Characteristics of Muscular Load in Computer Data Entry Workers Assessed by EMG and Postural Angles

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The goal of this study was to characterize the muscular load in computer data entry workers. Electromyography (EMG) parameters of trapezius muscle and postural angles of head, arm, and back were chosen as indicators of musculoskeletal load. The examination was done according to the methods and protocol of international MEPS studies (the “Musculoskeletal, Visual, and Psychosocial Load in VDT [Video Display Terminal] Operators in Optimized Environment” international program). The musculoskeletal load during routine VDT data entry work performed by a group of 36 women was assessed on the basis of 1-hr physiometer recordings. Results show that the musculoskeletal load associated with data entry is relatively high compared to other VDT operators' tasks described in the literature. An analysis of the measured parameters shows that most of the time women worked with a muscular load higher than optimal. It is postulated that the main reason for the heavy musculoskeletal load was improper posture compelled by unergonomic spatial configuration of work stands.

1. INTRODUCTION

Several studies have shown that there is a high risk of developing musculoskeletal injury, not only in traditional industrial employment but also in connection with the computerization of office work (Bjelle, Hagberg, & Michaelsson, 1979; Hunting, Laubli, & Grandjean, 1980b; Maeda, 1977). Studies by Aaras (1990) have shown that many people performing manual handling work complain about pain located in the trapezius area. Medical examinations conducted in his studies confirmed disorders in this part of the musculoskeletal system.

Other studies (Andersson 1984; Maeda, Hunting, & Grandjean, 1980; Westgaard & Aaras, 1984, 1985) have shown that there is a relation between stressful postures at work and functional disturbance, or pain, in various parts of the musculoskeletal system.

As a consequence of imposed posture and a high repeatability of movements, the video display terminal (VDT) data entry operators' work is associated with a high risk of musculoskeletal disorders in the shoulder-neck and back areas (Hagberg & Wegman, 1987).

Studies, the results of which are presented in this article, were conducted as a part of the “Musculoskeletal, Visual, and Psychosocial Stress in VDT Operators in Optimized Environment” (MEPS) international project, addressing a broad spectrum of problems associated with VDT operators' working environment.

In this article, we present an assessment of musculoskeletal load associated with VDT data entry work. Electromyography (EMG) data from selected muscle groups and body motion recordings are often used to assess the magnitude of workload (Aaras & Westgaard, 1987; Corlett & Manenica, 1980; Hunting, Grandjean, & Maeda, 1980a). The trapezius muscle...
participates in the movement of arm and neck by supporting the gleno-humeral joint, and it takes part in the movement and stabilization of the scapula. Therefore, its EMG is often used to investigate musculoskeletal load during work conducted in sedentary conditions (Christensen, 1986; Lannersten & Harms-Ringdahl, 1990).

In this study, the EMG signal parameters of trapezius muscle and postural angles of arm, back, and head were used as indicators of musculoskeletal load.

2. METHOD

2.1. Participants
Thirty-six women employed as full-time data entry operators in Statistical and Telkom Offices were examined. The average age of this group was 32 (range: 22–44 years). The women had been working with VDT for an average of 6 years and 8 months (1 year and 2 months to 13 years).

2.2. Task
The main task of the women was to read figures from sheets of paper and to type them on the keyboard. The operators turned the sheets of paper with their left hand and operated the numerical keypad with the right hand. The women worked in a sitting position slightly turned to the left. The head was bent and rotated to the left side. They hardly ever looked at the screen. In many cases, women worked without arm support.

2.3. Procedure
The musculoskeletal load during work was assessed on the basis of 1-hr recordings registered during standard VDT work assignments. The recordings were performed by means of a physiometer (a portable computerized apparatus to measure and process electromyography and postural angle signals) produced by Premed from Norway. A description of the physiometer can be found in Aaras (1987) and Aaras and Stranden (1988).

2.3.1. EMG of the Right Trapezius Muscle
Muscular activity was recorded using bipolar surface electrodes. The electrodes were placed along the fiber stretched over the descending part of the right trapezius muscle. The interelectrode resistance was kept below 8 kΩ.

The EMG signal was expressed as a percentage function of the maximum voluntary contraction (% MVC) of trapezius muscle.

A calibration platform equipped with two adjustable slings was used for the force-EMG calibration procedure. The slings contained force transducers that served to measure the magnitude of the pulling force. The participant stood on the platform with both arms hanging down and pulled the sling handles. The calibration procedure had to be performed by smooth pulling of the handles using shoulders (without flexion in the elbow joint). The participant observed the force and EMG signals on the screen. When the pulling was too jerky, it had to be repeated.

Muscle load was quantified in terms of cumulative amplitude distribution function. Static, median, and peak levels of the load were determined on the basis of probability distribution function of the RMS (root mean square) signal (Ericson & Hagberg, 1977; Hagberg, 1979). The static, median, and peak levels (SL, ML, and PL, respectively) were defined as load levels corresponding to the probability of 0.1, 0.5, and 0.9, respectively, which means that the women worked below a certain load level.

