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Elizabeth Dowler^a, Bruno Kappes^b, Andrea Fenaughty^b & Gregory Pemberton^a

^a Situs Inc., USA

^b University of Alaska, Anchorage USA

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Elizabeth Dowler

Situs, Inc., USA

Bruno Kappes

University of Alaska, Anchorage, USA

Andrea Fenaughty

University of Alaska, Anchorage, USA

Gregory Pemberton

Situs, Inc., USA

This study focused on developing a new approach to seated work positions as conducted on 67 office workers who use a Visual Display Terminal (VDT) as a major function of their working day. Muscle tension was measured by surface electromyography (sEMG) while participants were asked to adopt 4 selected working postures. Pain was measured before and after ergonomic intervention on the Nordic scale, which was modified for this study. Adjustable workstations were used to place participants in desired positions during the clinical testing sessions and the extended intervention period. Results indicate the effects of this ergonomic intervention may have positive effects on muscle tension and pain, significant enough to encourage employers to implement training and workstation modifications following these guidelines.

Video Display Terminal sEMG working position keyboard position
workstation modifications

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Correspondence and requests for reprints should be sent to Elizabeth Dowler, 1549 E. Tudor Road, Anchorage, Alaska 99507, USA. E-mail: <situsdow@aol.com>.

1. INTRODUCTION

Upper extremity musculoskeletal disorders are proving to be one of the most costly work-related injuries of the 1990s. The U.S. Bureau of Labor Statistics (<http://stats.bls.gov/>) estimates that 64% of all workplace injuries in 1998 resulted from stress of repetitive motion on muscles and tendons. There were 253,275 repeated trauma injuries reported in 1998, which represents 4.2% of all work-related injuries.

Studies conducted in Europe and the USA reveal a high incidence of health complaints, especially visual and musculoskeletal problems, among clerical workers. Static muscle tension has been demonstrated to be a recurring problem among office workers (Kilbom, 1994; Schuldt, 1988; Winkel & Westgaard, 1992). Thirty-three percent of office workers have reported almost constant discomfort in the low back, followed by 27% in the neck and shoulders, and 15% in the right shoulder (Sauter, Schleifer, & Knutson, 1991). Physical factors in the workplace that increase the probability of hand-wrist disorders are high rates of repetitive action (seen in computer operators who type more than 18,000 strokes per hour), awkward, unnatural positions, excessive force, and lack of adequate rest periods (Dainoff, 1982).

The most commonly followed design standard in the USA to date is Standard No. ANSI/HFS 100-1988 (*American National Standard*, 1988). However, the effectiveness of chair, table, and keyboard heights outlined by this Standard is in question (Sauter et al., 1991). The concept of traditional seating does not have a very firm foundation; office chair design primarily has been based on traditional sitting postures that workers apparently do not find comfortable (Verbeek, 1991).

Corlett (1983) defines working posture as the “position adopted because it is appropriate for the task being performed” (p. 11). Factors that exert the main influence on posture in the office environment are individuals’ skeletal structures and the specific biomechanics of human structure in relation to vision, reach, manipulation, and force exertions (Haslegrave, 1994).

Since the 1980s researchers have recommended new Visual Display Terminal (VDT) workstation models, including those with taller chairs sloped forward, promoting neutral back posture (Mandal, 1984), higher writing surfaces (Mandal, 1981), and lower keyboard surfaces sloping away from the operator (Stack, 1987).

The purpose of the study was to explore the muscle tension between neutral working posture (defined in this study), the ANSI Standard (*American National Standard*, 1988), and VDT users’ position as they were found.

Recommendations for workstation modifications, education, and increased productivity are made as a result of this applied research.

2. METHOD

Four positions were selected for this study that were determined to be relevant to real work environments, previous research, and specific keyboard placements. Seated posture was modified through chair adjustments; head and wrist positions were controlled by equipment height and location. Position 1 was the position in which participants were found prior to the study. Position 2 follows the ANSI VDT technical design standard (*American National Standard*, 1988). Positions 3 and 4 were designed for this research and were alike except for keyboard placement. Both positions 3 and 4 place chairs in 8° of forward tilt, monitor directly in front of worker with top of screen equal to eyebrow (but adjusted for specific needs of the worker), and document between keyboard and monitor. Position 3 has keyboard on the desk surface with elbows at 90° of flexion, with a wood palmrest. Position 4 places the keyboard in a tray sloping down and away from the user at 15°.

