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# Assessment of video display workstation set up on risk factors associated with the development of low back and neck discomfort

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## Abstract

Approximately 33% of visual display terminal (VDT) operators report back and neck pain annually. As a result, a number of “ergonomic” chairs have been developed ranging the price spectrum. The objectives of this study were to (1) assess the effects of monitor height and chair type on low back and neck muscle activity, perceived level of discomfort (PLD), and posture shifts; and (2) determine if chairs at opposing ends of their price spectrum differ in the physiological benefits. Two levels of monitor height and chair type were assessed. The findings of this research indicate that the interaction of monitor height and chair type significantly affects the loads placed on the human body. Task demands also play an important role in the loads placed on the body, posture fixity, and level of discomfort reported. Therefore, the location of VDT equipment and chair selection should be based on task demands to minimize static loading and discomfort. In general, no gross physiological differences were identified between high and low cost chairs, again supporting the recommendation that chair selection be based on task demands.

*Relevance to industry:* This research assesses differences in high and low cost ergonomic chairs as they relate to physiological responses of the back and neck and user perceived discomfort. This information can be used to guide organizations in the purchase of office equipment.

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*Keywords:* Work-related musculoskeletal disorder; Low back pain; Neck pain; VDT; Workstation set up

## 1. Introduction

Back pain has been identified as the most prevalent and costly work-related musculoskeletal disorder (WMSD) in US industries (NIOSH, 1997). It is estimated that approximately 75% of

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all workers in industrial countries are employed in sedentary jobs (Pope et al., 1999), with about 35% of these persons reporting back pain (Rowe, 1969). Although neck pain accounts for a much smaller percentage of WMSDs than back pain, it has been frequently studied, especially for sedentary job tasks associated with significant amounts of computer usage. Approximately 33% of visual display terminal (VDT) operators report back pain (Smith et al., 1980) and neck pain yearly (Nishiyama et al., 1984). Hettinger (1985) concluded that since workers in the administrative sector reported more sick days associated with back pain than the industrial sector, seated postures should be considered on the same hazardous level as lifting tasks and tasks involving vibrating equipment.

Numerous studies of VDT workstations have investigated the impact of chair design parameters and VDT equipment positioning on back pain and neck pain, respectively. Studies have evaluated the influence of numerous chair parameters on the development of back pain, including seat type (Rogers and Thomas, 1990), seat height (Helander et al., 1995), backrest type (Helander et al., 1995), backrest angle (Burton, 1984; Grandjean et al., 1983), lumbar support (Van Popple et al., 2000), and presence of armrests (Andersson and Ortengren, 1974; Kroemer et al., 2000). These studies have identified the effects of these parameters and adjustability features on physiological responses (such as muscle activity) and subjective discomfort ratings and user perceptions. An outcome of this body of work was the development and identification of minimum ergonomics chair design parameters. Several ergonomic chair designs have been developed from this research and are available commercially, ranging in price from less than \$100 to several thousand dollars. No research has investigated if ergonomic chairs at opposing ends of the price spectrum with similar functionality differ in their physiological benefits to users. It is hypothesized that higher price chairs have superior designs and therefore should provide additional benefit over a lower cost chair.

Optimal monitor height placement continues to be debated as monitor placement represents a compromise between the visual and musculoskeletal systems. Straker and Mekhora (2000) and

Psihogios et al. (2001) reviewed the literature, and monitor height recommendations can be classified as high or low monitor placements. Results from the studies they reviewed indicated that high monitor placements have been reported to allow for better viewing angles, less neck flexion and extensions, wider range of neck mobility, lower muscle loads in the shoulder and upper back region, and decreased reports of discomfort (Kumar, 1994; Straker and Mekhora, 2000); while low monitor heights are reported to promote decreased muscle loads in the neck, improved neck postures, better overall working postures, and decreased reports of discomfort (de Wall et al., 1992; Sommerich and Joines, 2001; Straker and Mekhora, 2000; Villanueva et al., 1996). Despite these generalities, there remain conflicting research findings. For example, some studies have identified increased discomfort associated with low monitor heights (e.g., Straker and Mekhora, 2000; Psihogios et al., 2001; Sommerich and Joines, 2001; Turville et al., 1998) while others have found no discomfort (Straker et al., 1997a, b). Many of the contradictions can be traced to variations in methodology (performance of typing tasks versus computerized games, variations in how postures are measured and named, evaluations of different muscle groups). Therefore, while general recommendations can be made on “optimal” monitor heights, there are significant gaps in the literature and sufficient inconsistencies in the literature to question the appropriateness of these recommendations.

