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Will Musculoskeletal, Visual and Psychosocial Stress Change for Visual Display Unit (VDU) Operators When Moving From a Single-Occupancy Office to an Office Landscape?

Magne Helland
Gunnar Horgen
Tor Martin Kvikstad

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

Tore Garthus

Alcatel Norway A/S, Fornebu, Norway

Arne Aarås

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

This study investigated the effect of moving from single-occupancy offices to a landscape environment. Thirty-two visual display unit (VDU) operators reported no significant change in visual discomfort. Lighting conditions and glare reported subjectively showed no significant correlation with visual discomfort. Experience of pain was found to reduce subjectively rated work capacity during VDU tasks. The correlation between visual discomfort and reduced work capacity for single-occupancy offices was $r_s = .88$ *(*$p = .000$*) and for office landscape* $r_s = .82$ *(*$p = .000$*). Eye blink rate during habitual VDU work was recorded for 12 operators randomly selected from the 32 participants in the office landscape. A marked drop in eye blink rate during VDU work was found compared to eye blink rate during easy conversation. There were no significant changes in pain intensity in the neck, shoulder, forearm, wrist/hand, back or headache (*$.24 \leq p \leq .67$*). Pain levels in different body areas were significantly correlated with reduced work capacity,* $.77 < r_s < .99$ *(*$p = .000$*).*

VDU workplaces lighting conditions office landscape visual discomfort musculoskeletal illness eye blinking

1. INTRODUCTION

Lighting conditions and optometric corrections must be optimized to keep visual discomfort at an acceptable level [1, 2, 3,]. Luminance and its distribution in the room are important for avoiding contrast glare. Luminaries with both direct and indirect lighting give better luminance distribution

Correspondence and requests for offprints should be sent to Magne Helland, Buskerud University College, Department of Optometry and Visual Science, P.O. Box 235, N-3601 Kongsberg, Norway. E-mail: <magne.helland@hibu.no>.

and better visual condition compared to direct lighting on its own [4]. Screen and surface glare has been found to correlate significantly with eye focusing problems and tired eyes [4]. Further, visibility may be reduced if objects with high luminance are seen directly or reflected in the screen [5]. Corrections of hypermetropia and astigmatic errors have been documented to reduce visual discomfort for visual display unit (VDU) workers [6]. Optometric corrections, if needed, must be given according to work task analysis [7] because they may influence both body posture and postural load [8, 9].

Epidemiological literature has indicated a relationship between VDU work and musculoskeletal complaints in the neck, shoulder and upper extremity [10]. Static muscle load, high frequency of repetitive movements and high force requirements of these movements seem to be predictors of the onset of musculoskeletal discomfort [11, 12]. Duration of repetitive movements of the upper arm was found to be associated with neck and shoulder symptoms [13]. There are indications of an exposure–response relationship between keyboard typing time and risk of upper extremity symptoms [14]. It has also been shown that upper extremity symptoms are more frequent in the mouse operating hand compared with the other arm and hand [15]. An association between neck and upper extremity symptoms with hours per day of mouse use has been found [16]. Odds ratios for developing symptoms with prolonged mouse use were 2.2 or higher for the shoulder, upper arm, elbow, wrist and hand/fingers for computer-aided design operators compared with telecommunication laboratory workers. The risk of tension neck syndrome increased fourfold when the weekly hours spent with a computer mouse exceeded 25 hrs a week compared to no or minor mouse use. A similar relationship was also found between the pain level in the forearm and the total time of using the mouse [17]. Neutral position and support of the forearm reduced pain in the upper extremity [18, 19, 20]. Psychosocial factors such as time pressure and a high perceived work load interact in the development of upper extremity and neck symptoms [21, 22]. Lighting design, ergonomic workplaces and optometric corrections are important elements in the current intervention study.

The aims of the study were to investigate if improved luminaries, ergonomic work places and optometric corrections in the new office landscape would change visual discomfort, headache and musculoskeletal pain compared with corresponding values from a traditional single-occupancy office. Further, what is typical eye blink rate during habitual VDU work in an office landscape?

2. METHODS

2.1. Design of the Study

Thirty-two VDU workers at Alcatel AB (Stockholm, Sweden) participated in the study. Their work involved sales and design projects of telecom products. Most participants did VDU work for over 5 hrs per day. The participants' mean age was 40.6 years (*SD* 7.8, range: 26–58). The new luminaries and the ergonomic workplaces were already installed when the company moved from single-occupancy offices to the new office landscape in May 2005 (Table 1). In September 2005 the participants underwent an optometric examination and new corrections were given for 7 participants. In November 2005, eye blink rate was recorded from 12 randomly selected workers with a digital video camera. From the same participants, postural load on the musculoskeletal system was measured with electromyographic (EMG) recordings from m. trapezius and m. infraspinatus with the physiometer (PreMed AS, Norway) [23]. Movements of the head, upper arm and back were recorded with inclinometers (PreMed AS, Norway) [24]. Participants worked at their personal workstations for ~30 min while electromyographic recordings and inclinometer measurements were taken. During this time, participants' eyes were videoed to record eye blink rate. The study followed the tenets of the Declaration of Helsinki.