2.1. Participants

A total of 67 office workers, who averaged a minimum of 2 hrs per day of computer work, were participants of three studies in different locations in Anchorage, Alaska, over a 2-year period. Only participants demonstrating average range for rest and work cycles, as tested on surface electromyography (sEMG), were involved in the research.

2.2. Apparatus

Clinical testing workstations included chairs with seat pan angles that could be adjusted to at least 8° forward. From the horizontal plane, the seat back could be adjusted from 10° forward to 15° backward. Chair height ranged from 40.6 to 61 cm (16 to 24 in.). Backrest adjustments were both vertical and horizontal. Seat pan tension adjustment was a standard feature of the chairs. Armrests with 6.5-cm (2.5-in.) vertical adjustment were standard.

A crank height adjustable table, ranging from 63.5 to 86.4 cm (25 to 34 in.) was supplied with a vertical and horizontal adjustable monitor arm, a document holder with a 15 to 45° adjustment range, a keyboard wrist rest made of wood 8.9 cm (3.5 in.) deep, 48.26 cm (19 in.) wide, 2.54 cm (1 in.) high at a 10° angle, transitioning into the front edge of the keyboard, and a keyboard tray with a wood palmrest 8.9 cm (3.5 in.) deep, 2.54 cm (1 in.) high at a 10° angle, and adjustable in angle from 0 to negative 20°, mounted below the desk with a height range of 54.6 to 75 cm (21.5 to 29.5 in.). See Figure 1.



Figure 1. Clinical testing room.

2.3. Experimental Design

A single independent variable, position, was manipulated to study muscle tension during work performance. For the purpose of this research, position was defined as the “working posture” maintained while typing at a VDT workstation. Four working positions were used across the three environments. The dependent variable was muscle tension during typing. Two experimental designs were embedded within one another: First, muscle tension was measured during clinical testing sessions for all participants when placed randomly in the four positions. Secondly, a pretest and post-test design measured muscle tension during typing, in control and experimental groups after 30 days.

2.4. Procedures

A prescreening involved the following: (a) Participants filled out medical history and recreation information; (b) sEMG data were recorded on upper trapezius muscle groups bilaterally for 5 min when performing a standardized typing test; (c) A diagnostic workstation assessment was performed using a format developed by the principal investigator.

During Clinical Test 1 (pretest) participants were given the Physical Examination Criteria for Various Medical Conditions developed by the National Institute for Occupational Safety and Health (NIOSH). They were escorted into the clinical testing room and seated in the participant's chair where their skin was cleaned with a mixture of one-fourth ether and three-fourths alcohol at the electrode sites. The electrodes were prepared with a bead of electrode cream and were placed parallel to the muscle fibers of the upper trapezius muscle, approximately 2.54 cm (1 in.) from the ridge of the shoulder and posteriorly towards the back, half way the spine and the lateral edge of the shoulder bilaterally. Forearm extensor electrodes were placed at an angle between the lateral epicondyle and medial wrist bone one-third the way down from the lateral epicondyle parallel to the extensor muscle fibers. Relative voluntary control (RVC) of the upper trapezius muscle and the forearm extensors was measured by having participants raise arms at the shoulders to 90° while forming the fingers into a claw position, five times for 5 s, and relaxing both at the beginning and end of each measurement. The middle 5 s of each work peak were used to average the %RVC.

The participants were randomly assigned to one of following positions (heights of the chair and workstation recorded during the prescreening were used to set furniture heights):

- Position 1—position as they were found—with the chair (actual), keyboard, monitor, and document heights and placement in relationship to desk as found at current workstation. No modifications were made.
- Position 2—ANSI position—with the chair seat pan tilted to -2° backward, height between 40.6 and 52.1 cm (16–20.5 in.) to achieve 90° at knees and hips, with feet flat on the floor. An adjustable lumbar support was present. The desk was adjusted to correct height; dependent on chair height to achieve elbows at 90° while typing. The keyboard was placed so elbows were at 90° from the superior frontal plane. The monitor was set with a clearance envelope 0–60° below horizontal plane passing through the eyes. The document was placed on document holder on right or left of monitor, depending on participant's preference (Figure 2).