Sommerich et al. (1998) conducted a study to determine possible interactions between monitor size, height, keyboard familiarity, and individual differences in visual capabilities. They determined that for VDT work, locating the center of the monitor within a viewing angle of  $0^\circ$  to  $-17.5^\circ$  resulted in lower muscle activity and higher levels of acceptance from operators than placing the monitor at  $-35^\circ$  viewing angle. Burgess-Limerick et al. (1999) determined that the posture adopted to view any target represents a compromise between visual and musculoskeletal demands. Thus, there still appears to be no definitive answer to the question of the optimal posture (or range of postures) for the head and neck.

Increases in VDT use has led to the development of a number of ergonomic chairs spanning the price spectrum, though no studies have been performed to determine if physiological differences exist between high and low cost chairs. Therefore, there were two objectives of this study: (1) to identify and quantify the effects of monitor height and chair classification on risk factors associated with developing musculoskeletal pain/discomfort of the back and neck, and (2) to determine if ergonomic chairs at opposing ends of the price spectrum provide different physiological benefits to users.

## 2. Methodology

### 2.1. Experimental design

A mixed model design was used to test for main effects and appropriate interactions of the independent variables—monitor height (high, low) and chair (high, low)—on low back and neck surface EMG, number of posture shifts, and perceived levels of discomfort (PLD). In addition, a fifth condition allowed participants to adjust the workstation and chair to their preferred settings, and the results were compared to the other four experimentally imposed conditions. Order of the preference condition was a between-subjects variable; participants 1–4 received this condition last, and participants 5–8 received this condition first. Participants completed five test sessions lasting approximately 2 h. A balanced Latin square was used to assign participants to treatment conditions, excluding the preference condition.

### 2.2. Participants

Eight participants (four males and four females) ranging in age from 18 to 33 years were selected from a university student population. The age range was restricted to a minimum of 18 years of age, which represents the youngest “working age” given in the literature (Mackfarlane et al., 1997). Other relevant demographic information is presented in Table 1.

Table 1  
Participant demographics

Demographic variable	Male ( $n = 4$ )	Female = (4)
Age (years)	21.00 (3.83)	24.25 (5.91)
Height (cm)	174.63 (4.81)	166.37 (2.54)
Weight (kgs)	67.61 (3.88)	60.57 (3.86)
Sitting eye height (cm)	134.62 (3.59)	133.35 (4.40)

Values are mean (standard deviation).

Inclusion in this study was based on the participants’ visual capabilities (corrected to normal vision), lack of injury or chronic neck or back pain evaluated via interview, and keyboard familiarity. Participants must have had no noticeable back/neck pain in the past year and no back/neck operation or serious musculoskeletal injury in their lifetime. Potential participants also had to have a net typing speed of 50 words per minute measured in a standard typing test (3 min test).

### 2.3. Independent variables

Monitor height and chair variables consisted of two levels, low and high. Monitor height was defined by the viewing angle created between the user’s sitting eye height and the top-half of the monitor screen. The monitor low ( $M_L$ ) condition was defined as a monitor height approximately 15–20° below the horizontal eye line, and the monitor high ( $M_H$ ) condition was defined as a monitor height approximately 10–15° above the horizontal eye line (approximately the ear–eye line). Sitting eye height, along with co-tangent calculations, yielded the specific height of the monitor for each testing condition. The table was adjusted such that the top of the screen was at a height congruent to the high and low conditions specified earlier. The monitor screen remained at a 0–5° tilt throughout the experiment. The distance between the participant and the monitor was not constrained to simulate a real-world scenario. Participants were allowed to select their working distance from the monitor at the start of the testing session and were given instructions to maintain this distance throughout the test session.

