Electromyography

A comparison between laboratory- and field measurements

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Supervisor at Nada was Jeanette Hellgren Kotalks
Examiner was Anders Lansner
ABSTRACT

This thesis compares shoulder muscle activation of medical secretaries in two typical computer tasks performed in a controlled laboratory setting to field recordings of computer related work. The hypothesis is that the controlled condition represents the field measurement (the individuals’ workday). Electromyography (EMG) measurements, of the right- and left trapezius for five subjects, were carried in a field recording during a regular workday and in a laboratory recording while performing two typical computer tasks: typing and editing. Throughout the field recording, observations of work task activities (PC- and “other secretary” activity) were made to later be distinguished in the EMG data. To analyze the EMG data three parameters were used: RRT (Relative Rest Time), and the 10th- and 50th-percentile of the muscle activity. To compare the parameters, for the different tasks, a deviation analysis was performed. Contrary to what was expected the result showed highest deviation when comparing the controlled typing task with the extracted PC activity in the field recording. However, the comparison between the controlled editing task and the “other secretary” activity (which corresponded to 60 % of their workday) best represented (least deviation) the muscle activity pattern of the medical secretaries in their workday.

Keywords: EMG, field-studies

Elektromyografi – En jämförelse mellan laboratorie- och fältmätningar

SAMMANFATTNING

Denna rapport jämför skuldermuskelaktivitet, av läkarsekreterare, i två typiska datauppgifter utförda i en kontrollerad laboratoriemätning med fältmätning från datarelaterat arbete. Hypotesen är att den kontrollerade mätningen representerar fältmätningen (en individs arbetsdag). Elektromyografi (EMG) mätningar av höger- och vänster trapezius genomfördes på fem försökspersoner i en laboratoriemätning (två olika PC uppgifter: textinmatning och redigering) och i en fältmätning under försökspersonernas arbetsdagar. Observationer genomfördes under fältmätningarna för att senare extrahera olika arbetsuppgifter (PC- och ”annan sekreterar” aktivitet) ur EMG signalen. Tre parametrar användes för att analysera EMG signalen: RRT (Relative Rest Time), samt 10- och 50 percentilen av den registrerade muskelaktiviteten. Vid jämförelsen av parametrarna för de olika uppgifterna användes en avvikelseanalys. Resultatet visar, i motsats till förväntat, högst avvikelse vid jämförelsen av den kontrollerade textinmatningsuppgiften med PC-aktiviteten i fältmätningen. Dock, visar jämförelsen mellan den kontrollerade redigeringsuppgiften och ”annan sekretar” aktivitet (vilken representerar 60 % av arbetsdagen) på bäst representation (minst avvikelse) av muskelaktivitetsmönster för läkarsekreterare under deras arbetsdag.

Nyckelord: EMG, fältstudier
PREFACE

This is a thesis for a Master of Science degree (M.Sc.) in Electrical Engineering with a specialization in biomedical technology, performed at the Department of Numerical Analysis and Computer Science (NADA) at the Royal Institute of Technology (KTH) in Stockholm. Supervised by PhD Jeanette Hellgren-Kotaleski and examined by Prof. Anders Lansner.

The Master’s project was carried out within the EU-project “Neuromuscular assessment in Elderly Worker” (the NEW-project) at the National Institute for Working Life/West (ALI) in Göteborg. One part of the NEW-project examines if a myofeedback system can prevent work related pain in the shoulder-neck region. PhD Leif Sandsjö and Associate Prof. Mikael Forsman supervised this work.

ACKNOWLEDGEMENT

I would like to thank following people who have contributed to this work:

My supervisor at ALI Leif Sandsjö for your valuable discussions and guidance. Mikael Forsman for giving me the opportunity to carry out the project at ALI and for your guidance. My supervisor at NADA Jeanette Hellgren-Kotaleski for your comments on the thesis. Stefan Thorn for helping out with MATLAB coding. To all co-workers at ALI – thanks for making me feel like one of the team.

Last, but not least, thank you Fredrik Wessberg for all your encouragement and help – D A, C.
**ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>APDF</td>
<td>Accumulative Distribution Probability Function</td>
</tr>
<tr>
<td>EMG</td>
<td>Electromyography</td>
</tr>
<tr>
<td>MU</td>
<td>Motor Unit</td>
</tr>
<tr>
<td>MUAP</td>
<td>Motor Unit Action Potential</td>
</tr>
<tr>
<td>MVE</td>
<td>Maximum Voluntary Electrical Activity</td>
</tr>
<tr>
<td>PC</td>
<td>Personal Computer</td>
</tr>
<tr>
<td>PCA</td>
<td>Principal Component Analysis</td>
</tr>
<tr>
<td>RMS</td>
<td>Root Mean Square</td>
</tr>
<tr>
<td>RRT</td>
<td>Relative Rest Time</td>
</tr>
<tr>
<td>RVE</td>
<td>Reference Voluntary Electrical Activation</td>
</tr>
<tr>
<td>sEMG</td>
<td>Surface EMG</td>
</tr>
<tr>
<td>WMSDs</td>
<td>Work-related Musculoskeletal Disorders</td>
</tr>
</tbody>
</table>
1 INTRODUCTION

Musculoskeletal complaints are common in the working population. For instance, in Sweden, according to Swedish Official Statistics (Statistics Sweden, 2001), one third of all working men and women aged 16-64 years reported pain every week in the upper back or the neck. Studies show that work-related musculoskeletal disorders (WMSDs) are common in light manual work such as computer work and that pain is common in the shoulder-neck region of computer operators. These ailments, such as myalgia\(^1\), are localized to muscle tissue.

Electromyography (EMG) is a technique to visualize muscle activity. EMG is used in ergonomics to detect harmful muscle activity patterns and in research to study objective estimates of the muscle activity patterns (Sandşö, 2004).

