83	3.25
Productivity (C)	4.38	2.30	4.54	2.93
<u>Strength Scores in Foot Pounds</u>	<u>Pre</u>		<u>Post</u>	
	<u>M</u>	<u>S</u>	<u>M</u>	<u>S</u>
Hand Strength (E)	57.50	10.89	63.67	12.49
Hand Strength (C)	74.71	43.76	74.86	37.07
Pinch Strength (E)	15.17	3.49	17.67	4.63
Pinch Strength (C)	16.71	4.11	18.00	6.45
<u>Endurance Scores in Seconds</u>	<u>Pre</u>		<u>Post</u>	
	<u>M</u>	<u>S</u>	<u>M</u>	<u>S</u>
Hand Endurance (E)	21.17	9.26	33.83	20.74
Hand Endurance (C)	30.00	21.45	34.14	34.42
Pinch Endurance (E)	23.67	6.38	53.83	25.38
Pinch Endurance (C)	14.00	6.40	16.71	14.32

Table 2

Descriptive Statistics Collapsed Over Experimental and Control Groups

<u>Self Perception Record Rating</u>	<u>Pre</u>		<u>Post</u>	
	<u>M</u>	<u>S</u>	<u>M</u>	<u>S</u>
Fatigue Hand	5.23	1.42	3.62	1.85
Fatigue Arm	5.62	1.61	4.00	1.96
Fatigue Shoulder	5.38	1.94	4.00	1.96
Productivity	4.38	2.30	4.54	2.93
<u>Strength Scores in Foot Pounds</u>	<u>Pre</u>		<u>Post</u>	
	<u>M</u>	<u>S</u>	<u>M</u>	<u>S</u>
Hand Strength	66.77	27.17	69.69	28.03
Hand Endurance	25.92	16.93	34.00	24.23
<u>Endurance Scores in Seconds</u>	<u>Pre</u>		<u>Post</u>	
	<u>M</u>	<u>S</u>	<u>M</u>	<u>S</u>
Pinch Strength	16.00	4.55	17.85	5.77
Pinch Endurance	17.69	7.72	33.85	26.44

Table 3

Summary of ANOVA Data for Pinch Endurance Between Groups

	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>
Group	3288.48	1	3288.48	11.87*
Error	3047.17	11	277.012	
PG Endurance Test	1928.02	1	1928.02	15.20*
PG Endurance Test *GP	1369.72	1	1369.72	10.8*
Error	1395.13	11	126.83	

*p < .05

Figure 1. Comparison of change in pinch endurance between no stretch and stretch groups.

The results in Table 3 above suggest the interaction of the stretch group and time of test was statistically significant ($F(1,11) = 11.87, p < .001$). The main effect is graphically represented in Figure 1 above. It was found that the stretch group performed significantly better on the pinch grip endurance measure on the posttest than on the pretest. The control group performance did not significantly differ from pretest to posttest. Additionally, though no statistically significant differences existed on the pretest between stretch and no stretch break groups, the data suggest that stretching led to significantly more pinch grip endurance.

Table 4

Summary of ANOVA Data for Handgrip Endurance

	SS	df	MS	F
Group	135.03	1	135.03	.157
Error	9470.43	11	860.95	
HG Endurance Test	456.44	1	456.44	6.59*
HG Endurance Test *GP	117.37	1	117.37	1.69
Error	762.10	11	69.28	

* $p < .05$

The results depicted in Table 4 indicate when the data are collapsed over the stretch break and no stretch groups, the mean effect for handgrip endurance was found to be statistically significant ($F(1, 11) = 6.59, p < .05$). It was found that the mean measurement of force in pounds for the posttest handgrip endurance ($M = 34.00, S = 25.92$) was significantly greater than the pretest handgrip endurance ($M = 25.92, S = 16.93$).

