

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

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A group of routine data entry operators (female) was included in the Polish MEPS (musculoskeletal—eyestrain—psychosocial—stress) study. Before the intervention, ergonomic assessment revealed improper working conditions such as inadequate lighting, uncomfortable chairs, and lack of forearm and wrist support while medical examination revealed that trapezius muscle load along with upper arm, head and back angles were higher than advisable. Subjects complained about neck and shoulder pain, visual problems, and psychosocial conditions. The ergonomic intervention included installation of new luminaires and Venetian blinds, new chairs, repair of ventilators, and optometric corrections. The results after the intervention showed mainly improvement in chair comfort, lighting conditions, visual strain, and sitting posture. However, financial limitations did not allow satisfactory completion of the intervention leading to a mixed interpretation of the results.

data entry operators workload ergonomic intervention

1. INTRODUCTION

At the time when the ergonomic examinations were carried out at routine VDT (visual display terminal) operator workstations, the knowledge of ergonomic rules regarding the organization of computer work was low among employers and employees in Poland. There were no regulations in this area. On the basis of the results of this project and EU directive 90/270 [1], in 1998 the Ministry of Labour and Social Policy developed the first

regulations concerning ergonomic requirements for office work with VDTs. Later knowledge about the ergonomics of VDT workstations was disseminated more effectively.

This paper contains the results of the Polish part of the international MEPS (musculoskeletal—eyestrain—psychosocial—stress) project [2, 3, 4].

The aim of the study was to evaluate short- and long-term effects of an ergonomic intervention on the musculoskeletal, psychosocial, and visual

strain of routine VDT data entry work. Studies were performed according to the MEPS protocol in a group of routine data entry operators (female) three times: before (Part I), 1 month (Part II) and 1 year (Part III) after the ergonomic intervention [2, 4].

Subjective (by operators) and objective (by experts) evaluations were carried out regarding lighting, VDT equipment, furniture, work space, microclimate, noise, visual and musculoskeletal discomfort, and psychosocial stress.

2. METHODS

The methods are described in detail in Dainoff et al. [4] (in this issue).

2.1. Subjects: Characteristics of the Polish Group

Demographic variables are based on a take-home questionnaire.

At the start of the study (Part I), the data entry group (DE) consisted of 33 healthy participant females, aged 22–45 ($M = 32$). One month after the intervention (Part II), this group consisted of 22 participants, aged 24–45 ($M = 34$). After 1 year (Part III) only 16 participants remained, aged 25–46 ($M = 37$).

The average time of employment of the participants was 6.7 years (range: 1.3–13). Ninety-one percent of the subjects worked 8 hrs a day, 9%—7 hrs a day. Daily duration of VDT activities for 50% of the operators was 6 hrs a day, for 34% it was more than 6 hrs.

All operators underwent medical, psychosocial, optometric, and musculoskeletal load examinations [5, 6, 7, 8].

2.2. Ergonomic Conditions

Ergonomic conditions at workstations—work space and the work environment (lighting, room climate, noise), office equipments (work desks, chairs, VDT equipment)—were assessed by experts and by the operators themselves.

The experts' evaluations were carried out by measurement, observation, subjective assessments, and interviews [9, 10, 11].

The ergonomic experts' questionnaire included

- usability features of work chairs, desks, keyboards, displays (monitors);
- the quality of the screen (the character and background luminance on the screen, reflections);
- lighting conditions (screen, paper and keyboard illuminations, glare luminance);
- work space, work posture, height and angular adjustment, viewing distances for various sources of information (visual tasks), room climate, and noise.

The ergonomic take-home questionnaire, completed by the operators, included

- usability features of work chairs, desks, keyboards, monitors;
- the quality of the screen (brightness and contrast level, readability, reflections), work space, room climate, and noise.

3. RESULTS AND DISCUSSION

This paper presents some of the results, which were obtained in the Polish part of the MEPS project.

3.1. Part I: Before the Intervention

3.1.1. Ergonomic conditions

3.1.1.1. Lighting and visual conditions. The results of illuminance measurements before the intervention indicated that only 7% of workstations fulfilled the lighting requirements on the document and the keyboard, i.e., lighting was equal to or higher than 500 lx.