1.1 The NEW-project at ALI

The European Union project, “Neuromuscular assessment in the Elderly Worker” (the NEW-project), is a multidisciplinary project set up to study the status of the neuromuscular system among elderly workers. As one of several activities under the auspices of the NEW-project a randomized control study is being carried out in parallel in The Netherlands and Sweden which investigate the possibilities of promoting muscle rest in subjects having WMSD problems in the shoulder-neck region. The purpose of the study is to develop a method of intervention at the workplace of occupational groups with high incident of myalgia in the shoulder-neck region. The project’s theoretical foundation is: muscular tension (i.e. insufficient muscular rest) increases the risk, for exposed workers, to develop chronic problems, which is likely to occur during light repetitive work such as computer related work activities. Also, workers with already developed problems are in need of the intervention to break the harmful muscle tension pattern (Hermens and Hutten, 2002).

Roessingh Research & Development, Enschede, The Netherlands, have developed a portable myofeedback system that informs the user to break a harmful muscle activity pattern when insufficient muscular rest is present in the trapezius muscle\(^2\) (Hermens and Hutten, 2002). This system can be used at the workplace for intervention among employees with shoulder-neck related problems.

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\(^1\) Pain in muscle; or pain in multiple muscles (Marriam-Webster, 2005)

\(^2\) A large flat triangular superficial muscle of each side of the upper back that arises from the occipital bone, the ligamentum nuchae, and the spinous processes of the last cervical (Marriam-Webster, 2005)
1.2 Master's project description

This Master’s project was assigned 20 weeks (20 credits) of fulltime work and was carried out within the NEW-project at ALI, Göteborg. The project involved five subjects (medical secretaries) provided by the NEW-project. For each subject EMG recordings, of right- and left trapezius, were carried out in a controlled laboratory procedure of two computer related tasks (typing and editing) and in a field recording during the subjects’ workday. Throughout the field recording observations of work task activities (PC- and “other secretary” activity) were made to later be distinguished in the EMG data. Nine comparison combinations were analyzed. To evaluate the EMG data for the comparison combinations three parameters were used: RRT (Relative Rest Time), and the 10th- and 50th-percentile of the muscle activity. To compare the combinations, for the three parameters, a deviation analysis was performed. Analysis and comparison were carried out in PortiLab 1.10 and in MATLAB 6.1/R12.

1.3 Aim of the thesis

The laboratory set up in the NEW-project was constructed to trigger muscle activities which represent the muscle activities during the subjects’ workday. In such a set up it is interesting to know how the muscle activities in laboratory measurements represent the field measurements.

The aim of this project is to evaluate how EMG data from a laboratory procedure compare with EMG data from field recordings (data from the participants’ workday). The hypothesis is that the muscle activity pattern in the laboratory procedure is a good representation of the muscle activity pattern found during computer related work at the workplace.

The thesis question is:

How do the laboratory measurements represent the muscle activity pattern of an individual during a workday?
2 THEORY

The understanding of the muscle anatomy and the way the muscle generates bioelectrical signals is of importance in the understanding of the sEMG signal. Also, in order to understand EMG as a method, there are some important facts to be aware of, see Ch 2.2.

2.1 Muscle physiology – the basics

There are three main types of muscles in the human body: skeletal muscle-, smooth muscle- and cardiac muscle tissues. This thesis concentrates on the skeletal muscle group and the skeleton motor system which controls the force and movement in humans. The motor programming takes place in the cortex, where the nerve signals converge and excite (or inhibit) various neurons. The output from the cortex influences the spinal cord where links exit to the motor neurons providing direct control of muscle activity in the muscle fiber, see fig 1.

The motor unit (MU) is the smallest controllable muscular unit. It consists of a single motor neuron, its neuromuscular junction and the muscle fiber (Moritani et al., 2004), see fig 1. Number of MUs in the human muscle varies from about 100, in the small hand muscles, to 1000 or more in the large limbs (Henneman, 1981). The larger the number of MUs recruited, and the higher their discharge frequency is, the greater the force of the muscle will be (Moritani et al., 2004).

Figure 1: The Motor Unit consists of a single motor neuron, its neuromuscular junction and the muscle fiber. This is the smallest controllable muscular unit. (Hall, 2003)

A motor unit action potential (MUAP) is the term given to the detected waveform resulting from the propagation of the depolarizing- and repolarizing wave along all
fibers associated with a given MU. The shape and the amplitude of the MUAP are not only a function of the MU (size, spatial distribution of the fibers, and propagation velocity) but also a function of the electrode type (contact area, material, interwire spacing) and the electrode location (distance from the MU and conductivity of intervening tissue). This has to be taken into account when observing the sEMG signal. A myoelectric signal is the name given to the total signal, from all active MUs, detected at an electrode or differentially between electrodes (Kumar and Mital, 1996).

### 2.2 Surface Electromyography

EMG is a technique used to visualize, and to make available for analysis, the myoelectric signal. During this project surface EMG (sEMG) is and the equipment consists of a recording device and electrodes. The recording device can be for example an oscilloscope, a computer or a portable myofeedback system. The latter, is the type used in this project and is a device used in ambulatory recordings, see Ch 3.3.2. The electrodes are typically a pair of electrodes forming a bipolar detection. In bipolar recordings, one electrode is connected to the positive input and the other to the negative input of a differential amplifier. The bipolar setup can detect the small sEMG signal before drowned in the noise of the system or electromagnetic interference. Surface EMG is a common tool to evaluate muscle activity, in occupational or work related settings, which provides “global information” about the muscle. It reflects both number of active MUs and firing rate of the MUs. When taking measurement with sEMG one is detecting voltage amplitude registrations, typically between a microvolt (µV) and a millivolt (mV). The absolute magnitude of these registrations allows determination of the force of contraction which permits a comparison between different tasks, stress, force etc (Sandsjö, 2004). Another EMG method, apart from sEMG, is intramuscular EMG which is commonly used in clinical trials.