Table 5

Summary of ANOVA Data for Maximum Pinch Strength

	SS	df	MS	F
Group	5.72	1	5.72	.11
Error	592.13	11	53.83	
Pinch Strength Test	23.15	1	23.15	5.37*
Pinch Strength Test *GP	2.38	1	2.38	.55
Error	47.46	11	4.32	

* $p < .05$

The results depicted in Table 5 indicate when the data are collapsed over the stretch break and no stretch groups, the mean effect for maximum pinch strength was found to be statistically significant ($F(1, 11) = 5.37, p < .05$). It was found that the mean measurement of force in pounds for the posttest pinch strength ($M = 17.85, S = 5.77$) was significantly greater than the pretest pinch strength ($M = 16.00, S = 4.55$).

Table 6

Summary of ANOVA Data for Perceived Hand Fatigue

	SS	df	MS	F
Group	9.16	1	9.16	.00
Error	32.85	11	2.99	
Hand Fatigue Test	15.72	1	15.72	5.93*
Hand Fatigue Test *GP	3.41	1	3.41	1.29
Error	29.13	11	2.65	

* $p < .05$

The results depicted in Table 6 indicate when the data are collapsed over the stretch break and no stretch groups, the mean effect for perceived hand fatigue was found to be statistically significant ($F(1, 11) = 5.93, p < .05$). It was found that the mean rating of fatigue level for the posttest hand fatigue ($M = 3.62, S = 1.85$), was significantly less than the pretest rating of hand fatigue ($M = 5.23, S = 1.42$).

Table 7

Summary of ANOVA Data for Perceived Shoulder Fatigue

	SS	df	MS	F
Group	1.69	1	1.69	.283
Error	65.85	11	5.99	•
Hand Fatigue Test	11.69	1	11.69	5.89*
Hand Fatigue Test *GP	1.69	1	1.69	.85
Error	21.85	11	1.97	

* $p < .05$

The results depicted in Table 7 indicate when the data are collapsed over the stretch break and no stretch groups, the mean effect for perceived shoulder fatigue was found to be statistically significant ($F(1, 11) = 5.89, p < .05$). It was found that the mean rating of fatigue level for the shoulders in the posttest ($M = 4.00, S = 1.96$) was significantly less than the pretest rating of hand fatigue ($M = 5.38, S = 1.94$).

CHAPTER 5

Discussion

The objectives of the study were to assess the effects of stretches on computer operator hand and finger maximum strength and endurance, to assess the effects of stretches on computer operator perceived level of productivity as well as hand, arm and shoulder fatigue, and to explore the use of the hand dynamometer, pinch gauge and self perception survey as effective tools for measuring changes in worker physical capacities.

The results of this study present a number of interesting findings. The pinch endurance test revealed the only statistically significant increase in the participant group performing regular stretching versus the control group performing no stretches during the 8-week study. This is consistent with the hypothesis in the present study that regular, brief periods of stretching would improve computer operator finger pinch endurance.

The use of multiple types of stretches for 10 seconds each during micro breaks may be a key factor in the effectiveness of the present study at increasing finger endurance. In one of the few similar field studies conducted, Henning et al. (1993) used micro breaks of similar length to the present experiment, however only one or two stretches were performed during the break for periods of 30 seconds or more. While Henning's study did not find a statistically significant effect for active micro breaks, increased variability in types of stretches may have been a significant contributing factor in the effect found in the present study. This is supported by the Garfinkel et al. (1998) study, which found a significantly increased grip strength level in participants performing a series of yoga stretches.

It was expected that pinch strength would increase significantly along with endurance, however this was not the case in the present study. One reason may be that the physiological effects of micro break stretching impacts the endurance capacity of muscles and tendons used for pinching much more than the maximum strength capacity. Additional analysis by individuals trained in this field might assist in a better understanding of such factors. Another factor may be that a stronger effect may have occurred with a larger participant sample. Attrition during the study was very high. While the original number of participants in this study was 36 (18 per group), employee turnover at the company used for this study was unusually high during the experimental period and the final total number of participants decreased to 13. This much smaller number of participants negatively impacted the statistical analysis making statistical significance more difficult to obtain between groups.

