Perceived Upper Extremity Discomforts among Thai VDT Users: Their Relation to VDT Task, Dominant Input Device, and Its Location

Busagarin Rurkhamet[1] and Suebsak Nanthavanij[2]
[1]Industrial Engineering Program, [2]Management Technology Program
Sirindhorn International Institute of Technology
Thammasat University, Pathum Thani 12121, Thailand

Abstract

A survey study to investigate the relation between video display terminal (VDT) task and input device location and the perceived upper extremity discomforts of Thai VDT users was conducted. Six categories of VDT task and three input device locations (as indicated by the layout style) were considered in the study. Questionnaires were sent to 153 Thai VDT users to collect information on their VDT tasks, VDT workstation, keyboard-mouse (K-M) layout style, and perceived physical discomforts. The results showed that the upper extremity discomforts were apparently high in certain combinations of dominant VDT task and K-M layout style. Additionally, it is observed that users who perform different dominant VDT tasks could be grouped according to the input device most frequently used (i.e., keyboard or mouse). After regrouping VDT users according to the dominant input device, high physical discomforts are found among "*mouse*" users and the K-M layout style in which the mouse is placed on a different surface level from the keyboard. In conclusion, VDT users who perform dominant VDT tasks that require an extensive use of the mouse tend to experience high upper extremity discomforts especially when they place the mouse far from the body.

Keywords: video display terminal, dominant input device, upper extremity, discomforts

1. Introduction

While it is true that personal computers help to increase the productivity of video display terminal (VDT) users when performing their assigned tasks, some adverse effects have also been reported as a result of prolonged VDT operations. Examples of these effects are cumulative trauma disorders (e.g., carpal tunnel syndrome) (Carter and Banister, 1994), upper extremity discomforts, eye fatigue, and tension neck syndrome. It is believed that the occurrence of these injuries and physical discomforts can be largely attributed to inappropriate design of computer accessories (keyboard and monitor), their positions (i.e., vertical distances as measured from the floor and horizontal distances as measured from the user), and the user's seated posture.

There are many research studies that have investigated if VDT workstation settings have any impact on the user's physical discomforts. VDT users are usually divided into groups according to the VDT task or occupation. In most studies, VDT tasks considered are data entry, word processing, computer programming, and graphics design. For example, Grandjean et al. (1983) used company employees whose job functions include data entry and word processing in their study of preferred workstation settings. Shute and Starr (1984) studied the effects of adjustable VDT workstations on physical discomforts of directory assistance operators. Sauter et al. (1991) only emphasized VDT data entry task in their study. Kim et al. (1992), however, investigated the effects of work environment and work characteristics on VDT users whose job functions include clerical VDT task (document preparation), professional VDT task (e.g., programming and graphics design), and data entry task. A recent study conducted by Mohammed et al. (1999) also studied two groups of VDT tasks, namely, data entry and document operation.

Regarding computer accessories, it is noted that most studies consider only the keyboard and the monitor since recommended settings are based on the positions of these two devices. Miller and Suther III (1981) determined preferred adjustment of both height level and angle (only the keyboard and the monitor). In the studies on physical discomforts, both position and angle of the keyboard and monitor were found to have significant effects (Sauter et al., 1991; Kim et al., 1992; Lu and Aghazadeh, 1993; Burgess-Limerick et al., 1999).

It is also customary to investigate the design and adjustment of a chair since it influences body posture while seating. Bendix (1984) investigated seated trunk posture at various seat inclinations, seat heights, and table heights. A study conducted by de Moraes (1992) went even further to focus on the design of footrests. Nevertheless, common VDT workstation settings recommended by most researchers include only keyboard level height and distance, monitor level height and distance, and seat level height (Miller and Suther III, 1981; Grandjean et al., 1983; Shute and Starr, 1984). Lu and Aghazadeh (1994) were among the few who considered the horizontal position of the keyboard and monitor in their study and examined their positions on the user's perceived discomforts and musculoskeletal complaints.

Nowadays, most computer applications are windows-based and users frequently use computer mouse, track-ball, touch pad, touch pen, and joystick as alternative input devices. The proportion of usage depends on the type of VDT task that one performs. Karlqvist et al. (1999) recently compared the seated posture, muscular load, and perceived exertion in VDT users when using computer mouse and track-ball as input devices. However, the number of research studies concerning these alternative devices is relatively small.