One should be aware of the limitations (sources of errors) of a sEMG measurement, see Ch 5.2. To use a µV measure of a sEMG signal, the technique must be standardized and the signal should be carefully calibrated, see Ch 3.3, before a conclusion can be drawn (Kumar and Mital, 1996).
3 MATERIAL AND METHODS

To collect sEMG data five medical secretaries were involved in a controlled laboratory recording and a field recording during a regular workday. Field observations were carried out during the field recordings to distinguish work task activities in the field measurement.

3.1 Subjects

Five medical secretaries, all women, volunteered to participate in the project. The subjects were selected from a larger group included in the NEW-project (Sandsjö, et al, 2003). The criteria for inclusion were according to the criteria for AFA2, see appendix C. There was a desire to include more subjects in this Master’s project, but unfortunately, no more subjects were available during the timeline of the project. Table 1 shows the background data for the subjects.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age (yrs)</th>
<th>Length (cm)</th>
<th>Weight (kg)</th>
<th>Hand dominance</th>
<th>Work experience (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>45</td>
<td>165</td>
<td>60</td>
<td>Right</td>
<td>7</td>
</tr>
<tr>
<td>200</td>
<td>30</td>
<td>159</td>
<td>52</td>
<td>Right</td>
<td>7</td>
</tr>
<tr>
<td>300</td>
<td>42</td>
<td>169</td>
<td>59</td>
<td>Right</td>
<td>3</td>
</tr>
<tr>
<td>400</td>
<td>36</td>
<td>163</td>
<td>55</td>
<td>Right</td>
<td>12</td>
</tr>
<tr>
<td>500</td>
<td>52</td>
<td>172</td>
<td>74</td>
<td>Right</td>
<td>30</td>
</tr>
</tbody>
</table>

*Table 1: Background data for the subjects.*

3.2 Field observations

Field observations were executed to complete a work task analysis and to distinguish between different work activities in the sEMG data collection. Prior to the field observation a criteria was set up, see table 2. Especially important in the field observation was the PC activity since the result of the field observations were to be compared with the laboratory measurements consisting of two computer-related tasks. It was, however, interesting to investigate the other, non computer-related, work tasks of the medical secretaries as well. The non computer-related secretary work tasks are referred to as “other” activity.
<table>
<thead>
<tr>
<th>Work task activity</th>
<th>Abbreviation</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PC activity</strong></td>
<td>PC</td>
<td></td>
</tr>
<tr>
<td>PC.a</td>
<td>PC</td>
<td>Exclusively keyboard handling e.g. dictating journals, writing email etc</td>
</tr>
<tr>
<td>PC.b</td>
<td>PC</td>
<td>Mouse handling mixed with keyboard handling e.g. filling out forms or editing journal</td>
</tr>
<tr>
<td>PC.c</td>
<td>PC</td>
<td>Other PC work e.g. keyboard- or mouse handling and “other” activity simultaneously</td>
</tr>
<tr>
<td><strong>“other” activity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper/Journal handling</td>
<td>Paperwork other than by PC i.e. writing with pen, organizing papers, faxing, printing etc</td>
<td></td>
</tr>
<tr>
<td>Colleague interactions</td>
<td>Colleague (-s) are entering the workspace and asking questions etc</td>
<td></td>
</tr>
<tr>
<td>Phone calls</td>
<td></td>
<td>Answering- and making phone calls</td>
</tr>
<tr>
<td>Break</td>
<td></td>
<td>Breaks from work routine i.e. coffee breaks</td>
</tr>
<tr>
<td>None observed</td>
<td></td>
<td>Work or other situations that has taken place outside the observation area (the workspace)</td>
</tr>
<tr>
<td>Unspecified</td>
<td></td>
<td>All other activities not specified above</td>
</tr>
</tbody>
</table>

*Table 2: Criteria for field observations to distinguish PC activity from “other” activity in the sEMG data.*

The observations were carried out at the participants’ workplace, a hospital environment, while wearing the myofeedback system. The system only collected data without giving any feedback to the subject. They were informed to carry on with their normal work activities while observations (and sEMG measurements) were performed. A protocol, *see appendix B*, was constructed with the exact times of each work task activity.

### 3.3 sEMG measurements

Surface EMG measurements gave an objective estimate of the muscle activity pattern and were used in a laboratory- and a field measurement session. For comparison reasons a calibration of the sEMG signal against a known reference was necessary: normalization. The normalization was performed in the same manner, in the laboratory- and the field measurement session, by using a rest- and a reference measurement, *see fig 2.*

![Figure 2](image-url)

*a)* The subject during a rest reference and *b)* during a reference contraction (*Illustration provided by Hans Sjöberg*).
A rest measurement recorded the muscle activity at rest (a rest reference). The subject was comfortably seated with the hands in the lap enabling the subject to relax in the shoulder region, see fig 2.a. Following this registration a reference measurement was made, recording the muscle activity during sub maximal voluntary contraction (a reference contraction). The subject was seated in the same position as during the rest measurement but with the arms held straight, horizontal and in 90° towards the frontal plane. During the reference contraction the subjects’ hands were unloaded and the palms pointing downwards, see fig 2.b. (Mathiassen, 1995).

3.3.1 Laboratory sEMG measurements

Material
A physical therapist and a research assistant supervised the laboratory measurements. The subject was informed of the procedure and thereafter the area of electrode placement was cleansed with alcohol to limit the impedance. Bipolar surface EMG electrodes (Medicotest children ECG electrodes) were placed, bilaterally over the descending part of the trapezius muscle, 2 cm lateral to a point midway between the acromion3 and the processus spinosus of the seventh cervical vertebra (C7). The inter-electrode distance was 2 cm. The reference electrode was placed over processus spinosus of C7. This placement is according to international guidelines (Hermen, et al., 1999).

