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The Effect of an Ergonomic Intervention on Musculoskeletal, Psychosocial and Visual Strain of VDT Data Entry Work: The Norwegian Part of the International Study

Arne Aarås
Gunnar Horgen

Department of Optometry and Visual Science, Buskerud University College, Kongsberg, Norway

Ola Ro

Premed, Norway

Ellen Løken

Alcatel Norway A/S, Norway

Geir Mathiasen

Standard Fysikalske Institute, Norway

Hans-Henrik Bjørset

Norwegian Technical University, Norway

Stig Larsen
Magne Thoresen

Medstat A/S, Norway

The Norwegian MEPS (musculoskeletal—eyestrain—psychosocial—stress) study included 3 groups: data entry, data dialogue (female) and data dialogue (male). Before intervention, the data entry group reported significantly more symptoms and signs of musculoskeletal illness and had longer periods in front of the video display terminal (VDT) without a break. The ergonomic intervention consisted mainly of ergonomic information and training. After intervention, the data dialogue female group reported a significant reduction in shoulder pain in parallel with a reduction in trapezius load. Increasing the understanding in how to adjust the work stand and chair may have been contributing factors to reducing the pain level. There was a significant reduction in eye problems in all groups; the greatest reduction in eye symptoms was seen in the groups who had new optometric corrections.

musculoskeletal   visual discomfort   psychosocial stress

Correspondence and requests for offprints should be sent to Arne Aarås, Alcatel STK A/S, P.O. Box 60 Okern, Ostre Aker vei 33, N-00508 Oslo 5, Norway. E-mail: <Arne.Aaraas@alcatel.no>.

1. INTRODUCTION

This paper describes the results of the Norwegian part of the international MEPS (musculoskeletal—eyestrain—psychosocial—stress) project National teams in Norway, the USA and Poland conducted the project.

The aim of the study was to evaluate short- and long-term effects of an ergonomic intervention in musculoskeletal, psychosocial and visual strain of video display terminal (VDT) data entry routine work of a female group. In addition, data dialogue female and data dialogue male groups were included in the Norwegian MEPS project. Studies were performed according to the MEPS protocol. The evaluation of the musculoskeletal, visual and psychosocial factors was performed before intervention, 1.5 and 2.5 years after the ergonomic intervention.

In Norway, two additional groups were established: one female and one male group performing dialogue work on the computer. A cross-country comparison of the results is presented in Horgen et al. [1] and Dainoff et al. [2] (both in this issue).

2. METHOD

The methods are described in detail in Dainoff et al. [3] (in this issue).

2.1. Subjects: Demographics of the Norwegian Groups

In the Norwegian MEPS, three groups—each consisting of 30 subjects—were included in the study. One data entry female (DE-F) group, one dialogue female (DD-F) group and one data dialogue male (DD-M) group participated in the study. All groups worked in the same environmental conditions. The age of the participants is shown in Table 1.

Table 1. Age Distribution

	Age		
Subjects	*M*	Median	Range
DE-F	41.1	39.6	24.2–58.5
DD-F	40.9	43.9	25.1–57.9
DD-M	43.9	45.0	28.6–60.0

Notes. DE-F—data entry female group, DD-F—data dialogue female group, DD-M—data dialogue male group.

All subjects were experienced VDT workers who had been in the same jobs between 67 to 89 months, as group median values. More than 70% of the subjects in each group were either married or cohabited. There were no significant differences between the groups regarding marital status, the number of children below 12 years of age and time in current work.

3. THE ERGONOMIC INTERVENTION

The ergonomic intervention consisted mainly of ergonomic information and training. Smaller improvements of workplace and lighting were done. The Alcatel Norway company has had for many years a detailed procedure and regulations regarding VDT equipment and work environment [4]. Therefore, the performed ergonomic adaptation in this project was rather limited. Most important was that the participants were trained in understanding how important it was to adjust the workplace to fit their anthropometric values and to avoid static muscle load by varying their work posture. In addition, how to reduce reflections and glare from the luminaires and windows was discussed. For most of the VDT workers, smaller physical improvements were possible to implement. Adjustment and rearrangements of the workplace were performed for most of the operators to achieve a reduction in awkward work positions. These improvements consisted of adjusting distances of the screen and documents in relation to the operators. Tables and chairs were adjusted to give more relaxed positions of the shoulders. Too high mounted armrests with fixed height were removed if possible. Many VDT workers had a too low illuminance level on the keyboard and the documents. Five of those operators received new luminaires and 15 received additional lighting or adjustment of the placement of the luminaires in relation to the screen.

After intervention, the ergonomic conditions were not optimal. Few operators had the possibility to support their forearms on the table top, which could have lead to reduced muscle load in the neck and shoulder. Some VDT operators could not adjust the armrests low enough to relax their shoulders. Sufficient knee space was not available for all workers in order to prevent forward bending of the trunk. This could have reduced the muscle load and the pain in the upper part of the body [5]. Very few operators received new tables and chairs due to financial reasons.

4. RESULTS

4.1. Optometry

There was a need to change the existing correction in about 40% of the cases. This figure was higher than expected, but it could be related to the fact that the age distribution in the groups was towards the presbyopic part of the population (mean age of about 41) (Table 1).

4.1.1. Prescribed corrections

The results are divided into positive (hypermetropic) and negative (myopic) corrections. Astigmatic errors are always given as minus values (Table 2).

TABLE 2. Spherical and Cylindrical Changes

Prescribed Correction		Positive (+)	Negative (–)
Spherical OD	*N*	19	12
	M	+0.62	–1.54
	Min-Max	0.00–2.00	–5.25– –0.50
Astigmatism OD	*N*	0	14
	M		–0.59
	Min-Max		–5.25– –0.25
Spherical OS	*N*	22	10
	M	0.70	–1.85
	Min-Max	0.00–2.00	–5.50– –0.25
Astigmatism OS	*N*	0	15
	M		–0.58
	Min-Max		–1.50– –0.25

Notes. OD—right eye, OS—left eye.

These data demonstrate that the power of the corrections was within normal limits, and that none were outside the inclusion criteria.

4.1.2. Difference in corrections from Part I to II

The differences were small. This may partly be explained by the fact that many workers changed spectacles because only the reading addition was changed. The distance portion may then have been unchanged, and this would strongly influence the figures. The relatively small values also underline the fact that the employees at Alcatel/STK have been followed up closely over the years prior to this study and therefore any gross defects in the corrections would have been adjusted earlier.

4.1.2.1. Visual acuity (VA). It can be seen from the figures that the values for most subjects were within normal limits. However, Table 3 also shows that some subjects had defective eyesight in one eye. There were no differences between the groups. The fact that the minimum value for VA binocular was lower than the monocular value OD (right eye)might be explained by poor binocular vision, or an error in testing. The Snellen visual acuity chart is rather gross at these low levels of visual acuity testing [6, 7].

4.1.2.2. Stereoscopic acuity. The findings show that most clients had normal stereoscopic acuity (mean between 41–49 seconds of arc). The subjects with only one eye, or gross manifest strabismus, were excluded in this figure.

4.1.2.3. Near addition. There was a statistically significant reduction of the near addition: the mean value = 0.32 DS (dioptre sphere) (p = .0001). This is in agreement with the clinical experience that many subjects are overcorrected for this type of work.

TABLE 3. Visual Acuity of Right and Left Eye

		Monocular Visual Acuity		
Subjects		OD	OS	Binocular
All*	*N*	71	71	71
	M	1.26	1.24	1.42
	Min-Max	0.40–1.50	0.02–1.50	0.20–1.50

Notes. OD—right eye, OS—left eye.

4.1.2.4. Accommodation. The results of the accommodation measurements were in line with the expected findings: the values closely follow the accommodation values by Duane [8] (Figures 1a, b, c).

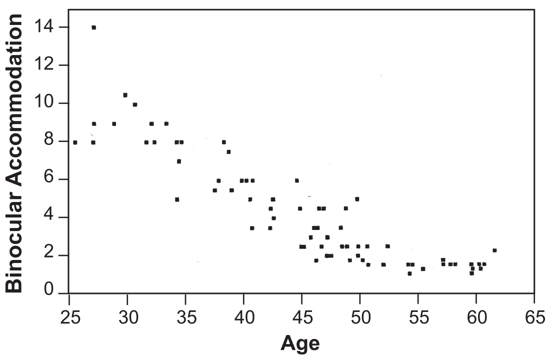

Figure 1a. Binocular accommodation related to age.