Direct glare from windows and luminaires was observed on all stands and was assessed as a very disturbing factor during visual work performance. The reasons were as follows: improper lighting luminaries for VDT work, lack of Venetian blinds, incorrect placement of workstations in relation to windows and luminaries.

The contrast ratios between screens and adjacent surroundings were too high (exceeding the recommended value of 1:10) [11]. On the

other hand, however, subjective assessment of the overall quality of the lighting indicated that generally operators were rather satisfied with the lighting system.

Measurements regarding the quality of the screen indicated that for 61% of VDTs character luminance was below recommended values [12]. However, 63% of operators reported readability of the screen as good. On 74% of VDTs bright reflections were observed on the screen, especially from bright windows.

For almost 50% of the cases, reflected luminance was much higher than character luminance, i.e., the reflective glare reduced readability.

Subjective assessment of the overall quality of lighting at workstations indicated that in general operators were rather satisfied with lighting systems, the mean value of their opinion was 58 mm, on a 100-mm VAS (Visual Analog Scale).

3.1.1.2. Work equipment. Ergonomic assessment of work equipment revealed the following conditions:

- a variety of old types of VDTs (some monitors and keyboards permanently joined, which made it impossible to achieve adequate work heights for keyboards);
- lack of forearm and wrist support, positions of monitors difficult to adjust in relation to the sources of light;
- no work desks had height adjustment.

In subjective evaluations, general work space was assessed by operators as sufficient, but leg space was reported as sufficient only by half of the operators. Lack of footrests was also reported. Climate conditions were assessed as poor: too warm in summer and too cold in winter.

3.1.1.3. Chairs. An ergonomic expert examination revealed old models of chairs that did not fulfil most ergonomic requirements. All types of chairs had unsatisfactory adjustment features for height, which required force adjustment, poor logical compatibility of adjustment, and poor angular adjustment of backrest and seat pan. The height of 60% of chair backrests could not be adjusted. All chairs had angular adjustment of the backrest,

but these were difficult to adjust. Two types of chairs had only four legs without wheels. Only half of the operators tried to adjust their chairs to their own needs, 11 found it difficult to adjust the height and in 4 cases there was no adjustment capability at all. However, the operators' subjective evaluation of chair comfort was relatively high. Almost 65% of operators rated their chairs as fairly comfortable and fairly adjustable in height. This finding may be explained by the lack of good reference examples. On the other hand, however, 57.8% of subjects did not make any adjustment. Their reasons for not adjusting were as follows: adjustment was difficult (36%), there was no reason for adjustment (27%), the chair was not adjustable (18%).

In summary, the results of the ergonomic investigation indicated that there were improper lighting conditions, such as a low level of illumination, strong direct glare from windows and lighting luminaries. Bright reflections on the screen and improper luminance ratio were measured. Chairs did not fulfil most of the ergonomic requirements.

3.1.2. Medical examinations

The results of medical examinations before the intervention indicated mainly headaches and possible problems in those parts of the operator's body that were stressed because of work posture related to VDT work. They showed that 86% of the subjects complained of headaches, over 80% of discomfort in forearms. Over 60% complained of hand, neck, shoulder, low back, and leg pain (Figure 1). The part of the body reported by operators as most painful while working was the low back.

Symptoms of Carpal Tunnel Syndrome were found in 15% of the operators. The average time of employment of the subjects with those syndromes was 10.3 years.

Palpation of the trapezius muscle showed muscle spasms and sore points in 27% of women: only 3 subjects reported tenderness during palpation of tendon attachment without resistance and 6% with resistance.