<table>
<thead>
<tr>
<th>Event</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest measurement</td>
<td>30 s</td>
</tr>
<tr>
<td>Reference measurement</td>
<td>4 x 15 s with a 30 s rest measurement between each reference contraction</td>
</tr>
<tr>
<td>Typing task</td>
<td>10 minutes</td>
</tr>
<tr>
<td>Rest measurement</td>
<td>3 x 15 s</td>
</tr>
<tr>
<td>Editing task</td>
<td>5 minutes</td>
</tr>
<tr>
<td>Rest measurement</td>
<td>3 x 15 s</td>
</tr>
<tr>
<td>Reference measurement</td>
<td>2 x 15 s with a 30 s rest measurement between each reference contraction</td>
</tr>
</tbody>
</table>

*Table 3: Events and duration of the laboratory recording*

Procedure
Table 3 shows the order of laboratory measurement events. Rest- and reference measurements were made for normalization purposes as described, see fig 2, after which the laboratory recording proceeded with two computer-related tasks: a typing task and an editing task. During the typing task the subject was retyping a text provided by the research assistant. The subject had no time-stress but was instructed to retype exactly what was written on the provided text. During the editing task the subject was instructed to edit the provided text by changing every other letter in the words of more then five- and odd numbers to a capital letter. This task was composed to entwine text editing with mental load which stresses the subject. The laboratory recording ended with two reference measurements each followed by a rest measurement.

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3 The outer end of the spine of the scapula that protects the glenoid cavity, forms the outer angle of the shoulder, and articulates with the clavicle (Marriam-Webster, 2005).
3.3.2 Field sEMG measurements

Material
A two-channel portable myofeedback system was used for the field recording. The system was combined with a harness which incorporated dry (non-gelled) silver-silver chloride electrodes to avoid skin irritation and enable a stable recording of the upper trapezius muscle, see fig 3. Duration tests have indicated a good constant contact, especially after the initial 5 minutes of use (Hermens and Hutten, 2002).

Figure 3: The myofeedback system with the control box and the individually adaptable harness with the embedded bipolar surface EMG electrodes (Illustrations from Hermens and Hutten, 2002).

The myoelectric signal was stored at 32 Hz, amplified (15x) and digitized (22 bits ADC). The myofeedback system has a capacity to store 60 hours of sEMG recordings. The subject was, prior to the measurement, instructed on how to dress and manage the myofeedback system properly (WP5B, 2002).

<table>
<thead>
<tr>
<th>Event</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest measurement</td>
<td>30 s</td>
</tr>
<tr>
<td>Reference measurement</td>
<td>4 x 15 s with a 15 s rest measurement between each contraction</td>
</tr>
<tr>
<td>Work activity</td>
<td>Ranged from 41 min to 3 hours</td>
</tr>
<tr>
<td>Reference measurement</td>
<td>3 x 15 s with a 15 s rest measurement between each contraction</td>
</tr>
</tbody>
</table>

Table 4: Events and duration of the field recording.

Procedure
Table 4 shows the order of field measurement events. The recording started with a rest- and reference measurement performed as described above, see fig 2. The subject was then told to carry on with work activities as usual and not mind the research assistant observing and taking notes. The field recording ended with three reference measurements each followed by a rest measurement.

3.4 Analysis
A work task analysis was made, based on the field observations, to distinguish PC activity from “other” activity in the sEMG data. It is difficult to make a scientific statement by merely observing the envelope sEMG signal, see fig 4, therefore a more thorough sEMG analysis was made in PortiLab 1.10 and MATLAB 6.1/R12.
3.4.1 Field observation analysis

After the field observations, the protocol information was imported to MS Excel where it was analyzed. Work task analyses were completed by extracting each work task activity, then calculating the accumulative time the subject were performing the work tasks. A mean, median and range parameter was assessed for the five subjects. Also, PC- and “other” activity sequences were extracted to enable sEMG analysis on these two different activities.

3.4.2 sEMG analysis

Myoelectric signals can be analyzed in a variety of ways. In this thesis the signal is analyzed in the time domain. An envelope (Env) signal is used in this project to study the muscle activity level. The Env signal is computed, from the raw sEMG signal, as a smoothed, rectified signal. To achieve this, the raw sEMG signal is filtered through a high-pass filter (cut-off frequency at 10 Hz to remove movement artifacts) and a low-pass filter to remove higher frequency components. It was then rectified so all data were above zero. At last it passed a low-pass filter (cut-off frequency at 10 Hz), thus creating an envelope of the raw signal (Hermen, et al., 1999). Figure 4 shows the Env signal from the laboratory recording (typing- and editing task), and the field recording (PC- and “other” activity). Notice the difficulty in visually comparing the Env signal of the different tasks.

Laboratory- and field measurements were treated in similar ways. First, the Env signal was imported from the portable myofeedback system to PortiLab 1.10 where its overall condition was evaluated. “Flat” signals i.e. a signal with zero volt amplitude over a period of 5 seconds, and signals with too much noise were disregarded. The desirable events, table 3 and 4, were extracted with the help of PortiLab for each channel (left and right trapezius).

![Figure 4: The Env signal, in PortiLab, The first two signals represents the Typing- and Editing task from the laboratory measurement and the signal under the two first represents the field measurement divided into PC activity and “other” activity.](image-url)
Secondly the signal was imported as a binary 32 integer to MATLAB. Left and right trapezius was processed separately but in the same way. By using the work task activity analysis, PC activity and “other” activity were extracted from the original field measurement.

**Normalization**

A normalization of the sEMG signal was necessary to allow a comparison quantitatively between different activities for the same muscle, activities on different days, and different subjects for same or different activities. A reference voluntary electrical activation level (RVE) was determined as the mean of the Env signal recorded during the reference measurement event, see Ch 3.3. The Env signal was normalized to the RVE value resulting in a data signal expressed as a percentage of the RVE (%RVE). Normalization of the signal was necessary to compare the laboratory- and the field signal (Mathiassen, 1995).