The study on ergonomics of VDT operations in Thailand is scarce. Very little is known about the number of VDT users who are suffering from VDT-related musculoskeletal disorders and the degree of discomforts. Mekhora et al (2000) conducted an investigation on the effect of poor work posture (caused by the VDT workstation) on tension neck syndrome among Thai VDT users. In their study, readjusting the workstation settings (basically the height and distance) was applied as ergonomic intervention and proved to be effective in alleviating the work stress. Nevertheless, the study was restricted to only tension neck syndrome and only a few VDT tasks were investigated in the study. Different types of VDT workstation and dominant input devices were not of their concern.

This paper focuses on VDT tasks and keyboard-mouse (K-M) layout styles that are common among Thai VDT users and whether or not they have any significant impact on the user's upper extremity discomforts. A field survey was conducted to gather essential data from real workplaces in the Bangkok Metropolitan area. Thai VDT users were grouped according to their dominant VDT task and the K-M layout styles were categorized according to the location of the keyboard and mouse. Physical discomforts at the upper extremity were subjectively assessed, not scientifically measured.

Additionally, it is suspected that the effects of VDT task and/or K-M layout style, if any, on physical discomforts may be partly explained by the level of utilization of the input device (*keyboard* or *mouse*) and its location on the computer table. To investigate this, VDT users are later regrouped according to their dominant input device and the data is reanalyzed.

2. Survey Method

2.1 Subjects

One hundred and fifty three Thai VDT users (76 males and 77 females) volunteered to participate in this field survey without receiving monetary compensation. These users were from two educational institutions, two government agencies, and eleven private organizations, all located in Bangkok, Thailand. Their job titles include university faculty member, engineer, secretary, accountant, financial officer, manager, programmer, personnel officer, and data entry operator.

Table 1 shows the summary of selected physical and work experience data of the 153 VDT users.

Table 1. Summary of physical and work experience data (from 76 males and 77 females)

	Gender	Minimum	Maximum	Average	Std. Dev.
Age (years)	Male	22	42	29.22	4.06
	Female	22	47	28.68	4.71
Body height (cm)	Male	157	180	170.31	5.20
	Female	147	178	158.87	6.22
Body weight (kg)	Male	49	90	64.29	8.31
	Female	39	69	50.13	7.07
Work experience (years)	Male	0	15	5.45	3.49
	Female	0.5	23	4.77	3.75
Computer usage (hours/day)	Male	1	10	5.74	2.00
	Female	1	12	5.79	2.28

2.2 Questionnaire

The questionnaire for collecting VDT data and physical discomforts is divided into five parts:

1. Personal data
2. VDT task
3. VDT workstation
4. Keyboard-mouse layout style
5. Physical discomfort

Most questions in the questionnaire are multiple-choice questions. Regarding wrist, lower arm, elbow, upper arm, and shoulder discomforts, VDT users were asked to indicate the perceived discomfort level that they usually experienced after their daily VDT operations (i.e., discomforts at the end of the workday) by marking on a straight line that connects two extreme discomfort levels, "0" and "10." Note that "0" represents "*no discomfort*" while "10" represents "*very painful.*"

Table 2 shows a list of information that was gathered by the questionnaire.

2.3 Data Collection

The authors personally handed out the questionnaire to each of the 153 VDT users, assisted them while they answered the questions, and then collected the answered questionnaires. As a result, the return rate was 100%. While the users were answering the questions, information about computer tables and chairs (e.g., style, dimensions, adjustment ranges), workstation arrangements, and location of keyboard and mouse were recorded by the authors.

3. Data Analysis

The data was initially summarized to categorize VDT workstations and keyboard-mouse layout styles, and to quantify physical discomfort levels.

3.1 VDT Workstations

The majority of Thai VDT users reported that their VDT workstations were provided by the organization. They were not involved in the selection and acquisition processes. VDT workstations used by Thai VDT users were categorized as five table styles according to the design of the computer table.

Single-level (SL) table - A single-level (SL) computer table is a table that has one horizontal surface (called work surface) to be used as the writing area. The surface level height is not adjustable. The table may come with drawers either at its left side or right side, or without drawers.

Bi-level-with-right-keyboard-drawer (BL-RKD) table - A bi-level-with-right-keyboard-drawer (BL-RKD) table is a table that has a separate keyboard drawer located at its right side and either storage shelves or drawers at the left side. The keyboard drawer is retractable and placed below the work surface (writing area) of the table. Both the work surface and keyboard drawer level heights are not adjustable. Because of its limited width, the keyboard drawer can only accommodate a keyboard.

Bi-level-with-left-keyboard-drawer (BL-LKD) table - A bi-level-with-left-keyboard-drawer (BL-LKD) table has all features that are identical to the BL-RKD table, except that the sides of the keyboard drawer and storage shelves (or drawers) are reversed.