Table 2  
Chair characteristics

Feature	Pneumatic executive task chair Model OM-105	Steelcase Model 453533IDW
<i>Arm rests</i>		
Inner distance (cm)	52	48
Height (lowest) (cm)	22	30
Height (highest) (cm)	25	42
<i>Seat pan</i>		
Width (cm)	53	48
Depth (cm)	42	46
Height (lowest point) (cm)	35	46
Height (highest point) (cm)	48	53
<i>Back rest</i>		
	Padded, contour, concave, curves in at lower back, not a 90° angle with chair, easy to adjust, approximately 10–15° of adjustability	Padded, contour, concave, curves in at lower back, not a 90° angle with chair, easy to adjust, approximately 10–15° of adjustability
Height (cm)	56	47
Width (cm)	48	48

Selection and definition of the high chair ( $C_H$ ) and low chair ( $C_L$ ) levels was dependent on cost and basic adjustability/ergonomic features. The high-cost chair was priced at over \$2000 (Steelcase, Model 453533IDW), while the low-cost chair was priced at under \$200 (Pneumatic Executive Task Chair, Model OM-105). To ensure chairs were not radically different, comparisons of chairs were conducted to identify chairs with similar adjustable features and adjustability ranges associated with these features (Table 2). The two specific chairs chosen to represent the “low” and “high” conditions are representative of a larger sample of chairs within the given price ranges, and these chairs were compared for gross physical effects on participants only. Participants were not aware of the retail values of the chairs used in the study. Participants were instructed to adjust the seat pan according to ergonomic recommendations (sit in an upright position, and adjust the height of the seat pan such that feet are touching the floor with their upper and lower legs forming a 90° angle). Armrests were adjusted to form a 90° angle at the elbow. Lumbar support, seat pan angle, and seat pan depth were adjusted by the participants to their preferences. Adjustability feature settings for each participant were recorded and recreated each day of testing for consistency.

In addition to the two chairs, a 17-in Dell monitor and a Generation IV fully adjustable bi-level table were used to manipulate monitor height. Keyboard height was adjusted so that the participants’ forearms were approximately parallel to the ground.

As a product of the experimental design, data entry task (standard data entry or simple math calculations) and task repetition (set of times each task was completed within each session) were also considered independent variables. Both of these variables are further discussed in Section 2.5 Task design/procedure.

#### 2.4. Dependent variables

The dependent variables included muscle activity, number of posture shifts, and PLD.

##### 2.4.1. EMG equipment and set-up

Surface EMG was used to measure muscle activity levels of selected trunk (multifidi-erector spinae complex (L1 and L5 region) and neck (splenius capitis) muscles using bipolar disposable electrodes (1 cm diameter, Ag/AgCl pre-gelled). Before attaching the electrodes, the skin was lightly shaved, abraded and cleansed with alcohol to ensure minimal resistance. Electrodes were

placed 3 cm below the mastoid process and 3 cm left of the midline to capture the activity of the splenius capitis (C7—neck muscle) (Takebe et al., 1974). Multifidi-erector spinae complex activity was captured by placing electrodes 3 cm left of the midline at the L1 and L5 level (Hermens et al., 1999). Inter-electrode distance was set to 1 cm. Signals were then transmitted through short (less than 30 cm) leads to pre-amplifiers (100 gain) taped to the body to reduce noise. EMG signals were hardware amplified, band-pass filtered (30–1000 Hz), RMS converted (55 ms time constant), and AD converted. The gain was set such that the signal did not exceed 2–3 V. Resistance was measured using a standard ohmmeter to ensure resistance was within acceptable levels (0–10 k $\Omega$ ). As EMG data were collected across multiple days, electrode locations were marked with a permanent marker to facilitate reapplication of electrodes in the same locations.

