

PHYSICAL AND PSYCHOSOCIAL FACTORS IN DISPLAY SCREEN EQUIPMENT ASSESSMENT

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Background: Healthy use of display screen equipment (DSE) has been one of the major concerns of workers at the workplace. This study aimed to identify the significant predictors of musculoskeletal discomforts among female sedentary workers.

Methods: A total of 67 female workers whose jobs required the use of a computer for more than 2 hours per day participated in an interview. This was followed by anthropometric measurements of the workers and their workstations.

Results: Mouse–elbow height match was a significant predictor for discomfort of the lower back, whilst keyboard–elbow height match was a significant predictor for discomfort of the shoulders and upper back. Psychosocial status and accumulative DSE usage of subjects were also significant factors for discomfort. Workstation–worker match attributed most significantly to workers' discomfort.

Conclusions: The study results further support the multifactorial nature of the relationships between musculoskeletal discomfort, workstation set-up and the psychosocial aspects of work. They also shed light on the parameters that might be important for risk assessment of computer use in the workplace.

KEY WORDS: Occupational health • DSE • Computer-human interface • Ergonomics
• Risk assessment

Introduction

With the rapid development of modern technology, visual display terminals or display screen equipment (DSE) have become a common part of the workplace. Previous studies reported associations between health disorders in the musculoskeletal system and use of DSE (Bergqvist, Wolgast, Nilsson et al., 1995). Work-related musculoskeletal disorders refer to a wide range of inflammatory and degenerative diseases and disorders (Buckle & Devereux, 2002). Common musculoskeletal complaints among DSE users involve the back, shoulders, neck, and, to a lesser extent, the arms and legs (Carter & Banister, 1994). The prevalence of musculoskeletal symptoms is reported to be as high as 63% among DSE users (Demure, Luippold, Bigelow et al., 2000a). These disorders have caused serious economic losses and decreased productivity (Amell & Kumar, 2001).

Previous studies revealed significant relationships between musculoskeletal discomfort and work-related disorders. For example, DSE operators experienced more discomfort than non-DSE office workers, and discomfort increased with workers' exposure to DSE-related tasks (Carter & Banister, 1994). A higher prevalence of discomfort was also associated with increased hours of work involving DSE. There were significant relationships between wrist/hand discomfort and working 7 hours or more on DSE (Demure, Luippold, Bigelow et al., 2000a). Gender was also a modulating factor of the prevalence of these disorders. Female sedentary workers who performed repetitive work were found to have higher discomfort levels when compared with their male counterparts (Hales & Bernard, 1996). Additionally, female workers were more likely to take on double work shifts than their male counterparts, which substantially increased their exposure to repetitive computer tasks (Demure, Luippold, Bigelow et al.,

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2000a). Female workers also preferred to be assigned to jobs that were less strenuous but which required more repetitive movements (Hales & Bernard, 1996).

What are the causes of musculoskeletal pain among DSE users? Previous studies have revealed that common causes include awkward position, inactivity, repetitive motion, and prolonged work periods. An awkward posture could be the result of a poorly designed workstation (Carter & Banister, 1994). For example, a higher than normal display screen (computer monitor) would result in a worker tilting the neck excessively in order to view the screen or working documents properly. If this posture is maintained for a prolonged period of time, it could lead to pain and serious injury (Occupational Safety & Health Administration, OSHA, 2003), adversely affecting task performances and operator workload (Amell & Kumar, 2001).

Assuming a sitting posture for a prolonged period of time is demanding on workers' backs. In a sitting position, the lumbar spine straightens from its normal lumbar curve, which undesirably increases the force on the intervertebral discs of the spine (Carter & Banister, 1994). Apart from excessive pressure, the lack of body movement during prolonged sitting reduces circulation to the muscles, particularly those in the back and neck (Carter & Banister, 1994). Excessive repetitive movements put stress on muscles and tendons. Previous studies indicate that repetitive work is significantly associated with upper limb discomfort, tendonitis and carpal tunnel syndrome (Latko, Armstrong, Franzblau et al., 1999). Workers in highly repetitive jobs had increased (2 to 3 times) risks of bodily discomfort compared to workers in less repetitive jobs (Latko, Armstrong, Franzblau et al., 1999). After a prolonged period of time, this could lead to quicker muscle fatigue (Carter & Banister, 1994).