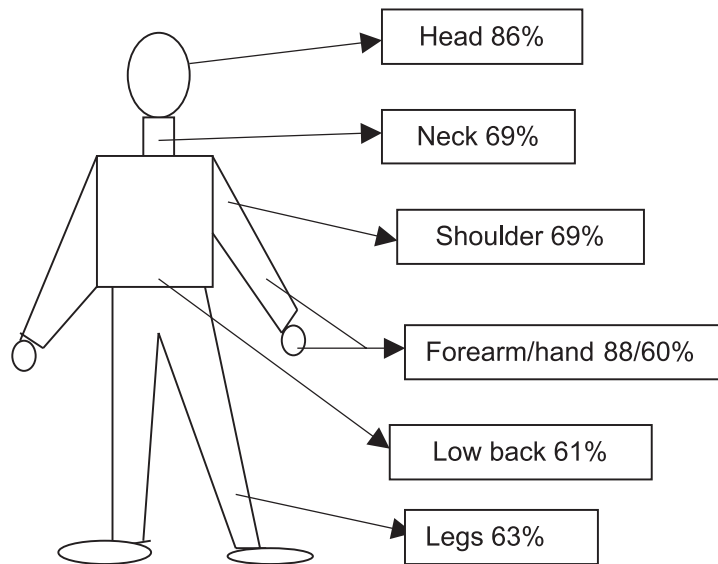


Figure 1. Percentage of VDT (video display terminal) operators with pain in different body areas. Total complaints of VDT operators, whole-day occurrence (subjective estimation, in 100-mm VAS). Notes. VAS—Visual Analog Scale.

3.1.3. Musculoskeletal load

According to the acceptable levels of muscular load for long-lasting static work proposed by Jonsson [13] the recommended static load (SL) should be below 2%MVC (admissible level) and it should not exceed 5%MVC (permissible level). For median load (ML) the admissible level was set at 10%MVC and the permissible level at 14%MVC. For peak load (PL), the admissible level is 50%MVC and the permissible level is 70%MVC.

In our studies, median values of SL, ML, and PL determined on the basis of electromyography (EMG) measurements were 3.1%MVC, 10.7% MVC, and 19.5%MVC respectively. This means that for SL and ML, values 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 exceeded 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 a high level of musculoskeletal static load, exceeding the recommended value.

Recording with a physiometer (Premed, Norway) showed that 67% of the subjects worked with head, shoulder, and trunk flexion angles which could be considered large. Most of the registered time, the operators were working with large angles of median head flexion (34°). The median angles of the upper arm in the gleno-humeral joint flexion and abduction were most of the time below 21° and 15° respectively. There was large flexion, but small extension of the back.

In summary, the mean values for static and median musculoskeletal load recorded during this study were within accepted admissible and permissible values. However, individually, one third of the tested participants exceeded these levels [14, 15].

Thus, a significant number of the tested women could be exposed to muscle load that increased the risk of musculoskeletal disorders. The load was probably caused by a contribution of an external load (the weight of unsupported arms) and by an improper work posture—high values of arm angles.

3.1.4. Visual problems

Visual problems were found in all 33 examined women—94% of the operators reported different intensities of visual fatigue and most of them suffered from eye burning or itching, redness of eyes, double vision, and sensitivity to light. Fifteen

subjects were emmetropic (no refractive error) and in 18 subjects myopia, hyperopia, or astigmatism were present. Five persons worked using their own spectacles and 7 required corrections for the first time.

The most frequent disorders in visual functions were changes in distant habitual phoria recorded for 19 subjects. Values of phoria in 18 subjects were lower than 4 prismatic diopters, where 11 subjects had esophoria and 8 persons had exophoria. Thirty persons showed changes of near habitual phoria, among them there were 27 subjects with exophoria and 3 persons with esophoria. In 19 subjects exophoria were equal or lower than 6 pDptr, and in 8 persons higher than 6 pDpr [16].

3.1.5. Psychosocial stress

The psychosocial survey showed these operators' work had many features of simplified work: low variability ($M = 24$) and lack of stimulation ($M = 40$). Estimation of the latitude of control depends on which aspects of control we take into account; operators could not determine which tasks they undertook ($M = 10$) and what work methods they used ($M = 15$). At the same time, they could influence the time frame of their work, they could determine the amount of work they

did per day ($M = 58$), and they could decide when to take a short break ($M = 85$). Opportunities to participate in decision-making was reported as low, however operators had many opportunities for social contacts with colleagues and supervisors ($M = 70$).

Basic needs for self-realization ($M = 24$) and job security ($M = 37$) were not sufficiently satisfied in the group.

In summary, the psychosocial survey showed many features of simplified work: low variability, little stimulation and low latitude of control, lack of participation in the life of the institution. As a result the need for self-realization was not satisfied and job satisfaction was rather low [17].

3.2. The ergonomic intervention

The ergonomic evaluation pointed to improper lighting conditions: a low level of luminance, strong direct glare from windows and the luminaires, bright reflections on the screen, improper chairs and parameters of desks, obsolete computer equipment, and unsatisfactory organization of the work area (Figure 2).

