In: Peper, E., Wilson, V.S., Gibney, K.H., Huber, K., Harvey, R. & Shumay. (2003). The Integration of Electromyography (sEMG) at the Workstation: Assessment, Treatment and Prevention of Repetitive Strain Injury (RSI). *Applied Psychophysiology and Biofeedback*, 28 (2),167-182.

This was the last electronic version before the proofs. The final small changes have not been included: See *Applied Psychophysiology and Biofeedback* for the final article.

The Integration of Electromyography (sEMG) at the Workstation: Assessment, Treatment and Prevention of Repetitive Strain Injury (RSI)

Erik Peper
San Francisco State University

Vietta S. Wilson
York University
Toronto, Ontario, Canada

Katherine H. Gibney
San Francisco State University

Kate Huber
San Francisco State University

Richard Harvey
University of California at Irvine

Dianne M. Shumay
University of Hawaii

For communications contact:
Erik Peper, Ph.D.
Institute for Holistic Healing Studies
San Francisco State University
1600 Holloway Avenue
San Francisco, CA 94132
Tel: 415 338 7683
Email: epeper@sfsu.edu

Abstract

This paper reviews the ergonomic and psychosocial factors that affect musculoskeletal disorders at the workstation. First is a model of a physiological assessment protocol that incorporated sEMG monitoring while working at the computer. Next is a study that showed that participants lack awareness of their muscle tension as compared to the actual sEMG levels. The final study illustrated how an intervention program can reduce RSI symptoms, decrease respiration rate, and lower sEMG activity. Recommendations include suggestions that successful safety and prevention programs need multiple components and that participants should to be trained to control physiological responses with respiration and sEMG biofeedback. All participants should to master these physiological skills just as they learn how to use the computer.

Keywords: RSI, sEMG, Respiration, Awareness, Computers, Prevention

The Integration of Electromyography (sEMG) at the Workstation: Assessment, Treatment and Prevention of Repetitive Strain Injury (RSI)

I. Ergonomic factors that affect musculoskeletal disorders at the workstation

II. Model physiological assessment protocol while working at the computer

III. Awareness of tension and sEMG at the workstation

IV. Psychophysiological prevention/intervention programs for repetitive strain injury (RSI)

V. Summary and implications for enhancing productivity and healthy work styles during computer use and suggestions to prevent computer related disorders

INTRODUCTION

Computer use is an activity that predominate work and permeate school and home environments. It is estimated that 90 percent of office workers use computers with 40 percent reporting usage of at least 4 hours per day. Computer usage of 4 hours or more a day greatly increases the risk of musculoskeletal disorders (Hedge, 2002). In addition to using computers in the classroom, which evokes more muscle tension than traditional classroom activities (Ritvanen,, et al, 2002), children use computers to play computer games. Even seniors citizens have taken to email and games.

The integration of computers in the worksite is associated with a concurrent increase in work related injuries. Discomfort and illness from computer use is often labelled as repetitive strain injury (RSI), which is the most common term currently used to describe the symptoms, although other terms are used. The discomfort is either described in process terms or symptom diagnosis. Process terms include computer-related discomfort, cumulative trauma disorders, overuse syndrome, work related musculoskeletal disorders (WRMSD-US), work-related neck and upper limb musculoskeletal disorders (WRULDS-European).Symptom diagnoses include carpal tunnel syndrome, thoracic outlet syndrome, dry eyes syndrome, and backache.

Most of the interventions designed to reduce or prevent discomfort associated with computer use have focused upon problems of ergonomics (e.g. adjusting office and computer equipment to the individual user) or problems of work-style (e.g. lack of task control and responsibility, increased workload, low social support). We argue that lacking awareness of, and training in controlling physiological arousal during computer use significantly contributes to RSI.

Purpose

This paper explores how applied psychophysiology, especially sEMG feedback, offers an approach well suited to explore discomfort at the computer. After a overview of RSI, the paper focuses upon research studies in the following categories: 1) ergonomic factors that affect musculoskeletal disorders at the workstation, 2) model physiological assessment protocol while working at the computer, 3) the importance of awareness and workstation psychophysiology, 4) psychophysiological prevention/intervention programs for RSI, and 5) summary and implications for enhancing productivity and healthy work styles during computer use.

I. ERGONOMIC FACTORS THAT AFFECT MUSCULOSKELETAL DISORDERS AT THE WORKSTATION

The U.S. Bureau of Labor and Statistics reported that musculoskeletal disorders accounted for 26 percent of all workplace injuries at a cost of $45-60 billion in workers compensation and related costs in 2000. In Great Britain, approximately a million people reported musculoskeletal disorders in 1995 (Jones,, et al, 1998). In Italy the number of claims for musculoskeletal disorders has more than doubled from 1996 to 1999, while in France compensated musculoskeletal disorders increased over 20% during the same time period (Helliwell, 1996). Prevalence of reported discomfort ranges by workers at the computer range from 15% to 70% depending upon the type of computer work demands (Fine, 1996; Faucett and Rempel, 1994). The aforementioned data include RSI from all job tasks that including computer users.

Approximately 30% of frequent computer users among hospital employees reported hand paresthesias (Stevens, Witt, Smith & Weaver, 2001) whereas, 96% of 197 college students reported mild to severe discomfort during exam time (Peper & Gibney 1999). Similarly, in a study of 212 younger students (mean age 12.4 years) more than 30% reported wrist pain. Discomfort was predicted by specific computer activities such as using a joystick or playing non-educational games (Burke and Peper, 2002). The problem is so widespread that a European Concerted Action Project has been developed to address muscle disorders in the operation of computer input devices (ref). NIOSH has also conducted a critical review of factors related to workplace disorders (NIOSH, 1997).

A number of critical review papers (Franzblau, 1999; Leonard, 2000; Lincoln,, et al, 2000; Rubenowitz ,1997; Smith,, et al, 1999; Westgaard & Winkel, 1997) have established that the ergonomics of the workspace is related to musculoskeletal disorders. Examples of problems include posture (Dowler, 2001; Middaugh,, et al, 1994) posture of children (Straker, 2002), video display terminals (Delleman & Berndsen, 2002; Lyon,1992), keyboard design and support arm (Hedge & Powers, 1995), force of keystroke (Martin,, et al, 1996), lap vs. desk usage (Moffet,, et al, 2002), work pace (Emurian,1993; Gerard,2001), overuse (Peper,, et al 1994) and mouse drag or point (Keir,, et al, 1999). Overall, ergonomic factors are important for the reduction of RSI but are insufficient to prevent RSI, since many employees with the correct ergonomic arrangement and training still suffer from RSI.

Psychosocial factors have also been implicated in the workstation musculoskeletal disorders (Bongers,, et al, 1993; Lundberg,et al, 2002). Examples include work organization (Carayon,, et al, 1999; Christensen, 2002), personality (Glasscock,, et al, 1999), lack of a mental rest (Lundberg,, et al, 2002), life style (Vogelsang,, et al, 1994), anxiety (Mathis,, et al, 1994; Van Galen,, et al, 2002), memory demands, (Finsen,, et al, 2001), disciplinary notices (Butler, 2002), social support (Lecler,, et al,2001) and time pressure (Birch,, et al, 2000). In almost all cases the above-described factors increased the risk of RSI, especially, if compounded by inappropriate ergonomic arrangements.

Although the underlying etiology of RSI is beyond the scope of this paper, heightened arousal, particularly during musculoskeletal involvement in repetitive tasks, increases the risk of RSI (Aaras & Ro, 1993; Buckles & Devereux, 200; Veiersted,1993). In addition, being under personal and work related stress also exacerbates muscle tension (Faucett & Rempel, 1994; Sauter & Swanson, 1996; VanGalen,, et al, 2002). In addition to increased muscle tension during stress, decreased end-tidal pCO_2 (Schleifer, Ley & Spalding, 2002) and increased respiration rate (Peper, Burke & Peper, 2001) occurred while working at the computer. These last two measures, decreased PCO_2 and increased respiration rate, are indicators of increased arousal and attention and encourage a catabolic physiological state (Nixon, 1997).

