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# Associations between working techniques, physical loads and psychosocial loads during VDU-work

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# List of papers

This licentiate thesis is based on the following two papers, which will be referred to by their Roman numerals.

I. Lindegård A, Wahlström J, Hagberg M, Hansson G-Å, Jonsson P, Wigaeus Tornqvist E. The impact of working technique on physical loads – an exposure profile among newspaper editors. *Ergonomics* 2003; 48:135-42.

II. Wahlström J, Lindegård A, Ahlborg G Jr, Ekman A, Hagberg M. Perceived muscular tension, emotional stress, psychological demands and physical load during VDU work. *Int Arch Occup Environ Health* (2003) 76:584-590.

# Contents

# 1 Introduction

## 1.1Visual display unit work

Interest in ergonomic problems associated with the work environment has shifted during the last two decades (especially in the last ten years) from being mainly concerned with heavy lifting and awkward postures in various industries, to focus more on new kinds of problems emanating from the massive use of information technology. The computer has become an indispensable work tool in both office work and industrial processes. In 2001 approximately 65% of the Swedish work force used Visual Display Units (VDU) to perform a great variety of work tasks. VDU-work often involves working in constrained postures for prolonged periods with few, or even no, natural breaks. The number of employees who report that they spend at least 50% of their total working hours with computer work has increased from 10% in 1989 to 35% in 2001 (72). The windows-based platform used in most applications, requires the use of a non-keyboard input device. The by far most common input device is the computer mouse. The introduction of other input devices has not so far not been very successful, thought studies have indicated that the use of alternatives might reduce the risk for upper extremity musculoskeletal symptoms (24)

## 1.2 Risk factors for musculoskeletal disorders in VDU-work

The aetiology of musculoskeletal disorders is believed to be multi-factorial. Several risk factors for upper extremity musculoskeletal disorders connected to VDU work have been recognized in numerous previous studies (10; 11; 16; 17; 28; 29; 40-42; 47; 88). These studies have indicated that non-neutral working postures (e.g. extreme wrist positions), work station design (e.g. non-adjustable work chairs and/or working tables), prolonged VDU-work, and high forces applied to the keyboard/computer mouse as well as psychosocial factors (e.g. high demands, low control), and individual factors (e.g. working technique or work style) might be risk factors, either individually or in combination, for upper extremity musculoskeletal disorders.

Recent research has also shown that mental stress can increase muscle activity during simulated VDU-work (57). An experimental study has indicated that mental stress leads to the application of increased forces to the computer mouse, increased muscle activity, and more rapid wrist movements during VDU-work (77). However, no previous studies have investigated the impact of working technique on muscular load and wrist positions/movements, nor the possible associations between psychosocial factors and working technique in an occupational setting. The main focus in this licentiate thesis was to explore the possible associations between these factors and working technique.

In order to elucidate possible pathways between different risk factors in VDU work and musculoskeletal disorders an ecological model has been proposed by Sauter and Swansson (69) (Figure 1). The model includes traditional ergonomic factors as well as biomechanical mechanisms and psychosocial and cognitive aspects of the problem.

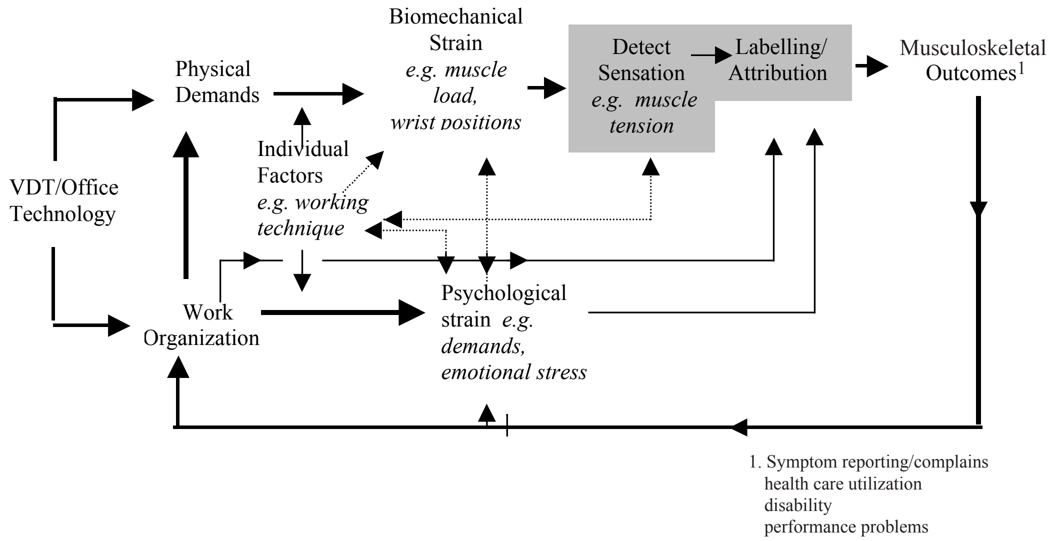


**Figure 1**. An ecological model of musculoskeletal disorders in VDU-work modified from Sauter and Swansson (69). Items in italics and broken lines/arrows indicate, respectively, factors and possible pathways explored in this licentiate thesis.

The different aspects of working technique explored in this licentiate thesis could be defined, following the model, as an individual factor with possible pathways to biomechanical strain (through higher physical loads), psychosocial strain, (through perception of high demands and high emotional stress), and muscle tension (defined in the model as a detect sensation) (Figure 1). It is likely to believe that a poor working technique might result in muscle tension but also that the perception of muscle tension may affect the working technique (elucidated by the two-way arrow). The same rationale may be applied to the two-way arrow linking psychological strain and working technique.

## 1.3 Working technique

A few authors (50; 54) have studied different aspects of working technique and their relations to musculoskeletal disorders. According to the latter study there are two basic elements that characterize working technique: the method or system of methods, and the individual motor performance used to carry out a given task. (54). In this licentiate thesis, working technique refers to the way a subject performs VDU-work (e.g. shoulder positions and the presence/absence of forearm support while working). The other element of working technique defined by Kjellberg et al. as the working method has not been considered in this licentiate thesis.

One specific element of working technique during VDU-work, working without forearm support, has shown to be related to increased muscle activity in the trapezius muscles (3; 48). However, the level of physical exposure, measured by direct measurements, in relation to observations of working technique, as well as possible interactions between working technique, psychological demands, emotional stress and perceived muscle tension in VDU-work has not been explored in earlier studies.

Work style, a similar concept to working technique has been shown, in previous studies, to bee related to frequency, intensity and duration of pain, and to functional limitations (25; 33). Factors found to be important for characterizing work-style in these studies were wrist postures, finger movements the speed/jerkiness of movements, and forces applied to the keyboard when performing VDU-work. Variables concerning psychosocial factors were also included in the definition of work style.

