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

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This special issue of the International Journal of Occupational Safety and Ergonomics (JOSE) *reports the results from an extensive multinational and multidisciplinary collaborative investigation of the impacts on visual display terminal (VDT) work of musculoskeletal, visual, ergonomic, and psychosocial factors. For brevity, this effort has been referred to as the MEPS project (musculoskeletal—eyestrain—psychosocial—stress). This paper lays out the basic methodological structure of the study. The study was conducted in 4 countries utilizing VDT data entry workers as the primary subject population. A battery of objective and subject assessment measures, including muscle load, visual function, physical and visual strain, postural, ergonomic and psychosocial factors, were assessed at 3 different points in time. A pre-test was given prior to an ergonomic intervention. Two post-tests were given 1 month and 1 year after the ergonomic intervention.*

ergonomic intervention VDT office ergonomics multidisciplinary

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1. INTRODUCTION

This paper describes the organization and methodology of an extensive multinational and multidisciplinary collaborative investigation of the impacts on visual display terminal (VDT) work of musculoskeletal, visual, ergonomic, and psychosocial factors. For brevity, this effort has been referred to as the MEPS project (musculoskeletal—eyestrain—psychosocial—stress). Subsequent papers in this special issue of the *International Journal of Occupational Safety and Ergonomics* (*JOSE*) will refer to results and discussion of various parts of the MEPS study.

From the early 1980s high levels of musculoskeletal and visual problems, as well as concerns regarding psychosocial stress among VDT workers had been described in the literature (e.g., [1, 2, 3, 4, 5, 6, 7]) More recent publications indicate that musculoskeletal, visual, and psychosocial issues still appear to cause problems for VDT workers [8, 9] (see [10] for a review). At the same time, other evidence indicates that combinations of ergonomic (workstation and lighting design), optometric (proper prescription of lenses), and organizational (work design, training) interventions can be effective in reduction of these complaints [9, 11].

The focus of the MEPS project was the possible interrelation of these three areas of problems. More specifically, it was argued that high levels of static muscle load could result from the interaction of poor work posture, poor lighting conditions, and organizational stress factors [12].

It was the attempt to operationalize the multiple perspective approach to ergonomic solutions in complex work environments that formed the core of the MEPS project. The project team, which developed the research protocol described in this paper, consisted of an international group of researchers (from Japan, Norway, Poland, Singapore, Sweden, and the USA) representing the professional disciplines of ergonomics, occupational medicine, optometry, social and industrial psychology, and work physiology. Ultimately, the full protocol was carried out in three countries: Norway, Poland, and the USA. A portion of the protocol was carried out in Sweden. The Swedish MEPS study has been described separately by Westlander, Viitasara, Johansson, and Shahnavaz [13].

2. THE PRINCIPLES OF THE PROJECT

In developing the overall structure of the MEPS research project, the following operating principles were adopted.

1. The overall goal of the project was to provide an assessment of the effectiveness of ergonomic interventions.
2. While the primary focus of the project was on reduction of musculoskeletal strain, it was emphasized that visual and psychosocial factors interact with musculoskeletal strain, and must therefore be explicitly included within the study protocol.
3. Organizationally, each country participating in the study agreed to establish at least one study site at which an ergonomic intervention would be carried out. The minimum conditions for participation were that the work site should consist of at least 24 female data entry workers. However, each country was free to include additional study sites. Accordingly, the structure of the overall project consisted of both an international component and several national components.
4. Each study site was free to design its own ergonomic intervention. The only constraint was that eyeglasses appropriate for VDT work should be a part of the intervention.

2.1. National Component

Each participating country had the responsibility for identification of study sites where a particular ergonomic intervention could be employed. In addition to the minimum sample of female data entry operators, provision was made for additional categories of VDT workers, should appropriate samples of such operators be available. A second type of VDT work called Data Dialogue was defined. It entailed interactive work with the computer for at least 60% of the workday. The

following set of binary categories was established yielding a potential set of eight categories of VDT work, any or all of which could be utilized by a given country: (a) Data Entry vs. Data Dialogue, (b) male vs. female, (c) full-time vs. part time.

The aim of each national component was to assess each national study sample with respect to (a) baseline (pre-intervention) measures, (b) short- and long-term effects of the intervention, (c) patterns of relationships among different class of the aforementioned variables.

Thus, it was expected that each national component could serve as an independently conducted investigation as well as a part of the international study.

2.2. International Component

The international component required that a minimum sample of 24 female data entry workers be included in the study sample from each participating country. Members of this group were seen as potentially the most susceptible to musculoskeletal disorders from VDT work. Data entry work entails one-way interaction with the computer for at least 60% of the workday.