Resting activity and sub-maximal voluntary exertions (SMVEs) were recorded for normalization of EMG signals. Resting EMG signals were sampled at 5 Hz for 60 s every other minute for 4 min while the participant was supine. SMVEs were taken while the participant was seated upright. SMVEs were used instead of maximum voluntary exertions (MVEs) to minimize the risk of injury or residual muscle soreness. It was not believed participants could safely maximally contract the muscles being evaluated, especially for the neck; and there was no assurance a maximum contraction could be obtained. SMVEs allow for standardization of the efforts and are more repeatable than MVEs. Neck reference contractions were obtained by attaching a 0.91 kg weight to the face mask of a helmet and having the participant look straight ahead and keep the neck in line with the spine (resist neck flexion). Back reference contractions were obtained by holding a 2.27 kg weight in each hand with arms abducted 90° in the frontal plane and arms parallel to the floor. Participants completed three five-second sub-maximal exertions with a 1-min rest period between exertions. The maximum signal obtained was used as the SMVE. EMG data was analyzed using a program created in LabView 7.0 and

expressed as mean %SMVE. SMVE and task EMG data were sampled at 1024 Hz.

#### 2.4.2. Number of posture shifts

Posture data was captured by a video camera (Panasonic PV-L558) stationed perpendicular to the participant at a fixed height of 76.20 cm (approximately elbow resting height). Neutral posture was defined as the back being upright (i.e. head, shoulders, and tailbone in a straight line). Posture shifts (PS) consisted of deviations from neutral and were classified according to the direction (move forward, move back, move side, move up, and other) and body part (neck, back, other [feet, shoulders, etc.]). Posture shifts were recorded and tallied for 15-min intervals throughout the testing session. A reference form was attached to the wall opposite of the camera with vertical lines to indicate the general neutral position of the neck, back, and lower legs with angular lines of  $\pm 5^\circ$  at approximate points of rotation for the neck, back, and knees. A change in posture was defined as a shift from neutral of  $\geq 5^\circ$ . Actual counts were made using video analysis and measuring changes from the screen's surface.

#### 2.4.3. Perceived level of discomfort

PLD was assessed using a modified Borg's perceived level of exertion scale, where zero equaled no perceived discomfort and ten equaled very, very high discomfort (Borg, 1973). Participants were asked to verbally rate their perceived level of discomfort for the back, neck and eyes every 15 min. The scale was mounted to the monitor to provide visual cues associated with scale anchors.

#### 2.5. Task design/procedure

Tasks alternated between standard data entry and completion of simple math (addition or multiplication of single digit numbers). Each task repetition lasted for 15 min, with three repetitions at each configuration, for a total of 90 min per configuration. During data entry participants re-created information presented in a window located in the top half of the monitor screen in a separate window located in the lower half of the screen

(Fig. 1). Participants began the data entry task where they had stopped for each repetition. The math problem task consisted of observing a math problem and answer presented on an Excel spreadsheet and typing either “T” for true or “F” for false (Fig. 2). A separate worksheet was completed for each repetition, which contained the same problems in random order, with some having

different answers (e.g.,  $2 \times 5 = 10$  might be on one worksheet, while on another  $2 \times 5 = 7$ ). Both tasks were restricted solely to the monitor screen in an effort to avoid confounding results with asymmetry of task. Twelve-point font was used to comply with ANSI/HFS 1988 standards.

Upon arrival, participants received a verbal and written description of the study and completed

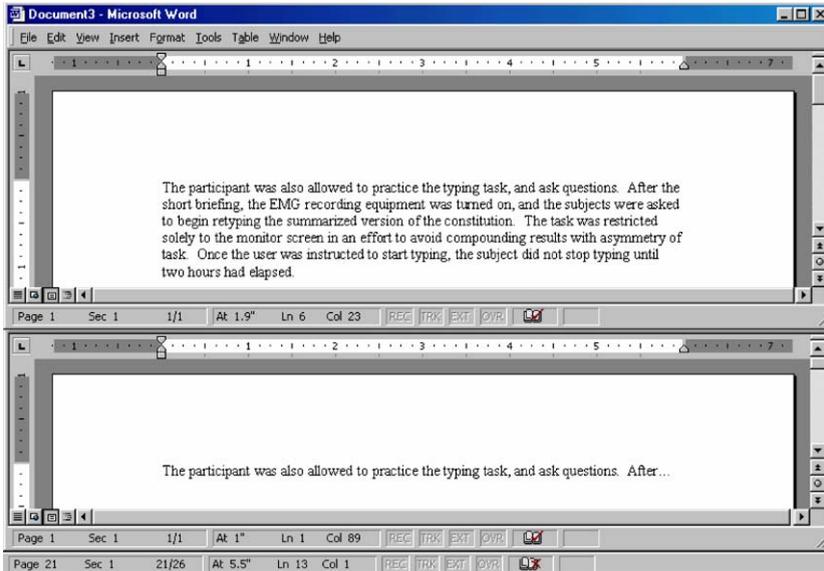


Fig. 1. Pictorial representation of typing task.