TABLE 4. Commencement (130-mm Visual Analog Scale [VAS])

		Pain	
Subjects		**Intensity**	**Frequency**
DE-F	*N*	30	30
	M	5.0	6.8
	95% CIM	4.0–6.0	5.6–8.0
	Median	5.3	6.6
	Min-Max	0.5–9.9	0.5–11.5
DD-F	*N*	30	30
	M	4.2	4.8
	95% CIM	3.1–5.2	3.7–5.9
	Median	3.4	6.3
	Min-Max	0.0–9.8	0.0–10.6
DD-M	*N*	30	30
	M	3.4	4.3
	95% CIM	2.3–4.4	2.9–5.7
	Median	3.0	2.9
	Min-Max	0.0–10.1	0.0–10.7
	P value	*P* = .03	*P* = .01

Notes. DE-F—data entry female group, DD-F—data dialogue female group, DD-M—data dialogue male group, CIM—confidence interval of mean.

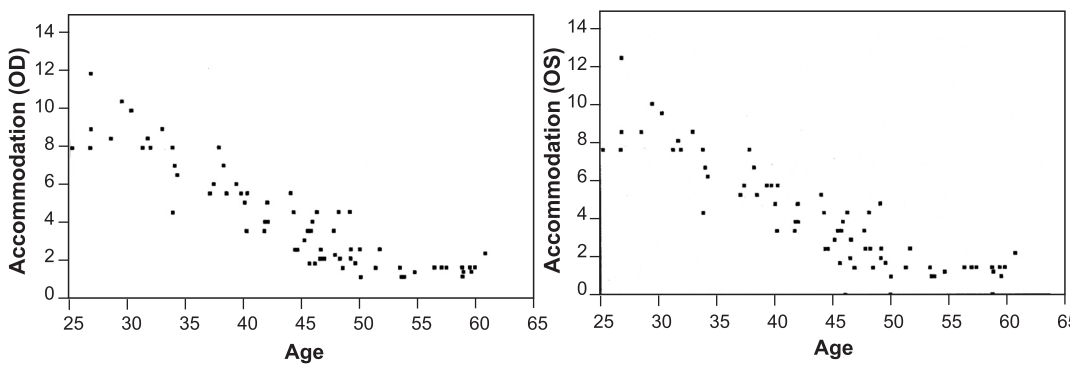

Figure 1 b, c. Accommodation related to age. *Notes.* OD—right eye, OS—left eye.

4.1.2.5. Head symptoms. At commencement, the level of headache differed significantly between the three groups, both for intensity and frequency (Table 4). Note that here a 130-mm Visual Analog Scale (VAS) was used. The DE females seemed to have the worst headaches and also the highest frequency. The difference between the two female groups was not significant ($p = .24$) regarding the mean intensity of headache. The difference between the DE females and DD males was however significant ($p = .02$), while the difference between the two DD groups was not significant ($p = .58$). Regarding the frequency, the DE female group was significantly different from both DD groups ($p = .01$).

After intervention, there were a slight tendency that the DE female group reported suffering less from headaches, both regarding intensity and frequency. The groups mean values were however small for all three groups. For those who suffered pain, the headache was unchanged for about 70% of the operators.

When looking at follow-up (Table 5), the mean intensity of pain in the head showed a difference between the groups. The DE female group had the worst headaches, both in intensity and frequency. The difference in intensity between the two female groups was not significant, but the difference between the DE female group and DD male was significant ($P = .02$). The intensity was however

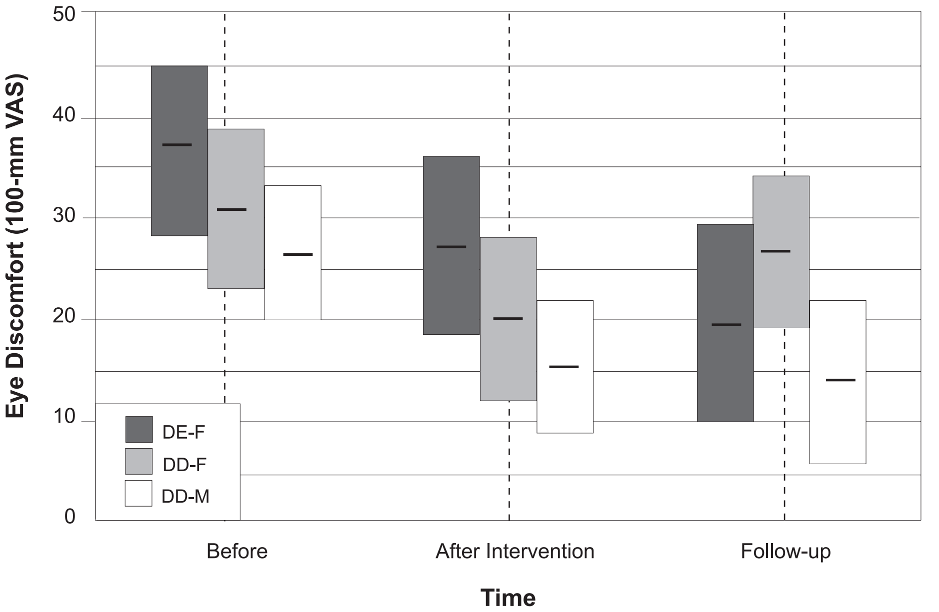

Figure 2. Intensity of eye discomfort in the past 6 months. The values are given as mean with 95% confidence interval before intervention, after intervention (1.5 years later) and at follow-up (2.5 years after intervention). On the ordinate 0 indicates *no discomfort*, while 100 is *very severe discomfort*. *Notes.* VAS—Visual Analog Scale.

not very high, corresponding to approximately *some headache* (25 on the VAS scale) for the DE female group. The frequency was significantly higher in the DE female group compared to the two DD groups corresponding to *occasionally* (40 on a 100-mm VAS).

TABLE 5. Average Intensity of Pain/Discomfort in the Head in the Past 6 months (100-mm Visual Analog Scale [VAS]) at Follow-Up

Subjects		Pain Intensity	Pain Difference
DE-F	*N*	23	23
	M	38.7	–5.3
	95% CIM	28.7–48.6	–10.5– –0.1
	Median	38	–3.0
	Min-Max	0.0–76	–28–17
DD-F	*N*	23	23
	M	18.6	2.8
	95% CIM	10.2–27	–2.5–14.1
	Median	20.0	0.0
	Min-Max	0–74	–50–52
DD-M	*N*	25	25
	M	17	6.2
	95% CIM	–8.1–25.9	0.5–11.8
	Median	8.0	8.0
	Min-Max	0.0–76	–31–36

Notes. DE-F—data entry female group, DD-F—data dialogue female group, DD-M—data dialogue male group, CIM—confidence interval of mean.

One must however bear in mind that Dr. Aarås and his team at Alcatel STK have been working on improving the environment for the last 15 years, so the baseline might be lower than in an ordinary situation. The difference in headache from commencement and after 1.5 years showed a slight tendency towards the DE female group reporting a lower level after intervention. The difference was however not significant in either group, and the group mean values were small in all groups.

4.1.2.6. Eye symptoms. When looking at Figure 2 at commencement, there was an indication that the DE female group had more eye discomfort than the other groups, especially the DD male group. This difference was however not significant (p = .30). The mean score was 3.6 for the DE females, 3.2 for the DD females and 2.7 for the DD males. When looking at the different types of eye problems, there were too few observations to do a significance test, but from the figures, one can see that there were no substantial differences between the different groups (Table 6).

Most subjects who experienced eye symptoms (about 50% of all cases), reported low intensity of eye fatigue. There was a vague tendency for the DE female group to have more eye problems than the other groups, but this was not significant.

TABLE 6. Eye Symptoms

	Symptoms				
Subjects	Fatigue	Burning	Red Eyes	Double/Hazy Vision	Undefined
DE-F	5	4	1	5	0
DD-F	8	8	4	6	0
DD-M	5	6	1	1	0
Total	18	18	6	12	0

Notes. DE-F—data entry female group, DD-F—data dialogue female group, DD-M—data dialogue male group.

The distribution of the symptoms showed no significant differences between the groups.

At Part I, 18 subjects complained of fatigue and also 18 subjects had a burning feeling in the eyes. There were 12 persons complaining of double or hazy vision, while only 6 persons complained of red eyes.