**Muscle activity parameters**

Three common parameters used in EMG analysis, within the ergonomic field, are: relative rest time (RRT), and the 10th- and 50th-percentile. The RRT parameter represents the percentage of recorded time at which the muscle is at rest, as defined below. The 10th-percentile and 50th-percentile was suggested by Jonsson (1982) to indicate the static load level and the median load level of the performed work.

The RRT parameter was calculated, for each subject and each trapezius side, as follows. First, a rest threshold was determined as the mean Env value of “the best rest measurement” (the rest measurement with the lowest muscle activity) and then with 10% RVE added (Sandsjö, 2004). Secondly, the RRT is defined as the percentage time at which the sEMG signal is below this rest threshold during the desired event measurement.

**3.4.3 sEMG comparison**

**Comparison combinations**

The comparison between laboratory and field measurement were done in nine comparison combinations, see table 5. These combinations were analyzed for each subject, each trapezius side, and each muscle activity parameter. The Lab signal is constructed of two measurements, the typing- and editing task, and the Field signal is constructed of one measurement from which PC- and “other” activity are extracted.

<table>
<thead>
<tr>
<th></th>
<th>Lab</th>
<th>Typing</th>
<th>Editing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field</td>
<td>√</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>PC activity</td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“other” activity</td>
<td>√</td>
<td></td>
<td>√</td>
</tr>
</tbody>
</table>

*Table 5: Comparison combinations of the sEMG recording events.*

**Comparison methods**

To evaluate and compare the nine combinations a linear graph was used. The hypothesis was that the laboratory measurement represented the field measurement therefore when plotting the parameter values for the five subjects (lab versus field) a linearization would be noticeable.
To evaluate the linear relations a deviation analysis was applied to each comparison combination. The hypothesized model suggested a proportional relationship between the observed field sEMG data, $y$, and the laboratory sEMG data, $x$. The hypothesized model was $\hat{y} = \beta * x$ (Box, et al, 1973). The constant of proportionality, $\beta$, was set to 1.

A comparison of the $y_u$ (the observed field sEMG data value from the $u^{th}$ subject) value with the corresponding $\hat{y}_u$ value (from the model) was made. The residuals were defined as the perpendicular distance from the observed data to the model, $\eta_u = (y_u - \hat{y}_u) / \sqrt{2}$. The sum of the squares, $S_R = \sum \eta_u^2$, of the residuals can be seen as the deviation from the model. That is, the sum of squared discrepancies between the observed values, $y$, and the values given by the model $\hat{y} = \beta * x$. Degrees of freedom, $\nu$, were defined as the sum of subjects, $n$, minus one. Consequently the deviation, $s$, is (Box, et al, 1973);

$$s = \sqrt{ \frac{S_R}{\nu} } = \sqrt{ \frac{\sum \eta_u^2}{(n-1)} } \quad (1)$$

Also, to better understand the variation of a parameter in the comparatively long field measurement (41-179 minutes), when compared with the short laboratory measurement (5-10 minutes), the field measurement was divided into 5-minute sequences. This resulted in an overview of the variation in the field measurement of the parameter when a visualized comparison was made.

No statistical tests were used to compare the laboratory- and field measurement because of the low number of subjects.
4 RESULTS

4.1 Field observations

The field observation resulted in a work task analysis in order to extract different work task sequences from field sEMG signal. Table 6 show the field observation result that is based on the work activity criteria stated in table 2. The work tasks were divided into PC activity and “other” activity (non computer-related task activity). For the subjects the accumulative PC activity ranged from 15-98 minutes (22-73% of observed time) and the accumulative “other” activity ranged from 25-119 minutes (27-78% of observed time).

<table>
<thead>
<tr>
<th>subject</th>
<th>Total observed time</th>
<th>PC activity</th>
<th>&quot;other&quot; activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>(%)</td>
<td>(%)</td>
</tr>
<tr>
<td>100</td>
<td>179</td>
<td>21</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>153</td>
<td>11</td>
<td>10</td>
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<tr>
<td>300</td>
<td>118</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>41</td>
<td>22</td>
<td>12</td>
</tr>
<tr>
<td>500</td>
<td>157</td>
<td>3</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>mean</td>
<td>127</td>
<td>18</td>
</tr>
</tbody>
</table>

Table 6: Work task activity results for each subject based on the field observations (%): Percentage of total field observation.

The resulting sEMG PC activity sequences ranged from 2-20 minutes and the “other” activity sequences ranged from 2-35 minutes. These sEMG sequences were compared to the laboratory sEMG measurement: typing (10 minutes) and editing (5 minutes). In field observations the mean percentage of PC activity was 39 and "other" activity was 61.
4.2 sEMG comparison

The sEMG comparison was completed for the three parameters: 10th-percentile, 50th-percentile and RRT.

Evaluation of zeros

To evaluate the sEMG signal an analysis of zeros were performed. Simply counting the number of zeros in the sEMG signal did this. Table 7 shows the percentage of zeros in the sEMG signals for right and left trapezius.

<table>
<thead>
<tr>
<th>Zeros in data (%)</th>
<th>Field</th>
<th>Lab: typing</th>
<th>Lab: editing</th>
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<tr>
<td></td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
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<tr>
<td>Subject 100</td>
<td>2.4</td>
<td>13.3</td>
<td>14.5</td>
</tr>
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<td>Subject 200</td>
<td>5.2</td>
<td>3.9</td>
<td>3.0</td>
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<td>Subject 300</td>
<td>70.8</td>
<td>7.8</td>
<td>9.4</td>
</tr>
<tr>
<td>Subject 400</td>
<td>12.7</td>
<td>18.2</td>
<td>3.4</td>
</tr>
<tr>
<td>Subject 500</td>
<td>16.7</td>
<td>16.6</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Table 7: An analysis of zeros in the field, Lab: typing and Lab: editing data (for the right- and left trapezius) to evaluate the sEMG signal. (%): Percentage of total sEMG signal.