A common strategy to investigate the underlying physiological patterns associated during task performance at the computer is a structured assessment. Such an assessment typically is used to identify somatic patterns that may contribute to discomfort or RSI at the computer and consists of a resting or pre-baseline condition, a stress or work condition, and a recovery or post-baseline condition (Schwartz, 1995; Peper and Gibney, 2000). The stress/work conditions usually consist of performing different types of data entry tasks. The following study reports on and illustrates a standardized physiological assessment protocol to identify physiological response patterns during intensive typing and pointing at a laptop computer.

II. MODEL PHYSIOLOGICAL ASSESSMENT PROTOCOL WHILE WORKING AT THE COMPUTER

Method

Participants

Eighteen volunteer participants (8 men and 10 women) were recruited from email announcements. The participants were experienced computer users from a metropolitan area whose ages ranged from 17 to 53 years with a mean age of 31.

Equipment and ergonomic setting

A 15” screen laptop using a stick pointing device was located on a fixed height desk. The participants had ergonomic chairs, document holders, foot supports and were shown how to obtain an ergonomically, comfortable position. The *Point and Type Test*, developed by E. Wherry (2002) was used in this study. In the *Point and Type Test*, a word appears directly above an edit box on the display screen. Users are asked to point and select the edit box and then type the given word. If the user types an incorrect character, the software program will sound an error tone and no character will be written into the edit box. In order to complete the task, the user must type the word exactly as shown on the screen.

The participants' physiological responses were monitored using a Biograph™ ProComp+™ (Thought Technology Ltd., Canada). Surface electromyography (sEMG) was monitored from four muscle locations: left upper trapezius, right upper trapezius, mousing arm anterior deltoid, and mousing arm forearm flexor/extensor muscles. Silver/silver chloride triode electrodes were used to monitor all muscles except the forearm muscles, where single electrodes were used. Respiration rate was monitored using a strain gauge placed in the mid-thoracic area, just above the umbilicus. This methodology has been previously described (Harvey and Peper, 1997; Peper and Gibney, 2000).

Procedure

Participants completed consent forms and questionnaires followed by ergonomic adjustments prior to physiological assessment.

During the demonstration and practice segments on how to use the pointing stick, participants were asked to perform the practice tasks at their own pace and comfort level. The testing protocol alternated between 1-minute rest periods with hands on the lap and 1-minute trials of integrated typing and pointing tasks using either the thumb or forefinger on the keyboard stick. After completing the task, participants completed self-report questionnaires about awareness of muscle tension and about perceived task difficulty.

Results

All participants showed a similar response of significantly increased respiration rate and forearm, deltoid, right trapezius muscle tension while performing intensive data entry. Importantly, they also showed contra-lateral increases in left trapezius muscle tension. Post-trial questionnaires ascertained that the participants were unaware of their increased shoulder tension and faster respiration rate. A representative comparison of physiological measures between rest conditions and point and type sequence is shown in Figure 1.

INSERT FIG 1 HERE

There is a significant difference in right forearm extensor/flexor muscle tension between point and type tasks and rest as shown in Figure 2. (t_{17} =13.79, p <.001).

INSERT Fig 2 HERE

There was a significant difference in anterior deltoid muscle tension between point and type tasks and rest as shown in Figure 3. (t_{17} =4.04, p <.001).

INSERT FIG 3 HERE

There is a significant difference in right upper trapezius muscle tension between point and type tasks and rest as shown in Figure 4. (t_{17} =3.32, p <.01).

INSERT FIG 4 HERE

There was a significant increase in respiration rate from resting to point and type tasks as shown in Figure 5. (t_{17} =8.37, p <.001).

INSERT FIG 5 HERE

Discussion, interpretation and implications of assessment data.

The physiological data confirmed earlier findings by Peper,, et al (1994). The assessment protocols are helpful to infer why participants may develop or experience discomfort during extended periods of computing tasks and include some of the following factors:

1. Continuous forearm muscle activity was evident during pointing and typing. The constant muscle tension may limit blood flow and lymph flow and, thereby, muscle regeneration.
2. Dysponetic contraction of the deltoid, right and left upper trapezius muscles was observed during pointing and typing. Inappropriate ergonomic positioning significantly increases this muscle tension. In addition, increased tension in the neck and shoulder is usually associated with the stress of demanding data entry tasks. The observed deltoid muscle tension is more a function of arm movement and ergonomic position. Usually participants are totally unaware of the deltoid muscle tension level until the discomfort of fatigue occurs.
3. Rapid breathing occurred during pointing and typing. The rapid shallow thoracic breathing may increase the risk of RSI. Namely, increased breathing rate and shallow breathing indicates increased arousal (Nixon, 1997) and usually increases neck and shoulder tension. It also increases the risk of chronic hyperventilation symptoms (Schleifer, et al., 2002). Computer operators are prone to experience

> discomfort from muscle fatigue (both skeletal and breathing muscles) because they are aroused, hold low chronic muscle tension and are immobile for extended periods of time. High arousal and immobility is a physiological state that is in opposition to our evolutionary background, one in which movement and muscle regeneration is more natural.

When asked post hoc and shown the physiological recording, most participants were surprised that they had increased breathing rates and heightened trapezius and deltoid muscle activity during the type and point tasks. Computing tasks often “capture” people. They are often so totally wrapped up in their work that they are unaware of tension patterns until they experience discomfort. In a 6-month survey by Digital Equipment Corporation of work performed by more than 7,000 employees, more than 50% reported losing themselves in computer work for hours and ignored advice to take breaks, (Digital work, 1999). Lehrer, et al (1988) in a related study found moderate correlations between self-report of tension and sEMG readings, which did not increase with training in high effort tense-release trials of progressive relaxation. The extent to which individuals are unaware of their physiological responses while at the keyboard was investigated in the following study.

III. AWARENESS OF TENSION AND sEMG AT THE WORKSTATION

> *"I thought my shoulders were relaxed, I had no idea that they were tight and that I breathed so much more quickly."*
>
> Person seeing her physiological recording during computing tasks

The quote above is a comment representative of the hundreds of participants, students and employees, who have participated in biofeedback monitoring and training while working at the computer (Peper & Gibney, 2000). The extent to which participants are unaware of muscle tension at the workstation is investigated in the following study that explored the correlation between sEMG, self-rating of muscle tension and keyboard location.

Method

Participants

Six men and seventeen women gave consent and volunteered for this study. The participants' mean age was 32.9 years, ranging from 21 to 46 years.

Equipment

Surface electromyographic activity was recorded using a J&J I-330 physiodata system (J&J Engineering, Poulsbo, WA) using the preamplifier module M-501 and collected in 24-second epoch averages (RMS). The participants performed a word-processing task at a standard computer station, with ergonomic features explained and used.

Surface EMG was recorded from the dominant forearm, trapezius and deltoid areas. The forearm sensors were placed to record the integrated extensor and flexor activity.

The keyboard was placed on a tray that could be moved forward or back and locked into position. The movable keyboard tray was marked with five positions at 4.5cm intervals. Position 1 was considered neutral, as it was the place considered ergonomically correct and most comfortable for the participant. In position (5), the keyboard was furthest away from the participant (22.5 cm); with each successive position change (positions 4 to 2), the keyboard was moved closer to the participant.

Procedure

Surface EMG sensors were applied and each participant was seated in front of a computer. The participants were monitored during sequential non-typing (hands on keyboard at home row without typing) and typing tasks. The typing text was identical for all participants and consisted of five 48-second periods. During the first period, the participant's hands rested in his or her lap. For periods two through five, the keyboard was moved into positions 2 through 5 in a random order. During the last 24 seconds of each period, the participant was asked to return his or her hands to the lap, the keyboard was moved into a new position and the participant was asked to move his or her hands into position on the keyboard. In order to avoid any movement artifacts, data were only collected during the last 24 seconds of the period, and participants were asked not to move from the new position. At the end of each period the participant rated his or her muscle tension in the shoulders and forearm on a scale from one to five with one being most relaxed and five being most tense.