In exposure assessment studies, exposure has usually been measured in one of three ways: direct measurements, observation assessments, or subjective ratings (listed in general order of decreasing precision) (79; 84). Although direct measurements might be regarded as a "golden standard" for exposure assessments, there is a need for more user-friendly, less expensive and less time consuming methods in general practice (56; 90). The advantages with observation assessments compared to direct measurements include there high capacity e.g. one trained observer can often perform many assessments during a short period of time, and also the fact that many relevant factors can sometimes be evaluated at the same time. Since working technique consists of many interacting factors, observation assessments, may provide a cost efficient, and less time consuming way of evaluating exposure to poor working technique in a valid and reliable way.

### 1.4 Psychosocial factors

The most common way of assessing psychosocial exposure has been through questionnaires. A variety of instruments have been elaborated over the years. One of the most widely used instrument has been the demand-control model developed and published by Karasek and Theorell (44).

Many studies have shown that a variety of psychosocial factors, such as high job demands, weak job control and lack of social support, can lead to high perceived stress levels, manifested as both symptoms from the musculoskeletal system as well as different kinds of psychological reactions (2; 4-6; 15; 17; 20; 88).

Several models focusing on the association between psychosocial working conditions and musculoskeletal symptoms have been proposed (17; 20; 37; 69; 85). Recent research has shown that mental stress can increased muscle activity during simulated VDU-work (57). Another study has shown that mental stress also tends to increase the forces applied to the computer mouse and leads to more rapid wrist movements during VDU work (77). The associations between mental stress and physical load have so far been studied in experimental settings. The work underlying this licentiate thesis has tried to elucidate the associations between physical loads (muscular load, wrist positions and movements) and psychosocial factors manifested as perceived muscular tension, psychological demands and emotional stress during VDU work under ordinary working conditions, i.e. while the subjects performed their regular VDU-work at their ordinary workstations.

## 1.5 Physical factors

Several physical factors, such as work place layout and working postures during VDU work, have been recognized in previous studies as potential risk factors for musculoskeletal disorders (1; 28; 40; 46; 47; 67). Here, physical factors are defined as factors relating to biomechanical forces generated in the body. In the literature this has also been defined as “mechanical exposure”, to indicate that the entire work environment (e.g. lighting, noise) was not considered (87).To quantify physical loads relevant for VDU-work a variety of methods have been used. In the studies this thesis is based upon, two different methods of direct measurements characterizing physical loads were used: electromyography and electrogoniometry. When a skeletal muscle contracts an electronic signal is generated. This signal can be recorded and analyzed: a process referred to as electromyography (EMG). This method of measuring muscular activity has been used for many years in ergonomic research. Measures of muscular activity, i.e. the amplitude distribution of the muscle activity, gap frequency and measures of muscular rest have been used in earlier studies to explore the relations between muscular activity and musculoskeletal disorders (32; 64; 83). Some of these studies have found that lack of muscular gaps may be a risk factor for neck/shoulder and upper limb disorders (39; 83) but other have failed to show differences in muscular gaps between subjects with and without such symptoms (81; 86).

Extreme positions of the wrist during hand-intensive work have been considered as a potential risk factor for symptoms from the wrist and hand (59; 89). Repetitive work in general has been associated with increased risk for developing wrist and forearm symptoms (58; 65).With exposure to both extreme postures and repetitive movements, it has been suggested that the risk increases (12). In addition to measuring wrist angles, electrogoniometers could be used to measure mean power frequency, which has been proposed in the literature as a measure of repetitiveness for wrist movements (31; 91).

## 1.6 Aims

The overall aim of this licentiate thesis was to evaluate whether working techniques, were associated with physical loads, and if psychological demands, emotional stress and perceived muscular tension were related to working technique.

The specific research questions addressed were:

Did subjects who were judged to have a poor working technique, work with higher muscular loads, and/or more extended or deviated wrist postures compared to subjects judged to have a good working technique?

Did subjects who perceived muscle tension, psychological demands or emotional stress work with higher muscular loads, more repetitive wrist movements compared to subjects who did not perceive these conditions?

Did subjects who perceived muscle tension, psychological demands or emotional stress use a poorer working technique compared to subjects who did not perceive these conditions?

# 2. Subjects and methods

## 2.1 Subjects

*Study I*

The subjects consisted of all personnel in the editorial department of a daily newspaper who according to the supervisor, had largely editing-based work tasks. Altogether, 36 employees fulfilled this inclusion criteria. Two men and two women were excluded due to long-term sick leave, or temporary work at another newspaper. The results are thus based on 32 subjects: 14 men and 18 women. The mean age was 44 (range 26-57) years for the men and 42 (range 28-55) for the women. Estimated time spend with VDU-work was 83% (range 33-100) of the total working hours for the men, and 78% (range 30-100) for the women. There were 18 subjects (58%) who reported neck/shoulder and/or upper extremities symptoms on the day of the measurements. The aims and procedures of the study were presented at information meetings, and all of the subjects volunteered to participate in the study. All the participants worked with the same software program (Quark express) and all of the subjects had adjustable working chairs as well as adjustable working tables.

*Study II*

The study group in *study II* included 57 office workers (28 women and 29 men) recruited from two different organizations (the editorial department of a newspaper and an engineering department of a telecommunication company). The mean age for the whole group was 39 (range: 26-57) years, and the median duration of daily VDU use was 70% of the total working hours for the men (range 44-80) and 75% (range 60-90) for the women. There were 25 subjects (44%) who reported pain in the neck or upper extremities on the day of the measurements. In both organizations the main procedures and aims of the project were presented at information meetings and then subjects volunteered to participate in the study. All the subjects had a modern workplace layout with easily adjustable chairs and working tables. The subjects in organization 1 all used the same software (Quark express), while the subjects in organization 2 used a variety of software, depending on the actual task performed.

*Ethical considerations.* The studies described in this licentiate thesis were approved by the Ethical Committee of Göteborgs University.

## 2.2 Procedure

The subjects in both studies answered a questionnaire about personal characteristics (e.g. age, sex, height, weight.), VDU exposure (amount of work with VDU, keyboard, input device etc.), perceived muscular tension, psychological demands, and symptoms related to the musculoskeletal system. In *study I* the questionnaire was distributed on the day of the measurements and collected by the investigators.

In *study II* the questionnaires were distributed the day before and collected on the measurement day in order to save time for both the subjects and the investigators.

After collecting the questionnaires, equipment for measuring muscular load and wrist positions/movements was attached and calibrated in an adjacent room. After the calibration, the subjects were allowed to get used to the equipment by working with their regular work tasks for a couple of minutes before the actual measurements began. In both organizations the workplaces had easily adjustable working chairs and working tables and the subjects were free to choose where to place the input device and the keyboard during the measurements. The subjects then performed their ordinary work task during 15 minutes. When analysing the data, measurements obtained in the first and last minutes of each 15-minute period were excluded, so data collected over 13 minutes was used for each subject in both organizations.

### 2.3 Methods

Two different direct measurements were used in both studies to characterize physical load: EMG to characterize muscular load and electrogoniometry to characterize wrist positions and movements.