Apart from physical factors, work-related psychosocial factors are also linked to work-related musculoskeletal disorders (Erez & Lindgren, 1999). These factors include job satisfaction, intensified workload, monotonous work, job control, and social support. The mechanisms by which these factors interact with the physical factors and work-related musculoskeletal discomfort are still controversial. Further studies should shed more light on both the physical and psychosocial factors involved in the workplace (Fine, 1996).

Different strategies were developed to attempt to reduce the incidence of musculoskeletal discomfort. For example, one study showed positive effects by launching ergonomics intervention programmes. The prevalence of neck, arm and hand disorders were decreased by about 67% after ergonomic workstation adjustments, longer lunch breaks, improvements in noise and illumination, and improved thermal control of the

environment (Aaras, Horgen, Bjorset et al., 2001).

Preventive measures play a major role in alleviating the problems associated with work-related disorders. Workplace risk assessment is one of the means to identify potential problems that might lead to work-related disorders. Strategies can then be developed to rectify the undesirable working conditions. In Hong Kong, the government passed the Occupational Safety and Health (Display Screen Equipment) Regulation in April 2002, which was enacted in July 2003. The aim of the regulation is to protect employees by addressing safety and health issues related to prolonged use of DSE. Under this regulation, employers are obliged to perform risk assessments of DSE workstations before they are first used by their employees. If risks are identified, preventive measures should be made to reduce the risk to the lowest extent possible.

Risk assessment can be facilitated by use of an interactive, user-friendly computer programme designed with built-in ergonomics assessment capabilities. Risk assessment is achieved by: 1) identifying the potential hazards of the DSE workstation; 2) evaluating the safety and health risks associated with the DSE workstation; 3) assessing the DSE workstation with respect to the display screen, input devices, work desk and chair, and accessories such as document holders and footrests. If possible, the software might have a recommendation section that provides useful materials for individuals to further improve their workstations.

This study explored the workstation-worker match, workstation design, and work-related psychosocial factors that influenced the extent of musculoskeletal discomfort among a group of women who worked with DSE. The study findings will shed light on possible parameters to be included in future designs of risk assessments. Additionally, the findings will help in developing preventive measures for musculoskeletal discomfort and, ultimately, work-related disorders for workers using DSE.

Methods

This study used a cross-sectional survey design among a group of women, working in small- to medium-sized companies, who used DSE daily. A questionnaire was used to guide interviews of the workers. An anthropometric measurement protocol was designed to quantify the workstation-worker match.

Subjects

A total of 67 female workers who used DSE daily were recruited from nine small- to medium-sized enterprises. All of the workers who participated in the study had been working

with DSE for more than one year, and their daily usage was over two hours. Subjects who already had work-related musculoskeletal disorders or cumulative traumatic disorders were excluded from the study. The mean age of the workers was 34.2 years, with most being between the ages of 23 and 43 years (89.0%). The demographic characteristics and job natures of the workers are shown in Table 1.

Procedures

The purposes of the study were explained to all of the workers prior to obtaining consent. The workers were first interviewed using the DSE-Worker Health Questionnaire (DSE-WHQ). The content of the questionnaire was modified from the Standardized Nordic Questionnaire (Ohlsson, Attewell, Johnsson et al., 1994; Siu, 1999). The questionnaire is composed of five sections: occupational history, checklist on utilization of ergonomic equipment, self-reporting of work-related musculoskeletal discomfort (in the past 7 days), work-related psychosocial status (in the past 7 days), and demographic characteristics.