TABLE 1. Time Span of the Project

Intervention/Activity	April 2005*	May 2005	Sept. 2005	Nov. 2005	April 2006
Lighting intervention		√			
Ergonomic intervention		√			
Optometric examination			√		
Eye blinks and EMG measurement				√	
Questionnaires	√				√

Notes. *—used as baseline.

2.2. Methods and Procedures

Questionnaires which dealt with headache, visual and lighting conditions, and discomfort as well as musculoskeletal pain, organizational and psychosocial factors were answered in April 2005, before moving to the office landscape (Table 1). The questionnaires were administered by the local health security officer, filled in individually, and returned anonymously in a sealed envelope to the company's medical doctor in Scandinavia (author Arne Aarås). Each factor was measured on a 100-mm visual analog scale (VAS) [25, 26]. Answers to questions were estimated by the participants using an average intensity for the previous 6 months. The same questionnaires were answered again 7 months after the optometric intervention, i.e., one year after the start of the study. A detailed description of the questionnaires and procedures of measuring lighting variables as well as musculoskeletal and optometric parameters are given by Aarås, Horgen, Bjørset, et al. [17] and Aarås, Dainoff, Ro, et al. [27].

2.2.1. Postural load

Muscle load was measured with EMG from m. trapezius and m. infraspinatus [23].

2.2.2. Postural angles

Dual inclinometers were used to measure postural angles of the head, upper right arm and back [24].

2.2.3. Eye blinking registration

Eye blink rate was recorded with a digital video camera (DCR TRV 22; Sony, Japan) and a video editing program (Pinnacle Studio DV 8, version 8; Pinnacle Systems GmbH, Germany) [28]. The total number of eye blinks counted was converted to eye blinks per minute. Eye blinks were counted both during active VDU work and during a rest situation at the same workplace with easy conversation (and no VDU work). For most participants the vast majority of the blinks were complete. For this reason no distinction between blinks was made.

2.2.4. Drop-out routine

A separate statistical analysis was carried out to investigate possible systematic biases regarding health parameters of participants who dropped out during the study period. This test was performed by comparing corresponding values at commencement of the study for those who had dropped out with those who completed the study. The variables analyzed for the two groups were visual discomfort, headache, pain in the neck, shoulder and upper arm as well as organizational and psychosocial factors.

2.3. Statistical Methods

Continuously distributed location parameters are presented as means with 95% CI (confidence interval). To test for changes in response between single-occupancy offices and the office landscape, the paired sample T test and the Wilcoxon signed-rank test were used. The T test was appropriate due to the relatively high number of participants. To test correlations between variables, Spearman's coefficient of rank correlation r_s was used. This was done to avoid assumptions of normality and linearity. R^2 was also used. All tests were two-tailed using the null hypothesis of equality or no correlation.

A multivariable regression model was used to analyze the relationship between physical and psychosocial factors, and pain in the neck and shoulder. All factors studied were tested in a simple regression model. Predictors with $p < .10$ were combined in a multiple model. Due to a strong correlation between pain in the neck and in the shoulder, the mean of the two was used as one variable.

3. INTERVENTION

3.1. Lighting and Visual Condition

These conditions are described in detail because glare problems are likely to appear due to large window areas in office landscapes. In the original building, all rooms were rectangular single-occupancy offices. Approximately 60% of the VDU screens were placed in the corner of the table close to the window, giving the operators a gaze direction 45° to the window (Figure 1). Glare from the windows was observed when Venetian blinds were not properly used (luminance of 10000 cd/m^2, clear weather). Thirty percent of the screens were placed further away from the window with a gaze direction 135° to the window. Reflections from the window were observed in the screen.

Most rooms had luminaries (Fagerhult Appolol 15107-17; Fagerhult, Sweden), with 3 × 36 W fluorescent tubes; one tube lit downwards, two tubes lit upwards (Figure 1). Illuminance of the relevant work areas varied from minimum 460 to maximum 650 lx. Luminance on the wall behind the screen was 80–100 cd/m^2. In the upper part of the visual field, luminance was higher (380–450 cd/m^2). Contrast (C) is measured as $C = (L_L - L_B)/L_B$, where L_L—luminance of the letters and L_B—luminance of the background. Contrast reduction (ΔC) is given with the expression $\Delta C = (C_{max} - C_{new})/C_{max} \times 100$ (%), where C_{new}—contrast that is measured with the room light on. Contrast reduction from the luminaries in the screen was 10.5% for a cathode ray tube (CRT) screen and 3.7% for a liquid crystal display (LCD) (Lab Top; Compaq EVO N1020V HP; Hewlett-Packard) screen. Values were measured without daylight. In a few rooms, the luminaries (Annell VX-22-455; Annell, Sweden; 4 × 55 W) gave only indirect

Figure 1. Typical VDU screen placement for a single-occupancy office—in the corner of the table close to the window. *Notes*. The luminaire had 3 x 36 W lighting tubes; one was lit downwards, two were lit upwards giving luminance from the ceiling of 380–450 cd/m^2.