### 2.4 Direct measurements

*Muscular load*

For measuring exposure to muscular load, the muscle activity from four separate muscles (m. extensor digitorum, m. carpi ulnaris of the mouse operating hand, and pars descendent of the right and left trapezius muscle) was recorded using bipolar surface EMG (ME 3000P4; Mega Electronics Ltd, Koupio, Finland). Raw data were monitored on-line for quality control and stored on a personal computer (PC) with a sampling rate of 1,000 Hz. The electrodes for the ED and ECU were placed as recommended by Perotto (66) and those for the trapezius muscles as recommended by Mathiassen (62) (Figure 2). Self-adhesive surface electrodes (N-00-S, Medicotest A/S, Ølstykke, Denmark) were placed with a 20 mm inter-electrode distance. Before attaching the electrodes, the skin was dry shaved and cleaned with alcohol, abraded with sandpaper and cleaned with water.

Each subject performed standardized maximum voluntary contractions against manual resistance for 5 s (MVCs) to obtain the maximal voluntary electrical activity (MVE) of the ECU and the ED muscles. For the trapezius muscles, a reference voluntary contraction (RVC) was performed with a 1 kg dumbbell in each hand with the hands pronated and arms abducted 90° in the horizontal line for 15 s to obtain the reference electrical activity (RVE).

Data were analyzed with Megavin software version 1.2 (Mega Electronics Ltd; Koupio, Finland). To characterize muscular activity, the raw EMG signal was full-wave rectified and filtered, using a time-constant of 125 ms, sampling with a 12-bit A/D converter (at 1000 Hz per channel) and a 8 Hz to 480 Hz band-pass filtered (3 dB). MVE for ED and ECU was calculated using a 1 s moving average window and then using the 1 s window with the highest average EMG activity as the reference value. The RVE for the trapezius muscles was calculated using a 10 s moving average the 10 s window with the highest average EMG-activity was chosen and the mean value of the three reference contractions was used as the reference value.

The 10th percentile (p0.10) and the 50th percentile (p0.50) of the amplitude distribution were calculated for each subject and used to describe the muscular load. For analyzing gap frequency and muscular rest of the trapezius muscles, a threshold of 2.5 % RVE was chosen. The RVE corresponds roughly to a load of 15%-20% MVC (30). Thus, the gap definition of 2.5% RVE corresponds to 0.4%-0. 5% MVC. Muscular rest was defined as the summed duration of the gaps relative to the total duration of the recording. The gap duration time was set to 125 ms (30).

In *study II* the measurement from m.extensor carpi ulnaris (forearm muscle) was excluded since the main focus in *study II* was to investigate the impact of psychosocial factors on muscular load, and previously conducted studies have shown that psychosocial loads affect the central postural muscles more than peripheral muscles (e.g. forearm muscles) (75). Thus, we concluded that no additional information relevant to the aim of the study could be obtained by analysing EMG signals from the forearm muscle.

**Figure 2** The positions of the EMG electrodes

**Figure 3** The instrumented glove used to measure wrist positions and movements.

*Wrist position and movements*

A glove, equipped with two electrogoniometers, and a data logger (Greenleaf Medical, Palo Alto, CA, USA) were used to collect information on wrist positions and movements of the mouse operating hand with a sampling rate of 20 Hz (Figure 3). The instrument was calibrated at four different wrist positions: 45° extension, 45° flexion, 25° ulnar deviation and 15° radial deviation, using a modified calibration fixture (Greenleaf Medical, Palo Alto, CA, USA). The reference (zero) position was recorded with the hand fully pronated and the palm of the hand lying flat, in neutral radial/ulnar and flexion/extension positions in the calibration fixture. The data were analysed by commercially available software (GAS, Ergonomic & Research Consulting, Seattle, Wash., USA). The program calculated the angular distribution, mean angular velocity and mean power frequency of the power spectrum (MPF) for both flexion/extension and radial/ulnar deviation. MPF is defined as the center of gravity for the power spectrum and has been used as a generalized measure of repetitiveness (31). The $10^{th}$ (p0.10), $50^{th}$ (p0.50) and $90^{th}$ (p0.90) percentiles of the registered angles in flexion/extension and radial/ulnar deviation were used to characterize wrist positions.

### 2.5 Observation

*Working technique*

Working technique was assessed with an observation protocol consisting of three different parts investigating different dimensions of VDU work (36). Part one investigated work place layout, part two working technique, and part three working postures of the neck/shoulders and upper limb. The assessments were performed by an experienced ergonomist. The observer was blind regarding the symptoms and measurement results. The observation protocol was used together with a key where all variables included in the protocol were explained.

*Development of the working technique scoring system*

The working technique was characterized with a score, comprising nine different variables (Table 1). The variables were selected and scored, by an expert panel, in accordance with findings in previous scientific studies of working technique characteristics and musculoskeletal load, in combination with the empirical experience of the members of the expert panel group.

An overall working technique score (range 1-25) was calculated as the sum of the scores for the individual variables. The higher the score, the better the working technique. The arm support was observed from the input device-operating side, both when evaluating input device work and keyboard work, since there were no differences in support for left and the right forearms when performing keyboard work.

Subjects having total scores of >15 were classified as having a good working technique (n=11; 5 men, 6 women), subjects with total scores between 14-15 as having an intermediate working technique (n=10; 3 men 7 women) and subjects with total scores <14 as having a poor working technique (n=11; 6 men, 5 women). In the analysis of the differences between good and poor working techniques, the intermediate group was excluded.

**Table 1.** Variables used for classification of working technique. The score range for each item is presented. The overall score ranged between 1 and 25 (the higher the score the better the working technique).

| Item | Categories | Score |
|---|---|---|
| Support of the arms during keyboard work (score 0-5). | No support at all | 0 |
| | Proximal part of the hand | 1 |
| | Wrist | 1 |
| | Distal part of the forearm | 1 |
| | Proximal part of the forearm | 1 |
| | Elbow | 1 |
| Support of the mouse-operating arm during input device work (score 0-5). | No support at all | 0 |
| | Proximal part of the hand | 1 |
| | Wrist | 1 |
| | Distal part of the forearm | 1 |
| | Proximal part of the forearm | 1 |
| | Elbow | 1 |
| Lifting of the computer mouse (score 0-3). | None | 3 |
| | Hardly ever | 2 |
| | Now and then | 1 |
| | Frequently | 0 |
| Range of movements during input device work (score 1-3). | Small | 3 |
| | Medium | 2 |
| | Large | 1 |
| Velocity of movements during input device work (score 0-1). | Normal | 1 |
| | Fast and/or jerky | 0 |
| Type of working method during input device work (score 0-2). | Whole arm | 0 |
| | Forearm | 1 |
| | Wrist/Fingers | 2 |
| Sitting in a tense position (score 0-2). | No | 2 |
| | Yes | 0 |
| Lifting the shoulders during keyboard work (score 0-2). | Not at all | 2 |
| | Yes, sometimes | 1 |
| | Yes, most of the time | 0 |
| Lifting the shoulders during input device work (score 0-2). | Not at all | 2 |
| | Yes, sometimes | 1 |
| | Yes, most of the time | 0 |

In *study II* we used the variable "working with lifted shoulders" as a proxy for working technique in the linear regression model, since the hypothesis was that psychosocial factors might have an especially large impact on this variable. A general assumption among practitioners has been that psychosocial factors (e.g. job demands and emotional stress) often manifest themselves physically as a tendency to "lift the shoulders" during stressful situations. Studies of psychosocial factors and musculoskeletal symptoms/disorders have indicated that mental stress more often was connected with symptoms (unspecific muscle pain) in muscles in the more central parts of the body than from more peripheral muscles in the arm or forearm (76).