No correlation was found between eye discomfort and duration and the number of times that the operators looked at the screen. The frequency of looking at the screen went down, while the duration of the time went up. The findings may indicate that the visual problems were to a small extent influenced by the VDT work, and that the visual stress as a whole was tolerable for most operators. However, there were a reduction in eye symptoms from the first to the second interview, when the different groups were looked at. The reduction was statistically significant in the DD male group. The eye discomfort seemed to have been reduced down to a tolerable level (mean between 2.0 and 3.5 cm in the different groups) (Table 7).

TABLE 7. Reduction in Eye Discomfort After Intervention (100-mm Visual Analog Scale [VAS])

Subjects	Eye Discomfort	Difference
DE-F	3.5	1.4
DD-F	2.6	1.5
DD-M	2.0	1.3

Notes. DE-F—data entry female group, DD-F—data dialogue female group, DD-M—data dialogue male group.

The whole population was divided into two main groups, one who needed new optometric correction and one who did not. In the group needing new corrections at commencement, there was a higher level of eye symptoms than in the group not needing new corrections. This difference was significant (Table 8).

TABLE 8. Average Intensity of Visual Problems in the Past 6 months: Corrected/Not Corrected Group (100-mm Visual Analog Scale [VAS])

All Subjects	*N*	Part I	Part II	Part III
Correction needed	30	40.6	25.4	23.8
Correction not needed	38	25.9	17.9	15.5
Difference	*P* value	0.004	0.1	0.1

The difference between the groups was smaller after intervention, and no longer significant. By subdividing the three participating groups into needing and not needing new correction, the two female groups showed no difference between those who needed corrections and those who did not need new correction at commencement. In the DD male group however there was significantly higher eye discomfort in the group who needed new correction compared to those who did not. After intervention there was no significant difference in the DE female and DD male groups. The DD female group however, showed a higher rate of discomfort in the subgroup needing new correction.

At Part III no significant differences were found between the groups.

4.1.2.7. Improvement of eye symptoms. There were significant improvements of visual discomfort in both main groups, i.e., both among those needing new correction, and the one not needing new correction, from before to after intervention. There was a tendency towards a higher rate of improvement of visual problems in the group who obtained new corrections compared to the group who did not. This however was not significant (Table 9).

From post-intervention to after 2.5 years, no difference within or between the groups was observed.

TABLE 9. Difference in Average Intensity of Visual Problems in the Past 6 Months (100-mm Visual Analog Scale [VAS])

All Subjects	*N*	Parts I–II	Parts II–III
Correction given	30	15.3*	1.5
No correction given	38	8.0*	3.4

Considering the improvement within the three participating groups, the DE females who received new corrections reported a significant reduction in visual problems compared to before and after intervention, while no such significant reduction was reported from the group who did not receive new corrections. There was a significant difference between the two female groups regarding improvement from before to after intervention. In the DD male group, the same pattern of differences could be seen, however it was not significant. In the DD females, there was a significant reduction in visual problems in the group who did not obtain new corrections, while the reduction in the group who did was not significant. When comparing post-intervention and after 2.5 years, no difference could be seen in any of the groups.

4.1.2.8. Head and gaze angles. The mean of the present screen settings (Figure 3) were as follows.

- Height of the top of the screen: 110 cm (average of all groups).
- Height of the bottom of the screen: 90 cm (average of all groups). This indicates a "fixation height" of approximately 100 cm. Average eye height was 118 cm. At 66-cm viewing distance, this expresses a downward angle of approximately arc tan (118–100)/66) $\cong 15^o$ to the center of the screen.
- Head angles (present setting) were approximately 8^o. This means that the eyes fixated $(15^o - 8^o) = 7^o$ downward for most of the time (the 10th percentile). The head angle when looking at the top of the screen and at the bottom of the screen, were the following: average head angle looking at the top of the screen: 6^o and looking at the bottom of the screen: 15^o. An average (17") screen is 24 cm vertically, which expresses an angle of arc tan $24/66 = 20^o$ at 66-cm viewing distance. Looking at the top of the screen led to head flexion of 6^o and therefore 1^o downward fixation by the eyes. Looking at the bottom of the screen, the same calculations gave head flexion of 15^o, the total demand was $(15 + 10) = 25^o$, i.e., approximately 10^o were taken up by the eyes. These figures are in line with earlier findings demonstrating that a

Figure 3. A demonstration of the means of the present settings. *Notes.* The numbers are averaged values from the three groups, and not accurate values from the picture.

prolonged downwards fixation is taken up more with the head movement than with eye movements [9]. Menozzi et al. found that eye fixation of more than approximately 20° below horizontal lead to increased eyestrain [10].

4.2. Intensity and Frequency of Pain

Measurements of both intensity and frequency of pain were performed. Since the results were similar for both measurements, only pain intensity is discussed. The DE group suffered an overall higher intensity of pain in the upper part of the body compared to the two dialogue groups.

4.2.1. Neck

The DE females reported a significantly higher mean intensity of neck pain compared with the DD groups before intervention ($p < .01$) (Figure 4). The DE female group reported a significant reduction in the mean intensity of neck pain after

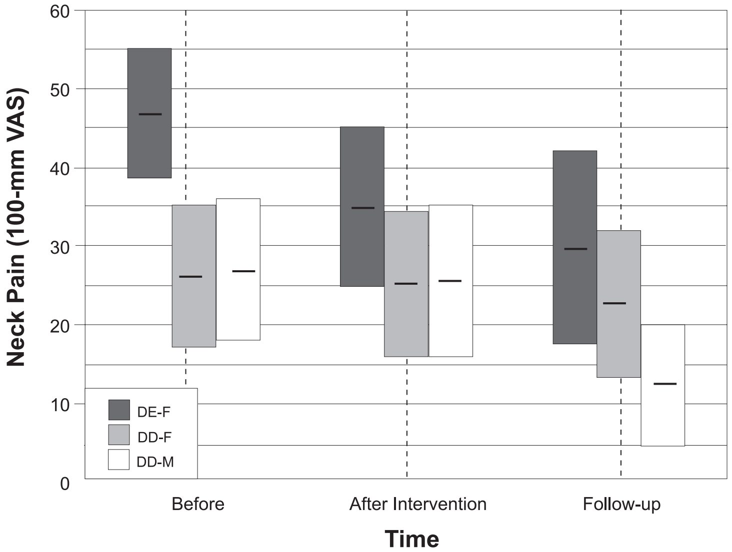

Figure 4. Intensity of neck pain in the past 6 months for the data entry female group (DE-F), data dialogue female group (DD-F) and data dialogue male group (DD-M). The values are given as mean with 95% confidence interval before intervention, after intervention (1.5 years later) and at follow-up (2.5 years after intervention). On the ordinate 0 indicates *no pain*, while 100 is *very severe pain*.
Notes. VAS—Visual Analog Scale.

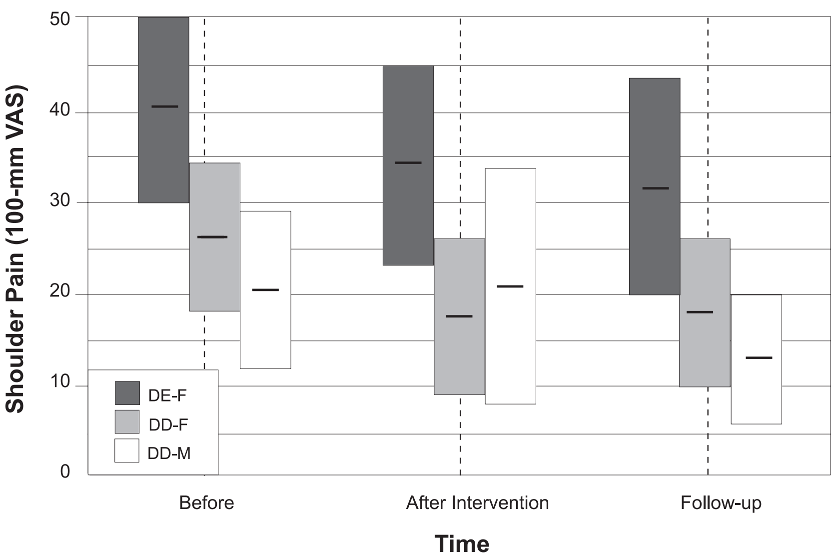

Figure 5. Intensity of shoulder pain in the past 6 months for the data entry female group (DE-F), data dialogue female group (DD-F) and data dialogue male group (DD-M). The values are given as mean with 95% confidence interval before intervention, after intervention (1.5 years later) and at follow-up (2.5 years after intervention). On the ordinate 0 indicates *no pain*, while 100 is *very severe pain*.
Notes. VAS—Visual Analog Scale.

versus before intervention (p = .05). The DD groups reported no significant changes regarding the level of pain. The DD male group reported a significant reduction in neck pain at follow-up compared with after intervention (p = .02). The DE female and DD female groups reported no significant changes in the same period. There were no significant differences between the groups with regard to relative changes in the mean intensity of neck pain (p = .67), when comparing after with before intervention.