A number of researchers, including Bohannon (1998), and Nitschke et al. (1999), have identified the Jamar hand dynamometer as an effective hand strength measurement device. However neither hand strength nor endurance, as measured by the handgrip dynamometer, showed a significant increase in the stretch group after 8 weeks as expected. There are a number of possible reasons for this in addition to the reduced sample size. The handgrip dynamometer may not be sensitive or accurate enough as a measuring instrument of exertion to register the effects of micro stretch breaks on strength and endurance. It is also possible that work on the computer keyboard and mouse does not stress the overall musculoskeletal structures of the hand and forearm used for gripping as much as it does the parts of fingers and hand used for pinching. Perhaps a

more in depth study of the distribution of stress in the hand and fingers as a result of extended periods working on the computer would reveal more about these differences.

Perhaps keyboarding at the computer tends to stress the fingers much more than the hands. It may be that the pinch gauge targets endurance capacities in the finger muscles and tendons more effectively than the hand dynamometer. It is also possible that the stretches chosen in this study are more effective at improving finger endurance than hand endurance. These factors could be controlled in future studies in order to identify more specific parameters regarding the use of measuring devices.

Although some researchers appear to have successfully used subjective measure of self-perception of fatigue and productivity, there were no significant effects identified in the pre and posttest stretches when comparing groups. The strongest case against the sensitivity of this tool may be that while the stretches group showed a significant effect for pinch endurance, this was not reflected in the pre and post rating for fatigue or productivity. However, a stronger experimental effect may have resulted in these subjective measures if more participants had remained in the study. In addition, another factor influencing the effectiveness of the present questionnaire may be the wording of the questions. The rating scale used the terms for rating of fatigue level as "very strong" and "very tired", which may have caused confusion for the participants. Also, the wording was oriented toward "fatigue", as oppose to the idea of perceived strength or endurance, which was the focus of the objective measures.

The within participants effect identified when collapsing stretch and no stretch groups for the variables of perception of shoulder and hand fatigue, hand endurance and

pinch strength is curious. It is most likely the result of the impact of a combined number of participants to the ANOVA calculations, along with a potential Hawthorne effect, in that all posttest measurements and ratings collected at the end of the study indicated an increase over pre test data (see Table 1, p. 32).

Additional limitations in the study include the lack of random selection of individuals for assignment to either the stretches or no stretches groups. In order to isolate those doing stretches from those not doing stretches, it was more practical to simply use two work groups separated by natural office barriers. While participants in each group were assumed by the employer to perform the same job, there may be some differences in the participants in each group, social or otherwise, that were not easy to identify.

The hypothesis of this study was that frequent, short stretch breaks by computer operators will significantly increase hand strength and endurance, and perceived productivity, and decrease perceived fatigue in the hands, arms and shoulders by the end of the experimental period. Based on the evidence of this study, the hypothesis is accepted only for the impact of stretches on pinch endurance.

Recommendations for Future Study

The tally sheets used in future studies would be more useful at controlling participant follow through on protocol if they were required to write down their stretch frequency, duration and how many different stretches were done. In addition, an actual measure of productivity could be used to assess whether productivity had significantly improved in

the stretch group. Many companies may have such measures as a part of their internal monitoring of worker performance.

Implications for Ergonomic Practice

The results of this study support the use of two underused tools for addressing work related musculoskeletal injuries in the development of office ergonomic programs. Implementing micro stretch programs could improve worker hand and finger endurance, and in turn increase keyboarding/mousing tolerance for extended periods of computer operation.

The pinch gauge could be used to measure the impact of moderate to heavy keyboarding on office workers in the attempt to predict potential for cumulative trauma injuries. This might involve setting up employee baselines and then periodically monitoring endurance performance for changes. Another use of the pinch gauge might be to assess the effectiveness of hazard intervention programs, office modifications, and stretch break schedules. This use might be particularly helpful with injured workers to confirm that modifications to their work area and schedule were having the desired effect.

Summary

Very few real-world studies are available which investigate the effects of active micro stretch breaks on computer operators. In those studies that have been done, methods to quantify results in the field typically rely on subjective measures in the form of participant perception questionnaires. The present study aimed at achieving strong ecological validity by testing computer operators in an actual work setting. There were three methods of assessment used to measure changes between the stretch break group

and no stretch groups. The first of these was handgrip maximum strength and endurance measurements using the Jamar Hand Dynamometer. The second was the measurement of finger pinch maximum strength and endurance using the B&L pinch gauge. The third was a self-perception survey of fatigue and productivity level modeled after subjective survey tools used effectively by a number of published researchers.