10th-percentile

An analysis of the 10th-percentile was made for the nine combinations. Figure 5 shows the 10th-percentile for the combination lab versus field of the right trapezius. The percentiles are represented as a percentage of RVE, recall Ch 3.4.2: normalization. The reference contraction was set to 100. This analysis was completed in MATLAB 6.1/R12.

The result of the 10th-percentile reveled an excess of zeros in the data. Figure 5 shows four out of five subjects with a 10th-percentile of zero in at least one of the two
measurements. Further evaluation of this parameter was disregarded because of the excess of zeros. However, to further study the result of the 10\textsuperscript{th}-percentile see appendix A, figure A1 and A2.

50\textsuperscript{th}-percentile
The 50\textsuperscript{th}-percentile was analyzed and the linear graphs were plotted for the right trapezius, see fig 6, and for the left trapezius, see fig 7. The dashed straight line in the graphs represents the hypothesized model, on which the 50\textsuperscript{th}-percentile values would appear to confirm the proposed model. The graphs also present, in the upper right corner, the deviation of the 50\textsuperscript{th}-percentile value of the asterisks (the subjects) to the hypothesized model. The percentiles are represented as a percentage of RVE, recall Ch 3.4.2: normalization. The reference contraction was set to 100.

![Figure 6: The 50\textsuperscript{th}-percentile comparison of the right trapezius for the nine combinations. (n=5)](image)

Figure 6: The 50\textsuperscript{th}-percentile comparison of the right trapezius for the nine combinations. (n=5)
(\(\rightarrow\)): The dashed line represents the hypothesized model.
(\(*)\): The asterisk represents the 50\textsuperscript{th}-percentile value of a subject.

Figure 6 shows how the 50\textsuperscript{th}-percentile values of the right trapezius resemble with the hypothesized model and how the values are scattered in the graphs. The 50\textsuperscript{th}-percentile is zero for one subject in the Field- and PC activity data. Lowest deviation appears in the comparison combination: Editing versus Field. The deviation in this combination is 13.8.
Figure 7: The 50th-percentile comparison of the left trapezius for the nine combinations. (n=5)

(--) : The dashed line represents the hypothesized model.

(*) : The asterisk represents the 50th-percentile value of a subject.

Figure 7 shows how the 50th-percentile values of the left trapezius resemble with the hypothesized model and how the values are scattered in the graphs. The 50th-percentile is close to zero for three subjects in the Lab and Typing data. Lowest deviation appears when comparing Editing versus “other” activity. The deviation for this combination is 8.4.

Relative Rest Time (RRT)

Finally, the nine comparison combinations for the RRT parameter, recall Ch 3.4.2: muscle activation parameters, were analyzed and graphed. The linear graphs were plotted for the right trapezius, see fig 8, and for the left trapezius, see fig 9. The dashed straight line in the graphs represents the hypothesized model, on which the RRT parameter was hypothesized to lie. The squares in the graphs represents the RRT value calculated for a subject for the full-length field measurement sequence while the dots represents the RRT values for the 5-minute field measurement sequences, recall ch 3.4.3. Hence, the squares in the graphs are referred to as full-length RRT value and the asterisk as 5-minute RRT. The graphs also present, in the upper right corner, the deviation of the RRT value of the squares for the hypothesized model.
Figure 8: RRT comparison for the right trapezius for the nine combinations. (n=5)

(--) : The dashed line represents the hypothesized model
(□) : The squares represent the full-length RRT value for a subject
(*) : The asterisks represent the 5-minute RRT in the field measurement

Figure 8 shows how the full-length RRT values (the squares) resemble with the hypothesized model and how the values are widely scattered in the graphs. In seven of the nine combinations the majority of the full-length RRT values are located above the hypothesized model. The three combinations that compare the Editing with the three field measurements were lower than the three combinations that compare Typing with the three field measurements. Lowest deviation appeared in the combination: Editing versus “other” activity. The deviation for this combination is 21.3. The variation, the subjects’ 5-minute RRT values, is smaller and more compact below the full-length RRT value and larger and more scattered above the full-length RRT value.
Figure 9: RRT comparison for the left trapezius for the nine combinations. (n=5)

(--) The dashed line represents the hypothesized model
(□): The squares represent the full-length RRT value for a subject
(*): The asterisks represent the 5-minute RRT in the field measurement

Figure 9, uses the same notations as figure 8, shows how the full-length RRT values resemble with the hypothesized model and how the values are scattered in the graphs. In all the nine combinations the majority of the full-length RRT values are concentrated under the hypothesized model. Similar to the right trapezius, the deviation showed to be lower when comparing Editing versus Field, PC activity and “other” activity than when comparing Typing versus Field, PC activity and “other” activity. Lowest deviation appeared in the combination: Editing versus “other” activity. The deviation for this combination is 18.1. The 5-minute RRT values are equally distributed above and below the full-length RRT value and are more scattered than for the right trapezius.
5 DISCUSSION

5.1 Field observations

The field observations were necessary to find work task sequences in the sEMG data to be able to compare laboratory- and field measurements. The nine work task criteria in table 2 were established to make field observations straightforward and to find valuable work task sequences in the sEMG signal. The distribution of the work tasks varied amongst the participants. This resulted in that, for example in subject 400, 50% of the observed time was categorized as “unspecified task” while, for example in subject 500, 0% of the observed time was categorized as “unspecified task”. Overall, the criteria were well balanced for the five subjects. The criteria were established on grounds of experience from the beginning of the Master’s project and from numerous hours of video analysis from other research projects.

The length of the field observations varied greatly (41-179 minutes) which affected the work task analysis. That is, some work tasks might be left out due to the short observation. It also affected the length of the sEMG signals and the length of the work task sequences extracted from the sEMG signal. However, the work task analysis result showed a balanced distribution amongst PC activity (mean: 39% of observed time) and “other” activity (mean: 61% of observed time) among the subjects.