Figure 2. In a few single-occupancy offices the luminaire was discus-shaped, suspended 30 cm from the ceiling. *Notes*. Four lighting tubes were lit upwards giving luminance from the ceiling of 1500–1800 cd/m^2.

Figure 3. In the office landscape the luminaires were positioned parallel to the length of the tables providing only indirect lighting. *Notes.* Luminance from the ceiling was 600–800 cd/m^2.

lighting. They were suspended 30 cm from the ceiling giving a luminance of the ceiling of 1500–1800 cd/m^2 (Figure 2). Illuminance of the relevant work areas was low (200–290 lx), while luminance on the wall behind the screen was ~50 cd/m^2. Contrast reduction from the luminaries in the screen was 3.4% for a CRT screen and 2.1% for a LCD (Lap Top) screen.

In the office landscape only a few workplaces were located along the window walls. For these workplaces the gaze direction was parallel to the windows and the workers sat at least 2 m. from the window wall. All windows had Venetian blinds. Luminance levels from the windows varied between 2500 and 3400 cd/m^2 (clear weather). The luminaries (Phenix pendel; Fagerhult, Sweden; 2 × 55 W TC-L) gave only indirect light. These were positioned parallel to the length of the tables (Figure 3). To reduce high luminance in the ceiling from the luminaries, the height from the ceiling was increased from 30 to 60 cm. This reduced luminance from 1500 to 600–800 cd/m^2. Illuminance levels were very similar whether the table was directly below the luminarie or between two luminaries (~600 lx), i.e., light was evenly distributed in the work area of the room. Luminance measured on the tabletop and walls in the gaze direction towards the screen varied between 85 and 140 cd/m^2. The luminance level on the ceiling above the nearest luminarie in the operator's visual field was 600–800 cd/m^2. These levels gave acceptable contrast reduction in the screen (5% for a flat LCD monitor; 6% for an LCD Lap Top screen). However, contrast reduction in the CRT screen was unacceptably high (12%). Therefore, all workers were given LCD screens. The measurements of illuminance and luminance were carried out with a Hagner luminance meter (model 51; B. Hagner AB, Sweden).

3.2. Intervention in the Workplaces

In the original building, each table could be adjusted to provide the correct height for a sitting position by adjusting each leg of the table. The tabletop gave the operators good support for their forearms and hands. After intervention, the tables were easily adjustable in height for sitting and standing positions using an electrical device. The tabletop gave good support for the forearm and hand and sufficient area for work tasks. The chairs were flexible and adjustable, allowing the operators to assume a backward leaning position to reduce the pressure on the intervertebral discs and isometric stress on the back muscles [29, 30].

3.3. Optometric Intervention

The participants underwent an optometric examination; 7 participants were supplied with corrections according to recommendations [6, 7, 31].

3.4. Criteria for Correction

Criteria for prescribing optometric corrections are not easily given, and some controversy exists around this topic. The criteria were adopted from guidelines in previous publications [7, 8, 9, 32].

3.5 Spectacle Lenses

The corrections were provided free of charge according to the provisions issued by the Swedish National Board of Occupational Safety and Health on Work with Display Screen Equipment (AFS 1998:5) (the Swedish adaptation to the European Community Directive No. 90/270/EEC[1]), and were custom-made for the participants' specific work tasks. The participants were instructed to use the corrections while working on the VDU [8, 9]. New designs of VDU lenses (the so-called VDU progressives, or VDU progressive addition lenses, PALs) give a longer focusing range without increasing postural load compared with ordinary PALs [2, 3]. The lenses were fitted according to the guidelines supplied by the manufactures.