Expert intervention proposals regarding the ergonomic intervention at VDT workstations included new luminaires, installing Venetian

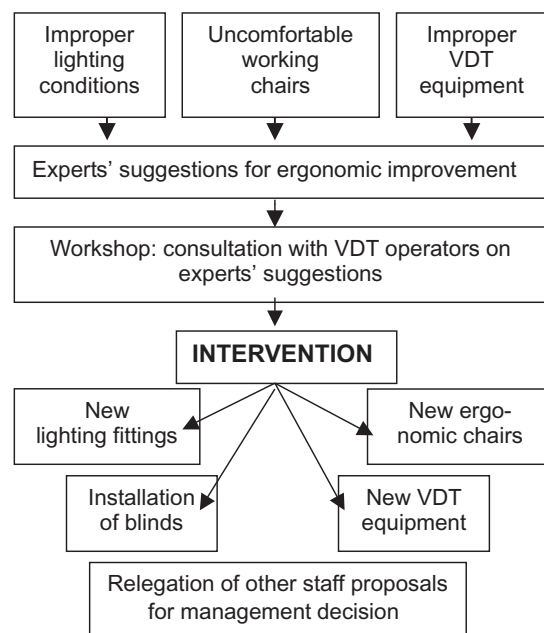


Figure 2. The main nonconformity of the examined routine VDT (video display terminal) data entry workstations and the range of the ergonomic intervention.

blinds in windows and new adjustable chairs with armrests, repair of the ventilation system.

The first part of the evaluation of the operators' status and work conditions was followed by a workshop, in which the experts and the subjects (workers and managers) discussed possibilities for work improvement.

Workshops (consultations) were organized after data relating to potential improvements was collected and a draft of necessary changes was developed. The goal of the workshop was to inform the operators about the result of the investigations and, according to the principles of participative ergonomics, to give workers an opportunity to participate in the improvement of their own working conditions [18]. During the first part of the consultation, the main results of the study and experts' recommendations for improving working conditions were presented. During the second part, a discussion was initiated in terms of the participants who were asked to present their opinions about the experts' draft and to give their additional proposals for improvement.

This discussion provided opportunities for operators to propose their ideas and suggestion of improvements. The ideas were discussed with supervisors and then submitted to the manager. The workers perceived their working conditions as not satisfactory and during the workshops they agreed with the experts' proposals for intervention.

The workers' proposals were as follows:

- dividing the room into a few separate smaller sections;
- abandoning piece-work;
- repairing the ventilation system;
- adapting a special room for recreation and smoking.

In accordance with the experts' opinions and the conclusion of the workshop, the ergonomic intervention included improvement of the physical working environment.

The main changes were as follows:

- replacement of old chairs with new, ergonomic models with an adjustment of the height of the seat, armrests, back support, and angular adjustment;

- rearrangement of the work area;
- installation of new luminaries;
- installation of Venetian blinds;
- equipment of the monitors with protective filters to control reflection glare;
- development of proper break schedules during the workday;
- implementation of spectacle corrections for 7 subjects with refractive errors.

As part of the ergonomic intervention, the experts decided that it was necessary to install keyboard supports. The reason for this was that the improper height of the work surface caused improper forearm position during work. A special keyboard support was developed, but only one woman agreed to have it installed at her desk [19]. It is important to stress that operators were frightened of changes because they decreased their speed of work and, as a consequence, lowered their pay.

Because of the limited financial sources of the institutions, computer equipment was modernized successively, also after the intervention. Installation of new monitors and keyboards meant a new arrangement of the work space on the desks. That was why operators changed their body positions during Part II and Part III of the examination, and one of the experts' activities was to train them how to optimize their work posture as well as the parameters of the chairs and lighting.

Nothing could be done to improve noise and microclimate at workstations.

3.5. The Effect of the Intervention—Part I, II, III—A Comparison

According to the MEPS protocol, 1 month and 1 year after the intervention, the same examinations were repeated and the results were compared with the results before the intervention.