## 2.6 Ratings

*Psychological demands*

*In study II* central components from the model suggested by Karasek and Teorell (44) were used to assess psychological exposure. A short Swedish version of the Job Content Questionnaire (74) was used to assess psychological demands. Five questions (Does your work demand that you work fast, Does your work demand that you work hard, Does your work demand a great effort, Do you have enough time to finish the work task, Does it exist conflicting demands at your work place) were asked in organization 2, and four of the questions (excluding the question about working hard) in organization 1, with specific reference to psychological demands during the preceding month. The response scale comprised four categories for each question: often, sometimes, seldom or never. For each subject, a median response (often, sometimes, seldom or never) was calculated. The group was then dichotomized. Subjects with a median response of "often" or "sometimes" were classified as having high psychological demands, and subjects with a median response of "seldom" or "never" were classified as having low psychological demands.

*Emotional stress*

An adjective checklist (51; 52) was used to assess emotional stress during the day of the measurements. The dimension stress comprises six items, three positively loaded, and three negatively loaded. The responses for the positively loaded items were inverted before a median response was calculated.

The following positively loaded items were included in the stress dimension: "rested", "relaxed" and "calm". The negatively loaded items were "tense", "stressed" and "pressured". The response scale comprised six categories for each adjective: very much, much, fairly, somewhat, almost not or not at all. For each subject a median response was calculated. The variables were than dichotomized; subjects with a median response of "fairly" to "very much" were classified as having high emotional stress, and subjects with a median response of "somewhat" to "not at all" were classified as having low emotional stress.

*Perceived muscular tension*

One of the questions from the questionnaire, "Have you during the past month experienced muscle tension (i.e. wrinkled your forehead, ground your teeth, raised your shoulder)?, was used to characterize muscle tension. The response scale comprised four categories: never, a few times, a few times per week, one or several times per day. The data were used to split the subjects into two groups: a high-tension group (experiencing tension a few times per week or once to several times per day) and a low-tension group (experiencing tension never or a few times).

## 2.7 Statistics

In *study I* descriptive data from measurements of muscular load (EMG) were presented as means with standard deviations (SD), and as medians with 25$^{th}$ and 75$^{th}$ percentiles. Goniometry data were presented as means and standard deviations (SD). All comparisons of independent groups were made with Wilcoxon´s Rank Sum tests for ordinal data and Fischer's exact two-tailed tests for nominal data. The statistical significance level was set to $p \leq 0.05$. All statistical analyses were performed using the statistical software JMP version 4.0.2. (SAS institute Inc., Cary, NC, USA).

In *study II* descriptive data were presented as medians and range, or as means and standard errors of the means (SEM). A multivariate linear regression model was used to analyze how psychological demands, perceived tension, emotional stress, organization and sex influenced the physical loads. The explanatory variables included in the model were decided *a priori*. The binary dependent variable *working technique* was analyzed with a logistic regression model with the same explanatory variables as described for the multivariate models.

Age and present musculoskeletal symptoms were accounted for in both the linear and logistic regression models. For analyzing differences in working technique, scores between subjects with perceived psychological demands, emotional stress and muscle tension, t-tests and Wilcoxon´s Rank Sum tests were used. All statistical analyses were performed with SAS statistical software, version 8.0 (SAS Institute, Cary, N.C., USA) and software JMP version 5.0.1. (SAS institute Inc., Cary, NC, USA). Statistical significance was set to $p \leq 0.05$.

# 3 Results

## 3.1 Working technique

Forearm support, when operating the input device, lifting of the input device and range of movements with the input device were the most important items differentiating a good working technique from a poor working technique (Table 2).

**Table 2** Score for each item for the two working technique groups. Median values and range (in brackets) are presented for each group.

| Observed item | Good Working technique (n=11) | Poor Working technique (n=10) |
|---|---|---|
| Support of the arms during keyboard work (score 0-5) | 0 (0-3) | 0 (0) |
| Support of the mouse-operating arm during input device work (score 0-5) | **3 (2-5)** | **1 (0-3)** |
| Lifting of the computer mouse (score 0-3) | **3 (2-3)** | **2 (0-3)** |
| Range of movements during input device work (score 1-3) | **3 (2-3)** | **2 (2-3)** |
| Velocity of movements duning input device work (score 0-1) | 1 (1-2) | 1 (0-1) |
| Type of working technique duning input device work (score 0-2) | 2 (1-2) | 2 (0-2) |
| Sitting in a tense position (score 0-2) | 2 (0-2) | 2 (0-2) |
| Lifting of the shoulders during keyboard work (score 0-2) | 2 (1-2) | 2 (1-2) |
| Lifting of the shoulders duning input device work (score 0-2) | 2 (1-2) | 2 (1-2) |

## 3.2 Working technique and physical loads

*Muscular load*

Subjects judged to have a good working technique tended to have lower levels of muscular activity in all measured muscles, with significant differences between them and subjects with poor working technique for the trapezius muscle on the mouse operating side (p0.10=0.02) (Figure 4), and for the forearm muscle ECU (extensor carpi ulnaris) (p0.50=0.03) (Figure 5).

Moreover, subjects with good working technique also tended to have more muscular rest in the mouse operating trapezius muscle than subjects who used a poor working technique, although these results were not statistically significant (p=0.09). The results also indicated that subjects who used a good working technique tended to report fewer symptoms from the neck/shoulder and upper limb than subjects using a poor working technique (p=0.08).