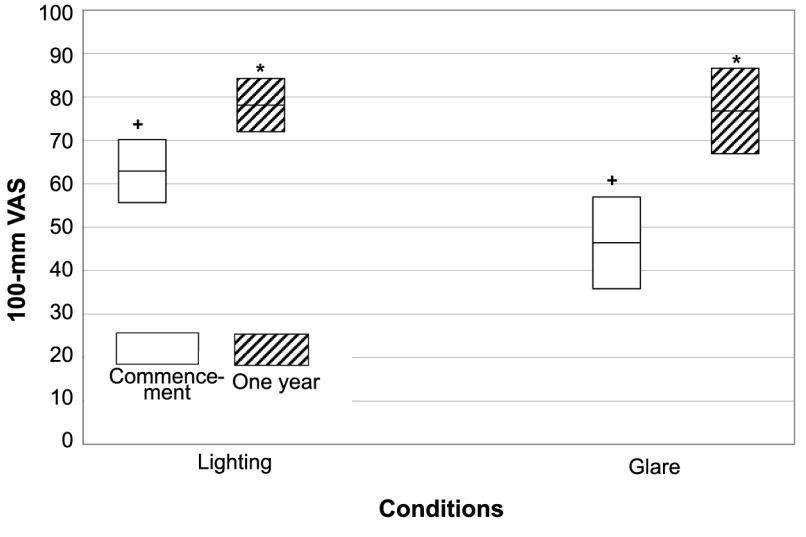

Figure 4. Subjective assessment of lighting and glare conditions. *Notes.* Mean with 95% CI (confidence interval) at commencement and after one year; 100-mm visual analog scale (VAS); 0—*extreme problems*, 100—*no problems*. *—a significant difference when compared with the column containing a +.

[1] Council Directive 90/270/EEC of 29 May 1990 on the minimum safety and health requirements for work with display screen equipment (fifth individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC), Official Journal of the European Communities. 1990;L156:14.

4. RESULTS

4.1. The Lighting Intervention

The operators reported significantly improved lighting conditions when moving from the original building to the office landscape, 15.8 (6.2–25.4) VAS as group mean difference with 95% CI (p = .002). The glare condition was also assessed to be significantly reduced 27.6 (15.0–40.2), group mean difference with 95% CI (p = .000) (Figure 4). Questions regarding lighting and glare at commencement were answered differently (p = .006), hence they were analyzed separately. Further, no significant correlation between visual condition and glare was found, r_s = .20 (p = .28).

4.2. Visual Problems

The VDU workers reported no significant change in visual discomfort when moving from single-occupancy offices to an office landscape, 1.9 (–13.1–16.8), group mean difference with 95% CI (p = .80) (Figure 5). When comparing different types of eye symptoms, feeling of tired eyes, redness of the eyes, stinging and itching of the eyes, gravelly sensation of the eyes, blurred vision as well as sensitivity to light, no significant differences were reported (.28 < p < .83). Subjectively rated visual condition and glare did not appear to be a source of visual discomfort either at commencement or after one year. The correlation was weak between visual condition and visual discomfort, r_s = .12, and glare and visual discomfort, r_s = .07, at commencement. Corresponding data after one year were r_s = .09 and r_s = –.26. When considering the relation between visual discomfort and pain in the upper body at commencement, a significant correlation was found between visual discomfort and pain in the forearm, r_s = .49 (p = .005). For headache, neck, shoulder, wrist/hand and back pain, no significant correlations were found, .05 < r_s < .34 (.062 < p < .780). In the same analysis after one year of the study, a significant correlation was found between visual discomfort and pain in the neck r_s = .44 (p = .038). For headache, shoulder, forearm, wrist/hand and back pain, no significant correlations were found, –.01 < r_s < .38 (.075 <p < .960).

The question regarding how visual discomfort influenced work capacity because of pain was

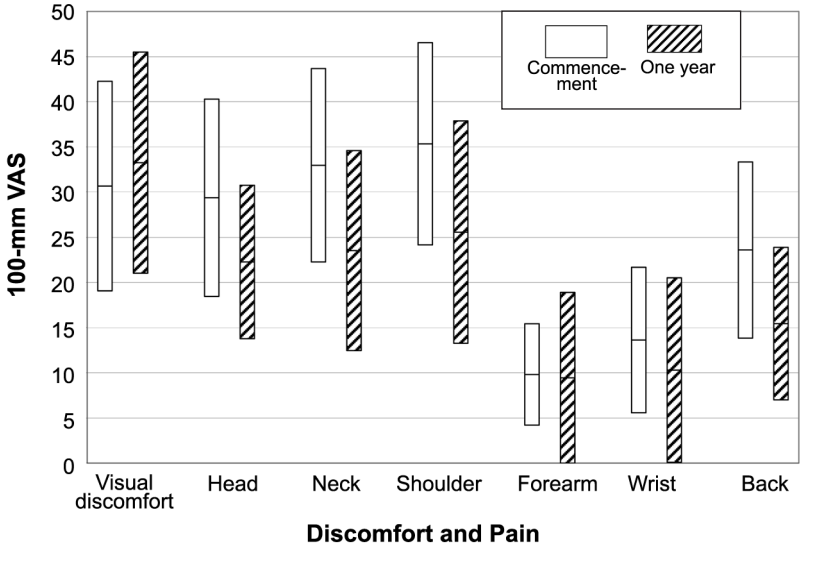

Figure 5. Subjective assessment of visual discomfort and pain in different body parts. *Notes.* Mean with 95% CI (confidence interval) at commencement (n = 32) and after one year (n = 23); 100-mm visual analog scale (VAS); 0—*no problems*, 100—*extreme problems*.