Parameters connected with the frequency and duration of work below the specific levels of load (2% and 5% MVC) were also assessed.
2.3.2. Postural Angles
Postural angles were assessed by continuous recordings of angular displacement of the right upper arm, head, and back. Displacements of the upper arm in the gleno-humeral joint were measured in two planes (flexion/extension and abduction/adduction). Changes in head and back position were measured in terms of the flexion/extension and sideways movements. The postural angles were classified in a manner similar to that used for the EMG signals (i.e., static, median, and peak posture levels of angles). The levels were calculated as part of the standard output of the physiometer.

The calibration procedure for determination of the angles was performed by setting up a zero angle at the reference body position. The reference body position was defined as standing in the upright position with shoulders relaxed and both arms loosely hanging down.

3. RESULTS

3.1 EMG Activity of the Trapezius Muscle
Median values of SL, ML, and PL determined on the basis of the EMG recordings were 3.1%, 10.7%, and 19.5% of MVC, respectively (Figure 1).

Figure 1 also shows the admissible and permissible load levels specified by Jonsson (1982) and Bjorksten and Jonsson (1977). Half of the examined group (18 women) worked above the arithmetic median values of the three load levels (SL, ML, and PL). At the SL, 24 women worked above 2% MVC (admissible load level) and 12 at a load above 5% MVC (permissible load level). For the ML, in 13 out of 18 participants who worked above 10% MVC (admissible load level), workload exceeded 14% MVC (permissible load level).

At the PL, with the exception of one participant, all women worked below the admissible level (50% MVC).

The median duration of work with the load level below 5% MVC was 10 min (Figure 2a). Seventeen women worked below 5% MVC for more than 10 min, and 11 women worked below that level for more than 20 min.

![Figure 1. Muscular load during registration—range and median value of % MVC (maximum voluntary contraction) for static, median, and peak load.](image-url)
The median value of the time the participants worked below the load level of 2% MVC was 3 min. Seventeen, out of the group of 36 women, never worked below that level.

During the recording time, the median number of crossings through the 5% and 2% MVC levels was 37 and 11, respectively (Figure 2b).

3.2. Postural Angles

3.2.1. Arm
Data pertaining to the postural angles of the right arm are presented in Figure 3. The mean value of the arm position in the abduction/adduction plane was below 15° during 90% of the registration time (PL).

The median value for the PL in the flexion/extension plane was 21°. The median values of the SL and PL in the abduction/adduction plane were 4.8° and 15°, respectively. For about 1 min, out of the total recording time of 60 min, the shoulder movements in the flexion/extension plane were in the range from −5° to +5°, in respect to the reference body position. For slightly longer, that is, for about 2 min, the movements in the abduction/adduction plane were also in that range.

3.2.2. Head
The angles of the head in the flexion/extension plane and the sideways movements are presented in Figure 4.

At the PL level, 23 women worked with the head flexed above 30°. All participants worked with the head flexion angle of above 15°. For half of the registration time, 32 women worked with head flexion of above 15°, and 14 women with head flexion of above 30°.

In the sideways movements of the head, the median value for the PL was 10.5°, and the extreme angles of turn to the right and to the left were 30.6° and 14.2°, respectively.

3.2.3. Back
The median values for the back angles in flexion were up to 12.7° for the PL and 3.9° for the SL (Figure 5). In the sideways movements, the median value for the PL was 3.4° and ranged from −4.8° (left) to 14.0° (right). This means that for most of the time the women worked slightly turned to the right.
4. DISCUSSION

The acceptable levels of muscular load for long-lasting static work were proposed by Jonsson (1982) and Bjorksten and Jonsson (1977; Figure 1). According to those authors, the recommended SL of load should be below 2% MVC (admissible level) and it should not exceed 5% MVC (permissible level). Jonsson (1982) and Bjorksten and Jonsson (1977) also proposed...
limits for ML at 10% and 14%, and PL at 50% and 70% MVC for admissible and permissible levels, respectively. Obviously, lower MVC levels are acceptable, but the upper limits should not be exceeded.

In our studies, median values for the SL and ML were above admissible but below permissible levels. During the testing period, two thirds of the women worked within those limits. However, one third of the women worked with a load that was above the permissible level. Overall, women worked with a load below 2% MVC for a total of about 3 min out of the 1-hr, registration time, and below 5% MVC for a total of 10 min. Only 11 women worked below the permissible level of load for more than 20 min. Thus, for most of the time, the majority of the women worked under high musculoskeletal static load level, exceeding the recommended value.

