THE EFFECT OF STRESS ON MYOELECTRIC SIGNAL PATTERNS IN THE TRAPEZIUS AND LEVATOR SCAPULAE MUSCLES DURING A TYPING TASK

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Abstract
The purpose of the study was to observe how the amplitude of the myoelectric signal (MES) and the number of "EMG gaps" recorded from the trapezius and levator scapulae muscles would change when computer work was performed with and without the induction of external stressors. Heart rate (HR) response and word per minute (wpm) count were also recorded for each condition.

Ten volunteers with no history of shoulder, upper back or neck disorders performed data entry during three test conditions (N = no stress; IS = stress induced by work pace reward; ISI = stress induced by work pace reward plus irritation). Each condition was 30-minutes in length. %RVE (percentage of amplitude of the MES based on a reference contraction) and number of "EMG gaps" were the independent variables in a repeated-measures analysis of covariance (ANCOVA) ($p<0.05$) model that tested for differences between the test conditions. %RVE and EMG gaps were capable of detecting different types of stressors. The stress response did not elicit an effect on HR however, changes in wpm count were found between test condition N and both IS and ISI.

Keywords: Electromyography, Stress, Work-Related Musculoskeletal Disorders (WMSD)

L'EFFET DU STRESS SUR L'ACTIVITÉ MYOÉLECTRIQUE DU MUSCLE TRAPÈZE ET DU MUSCLE ÉLÉVATEUR DE LA SCAPULAE, AU COURS D'UNE ACTIVITÉ DE DACTYLOGRAPHIE

Résumé
Le but de cette étude était d'observer l'amplitude du signal myoélectrique [MES] et le montant de lacunes EMG, documentés du muscle trapèze supérieur et muscle élévateur de la scapluae qui allaient changer, dependant si le travail a l'ordinateur était accompli avec ou sans l'inducton des facteurs de stress externes. La fréquence cardiaque et le montant de mots par minute furent aussi évalués pendant chaque période d'essai.

Dix volontaires, sans désordes auparavant d'épaules, de dos supérieure ou de cou ont accompli la tâche d'entrer données pendant trois périodes d'essai [N = sans stress; IS = stress induit par la récompense du pas de travail; ISI = stress induit par le pas de travail plus l'irritation]. Chaque période d'essai durait trente minutes. %RVE [pourcentage de l'amplitude du signal myoelectrique], basé sur une contraction de référence et le montant de lacunes EMG, étaient les variables indépendant dans l'analyse répétée de covariance [$p< 0.05$] modèle qui examinait les différences entre les périodes d'essai. %RVE et les lacunes EMG montraient les differences des types de stressants. La réponse stressante n' avait aucun effet sur la fréquence cardiaque. Cependant, on a remarqué des changements du compte des mots par minute entre les périodes d'essai N, ainsi que les deux IS et ISI.

Mots clés : Electromyography, Stress, Troubles musculosquelettiques reliés au travail.

INTRODUCTION

In the development of Work-Related Musculoskeletal Disorders (WMSDs) of the neck and shoulders it is hypothesized that continuous activation of type I muscle fibres leads to metabolic disturbances, affecting the muscles' ability to resist fatigue, resulting in a predisposition to trapezius myalgia (7,3). However, there have been conflicting findings regarding the role of low-level muscle activation as a risk factor for the development of WMSDs (8). Electromyography (EMG) "gaps" were reported by Vereisted (1990) as periods of at least 0.2s duration during which EMG signal remained below a threshold resting level. The role played by EMG gaps has not been firmly established, but it is believed that they may reflect a natural preventive strategy whereby active motor units (in the pick-up area of surface electrodes) frequently take short rest periods (9,1).

Researchers have shown that psychological stress plays a key role in the development of WSMDs (1,4,6,10). A decreased prevalence of EMG gaps and the inability to reduce EMG amplitude to resting levels after the presentation and subsequent removal of a stressor are two possible mechanisms to investigate the link between psychological stress and WMSDs (2,10).

The purpose of this study was to look at the effect of stress on muscle activity (trapezius and levator scapulae muscles) during a data entry task in individuals without a history of shoulder, upper back, or neck disorders. It was hypothesised that with the introduction of stressors (induced work pace and induced work pace and irritation):

H_A 1: At each recording site, muscle activity (amplitude represented as %RVE) would increase from test condition N to IS to ISI.