The use of a standardized protocol was intended to ensure that (a) whatever ergonomic intervention was employed in a given country it would be assessed in a uniform manner, and (b) a standardized optometric analysis and intervention would be employed. Thus, standardized methods and questionnaires were developed so that comparable operational definitions of measured variables and health outcome criteria would be employed across countries. This required comparability of training of investigators from each country—particularly regarding measurement of electromyography and postural analysis as well as definition of optometric measures, criteria, and prescription of corrections. In addition, a standardized data registration system was employed, so that results from each participating study site would be included in a common database.

Accordingly, the aims of the international component were to assess each study sample with respect to (a) baseline (pre-intervention) measures, (b) short- and long-term effects of the intervention, (c) patterns of relationships among different class of the aforementioned variables, (d) patterns of relationships compared across study sites.

2.3. Predicted Relationships

The predicted outcomes of this investigation can be conceptualized in terms of combinations of the preceding classes of dependent variables. The primary focus is on the impact of ergonomic and optometric interventions on reduction of musculoskeletal load. In this framework, visual and psychosocial variables would function as moderators while ergonomic variables describe the physical environment before and after intervention.

An overview of this overall rationale and study design is presented in Figure 1. This figure depicts the hypothetical level of musculoskeletal load in a group of VDT data entry operators at four different time periods. During the pre-test, the level of load for these individuals fell within a certain range of values, as indicated by the vertical double-headed arrows. Individual operators fell at different points within this range depending on the combination of postural, visual, and psychosocial factors influencing each person at this point in time. Next, an intervention occurred in which the workplace was improved and appropriate eyeglasses provided. The expected effect of the intervention was to reduce the overall average level of musculoskeletal load as measured during a post-test 1 month after working under the improved conditions. We further expected that, after 1 year of working under improved conditions, the low level of musculoskeletal load would be maintained or even drop further. This is the picture depicted in Figure 1. However, one possible alternative outcome might have been that the effect of the intervention was successful (a drop in load between time periods 1 and 3), but that organizational changes between time periods 3 and 4 would lead to an increase in psychological stress levels, which would oppose and partially reverse the change in musculoskeletal load.

A second focus of analysis was on visual factors per se. Thus, Figure 1 could be redrawn with the ordinate now depicting combined visual load

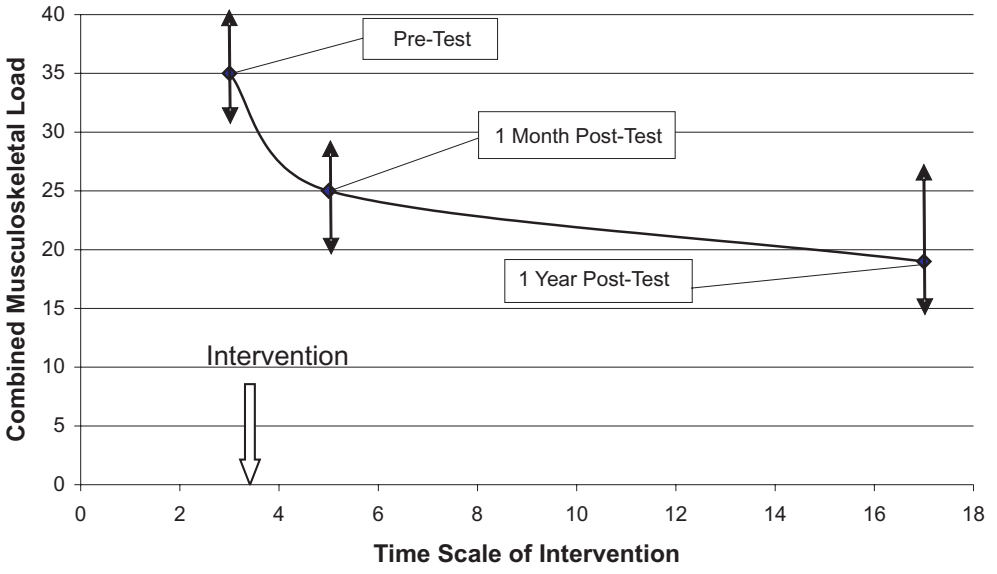

Figure 1. Theoretical predicted outcomes of the effects of an ergonomic intervention on musculoskeletal load. Variations around plotted points on the theoretical curve represent moderator effects of visual and psychosocial factors.

or symptoms. In this analysis, musculoskeletal as well as psychosocial factors would act as moderating variables.

2.4. Enumeration of Dependent Variables

Measurements within the four major classes of dependent variables were obtained from a number of sources. These included questionnaires, interviews, medical examinations, optometric examinations, electromyographic and postural measurements during a standard work sample, ergonomic assessment, by ratings and measurement of each participant's workstation, and by expert observations of each participant's workstation and working posture during work periods. From these sources, which are described in detail in section 3, the following classes of dependent variables were derived: musculoskeletal (musculoskeletal function, postural load, musculoskeletal symptoms); visual (optometric function, visual symptoms); ergonomic (workstation measurements, workstation assessment by experts and users); and psychosocial (demographic profile, organizational characteristics, personal and family characteristics and potential sources of stress).