4.2.2. Shoulder

The DE females reported a higher mean intensity of shoulder pain compared to the DD male group before intervention ($p < .01$) (Figure 5). The DD female group reported a significant reduction in the mean intensity of shoulder pain after compared with before intervention ($p < .01$), while no significant changes were observed in the DE female group and the DD male group. There were no significant differences between the groups with regard to relative changes in the mean intensity of shoulder pain (p = .18). This was also true when comparing the pain level at follow-up with after intervention.

4.2.3. Forearm

The DE female group reported more pain in the forearm compared with the DD groups (Figure 6). Pain data in the forearm was only taken at follow-up.

4.2.4. Back

No significant differences between the groups were found regarding the mean intensity of back pain before intervention (p = .57) (Figure 7). No significant changes were observed regarding back pain in any of the groups considering the pain level after versus before intervention. The DE female group reported an almost significant reduction in the mean intensity of back pain at follow-up versus after intervention (p = .06). In the DD groups a reduction in back pain was observed but it was not significant. Regarding relative changes in the intensity and frequency of back pain, no significant differences were found between the three groups during the study period.

Considering the intensity of pain for all body parts, few operators in each group reported much pain of daily occurrence. This result was supported by the fact that very few received physiotherapy during the previous month and reported low consumption of painkillers. Sick leave due to

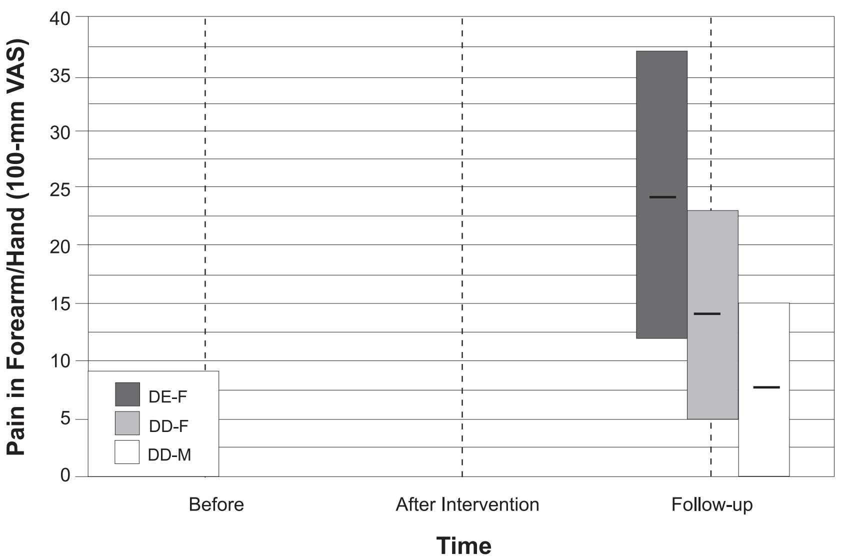

Figure 6. Intensity of pain in the forearm and hand in the past 6 months for the data entry female group (DE-F), data dialogue female group (DD-F) and data dialogue male group (DD-M). The values are given as mean with 95% confidence interval before intervention, after intervention (1.5 years later) and at follow-up (2.5 years after intervention). On the ordinate 0 indicates *no pain*, while 100 is *very severe pain*. *Notes.* VAS—Visual Analog Scale.

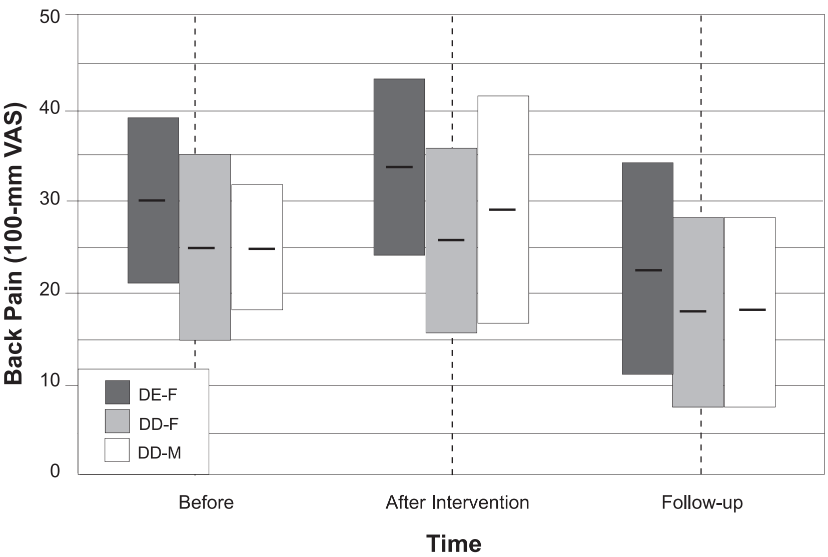

Figure 7. Intensity of back pain in the past 6 months for the data entry female group (DE-F), data dialogue female group (DD-F) and data dialogue male group (DD-M). The values are given as mean with 95% confidence interval before intervention, after intervention (1.5 years later) and at follow-up (2.5 years after intervention). On the ordinate 0 indicates *no pain*, while 100 is *very severe pain*. *Notes.* VAS—Visual Analog Scale.

musculoskeletal illness was low only with 2 to 4 days as group mean values.

4.3. Clinical Examination

4.3.1. Movement of the neck

Very few operators had a restricted range of movement of the neck regarding flexion and extension. Sideways movements of the neck were also normal for almost all the operators. Pain during sideways movements of the neck was reported significantly higher in the DE female group than in the DD female group ($p = .02$) before intervention, while the DE group had higher pain versus the DD males at follow-up (Figure 8). No significant changes were reported within the groups during the study period. The same pattern

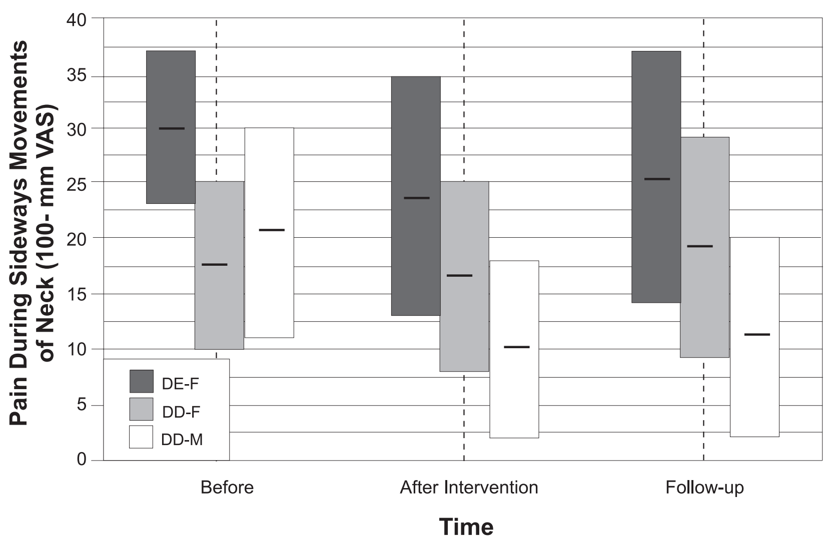

Figure 8. Intensity of pain during sideways moving of the neck for the data entry female group (DE-F), data dialogue female group (DD-F) and data dialogue male group (DD-M). The values are given as mean with 95% confidence interval before intervention, after intervention (1.5 years later) and at follow-up (2.5 years after intervention). On the ordinate 0 indicates *no pain*, while 100 is *very severe pain.* *Notes.* VAS—Visual Analog Scale.

regarding pain was also reported for flexion and extension of the neck.

4.3.2. Trigger points

The number of trigger points per subject was significantly higher in the DE female group compared with the DD groups before intervention ($p < .01$) (Figure 9). The DE females and DD females had a higher number of trigger points than the DD males at follow-up. There was a clear tendency to an increase in the number of trigger points in the DD females comparing follow-up with before intervention.