After completion of the face-to-face interview, the anthropometric and workstation dimensions were measured by the researchers. To further increase the effectiveness and accuracy of the measurements, a set of custom-designed anthropometric measurement tools was fabricated. It included two adjustable aluminium bars, with squared-off edges, perpendicular to each other (Figure 1A). Spirit levels were attached to each bar, with one level on the horizontal bar (x axis) and the other on the vertical bar (y axis). Measurements for each workstation-worker were obtained by two researchers. One researcher was responsible for anchoring the measuring tools next to the worker and maintaining the axes of measurements, whilst the other researcher was responsible for taking the measurements using the tools (Figure 1B). The anthropo-

metric measurements included the worker's eye level, elbow height (elbow at 90° flexion), and seat height when the subject was initially sitting at their workstation at the time of the interview. The same measurements were taken when the subject was instructed to sit with an upright posture (Figure 1C). The distance between the bottom of the knee (popliteal fossa) and the floor when the subject was sitting with an upright posture

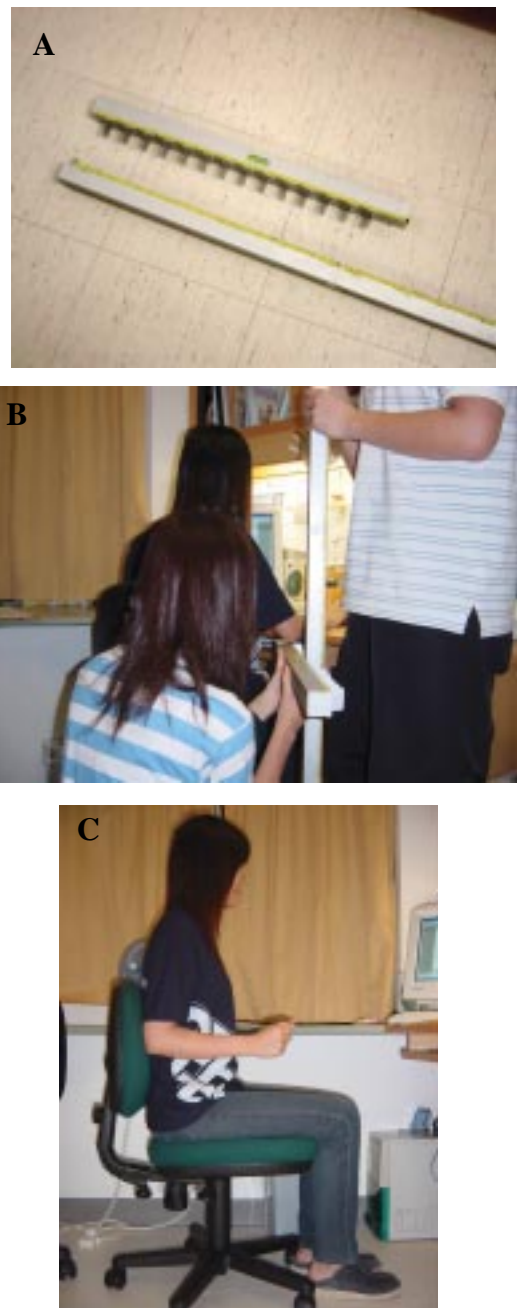


Table 1. Demographic characteristics and job natures of the workers ($n = 67$)

Demographic characteristics	Mean \pm SD
Accumulative DSE usage, yr	8.74 \pm 4.50
Average DSE usage/day, hr	5.60 \pm 1.65
Age, yr	34.17 \pm 7.59
Job nature	%
Administrative	16.4
Clerical	67.2
Technical	3.0
Professional	6.0
Others	7.5

SD = standard deviation; DSE = display screen equipment.

Figure 1. Tools for obtaining anthropometric measurements and the measurement procedure: A) custom-made measurement tools; B) measurement procedure; C) upright posture in which the eye level, elbow height, and seat height were measured.

was also measured. Other workstation dimensions were: monitor height, keyboard height, and mouse height; measurement specifications are listed in Table 2.

Instruments

Three additional questionnaires were also used. The first questionnaire was designed to gather information on the workers' utilization of ergonomic equipment. Subjects were asked to self-report on the items that were part of the workstation that they used at the time of the interview. These items included the ergonomic features of the DSE, desk, chair and other accessories.

The second questionnaire was a self-report of work-related musculoskeletal discomfort. The workers were asked to rate their discomfort levels for different body parts. A visual analogue scale (VAS) was used, with "0" indicating no discomfort to "10" indicating extreme discomfort. The body parts rated were the eyes, neck, shoulders, elbows, forearms, wrists, fingers, upper back, and lower back.