3. RESEARCH METHODS

Based on these principles, a standardized assessment protocol was developed [14]. The basic structure of the protocol consisted of procedures for the measurement of musculoskeletal, visual, ergonomic, and psychosocial variables. These measurements were to be first carried out in the existing workplace prior to the intervention, and then 1 month and 1 year following the ergonomic intervention. This protocol would be employed by each participating country, with the resulting data to be incorporated into a common database. MEDSTAT Research, Norway, was designated as administrative secretariat for the MEPS project and was responsible for developing the database structure and for conducting statistical analyses for data collected under the MEPS protocol.

3.1. Background (Demographic, Social, Organizational) Factors

Interviews with either the subjects or an appropriate person in the organization were used to obtain the following types of data.

3.1.1. Demographic data

Demographic data included age, gender, type of VDT work (Data Entry, Data Dialogue-Routine, Data Dialogue-Non-Routine), duration of VDT

work, total days of sick leave during the past 6 months, and sick-leave days attributable to musculoskeletal problems.

3.1.2. Social conditions

Data relating to social conditions included composition of household, number and ages of children, subjective assessment of satisfactoriness of economical and family situation, sleep problems, feelings of tenseness and psychological problems, extent of sport/physical activity.

3.1.3. Organizational characteristics

Data related to organizational characteristics included characteristics of VDT-related occupational health policy including trained supervisory staff, organization's assessment of the project, basic organizational data regarding type of organization, number of employees, number of VDT employees, computer support services.

3.2. Medical Assessment of the VDT Workers

In addition to musculoskeletal sick leave, it was also important to consider other health parameters related to musculoskeletal complaints even when they did not lead to sick leave. This study investigated both intensity and duration of pain during work. All subjects were interviewed and clinically examined by the same medical researcher in each country.

3.2.1. Medical questionnaire

Questions were asked about physical exercise, psychological problems, if the subject felt tense and had sleeping problems. Pain intensity and duration were assessed regarding head, neck, shoulder, forearm/hand, back, and legs. These symptoms were quantified for the previous month and the previous 6 months before the interview [15]. These subjective assessments were done on a Visual Analog Scale (VAS).

The reliability of the VAS was established by interviewing 19 randomly chosen subjects twice, about 3 months apart. The reproducibility of the answers to the aforementioned questions was in most cases 5% or better, in terms of difference in their responses [16]. It is also interesting to note that these results corresponded fairly well with the reported frequency of 5% differences in responses for the VAS investigated by Larsen, Aabakken, Lillevold, and Osnes [17] and Jensen, Karoly, and Braver [18].

3.2.2. Clinical examination

Clinical examination was carried out directly after the medical questionnaire interview. The examination consisted of a general observation of the musculoskeletal system, measurements of the range of passive movements of the neck and head, palpation of muscle spasm and sore spots (trigger points) of trapezius muscle [19], and measurements of the pressure of the most painful trigger point (type 719 gauge; Chatillon, USA). The values were taken when the subject reported serious or radiating pain. Palpation of tendon attachments to supraspinatus and deltoidus was performed with relaxed muscles and against active resistance during the muscle contraction. Tenderness or pain when palpating the tendon attachment was recorded as positive. Isometric and endurance tests were performed by (a) lifting the shoulder with the upper arms hanging relaxed beside the body, (b) abduction of the upper arms to 90^{o}.

The isometric test involved maximum contraction against resistance and prolonged contraction against resistance for 15 s.

The endurance test was carried out by holding muscle contraction against the weight of the limb and body part for 1 min, i.e., low force of long duration. Thus, the endurance test attempted to simulate the physiological work pattern. If the subject felt tender or experienced continuous pain for more than a minute after cessation of the test, the result was classified as positive.

Restriction of the movements for the cervical spine was examined in terms of flexion, extension, and sideways movement. The range of movement of the upper arm in the gleno- humeral joint was examined with fixed scapula to evaluate shrinkage of the capsule of this joint. Passive movement of the upper arm in the gleno-humeral joint was examined for both flexion and abduction.

Symptoms and signs of carpal tunnel syndrome were examined with a detailed questionnaire of symptoms of pressure on the median nerve and test on sign of such pressure by using Phalen's sign and Flick's sign. In order to standardize the clinical examination in the three countries, a video was made to show in detail how the examination was performed.