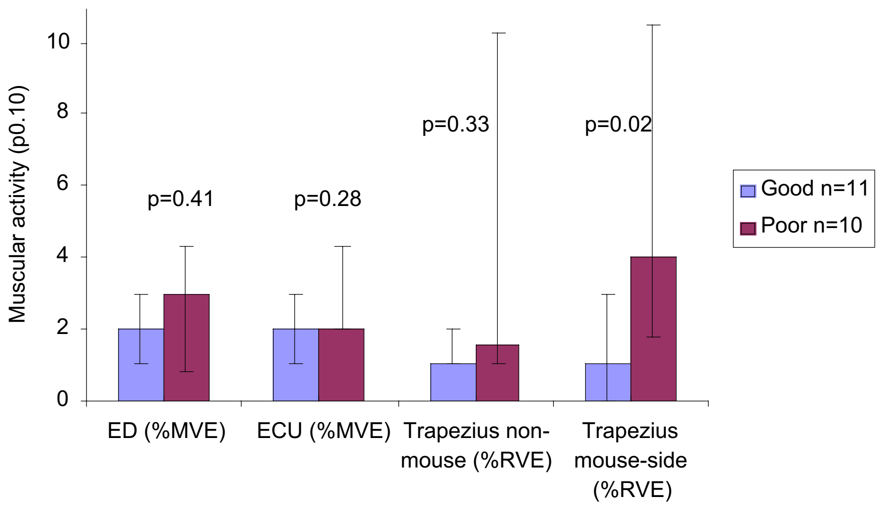


**Figure 4.** Muscular activity for the 10th percentile (medians, 25th p and 75th p) showing that activity tended to be higher in all measured muscles except ECU in the poor working technique group compared with the good working technique group and there was a significant difference between the groups for the trapezius muscle on the mouse operating side (p=0.02).

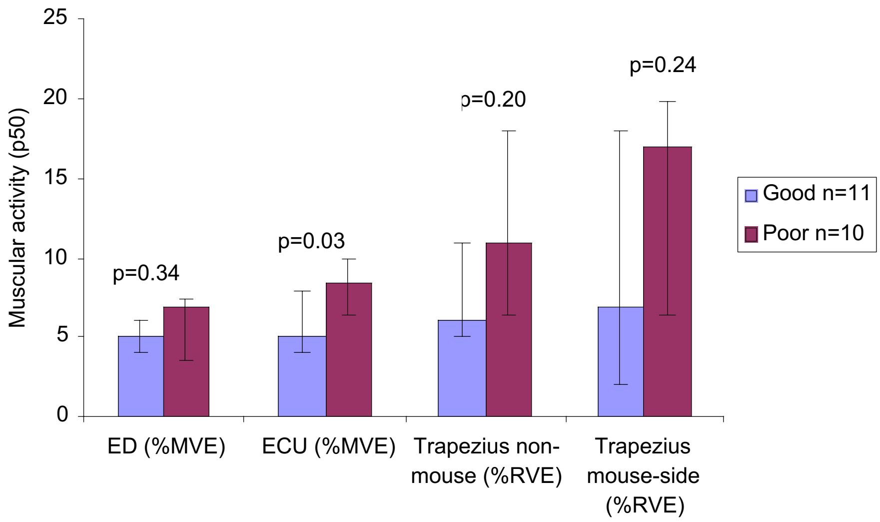


**Figure 5.** Muscular activity for the 50th percentile (medians, 25th p, 75th p) showing that activity tended to be higher in all measured muscles in the poor working technique group compared with the good working technique group, and there was with a significant difference between the groups for the forearm muscle ECU (p=0.03).

*Wrist positions and movements*

Regarding wrist positions and movements, subjects with good working technique worked with less extension in the wrist (p0.10, p=0.04) than subjects with poor working technique *(study I)*. Moreover, subjects with good working technique had a tendency to work with less ulnar deviation than subjects with poor working technique, although these results were not statistically significant (Figure 6).

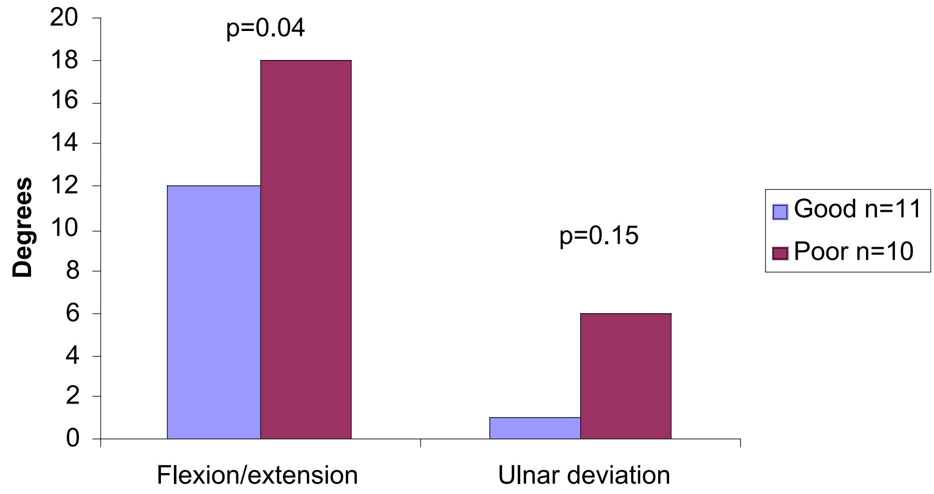


**Figure 6.** Mean values for wrist positions in the 10th percentile (p0.10) for the two working technique groups.

In *study II* we analyzed repetitive movements in the wrist in relation to muscular tension, emotional stress and psychological demands and found no associations between repetitive movements (characterized by mean power frequency) and perceived muscular tension, emotional stress or psychological demands.

### 3.3 Psychosocial factors and physical loads

In *study II* a higher muscle activity in the non-mouse operating m.trapezius was associated with both high emotional stress and high perception of muscle tension (8%RVE p=0.006) and (5% RVE p=0.05, respectively), when we controlled for all explanatory variables in the multivariate model. Subjects who reported high perceived muscle tension, also had higher muscle activity in the trapezius muscle on the mouse operating side (P=0.05) Descriptive data are presented in Table 3. The explained variance ($r^2$) in the models was 0.29 for the non mouse-operating trapezius muscle, and 0.13 for the trapezius muscle on the mouse-operating side. The inclusion of age and ongoing musculoskeletal pain did not change the results. The relative duration of muscular rest in the trapezius muscles was lower for subjects who perceived muscle tension at least a few times per week (Table 3).

### 3.3.Working technique and psychosocial factors

Subjects reporting high psychological demands and high emotional stress, worked with lifted shoulders more often than subjects reporting low psychological demands and low perceived emotional stress, respectively (Table 4).

When using the scoring system for working technique, described in table 1, the results showed that subjects reporting high psychological demands and high muscular tension worked with poorer working technique than did subjects with low demands and no perception of muscular tension, respectively (p=0.03 and p=0.02) (Figure 7 and Figure 8). There were no major differences in working technique scores between subjects with high and low perception of emotional stress.