Table 2. Information gathered by the questionnaire

Category	Information
Part 1: Personal data	Age Gender Body height Body weight Visual accommodation capacity (i.e., normal, nearsightedness, and farsightedness) Preferred hand Job title (e.g., secretary, programmer, and designer) Work experience (in years)
Part 2: VDT task	Average daily usage of VDT (in hours/day) Types and proportions of VDT task routinely performed Types of input device and proportions of usage
Part 3: VDT workstation	Personal VDT workstation or shared VDT workstation Workstation designed for VDT or regular writing desk Computer table: type, dimensions, design features, and adjustment range(s) Chair: type, dimensions, design features, and adjustment range(s) VDT workstation adjustment habit
Part 4: Keyboard-mouse layout style	Arrangement of keyboard and mouse: by the user or by the organization Paired arrangement of keyboard and mouse: Same level (on the keyboard drawer) Same level (on the work surface) Different levels
Part 5: Perceived physical discomfort	Body parts where physical discomforts due to daily VDT operations are usually experienced: Wrist Lower arm Elbow Upper arm Shoulder

Bi-level-with-central-keyboard-drawer (BL-CKD) table - A bi-level-with-central-keyboard-drawer (BL-CKD) table has a retractable keyboard drawer that extends from the left side to the right side, without any storage shelves or drawers. Both the keyboard and mouse can be placed on this keyboard drawer. Neither the work surface nor keyboard drawer level height is adjustable. This style is the most common style among ready-made computer tables.

Custom-design (CD) table - The style of a custom-design (CD) table depends on the customer's preference. Design specifications may follow recommended guidelines or may be different. An example of the custom-design table is an L-shaped unit that combines a writing desk and a computer table together.

Table 3 shows the summary of design specifications of the five table styles.

3.2 Layout of Keyboard and Mouse

Three styles of keyboard-mouse layout are found to be common (perhaps from the styles of computer table that can be conveniently purchased from local office supply stores). These layouts can be described as follows.

Layout I - For this layout style, users will place the keyboard and mouse on a bi-level computer table (BK-CKD table style). Both the keyboard and mouse will be placed side by side on the retractable drawer (while the monitor will be placed on the work surface (top level) of the table) (see Fig. 1a). This layout is common since most computer tables are bi-level tables.

Table 3. Summary of computer table design specifications (all dimensions are in centimeters)

Style of Computer Table		Work Surface Depth	Work Surface Width	Work Surface Height	Keyboard Drawer Depth	Keyboard Drawer Width
SL[a]	Minimum	30	60	70	-	-
	Maximum	80	180	80	-	-
	Average	60.91	127.27	75.45	-	-
	Std. Dev.	17	42.21	2.69	-	-
BL-RKD	Minimum	50	100	75	34	57
	Maximum	50	100	75	34	57
	Average	50	100	75	34	57
	Std. Dev.	0	0	0	0	0
BL-LKD	Minimum	45	65	75	28	55
	Maximum	80	135	75	40	83
	Average	64.28	119.28	75	34.28	65.57
	Std. Dev.	11.70	24.90	0	4.61	10.15
BL-CKD	Minimum	45	75	75	25	55
	Maximum	85	100	75	37	85
	Average	65	83.33	75	32.11	65.55
	Std. Dev.	12.50	7.50	0	4.83	9.89
CD[b]	Minimum	-	-	75	-	-
	Maximum	-	-	75	-	-
	Average	-	-	75	-	-
	Std. Dev.	-	-	0	-	-

[a]*Single-level tables do not have a keyboard drawer.*
[b]*There is only one L-shaped, custom-design table. The depths and widths of both segments are unequal, thus not recorded. A keyboard drawer is not provided.*

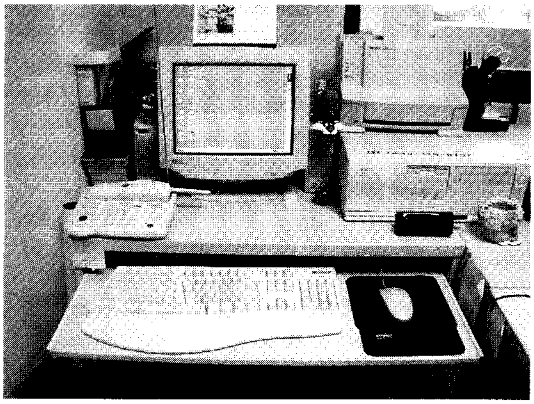
Layout II – With Layout II, the style of computer table is either the BL-RKD or BL-LKD table style. The keyboard is placed on the retractable drawer. However users will place the mouse on the work surface of the table (at the side of the monitor). This is due to the fact that the retractable drawer does not have enough space for the mouse. Figure 1b shows an example of Layout II. Note that the style of computer table demonstrated in the figure is BL-LKD. This layout style is also common due to its inexpensive cost.