3.3. Assessment of Load on the Musculoskeletal System

3.3.1. Electromyography (EMG)

The muscle load of the neck and shoulder was quantified by using surface electrodes. The recording was done from the descending part of m. trapezius. All subjects were recorded by the same researcher in each country. The physiometer (Premed, Norway) was used for these measurements [20] (see Figure 2). The skin was cleaned with a

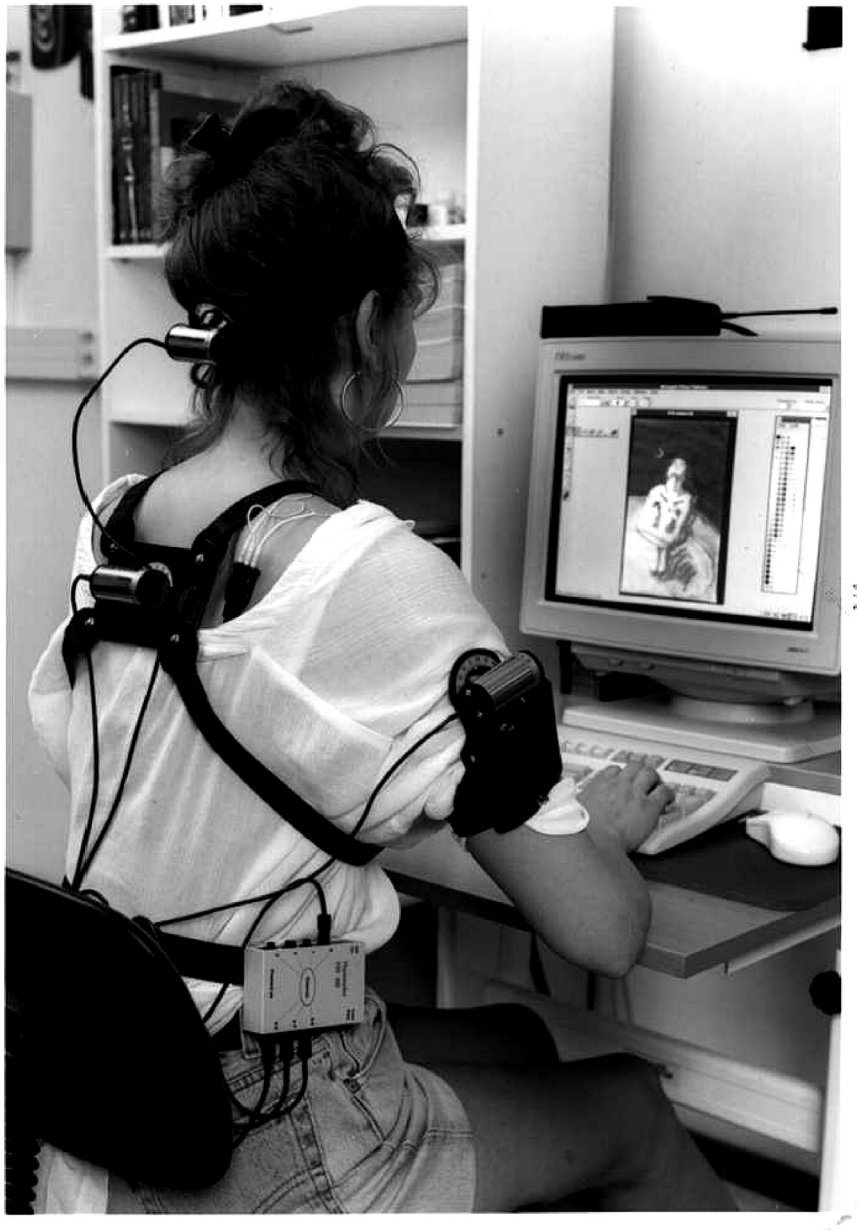

Figure 2. The physiometer (Premed, Norway) records EMG (electromyography) on 4 channels and postural angles on 6 channels. Inclinometers are attached to the upper arm, head, and back.

mixture of 1/4 ether and 3/4 alcohol, abraded with a rasp and if necessary shaved before mounting the electrodes. Two surface electrodes (Ag-AgCl, type H-10-VS, Medicotest A/S, Denmark) and a common reference electrode were used. The diameter of the electrode area was 6 mm. The interelectrode resistance was below 5 kΩ. The location of the electrodes on the descending part of the trapezius was within 20 mm of the center of the muscle belly, longitudinal to the direction of the muscle fibre.

The distance between the two active electrodes varied from 30 to 40 mm. The physiometer used a preamplifier at electrode levels with a gain of 216, input impedance >5 GΩ and a common mode rejection ratio (CMRR) >100 dB. The signal was filtered by a band pass filter from 15 to 800 Hz, amplified by a two-step variable gain amplifier (VGA), sampled at 1600 Hz, and digitized by a 12-bit Analog to Digital Converter (ADC). The Root Mean Square (RMS) value of the myoelectric signal (EMG_{RMS}) was calculated over 0.1-s intervals taking into account the gain of the VGA (either 1 or 10).