Figure 2. Position 2.

- Position 3—Situs desktop position—with the chair adjusted to 8° forward seat slope measured at top of seat perpendicular to lift, matching height from floor to top of knee. The desk height was determined by elbow at 90° when sitting in a chair at the corrected height. The keyboard height was set at 90° of elbow flexion with wood palmrest. The monitor height was set to match eyebrow to top of screen; adjusted for bifocals and trifocals. The document was positioned in front of worker in direct line of vision between monitor and keyboard (Figure 3).



Figure 3. Position 3.

- Position 4—Situs keyboard tray position—with the chair seat slope set at 8° forward measured at top of seat perpendicular to lift, matching height

from floor to top of the knee. The desk height was determined by elbow at 90° when sitting at chair at corrected height. The keyboard was set at negative 15° sloping away from participant set at appropriate height so palms rest on palmrest, elbow angle is approximately 115° when the upper arms are nearly vertical. The monitor was set so eyebrow matched the top of screen; adjusted for bifocals and trifocals. The document was placed in front of worker in direct line of vision between monitor and keyboard (Figure 4).



Figure 4. Position 4.

Modifications (following recommendations based on the workstation assessment completed during the prescreening) were installed in each participant's work area selected for the experimental group. The control groups in each study had no modifications done and continued working as usual.

Clinical Test 2 (post-test) was repeated with the same procedures as Clinical Test 1. Participants were asked if there were any unusual occurrences that day that would affect their ability to test, and if they had a choice, would they change back to their previous workstation arrangement or keep the modified workstation.

3. RESULTS

Data analyses were performed to assess the effects of the independent variable, position on muscle tension at four muscle sites during clinical testing before and after ergonomic intervention. (a) Repeated measures of Analyses of Variance (ANOVA) were performed on surface electromyography

data (mean $\mu\text{V/s}$) to determine the differences in four muscle sites during typing tests (presented by study); (b) An A Priori Contrast was performed to determine the differences in muscle tension between positions 1, 2, 3, and 4; (c) Statistical analyses were performed for study 3 on normalized data obtained after determining %RVC. (d) Analyses of Variance (ANOVA) was run to determine the significance of the rest cycles in each of the muscle sites in the four working positions. Results were based on participants used as their own control. Each participant was tested in all positions and compared to herself or himself across time, group, and muscle site.

3.1. Muscle Tension

The results of the ANOVA (Table 1, Figure 5) for muscle activity in the upper trapezius was significantly lower than in the forearm extensors, but there was no significant difference between right or left for the upper trapezius or extensors, $F(3, 61) = 111.77$, $p < .001$). Muscle activity in the upper trapezius and forearm extensor muscle sites was significantly lower in position 4 compared to all other positions, $F(3, 62) = 11.97$, $p < .001$. (Table 2, Figure 6).

TABLE 1. Surface Electromyography (sEMG, in μV), Muscle Sites by Position, Pretest, Combined Group, $N = 67$

Muscle Site	<i>M</i>	<i>SD</i>
Left UTr	7.43	4.39
Right UTr	8.15	5.75
Left Extensor	38.39	14.18
Right Extensor	42.86	14.82

Notes. UTr—upper trapezius.

TABLE 2. Surface Electromyography (sEMG) Placement (in μV), Combined Studies, $N = 67$