The third questionnaire was a self-report of work-related psychosocial status, consisting of 10 items. Each worker was required to rate each of the 10 items using a VAS, to reflect their perceptions at the time of the interview. The 10 items related to workload, working hours, cognitive demands, control over work, communication with colleagues, relationships with

colleagues (including their supervisors), job satisfaction, peer support, job security, and enjoyment of work.

Results

Discomfort, Psychosocial Status and Workstation Ergonomic Features

The mean musculoskeletal discomfort of the workers ranged from 1.27 for the forearms to 3.75 for the shoulders (Table 3). The mean psychosocial status of workers ranged from 2.03 for "good communication with colleagues" to 6.76 for "heavy workload".

The majority of the workers' workstations had adjustable-height chairs with backrests. Monitors had adjustable brightness, contrast and colour, and glare filters; keyboards were tilted. Features with a lower frequency included chairs with armrests, sufficient leg room, wrist support, document holders, footrests, and adjustable-height desks (Table 4).

To further analyse how ergonomic features modulated workers' musculoskeletal discomfort, the workers were divided into "yes" and "no" ergonomic features groups. In the questionnaire, the answer "yes" for this part meant that the subjects were provided with that ergonomic feature and that they used it to some extent. When the answer "no" was given, it reflected that the workers either had no such ergonomic

Table 2. Specifications of the measurements used for anthropometric and workstation dimensions

Anthropometric measurements when workers initially sat at their workstation

Eye level	Distance between the horizontal eye level and the floor
Elbow height (elbow at 90° flexion)	Distance between the base of the olecranon and the floor

Anthropometric measurements when workers sat with an upright posture

Eye level	Distance between the horizontal eye level and the floor
Elbow height (elbow at 90° flexion)	Distance between the base of the olecranon and the floor
Popliteal fossa height	Distance between the bottom of the popliteal fossa and the floor

Workstation dimensions

Monitor height	Distance between the top margin of the screen on the monitor and the floor
Keyboard height	Distance between the base of the keyboard and the floor
Mouse height	Distance between the base of the mouse and the floor
Original seat height	Distance between the surface of the chair and the floor
Ideal seat height (knee at 90° flexion)	Distance between the surface of the chair and the floor

Workstation-worker match measurements

Monitor-eye level mismatch	Discrepancy between the horizontal eye level and the top margin of the screen on the monitor (Mismatch = Eye level – Monitor height)
Keyboard-elbow mismatch	Discrepancy between the base of the olecranon and the base of the keyboard (Mismatch = Elbow height – Keyboard height)
Mouse-elbow mismatch	Discrepancy between the base of the olecranon and the base of the mouse (Mismatch = Elbow height – Mouse height)

Table 3. Musculoskeletal discomfort levels and work-related psychosocial status of workers

	Mean \pm SD
Musculoskeletal discomfort	
Eyes	3.45 \pm 2.42
Neck	3.27 \pm 2.70
Shoulders	3.75 \pm 2.74
Elbows	1.42 \pm 2.06
Forearms	1.27 \pm 1.82
Wrists	1.84 \pm 2.45
Fingers	1.69 \pm 2.49
Upper back	2.82 \pm 2.74
Lower back	2.54 \pm 2.73
Musculoskeletal discomfort index*	12.37 \pm 9.18
Psychosocial status	
Workload	6.76 \pm 1.69
Working hours	6.42 \pm 1.59
Cognitive demands	6.32 \pm 1.87
Control over work	3.76 \pm 2.31
Communication with colleagues	2.03 \pm 1.64
Relationship with colleagues	2.21 \pm 1.87
Job satisfaction	3.47 \pm 1.73
Peer support	2.82 \pm 1.54
Job security	3.85 \pm 1.70
Job enjoyment	2.97 \pm 1.86
Psychosocial status index [†]	40.61 \pm 8.42

*Musculoskeletal discomfort index is the sum of the ratings for discomfort levels of the neck, shoulders, and upper and lower back (the maximum is 40, based on the visual analogue scale, from “0” indicating no discomfort to “10” indicating extreme discomfort). [†]Psychosocial status index is the sum of the ratings for the 10 psychosocial items (the maximum is 100, based on the visual analogue scale). SD = standard deviation.