Layout III - Users will place the keyboard and mouse (and monitor) on the work surface of the table. Usually the computer table is a single-level table (SL table style) that is similar to a writing desk (see Fig. 1c). This may be due to lack of office space for placing an additional computer table or may be because users have to frequently alternate between writing and operating the keyboard (and mouse). In some cases, users may use a bi-level table but choose to place both keyboard and mouse on the work surface of the table.

3.3 Physical Discomforts

An assessment of physical discomforts is based on subjective opinion. The discomfort is divided into 10 levels, where level 0 represents "*no discomfort*" and level 10 "*very painful.*" In the questionnaire, VDT users were asked to indicate the level of wrist, lower arm, elbow, upper arm, and shoulder discomforts that they usually experienced after daily VDT operations by marking on the line (that represents the discomfort level scale). The results were then converted into numeric discomfort levels.

It is noted that the user's posture could, to some extent, be influenced by the location of the input devices. For example, users who arrange the keyboard and mouse according to either Layout II or Layout III have to extend their right shoulder when they operate the mouse. As a result, these users especially those mostly performing mouse-based VDT tasks, are suspected to experience higher upper extremity discomforts than others.



(a) Layout I

(b) Layout II

(c) Layout III

Figure 1: Three common computer accessories layouts

4.Results

4.1 Analyses based on Dominant VDT Task

One of the questions in the questionnaire requires responders to choose VDT tasks that they routinely performed. The listed VDT tasks include: programming, data entry, data acquisition and/or analysis, computer graphics and/or design, and document preparation. In case that the user performed several VDT tasks, the task that required at least 50% of the user's time was designated as the dominant VDT task. If the dominant task could not be designated, the user was considered to perform multiple tasks. The number of VDT users who performed dominant tasks is 96 users, which accounts for 62.75% of all users. Among them, twelve users (7.84%) performed the "*programming*" task, twenty-eight users (18.30%) performed the "*data entry*" task, thirteen users (8.50%) performed the "*data analysis and/or acquisition*" task, fifteen users (9.80%) performed the "*computer graphics and/or design*" task, and twenty-eight users (18.30%) performed the "*document preparation*" task. The other fifty-seven users (37.25%) were considered to perform "*multiple tasks*".

The physical discomfort data of different body parts is presented in Table 4. The numerical values are quantitative discomfort levels determined from the positions of discomfort marks that VDT users indicated on the discomfort scales. Each number shown in the table is the average of all of the discomfort levels in a given combination of VDT task and keyboard-mouse layout style. Note that the numbers (in *italics*) shown in the parentheses are the standard deviations.

Two-Factor Analysis of Variance (ANOVA) is applied to determine the effects of dominant VDT task and keyboard-mouse layout style on wrist, lower arm, elbow, upper arm, and shoulder discomforts. For wrist and lower arm discomforts, it is found that all of the factor effects (including the interactions between both factors) are insignificant (at α = 0.05). However, for elbow, upper arm, and shoulder discomforts, the interaction effects are found to be significant (at α = 0.05). This result indicates that there are certain combinations of dominant VDT task and keyboard-mouse layout style that have significant effects on these body part discomforts.

To further investigate the interaction effects of both factors, it is necessary to consider all possible combinations of VDT task and keyboard-mouse layout style. Figure 2 depicts the mean response plots (a, b, and c) of elbow, upper arm, and shoulder discomfort data based on different combinations of dominant VDT task and keyboard-mouse layout style, respectively. One can see that in all three plots, VDT users whose dominant VDT task is "*data acquisition and/or analysis*" or "*computer graphics and/or design*" demonstrate high physical discomforts when the keyboard and mouse are arranged according to Layout II. Additionally, "*data entry*" users whose keyboard-mouse layout style falls in the Layout I style show high level of elbow discomfort.

From the data (in Table 4), it is noticed that VDT users who reported high physical discomforts were those who mostly performed VDT tasks requiring extensive use of the mouse. Thus it is suspected that the dominant input device may have some impact on the physical discomfort. To investigate this, Thai VDT users are then regrouped according to the type of dominant input device; then, their physical discomfort data is reanalyzed.