The EMG_{RMS} was calibrated to muscle force using the following procedure.

1. First a measurement of Maximum Voluntary Contraction (MVC) was carried out; the contraction was held for no longer than 2 s to avoid fatigue. The subjects were trained and motivated to obtain a true MVC.
2. Then the subject increased the force linearly from 0 up to 30%MVC by tracking a straight line on the screen (biofeedback). During this linear increase, which lasted approximately 10 s, simultaneous values of force and EMG_{RMS} were recorded.
3. The EMG_{RMS}/force relationship was calculated by performing a linear regression on the recorded values.

The trapezius muscle was calibrated in standing position with the arms positioned vertically. The subject pulled the force transducer with straight arms by isometric lifting the shoulders. The EMG_{RMS}/force relationship obtained during the calibration procedure was used to convert the EMG_{RMS} recorded to %MVC:

$$\%MVC = (EMG_{RMS} - m) \bullet 100\%/(a \bullet F_{max}),$$

where F_{max} is the maximum force in N during the MVC, a is the slope of the linear regression line in μV/N, and m is the minimum value of the EMG_{RMS} signal in μV during relaxation.

By calibrating EMG in this way, measurements could be compared between different subjects at different occasions [21, 22].

Quantification of the muscle load was done by ranking the interval estimate (0.1 s) to produce an amplitude distribution function (ADF) according to Jonsson [23, 24]. Static and median load are defined as the ADF levels 0.1 and 0.5 respectively. For development of musculoskeletal illness, both the ADF and the number of time periods with low levels of muscular activity may be important factors [25, 26, 27]. Several studies have documented a relationship between trapezius load parameters and development of musculoskeletal discomfort in the upper part of the body [12, 26, 28, 29, 30, 31]. Therefore, the duration and number of periods below 1%MVC were calculated from the EMG_{RMS} values.

3.4. Measurement of Postural Angles During Work

Workload on local body structures was assessed by recording body movements and posture at the workplace. To perform continuous measurements of postural angles, three dual-axis inclinometers were employed. These were also part of the physiometer (see Figure 2). The sensors were attached to the upper arm, head, and back. Postural angles were measured in terms of deviations from a reference body position. This was defined as a sitting position with well balanced, neutral head and trunk posture, relaxed shoulders, and both arms hanging relaxed. The head angle was set to zero when the subject looked at a spot in eye height at a distance of 5 m ahead. For the upper arm, both flexion (+)/extension (–) and abduction (+)/adduction (–) were recorded. For the head and back flexion (+)/extension (–) and sideways movement were measured. The total duration and the number of periods per minute when the upper arm was in a sector of $\pm 5^{o}$ flexion/extension and $\pm 5^{o}$ abduction/adduction was calculated.

When the arm is in these sectors, the shoulder load is considered to be low. The analysis of the signals from the inclinometers and the limitations of the method are discussed elsewhere [16, 32, 33]. In order to standardize the procedure of measuring EMG and postural angles, a video was made showing in detail how to use the physometer. In addition, Aarås trained the researchers in both Poland and the USA in how to do the measurement.

3.5. Psychosocial Questionnaire

All operators were requested to answer a questionnaire on the work situation. This was recommended to be done at home or at another place where the respondent would have privacy. Not more than 1 hr was required to complete the questionnaire, which was returned to the investigator the next day.

The questionnaire had six parts.

3.5.1. Working conditions in general

This part consisted of four questions relating to length and flexibility of working hours, breaks, and overtime.

3.5.2. VDT work especially

This part consisted of six questions relating to types of VDT tasks, time spent at the VDT (including breaks), extent of contact with other employees, and amount of stimulation provided.

3.5.3. Other tasks

This part consisted of five questions relating to description of other work tasks as well as comparisons of these tasks with VDT tasks with respect to physical demand, stress, stimulation, and contact with others.

3.5.4. Work on the whole

This part consisted of 15 questions relating to characteristics of work tasks, capability of the respondent to control demand and pace of work, capability to take breaks on demand, utilization of skills and abilities, contact with supervisors, job security, pay, and overall job satisfaction.

3.5.5. Additional paid employment

This part consisted of eight questions relating to characteristics of paid employment in addition to the respondent's current job (not including overtime). Questions were included regarding amount of additional work, reasons for doing additional work, and comparing the additional work with the primary job with respect to physical demand, stress, mental stimulation, and contacts with others.

3.5.6. Work-related conditions of the life situation

This part consisted of nine questions related to conditions in the respondent's home life. Questions were included regarding who the primary providers were, if there were others requiring support from the respondent (children, aged or infirm persons), commuting time, physical characteristics of the living space, availability of support from others, free time not spent sleeping.

3.6. Cluster Analysis: Combining Background and Psychosocial Data

A set of indexes were derived by combining responses from background data obtained from interviews (see section 3.1) and psychosocial data obtained from the take-home questionnaire (see section 3.5). These are outlined in the following sections.