Position	<i>M</i>	<i>SD</i>
1	24.75	7.72
2	24.93	7.99
3	24.21	7.47
4	22.93	7.15

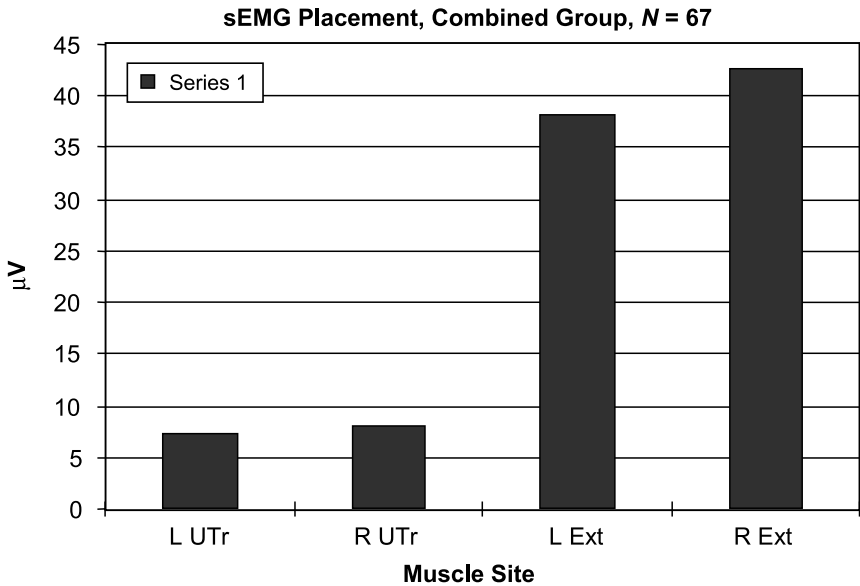


Figure 5. Surface electromyography (sEMG) by muscle groups. Notes. L UTr—left upper trapezius, R UTr—right upper trapezius, L Ext—left extensor, R Ext—right extensor.

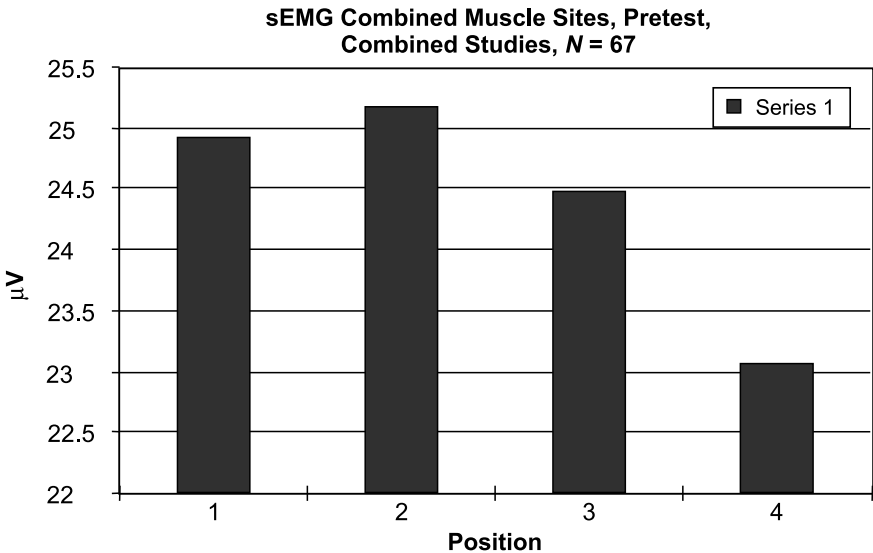
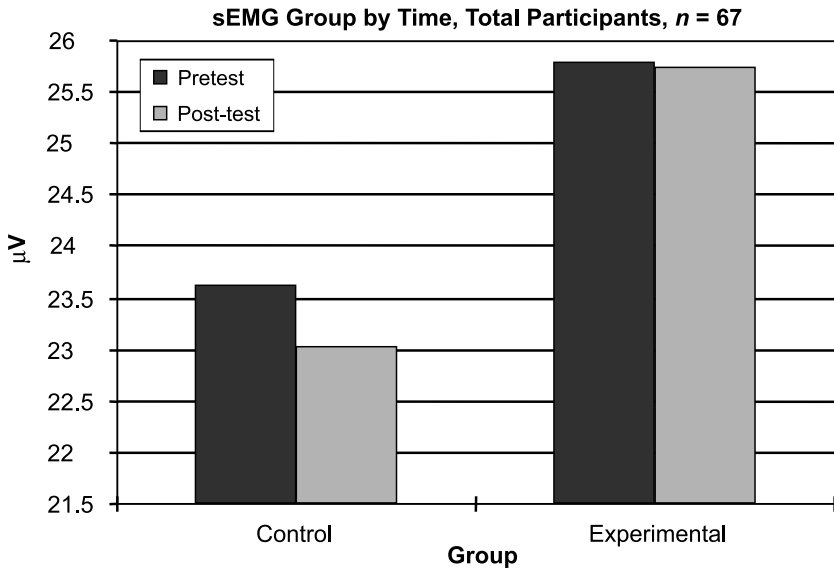


Figure 6. Surface electromyography (sEMG) by position. Notes. L UTr—left upper trapezius, R UTr—right upper trapezius, L Ext—left extensor, R Ext—right extensor.