4.3.4. Isometric tests

These tests provoked more tenderness and pain in the DE female group compared with the DD groups ($p < .01$). In the DE group 16 subjects felt tenderness and 8 felt pain. In the DD female group only 7 felt tenderness and 4 felt pain, and in the DD male group 6 felt tenderness and 4 felt pain respectively. There was a clear tendency that fewer subjects reported tenderness and pain after intervention and at follow-up compared with before intervention. After intervention the tenderness and pain were reported as follows: DE females 7 and 2; DD females 1 and 3; DD males 3 and 1. At follow-up: DE females 4 and 2; DD females 0 and 3; DD males 3 and 0.

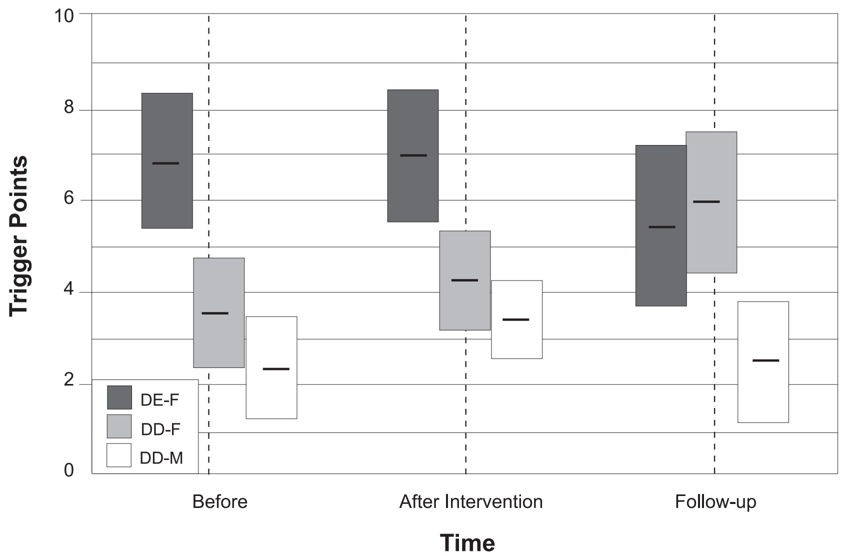

Figure 9. Number of trigger points for the data entry female group (DE-F), data dialogue female group (DD-F) and data dialogue male group (DD-M). The values are given as mean with 95% confidence interval before intervention, after intervention (1.5 years later) and at follow-up (2.5 years after intervention).

4.3.3. Pressure measurements of the trigger points

Pressure was measured at the most painful trigger points. Values were recorded at the level where the subject reported serious or radiating pain. The mean values of pressure with 95% confidence intervals of the mean were much higher in the DD male group compared with the DE and DD female groups: 1020 g (840–1200) versus 520 g (240–800) and 510 g (320–700) respectively. Very small changes in pressure values were observed within each group from after intervention to follow-up.

4.3.5. Palpation of the attachments of musculus supraspinatus and musculus deltoideus

In the DE group significantly more subjects (14) reported tenderness compared with the DD female (3) and DD male (1) groups when the attachment of the tendon was palpated with resistance against contractions of the muscles ($p < .01$). After intervention and at follow-up, the number of subjects who reported tenderness was reduced in the female groups; DE (3 to1); DD (1 to 0) respectively.

4.3.6. Carpal tunnel syndrome

One subject in the DE female group suffered carpal tunnel syndrome after intervention. After operation, no symptoms or sign of the disease were found at follow-up.

4.4. Psychosocial and Organizational Factors

Data from the psychosocial part of the study was collected first after the physical environmental intervention and in the follow-up part of the study. The study procedure and the registration methods are fully described in Dainoff et al. [3] (in this issue). The main results from the psychosocial part follow.

4.4.1. The amount of work and breaks

All participants worked full time, i.e., 8 hrs per day. The average working period in front of the VDT before a break was reported as significantly longer for the DE females compared to the DD females both after intervention (77 versus 49 min, $p = .0004$)) and at follow-up (73 versus 50 min, $p = .003$) as group mean values. There was also a significant difference between the DE females and DD males ($p = .05$). All three groups reported that to a large extent they could decide when to take a short break. The amount of work to be performed during the day was less known for the DE females compared with the DD groups. However, all groups reported that they could to some extent decide on the amount of work and which tasks to perform from day to day. A significantly greater number of the DD males reported to have worked overtime during the previous 6 months compared with the DD females.

4.4.2. Learning and job satisfaction

All groups assessed that their jobs were genuinely satisfying for most of the day. The DD males reported significantly higher job stimulation by VDT work than DE females. More than half of the operators in each group said they had the possibility to learn something new and considered their jobs to increase their skills. Most employees in the three groups considered their abilities to be used to some extent. Operators in the three groups reported that their work gave them some variation in the job, i.e., that their work tasks were to some extent different from day to day.

4.4.3. Social support and contact with others

There were no significant differences between the groups regarding opportunity to get contact in order to solve different problems with their immediate job superior. Work with other tasks gave a greater possibility to get contact with other employees than VDT work. Social support was assessed as good in terms of almost all subjects reporting that they could rely on and get help from some persons if they needed to. Almost all subjects in each group shared the burden of household work with other persons. Travelling time to work was by most subjects in the three groups assessed to be acceptable. About half of the VDT workers assessed to some extent their job to have high security.

4.5. Individual Variables

The housing situation was reported to be good for almost all of the subjects. Most employees described their financial situation as satisfactory. All three groups reported very good family support, as a mean group value. Psychological and sleeping problems were low in all groups. Some sport and physical activity were practised in all three groups. Most married and cohabitant workers got good support from their spouses in doing necessary housework. However, all reported some workload at home. No significant differences were found between the groups regarding the aforementioned factors. No significant changes were seen during the study period within the three groups regarding civil status, the number of children below 12 years of age, family situation, economic conditions, sport and physical activity, workload at home, sleeping and psychological problems. Furthermore, no significant differences were found between the groups during the study period. The feeling of tenseness was significantly higher in the DE-F

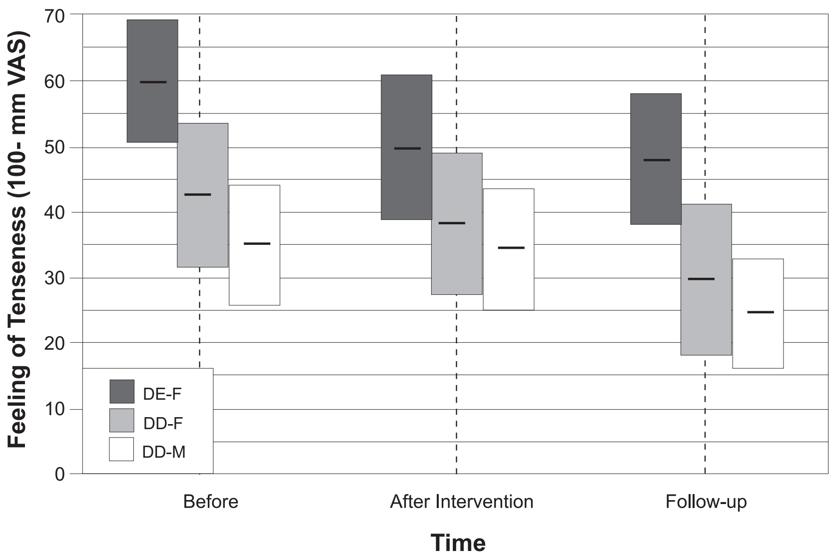

Figure 10. Feeling of tenseness for the data entry female group (DE-F), data dialogue female group (DD-F) and data dialogue male group (DD-M). The values are given as mean with 95% confidence interval before intervention, after intervention (1.5 years later) and at follow-up (2.5 years after intervention). On the ordinate 0 means *no tenseness*, while 100 means *extreme feeling of tenseness*. *Notes.* VAS—Visual Analog Scale.

group compared with the DD groups during the study period ($p < .01$) (Figure 10).