3.6.1. Amount of VDT Work

This index combines three dimensions (frequency of VDT use, total amount of time per day, length of periods) to yield 10 categories ranging from high amount of VDT work to a small amount of VDT work.

3.6.2. Kinds of VDT tasks

The operators were asked which sort of VDT tasks they had. This was a way of controlling at the time of assessment that the operator had not changed from pure Data Entry/Data Dialogue to other or additional tasks.

3.6.3. Contacts

Questions were asked about the number of contacts (a) during VDT work, (b) during work with other tasks, (c) during the time for possible extra jobs. A question was also asked about the need and satisfaction regarding contacts.

3.6.4. Job satisfaction

Questions were asked about satisfaction with VDT work, with other tasks, and with work on the whole. Another question was asked about satisfaction from possible extra jobs.

3.6.5. Physical demands

The respondents were requested to compare the physical demands of the VDT job with those of other tasks of the ordinary job and with those of possible extra jobs.

3.6.6. Mental demands

The respondents were requested to compare the mental demands of the VDT job with those of other tasks of the ordinary job and with those of possible extra jobs.

3.6.7. Variation

Two questions were asked in order to characterize work with respect to the degree of variation and to problems which could arise.

3.6.8. Control

Six questions concerned self-determination (choice of tasks, amount of work, predictability, short breaks, and contacts in general and with supervisor). Together they constituted a work content-lack of control index.

3.6.9. Self-realization

Three questions concerned opportunity to learn, increase in job skills, utilization of capacity. Together they constituted a work content-degree of self-realization index.

3.6.10. Basic need satisfaction

Security in present employment, dependency on the results for payment, attitude to amount of income indicated to what extent basic needs were satisfied.

3.7. Vision Analysis

The visual problems and eyestrain were assessed together with headache (location and intensity).

The subjects underwent a detailed vision analysis. Symptoms and case history were registered in the consulting room. All symptoms that could relate to the work situation were carefully registered and marked on the VAS. Additional information that was judged to be of interest in determining the final correction was taken down on a separate sheet, but it was not included in the statistical material.

3.7.1. Vision analysis

1. Visual acuity. This was tested on an ordinary letter chart (Snellen) under good viewing conditions. It was recorded in decimal form, i.e., 20/20 equals 1.0, 20/30 equals 0.67, etc. If 1.0+ was recorded (i.e., a little better than 1.0 but not 1.1), it was put down as 1.05. The test was performed with the subject wearing his/her habitual correction, if any.
2. Static retinoscopy. Cycloplegia was not used. Based on the age of the subjects, this was considered not to be necessary.
3. Subjective refraction, monocular with binocular adjustment. Binocular adjustments was done according to Borish's method [34].
4. Oculomotor balance. Cover test for distance and near was performed as a normal cover test. A prism bar was used to give correct figures for any deviations. Induced phoria and fixation disparity were tested only for near vision. The Mallet near fixation disparity test was recommended [35, 36].
5. Amplitude of accommodation. This was tested with the push up method. The vital point was to determine the near point of accommodation, from which the amplitude of accommodation was calculated. If presbyopia was present, an addition for near work was calculated using Borish's recommendations: $X = (1/Y - Z/2)$,

where *X*—reading addition in dioptres, *Y*—working distance in meters, and *Z*—amplitude of accommodation in dioptres [34]. The final near addition was tested directly on a setup that had the same distances and gaze angles as at the employee's own workplace.

6. Stereoscopic acuity. This was tested with a polarized Titmus Fly test.
7. Ocular motility. This was tested with a penlight and inspection.
8. Visual fields (ad modum Donders). This was a confrontation test designed to detect serious abnormalities within the peripheral field of vision.
9. Pupil reflexes. They were tested under reduced illumination. Both direct, indirect, and near reflexes (if necessary) were tested.
10. Ocular inspection was performed at all examinations.

Optimal lenses were chosen based on a priori knowledge. The lenses were prescribed to optimize visual conditions at the workplace. Corrections were given with single vision lenses as the first lenses of choice. Where other solutions were absolutely necessary, special considerations had to be taken according to the ergonomic layout of the workplace [37].

3.7.2. Criteria for optometric corrections

Criteria for corrections are not easily established. In 1962, the Ministry of Health in the United Kingdom did an analysis of more than 9,000 prescriptions and found that around 15% of the total number of prescriptions were in the area from +0.62 to +1.00 dioptres [38, 39]. The difficulty in setting such criteria is that small errors of refraction can give rise to systemic disturbances [40]. In the same book it is also stated; "It is not the error itself that causes the trouble, but the continuous physiological effort called forth to correct for it" (p. 564). Another famous optometrist wrote "there is no doubt that the physiological compensation of slight errors of refraction can cause symptoms, the severity varies according to occupation, temperament and age of the patient" (p. 287) [41].