Table 4. Ergonomic features of workstations

Ergonomic feature	Use of feature, %
Adjustable-height desk	1.5
Adjustable-height chair	94.0
Chair with backrest	100.0
Chair with armrest	67.2
Sufficient leg room	61.2
Footrest	7.5
Monitor with glare filter	85.1
Monitor with adjustable brightness, etc.	97.0
Tilted keyboard	97.0
Wrist support	34.3
Document holder	26.9

feature or that they never used it even when it was provided. The mean discomfort levels of the two subgroups were compared using the independent *t* test for each of the ergonomic features. There were no significant differences in the discomfort levels between the two subgroups ($p > 0.05$).

Workstation–worker Match and Body Discomfort

The anthropometric measurements of the workstations and workers are shown in Table 5. To analyse how the anthropometric measurements related to the workers’ musculoskeletal discomfort, stepwise multiple regression analysis was carried out. The outcome variable was the discomfort level of the different body parts, and the predictors were the anthropometric measurements, demographic characteristics, and DSE usage. Of the anthropometric measurements, the “mouse–elbow match in upright posture”, “keyboard–elbow match in upright posture”, “accumulative DSE usage per day”, and “psychosocial status index” were significant predictors of workers’ discomfort levels (Table 6). Among the body parts tested, “mouse–elbow match” was the only significant predictor for discomfort of the lower back (beta weight = 0.171, $p = 0.037$). The “keyboard–elbow match” was a significant predictor for discomfort at the shoulders (beta weight = 0.219, $p = 0.024$) and upper back (beta weight = 0.219, $p = 0.024$). The “accumulative DSE usage per day” was also a significant predictor for discomfort at the shoulders (beta weight = 0.426, $p = 0.037$).

Psychosocial Status and Body Discomfort

Multiple regression analysis showed that psychosocial status of the workers (mean of 10 psychosocial items) significantly predicted discomfort of the forearm (beta weight = -0.061 , $p = 0.015$) (Table 6), but not of the other body parts.

Table 5. Workstation dimensions and workstation–worker match calculations

	Mean \pm SD, cm
Workstation dimensions	
Monitor height	113.13 \pm 6.24
Keyboard height	68.01 \pm 6.68
Mouse height	72.20 \pm 4.96
Original chair height	46.77 \pm 3.21
Workstation–worker match	
Monitor–eye level match	4.42 \pm 3.52
Keyboard–elbow match	4.96 \pm 3.48
Mouse–elbow match	6.51 \pm 4.19

SD = standard deviation.

Discussion

The study results are largely consistent with those of other studies of computer usage and musculoskeletal discomfort. In this study, the anthropometric match between the workstations and workers was one of the major factors accounting for workers' musculoskeletal discomfort. In particular, the matches between mouse height on the workstation and elbow height and between keyboard height and elbow height, when the worker sat with an upright posture, were the most important. The results also indicated that the average DSE usage per day and psychosocial status were factors that influenced the discomfort levels of workers.

Previous studies have shown that using different ergonomic features for workstations has an impact on the musculoskeletal discomfort of workers (Demure, Mundt, Bigelow et al., 2000b). However, our findings did not reveal such an effect. In fact, in all the comparisons made between those who used the ergonomic features and those who did not, no significant differences in discomfort levels were found. One major reason that might account for this discrepancy between our study and others could be that, in the questionnaire that we administered, no information was gathered on the way and frequency with which the ergonomic feature was used. During the interviews with the workers, it was common to find that the ergonomic

equipment provided to them was not properly laid out and used. Ironically, the ways in which the ergonomic equipment was used seemed to be determined by the particular job tasks that the workers had to perform. For example, document holders were provided by most of the companies, but only a few workers reported that they used them while typing documents. Instead, a good proportion of the workers reported that they used it as a place for unused documents. Observations of this kind suggest that when ergonomic equipment is not properly used, its effectiveness in relieving and preventing discomfort is hampered. The improper use of ergonomic equipment also has implications for the design of risk assessment instruments. An effective assessment should, therefore, include both the availability and proper utilization of the equipment.