Results

Participants rated shoulder tension significantly higher during typing than non-typing (t for rank data $t_{109}=3.05$ $p<.05$). Forearm tension was also rated significantly higher during typing than non-typing ($t_{109}=3.71$ $p<.05$). The actual sEMG for trapezius, deltoid and forearm was significantly higher during typing than non-typing (t test for matched pairs, $t_{109}= 18.23$, $p<.001$, $t_{109}= 7.08$ $p<.001$, $t_{109}= 12.39$, $p<.001$ respectively)

There were a few significant but very low Pearson correlations (r=-.07 to .26) between self-reported tension levels and sEMG recordings at rest. There were significantly higher positive correlations between self-reports of tension and sEMG in the trapezius (r= .26), deltoids (r= .34) and forearms (r= .57) during the actual computer tasks. There were large intra group differences in awareness of muscle tension but most showed little awareness as shown in a single participant's data in Figure 6.

INSERT FIG 6 HERE

Discussion

This study illustrates that as expected, participants did report and experience more tension in the muscles when typing compared to a resting position. Also, participants' subjective ratings did not account for a great deal of variance in the objective sEMG of their shoulders and forearms when their arms were in different positions due to slight changes in keyboard position. Individuals may unknowingly engage unnecessary muscles (dysponesis) when carrying out tasks and will be unable to reduce RSI risks.

This lack of awareness needs to be accounted for in training programs. It may also explain why purely ergonomic adjustments may be insufficient because the person may still continue to work in dysfunctional and hyper-aroused states. Therefore, intervention programs should include awareness training.

IV. PSYCHOPHYSIOLOGICAL PREVENTION/INTERVENTION PROGRAMS FOR REPETITIVE STRAIN INJURY

Corporations and governments have established programs for the prevention of musculoskeletal disorders at the workplace (Hagg, 2002). The majority of programs have focused on the ergonomics related to non-computer jobs with high repetitive strain motions such as assembly lines. Lincoln, et al (2000) reviewed 24 studies that provided interventions for the prevention of carpal tunnel syndrome, but many were assembly line tasks and many others keyboard design tests. In summary, while multiple component programs were beneficial, they concluded that none of the studies conclusively demonstrated that the interventions would prevent carpal tunnel syndrome in the population. Thus, the simple factor of lowering sEMG does not translate into reduction in symptoms, which shows that RSI is a complex phenomenon. These data would support our view that awareness and lower arousal training needs to be incorporated in multi component intervention studies.

In a newer and more extensive study of computer users at the worksite, Faucett, et al (2002) trained participants for six weeks with reinforcement training at 18 and 32 weeks and then compared sEMG and symptom complaints. Group one received sEMG training while a second group received small group training to enhance stress management, problem solving, and communication skills; the third received no intervention, being the control group. They concluded that symptoms increased for the control group, declined modestly for the education group, and found little change for the sEMG group. The sEMG group was consistently effective in reducing muscle tension in the trapezius and only partially effective in the forearms. The authors identify the need for more periodic reinforcement and the combination of the two treatments as potential factors for future studies.

A more comprehensive training program was utilized in a study by Shumay and Peper (1997). They trained 26 experienced computer users who reported mild or moderate RSI symptoms. Seven sessions of training included worksite ergonomics, sEMG biofeedback modulated somatic awareness exercises, diaphragmatic breathing, micro-breaks (drop sEMG to low levels for 1-2 seconds) and macro-breaks (get up and move), cognitive and somatic relaxation, stretching and strengthening, weekly homework assignments and group support for implementing changes. The results following seven weeks of training included (1) reduced trapezius sEMG activity, (2) reduced breathing rate, (3) increased peripheral temperature, and (4) decreased reports of physical strain symptoms during data entry. In a one-year telephone follow-up the participants reported that the program had been very beneficial. They identified awareness and training in muscle tension as most beneficial followed by micro-breaks, ergonomics, relaxation skills and breathing.

Previous work (Fogelman & Brogmus, 1995; Karlqvist,, et al, 1994; Keir,, et al, 1999; Middaugh, Kee & Nicolson, 1994) identified different muscular stresses on participants while using the mouse rather than the keyboard. Most recently, Huber, Peper and Gibney (2002) investigated a multi-component training program emphasizing somatic awareness with sEMG biofeedback for individuals doing mousing tasks at the computer as described in the following study.

Method

Participants

Twenty-two women and five men, mean age of 27.6 years with a range between 21 and 42 years, volunteered and were randomly placed in two groups. The training group had 14 participants and the no training control group had 13.

Equipment and Sensor Placement

Physiological activity was recorded with a Flex Comp™ Biograph™ 2.0 biofeedback system (Thought Technology, Ltd., Canada). sEMG sensors were attached on each participant's mousing arm and shoulder on the following muscle groups: 1) forearm flexor muscle; 2) forearm extensor muscle; 3) anterior deltoid muscle; and, 4) upper trapezius muscle. Respiration was recorded with two strain gauges placed around the upper chest and the abdomen. Peripheral temperature was recorded with a thermistor placed on the forefinger of the participant's non-mousing hand.

Procedure

Participants completed an assessment questionnaire at the beginning of the study. Questions included demographics, lifestyle and work attitudes, computer use and discomfort experienced while working at the computer. Participants were then seated at a computer workstation with a computer keyboard and standard mechanical mouse placed on their mousing side. After sensors were attached and the procedure explained, the participants performed the 1-minute trials of the following sequence: Sitting quietly with hands in lap, hand resting on mouse, tracing task (using the mouse to guide the cursor on the screen to follow the edges of enlarged letter pattern), a correcting task (using the mouse for cutting and pasting words), hand resting on the mouse, and finally, hands resting on lap.

When finished, participants completed a questionnaire of the session experience rating muscle tension (all muscle groups) and symptoms of strain. At this point, the no-training control participants had the sensors removed and were asked to return in three weeks, for the final physiological assessment and subjective questionnaire. The experimental participants continued with the following training protocol.

Training

Experimental participants remained seated with the electrodes and sensors attached during the first session. The initial data were interpreted for the participant. All experimental participants were then trained according to their individual needs. They received 20-30 minutes of guided sEMG feedback training to demonstrate the concepts of mousing with a relaxed shoulder, relaxation during micro-break, and diaphragmatic breathing patterns. They were asked to practice diaphragmatic breathing during the week and to be aware of, and let go of, dysponesis while working at the computer.

Participants returned the following week for continued individual training using sEMG biofeedback, with an emphasis on micro-breaks. At the end of the training session they were given a log on which to record the frequency of their home practice of diaphragmatic breathing, micro-breaks, and awareness and letting go of dysponesis.

Participants returned at the end of the third week for the final physiological assessment and subjective questionnaire.

Results

During the pre-study initial assessment, all participants showed similar physiological patterns. For example, respiration rates for all participants were generally irregular, rapid and thoracic. Regarding muscle tension in several muscle groups, abduction of the mousing arm was the norm; increased sEMG of the upper trapezius muscle was prevalent; prolonged uninterrupted sEMG activity of the mousing forearm flexor/extensor muscle groups was the dominant pattern. Average hand temperature was 89^0 F.

After training, the experimental group showed a significant improvement in subjective rating of symptoms (see Figure 7). They also breathed significantly slower and diaphragmatically as shown in Figure 8. They also had reduced upper trapezius sEMG activity as shown in Figure 9. No significant differences were found in deltoid muscle or hand temperature.

INSERT FIG 7, 8 AND 9 HERE

Discussion

In summary, this intervention study once again demonstrated that across a short time period, the participants could learn to lower trapezius sEMG activity and respiration rate and reduce symptoms of RSI. The most important factors that facilitated the learning were:

1. Visual feedback of the muscle and respiratory patterns
2. Learning to relax neck and shoulders
3. Practicing lower breathing during computer work
4. Incorporating micro-break and larger movement breaks
5. Ergonomic and work-style changes

V. SUMMARY AND IMPLICATIONS FOR ENHANCING PRODUCTIVITY AND HEALTHY WORK STYLES DURING COMPUTER USE AND SUGGESTIONS TO PREVENT COMPUTER RELATED DISORDERS

Computer operators are prone to experience discomfort from muscle fatigue (both skeletal and breathing muscles) because they are aroused, hold low chronic muscle tension and are immobile for extended periods of time. High arousal and immobility create a physiological state that is in opposition to our evolutionary background—episodic alternations between movement/activity and rest/regeneration.