The ANOVA revealed participants in the experimental group did not demonstrate significantly lower muscle activity than participants in the control group after ergonomic changes had been implemented for 30 days, $F(1, 63) = 0.40, p > .05$. Neither control nor experimental group experienced a change in sEMG scores from pretest to post-test (Table 3, Figure 7).

TABLE 3. Surface Electromyography (sEMG, in μV), Control Versus Experimental Group, $N = 67$

Group	Pretest		Post-Test	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Control, $n = 43$	23.64	17.58	23.03	7.02
Experimental, $n = 24$	25.79	8.14	25.75	8.21

**Figure 7. Muscle tension, all muscles by group at pretest and post-test for combined group.**

3.2. Rest/Work Cycles

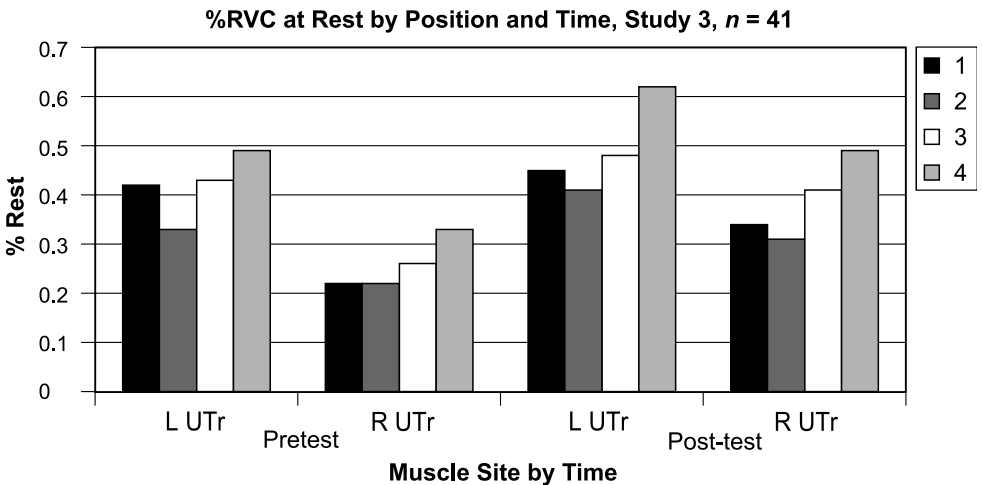
The ANOVA revealed participants demonstrated a higher percentage of rest cycles in all muscle sites during typing task when positioned in position 4 over positions 1, 2, and 3, $F(3, 38) = 4.60$, $p < .01$. Upper trapezius muscles on both sides have significantly more rest cycles than forearm extensor muscles bilaterally (Tables 4, 5; Figures 8, 9). When muscle sites were viewed separately, differences occurred in the upper trapezius muscle group rather than the extensor group. Percent rest was longer in position 4 when compared to each of the following positions: 1, 2, and 3. A Priori Contrast Comparison revealed there was a significant difference between positions 1 and 4, $F(1, 40) = 7.84$, $p < .01$; positions 2 and 4, $F(1, 40) = 14.01$, $p < .01$, and position 3 and 4, $F(1, 40) = 2.92$, $p < .1$.