The effect for hand or finger strength, hand endurance, or accurate self-perception may have been biased by the limitations in this study. Future field studies in the area of micro stretch breaks might use a random selection of participants rather than a natural grouping as was done here. Also, participant attrition may have been more easily controlled if more consideration had gone into the type of business selected for the study and employee turnover. In addition, consistency in the wording of the subjective questionnaire, which addressed participant "fatigue", and the "strength" and "endurance" measured by the dynamometer or pinch gauge may strengthen the effect of self-perception methods

Still, given the small number of participants remaining in this study, to detect an experimental effect for pinch endurance, as was the result here, suggests that the beneficial effects of active micro breaks were relatively robust. Therefore, while the subjective measures of experimental effect did not appear particularly sensitive to changes between stretch and no stretch groups, the use of the pinch gauge appears a very effective tool.

The present results suggest that the use of short, frequent micro breaks is a beneficial method of improving finger and hand strength as a protective measure against

cumulative stressors on the hand during moderate to heavy computer work. In addition, this study reveals that the pinch gauge may be a valuable tool for monitoring musculoskeletal injury risk for workers in the office environment and supporting ergonomic programs.

While the present study suggests that regular micro breaks for stretching improve computer worker finger endurance, it is beyond the scope of this study to establish this as a preventive measure for cumulative trauma or repetitive stress injuries. Future studies might consider further investigation of the metric tools used here in order to establish valid and reliable tool for measuring the impact of computer operation. Additional studies might also continue assessing the impact of various work methodologies that improve hand/finger endurance and strength, and monitor the impact of these methods on cumulative or repetitive trauma injuries, or early symptoms of such injuries.

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APPENDIX A
AGREEMENT TO PARTICIPATE IN RESEARCH

BAY AREA CREDIT SERVICE

Agreement to Participate in Research

Responsible investigator: Dan Kelso

Telephone #: (408) 232-2878

You are being asked to participate in a study of computer operators at your company between the dates of _____ and _____.

By participating I understand the following:

1. I will be asked to briefly document certain activities or impressions and perform specific hand strength measurements using a hand dynamometer and pinch gauge.
  2. No discomfort or risk of any kind is anticipated due to participation in this study.
  3. Potential benefits to participation in this study are decreased risk of musculoskeletal injury and improved physical performance.
  4. The results of the study may be published but not information identifying me will be included.
  5. I may address questions to the investigator noted above, or complaints about the research may be presented to Department Chair: Kevin Corker (408) 924-3988. Questions about research, participant' rights, or research-related injury may be presented to Nabil Ibrahim, Ph.D., Associate Vice President for Graduate Studies and Research, at (408) 924-2480
  6. No service to which I am entitled will be lost or jeopardized if I choose not to participate.
  7. My participation is voluntary and I may choose to discontinue my involvement at any time without consequence.
  8. I have received a signed and dated copy of this form.
  9. I understand that to bring forth the best results of this study, a serious effort on my part is needed.
- The signature of a subject on this document indicates agreement to participate in the study.
  - The signature of a researcher on this document indicates agreement to include the above named subject in the research and attestation that the subject has been fully informed of his or her rights.

_____
Signature

_____
Date

_____
Investigator's Signature

_____
Date

2185 The Alameda, San Jose, CA 95126

(408) 248-5570

APPENDIX B
SELF PERCEPTION RECORD

Self Perception Record

Please enter the date and time, then read each question carefully and circle the appropriate numbers below.

Date: _____

Time:

- 1. How would you rate your present fatigue level in your hands?**

0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10
Very Strong   Somewhat   Neutral   Somewhat   Very Tired
Strong   Tired

- 2. How would you rate your present fatigue level in your arms?**

0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10
Very Strong   Somewhat   Neutral   Somewhat   Very Tired
Strong   Tired

- 3. How would you rate your present fatigue level in your shoulders?**

0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10
Feel Strong   Somewhat   Neutral   Somewhat   Feel Tired
Strong   Tired

- 4. How would you rate your productivity level at present?**

0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10
 Very   Somewhat   Average   Somewhat   Very
 Productive   Productivity   Productivity   Unproductive   Unproductive

APPENDIX C
STRETCH BREAKS PERMISSION LETTER

Facsimile transmittal.....