The computer assessment using sEMG and physiological responses demonstrated the common tendency to elevate the shoulders and increase respiration rate when the person is captured by the computer. Often the individuals continued to work without allowing momentary episodic rest periods. In almost all cases, the participants failed to take micro-breaks that would allow the sEMG levels to return to resting levels. This information is important for the investigator, but it is critical for participants to observe their own responses. With the information of their physiological response patterns, participants appear to better understand the RSI processes, become motivated to work on changes, and have a shift in their belief structure about their ability to change and control their mind/body responses.

From our work on awareness we observed that individuals have little to no awareness of their muscle tension when computing, especially while at 'rest'. This implies that training for awareness, perhaps specific to each computer task such as mouse, keyboard, etc., needs to be practiced at the job site. Training needs to focus on awareness and practicing intervention strategies (breaks, movement) while actually at work.

The lack of awareness might explain why ergonomic changes alone have not always prevented or reduced RSI. In particular, the use of sEMG as a muscle awareness tool is paramount. Additionally, it is our experience that breathing is a critical component for self-regulation at the computer and in life in general. Learning slower, diaphragmatic breathing to reduce arousal, and as a tool to "check in," is one of the most helpful skills to teach. As the person checks in and shifts to slower diaphragmatic breathing, they are implementing a micro-break.

From our clinical experience we also recommend that periodic 'boosters' be provided by others as individuals tend to lapse at correctly performing tasks across time. This needs to be incorporated into the actual work/home site. In summary, individuals who use computers should become aware of and utilize correct ergonomic principles. Additionally, they need to understand that psychosocial events, such as stress, time pressure, feelings of failure or anxiety, influence how they position their body and use the computer and this effect is typically detrimental to their health. They should learn how to regenerate--not merely take time away from the computer. The skills include stress management, stretching and strengthening, logbooks, mental quieting, etc., and thereby form the basis of the successful multi-component programs. In addition, we would consider a basic program to include assessment for motivation and changing beliefs, sEMG and breathing for awareness and control of psychophysiological responses, micro-breaks for regeneration, and group support for compliance.

Currently corporations, education institutions and private individuals spend billions of dollars on hardware, software and how to operate both. Yet, little or nothing is spent on ‘bodyware,’ which is the skill necessary to use oneself correctly and efficiently at the computer while maintaining health. While longitudinal research on the cost and effectiveness of sEMG based multi-component programs is important, we believe that the existing current information on how to lessen RSI from a psychophysiological perspective needs to be provided to every person when they first begin using a computer or game box, be that at school, home or the worksite.

References

Aras, A., & Ro,O. (1997). Workload when using a mouse as an input device. *International J Human-Computer Interaction.* 9, 105-118.

Banks,S.L.,Jacobs,D., Gevirtz,R., & Hubbard, D. (1998). Effects of autogenic relaxation training on electromyographic activity in active myofascial trigger points. *J of Musculoskeletal Pain*, 4, 23-32.

Barther, H., Miller,L., Deardorff, W. & Poertenier, R. (1998). Presentation and response of patients with upper extremity repetitive use syndrome to a multidisciplinary rehabilitation program: a retrospective review of 24 cases. *J Hand Therapy*,. 11, 191-199.

Birch,L., Juul-Kristensen, B., Jensen,C., Finsen, L. & Christensen, H. (2000). Acute response to precision, time pressure and mental demand during simulated computer work. *Scandianavian J of Work, Environment & Health*, 26,299-305.

Bongers P., deWinter, C., Kompier, M. & Hildebrant, V. (1993). Psychosocial factors at work and Musculoskeletal disease. *Scandinavian J Work & Environmental Health*, 19, 297-312.

Buckles, P.W. & Devereux,J.J. (2002), The nature of work-related neck and upper limb Musculoskeletal disorders. *Applied Ergonomics*, 33, 207-217.

Burke, A. & Peper, E. (2002). Cumulative trauma disorder risk for children using computer products: Results of a pilot investigation with a student convenience sample. *Public Health Reports*,117, 1-13.

Butler,R.J. (2002). Job performance failure and occupational carpal tunnel claims. *J of Occupational Rehabilitation*, 12,1-12.

Bystrom, J., Hansson,G., Rylander,L. Ohlsson,K., Kallrot, G. & Skerfving,S. (2002). Physical workload on neck and upper limb using two CAD applications. *Applied Ergonomics*, 22,63-74.

Carayon,P., Smith, M. & Haims, M. (1999), Work organization, job stress and work-related musculoskeletal disorders. *Human Factors*, 41,644-663.

Christensen, H. & Lundberg,U. (2002). Musculoskeletal problems as a result of work organization, work tasks, and stress during computer work. *Work and Stress*, 16, 89-93

Delleman, N., & Berndsen, M. (2002). Touch typing VDU operation: workstation adjustment, working posture and workers' perceptions. *Ergonomics*, 45,514-35.
Digital Work http://www. digitalwork.com 1/13/99
Dowler, E., Kappes, B., Fenaughty, A. & Pemberton, G. (2001), Effects of neutral posture on muscle tension during computer use. *International J. Occupational & Safety Ergonomics*, 7,61-78.
Emurian, H. (1993). Cardiovascular and electromyograph effects of low and high density work on an interactive information system. *Computers in Human Behaviour*, 9,353-370.
Faucett,J., Garry,M., Dadler, D. & Ettare, D. (2002). A test of two training interventions to prevent work-related musculoskeletal disorders of the upper extremity. *Applied Ergonomics*, 33,337-347.
Faucett,J. & Remplel,D. (1994). VDT-related musculoskeletal symptoms: Interactions between work posture and psychosocial work factors. *American J of Industrial Medicine*. 26,597-612.
Feurerstein, M. (1996). Workstyle: definition, empirical support and implication for prevention, evaluation and rehabilitation of occupational upper extremity disorders. In S. D. Moon and S.L. *Sauter Beyond Biomechanics: Psychosocial Aspects of Musculoskeletal Disorders in Office Work*, Taylor & Francis, London.
Feurerstein,M., Armstrong, T., Hickey, P. & Lincoln, A. (1997), Computer keyboard force and upper extremity symptoms. *J Occupational and Environmental Medicine*, 39, 1144-1153.
Fine, L. J. (1996). Musculoskeletal disorders in office work. In: Moon, S. D. and Sauter, S. L. (Eds). Beyond Biomechanics. London: Taylor & Francis, 295-305.
Finsen, L., Sogaared,K. & Christensen, H. (2001). Influence of memory demand and contra lateral activity on muscle activity. *J Electroyography and Kinesiology*, 11,373-80.
Fogleman, M. & Brogmus, G. (995). Computer mouse use and cumulative trauma disorders of the upper extremities. *Ergonomics*, 38, 2465-2475.
Franzblau, A. (1999). The epidemiology of workplace factors and musculoskeletal disorders: assessment of the NIOSH review. Work-related musculoskeletal disorders: Report, Workshop Summary and Workshop Papers. National Research Council. Washington .D.C.c. pp 155-158.
Fridlund, A., Hatfield, M., Cottam,G. & Fowler, S. (1986). Anxiety and striate-muscle activation: Evidence from electromyographic pattern analysis. *J of Abnormal Psychology*, 95,228-236.
Gerard, M., Armstrong,T., Franzblau, A., Martin,B. & Rempel, D. (1999). The effects of keyboard stiffness on typing force, finger electromyography and subjective discomfort. *American Industrial Hygenic Association J*, 60, 762-769.
Glasscock, N., Turville, K., Jones, S. & Mirka, G. (1999). The effect of personality type on muscle coactivation during elbow flexion. *Human Factors*, 41,51-60.
Hagg,G. (2003). Corporate initiatives in ergonomics-an introduction *Applied Ergonomics*, 34, 3-15.
Harvey; R. & Peper, E. (1997). Surface electromyography and mouse position use. *Ergonomics*,40 (8), 781-789.