also analyzed. At commencement, a significant correlation was found between visual discomfort and reduced work capacity, $r_s = .88$ ($p = .000$). Similar results after one year of the study were $r_s = .82$ ($p = .000$). At commencement there was also a highly significant correlation between visual discomfort and different types of eye symptoms, feeling of tired eyes, redness of the eyes, stinging and itching of the eyes, gravelly sensation of the eyes, blurred vision as well as sensitivity to light, $.42 < r_s < .64$ ($p \leq .018$). Corresponding data after one year were $0.53 \leq r_s < .73$ ($p \leq .01$).

4.3. Optometry

All participants had normal eyes and vision. New optometric corrections were given to 7 participants. One was given single vision correction, 5 were given a computer-progressive correction giving a range of clear vision out to ~1 m (Essilor Interview; Essilor, France), one received a data-progressive correction giving clear vision out to ~2 m (Essilor Dataview), and one participant who worked mainly on a laptop computer was evaluated to be best served with ordinary progressive lenses. All corrections were given according to a task analysis that was done before the eye examination. Twenty-two participants were evaluated to have satisfactory vision for their VDU work situation, either with their present correction or uncorrected. One participant failed to attend the eye examination.

4.4. Eye Blinking

Eye blink rate per minute during habitual VDU work was 5.2 (3.6–6.8) as mean with 95% CI. Corresponding data during the rest period after ~30 min of active habitual VDU work was 11.1 (7.9–14.3) (Figure 6).

4.5. Muscle Load

Static and median trapezius load with 95% CI was 0.8% of maximum voluntary contraction (MVC) (0.3–1.2) and 3.1% MVC (1.1–5.2), respectively. Similar data for m. infraspinatus was 0.8% MVC (0.5–1.1) and 1.4% MVC (0.9–1.8).

4.6. Postural Angle Measurement

Head movements were small both in the sagittal and coronal plane. The static angle of head flexion was 4° (–4°–11°) as group mean value with 95% CI. This means that the head was extended only a few degrees for a short period. Head flexion was 4° static and 24° peak as mean group values. This describes the area of movement for 80% of the time. Head sideway movement was between 2° to the right and 8° to the left for 80% of the time.

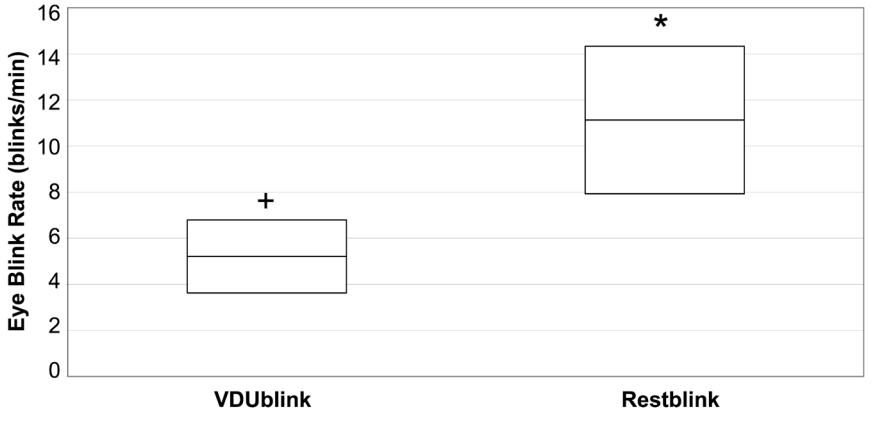

Figure 6. Eye blink rate (blinks/min) during a VDU work session (VDUblink) and at rest (Restblink) (*n* = 12 VDU operators). *Notes*. Mean with 95% CI (confidence interval). *—a significant difference when comparing with the column containing a +.

TABLE 2. Correlation Between Pain in Different Body Areas and Work Capacity at Commencement and After One Year of the Study (Stockholm, Sweden)

	Commencement (Single-Occupancy Offices)		After One Year (Office Landscape)	
Body Area	r_s	p	r_s	p
Head	.71	.000	.77	.000
Neck	.92	.000	.93	.000
Shoulder	.83	.000	.94	.000
Forearm	.91	.000	.99	.000
Wrist	.85	.000	.96	.000
Back	.86	.000	.91	.000

Notes. r_s—Spearman's coefficient of rank correlation.

No significant correlation was found between neck pain and shoulder pain and flexion of the head. The group mean flexion of the upper arm in the shoulder joint when supporting the forearm on the tabletop was 7°–25° for 80% of the time. Corresponding data for arm movement in the coronal plane was 2° adduction to 17° abduction. The movement of the back were within 3°–17° flexion. There was a bending of the back to the right of 0°–9°.