H_A 2: At each site, the number of EMG gaps would decrease from test condition N to IS to ISI.

H_A 3: The heart rate (HR) would increase from test condition N to IS and from N to ISI.

H_A 4: The word per minute (wpm) count would increase from test condition N to IS, but would decrease from test condition IS to ISI.

METHODS

Ten volunteers (six females, four males) with no medical history of acute or chronic pain or discomfort in the neck or upper extremity region were recruited by word of mouth. Subjects had a mean age of 23.0 (SD=2.0) with a range of 21-28 years old and were proficient typists (touch typists with minimum of 45 wpm). Data were collected in a laboratory setting located in the Dalhousie University School of Physiotherapy. A split-level height adjustable workstation was fit to each subject based on ergonomic principles. EMG surface electrodes were placed on four muscle sites (upper trapezius 1–UT1; upper trapezius 2–UT2; middle trapezius–MT; levator scapulae–LS) with interelectrode spacing of 20 mm (collar to collar), and aligned with the direction of the underlying muscle fibers.

Surface myoelectric signal (MES) data were sampled at 1024 Hz per channel and digitized using a 12 bit A-D converter. Files were collected for a 30-second duration, at a frequency of one file per minute. Labview™ software was used to collect the data. Matlab™ software was used to obtain root mean square (RMS) amplitude (which was then converted to %RVE) and EMG gap values over each data file Minitab™ software was used for statistical analyses.

Prior to the actual test, MES activity was recorded for 30 seconds (with the subject sitting quietly) to determine resting levels and for three four-second reference contractions (holding their arm straight at a position of 90° in the scapular plane) normalizing the data to a percentage of a reference voluntary contraction (%RVE). Before and after each trial, a 30 second subject bias file was collected while the subject was sitting comfortably and quietly.

After each trial the word per minute totals were recorded.

A five-minute warm-up session was performed to lower subject anxiety levels and to allow the subject to become familiar with the style of text, the equipment, and the testing room. A Polar Pacer HR monitor with Polar T31 transmitter was used to record HR at one minute prior to the test, 10, 20, 30-minute mark, and one minute after completion of each test condition.

Each subject performed three 30-minute typing trials with standardized reference material interrupted by 30-minute breaks. Condition N was presented first with subjects instructed to type at a comfortable and relaxed pace to establish a non-biased MES recording. The presentation of the final two conditions was randomized. The IS condition was created by using a reward (movie tickets) to induce an increase in work pace. The ISI condition used the same reward system plus the addition of an alarm clock sounding in the room and the researcher looking over the subject's shoulder calling out mistakes as they typed, inducing greater psychological stress.

RESULTS

EMG amplitude

Examination of the data showed that all four muscle sites acted similarly for test condition N and IS, however a large increase in %RVE occurred during test condition ISI with the addition of mental distraction (stress). In addition to differences between test conditions, the %RVE level increased over the duration of the ISI test. Figure 1 displays %RVE levels for individual muscle sites averaged for each test condition as a proportion of the reference contraction.

ANCOVA results revealed a significant interaction between test condition and time for all muscle sites ($p<0.0005$; except MT $p<0.002$) indicating that there was an effect of time for % RVE over the duration of each test. Significant interactions were found for test condition by order and order by time at all sites ($p<0.001$; except MT $p<0.034$). Upon fixing order, comparing test condition using a Scheffé post-hoc analysis, non-significant differences between conditions N and IS for both orders were revealed. Significant differences were found when comparing N to ISI and IS to ISI ($p<0.05$).