**Table 3** Mean (SEM) of the different variables used to characterise the physical load, grouped by the different explanatory variables used in the linear regression models.

| **Response** | **Explanatory variables** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Muscular tension** | | **Emotional stress** | | **Psychological demands** | | **Organisation** | | **Sex** | |
| | No (n=26) | Yes (31) | Low (45) | High (11) | Low (23) | High (34) | 1 (32) | 2 (25) | Men (29) | Women (28) |
| Muscle activity (%RVE), Trapezius mouse-side | 6.8 (1.6) | 12.1 (1.4) | 9.2 (1.2) | 12.2 (3.1) | 8.9 (1.7) | 10.3 (1.4) | 10.9 (1.5) | 8.1 (1.5) | 9.5 (1.7) | 9.9 (1.4) |
| Muscle rest (% time), Trapezius mouse-side | 20.6 (3.4) | 13.6 (3.0) | 16.3 (2.5) | 18.1 (6.0) | 17.0 (3.7) | 16.7 (2.9) | 16.0 (3.1) | 17.8 (3.5) | 17.3 (3.2) | 16.3 (3.3) |
| Muscle activity (%RVE) Trapezius, Non-mouse side | 5.2 (1.0) | 11.3 (1.9) | 6.6 (0.9) | 16.3 (4.3) | 6.1 (1.3) | 10.2 (1.8) | 9.0 (1.5) | 7.9 (2.0) | 8.4 (1.5) | 8.6 (1.9) |
| Muscular rest (% time) Trapezius non-mouse side | 22.1 (3.4) | 13.6 (2.7) | 19.4 (2.5) | 9.3 (3.8) | 21.8 (3.9) | 14.4 (2.4) | 16.5 (3.0) | 18.8 (3.2) | 18.4 (3.3) | 16.6 (2.9) |
| Muscle activity (%MVE), Extensor digitorum | 6.0 (0.42) | 5.9 (0.38) | 6.0 (0.32) | 5.5 (0.61) | 5.8 (0.32) | 6.0 (0.42) | 5.7 (0.37) | 6.3 (0.42) | 5.5 (0.44) | 6.4 (0.33) |

**Table 4** Relative frequencies (%), (absolute numbers in brackets) of subjects who worked with lifted shoulders amongst (a) subjects who perceived muscle tension, emotional stress and psychological demands, respectively, and (b) who did not.

| **Response** | **Explanatory variables** | | | | | |
|---|---|---|---|---|---|---|
| | Muscular tension | | Emotional stress | | Psychological demands | |
| | No (n=26) | Yes (n=31) | Low (n=45) | High (n=11) | Low (n=23) | High (n=34) |
| Lifted shoulders | | | | | | |
| No (n=40) | 69 (18) | 71 (22) | 78 (35) | 45 (5) | 78 (18) | 65 (22) |
| Yes (n=17) | 31 (8) | 29 (9) | 22 (10) | 55 (6) | 22 (5) | 35 (12) |

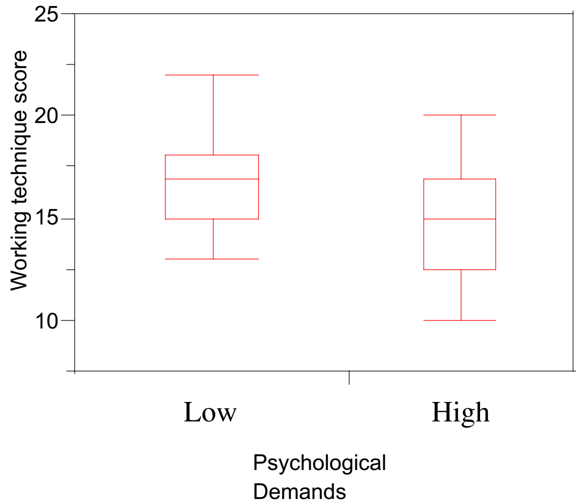


**Figure 7.** Working technique scores (high score=good working technique) for subjects with low and high psychological demands. The median, 25$^{th}$p and 75$^{th}$ p and inter quartile range are presented.

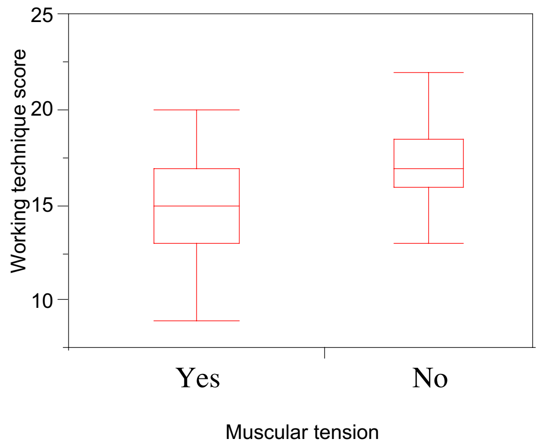


**Figure 8.** Working technique score (high scores=good working technique) for subjects who perceived muscle tension compared to those who did not. The median, 25$^{th}$p and 75$^{th}$ p and inter quartile range are presented.

# 4 Discussion of the results

The results from both *study I* and *study II* showed low levels of muscular load in general compared with results from earlier studies of other occupational groups performing repetitive work tasks e.g. material handling work (7; 32). However, they were consistent with previous studies on computer mouse work both in field studies and in experimental laboratory settings (19; 45; 48; 78).

### 4.1 Working technique and physical factors

Poor working technique, along with poor work place layout, constrained and/or extreme postures and different types of psychosocial risk factors (i.e. mental stress, and/or high psychological demands) have been recognized in previous scientific studies as factors that might have an impact on both exposure and future musculoskeletal health during intensive VDU-work (2; 6; 17; 28; 29).

The results from *study I* showed that subjects judged to have a good working technique had lower levels of muscular load in the forearm muscles and in the trapezius muscle on the mouse-operating side than subjects with a poor working technique.

The analysis of gaps and muscular rest, on the other hand showed no statistically significant differences between subjects with good working technique compared to subjects with poor working technique, although there was a tendency for the former to have more muscular rest (p=0.09).

Regarding EMG gap frequency, there were no major differences between the two working technique groups. Some studies have found no statistical differences in EMG-gaps between subjects with and without symptoms (81; 86), while others have shown that lack of gaps may be a risk factor for neck and upper extremity disorders (39; 82).

Muscular rest and gap frequencies have previously been explored among cleaners and office workers (64). The cleaners in the study by Nordander and co-workers had a high risk of neck/shoulder pain, and much less muscular rest than office workers (median value of muscular rest time for the cleaners and office workers were 1.5% and 12%, respectively). In the same study there were no significant differences in gap frequency between the two occupational groups. Among the office workers, low values of muscular rest and high gap frequencies were registered in subjects with a low subjective tendency to experience muscular tension. These findings, together with the results from our study, where subjects with a poor working technique were found to have lower values of muscular rest than subjects with good working technique implies that muscular rest could be a more suitable measure to use than gap frequencies regarding VDU-work.

Results from *study I* showed that a good working technique compared to poor was associated with less extension in the wrist. Previously conducted studies on wrist positions and finger movements have indicated that extreme wrist extension is associated with a risk of developing carpal tunnel syndrome, as well as forearm pain during repetitive work (e.g.VDU-work) (21; 49). According to these results it may be relevant to focus on working technique training in ergonomic interventions concerning office work in general and VDU-work in particular.