When attempting to give exact figures for optometric intervention criteria, there is always a risk that these criteria will result in prescribing spectacles to subjects who could do well without. There is also a risk that it will lead to not prescribe spectacles to patients that would benefit from them. The reasons for giving the following figures are also for statistical purposes. It must be kept in mind that a careful evaluation of symptoms together with refractive errors is a necessity in practical work with these problems.

In two former studies [42, 43] a significant number of the subjects tested had total or partial relief of their problems when wearing corrections that were given according to the following criteria: in hypermetropia (a) under the age of 30 years >+0.75 Dioptre sphere (DS), (b) over the age of 40 >+0.50 DS, (c) myopia ≥–0.50 DS, (d) astigmatism ≥0.50 Dioptre cylinder (DC)[1].

Prism corrections were recommended based both on the phoria measurements and fusional reserves (Shears criterion) and Mallet fixation disparity test. The reason again was to choose values that are universally accepted.

If, after a professional judgment, the doctor felt that the patient had gross, not correctable visual problems that made him/her unable to participate in the study, the subject was omitted from the study, labeled as eye pathology, which was one of the exclusion criteria.

Contact lens wearers were treated in the following way. The eye examination and refraction were carried out with the contact lens in situ, and if the new correction was outside the criteria, a new contact lens was fitted. If this was impossible, a spectacle correction was fitted on top of the contact lenses.

If new corrections were fitted, the clients had reasonable time to adapt to the new corrections. A minimum of 3 weeks' adaptation time was recommended.

3.7.3. Visual load

Visual load was assessed by measuring fixation time on screen and other working areas. Eyestrain was assessed with interviews.

[1] It is accepted that oblique astigmatism can complicate this criterion, but for simplicity this is ignored, and all types of astigmatism should be corrected according to the above criterion.

Visual problems associated with eyestrain were assessed by administering a VAS questionnaire. Symptoms were divided into the following groups: (a) feeling of tiredness, (b) redness of the eye, (c) stinging or itching/irritation, (d) gravely sensation, (e) double vision or blurred vision, (e) sensitivity to light.

3.7.4. Headaches

Headache was assessed by administering a VAS questionnaire. Questions were asked regarding headache intensity and location. The location parameters were the following: (a) around the eyes, (b) frontal, (c) occipital, (d) feeling of pressure on the head, (e) undefined.

3.8. Ergonomic Investigation

The ergonomic investigations were performed by the ergonomic expert at the work site through both observation and interview.

3.8.1. Expert observation

The expert ergonomic investigation (38 questions) dealt with factors such as illumination, features of the working space, room climate, noise, work hazard, office equipment, working desk, chair, VDT, and keyboard. The working station, environment, and the working posture were examined as well.

Objective measurements focused on (a) illuminance on keyboard, (b) illuminance on display screen, (c) luminance of characters on screen, (d) luminance of background of screen, (e) luminance of brightest objects, (f) direction of view to nearest window (angular measure), (g) distance to nearest window, (h) character contrast.

Subjective measurements involved (a) description of lighting, (b) description of daylight control.

The visual environment was recorded partly with objective measurements and partly with subjective assessments.

The illuminance was measured on the keyboard and on the front of the display unit. The illuminance was also measured in front of the operator and on the source document (when relevant).

The luminances L_{ch} of the characters on the screen and their background L_b were measured. When different colours were used for the characters, characters of the most frequently used colours were measured. Then, the contrast C for the characters was calculated from the formula

$$C = \frac{L_{ch} - L_b}{L_b}.$$

The screen was observed from the operator's position and any possible high luminance objects reflected in the screen were recorded.

In the case of rooms with windows, the direction of view relative to the windows and the distance from the workplace to the nearest window were reported. Different kinds of lighting equipment and daylight control were also recorded.

3.8.2. Ergonomic take-home questionnaire

All operators were asked to answer the ergonomic take-home questionnaire, which had 22 questions regarding environmental features, productive work time lost, and any negative impacts on performance due to environmental factors.

This was asked to be done at home or at another place where the respondent could have an hour (not more) in privacy. The questionnaire was returned next day to the investigator. Operators were instructed how to fill in the questionnaire, which was based on VASs and multiple-choice questions.

3.9. Computerized Journal System

In order to standardize data entry and increase the data quality of the final database, a computerized journal system for data entry was constructed.

3.10. Study Procedure

Standard operating procedures were established for administration of the research protocol. They were expected to be followed by each participating unit. These are outlined in the following sections.

3.10.1. Initial interview

Organizational and demographic data (see section 3.1) were collected by the interviewer.

Task analyses were conducted in order to assign subjects to appropriate experimental conditions (Data Entry/Data Dialogue).