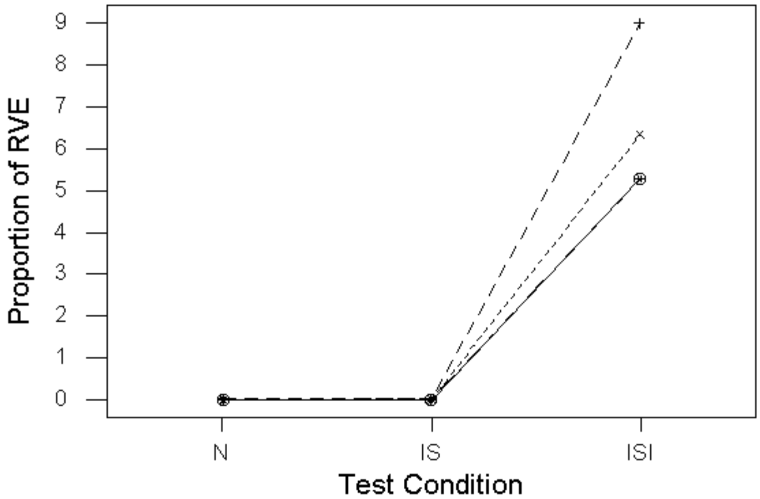

Figure 1: Proportion of %RVE plotted against test condition. (o) UT1, (+) UT2, (3) MT, and (*) LS. Results on the y-axis are displayed as a proportion of the electrical activity of the reference contraction. (Note that a proportion of 1 is wqivalent to 100% of the RVE activation level.)

EMG gaps

The EMG gaps data were analyzed on nine of ten subjects (subject 10 experienced no gaps in any test condition, perhaps due to high resting levels of muscle activity) using an ANCOVA. Test condition was a significant factor for UT1, MT, and LS ($p<0.0005$). For UT1 a test condition versus time effect was also found ($p<0.02$). Muscle sites UT1, MT, and LS all showed significant test condition by order interactions ($p<0.0005$). For sites MT and LS, time was a non-significant factor and was removed from the analysis.

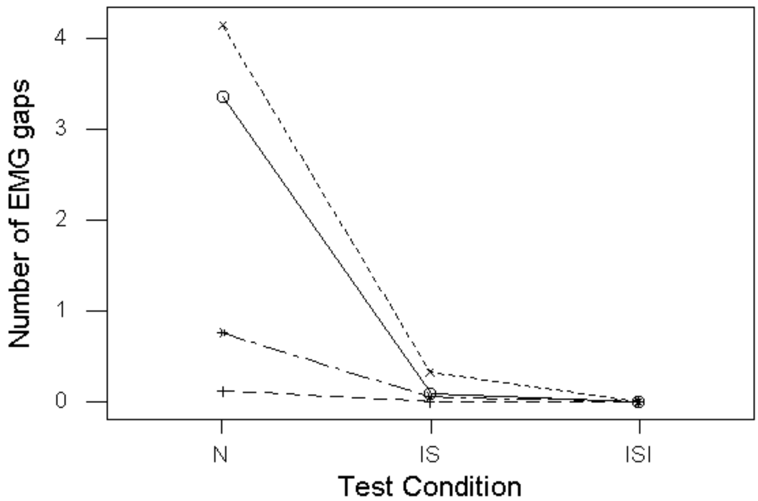

Figure 2: Number of EMG gaps versus test condition. Y-axis values are the mean number of EMG gaps averaged over each 30 second data sample for the 30 minute trial. (o) UT1, (+) UT2, (3) MT, and (*) LS

Fixing order during post-hoc analysis revealed the differences between test conditions (Table 1). When order 1 was fixed for UT1 a significant difference was found between test conditions N and IS and between test conditions N and ISI, with no difference between the IS and ISI conditions. When order 2 was fixed, a similar trend was observed ($p<0.10$), however, it was not statistically significant according to an $\alpha= 0.05$. Muscle site LS, responded similarly to UT1 when order 1 was fixed as test condition N was significantly different from IS and ISI. Unlike UT1 however, LS did not show a strong trend when order 2 was fixed. For MT, the only significant observation when order 2 was fixed as test condition N differed from both IS and ISI. For UT2, no significant differences in the number of EMG gaps recorded as the value was zero during all data samples.

Order 1 fixed	UT1	MT	LS	Order 2 fixed	UT1	MT	LS
N vs IS	S	NS	S	N vs IS	NS*	S	NS
N vs ISI	S	NS	S	N vs ISI	NS*	S	NS
IS vs ISI	NS	NS	NS	IS vs ISI	NS	NS	NS

Table 1: Scheffé Post-hoc analysis on the number of EMG gaps for muscle sites UT1, MT, and LS. [* indicates a non significant effect, however the existence of a trend ($p<0.10$) at $\alpha=0.05$.]