4.6. Correlation Between Intensity of Pain and Important Variables of Demographic and Individual Variables

Indications were found that the feeling of tenseness was positively correlated to pain intensity ($r = .48$) and pain frequency ($r = .43$) in the upper part of the body. Pain was also found to be associated with movement of the neck. This means that a high feeling of tenseness seems to be correlated to high pain intensity and high pain frequency. Indications were also found that the level of sport and physical activities was negatively correlated to both the mean intensity of pain ($r = -.20$) and mean frequency of pain ($r = -.23$). Thus, a high level of sport and physical activities seems to be correlated to low intensity and frequency of pain. A weak negative correlation between economical conditions and the mean intensity of pain was found for the shoulder area ($r = -0.29$). Sleeping problems and psychological problems were positively correlated to the intensity of pain in the upper part of the body ($.23 < r < .35$). The amount of work at home was correlated to mean the intensity of pain in the forearm/hand and the lumbar part of the back. The strongest correlation was found for a feeling of tenseness and an average pain level in the neck area ($r = .56$, i.e., $R^2 = .31$).

4.7. Physical Work Environment

4.7.1. Lighting and visual conditions

The illuminance on the keyboard, documents and papers was approximately 500 lx as a median value of the groups. That means that half of the workers had a lower illuminance level than recommended for VDT work. There were no significant differences between the three groups. The luminance of VDT characters and the main background was below 3:1 for most operators. That means that contrasts were for most operators far below the values recommended by the International Commission on Illumination (CIE) of contrast level preferably between 5:1 and 10:1 [11, 12]. Very few operators had the possibility to adjust both background and character luminance. Fewer than half of the operators in each group had reflections on their screen. However, for some operators the level of luminance in the reflected areas was so high that the text in those areas could not be read due to almost no contrast between the characters and the background. For most subjects the percentage of the screen covered by reflections was small. There were no significant differences between the groups regarding the latter two parameters. The size of the screens showed no significant differences between the groups. Badly designed luminaries or incorrect positions of the screen relative to the luminaries and window also contributed to glare problems.

4.7.2. Ergonomic measurements and evaluation of VDT work conditions by an expert

Ergonomic working conditions were measured and assessed by an expert before and after intervention.

4.7.3. Assessment of the work position

The expert assessed that the sitting positions were more comfortable for the DD groups compared with the DE group before intervention. Further, the sitting positions were significantly more comfortable after versus before intervention for all three groups. The number of the DE females with working posture resulting in high static load, awkward wrist angle, the forearm excessively above or below the horizontal and an awkward head/neck angle were significantly reduced after versus before intervention. There was also a tendency to the same improvements of the work posture within the DD male group.

4.7.4. Assessment of the training

There was a small but significantly increased understanding after compared to before intervention in (a) how adjustment mechanisms operated, (b) what postures were expected to result in reduced load and (c) why it was important to avoid awkward postures. After intervention, there were no significant differences between the groups regarding understanding which work postures reduced the workload and how this could be achieved.

4.7.5. Assessment of using the adjustments of the workstation

All heights and distances of the workplace were measured. All angles of the table and the chair were measured with a Regulus inclinometer. In spite of this information, few workplaces and screens were adjusted during the intervention. Very small changes in height adjustments were found when comparing before with after intervention. This was true for the seat pan, armrests, lumbar support, knee space, keyboard, VDT support. The distances were measured from the floor. Further, very few workplaces and screens were adjusted in height during the intervention. The distance in eye height, bottom and top of the screen from the floor as well as the distance between the seat pan and the keyboard were the same before versus after intervention. There was no significant change in angular adjustments of the keyboard, seat pan and backrest of the chair as well as the support of the screen. Adjusting work tables and chairs was time-consuming. Approximately half of the operators assessed the keyboard support and VDT support to require great force to be adjusted. The mechanisms of adjustment were also difficult to understand.

4.7.6. Ergonomic features of the workplace

The lower bound of the armrest and the upper bound indicated that the range of adjustments would create problems for some operators to adjust the armrest low enough. Such armrests were removed. Further, keyboard height could not be optimally adjusted for all operators. An explanation for not adjusting the workplace may be that the keyboard support was difficult to understand how to operate, not easy to adjust and the adjustment required rather great force. Measuring present settings of the knee space and the lower bound indicated that not all participants could have sufficient knee space at all workplaces. All keyboards were low in height, measured as the distances between keyboard support and the second row on the keyboard. The force required to make the key click was measured for seven keyboards. The force required was between 60 and 100 g. The keyboards were mostly of the same design. In all groups the chairs were assessed to have adjustment mechanisms which were easy to understand and operate. Very few operators had forearm support.

4.7.7. Environmental factors

Regarding environmental factors such as climate conditions, noise and working space, there were no differences between the groups. More than half of the operators in each group reported to have acceptable climate conditions at the work site, noise level as well as sufficient working space.

4.8. Ergonomic Assessment by the Participants

The assessments of the participants regarding the VDT workplace, chair, VDT screen, the working site as well as the work environment did not show any significant differences between the groups. Most of the participants in each group reported their chairs to be comfortable. They were satisfied with the possibility to adjust the chair's height, less satisfied with the possibility to tilt the seat backward and forward. More than half of the participants in each group did not adjust their chair, mostly because they did not find a reason to do so. The participants were less satisfied with the possibility to adjust the keyboard and the VDT compared with the adjustments of the chair. Very few reported to adjust the keyboard and the VDT. Difficulty in adjusting or interference with their work in different ways were the reasons they gave for not adjusting. Most operators reported the readability of the VDT and the possibility to control the brightness and contrast of the VDT to be fairly good. Approximately half of the operators had problems with controlling the reflections on the screen and the glare at the work site. The quality of the lighting was considered acceptable at the workplace. This was also true regarding how good the possibility of adjusting the level or position of task lighting was. The operators were not satisfied with their working space. Many participants reported that it was difficult to reach the necessary working materials without twisting and stretching. Approximately half of the operators reported not to be satisfied with the level of noise and the overall climate at the work site.

4.9. Electromyographic (EMG) Measurements

Before intervention, there were no significant differences between the three groups regarding static and median muscle loads of trapezius as well as the number of periods per minute below 1% Maximum Voluntary Contraction (MVC) (Figures 10, 11 and 12). Static trapezius load was rather low for the female groups (1.6 to 2.1%MVC), while the male group had higher static load (3.2%MVC).

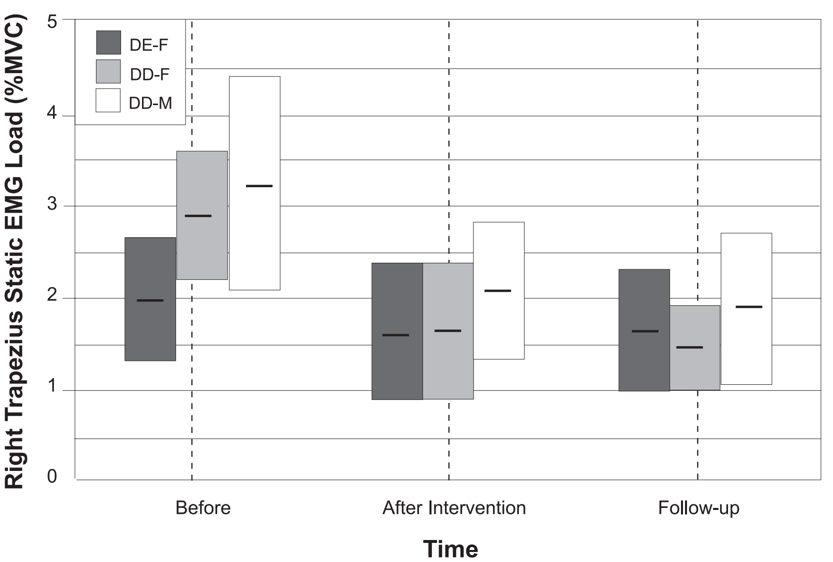

Figure 11. Right trapezius static electromyographic (EMG) load for the data entry female group (DE-F), data dialogue female group (DD-F) and data dialogue male group (DD-M). The values are given as mean with 95% confidence interval before intervention, after intervention (1.5 years later) and at follow-up (2.5 years after intervention).