To: DAN KELSO, E.O.R.M.

Fax#: 408 822 8001

Re: permission to use COMPUTER & DESK STRETCHES

Date: 5.11.99

Pages: one, including this cover sheet

FROM: John E. Anderson STRETCHING INC.

P.O.Box 767, 120 Glenway, PalmerLake CO 80133-0767

1-800-333-1307/ 719-481-3928/ fax 719 481-9058/ email office@stretching.com

website <http://www.stretching.com>

I processed your order for one pad of COMPUTER & DESK STRETCHES and it will be shipped tomorrow via Priority US Mail.

* You have our permission to use our COMPUTER & DESK STRETCHES routine in your research as you described it on the phone today. We would appreciate it if you could send us a copy of the research results for our records.

Thank you for your interest in Stretching.

I also included one of our catalogs with the pad we will send tomorrow. In it on page 3 you will see that we have several formats for the stretches for use by computer operators and people who work at a desk. It is available in a color 17"x22" poster, an 8½"x11" laminated card, a book entitled STRETCHING AT YOUR COMPUTER OR DESK, and in a software program. Please let us know if you'd be interested in anything else we offer.

APPENDIX D

STRETCH BREAK INSTRUCTIONS AND DESCRIPTIONS

STRETCH BREAK INSTRUCTIONS

Please stop keyboard and mouse work briefly every 30 minutes and pay attention to your body to see where you feel tired, stiff or sore. For a 3 minute break period, perform those stretches that address the areas you have identified as most tired, stiff or sore spending 10 seconds only per stretch. If time permits, stretch other areas until you reach the end of the 3 minute period. Please stand while stretching (unless the stretch requires sitting) and breathe a little deeper to increase circulation and oxygen while doing stretches.

HAND, ARM & SHOULDER STRETCHES

For a free catalog of Stretching Inc.
publications send to:
P.O. Box 787 • Palmer Lake CO 80133-0787
1-800-333-1307
website: <http://www.stretching.com>
e-mail: office@stretching.com
fax: 719-481-8058

* Note: If you have had any recent surgery, muscle, or joint problem, please consult your personal health care professional before starting a stretching or exercise program.

Use all or part of this routine whenever you feel the need to stretch your hands, arms or upper body.

Stretching should be done slowly without bouncing. Stretch to where you feel a slight, easy stretch. Hold this feeling for 5-15 seconds. As you hold this stretch, the feeling of tension should diminish. If it doesn't, just ease off slightly into a more comfortable stretch. The easy stretch reduces tension and readies the tissues for the developmental stretch.

After holding the easy stretch, move a fraction of an inch farther into the stretch until you feel mild tension again. This is the developmental stretch which should be held for 5-15 seconds. This feeling of stretch tension should also slightly diminish or

※ The dotted areas are those areas of the body where you will most likely feel the stretch.

4 Repeat stretch 1

fig. 1

fig. 2

With your arms straight out in front of you, bend your wrists with fingers pointing upwards (fig. 1). This will stretch the back of your forearms. Hold for 10-12 seconds. Do twice.
Then bend your wrist with your fingers pointing downwards (fig. 2) to stretch the top of your forearms. Hold for 10-12 seconds. Do twice.

5

6

Start with index finger and thumb gently holding individual finger or thumb of opposite hand. Use your index finger and thumb to rotate each finger and thumb 5 times clockwise and counter-clockwise.

1

Interlace your fingers in front of you and rotate your hands and wrists clockwise 10 times. Repeat counter-clockwise 10 times. This will improve flexibility of hands and wrists and provide a slight warm-up.

7

Repeat stretch 1

Next gently pull each finger or thumb straight out and hold for 2-3 seconds.

2

Separate and straighten your fingers until tension of a stretch is felt. Hold for 10 seconds, then relax.

3

Next, bend your fingers at the knuckles and hold for 10 seconds. Relax.

9

Shake your arms and hands at your sides for 10-12 seconds. Keep your jaw relaxed and let your shoulders hang downward as you shake out tension.