Heart rate and word count

Due to equipment constraints HR recordings were recorded for only 8 of the 10 subjects. The mean HRs for each test condition were 76.3 (SD=6.1), 78.3 (SD=8.2), and 78.2 (SD=7.8) for N, IS, and ISI respectively. An increase in HR was observed between test conditions N and IS and test conditions N and ISI ($p<0.002$). Heart rate was consistent between the IS and ISI test conditions with no significant difference between the two conditions.

The mean wpm including all trials was 54.5 wpm (SD=10.89). An increase was observed in wpm between test condition N and IS and test condition N and ISI while the wpm value of test condition ISI was lower than that of IS. Scheffé post-hoc analysis revealed a significant difference between test condition N and both the IS and ISI conditions ($p<0.05$), whereas there was no significant difference between IS and ISI.

DISCUSSION

In the current literature, there exists debate as to what role sustained muscle activity and the occurrence of EMG gaps play in the development of WMSDs. By gaining an understanding of how psychological stressors interact with the musculoskeletal system (through MES patterns) we may begin to understand the etiology of WMSD. The purpose of this study was to determine the influence of psychological stress on muscle activity in the trapezius and levator scapulae muscles during a VDU task in individuals without a history of shoulder, upper back, or neck disorders.

A significant difference in %RVE activity was not found between test conditions N and IS (post-hoc $p<0.05$), meaning an induced work pace did not have an effect on MES amplitude (%RVE). A significant difference was found when test condition N was compared to ISI and when IS was compared to ISI. These findings apply to all four muscle sites and indicate that an induced pace coupled with mental distraction was needed to induce a change in MES amplitude (%RVE).

The analysis of EMG gap data revealed that counting EMG gaps might be a more sensitive measure of the physical manifestation of an external stress (induced work pace) than MES amplitude. The overall trend was a decline in the number of EMG gaps when an induced work pace was implemented, which remained reduced with the addition of additional stress (ISI). (These significant differences (post-hoc analysis, p<0.05) were found for UT1 and LS for order 1 and MT for order 2). This finding may be useful in assessing the level of psychological stress to which workers are exposed, as EMG gaps appear to be a more sensitive measure of induced pace, whereas %RVE appears to be a more sensitive measure of caused by distraction and irritation.

As the effect of time (as a covariate) was significant in both the %RVE and the number of EMG gaps, it is possible that the subjects experienced some degree of local muscle fatigue during the 30 minute typing tasks. These findings may be a result of slowing of motor unit conduction velocity, recruitment of additional motor units, and/or an increase in tissue depth due to fluid accumulation, all of which have been shown mathematically to increase the amplitude and slow the frequency characteristics of the surface-recorded MES (5,11).

Counting EMG gaps may shed light on fatigue prevention strategies adopted by the local muscle. It has been observed that EMG gaps occur in conjunction with motor unit rotation in the pick-up area of the surface electrode pair (11). It has also been noted that motor unit rotation may occur without the observation of a gap in EMG activity (11). When the EMG gap recordings were viewed along side the %RVE findings, the time effect could be seen at the UT1 site. However MT and LS did not have a significant time effect, possibly due to the lower level (non-fatiguing) to which the MT and LS sites were activated during the testing.

Analysis of HR showed that while there was an increase in HR during the test conditions, there were no statistical differences between the three test conditions, which did not support Ha3.

There were significant increases in wpm between test condition N and both IS and ISI. There was a slight decrease in wpm values between IS and ISI although it was not statistically significant. While the number of errors has not yet been assessed, the different stressors might have affected the task performance of subjects by affecting their concentration, as more errors were made subjects might have decreased their speed in order to increase their accuracy.

Limitations

The limited number of subjects may not be representative of the general population and could potentially have biased these results. Other limitations include the level of the stressors, which or the perception of the stressors may not have been enough to elicit a stress response in some subjects or may have elicited an above average response in others. Motivation/competitiveness may have affected the results if, in the normal test condition, a subjected attempted to type as fast as they could due to their personality. Conversations with the subjects upon completion revealed the researcher standing over their shoulder was more stressful than the alarm clock.

CONCLUSION

The findings from this study revealed that %RVE and EMG gaps differentiated between two types of stressors. An increase in muscle activation (%RVE) occurred with the application of mental distraction above and beyond an induced work pace. In the case of EMG gaps, a decrease in number occurred with the induced work pace. More work must be done in order to understand the full effect psychological stress has on MES patterns and the mechanisms through which it works.

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