Hedge, A. (2003) as cited in C. Allbritton Ergonomics with flair: *Popular Mechanics*, 108, 28-29.
Hedge, A. & Powers, J. (1995). Wrist postures while keyboarding: effects of a negative slope, keyboard system and full option forearm supports. *Ergonomics*, 38,508-517.
Helliwell, P. (1996). Diagnositic criteria for work-related upper limb disorders. Britisch J Rheumatology. 35,1195-1196.
Huber, M., Peper, E. & Gibney, K. H. (2002). Reducing computer mousing symptoms: A controlled biofeedback outcome study. *Proceedings of the 33rd Annual Meeting of the Association for Applied Psychophysiology and Biofeedback.* Wheat Ridge, CO: AAPB, 19-22.
Galinsky, T.L., Swanson, N.G., Sauter, S.L., Hurrell, J.J., Schleifer, L.M. (2000). A field study of supplementary rest breaks for data-entry operators. Ergonomics. 43(5), 622-38.
Jones, J., Hodgson, T., & Elliott,R. (1998).Self-Reported Work Related Illness in 1995: Results from a Household Survery, Sheffield: HSE Books
Karlqvist, L.,Hagberg,M. & Selin,K. (1994). Variation in upper limb posture and movement during word processing with and without mouse use. *Ergonomics*, 37,1261-1267.
Keir, P., Bach, J. & Rempel, D. (1999). Effects of computer mouse design and task on carpal tunnel pressure. *Ergonomics*, 42,1350-1360.
Koga, S. (1991). Awareness and electromyograph biofeedback in the acquisition of control of a novel muscular activity. *Shinrigaku, Kenyu*, 62, 308-315.
Lecler, A., Landre, M.,Chatang, J., Niedhammer, I., & Roquelaure, Y. (2001). Upper-limb disorders in repetitive work. *Scandinavian J of Work, Environment & Health*, 28,268-278.
Lehrer, P., Batey, D., Woolfold, R., & Remde, A. (1988). The effect of repeated tense-release sequences on EMG and self-report of muscle tension: An evaluation of Jacobsonian and post-Jacobsonian assumptions about progressive relaxaton. *Psychohysiology*, 25, 562-569.
Leonard, D. (2000). The effectiveness of intervention strategies used to educate clients about prevention of upper extremity cumulative trauma disorders. *Work*, 14, 151-57.
Lincoln, A. Vernick, J.,Ogaitis,S.,Smith,G., Mitchell,C. & Agnew,J. (2000). Interventions for the primary prevention of work-related carpal tunnel syndrome. *American J of Preventive Medicine*, 18,37-50.
Lundberg, U., Forsman, M., Zachau,G., Ekloef,M., Pamerud,G., Melin,B. & Kadefors, R. (2002). Effects of experimentally induced mental and physical stress on motor unit recruitment in the trapezius muscle. *Work & Stress*, 16,166-178.
Lundberg,U. & Johansson,G. (2000). Stress and health risks in repetitive work and supervisory monitoring work. R. Backs & W. Coucsein(Eds) Engineering Psychophysiology,339-359.Hillsdale,N.J.: Lawrence Erlbaum.
Martin, B., Armstrong, T., Foulke, J.,Natarajan, S., Klineneberg, E., Serina, E. & Rempel, D. (1996). Keyboard reacton force and finger flexor electromyograms during computer keyoard work. *Human Factors*, 38, 64-664.

Mathis, L.,Gatchel,R., Polatin,P., & Boulas,H.l (1994) Prevalence of psychopathology in carpal tunnel syndrome. *J of Occupational Rehabilitation*, 4, 199-210.

McCann, K & Sulzer-Azaroff, B. (1996). Cumulative trauma disorders: behavioral injury prevention at work. *J of Applied Behavioral Science*, 32, 277-291.

Middaugh, S.J., Kee, W.G. & Nicholson, J.A. (1994). Muscle overuse and posture as factors in the development and maintenance of chronic musculoskeletal pain. In R.C. Grezesiak & D.S. Ciccone (Eds.), Psychological Vulnerability to Chronic Pain. New York: Springer Publishing Co

Moffet,H, Hagberg,M,Hansson-Risberg,E & Karlqvist,L. (2002). Influence of laptop computer design and working position on physical exposure variable. *Clinical Biomechanics*, 17,368-76.

Nixon,P. & King,J. (1997). Ischemic heart disease: Homeostasis and the heart. In A.Watkins (Ed). Mind-Body Medicine. New York: Livingstone.

Peper, E., Burke, A. & Peper, E. J. (2001). Captured by the Computer: A Psychophysiological Profile of Boys Playing Computer Games. *Proceedings of the Thirty Second Annual Meeting of the Association for Applied Psychophysiology and Biofeedback*. Wheat Ridge, CO: AAPB. Also in: *Applied Psychophysiology and Biofeedback.* 26(3), 241.

Peper, E., & Gibney, K, H. (1999). Computer related symptoms: A major problem for college students. *Proceedings of the Thirtieth Meeting of the Association for Applied Psychophysiology and Biofeedback*. Wheat Ridge, CO: AAPB, 119-122.

Peper, E. and Gibney, K.H. (2000). *Healthy Computing with Muscle Biofeedback: A Practical Manual for Preventing Repetitive Motion Injury*. Woerden: Biofeedback Foundation of Europe. Available in the USA from: Work Solutions USA, 2236 Derby Street, Berkeley, CA 94705

Peper, E., Tibbetts, V. & Shumay, D. (1995). Listen to your body: Psychophysiological assessment, biofeedback training, and stress management to prevent and reduce computer user injury. Proceedings of the Fifth International Conference on Stress Management. The Netherlands.

Peper, E., Wilson, V.S., Taylor, W., Pierce, A., Bender, K., & Tibbetts, V. (1994). Repetitive strain injury. Electromyography: Applications in Physical Therapy. Physical Therapy Products, 5(5), 17-22.

Ritvanen,T.,Koskelo,R & Haenninen, O. (2002). Myoelectric activity differences in three learning sessions. *J of Pyschophysiology,* 16, 92-96.

Rubenowitz,S. (1997). Suvery and intervention of ergonomic problems at the workplace. *International J. Industrial Erogonomics*. 19,271-275.

Sauter, S., Hales, T., Bernard, B., Fine, L., Petersen, M., Putz-Anderson, V., Schleifer, L., & Ochs, T. (1993). Summary of two NIOSH field studies of musculoskeletal disorders and VDT work among telecommunications and newspaper workers. In: Luczak, H., Cakir, A. And Cakir, G. (Eds.). Work with Display Units. Elsevier Science Publishers, B.V. pp. 229-234.

Schleifer, L.M., Ley, R. & Spalding, T.W. (2002). A hyperventilation theory of job stress and musculoskeletal disorders. *American J Industrial Medicine,* May;41(5):420-32.

Segreto, J. (1995). The role of EMG awareness in EMG biofeedback learning. *Biofeedback & Self Regulation*, 20,155-67.

Schwartz, M. S. (1995). *Biofeedback A Practitioner's Guide 2nd Ed*. New York: Guilford Press, pp.144-175.

Scholz,O., Ott, R., & Sarnoch,H. (2001). Proprioception in somatoform disorders. *Behavioral Research Therapy*, 39, 1429-38.

Shumay, D.M. & Peper, E. (1995). Subjective awareness of muscle tension at the keyboard. Proceedings of the Twenty Sixth Annual Meeting of the Association for Applied Psychophysiology and Biofeedback. Wheat Ridge, CO: AAPB.

Shumay, D. and Peper, E. (1997). Healthy Computing: A comprehensive group training approach using biofeedback. In: Salvendy, G., Smith, M. J. and Koubek, R.J. (eds). *Design of Computing Systems: Cognitive Considerations*. New York: Elsevier, 555-558.

Sjogaard,G., Lundberg,U. & Kadefors, R. (2000) The role of muscle activity and mental load in the development of pain and degenerative processes at the muscle cell level during computer work. *European J Applied Physiology*, 83, 99-105.

Smith, J., Karsh, B. & Moro,B. (1999). A review of research on intervetnions to control musculokeletal disorders. Work-related musculoskeletal doroders: Report, Workshop Summary and Workshop Papers. National Research Council. Washington .D.C.c. pp 200-229.

Stevens, J.C., Witt, J.C., Smith, B.E. & Weaver, A.L. (2001). *Neurology*. 56 (11), 1568-1570.