### 4.2 Working technique and psychosocial factors

In *study II,* when analyzing the data using a proxy for working technique (lifted shoulders) the results suggested that both emotional stress, and psychological demands may be associated with working technique. Subjects who reported high psychological demands and emotional stress more often worked with lifted shoulders (poor working technique) than subjects who did not report these conditions. The reason for choosing just one of the variables contributing to the working technique score to characterize working technique in *study II,* was that we considered *a priori* lifted shoulders to be the most important factor in the score reflecting the reactions to mental loads. This decision was based on clinical experience and clinical findings in patients suffering from stress-related disorders. Musculoskeletal pain is commonly localized in the trapezius muscles of subjects reporting high levels of work-related stress, and it seems likely that this could be related to habitually lifting the shoulders. Studies have previously found an association between upper limb disorders and psychosocial factors (4; 6; 17; 18).

Using the score for working technique, instead of a single-item characteristic, the results showed that subjects reporting high psychological demands and perceived muscular tension used a poorer working technique than did subjects with low demands and no perception of muscular tension, respectively. No major differences were seen in working technique among subjects with emotional stress compared to subjects without emotional stress. Similar studies from Westgaard and colleagues have observed an association between “perceived general tension” (which can be regarded as similar to the definition of muscle tension used *study II*) and pain in the neck/shoulder area (34; 35; 80). In contrast other studies from the same research group have failed to show such an association (8; 9). However, a recently published study by Holte et al. has demonstrated that there is an association between muscle activity in the trapezius muscle and hourly tension in an intra-subject comparison of low-tension and high-tension periods during a working day (34).

### 4.3 Psychosocial and physical loads

Perceived emotional stress during the measurements was associated with higher muscle activity in the trapezius muscle on the non-mouse-operating side. A previous study on cashiers in a supermarket has found a correlation between muscular load during work and ratings of stress together with a stronger correlation for the left side than for the right side (68). A possible explanation for the findings that the differences were more pronounced for the non-active trapezius muscle could be that the active side, besides being influenced by different kinds of stress, is also exposed to physical loads that might “mask” the effects of the psychosocial loads.

## 4.4 Working technique and musculoskeletal disorders

Several hypotheses have been proposed for the pathogenesis of work-related musculoskeletal disorders in connection with low static muscle contraction levels. (38; 43; 55; 70). In VDU-work one possible mechanism responsible for musculoskeletal symptoms could be prolonged use of input devices in constrained postures, in combination with active contraction in the neck and shoulder muscles, as well as in the forearm muscles. Since the results from *study I* showed that using a poor working technique was associated with increased muscle activity and more extreme wrist postures than a good working technique, subjects with poor working technique would be more disposed to musculoskeletal symptoms in the upper extremity than subjects with a good working technique. The results from *study I* also indicated that subjects judged to have a good working technique had less ongoing symptoms upper extremity symptoms than subjects with a poor working technique. One could argue that having symptoms might result in a change of working technique, but even so, it seems unlikely to believe that subjects with symptoms would apply a poorer working technique, since that would probably increase the load and symptoms. The findings rather indicate that poor currant poor working technique contribute to the symptoms.

Using a certain working technique could be characterized as a habitual behaviour pattern, and such behaviours are according to the literature difficult to change. A study by Gerr et al. has showed that VDU-users seldom work in the recommended neutral positions and moreover, that they seldom change the positions in the neck/shoulder or wrists (29).

In the model of musculoskeletal disorders and VDU work proposed by Sauter et al. (Figure 1), it is assumed that individual factors is a pathway to physical demand which might result in biomechanical strain leading to musculoskeletal symptoms/disorders (69). In accordance with the model, working technique might be one individual factor that is important to consider, since results from this licentiate thesis have shown that there is a pathway between working technique and physical loads, and moreover, that high emotional stress and perception of high muscle tension adversely influenced the working technique. These findings suggest that the model should be modified by including new and direct pathways between psychological strain (emotional stress) and individual factors (working technique) and between detect sensation (muscle tension) and working technique. It seems likely to believe that the pathways operate in both directions. A shortcoming of this model is that factors outside work, such as home life factors and productivity are not included in the model. These factors might be important factors to consider in further modifications of the model.

## 4.5 Development of the working technique scoring system

In the literature various ways of defining working technique has been presented. Some previous studies have used the term “work-style”, defined as an individual pattern of behaviours, cognitions and physiological reactions to work factors while performing different tasks. Variables such as wrist positions, hand/finger movements and speed/jerkiness of movements have been included in these definitions. It has been suggested that individual variations in work style may have an impact on the development of upper extremity musculoskeletal disorders. (26; 27).

In a study by Kjellberg et al., the concept of working technique was divided into two elements: method and individual performance (54). According to this definition, the score for working technique used in this licenciate thesis might be defined as the individual performance of a VDU working task. The main focus for developing the working technique scoring system was to characterize individual movement patterns in a structured way, based on findings in scientific literature and empirical experience of physical risk factors.

The decision to use a multi-variable working technique scoring system, instead of a single variable to characterize each individual's way of performing VDU-work, was based on the hypothesis that loads applied to the forearm, wrist and hand/fingers also affect the loads applied to the neck/shoulder during such work. A previous study measuring muscle activity in the forearm (stereotyped finger activity and computer mouse work) has shown that co-activity was generated in the contra lateral forearm (the non-mouse operating side) during finger movements in the mouse-operating side (71). Another study on the effects of precision and force demands on muscular load showed that the load in postural muscles with stabilization functions increased during precision work with the hand/fingers (63).

The method of using a score for evaluating working technique should in general be regarded with care for several reasons. Adding the scores for different items into an overall score might be criticized since the ordinal level of the data in traditional statistics does not permit additions (73). Nevertheless, this way of treating ordinal data is very common in health sciences. Since we are not fully aware of the importance of each variable, regarding the risk of developing musculoskeletal disorders, the score given to each variable was a crude estimate and based on empirical experience and the assumed potential magnitude of each risk factor. Another possible disadvantage could be that identical scores could have different profiles, but since the observation protocols containing specific information concerning each variable it was always possible to go back to "the source" if necessary.

The method of calculating a score from different items has not been frequently used by other researchers, although some intervention studies, have used observation protocols for assessing variables, such as workplace layout, working postures and psychosocial factors and analyzed the effects of the interventions separately for each variable (22; 23).

Other studies have used single items such as use of forearm support to characterize working technique in computer work and found lower muscular activity in the trapezius muscle for subjects working with forearm support compared to subjects working without or with less forearm support (3; 45). When analysing the importance of each variable included in the working technique scoring system, forearm support turned out to be one of the most important factors for differentiating a good working technique from a poor working technique.

An important aspect of working technique to include in a future and extended version of the working technique scoring system is the break pattern among VDU-workers, since the duration of intensive VDU-work with few breaks, have shown to be related to increased risk of developing upper extremity musculoskeletal disorders (40).

### 4.6 Methodological considerations and limitations

In order to ensure good reliability we constructed a key for each variable in the observation protocol, where we described in detail how to interpret and evaluate each variable. We also trained the observers until good agreement was reached before they were allowed to take part in the studies. Some of the items included in the score are more difficult to judge than others (i.e. fast and jerky movements) and reliability problems might occur, but with relevant training of the observers in combination with the use of the key, this risk may be reduced substantially.