4.7. Pain Assessment

When moving from the original building to the office landscape, there were no significant changes in pain intensity in the neck, shoulder, forearm, wrist/hand, back and headache ($.24 < p < .67$) (Figure 5). A multiple regression model was computed including selected predictors at commencement of the study (job satisfaction, utilization of your ability, time at your own disposal, other work tasks more stressful than VDU work, contact with your job superior, new VDU screen, intensity of dry eyes, bothered by dry eye, stinging or itching/ irritation of the eye, subjective tenseness, pain in the forearm, back pain, blurred vision, eye fatigue, headache, dry mouth, gravelly sensation of the eye) with mean pain in the neck and shoulder as the dependent variable. The selected predictors were found to explain 98% of the variance in neck and shoulder pain. When the model was reduced to include only headache, dry mouth and subjective tenseness as predictors, these independent variables explained 76% of the variance of neck and shoulder pain. By considering each of the three variables separately in a simple regression model the explanation percentages were subjective tenseness 57%, headache 44% and dry mouth 28%.

After one year of the study the following selected predictors were included in a multiple regression model: job variation, contact with your job superior, subjective tenseness, dry mouth, type of mouse, headache, eye fatigue and gravelly sensation of the eye. Mean pain in the neck and shoulder was the dependent variable. The selected predictors were found to explain 74% of the variance of neck and shoulder pain. When the model was reduced to include only headache, dry mouth and subjective tenseness as predictors, these independent variables explained 71% of the variance of neck and shoulder pain. For each selected predictor viewed separately the mean of neck and shoulder pain was explained by the following percentages of the variance: subjective tenseness 37%, headache 36% and dry mouth 29%.

Participants were asked to rate how pain influenced work capacity (i.e., if pain was so severe that it influenced work capacity). High correlations were found between pain and reduced work capacity for different body areas both at commencement and after one year of the study (Table 2).

There were significant correlations between pain in the following body areas at commencement and after one year of the study: headache, $r_s = .48$ ($p = .020$); neck, $r_s = .59$ ($p = .003$); shoulder, $r_s = .51$ ($p = .012$). This suggests that the same

workers who suffered headache, neck and shoulder pain at commencement also suffered the same problems after one year. No significant correlations were found for forearm, wrist/hand and back. There appeared to be a high influence of pain in closely related anatomical areas, such as head and neck, head and shoulder, head and back, neck and shoulder as well as neck and back. Headache correlated significantly with pain in the neck, $r_s = .56$ ($p = .001$). Correlations for the other areas were headache with shoulder pain, $r_s = .74$ ($p = .001$); headache with back pain, $r_s = .43$ ($p = .015$); neck pain with shoulder pain, $r_s = .71$ ($p = .000$); and neck pain with back pain, $r_s = .48$ ($p = .005$).

4.8. Relation Between Pain, Muscle Load and the Time the Operators Used the Mouse

At commencement, there were no significant correlations between pain in the head, neck, shoulder, forearm, wrist/hand and back and the time the mouse was used, $-.17 < r_s < -.03$ ($.34 < p < .86$). No significant correlation was found between median trapezius load and the time the mouse was used , $r_s = .10$, $p = .77$. This was also the case for median infraspinatus load, $r_s = .38$ ($p = .24$).

4.9. Relationship Between Trapezius EMG and Pain in the Neck and Shoulder

There was no significant correlation between trapezius EMG median value of amplitude distribution function and pain intensity in the neck, $r_s = .41$ ($p = .21$).

4.10. Organizational and Psychosocial Factors

Organizational and psychosocial factors might act as confounding factors for the dependent variables, e.g., pain. Therefore, these factors were tracked during the study period [27]. The difference between the factor(s) at commencement and after one year of the study is presented as mean group value with 95% CI. The only two factors which the operators reported significantly changed were longer working hours per day at the VDU, 0.8 hrs (0.2–1.47) ($p = .013$), and longer time before taking a break from VDU work, 26 min (3.8–48.7) ($p = .025$). Other important factors including job satisfaction, job control, self realization, work-related conditions, the work task, working hours per week, other work tasks compared with VDU work, the VDU workplace at home compared with the workplace at the office, work tasks other than VDU work and the daily journey to work showed no significant differences (p values between .08 and 1.00).

4.11. Drop-Outs

Ten participants dropped out from commencement to one year of the study. The main reason for dropping out was rationalization in the company which resulted in a reduction in the workforce. Those who dropped out of the study from commencement to one year were compared with those who were still in the company after one year ("completers"). There were no significant differences in any measured variable (visual discomfort, headache, neck pain, shoulder pain and pain in the forearm) at commencement ($.13 \leq p < .48$).