Straker, L., Briggs, A. & Grieg, A. (2002). The effect of individually adjusted workstations on upper quadrant posture and muscle activity in school children. *Work*, 18, 239-48.

Thought Technology Ltd. 2180 Belgrave Ave, Montreal, Quebec, H4Q 2L8, Canada; email: mail@thoughttechnology.com

Thomas, R., Vaidya, S., Herrick, R. & Congleton, J. (1993), The effects of biofeedback on carpal tunnel syndrome. *Ergonomics*, 36,353-61.

Van Galen, G., Muller, M., Meulenbroe, R . & Van Gemmert, A. (2002). Forearm EMG response activity during motor performance in individuals prone to increased stress reactivity. *American J Industrial Medicine*, 41, 406-19.

Veiersted, K. (1993). Sustained muscle tension as a risk factor for trapezius myalgia. In R. Nielsen and K. Jorgenson (Eds) Advances in Industrial Ergonomics and Safety, London: Taylor and Francis

Vogelsan, L., Williams, R. & Lawler, K. (1994). Lifestyle correlates of carpal tunnel syndrome. *J of Occupational Rehabilitation*, 4, 141-152.

Wherry, E. Human Factors Research, Synaptics, Inc., 2181 Bering Drive, San Jose, CA 95131, personal communication, August, 2002.

Westgaard, R., & Winkel, J. Ergonomic intervention research for improved musculoskeletal health: a critical review. *International J Industrial Ergonomics*, 20,463-500.

Wexler, B., Warrenbug,S., Schwartz, G., & Janer, L. (1992). EEG and EMG response to emotion-evoking stimuli processed without conscious awareness. *Neuropsychologia*, 30, 1065-79.

Legends

Fig. 1. A representative physiological recording of rest and work (typing and pointing) at the computer. During the work, his forearm, deltoid, right and left trapezius muscles tension significantly increased and stayed tense while his breathing rate increased from 13.3 breaths per minute to 20.0 breaths per minute from rest to the work periods.

Fig. 2.Average sEMG forearm muscle tension for point and type and hands on lap rest conditions.

Figure 3. Average sEMG anterior deltoid activity for point and type and hands on lap rest conditio

Fig 4. Average sEMG right upper trapezius activity for point and type and hands on lap rest conditions

Fig. 5. Average respiration rate for all point and type and hands on lap rest conditions.

Fig 6. Average EMG levels for deltoid in different keyboard positions with subjective ratings for one subject

Fig. 7. Comparison of the symptom changes between the trained and control groups during the mousing study. Note the symptoms decreased for the trained group.

Fig. 8. Comparison of the respiration rate between the trained and control groups during the mousing study. Note the respiration decreased for the trained group

Fig. 9. Comparison of sEMG changes between the trained and control groups during the mousing study Note the sEMG decreased for the trained group.

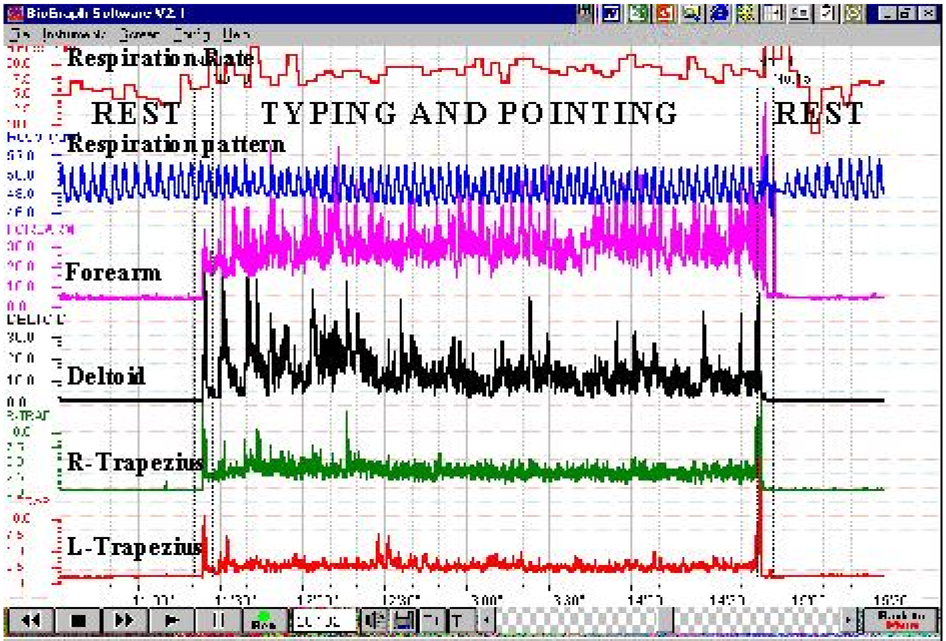
Respiration Rate
REST
TYPING AND POINTING
REST
Respiration pattern
Forearm
Deltoid
R-Trapezius
L-Trapezius

Figure 1

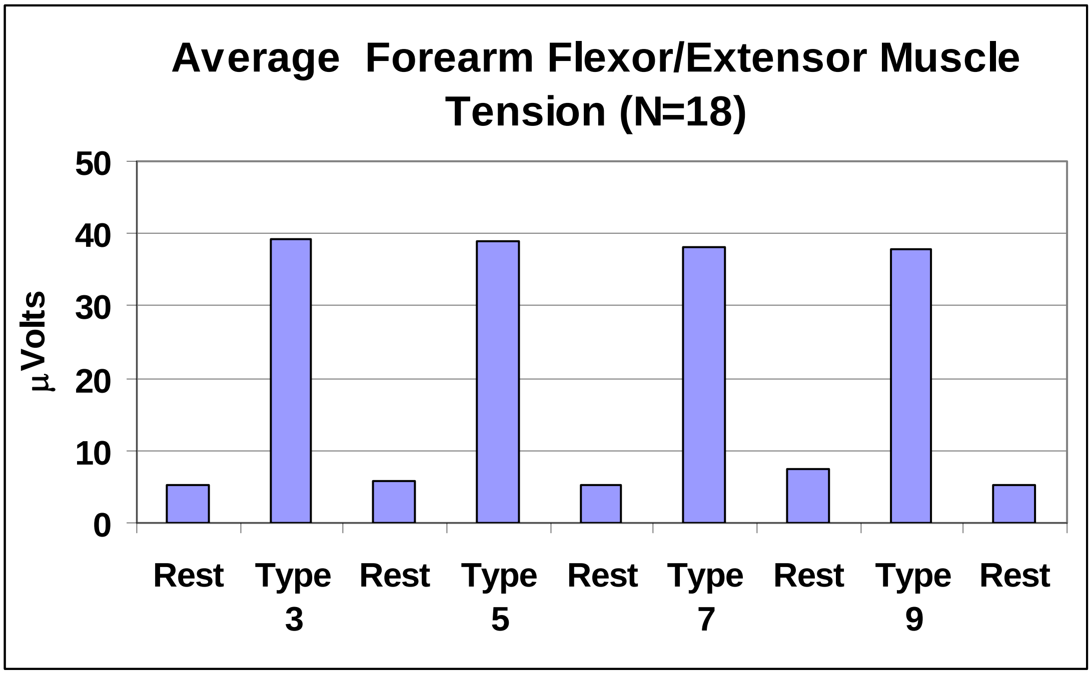
Average Forearm Flexor/Extensor Muscle Tension (N=18)
µVolts
50
40
30
20
10
0
Rest
Type 3
Rest
Type 5
Rest
Type 7
Rest
Type 9
Rest