APPENDIX E
STRETCH BREAK TALLY SHEET

Stretch Break Tally Sheet

Each day, mark the date, then place an "X" under the date at the appropriate 30 minute break mark as you complete each stretch period. Please keep this sheet nearby your computer for the duration of the study and take breaks on schedule. If you miss a stretch break, leave the space blank.

Date: Date: Date: Date: Date:

30
1
30
2
30
3
30
4
30
5
30
6
30
7
30
8
30
9
30
10
30

APPENDIX F
PARTICIPANT INSTRUCTIONS

Participant Instructions

Thank you for participating in this study of computer operators. The study is scheduled to take 8 weeks to complete. You will be given a “Self Perception Record” form to monitor your physical fatigue level and perceived productivity level. Please complete these short questionnaires at the end of each day during the study as instructed. Your grip strength and endurance will be tested using a standard hand dynamometer, which works something like a bicycle break. Also your pinch strength and endurance will be tested using a pinch gauge. Please do not discuss your participation in the study with anyone until the study period has ended.

APPENDIX G
PARTICIPANT INFORMATION

Participant Information

Time: _____ Date: _____

Participant number: _____ Age: _____

Number of hours on the computer per day: _____

Percentage of work keyboarding: _____ Mousing or other device: _____

Mean handgrip dynamometer scores:

Maximum: (Beginning) _____ (End) _____

Endurance: (Beginning) _____ (End) _____

Mean pinch grip dynamometer scores:

Maximum: (Beginning) _____ (End) _____

Endurance: (Beginning) _____ (End) _____

APPENDIX H
RAW DATA SPREADSHEET

Participant Raw Data

Subid	group	age	hrcamp	hrckeyb	hramouse	hgpremax	hgposmax	hgpreend	hgpoend	pgpremax
1	Control	27	8	90%	10%	72	60	70	85	17
2	Control	25	8	90%	10%	65	68	25	37	12
3	Control	23	8	90%	10%	111	124	15	11	22
4	Control	26	8	90%	10%	51	51	12	13	16
5	Control	23	8	90%	10%	71	66	21	20	16
6	Control	21	8	90%	10%	25	28	18	13	9
7	Control	37	8	90%	10%	128	127	49	60	25
8	Experimental	41	8	90%	10%	51	71	34	72	20
9	Experimental	18	8	90%	10%	65	79	32	36	16
10	Experimental	37	8	90%	10%	70	62	17	17	18
11	Experimental	42	8	90%	10%	50	58	14	16	12
12	Experimental	21	8	90%	10%	43	43	16	25	11
13	Experimental	28	8	90%	10%	66	69	14	37	14

Pgposmax	Pgpreend	Pgposend	prefath	posfath	prefata	posfata	prefats	posfats	preprod	posprod
16	10	22	7	2	6	2	7	2	5	2
15	22	39	5	1	5	1	5	2	10	10
29	10	7	7	5	7	5	7	5	6	5
18	8	11	7	3	7	3	10	7	1	2
15	14	13	5	5	5	6	5	5	2	4
8	10	10	5	5	5	5	5	5	5	5
25	24	15	3	2	2	2	2	2	3	2
25	35	74	5	7	5	7	5	7	5	7
19	18	63	5	5	6	5	6	5	5	5
16	18	50	4	5	5	5	5	5	5	3
16	21	28	7	3	6	5	5	3	2	10
11	25	22	5	1	9	1	5	1	5	1
19	25	86	3	3	5	5	3	3	3	3

APPENDIX I
INSTITUTIONAL REVIEW BOARD
HUMAN SUBJECTS COMMITTEE APPROVAL LETTER

San José State
UNIVERSITY

TO: Dan Kelso
374 Tyrella Ave.
Mountain View, CA 94043

FROM: Nabil Ibrahim, N
AVP, Graduate Studies & Research

DATE: May 11, 2000

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"The Effects of Frequent, Active Microbreaks during Computer Operation"

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The Board's approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Nabil Ibrahim, Ph.D., immediately. Injury includes but is not limited to bodily harm, psychological trauma and release of potentially damaging personal information.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.