4.12. Comparison of Visual Discomfort and Pain Between Alcatel Stockholm and Alcatel Oslo Both for Single-Occupancy Offices and Office Landscape

4.12.1. Single-occupancy offices

All operators worked in single-occupancy offices before they moved into an office landscape. In Oslo, Norway, the lighting, optometry and workplace interventions were implemented [1]. In Stockholm, no such interventions were performed (see section 3). The dependent variables (lighting, glare, visual discomfort and pain in the neck and shoulder) were reported significantly worse in Stockholm compared with Oslo. For pain in the forearm and headache no significant differences

TABLE 3. Comparison of Visual Discomfort and Pain in Different Body Areas Between Alcatel Stockholm, Sweden, and Alcatel Oslo, Norway, in Single-Occupancy Offices and Office Landscapes

	Single-Occupancy Office			Office Landscape		
Discomfort/Pain	**Mean Difference**	**95% CI**	***p* Value**	**Mean Difference**	**95% CI**	***p* Value**
Lighting	–15.4	–23.3– –7.4	.000	11.4	1.3–21.5	.028
Glare	–24.7	–37.4– –11.9	.000	18.0	3.9–32.2	.013
Visual discomfort	17.0	4.3–29.6	.010	8.1	–6.6–22.8	.270
Head	9.9	–2.6–22.4	.120	–4.6	–16.4–7.2	.440
Neck	15.9	3.9–28.0	.011	3.0	–10.6–16.5	.660
Shoulder	25.0	12.4–137.6	.000	6.2	–8.3–20.7	.390
Forearm	–4.2	–13.2–4.9	.360	–7.1	–19.1–5.0	.240

were reported. The results for single-occupancy offices are given as mean difference with 95% CI (Table 3).

Considering psychosocial factors, the jobs were reported to be more variable in Oslo compared to Stockholm, 8.8 (1.7–16) (p = .017), while work-related factors were reported better in Stockholm compared with Oslo, 24.4 (18.6–30.2) (p = .000). For job control and self realization, there were no significant differences ($.087 \leq p < .420$).

4.12.2. Office landscape

All operators worked in an office landscape. Both in Alcatel Stockholm and Alcatel Oslo, lighting, optometry and workplace interventions were performed before moving to the office landscape. After interventions, lighting and glare condition were reported to be significantly better in Stockholm compared with Oslo. For the other dependent variables (visual discomfort, pain in different body areas and headache) no significant differences were found. The results for office landscape are given as mean difference with 95% CI (Table 3). Considering psychosocial factors, job control was reported to be better in Oslo compared with Stockholm, 7.4 (+0.0–14.7) (p = .049), while work-related factors were reported to be better in Stockholm than Oslo, 28.0 (20.6–35.4) (p = .000). For job variation, self realization and job satisfaction there were no significant differences ($.073 \leq p \leq .47$).

The dependent variables (visual discomfort and the pain level in different body areas) and work capacity for VDU work showed no significant differences between Stockholm and Oslo, either at commencement or at one year of the study.

5. DISCUSSION

When using VDUs, office landscape might be problematic because of glare from the windows and luminaries [33]. In Stockholm, however, the VDU operators assessed the visual and the glare conditions to be significantly improved when they moved from single-occupancy offices to an office landscape. This was contrary to an earlier finding [34]. One reasonable explanation for this result may be that the operators were not glared from the windows. Most workplaces were positioned along walls without windows. For those workers who had workplaces positioned along the window wall, all operators had the gaze direction to the VDU screen parallel with the windows and sat more than 2 m away from the windows. This reduced the light contribution from the windows and glare as well as reflections in the screen [4, 5]. In addition, automatic Venetian blinds were installed to reduce glare from the windows.

The luminaries may be a small source of glare since the contrast reduction in the LCD screen from the luminaries was measured to be 5–6%. Further, no significant correlation between lighting condition and visual discomfort (r_s = .09) and glare and visual discomfort (r_s = –.26) were found. All VDU workers were given 19″ LCD screens because the contrast reduction for the CRT screens was 12%, which was unacceptable. Hence, in an office landscape CRT screens should be avoided. The VDU workers did not

report significant changes in visual discomfort and other eye symptoms when moving from single-occupancy offices to an office landscape in spite of reporting improved lighting and glare conditions. One possible explanation may be that working hours per day and time before taking a break from VDU work were reported significant longer after moving to the office landscape. These factors may increase visual load.

Visual discomfort correlated significantly with neck pain after one year of the study (p = .04). This result confirms findings from other researchers [17, 34, 35]. Further support for the correlation between visual discomfort and pain in the neck has been reported [36]. It showed that eye movements away from a position of rest increased the muscle load in trapezius.