In the operators' evaluation, the intervention effectively improved their physical working conditions. In particular, lighting quality and reflection and glare control were evaluated as excellent (Figure 3). The differences between before and after the intervention for assessment of visual problems were statistically significant, especially sensitivity to light distinctly decreased ($p < .01$)

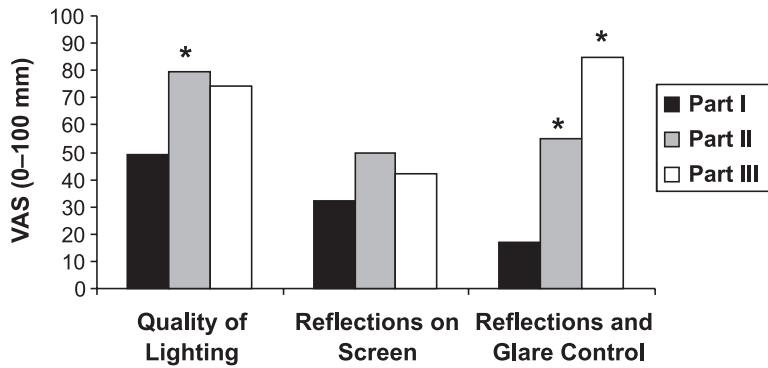


Figure 3. Subjective assessment of lighting before intervention (Part I) and after intervention: 1 month (Part II) and 1 year (Part III), expressed in mean of the VAS, mm. Notes. *statistically significant changes ($p < .05$); 0—very poor, 100—excellent, VAS—Visual Analog Scale.

(Figure 4). However, similar after-intervention improvements were not found in operators' evaluations of lighting conditions, related to the monitor screen itself [11] (Figure 5).

The operator's evaluation of their chairs showed statistically significant increases in comfort and adjustability, also 1 month and 1 year after the intervention compared before the intervention (Figure 6).

The ergonomic intervention influenced the results obtained from EMG signal measurements (Figure 7). One month after the intervention the values of SL, ML, and PL increased, whereas after 1 year they statistically significantly decreased. The increase in the load of the trapezius muscle

1 month after the intervention could have been caused by stress derived from the new arrangement of workstations and the necessity to adjust to a new situation [15, 20, 22, 23, 24, 25].

However, since the ergonomic intervention did not include changing desks, the operators' work posture was not optimal. Old desks with new monitors meant spatial organization of the workstation that imposed back and neck rotation.

Each examined operator adopted a different posture, which very often caused an increase in postural angles and a high variability of the angles—dispersion of values. Tables 1, 2, and 3 show some examples of postural angles and their differentiation.

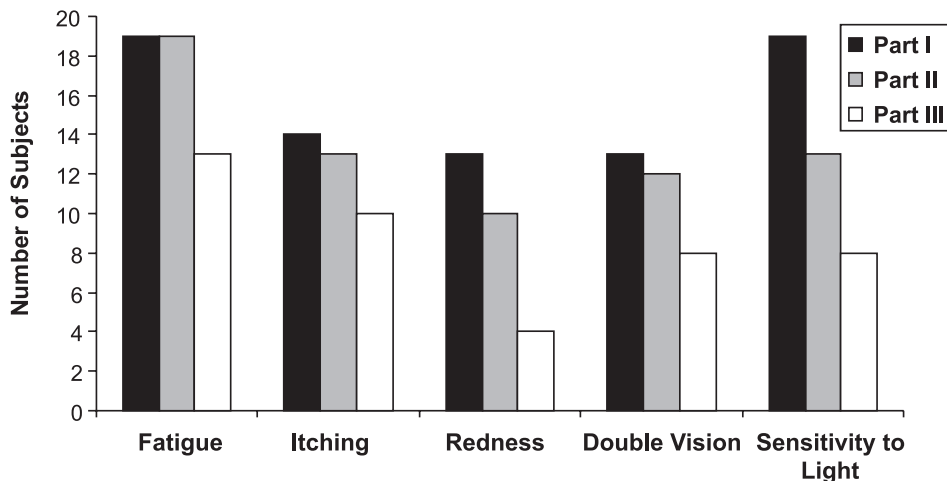


Figure 4. Frequency of visual problems before intervention (Part I) and after intervention: 1 month (Part II) and 1 year (Part III). The number of subjects with problems. Notes. *statistically significant changes ($p < .05$).