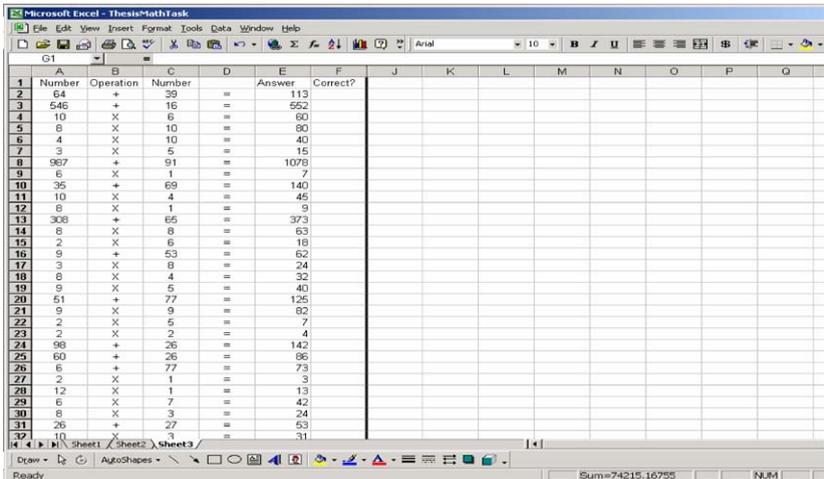


Fig. 2. Pictorial representation of math task.

informed consent documents, followed by screening and completion of a demographic questionnaire. Electrodes were applied, the workstation was configured, and a 5-min practice session on each of the two tasks was provided to the participants. After insuring resistance values were within normal ranges, resting and sub-maximal muscle activity levels were collected. Testing commenced with the participant alternating between tasks every 15 min. Scheduling of the next testing session was performed with no session closer than 48 h and no farther than 1 week apart to minimize fatigue effects. At the end of the fifth day of testing, participants rank ordered the configurations and rated how comfortable they perceived the monitor and chair levels to be, ranging from 0 = low to 7 = high. The participants were compensated at the end of all five trials or, in the case of attrition, proportionally for time spent in the laboratory.

2.6. Data analysis

A mixed factors ANOVA was used to test for the effects of the independent variables on the dependent variables, and to determine if there were differences between user preferred settings and the experimentally defined settings, as well as order, task repetition, and gender effects. Tukey’s honestly significant difference was used for post hoc analysis on all significant results,  $p < 0.05$ . Final ranks of the workstation configurations were analyzed using Friedman’s test.

3. Results

Descriptive statistics for the dependent variables are presented in Table 3. No configuration resulted in a consistent trend in muscle activity across all three muscles evaluated. Configurations containing the low monitor height were associated with the lowest muscle activity in the back, while configurations containing the high-cost chair resulted in the highest back muscle activity. In general, C7 muscle activity was lower for  $M_{HC_H}$  than any other configuration, L1 muscle activity appeared higher for  $M_{LC_H}$  and  $M_{LC_L}$  than any other configurations, and PSB had highest mean values for  $M_{LC_L}$ ,  $M_{HC_L}$ , and the preference section. No single configuration had consistently lower or higher mean values than another (it appeared that no trends existed).

Significant order and task repetition effects were found for some dependent variables (Table 4). Inspection of order effects did not identify any consistent trends. Since a balanced Latin square design was used, it is posited that these effects on other results are minimal. Task repetition effects (repetitions of the tasks within a single test session) were found for PLD and PSs, with increasing values across the repetitions. These findings were expected due to the length of the test session (2 h).