TABLE 4. Percent Rest for Upper Trapezius (UTr) Muscles at Pretest and Post-Test for Study 3, $n = 41$

Position	Pretest				Post-Test			
	Left UTr		Right UTr		Left UTr		Right UTr	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
1	0.42	0.41	0.22	0.32	0.45	0.40	0.34	0.99
2	0.33	0.39	0.22	0.36	0.41	0.41	0.31	0.38
3	0.43	0.42	0.26	0.36	0.48	0.43	0.41	0.43
4	0.50	0.43	0.33	0.39	0.62	0.39	0.49	0.43

TABLE 5. Percent Rest During Typing Task for Forearm Extensor Muscles at Pretest and Post-Test for Study 3, $n = 41$

Position	Pretest				Post-Test			
	Left Extensor		Right Extensor		Left Extensor		Right Extensor	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
1	0.05	0.13	0.07	0.17	0.01	0.04	0.03	0.11
2	0.05	0.17	0.08	0.19	0.01	0.05	0.02	0.06
3	0.07	0.15	0.09	0.20	0.01	0.05	0.03	0.12
4	0.07	0.15	0.10	0.20	0.02	0.05	0.03	0.10

**Figure 8. Percentage of time at rest for upper trapezius muscles during typing task for each position, pretest and post-test for study 3. Notes. RVC—relative voluntary control, L UTr—left upper trapezius, R UTr—right upper trapezius.**

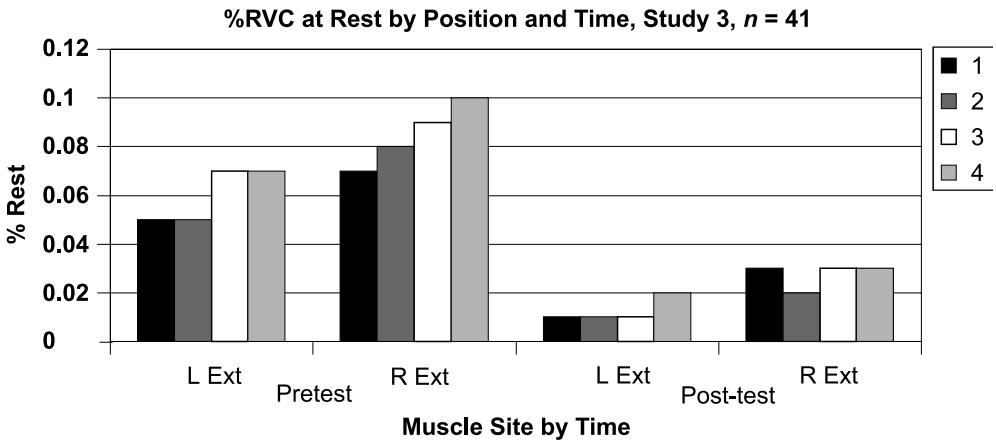


Figure 9. %RVC at rest for forearm extensor muscles during typing task for each position, pretest and post-test for study 3. *Notes.* RVC—relative voluntary control, L Ext—left extensor, R Ext—right extensor.

4. DISCUSSION

4.1. Working Posture and Muscle Tension

The literature review on electromyography reveals a substantial difference occurs in muscle activity between upper trapezius and forearm extensors while typing (Kasman, Cram, & Wolf, 1998). In this study, upper trapezius muscle activity averages ranged between 6.73 and 9.16 μV . Wrist extensor muscle activity averages ranged from 34.87 to 46.66 μV . Wrist extensor muscles work much harder than upper trapezius muscles during work at a VDT because typing is a dynamic action done primarily with the finger tendons that originate at the condyles of the elbow. The upper trapezius acts as a stabilizer for the head and works to support the arms from the shoulder. A comparison of left versus right side showed no reliable differences.

A comparison of muscle activity and working position during VDT work was examined. Muscle activity scores for all four muscle sites were collapsed and compared across positions. Results revealed participants experienced an almost immediate reduction in muscle activity in position 4 over positions 1, 2, and 3 in all studies and as a combined group. (Note: participants were not trained in muscle tension or relaxation techniques.) More importantly, this reduction in muscle activity score was demonstrated in the first clinical test (pretest). Participants' upper trapezius and wrist extensor muscles relaxed almost immediately when their hands were placed on a palm-supported

keyboard tray sloping away from the user, just above the lap. Using the negative-sloping keyboard tray, position 4, resulted in the lowest levels recorded of the mean μV levels, and normalized (RVC) muscle activity. In this position, the palms, resting on a palmrest, are allowed to glide easily over the rest. The wrists are in neutral position, and fingers arched, thus reducing extended reaching. The elbows are in an open angle of approximately 115° , which allows the upper trapezius muscle to rest, and opens the elbow angle to decrease stress on the upper and lower arm.