Our finding that the anthropometric match between workers and workstations accounted for workers' musculoskeletal discomfort is consistent with those reported in other studies. For example, Demure, Luippold, Bigelow et al. (2000a) revealed that computer workers who reported higher musculoskeletal pain intensity were more likely to require ergonomic intervention for improving their work posture. These interventions were also found to be effective for relieving the symptoms. The common problems encountered by the workers were misfit between the worker and keyboard position and layout of the

Table 6. Stepwise regression statistics for workstation-worker match and discomfort levels at different body regions

Outcome variables	Predictors*	β	SE	Sig	R ²	F	p
Eyes discomfort	—	—	—	—	—	—	—
Neck discomfort	—	—	—	—	—	—	—
Shoulders discomfort	Keyboard mismatch	0.219	0.095	0.024	0.138	4.810	0.012
	Accumulated DSE usage	0.426	0.200	0.037	—	—	—
Elbows discomfort	—	—	—	—	—	—	—
Forearms discomfort	Psychosocial status index	-0.061	0.024	0.015	0.092	6.211	0.015
Wrists discomfort	—	—	—	—	—	—	—
Fingers discomfort	—	—	—	—	—	—	—
Upper back discomfort	Keyboard mismatch	0.219	0.095	0.024	0.081	5.353	0.024
Lower back discomfort	Mouse mismatch	0.171	0.263	0.037	0.069	4.538	0.037
Musculoskeletal discomfort index	—	—	—	—	—	—	—

*All the significant predictors are for measurements of workers in the upright posture. SE = standard error; Sig = statistical significance of predictors.

workstation (Demure, Mundt, Bigelow et al., 2000b).

To further understand the phenomenon, we divided the workers according to the extent of the mismatch and the discomfort level reported. For example, for the monitor and eye level match, we divided the workers into 10 subgroups, ranging from the monitor height higher than eye level height (5 groups, +1 to > +8 cm) to the monitor height lower than eye level height (5 groups, -1 to < -8 cm). The distribution of discomfort scores across the 10 groups indicated inconsistent patterns. For example, the highest discomfort levels of the neck were found in both the +4.00 to +5.99 cm (3.91, $n = 11$) and -4.00 to -5.99 cm (5.67, $n = 6$) groups instead of in the +6.00 to +7.99 cm (3.33, $n = 3$) and -6.00 to -7.99 cm (5.00, $n = 3$) groups. Another example was in the keyboard-elbow match where the discomfort level was the lowest in the +4.00 to +5.99 cm group (1.80, $n = 5$) and the -4.00 to -5.99 cm group (3.09, $n = 11$). However, due to the comparatively small sample sizes of each group, quantitative analyses were not performed to test the significance of the differences in discomfort levels across the groups. Our findings may offer a plausible reason to explain why other studies did not reveal consistent and strong relationships between workstation setup (such as height of the monitor) and discomfort levels of workers. For example, Turville, Psihogios, Ulmer et al. (1998) found no significant differences in visual acuity, operator performance or heart rate when the centre of the screen was positioned at 15° or 40° below the horizontal eye level. However, the sample size and design of this study do not enable us to draw a better conclusion, but provide insight for further research into this area.

We found that the workers' psychosocial status was a significant predictive factor of musculoskeletal discomfort. Our findings are consistent with other studies that also associated negative psychosocial status in the workplace with adverse health effects (Smith, 1997). The results of a longitudinal study cited by Smith suggested that monotonous computer work is associated with increased psychosomatic complaints and less job satisfaction. Smith further explained that computer tasks are characterized by sedentary and intensive

cognitive processing. These demands are related to increased work pressure and job stress (Carayon, Smith & Haims, 1999).