3.1. Muscle activity

EMG data, expressed as %SMVE, was averaged across repetitions relative to task. In general,

Table 3  
Descriptive statistics of the dependent variables

DV	$M_{LC_H}$	$M_{HC_H}$	$M_{LC_L}$	$M_{HC_L}$	Preference
L5 (%SMVE)	12.03 (6.88)	18.78 (19.82)	18.32 (18.62)	18.35 (17.82)	14.62 (16.44)
L1 (%SMVE)	20.18 (19.67)	10.39 (7.11)	7.93 (5.68)	9.91 (5.10)	9.54 (6.78)
C7 (%SMVE)	15.47 (16.90)	8.42 (6.98)	13.35 (11.53)	15.61 (15.03)	12.60 (7.93)
PLD <sub>Neck</sub> (mean rating)	0.9 (0.9)	7 (7)	1 (1)	8 (9)	6 (1)
PLD <sub>Back</sub> (mean rating)	1.5 (2.1)	1.2 (1.7)	1.4 (1.4)	1.5 (1.6)	1.4 (1.7)
PLD <sub>Eyes</sub> (mean rating)	1 (1.4)	0.7 (0.9)	0.8 (0.9)	1.1 (0.9)	0.9 (1.4)
PS <sub>Neck</sub> (frequency)	7 (4.5)	7 (4)	6.8 (4.3)	7.3 (4)	7.6 (4.3)
PS <sub>Back</sub> (frequency)	1.8 (1.5)	1.7 (1.6)	2.5 (2)	2.9 (2.8)	2.3 (1.9)
PS <sub>Feet</sub> (frequency)	4.6 (4.7)	4.5 (4.5)	3.4 (3)	4.3 (4.5)	4.4 (4.2)

PLD = perceived level of discomfort, PS = posture shifts.  
Values are mean (standard deviation).

Table 4  
Summary of significant factors for the dependent variables

% SMVE		PLD		Posture shifts	
Muscle site	Factor	Body part	Factor	Body part	Factor
L5	Order*** M* C**	Back	Sample***	Neck	Task*
L1	MH × C* Order** Task*	Neck	Order** Task*	Back	Sample**
C7	MH × C***	Eyes	MH × C** Sample***	Feet	Sample* Task***

\*Significant at 0.05, \*\*Significant at 0.01, \*\*\*Significant at 0.001; MH = monitor height, C = chair.

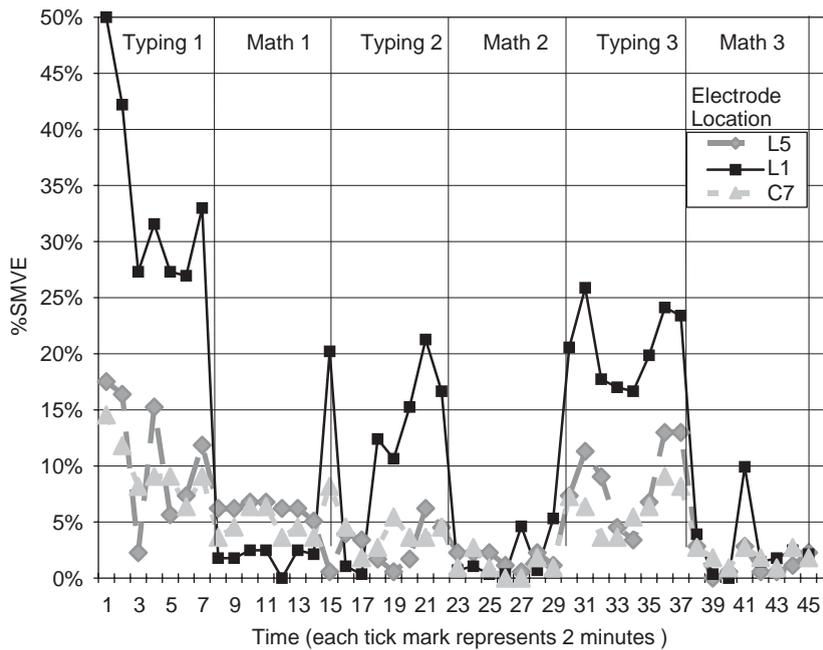


Fig. 3. Example of a normalized EMG profile for a single participant for a single test condition.

muscle activity was highest in the beginning of a repetition and for typing in general. L1<sub>EMG</sub> was most affected by task repetition. Fig. 3 provides an example of the EMG profile for a single participant in one condition. Apart from the first task repetition, muscle activity across repetitions was fairly constant.