There is an uncertainty in the data collecting. The observations were made merely by observing the subject and at the same time taking notes of the work task and the time at which the subject performed the specific task. Some of the work tasks, PC.a and PC.b for instance, changed quickly which made it difficult to document the right time. This, however, did not affect the PC activity sequence (shortest sequence: 2 minutes) and the “other” activity sequence (shortest sequence: 2 minutes) since those were rather long compared to the more detailed work tasks (shortest sequence a few seconds long).

5.2 sEMG comparison

Comparison method

The laboratory measurement was set up to represent the subjects work situation. Consequently the hypothesized model is defined as a straight line with a slop of 1. This relationship makes the choice of residual insignificant for the deviation analysis. However, another choice of residual, instead of the perpendicular distance used in this project, could be the distance in y (the difference between the y value in the data point and y value of the hypothesized model).
10th-percentile
The results of the 10th-percentiles gave values which were constrained due to the large amount of zeros in the sEMG data. The zeros in the data are a result of one, or several, of three scenarios. Firstly, there may be an imperfect skin contact of one or several of the sEMG electrodes. Secondly, if the input signal is too large with respect to the reference the sEMG-system goes into an overflow state, which sets the signal to zero. Finally, if the zeros are randomly scattered in the sEMG signal, the signal has just been very low. An analysis of the zeros showed a high percentage of zeros in the field data, which could be caused by an imperfect connection of the electrodes. The 10th-percentile is zero for four of five subjects in all of the nine comparison combinations, which made the parameter impossible to compare. To further study the linear graphs of the 10th-percentile see appendix A, figure A1 and A2.

50th-percentile
For the right trapezius the 50th-percentiles do not resemble as well as suspected with the hypothesized model. One subject had a 50th-percentile of zero which was a result of the large amount of zeroes in the sEMG data. A visual evaluation showed no long sequences of zeros in the signal for this subject, which would be a result of imperfect connection. The deviation analysis reveals highest resemblance between the Editing task in the laboratory measurement and the field measurement (13.8). That is the Editing task best represents the 50th-percentile for the right trapezius of subjects during the field measurement.

For the left trapezius the 50th-percentiles were scattered in the graphs, recall fig 7. Three of the subjects had a 50th-percentile close to zero in the Typing data of the Lab session, these signals were visually evaluated and no long sequences of zeros were present in the data. For the left trapezius, the deviation was lowest when comparing Editing versus Field, PC activity and “other” activity. Especially low is the deviation in the Editing versus “other” activity (8.4) comparison. That is the Editing task best represents the 50th-percentile for the left trapezius of the subjects during the “other” activity (61% of the workday) in the field measurement.

Relative Rest Time (RRT)
The RRT analysis for the right trapezius gave results of the full-length RRT and the variation of RRT in the field measurement. The full-length RRT values did not resemble as well as suspected with the hypothesized model. In seven of the combinations the values landed above the hypothesized model, see fig 8. Hence, the subjects experience a higher percentage of rest in the field sEMG measurement than in the laboratory sEMG measurement. The highest deviation (36.9) was observed when comparing the Typing task versus the “other” activity indicating low resemblance in these tasks. The lowest deviation (21.3) was observed when comparing the Editing task versus the “other” activity. That is, for the right trapezius, the Editing task best represents the RRT values during “other” activity (61% of the workday) in the field measurement.

For the left trapezius the full-length RRT values did not resemble as well as suspected with the hypothesized model. In all the nine combination the values landed under the hypothesized model, see fig 9. Hence, the subjects experience a higher percentage of rest in the laboratory measurement than in the field sEMG
measurement. The highest deviation (35.3) was observed when comparing the Typing task versus the “other” activity indicating low resemblance in these tasks. The lowest deviation (18.1) was observed when comparing the Editing task versus the “other” activity. That is, for the left trapezius, the Editing task best represents the RRT values during “other” activity (61% of the workday) in the field measurement.

Overall the comparison analysis of the 50\textsuperscript{th}-percentile and the RRT suggest lowest deviation (highest resemblance) between the Editing task in the laboratory measurement and the “other” activity in the field measurement. Since “other” activity corresponds to 61% of the subject’s workday the muscle activity in the controlled Editing task best represents the majority of the muscle activity throughout the workday. Contrary to the hypothesis the results showed highest deviation (lowest resemblance) when comparing the controlled Typing task with the extracted PC activity in the field recording. This may be due to the fact that the subjects are relatively relaxed during the controlled Typing task and quite stressed in their work environment. Research shows that stress is a factor which elevates muscle activity in subjects (Sandsjö, 2004).

Sources of error
The change of the muscle fibers, during contraction and relaxation, affect the signal characteristics (frequency, amplitude etc) of the sEMG signal. Individual anthropometrics\textsuperscript{4} characteristics play a big role in the magnitude of the recording due to the differences in physical conditions such as subcutaneous fat, thickness of skin, and oil and/or hair on the surface. This occurs because the relative position of electrodes and active fibers is changed during contraction and this affects the spatial filtering characteristics of the detection arrangement. The relative movement of the electrodes and muscle fibers also affect the signal stability (De Luca, 1997). In addition, slight differences in electrodes, electrode jelly, and lead characteristics can also modify the values recorded significantly due to varying levels of electrode impedance. Therefore, calibration is conducted in the most sensitive range of the equipment to obtain meaningful information (Kumar and Mital, 1996). Other errors that one has to take into account are surrounding noise, measurement methods, signal processing, observation techniques etc.

The errors above are technical errors related to the sEMG technique. However, there are other errors such as: observation and recording. In the field observation the observer evaluated, and wrote down time periods of, different work tasks. Recording the subject with a video camera could eliminate this error. In the field recording there may be an error in the difference between the observers’ timing equipment and the time device in the sEMG recording device. In the laboratory- and field recording different electrodes were used which might introduce an error in the analysis. This could result in a different slope of the linear graphs. Using the same equipment could eliminate this error. Also, the laboratory- and field measurements are two different recordings which results in two different electrode placements. This affects the measurements since the electrodes may be placed at two different areas of the muscle. Normalization does not fully compensate for this problem. To eliminate this source of error the field recording would have to be performed in sequence with the laboratory recording without removing the equipment.