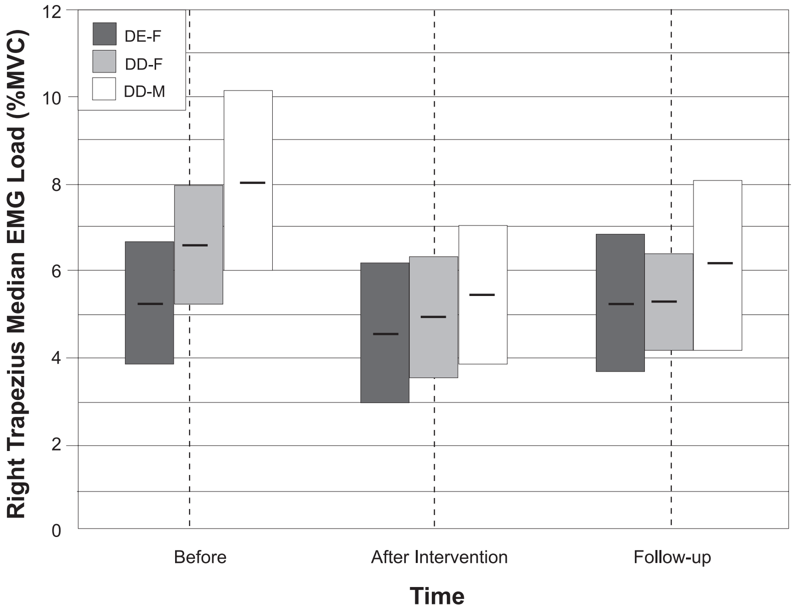

Figure 12. Right trapezius median electromyographic (EMG) load for the data entry female group (DE-F), data dialogue female group (DD-F) and data dialogue male group (DD-M). The values are given as mean with 95% confidence interval before intervention, after intervention (1.5 years later) and at follow-up (2.5 years after intervention).

There was a significant decrease in static and median trapezius load in the DD female group comparing after with before intervention ($p < .01$). There was also a tendency to a reduction in the DD male group regarding static load ($p = .07$), while a significant reduction was recorded in median load ($p < .01$). For all three groups, no significant differences were found within the group comparing after intervention with follow-up.

The number of periods per minute below 1%MVC increased significantly in the two female groups comparing after with before intervention ($p < .01$), while no significant changes were observed from after intervention to follow-up (Figure 13). In the DD male group, no significant changes were recorded in the number of periods per minute below 1%MVC during the study period.

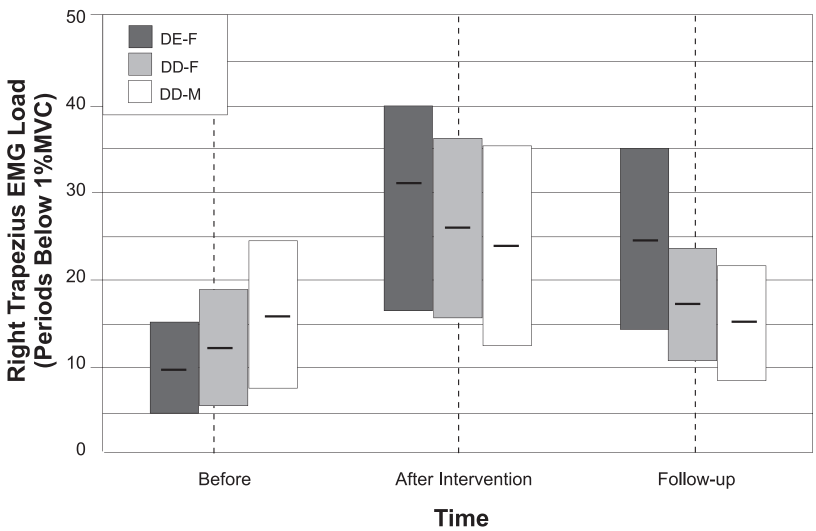

Figure 13. Right trapezius electromyographic (EMG) load in terms of the number of periods below 1% Maximum Voluntary Contractions (MVC) for the data entry female group (DE-F), data dialogue female group (DD-F) and data dialogue male group (DD-M). The values are given as mean with 95% confidence interval before intervention, after intervention (1.5 years later) and at follow-up (2.5 years after intervention).

EMG measurements were also taken for "other tasks"; there were no noticeable changes in static trapezius load from VDT work to other work tasks for all groups.

4.10. Postural Angle of the Upper Arm and Back

4.10.1. Flexion of the upper arm before intervention

The DE females had the lowest group value of median and peak flexion of the upper arm in the shoulder joint (glenohumeral joint) compared to the two DD groups. The static, median and peak angles were -3^o, 5^o and 15^o (DE females), -2^o, 8^o and 21^o (DD females) and 3^o, 12^o and 23^o (DD males) respectively. The DE female group had a significantly lower value of the peak angles versus DD males.

4.10.2. Abduction of the upper arm before intervention

Similar values as for flexion were also found for corresponding angles of abduction of the upper arm: 3^o, 6^o and 11^o (DE females), 4^o, 9^o and 16^o (DD females) and 5^o, 12^o and 21^o (DD males). The DE females had significantly lower median and peak angles compared to the DD males.

4.10.3. Low shoulder moment before intervention

The number of periods with low shoulder moment was significantly higher for the two female groups compared with the male group. (Low shoulder moment is defined as the angle of the upper arm in the sagittal plane between 5^o flexion and 5^o extension and angles in the coronal plane between 5^o abduction and 5^o adduction.)

4.10.4. After intervention

The flexion angles increased approximately 5^o in all groups. Due to an increase in the flexion angles, a reduction in the number of periods in low shoulder moment was recorded. The abduction of the upper arm in the glenohumaral joint had almost the same values after versus before intervention and varied by only a few degrees. There were no significant differences of flexion and abduction of the upper arm between the groups with regard to changes from before to after intervention. This was also true for the number of periods per minute in low shoulder moment.

At follow-up the peak of the flexion angles of the upper arm in the glenohumeral joint increased by approximately 10^o in all the three groups, while the abduction showed a variation of a few degrees. There were no indications of differences in flexion and abduction between the groups with regard to relative changes from after intervention to the follow-up of the study.

4.10.5. Neck and back angles

The flexion, extension and sideways movements of the back were recorded only at follow-up. The group values of static back flexion/extension were low for all groups considering the mean and median values, -4^o to 0^o. The corresponding values for median flexion were between 3^o and 8^o, while peak flexion of the neck varied between 13^o and 18^o. There were very small differences in those values when comparing the three groups. The range of the back sideways movements was small for all groups. In 80% of the recording time the mean and median values varied from between 4^o to 6^o bending to the right and between 5^o to 7^o bending to the left.

4.11. Correlation Within Postural Load Variables as Well as Postural Load Variables and Subjective Discomfort/Pain

The load variables, peak trapezius load and peak flexion as well as peak abduction of the upper arm in the glenohumaral joint showed a positive correlation. This correlation was stronger when the sum of peak flexion and peak abduction was compared to peak trapezius ($r = .28$, $p = .009$). A weak correlation was found between an increase in sideways flexion of the back and an increase in shoulder pain ($r = .31$). Otherwise, there were no indications of correlation between the EMG parameters as well as postural angles in the glenohumeral joint and pain intensity.

4.12. Dropouts

In the female groups 7 subjects dropped out in each group, while 5 dropped out in the DD male group. In the DE female group 5 participants were dismissed, while 2 got new jobs outside the company. In the DD female group all 7 participants were dismissed. Four subjects in the DD male were dismissed, while 1 had to terminate work due to illness (excessive myopia). The reason for the great number of participants being dismissed was that the production of telephone switching equipment was closed down.

5. DISCUSSION

For many years Alcatel STK has had a detailed procedure and regulations regarding introducing VDT equipment. Thus, many subjects participating in this study had already had ergonomic work places, lighting and optometric corrections (if needed) before commencement of this study. Therefore the magnitude of the intervention was relatively small and large differences in perceptual complaints such as musculoskeletal discomfort in different body areas and visual complaints were not expected comparing before and after intervention parts as well as after intervention and the follow-up part.

The optometric examination showed normal values regarding accommodation, visual acuity, binocular vision and stereoscopic acuity. The change in the corrections was, on average, small, and the plus additions for near use (VDT use) were reduced in power. This reduction clearly demonstrates the need for special considerations when prescribing corrections for these types of workplaces. The power of a plus addition reduces the range of clear vision for an emmetrope or ametrope with distance correction [13]. An increase from +1.5 to 2.0 DS reduces the outer part of the range of clear vision from 67 down to 50 cm [14]. This clearly may impose awkward body posture in order to focus clearly on the screen.

There was a tendency towards a reduction in eye complaints in the groups after 2.5 years. The reduction was higher for the corrected group as a group mean value, considering the population as a whole. In the DE female group this difference was significant from before to after intervention. In the DD female group, the same pattern could be seen, but in the DD male group the reduction in eye discomfort was higher for the non-corrected group. One possible explanation is the significant age difference between the groups. In the corrected group the mean age was 48.7 years, and in the non-corrected one it was 40.4 years. Subjects younger than 40 years old are usually not presbyopic. Improving lighting and the ergonomic factors may also influence the level of eye discomfort and pain in the musculoskeletal system. The DD male group who did not need new corrections was small, with only 9 subjects.