No configuration effects were found to affect L5 activity. Monitor height, chair, their interaction

and configuration were significant for L1 activity. Low monitor height ( $M_L$ ) generated significantly more activity (13% SMVE) than the high monitor height ( $M_H$ ) (8% SMVE), and the high-cost chair ( $C_H$ ) generated more activity (15% SMVE) than the low-cost chair ( $C_L$ ) (7% SMVE). The  $M_L C_H$  configuration had significantly higher muscle activity than all other configurations for L1. Task was also significant for L1, with higher mean

values associated with data entry (14% SMVE) than with completing math problems (8% SMVE). Only the interaction between monitor height and chair was significant for C7 activity,  $M_L C_H$  resulted in significantly more activity than  $M_H C_H$  and  $M_L C_L$ .

### 3.2. Perceived level of discomfort

Task was found to significantly affect PLD ratings of the neck, with higher ratings observed for the math task (0.5) compared to the data entry task (0.17). However, both of these rating values are very, very light or lower. The interaction between monitor height and chair was found to be significant for ratings of PLD of eyes, though no trends could be identified through post hoc analysis.

### 3.3. Posture shifts

Only two factors, task repetition and task, were significant for PS for different body parts. A larger number of neck PSs were associated with data entry task (7.4) than the math task (5.7); whereas the inverse is true for feet PSs (typing task = 1.5 and math task = 4.5). Also, posture shifts significantly increased across task repetitions.

### 3.4. Gender effects

The only gender effect identified related to PSs, with females having significantly more neck PSs (8.5) than males (4.1).

### 3.5. Ratings and rankings of workstation parameters

The final average rating of the high-cost chair was “5”, and the final average rating of the low-cost chair was “4”, average. Overall, five of the eight participants preferred the high-cost chair. No differences were found with respect to the mean ratings for the different monitor heights (mean rating “4”, average, for both monitor heights). When ranking the different workstation configurations, participants preferred the  $M_L C_H$  configuration (mean rank = 2.1), followed by  $M_H C_L$

(mean rank = 2.4),  $M_H C_H$  (mean rank = 2.5), and  $M_L C_L$  (mean rank = 3.0); however, the mean rankings did not differ significantly ( $p = 0.49$ ).

Since half of the participants received the preference condition at the beginning of the study, comparisons were made between their initial selection and their final ranking. Two of the four people who received the preference order on the first day changed their preference, one to the low-cost chair and one to the high-cost chair.

## 4. Discussion

### 4.1. Muscle activity

In general, monitor height and chair classification affected L1 muscle activity when considered alone, but their interaction had effects on L1 and C7 activity. The low monitor height and the high-cost chair resulted in higher muscle activity levels than the other configurations. Straker and Mekhora (2000) and Turville et al. (1998) also found increased muscle activity for similar muscle groups. The lack of significant effects on the L5 region may have been due to similarities between the chairs specifically affecting the L5 region (e.g., lumbar support). Chair design differences, such as back rest size (the high-cost chair provided less upper back support) and arm rest size, may have also affected activity levels. Aaras et al. (1997) found that muscle activities of the trapezius and L3 region were significantly lower when the forearms are supported during keying and mouse activity, and participants in this study utilized the armrests on the high-cost chair to a lesser extent. Increases in muscle activity may have been due to localized muscle fatigue, though this variable was not studied specifically. Turville et al. (1998) did not find fatigue to differ between the monitor heights studied, though few EMG fatigue estimators were evaluated.