There was an indication of individual sensitivity to visual discomfort since many of those who suffered visual discomfort in single-occupancy offices also suffered the same problem in the office landscape. These results are consistent with earlier findings [17, 35]. In this study visual discomfort was reported to be so painful that it influenced work capacity. The correlation between visual discomfort and reduced work capacity was r_s = .88 (p = .000). In addition, pain in the different body areas was also reported to affect productivity. Pain in all body areas (head, neck, shoulder, forearm, wrist/hand and back) was significantly correlated with work capacity both at commencement and after one year (Table 2). Similar correlation has been reported previously [37].

The pain level was still low after one year of the study and was not significantly different when comparing commencement with one-year follow-up. The mean values for different body areas varied between 10 and 35 mm (VAS) at commencement versus 9–26 mm (VAS) at one year. The static trapezius and infraspinatus load was less than 1% MVC when the forearm was supported. These results are in line with another study of VDU workers [17].

Headache and subjective tenseness seem to be important factors for neck and shoulder pain. In a simple regression model, headache explained 36% of the variance, while subjective tenseness accounted for 37% of the variance of the mean of neck and shoulder pain in the office landscape.

Both increased working hours per day and longer time before taking a break from the VDU may increase the work load, stress and musculoskeletal symptoms [38, 39, 40, 41, 42]. Even though these two factors were reported as worse, the VDU workers reported only a small and not significant decrease in the pain level regarding different body areas. The other organizational and psychosocial factors tracked did not show significant changes from commencement to after one year of the study.

Drop-outs may influence the outcome variables. In this study, the drop-outs were not available. However, the analysis at commencement showed no significant differences between the drop-outs and the completers regarding the outcome variables.

Visual discomfort was not significant different in the office landscape when comparing the VDU workers in Stockholm and Oslo (p = .27). The quality criteria for lighting, illuminance levels, luminance levels and contrast reduction in the VDU screen were approximately the same in the two offices. This supports the findings of Gobba, Broglia, Sarti, et al. [43] that high-quality lighting is important in preventing visual discomfort.

Pain levels in different body areas (neck, shoulder, forearm, wrist/hand and back) were not significantly different when comparing the VDU workers in Oslo and Stockholm ($.25 < p < .95$). In both locations, the tables and chairs had the same ergonomic features. These results may indicate that ergonomic tables and chairs may have an influence on muscle discomfort. There was no significant correlation between pain and the time the mouse was used, which is contrary to results from other studies [17, 34, 44].

In Stockholm the workers reported significantly higher visual discomfort in single-occupancy offices than the workers in Oslo. Seventy percent of the workers in Stockholm had a gaze direction 45° to the windows during VDU work, while in Oslo the workers had a gaze direction parallel to the windows. Luminance at windows varied between 4000 (cloudy weather) and 10000 cd/m^2 (clear weather). Further, glare problems were

reported as significantly worse in Stockholm than in Oslo. Hence, glare from windows may be one reason for the difference in visual discomfort between Stockholm and Oslo. The importance of glare as a source of visual discomfort is also supported by the results on the office landscape in Oslo. Many operators in Oslo had their workplace along the windows, while very few had such a location in Stockholm. Further, the visual condition and glare were reported significantly better in Stockholm although the measurements of the visual conditions (illuminance, luminance and contrast reduction in the screen) were very similar in the two locations. Other research has also found glare as an important factor for visual discomfort in office landscapes [33].

Another possible cause of fewer glare problems in Stockholm compared with Oslo might be that the VDU workers in Stockholm were significant younger. In Stockholm the mean age was 40.6 years (*SD* 7.8, range: 26–58) compared with 53.2 years (*SD* 5.7, range: 43–62) in Oslo. Even though an eye examination (Oslo) or an interview (Stockholm) did not reveal any eye pathology either in Stockholm or Oslo, normal physiological age-related ocular changes might influence the results. Even without visible and clinically significant eye pathology a normal age-related reduction in pupil size (senile miosis), transparency of the ocular media and retinal sensitivity can result in more glare problems [45].

6. CONCLUSION

By careful design and construction of an office landscape with regard to lighting and visual conditions a transfer from single-occupancy offices may be acceptable from a visual-ergonomic point of view. In this study, by moving from single-occupancy offices to an office landscape, the VDU operators reported significantly improved lighting and glare conditions, while no significant change in visual discomfort was observed. Visual condition and glare did not appear to be a source of visual discomfort either at commencement or after one year. The correlation was weak between lighting condition and visual discomfort, $r_s = .12$, and glare and visual discomfort, $r_s = .07$, at commencement. Corresponding data after one year were $r_s = .09$ and $r_s = –.26$. There was no significant change in pain level. Subjective tenseness and headache seem to be factors influencing neck and shoulder pain. These factors when viewed separately explained 57 and 44% of the variance at commencement, and 37 and 36% after one year. Also a marked drop in eye blink rate during VDU work was found.

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