\textsuperscript{4} Medical term: the study of human body measurements especially on a comparative basis.
5.3 Recommendations for future research

Due to the low number of subjects there were no statistical tests performed in this Master’s project. To further evaluate the thesis question more subjects ought to be involved.

An EMG gap is a parameter that could be used in the comparison between the laboratory measurements and the field measurements. Veiersted et al introduced the EMG gap concept in 1990, which focus on the low-level muscle activation aspects by identifying events, “EMG gaps”, where the sEMG signal is below 0.5% of MVE for a period between 0.2-2 seconds. This parameter, however, is very similar to the RRT and was therefore discarded from this thesis (Hansson, 2000).

Another method to compare the data could be the EVA analysis (exposure variation analysis). It is a development of APDF (amplitude probability distribution function). It is, like the APDF, based on the relative occurrence of different amplitudes recorded over time. However, the occurrence is not accumulated and it has a second time axis that displays distribution of duration within each amplitude class. The result of an EVA analysis is a three dimensional plot with sEMG amplitude on the x-axis, duration of contraction (periods, s) on the y-axis and percent of total time on the vertical z-axis (Mathiassen and Winkel, 1995). However, this representation is difficult to address statistically.

One approach applied by Fjellman-Wiklund (2004) is a Principal Component Analysis (PCA). The PCA may be performed. PCA classifies the sEMG activity pattern of the subjects at a group level. It uses a mathematical procedure that performs a set of correlated response variables into a smaller set of uncorrelated variables called principal components (Johnson 1998). The first principal component accounts for as much of the variability in the data as possible and each succeeding component accounts for as much of the remaining variability as possible. By plotting the principal components that counted for most of the variance, an overview is given of how the subjects’ data differ with respect to their sEMG activity patterns. This analysis may be performed on the results from an EVA analysis (Fjellman-Wiklund, 2004).
6 CONCLUSIONS

The deviation analysis for the nine comparison combinations, of the 50\textsuperscript{th}-percentile and the RRT, suggest highest resemblance (lowest deviation) between the Editing task in the laboratory measurement and the “other” activity in the field measurement. That is; the highest resemblance appears when comparing the laboratory task, which was constructed to mentally load and stress the subject, with the majority of the workday, “other” activity represented 61\% of the field measurement. This may be due to the fact that the subjects are quite stressed in their work environment.

Contrary to the hypothesis the result showed lowest resemblance (highest deviation) when comparing the controlled Typing task with the extracted PC activity in the field recording. This may be due to the fact that the subjects are relatively relaxed during the controlled Typing task and, as suggested above, quite stressed in their work environment.

There is however a low number of medical secretaries involved in this project and no statistical tests have been performed on the data. To draw further conclusions more subjects has to be involved.
REFERENCES


“WP5B: Neck-shoulder problems in elderly workers.” A research protocol for the effects of myofeedback to alleviate pain and adverse muscle patterns, Roessingh Research and Development Enschede, The Netherlands. August 31, 2002

Appendix A

Master’s thesis, Caisa Carlzon

Figure A1: The 10th-percentile comparison of the right trapezius for the nine combinations. (n=5)
(--): The dashed line represents the hypothesized model
(∗): The asterisk represents the 10th-percentile value of a subject

Figure A2: The 10th-percentile comparison of the left trapezius for the nine combinations. (n=5)
(--): The dashed line represents the hypothesized model
(∗): The asterisk represents the 10th-percentile value of a subject
PROTOCOL
Field observations

A. Subject

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<th>Date:</th>
<th>Sub-nr:</th>
<th>Myo-system nr:</th>
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<tbody>
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<tr>
<td>Workplace:</td>
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<td>Age:</td>
<td>Gender:</td>
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<td>Dominant hand:</td>
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</table>

B. Reference sEMG registrations

**Trapezius**
Registration of test contraction (4x15s with 15s rest in-between):

Registration of rest (1x30s):

C. Field Observations

<table>
<thead>
<tr>
<th>Time</th>
<th>Work task</th>
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Inklusion och exklusion av deltagare till studien ”AFA friska”

Inclusion and exclusion of participants in the study ”AFA friska” (AFA healthy)

Följande kriterier skall kontrolleras i screeningenkäten inför deltagande i studien ”AFA friska”

- Deltagare skall ha samtyckt till deltagande (fylld i namn och adress och/eller telefonnummer på försättsblad).
- Deltagare skall arbeta minst 20 timmar/vecka (fråga 5). Arbetstidens förläggning bör vara sådan att man varje vecka arbetar minst 20 timmar (dvs. en förläggning av arbetstiden som innebär att man jobbar 40 timmar varannan vecka och 0 timmar varannan vecka utgör ett kriterium för exklusion).
- Deltagare skall ha arbetat med nuvarande eller liknande arbetsuppgifter i minst ett år (fråga 8).
- Deltagare skall ej ha haft uppehåll från sitt arbete i mer än 5 sammanhängande arbetsdagar under den senaste månaden (fråga 10).
- Deltagare får ej rapportera besvär i nacke/halsrygg eller skuldra i mer än 2 dagar den senaste månaden (fråga 12 nacke/halsrygg och skuldra).
- Deltagare får ej ha haft besvär i någon annan kroppsregion i mer än 10 dagar under den senaste månaden (fråga 12).
- Deltagare skall rapportera muskelspänning (fråga 16a) ”några gånger/vecka” eller ”en eller flera gånger/dag”.
- Deltagare som rapporterar besvär som kan påverka interventionen (exempelvis MS) exkluderas. (Fråga 11 – individuella bedömningar görs i varje enskilt fall).