The Way Forward – Design of a Risk Assessment System

The Display Screen Equipment Risk Assessment and Management (DSE RAM) system is designed to facilitate the administration of DSE risk assessment in the workplace. It operates on a Web-based platform (Figure 2). The DSE RAM system incorporates the findings of this study and other major databases that have been generated by our research team in the past few years. Additionally, the assessment procedure and content are based on the requirements stipulated by the Occupational Safety and Health (DSE) Regulation (Labour Department, 2003). The DSE Regulation was enacted in 2003 and demands that employers conduct risk assessments of their workstations when employees use the workstations consecutively for 4 hours or accumulatively for 6 hours in a work shift. The results of several studies on implementation of risk assessments indicated that the use of a standardized assessment procedure was effective for improving the quality and validity of the risk assessment (Eakin, Lamm and Limborg, 2000; Johansson, Johansson, Lundqvist et al., 1998;). Rule-based recommendations on workstation improvement and other ergonomic features further enhance the workstation-worker match and effectiveness of implementing ergonomic interventions (Feyen,



Figure 2. Introduction page of the Display Screen Equipment Risk Assessment and Management (DSE RAM) system.

Liu, Chaffin et al., 2000).

The beta version of the DSE RAM system is comprised of five functions: Part I – identification of potential DSE risks; Part II – generation of recommendations for DSE improvement; Part III – automatic report collation for printing; Part IV – system-driven review and follow-up activities; Part V – build-in occupational health measures.

The user of the DSE RAM system is required to supply information on their workers, such as age, gender, job nature, DSE usage, workstation design, ergonomic features, anthropometric and workstation dimensions (involves actual measurements). The assessor then completes a 23-item questionnaire that covers subjective evaluation of the DSE, workstation and environment (Labour Department, 2003). The worker then completes two self-reporting questionnaires: one on fatigue and the other on musculoskeletal discomfort. Based on the information submitted, the programme analyses the parameters and uses the predetermined rules for risk identification and recommendations. For example, two of the rules are: mismatch threshold for monitor–eye level is set between 0 to –4 cm difference, whilst that for keyboard–elbow and mouse–elbow is –2 to +2 cm difference. Depending on the risks identified, the recommendations might be for improvements to the layout or dimensions of the workstation, and height and positioning of the monitor, mouse, keyboard, and chair. To further help risk assessors to use the results of the risk assessment, the recommendations are classified as: DSE Regulation specific (i.e. essential for statutory risk assessment); recommendations on workstation–worker match; and recommendations on general occupational health issues. This enables assessors and DSE users to discuss the feasibility of implementing each of the recommendations. The programme also has a review function that provides information on ergonomic products and equipment available in the local market. Finally, there is a print function so that the report can be printed.

Study Limitations

The small sample size of this study did not enable us to conduct more sophisticated analyses, particularly on the pattern of discomfort levels across different workstation–worker mismatches. Further study with a larger sample would address this issue. The participants of the study also limit the generalization of the results to other worker groups such as male sedentary workers and workers in large corporations who might have different working and psychosocial environments. A similar study can be made to study male sedentary workers who have different body builds and psychosocial statuses than

the female participants of this study. Further study should be conducted to test the effectiveness of the beta version of the DSE RAM system, which is designed for assessing the risks of workers using DSE.

Conclusions

The results of this study indicate that the anthropometric match between the workstation and the worker is a significant predictor of musculoskeletal discomfort. Psychosocial status and prolonged DSE usage were also identified as contributory factors to musculoskeletal discomfort. As musculoskeletal discomfort is associated with work-related disorders, a multi-factorial and systematic way to assess the risks of DSE use is desirable. The DSE RAM system is designed to meet this need.