Figure 2

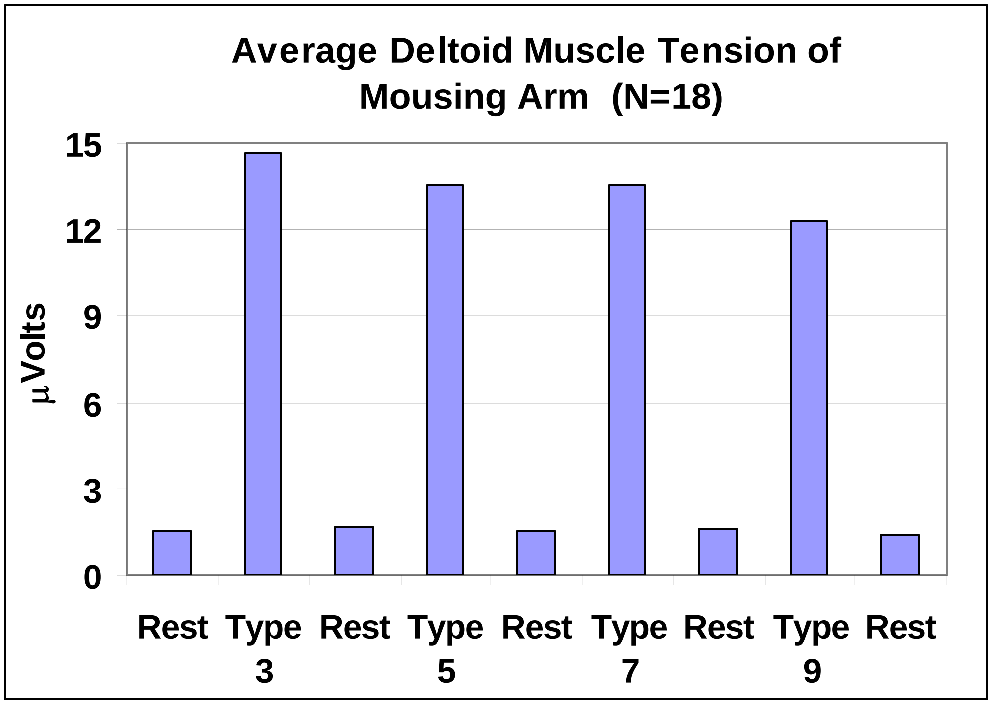
Average Deltoid Muscle Tension of Mousing Arm (N=18)
µVolts
15
12
9
6
3
0
Rest
Type 3
Rest
Type 5
Rest
Type 7
Rest
Type 9
Rest

Figure 3

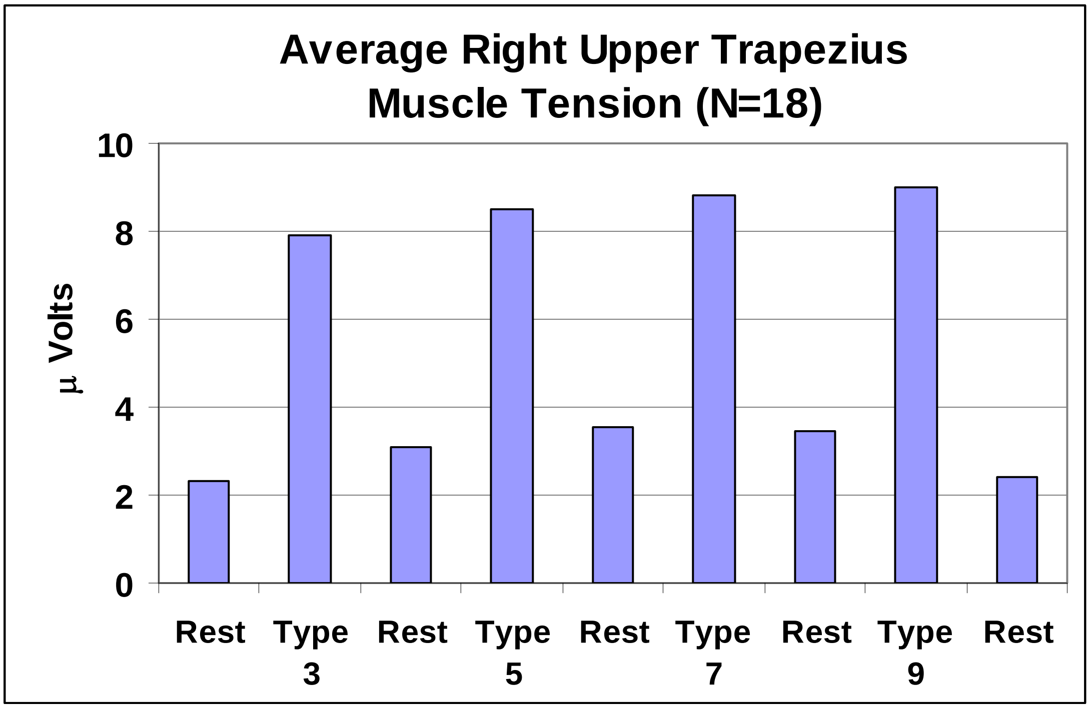
Average Right Upper Trapezius
Muscle Tension (N=18)
µ Volts
10
8
6
4
2
0
Rest
Type 3
Rest
Type 5
Rest
Type 7
Rest
Type 9
Rest

Figure 4

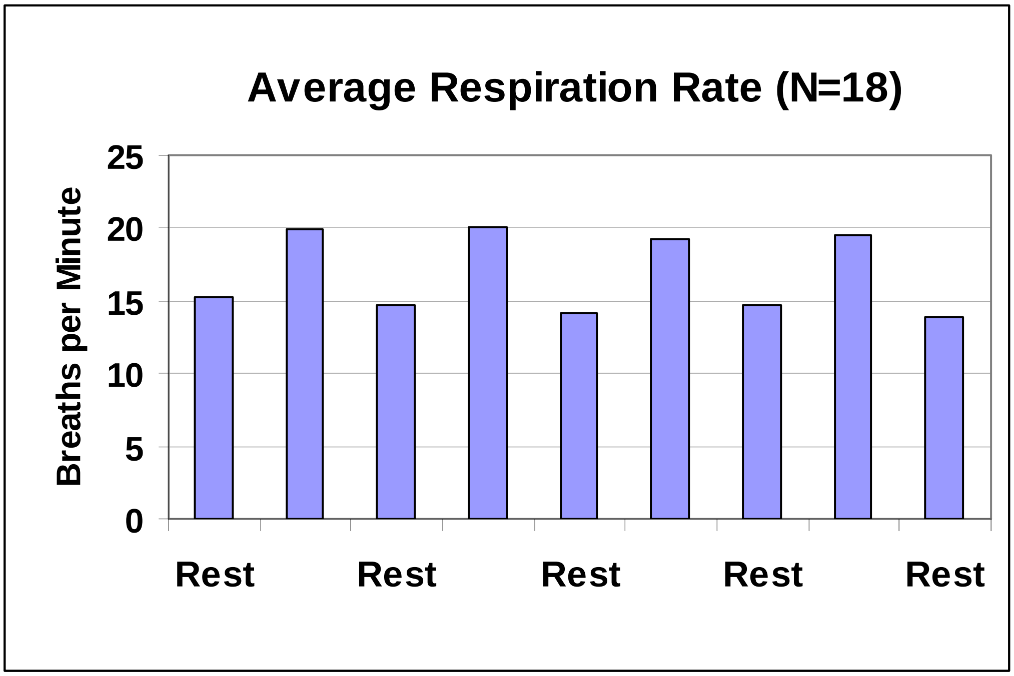
Average Respiration Rate (N=18)
Breaths per Minute
25
20
15
10
5
0
Rest
Rest
Rest
Rest
Rest

Figure 5

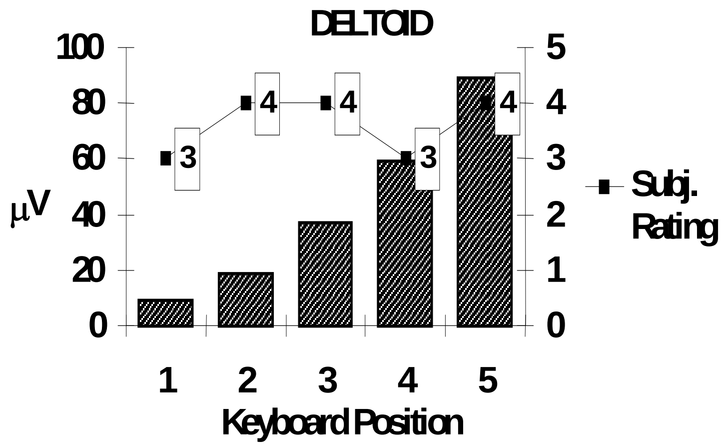
DELTOID
100
80
60
40
20
0
μV
5
4
3
2
1
0
3
4
4
3
4
Subj.
Rating
1
2
3
4
5
Keyboard Position