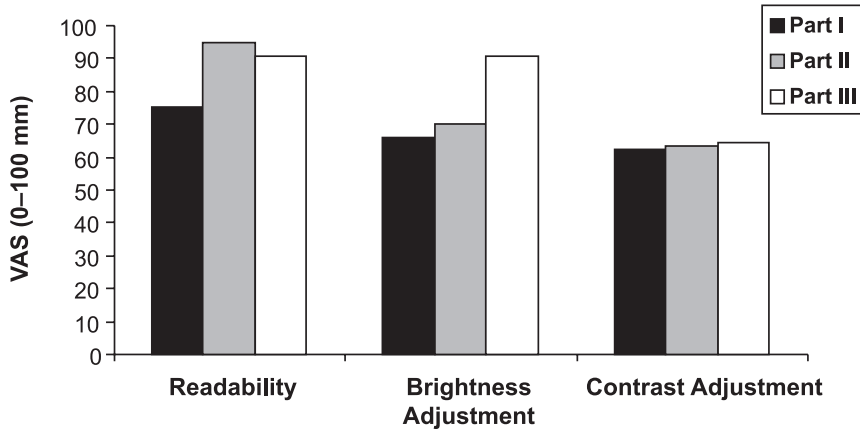


Figure 5. Subjective assessment of lighting parameters on the screen before intervention (Part I) and after intervention: 1 month (Part II) and 1 year (Part III), expressed in mean of the VAS, mm. Notes. Changes not statistically significant; 0—very poor, 100—excellent, VAS—Visual Analog Scale.

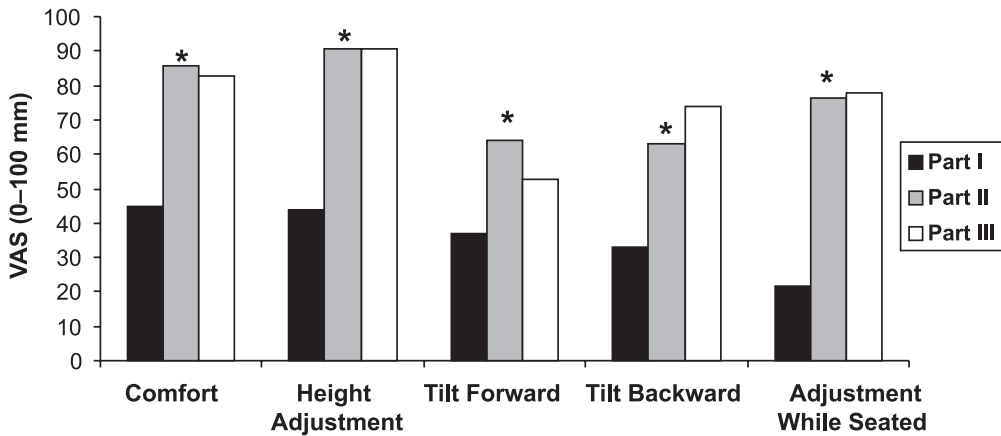


Figure 6. Subjective assessment of chairs before intervention (Part I) and after intervention: 1 month Part II) and 1 year (Part III), expressed in mean of the VAS, mm. Notes. *statistically significant changes ($p < .05$); 0—very poor, 100—excellent.

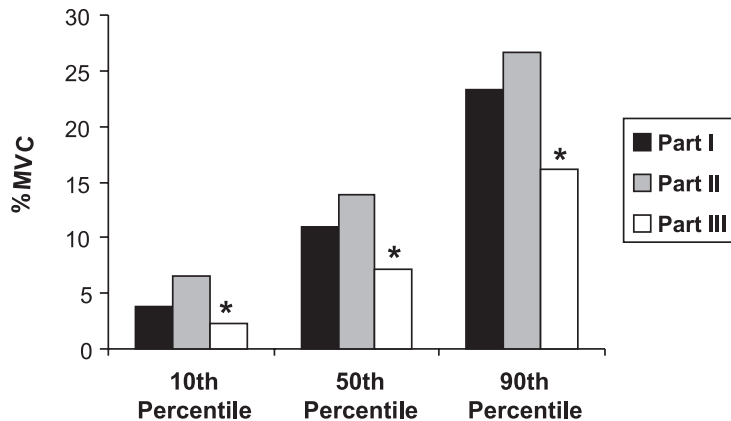


Figure 7. Right trapezius muscle load during an operator's work before intervention (Part I) and after intervention: 1 month (Part II) and 1 year (Part III), in %MVC. Notes. *statistically significant changes ($p < .05$).