3.10.2. Follow-up interview

Subjects were oriented to the experiment and informed consent forms were administered. Additional background information was obtained from individual subjects by interview (see section 3.1).

3.10.3. Pre-intervention data collection

The first phase of data collection was carried out just prior to the ergonomic intervention. It consisted of the following steps.

1. Distribution of psychosocial and ergonomic take-home questionnaire (see sections 3.5 and 3.8),
2. Collection of take-home questionnaires,
3. Vision examination (see section 3.7),
4. Medical examination (see section 3.2),
5. Work sample/ergonomic assessment; during this step, EMG and postural load measurements were carried out while each subject performed a typical VDT work task for approximately 1 hr. At the same time, the expert ergonomic assessment was performed while the subject was at the workstation. Calibration procedures and load measurements are described in sections 3.3 and 3.4. The ergonomic assessment is described in section 3.8.

3.10.4. Ergonomic intervention

The ergonomic intervention was carried immediately after the first phase of data collection. No attempt was made to standardize the nature of the intervention across participating countries for reasons of practicality. However, it was agreed that providing corrective lenses for those subjects requiring them for VDT work would be part of each intervention.

3.10.5. 1-month post-intervention data collection

The second phase of data collection was accomplished 1 month after completion of the ergonomic intervention. Steps 1–5 in section 3.10.3. were repeated.

3.10.6. 1-year post intervention data collection

This third phase of data collection was accomplished 1 year after completion of the ergonomic intervention. Steps 1–5 in section 3.10.3. were repeated.

3.10.7. Drop-out routine

The subjects who dropped out during the second and the third part of the study for reasons not related to the intervention were not included in the analysis of Parts II and III. These subjects were, however, included in the analysis of the first part and were specially reported in the statistical reports.

The subjects who withdrew from the study during Parts II and III for reasons related to the intervention were included in the analysis with the last observed results.

3.11. Statistical Aspect

3.11.1. Minimum number of subjects to be completed

Let X_{ij} and Y_{ij} denote the main variable in part i to worker number j in the Data Entry group and worker number k in the Data Dialogue group. Assume X_{il} ... X_{in} dependent and identically distributed $F(x)$ with the expected value μ_x and standard deviation σ_x. Assume Y_{il} ... Y_{in} independent and identically distributed $G(y)$ with the expected value μ_y and standard deviation σ_y. The hypothesis to be tested is

$$H_o : \mu_x = \mu_y, \quad A : \mu_x = \mu_y.$$

We define a clinically relevant difference as follows: two populations are said to be clinically relevant different if the difference between the two groups on the main variable is at least σ.

The model must meet the following requirements:

1. The probability of erroneously claiming differences between the groups on the main variable shall at most be 5% ($p < .05$),
2. If there is a true clinically relevant difference between the two groups on the main variable, the probability of detecting this shall be at least 90%.

By using the definitions of a clinical relevant difference together with the two requirements in an ANOVA model, the minimum number of workers to be completed in each group is $n = 23$ (50).

3.11.2. Statistical analysis

For estimation of the location parameters in assumed continuously distributed variables, both means and medians were used. As an index of dispersion, the standard deviations (*SD*), the 95% confidence intervals for the means, and the total ranges were used. For calculation of the confidence intervals for the medians, the Bernoulli-Wilcoxon procedure was used.

Essentially three analyses were made on this project. Within each country, groups were followed over time and changes from before to after the intervention were analyzed. In Norway there were three different groups. These groups were also compared both with regard to changes over time, and also with regard to the current situation at specific time-points. All these analyses were done non-parametrically [44], with Wilcoxon's signed rank test for changes over time and Kruskal-Wallis test for comparisons of the groups [45]. In the case of significant differences between groups, pairwise Mann-Witney tests with Bonferroni correction were performed to pinpoint the differences.

Cross-country comparisons were made on specific parameters. These analyses were performed with analysis of covariance (ANCOVA). Again, pairwise comparisons with Bonferroni correction were made in the case of significant differences between the groups [46, 47, 48, 49].

Further, analyses were done on the merged baseline data for associations between pain in different body parts, and several explanatory variables. These analyses were performed with linear and logistic regression. All these analyses were adjusted for group.

All tests were performed two-tailed with a significance level of 5%. It is important to be aware of the extremely high level of significance of the tests performed. This gives so-called multisignificance problems; the probability of rejecting at least one null hypothesis just by poor chance increases. Continuous variables are presented as mean values with 95% confidence intervals, while categorical variables are presented as percentages.

3.12. Ethical Issues

All information given by the included worker was handled confidentially. It is stressed that the participants were informed and gave their informed consent to participate, in accordance with the revised Helsinki Declaration, article II. The workers received both verbal and written information, including statements that they were free to withdraw from the project any time, without giving any reason.

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