Previous studies of similar work tasks demonstrated either similar or smaller musculoskeletal loads. Winkel and Oxenburgh (1990) have shown that for VDT operators' work, the SL load for shoulder-neck muscles is 2.2% MVC. In Hagberg and Sundelin's (1986) studies of word processing, the median value of the SL of the right trapezius was found to be 3.2% MVC, which is indeed very similar to our results. However, they found the median values of ML and PL to be 7.3% MVC and 11.7% MVC, respectively. These values are much smaller than those obtained in our study (Figure 1). Also, the extreme values of the SL, ML, and PL parameters reported by Hagberg and Sundelin were smaller than those observed in this study. These results indicate that the muscular load measured in this study is relatively high compared to similar VDT operators' tasks. Also, the results of the studies conducted by Johansson (1992) on a similar group of VDT operators have shown much less muscular load for all of the three load level values (SL, ML, PL) than those found in our study. This might have been caused by differences in the performed task (data entry and phone operators) and also by different ergonomic conditions connected with table and chair design.

A direct correlation between arm position and the EMG of the trapezius muscle was shown in laboratory studies of Sigholm, Herberts, Almstrom, and Kadefors (1984) and Hagberg (1981). Aaras, Westgaard, Stranden, and Larsen (1990) suggested that postural angles of $-5^\circ$ to $+5^\circ$ result in low muscular load. However, other studies involving larger postural arm angles (simulated task of solitaire games in the sitting position by Bendix, Krohn, Jessen, & Aaras,
1985, and post office letter sorting task by Jorgensen, Fallentin, & Sidenius, 1989) have shown
musculoskeletal load similar to that of our group of VDT operators. This suggests that the
postural arm angles of the examined group may have been larger than normally encountered
in a keyboard operation. Indeed, our results show that for 57 out of 60 min, the women worked
with arm angles above the recommended values (5°). However, even a casual observation of
the letter sorting task or a solitaire game reveals that the postural angles involved are much
larger than angles related to any routine VDT work. Thus, we must consider the possibility that
other factors may have also influenced the magnitude of the registered workload.

Studies by Waersted, Bjorklund, and Westgaard (1991) established that family situation,
stress, social, and personality problems influence musculoskeletal load. Weber, Fassler, Hanlon,
Gierer, and Grandjean (1980) have found that visual strain or mental workload may cause
elevation of scapula and thus higher muscular load. Other studies conducted as part of the
MEPS project on the same group showed that all those factors to some extent influenced the
musculoskeletal load (Widerszal-Bazyl & Żołnierczyk, 1995). It seems likely, however, that
eronomic factors such as an outdated design of the keyboard, improper spatial arrangement,
lack of arm support, poor illumination of the workstation, and so forth, are the most important
determinants of the musculoskeletal load (Bugajska, Wolska, Roman, & Konarska, 1994;
Wolska, Bugajska, & Konarska, 1994).

Studies by Kilbom, Persson, and Jonsson (1986), Kilbom and Persson (1987), and Melin
(1987) have shown that even during light work tasks some participants may overstrain their
muscles because of their improper work technique. Kilbom et al. (1986) studied the relation­
ship between the number of movements of the upper arm and the occurrence of shoulder-neck
disorder symptoms. They found that the more dynamic the work technique, the fewer the
symptoms of musculoskeletal disorders. Those observations are in step with the findings of
Westgaard (1988) that both the load level and the load pattern are equally important in
developing symptoms of musculoskeletal disorders. Even at a very low level of muscle activity
some motor units are continuously activated (Milner-Brown & Stein, 1973), and thereby they
are under persistent strain. In our studies, crossings through the level of 5% MVC took place
about four times per minute, which seems to indicate relatively static work technique.

Harms-Ringdahl and Ekholm (1986) found that head flexion does not affect the muscle
trapezius EMG signal. Nonetheless, head flexion triggers force moment in the cervical spine,
which results in spine disorders. Chaffin (1973) and Chaffin and Andersson (1991) suggested
that head flexion should not be higher than 30°. According to their results, an angle of 15°
produces no subjective discomfort, and there is no change in EMG activity after 6 hrs of work.
In our studies, for more than half of the time women worked with the angle of head flexion of
less than 30° and for 10% of the time with head flexed less than 15°. Thus, it can be expected
that muscular load in the cervical spine caused by this head position is rather strenuous and
may be another important cause of musculoskeletal disorders.

Median values of back angles for movements in flexion/extension plane were rather small,
and even smaller in the sideways movements. For most of the time, women flexed their back
at 12.7°. This is very similar to preferred sitting position of other examined groups of VDT
operators (Grandjean, 1991). However, it should be noticed that for the group examined in this
study, position of the back in the flexion/extension plane was observed to be in the range from
−3° to 51° for the PL. It indicates that during work women can assume very different postures.
Generally, their trunk was turned to the right. This posture may have been enforced by the
specific work task (turning off the sheets with data they copied). Thus, it is not unlikely that
the work posture might have been an additional source of musculoskeletal disorders.

5. CONCLUSION

The mean values for static and median musculoskeletal load recorded during this study are
within accepted admissible and permissible values. However, individually, one third of the
tested participants exceeded these levels. Thus, a significant number of tested women may be
vulnerable to musculoskeletal disorders. The load was likely caused by the contribution of external load (the weight of unsupported arms) and by an improper work posture (high values of arm angles).

REFERENCES