TABLE 1. Position Angles of the Head: Flexion/Extension, Median Value

Stage	N	M	SD	Median	Min-Max
Before intervention	33	26.3	9.12	26.0	4.0–40.0
1 month after intervention	23	34.9	20.20	32.0	–3.0–77.0
1 year after intervention	18	37.8	17.10	40.8	–2.3–60.0

TABLE 2. Position Angles of the Back: Flexion/Extension, Median Value

Stage	N	M	SD	Median	Min-Max
Before intervention	33	9.7	10.9	8.0	–6.0–49.0
1 month after intervention	23	29.7	35.2	24.0	–5.0–171.0
1 year after intervention	17	17.1	13.2	18.1	–10.0–37.0

Such unstable work postures probably influenced subjective evaluations of pain intensity (Figure 8). The index of evaluation was rather low on the VAS scale (below 50 mm) and changes after the intervention were not large. However in some cases the results showed a tendency to increased pain intensity after the intervention. The tendency to increased intensity of shoulder pain (about 12 mm) or leg pain (about 10 mm) 1 year after the intervention is one such example. It is difficult to provide one interpretation of this, because in the case of the shoulder, the situation seemed to be better in objective measures (EMG). The intensity of leg pain, which increased after the intervention in both cases, 1 month and 1 year

TABLE 3. Position Angles of the Back: Sideways Right/Left, Median Value

Stage	N	M	SD	Median	Min-Max
Before intervention	33	0.50	2.97	1.0	–6.0–8.0
1 month after intervention	22	10.50	30.70	0.5	–18.0–136.0
1 year after intervention	17	0.74	3.77	0.0	–5.0–10.0

after the intervention was perhaps caused by lack of sufficient leg space (an old type of desk) and no footrest.

Improved working conditions did not influence the evaluation of psychosocial conditions. General job satisfaction remained low.

Psychosocial strain reported by subjects remained almost the same before and after the intervention, for example, sleeping problems before the intervention ($M = 39$), 1 year after $M = 33$; feeling of tenseness, respectively $M = 56$ and $M = 59$ (Figure 9). Reported social aspects of work, such as contacts with superiors and colleagues did not change after the intervention [23] (Figure 10).

Ergonomic intervention influenced the subjective evaluation of physical working conditions, even though changes were not satisfactory in the objective (experts’) evaluation because

- there was still glare from windows (at 43% of workstations);

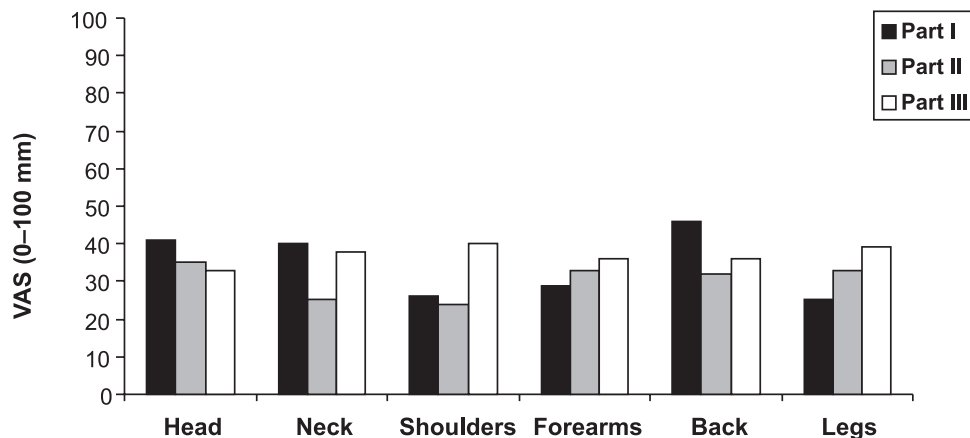


Figure 8. Subjective assessment of pain intensity in different parts of VDT operators’ bodies before intervention (Part I) and after: 1 month (Part II) and 1 year (Part III), expressed in mean of the VAS, mm. Notes. Changes not statistically significant; 0—none, 100—unbearable; VAS—Visual Analog Scale.