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References

- Aaras, A., Horgen, G., Bjorset, H.H., Ro, O. & Walsøe, H. (2001). Musculoskeletal, visual and psychosocial stress in VDU operators before and after multidisciplinary ergonomic interventions. A 6 years prospective study—Part II. *Applied Ergonomics*, 32, 559–571.
- Amell, T. & Kumar, S. (2001). Work-related musculoskeletal disorders: design as a prevention strategy. A review. *Journal of Occupational Rehabilitation*, 11, 255–265.
- Bergqvist, U., Wolgast, E., Nilsson, B. & Voss, M. (1995). The influence of VDT work on musculoskeletal disorders. *Ergonomics*, 38, 754–762.
- Buckle, P.W. & Devereux, J.J. (2002). The nature of work-related neck and upper limb musculoskeletal disorders. *Applied Ergonomics*, 33, 207–217.
- Carayon, P., Smith, M.J. & Haims, M.C. (1999). Work organization, job stress, and work-related musculoskeletal disorders. *Human Factors*, 41, 644–663.
- Carter, J.B. & Banister, E.W. (1994). Musculoskeletal problems in VDT work: a review. *Ergonomics*, 37, 1623–1648.
- Demure, B., Luippold, R.S., Bigelow, C., Ali, D., Mundt, K.A. & Liese, B. (2000a). Video display terminal workstation improvement program: I. Baseline associations between musculoskeletal discomfort and ergonomic features of workstations. *Journal of Occupational and Environmental Medicine*, 42, 783–791.
- Demure, B., Mundt, K.A., Bigelow, C., Luippold, R.S., Ali, D. & Liese, B. (2000b). Video display terminal workstation improvement program: II. Ergonomic intervention and reduction of musculoskeletal discomfort. *Journal of Occupational and Environmental Medicine*, 42, 792–797.
- Eakin, J.M., Lamm, F., & Limborg, H.J. (2000). In: Frick, K., Jensen, A., Quinlan, M., Wilthagen, J. (eds). *Occupational Health and Safety Man-*

- agement – *Perspectives on International Development*, 227–250. London: Pergamon.
- Erez, A.B.H. & Lindgren, K.N. (1999). *Psychosocial Factors in Work-Related Musculoskeletal Disorders, Ergonomics for Therapists*. Boston: Butterworth-Heinemann.
- Feyen, R., Liu, Y., Chaffin, D., Jimmerson, G. & Joseph, B. (2000). Computer-aided ergonomics: a case study of incorporating ergonomics analyses into workplace design. *Applied Ergonomics*, 31, 291–300.
- Fine, L.J. (1996). Musculoskeletal Disorders in Office Work: the Need to Consider Both Physical and Psychosocial Factors. In: Moon, S.D., ed. *Beyond Biomechanics: Psychosocial Aspects of Musculoskeletal Disorders in Office Work*, 295–298. London: Taylor & Francis.
- Hales, T.R. & Bernard, B.P. (1996). Epidemiology of work-related musculoskeletal disorders. *The Orthopedic Clinics of North America*, 27, 679–709.
- Johansson A., Johansson G., Lundqvist P., Akesson I., Odenrick P., & Akselsson R. (1998). Evaluation of a workplace redesign of a grocery checkout system. *Applied Ergonomics*, 29, 261–266.
- Labour Department. (2003). *Code of Practice for Working with Display Screen Equipment*. Hong Kong: Occupational Safety and Health Branch, Labour Department.
- Latko, W.A., Armstrong, T.J., Franzblau, A. Ulin, S.S., Werner, R.A. & Albers J.W. (1999). Cross-sectional study of the relationship between repetitive work and the prevalence of upper limb musculoskeletal disorders. *American Journal of Industrial Medicine*, 36, 248–259.
- Occupational Safety and Health administration (OSHA). (2003). *Computer Workstation eTool*. From http://www.osha.gov/SLTC/etools/computerworkstations/components_monitors.html [Accessed: August 2003]
- Ohlsson, K., Attewell, R.G., Johnsson, B., Ahlm, A. & Skerfving, S. (1994). An assessment of neck and upper extremity disorders by questionnaire and clinical examination. *Ergonomics*, 37, 891–897.
- Siu, Z.K.F. (1999). *Work Exposure and Cumulative Trauma Disorders Among Visual Display Terminal (VDT) Users in Hong Kong*. Unpublished Masters' Thesis. Hong Kong: The Hong Kong Polytechnic University.
- Smith M.J. (1997). Psychosocial aspects of working with video display terminals (VDTs) and employee physical and mental health. *Ergonomics*, 40, 1002–1015.
- Turville, K.L., Psihogios, J.P., Ulmer, T.R. & Mirka, G.A. (1998). The effects of video display terminal height on the operator: a comparison of the 15 degree and 40 degree recommendations. *Applied Ergonomics*, 29, 239–246.