### 4.2. Perceived level of discomfort

Discomfort effects associated with monitor height and chair placement are conflicting, as stated in the introduction. The interaction of these

parameters was found to significantly affect discomfort ratings of the eyes though post hoc analyses were inconclusive. This finding may be due in part to the split preferences in monitor height placement discussed later in Section 4.4. Discomfort ratings for the neck were higher when performing the math task. The low number of posture shifts in the neck may have increased discomfort ratings due to static and fixed postures. Villanueva et al. (1996) also found more fixed postures associated with tasks requiring high visual demands (such as the math task), and NIOSH (1997) found fixed postures to be correlated with increased discomfort.

#### 4.3. Posture shifts

Task significantly affected the number of postures of the neck during typing and of the feet during math problems. It is hypothesized that task demands dictated these findings. For example, it is likely that participants shifted their gaze between the keyboard and the screen during typing increasing neck movements. While during the math task, participants were required to focus more attention on the screen and use only three keys for answering (T or F and enter), which resulted in less movement in the neck, trunk, and upper extremity. Villanueva et al. (1996) also found decreased body motion during a computerized game task with the majority of body movement concentrated in the upper extremity and neck/thoracic region. Regardless of task, posture shifts were found to increase over the duration of the test session though they were affected by test condition, similar to Turville et al. (1998).

#### 4.4. Ratings and rankings of configurations

The most preferred configuration was  $M_L C_H$ , followed by  $M_H C_L$ , the exact opposite. The chairs were rated approximately the same. However, half of the participants ranked the low monitor very comfortable while the other half ranked the high monitor height as very comfortable. This mixed response could have surfaced in the rankings of the configurations. When participants rank-ordered the configurations, they typically chose one

variable (monitor height or chair preference) over the other and based their rankings on this variable regardless of the level of the other factor. Similar findings on preferred monitor height settings have been found by Turville et al. (1998) and Straker and Mekhora (2000).

#### 4.5. Participant-selected configurations

No differences were found between the experimenter imposed and participant-selected configurations. Previous experience with ergonomic chairs and ergonomic workstation criteria may have influenced preferred settings and ratings. Shute and Starr (1984) and Coleman et al. (1998) both found that even with anthropometric information available, people would not adjust their workstation accordingly. Burgess-Limerick et al. (1998) found that participant-selected monitor heights were influenced by the initial monitor set up. Though this study did not investigate these effects on self selected preferences, the lack of significant findings leads us to hypothesize that these effects were minimal. Therefore, as stated by Helander and Zhang (1997), what is comfortable to the participants might be the best practice. However, the current study did not find that comfort was assessed instantaneously; two participants indicated that they would change their preference of chair and monitor height after completing the study.

#### 4.6. Limitations

There were several limitations in the current study. First, the use of sub-maximal exertions to normalize EMG data presents difficulties in comparing results across studies and facilitating inferences relating to human capacities. However, given the unreliability of maximum exertions across days, the use of sub-maximal exertions allowed for a consistent effort across testing days.

Additionally, quantitative posture data were not collected. The method employed relied on the experimenter's judgment to identify a change in posture and the accuracy associated with taking angular measurements from a TV screen. The curvature of the screen may have distorted the

angular measurements. The methods employed can only provide estimates of the number of postural shifts. More detailed quantitative data would be needed to provide a more accurate measurement of posture changes (such as by using electrogoniometers). The reliability of the data collection method may be poor, but since a single experimenter collected that data, error in measurement should have been consistent across all assessments.

Though the chairs selected for use in this study were intended to represent a broader class of chairs, there are several ergonomic chairs with advanced features and adjustability, and it would be difficult to apply these results to those chairs. However, these results should apply to chairs with basic adjustability features similar to those in this study.

## 5. Conclusions

There seems to be a complex interplay between monitor height placement, chair design/chair settings, and task demands that will affect optimal workstation setup guidelines. The question of “What is the optimal monitor height placement?” requires an investigation of all of these factors at a minimum. Though no gross physiological differences were found between the two chair types, other high-cost chairs have special features that may influence the effects of task demands on physiological responses. Also, given the increased exposure of persons to ergonomic issues and workstation design guidelines, self-selected configurations may be appropriate for reducing discomfort ratings for individuals, though injury risk may not be lowered, and further research should be directed at quantifying the risk probability. Additionally, fatigue, considered to be a precursor to injury, may provide more complete information on injury risk.

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