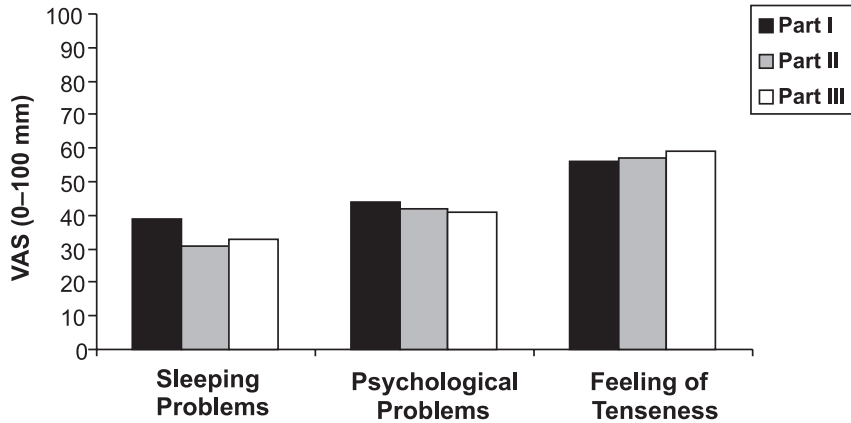


Figure 9. Psychological strain before intervention (Part I) and after intervention: 1 month (Part II) and 1 year (Part III), expressed in mean of the VAS, mm. Notes. Changes not statistically significant; 0—none, 100—very much; VAS—Visual Analog Scale.

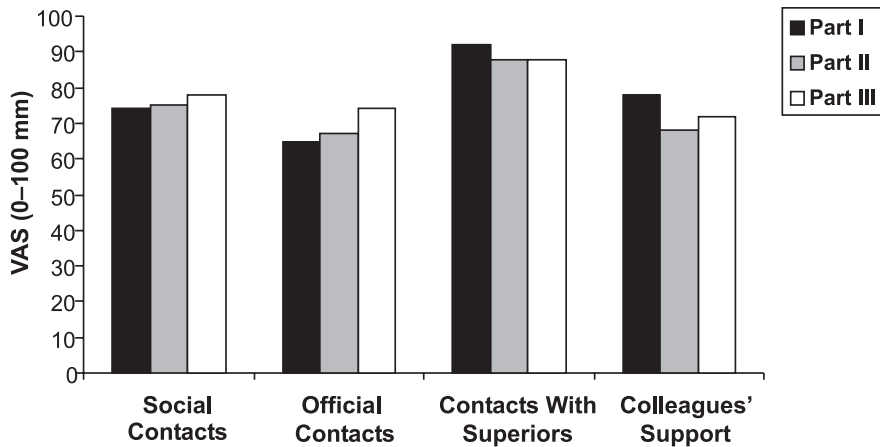


Figure 10. Social aspects of work before intervention (Part I) and after intervention: 1 month (Part II) and 1 year (Part III), expressed in mean of the VAS, mm. Notes. Changes not statistically significant; 0—poor, 100—good; VAS—Visual Analog Scale.

- character contrast on the screen decreased (contrast in 50% of displays was too small);
- there was still improper luminance distribution (an influence of daylight);
- operators rarely used armrests and chair adjustment;
- it was not possible to replace desks during the intervention (too little space for legs, improper height of the work surface).

Lack of improvement in working conditions in this area can increase pain assessment in shoulders, forearms, and legs. This tendency was observed after the intervention.

4. CONCLUSIONS

- Before the intervention, the experts' examination revealed generally poor working conditions: improper lighting conditions and work equipment, chairs did not fulfil the majority of the ergonomic requirements. Muscular load of the static trapezius muscle (EMG values) recorded for 1 hr, randomly chosen from the work shift, showed 3.1%MVC. These values were greater than advisable. Visual problems were common among all examined operators. Fatigue of the visual system was reported by 94% of operators.
- The ergonomic intervention (changes in lighting, visual work conditions, and chairs) led

to some improvement in working conditions in the experts' and the operators' opinions. There was less eye pain and slightly less pain in the head, neck, and back 1 year after the intervention compared with before. The tendency to increased pain in shoulders, forearms, and legs indicated that ergonomic improvement was not complete. The range of the ergonomic intervention was limited by financial resources of the institutions, which did not carry out satisfactory ergonomic interventions before Part II of the examinations.

- The improvement in working conditions did not influence the evaluation of psychosocial conditions. Psychosocial strain reported by subjects remained almost the same before and after the intervention. General job satisfaction remained low.

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