It seems that visual stress as a whole was tolerable for most of the operators at the 2.5-year follow-up. Eye discomfort seems to have been reduced down to a tolerable level, corresponding to *little discomfort* (21–35 mm) in the different groups.

In the groups where new corrections were fitted, the level of complaints was reduced to a level comparable with the subjects who did not need new corrections. This shows the importance of an optometric evaluation and intervention in the process of improving vision and visual performance for VDT workers.

At Part III, after 2.5 years of the study, the same pattern was still seen. The DE females who got corrections, reported a significant reduction in visual symptoms, while no such reduction was reported in the group not requiring new corrections. When comparing after intervention and 2.5-year follow-up, no significant differences regarding these symptoms can be seen in any of the groups.

The total time of looking at the screen may be important for the development of visual discomfort. The fixation time on the screen as a percentage of the total recording time was similar between the groups and no substantial changes were observed after intervention. The number of periods looking at the screen showed a reduction only in the DD male groups.

Headache and back pain do not seem to be so closely related to the work situation. There was no significant effect on the discomfort level of the aforementioned body areas before to after intervention. Further, for those who suffered pain, the start of discomfort was outside the working hours for many subjects.

Both for headache and back pain many risk factors have been suggested [15, 16, 17]. The DE females reported longer duration of headache and back pain than the DD groups, while the intensity of pain was similar for the three groups.

The flexion of the head was also similar between the groups considering after intervention and the follow-up part.

The DE female group reported a significantly higher intensity of pain in the upper part of the body compared with the DD groups before intervention. DE work is also reported in other studies to be associated with higher pain or discomfort in the musculoskeletal system compared to other VDT work tasks [18, 19, 20]. Considering all subjects, about 80% reported discomfort in the neck compared with 73% for the shoulder area. Other researchers had reported similar prevalence of pain in those body areas [21, 22].

The DE females also reported significantly higher discomfort during clinical examinations of flexion, extension and sideways movement of the neck compared with the DD female workers. However, the intensity of pain was low for all groups regarding the mobility test of the cervical spine. A significantly higher number of the DE females reported tenderness and pain after cessation of the isometric tests compared with the DD groups. Painful pressure points on tendon attachments and trigger points in the neck and shoulder were recorded by 90% of the DE females. This prevalence is higher than the 60% corresponding clinical signs found in a data entry group by Grandjean [18]. The DE females reported significantly lower pressure at their trigger points before radiating pain compared with corresponding measurements of the DD males.

Back pain was reported approximately at 35 mm on the 100-mm VAS as mean values for the three groups. No significant differences between the groups regarding back pain were found. Other researchers have found similar results for VDT workers [21, 22].

Considering the intensity of pain for all body parts, few operators in each group reported much pain of daily occurrence. This was also reflected in the health consequences for the operators in terms of low consumption of painkillers and few subjects received physiotherapy during the previous month. The pain level for the DD groups was very similar to the pain level found in another study of software engineering tasks [5]. Further sick leave due to musculoskeletal illness was low, 2 to 4 days per year as group mean values.

Perceptual complaints such as musculoskeletal discomfort may be related to a variety of demographic and individual factors [23, 24]. The feeling of tenseness was reported significantly higher in the DE female group compared with the DD groups. Further, the feeling of tenseness was found to be rather strongly correlated to both the intensity and frequency of pain in the upper part of the body. This may have contributed to a higher pain level in the DE female group compared with DD groups. There were also indications that more females than males had higher workload at home and that males were slightly more physically active outside home than females. This may also have contributed to less pain for males compared to females.

The relationship between psychosocial factors at work and musculoskeletal illness has been evaluated [25]. The DE females reported significantly longer periods in front of the VDT before a break compared to the DD groups. Longer working periods at the VDT for the DE females mean greater doses of workload. A connection between time spent in front of the VDT and the level of complaints has been shown earlier [26, 27, 28]. Many studies have reported an association between neck and shoulder pain and job control [29, 30, 31, 32]. The DE females reported less self-determination how to carry out the amount of work during the day compared with the DD groups. A greater number of the DE females reported that they did not know the amount of work which was demanded of them 10 min in advance compared with such a demand for the DD groups. In addition, the DE females reported that they were frequently interrupted by work tasks, which they had to implement more or less immediately. There was a clear longer unplanned period of work for the DE females compared with the DD groups. Other important psychosocial factors such as job satisfaction, stimulation participants had from VDT work, the opportunity to learn something new, to increase job skills and to fully utilize one's abilities, social support and the possibility to have contact with other employees when needed, were all assessed as satisfactory. This was the case for most operators in all groups. Further, those variables did not show any significant differences between the three groups.

Static trapezius load was rather low as group mean values (2.1 to 3.2%MVC). However, even this low trapezius load seemed to give an unacceptable high prevalence of musculoskeletal complaints [33, 34]. Static trapezius load for the DE females was in line with trapezius load (descending part) measured in the same type of work in other studies. Winkel and Oxenburg [35] measured average static trapezius load level of 2.2%MVC, while Hagberg and Sundelin [36] reported between 3.0 and 3.2%MVC, and Sundelin and Hagberg [37] between 2.5 and 3.2%MVC. The number of periods below 1%MVC per minute was higher in VDT work compared with assembly work (10–16 versus 2 periods). Pain intensity of assembly workers was higher (for some assembly workers it was difficult to perform work due to the pain level) [34]. Before intervention, no significant differences were found between the three groups regarding static and median trapezius load as well as the number of periods per minute below 1%MVC. However, expert evaluation of the VDT work conditions showed that sitting positions were more comfortable for the DD groups compared with the DE group before intervention.

Flexion and abduction in the glenohumeral joint influence the trapezius load much more than flexion of the head [38]. However, mean group values for these angles were lower than 12^{o}.

After intervention, the DE females reported a significant reduction in the intensity of neck pain compared with before intervention, while the DD females reported a significant reduction in shoulder pain. In the DD female group a significant reduction in static trapezius load as well as a significant increase in the number of periods per minute below 1%MVC was recorded after compared to before intervention. The DD males reported a significant reduction in neck pain at follow-up compared with after intervention. The same group had a clear tendency to reduced static trapezius load after compared with before intervention. The expert considered sitting positions to be significantly more comfortable after versus before intervention for all three groups. Further, the expert considered operators to have an increased understanding of how to adjust the work stand and chair as well as benefit from changing work positions. However, measurements of the dimensions and the angles of the workplace and chairs showed small changes after versus before intervention. This clearly indicates that few operators adjusted their workplaces and chairs. This is supported by the fact that postural angles of the upper arm in the glenohumeral joint showed very small variation after compared with before intervention. More than 50% of the subjects in all groups reported back pain to be approximately 25 mm on the 100-mm VAS. The range of back flexion/extension was in line with the recommendations by Jørgensen [39], who stated that most individuals were able to maintain a stooped posture with 20^{o} forward inclination of the back. This is also in line with our results from assembly workers [40].

6. CONCLUSION

Three groups of VDT operators participated in the study. One data entry female (DE-F) group, one data dialogue female (DD-F) group and one data dialogue male (DD-M) group. Before intervention, the DE group reported more symptoms and signs of musculoskeletal illness compared to the two DD groups. The symptoms and signs were as follows.

There was a significant reduction in eye problems in all groups; the greatest reduction in eye symptoms was seen in the groups who obtained new optometric corrections.

Higher pain level in the upper part of the body, higher pain level during sideways movements of the neck, more tenderness and pain during an isometric test, more tenderness when palpating tendon attachment of musculus supraspinatus and musculus deltoid, more trigger points, lower pressure before radiating pain from the trigger point. In addition, a stronger feeling of tenseness.

Further, the DE group had significantly longer periods of time in front of the VDT without a break, less self-determination of the amount of work to be carried out during the day and less comfortable sitting positions during VDT work compared with the two DD groups.

After intervention, the DD-F group reported a significant reduction in shoulder pain in parallel with a reduction in static and median trapezius load as well as a significant increase in the number of periods per minute when the trapezius load was below 1%MVC. The DD-M group reported significantly less neck pain at follow up compared with after intervention. The same group recorded reduced trapezius load after intervention.

Other factors contributing to reduced discomfort after intervention may be increased understanding—due to information and training—of how to adjust the work stand and chair as well as of benefits from changing work positions.

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