Results of sEMG evidence during the clinical testing sessions revealed the difference between positions 3 and 4 was the same as the differences between positions 1 and 4, and 2 and 4. This consistent difference suggests using a palmrest on the desktop will not reduce muscle tension in either the upper trapezius nor wrist extensors much more than will the use of no palmrest. Likewise keyboard height was not as important as keyboard angle when considering muscle activity. Muscle activity scores in both muscle groups decreased consistently when a keyboard tray sloping down and away from the participant was implemented. Workers who use a computer most of the day may benefit from acquiring typing skills so they can make use of a rearward-sloping keyboard tray.

In all independent studies, and as a total group, the third-highest sEMG level among the four positions was position 1. This was the participants' working posture when found, the one to which their muscles had adapted. It might have been expected that because of this adaptation the muscle tension would be at its lowest levels. This was clearly not the case.

Participants in position 2 (ANSI position; when the chair seat pan was tilted to -2° backward, height 16–20.5" to achieve 90° at knees and hips, with feet flat on the floor. The keyboard was placed so elbows were at 90° from the superior frontal plane. The monitor was set with a clearance envelope 0 – 60° below horizontal plane and the document was placed on right or left of monitor) recorded the highest muscle activity level in two of the three studies and in the combined group analysis. This position did not provide a palmrest, thus requiring the operators to support their arms from the shoulders when typing. This lack of a palmrest could explain higher upper trapezius activity despite lower keyboard placement.

A post-test session was repeated in the clinical setting after ergonomic intervention of 30 working days. When collapsing all muscle groups the results revealed there were no significant changes in muscle activity between the control group and the intervention group from the pretest to the post-test session in any of the studies. This evidence again may support the

fact that muscle activity decreases by immediate position of the arms and that time is not a significant factor.

Upper trapezius muscle activity was further analyzed during VDT work in the four positions before and after implementation of ergonomic interventions. The upper trapezius muscles consistently worked the hardest in position 2. Position 4 was always the lowest activity level in both pretest and post-test sessions, and there was little difference between sides. This finding supports the importance of workstation ergonomics. The results of placing the body in a posture that requires less muscle activity to support its own weight will have an overall positive lowering effect on muscle activity during work.

Sitting posture also contributes to the workload of the upper trapezius muscles. In both positions 1 and 2, the participants were sitting on flat seats, which promoted forward head posture as described by Bendix (1984), Mandal (1984), and Bridger (1988). In positions 3 and 4, the participants were positioned on forward-tilting seat pans, which places heads in midline over the shoulders. Their elbows were then allowed to rest at their sides, thus reducing upper trapezius muscle activity, although as noted earlier, the position of the forearm in relation to upper arm had a further effect on upper trapezius tension.

Document placement was another factor in the selection of positions used in this study. It affects head and neck position, thus effecting upper trapezius muscle activity. In position 2, documents were placed on a slanted surface to the side of the monitor, as required by the American National Standards Institute (ANSI; 1988). Position 2 requires the worker's head to turn to one side up to 70° while entering data (Grandjean, 1988; Jaschinski-Kruza, 1984; Noro, 1992); this head posture results in increased upper trapezius muscle activity. Positions 3 and 4 placed the document between the keyboard and the monitor at a 45° slant, thus reducing the need for head flexion or rotation.

Wrist extensors' working muscle activity level ranged from 34.87 to 46.66 μV in this research. When the wrists are in extension, the forearm muscles work harder, and when the wrist is in flexion, the forearm flexors work harder. Both positions create an increase in carpal pressure, especially over extended periods of time. Extensor tendinitis is a result of extended finger position and repetitive action with the wrists in extension. Using a negatively sloped keyboard system reduces wrist extension to an average of 1° flexion below the horizontal plane with slight ulnar deviation (Hedge & Powers, 1995). Finger action becomes easier because the fingers form an

arc of 45° of metacarpalphalangeal flexion. This arc matches the natural position of the hand when the wrist is raised vertically from dorsal extension through palmar flexion. Rempel describes this position as neutral hand position, and it is the position where intracarpal pressure is the lowest.