Figure 6

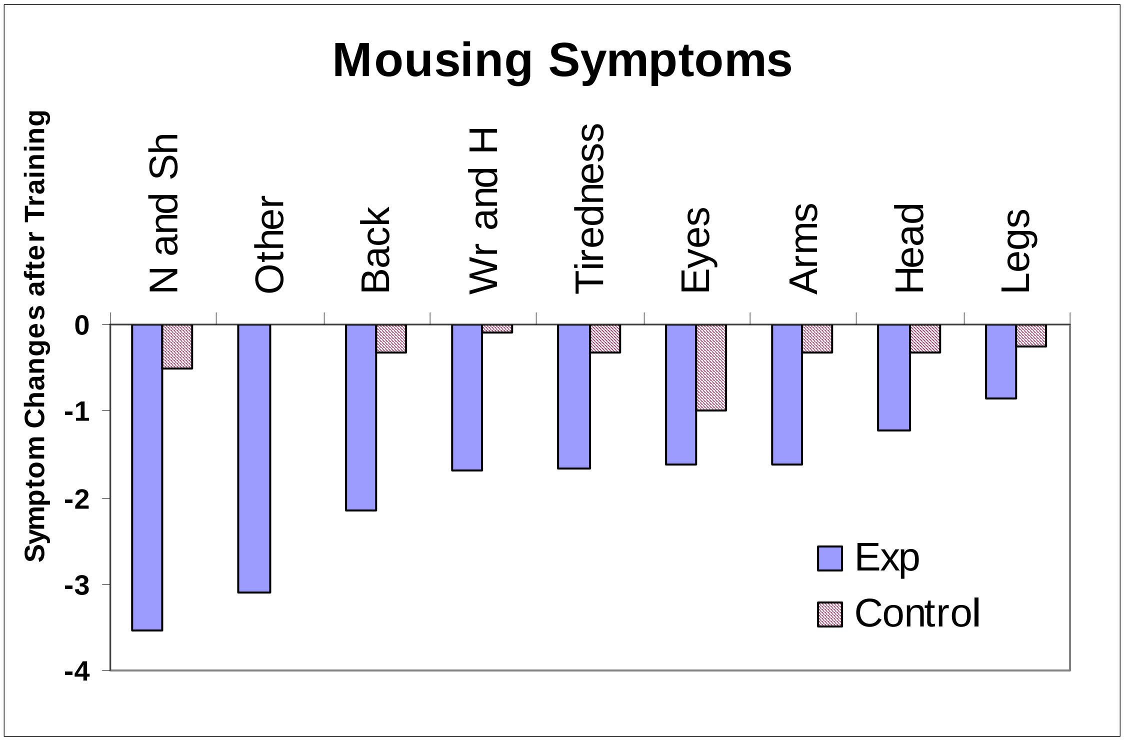
Mousing Symptoms
Symptom Changes after Training
N and Sh
Other
Back
Wr and H
Tiredness
Eyes
Arms
Head
Legs
0
-1
-2
-3
-4
Exp
Control

Figure 7

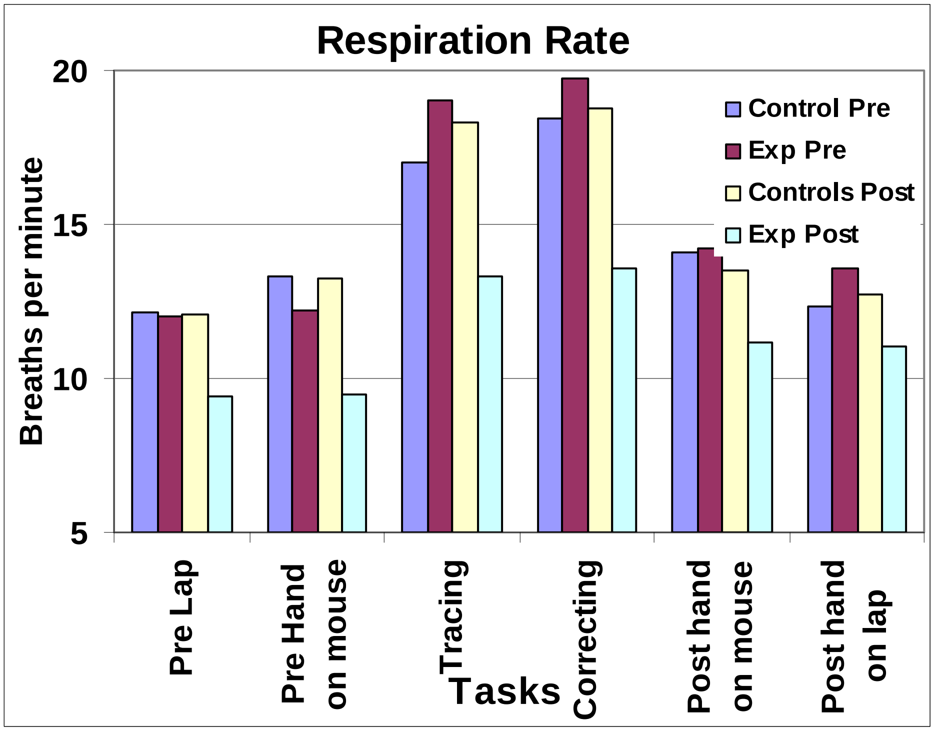
Respiration Rate
20
15
10
5
Breaths per minute
Control Pre
Exp Pre
Controls Post
Exp Post
Pre Lap
Pre Hand on mouse
Tracing
Correcting
Post hand on mouse
Post hand on lap
Tasks

Figure 8

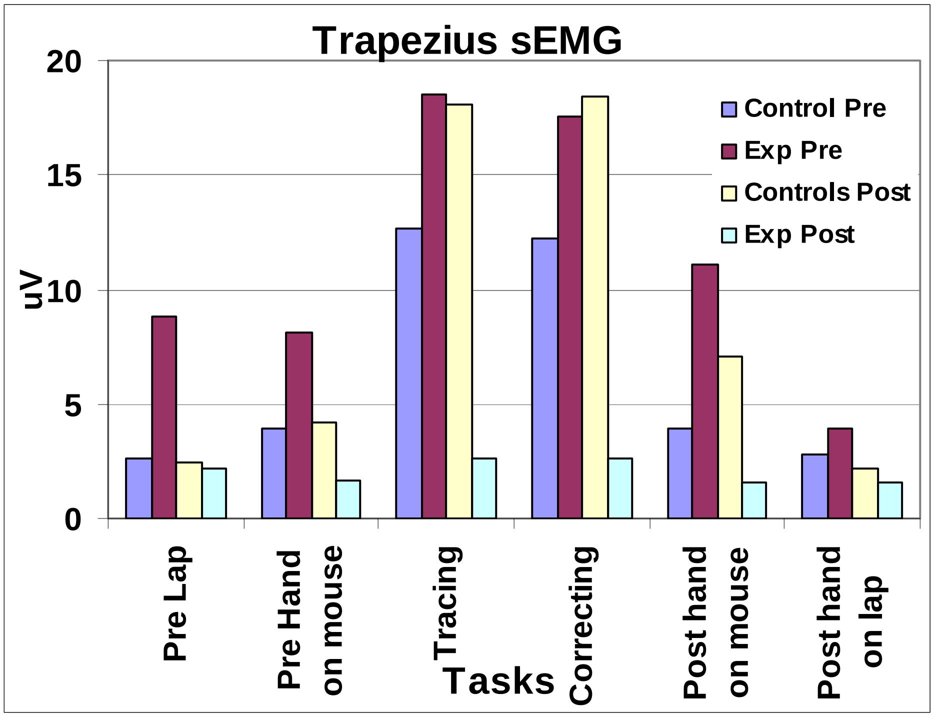
Trapezius sEMG
20
15
10
5
0
uV
Control Pre
Exp Pre
Controls Post
Exp Post
Pre Lap
Pre Hand on mouse
Tracing
Correcting
Post hand on mouse
Post hand on lap
Tasks

Figure 9