Recently published studies have indicated that it is possible to improve accuracy in observations by training the observers (14). However, another study on inter-observer reliability found considerable inconsistency between observers judging ankle motions of the same subject (92). None of these studies used an evaluation key, and it seems likely to believe that the use of such a key would have improved both the validity and the reliability. Concerning the reliability of the working technique scoring system used in our studies, there are reliability tests in progress, but no definite results are available yet.

The validity of observation assessments has been questioned in the scientific literature. In comparison with direct measurements, observations have often been regarded as “a second best choice”. However, since the aetiology of upper extremity disorders, is to a great extend unknown, and accordingly we do not have a direct measurement that we could consider as “golden standard” the use of observations instead of technical measurements for characterizing exposure to poor working technique in relation to musculoskeletal disorders might be quite as good. A study of validity for an observation method concerning joint angles and movement speed in relation to three-dimensional instrumental analysis has showed that experienced physiotherapists were able to accurately and reliably judge kinematic aspects of upper limb movements (13). To assess the predictive validity of the working technique score longitudinal studies are needed.

Another problem relevant to discuss is the length of the observation and measurement time in exposure assessments. The question that arises is whether it is possible to characterize the working technique used during a whole working day on the basis of measurements and/or observations conducted over just 15 minutes. Previous studies have indicated that it might be possible, due to the fact that the work postures among VDU-users did not change much over time and could be characterized by a single measurement (29; 60). According to the same study, the intra-subject variability of the postural measures was smaller than the between-subject variability of the postural measure. Furthermore, the measures were stable over time (29). Other studies, in contrast have proposed that long observation period, is needed to characterize working technique (53). These studies were related to lifting and manual handling tasks a more complex combination of movements with more variation over time than VDU-work.

Concerning conclusions drawn from EMG measurements covering a short periods of time, different opinions have been expressed in the literature, but most studies point out, that measurements over a long period of time and repeated measurements, are preferable to characterize muscular activity in repetitive work tasks (32; 61; 64).

Another potential problem is the fact that VDU-workers cannot be considered as a homogeneous and well-defined group of workers. VDU work consists of a great variety of different work tasks, demanding different kind of skills from the operator. It is likely to believe that different work tasks generate different levels of both physical and psychosocial loads. In *study I* the study group consisted of a well-defined group of VDU-workers (editors) performing the same work tasks with the same computer program while in *study II* approximately 40% of the subjects had much more variation in work tasks. Of course, this can be regarded as a problem in all kinds of research concerning VDU-work, and can only be eliminated by well-designed studies on well-defined groups of VDU-workers performing a few well-defined work tasks.

# Conclusions

### General conclusion

Working technique during VDU-work is associated with both physical and psychosocial loads.

### Specific conclusions

In the present study:

- Subjects, using a poor working technique had higher muscular loads in their mouse-operating trapezius muscle and in the forearm muscle (ECU), and worked with a more extended wrist compared to subjects with a good working technique.
- Subjects, who perceived muscle tension or emotional stress had higher muscle activity in their non-mouse operating trapezius muscle than subjects who did not perceive these conditions. Moreover, subjects who reported high levels of perceived muscle tension, had higher activity in their trapezius muscle on the mouse-operating side compared to subjects who did not perceive these conditions.
- Subjects who perceived muscle tension or psychological demands used a poorer working technique than subjects who did not perceive these conditions.

# Summary

Lindegård Andersson A (2004) *Associations between working techniques, physical and psychosocial loads during VDU work.* Arbete och Hälsa 2004:5, National Institute for Working Life, Stockholm.

The overall aim of this licentiate thesis was to evaluate whether working technique was associated with physical loads and psychosocial loads during VDU work. The thesis is based upon two separate field studies, conducted in two different organisations, one at the editorial department of a daily newspaper, and one at a department for engineering in a telecommunication company.

To investigate physical loads two methods were used 1) electromyography for measuring muscular activity and 2) electrogoniometry for measuring wrist postures and movements. Psychological loads (psychological demands, emotional stress and perceived muscle tension) were measured with questionnaires. Observations and evaluations of working technique were made, according to an observation protocol.

The results indicated an association between working technique and both physical and psychosocial loads. In *study I* subjects working with a poor working technique had higher muscle activity in the trapezius muscle on the mouse operating side, and in the forearm muscle. Moreover subjects using a poor working technique worked with more extended wrist than subjects using a good working technique. In *study II* higher muscular activity (trapezius non–mouse side) was associated with emotional stress and perceived muscle tension, respectively. Perception of high muscle tension and high psychological demands, respectively, were associated with poor working technique.

In conclusion, the results showed that working technique during VDU work has an impact on physical loads, and moreover, the results indicated an association between working technique and psychosocial loads.



Keywords: computer work, musculoskeletal disorders, working technique, physical load, psychosocial load.

# Sammanfattning (Summary in Swedish)

Lindegård Andersson A (2004) *Sambandet mellan arbetsteknik, fysiska och psykosociala faktorer vid datorarbete.* Arbete och Hälsa 2004:5, Arbetslivs-institutet, Stockholm.

Det övergripande syftet med denna licenciat avhandling var, att undersöka möjliga samband mellan arbetsteknik, fysisk, samt psykosocial belastning vid datorarbete.

Licenciat avhandlingen bygger på två separata fältstudier, utförda dels på en redigeringsavdelning på en dagstidning, och dels på en teknisk utvecklingsavdelning på ett telekommunikations företag.

För att undersöka fysisk belastning, använde vi oss av två metoder 1) elektromyografi för att mäta muskelaktivitet, samt 2) elektrogoniometer för att mäta handledsvinklar och handledsrörelser. Den psykosociala belastningen mättes med frågeformulär. Arbetsteknik bedömdes med hjälp av ett observationsprotokoll.

Resultaten visade på ett samband både mellan arbetsteknik och fysiska faktorer, samt mellan arbetsteknik och psykosociala faktorer. I *Studie I* fann vi att personer som bedömts arbeta med en dålig arbetsteknik hade högre muskulär belastning i trapeziusmuskulaturen på den sida som hanterade datormusen, samt i underarmsmuskulaturen. Vidare fann vi att personer med dålig arbetsteknik arbetade med större handledsextention än personer med god arbetsteknik. I *studie II* visade resultaten att hög muskel aktivitet i trapeziusmuskulaturen (icke datormussidan) hade samband med hög emotionell stress och/eller hög grad av upplevd muskelspänning. Dessutom visade resultaten att höga krav och hög muskelspänning, var för sig, var associerade till dålig arbetsteknik.

Sammanfattningsvis visar dessa studier att den fysiska belastningen vid datorarbete påverkas av arbetsteknik, samt att psykosociala faktorer (höga krav, upplevelse av hög muskelspänning samt emotionell stress) har samband med arbetsteknik.

Nyckelord: datorarbete, muskuloskeletala sjukdomar, arbetsteknik, fysisk belastning, psykosocial belastning.

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