In position 4, the μV levels were lowest in all three studies, and for the total group. sEMG scores for wrist extensors were highest in position 1 over all other positions. The scores on the right side were higher than the left side by only a small margin when looking at the four groups' pretest and post-test scores. Position 2 consistently showed the second highest level of extensor activity bilaterally, with right side higher than left side.

4.2. Rest/Work Cycles

Taylor (1994) reports that microbreaks of work, defined as 1–5 s of work interspersed with 1–5 s of rest will reduce symptoms associated with cumulative trauma disorders.

The rest cycle scores in this study were consistently lower for position 4 in both the pretest and post-test for both the right and left upper trapezius muscle groups. The typist was able to take microbreaks automatically, thus reducing the overall load on the upper trapezius muscles, as predicted by Taylor (1994). When the keyboard was positioned with the participant's elbow at 90° of flexion with a palmrest (position 3), the rest cycle was somewhat lower than position 4, but better than positions 1 and 2. The rest cycles in position 2 were the lowest of the four positions tested. This was expected because in position 2 there was no palmrest. The upper trapezius muscles assist in holding the arms while the fingers do the keying. The lower muscle tension scores seen in surface electromyography may be a result of intermittent rest cycles, and more rest cycles occur when using the tilt away keyboard tray at negative 15°.

5. SUMMARY AND CONCLUSION

Increased worker compensation costs have heightened the need to address ergonomics in the office work environment. Static muscular tension, combined with prolonged shoulder elevation, has been demonstrated to produce significant pain in VDT operators. Static and repetitive postures are repeatedly cited as the major causes of cumulative trauma disorders. Generally VDT

standards do not typically follow neutral body posture or encourage appropriate biomechanical movement patterns. The effectiveness of chair, table, and keyboard heights outlined by the current VDT Standard (*American National Standard*, 1988) has been questioned. The traditional concept of seating does not have a very firm foundation.

A neutral working posture was defined through a review of literature and clinical experience. The lowest levels of muscle tension, while typing, were observed using surface electromyography when participants worked in this posture, rather than the other postures tested. Results revealed participants experienced an almost immediate reduction in muscle activity in the neutral posture (position 4), over the working position as we found them, (position 1), the ANSI standard (position 2), and the neutral sitting position with keyboard on the work surface at 90° elbow flexion (position 3). Results were obtained in all studies and as a combined group without training in muscle tension or relaxation techniques. More importantly, this reduction in muscle activity score was demonstrated in the first clinical test (pretest). Participants' upper trapezius and wrist extensor muscles relaxed almost immediately when seated on adjustable forward tilting chairs. Monitors and documents were placed in midline and at the correct heights with their hands placed on a palm-supported keyboard tray sloping away from the user, just above the lap.

The upper trapezius muscles consistently worked the hardest in posture following the ANSI standard (position 2). There was relatively little change between pretest and post-test scores. The neutral position (position 4) was always the lowest activity level in both pretest and post-test sessions, and there was little difference between sides. The results of placing the body in a posture that requires less muscle activity to support its own weight will have an overall effect on muscle activity during work. This finding supports the importance of workstation ergonomics. Because of the independent replication, these results are strong enough to be generalized in other office environments. Suggestions are made for conducting workstation assessments, implementing modifications, and providing education as specifically described in this research.

Working position appears to have the greatest influence on muscle tension in the office environment. The most important influential positional factor appears to be the keyboard placement. Muscle tension decreased almost immediately when participants were placed in position 4. The negative sloping keyboard tray used in position 4 contributed to the greatest increase in rest cycles. Rest cycles appeared automatically between 33 and 66% of

the time allowing for microbreaks of rest. This break allowed the upper trapezius muscles to recuperate while maintaining the established working posture.

It is recommended that future research of negative sloping keyboard systems include the use of mouse and the differences between various input devices including ergonomic keyboards. Studying a larger range of forearm muscles and their relationship to typing tasks may provide more comprehensive information on rest/work cycles of forearm muscles. Additionally, continuing to study the relationship of posture to reported pain levels and ultimately the reduction of cumulative trauma disorders needs to continue. Longer time periods of ergonomic interventions may demonstrate stronger results.

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