4.2 Analyses based on Dominant Input Device

Alternatively, VDT users can be divided into three groups according to the percent utilization of two input devices, namely, keyboard and mouse, as follows.

1. *Keyboard* users: users who utilize the keyboard as an input device more than 70% of the time.
2. *Mouse* users: users who utilize the mouse as an input device more than 70% of the time.
3. *Multi-device* users: users who utilize both the keyboard and mouse relatively equally (40-60% of the time).

Table 5 shows the relationship between the groupings of users by VDT task and by percent utilization of input devices. Firstly, let us consider the users who can be categorized by dominant VDT tasks (the first five rows) and multiple input devices (keyboard and mouse). It is seen that the majority of VDT users who mostly perform the "*computer graphics and/or design*" task are "*mouse*" users. On the other hand, users who usually perform the "*data entry*" or "*document preparation*" tasks are basically "*keyboard*" users. When considering "*multiple tasks*" users, one can see that the majority of these users also are "*keyboard*" users. Thus there appears to be some relationship between dominant VDT task and percent utilization of input device.

It is also noted that for each dominant VDT task, several users indicated that they equally utilized both the keyboard and mouse.

Next, a two-factor ANOVA is applied to investigate the effects of dominant input device and keyboard-mouse layout style on the physical discomforts. The results of the statistical analyses show that the effect of the keyboard-mouse layout on shoulder discomfort is significant (at α = 0.05) while that of the dominant input device is not. For wrist, lower arm, and upper arm discomforts, the interaction effects are found to be significant (α = 0.05). None of the factors has a significant effect on elbow discomfort.

Table 4. Physical discomfort data

a) Perceived *wrist* discomfort data

VDT Task	Keyboard-Mouse Layout		
	Layout I	Layout II	Layout III
1. Programming	5.00	4.00	2.25
2. Data entry	3.64	2.70	3.50
3. Data acquisition and/or analysis	3.17	4.00	3.17
4. Computer graphics and/or design	2.38	6.00	2.00
5. Document preparation	3.61	1.50	3.33
6. Multiple tasks	2.90	2.31	3.80

b) Perceived *lower arm* discomfort data

VDT Task	Keyboard-Mouse Layout		
	Layout I	Layout II	Layout III
1. Programming	1.00	4.00	2.50
2. Data entry	2.64	1.70	3.00
3. Data acquisition and/or analysis	2.17	4.00	2.67
4. Computer graphics and/or design	1.63	5.50	3.67
5. Document preparation	1.61	1.25	2.50
6. Multiple tasks	1.86	1.38	3.25

c) Perceived *elbow* discomfort data

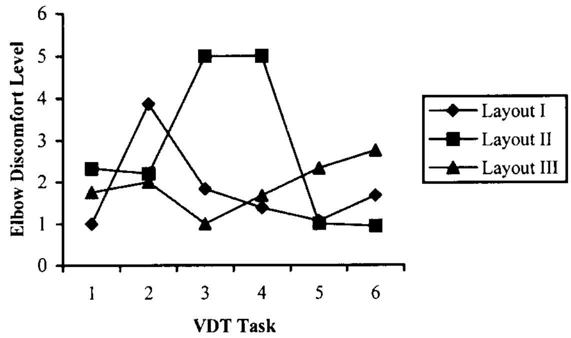
VDT Task	Keyboard-Mouse Layout		
	Layout I	Layout II	Layout III
1. Programming	1.00	2.33	1.75
2. Data entry	3.86	2.20	2.00
3. Data acquisition and/or analysis	1.83	5.00	1.00
4. Computer graphics and/or design	1.38	5.00	1.67
5. Document preparation	1.06	1.00	2.33
6. Multiple tasks	1.67	0.94	2.75

d) Perceived *upper arm* discomfort data

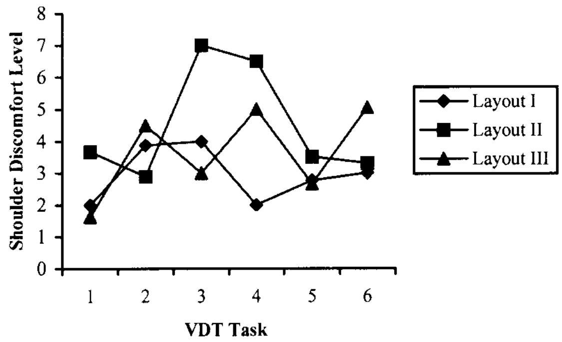
VDT Task	Keyboard-Mouse Layout		
	Layout I	Layout II	Layout III
1. Programming	2.00	3.67	1.63
2. Data entry	3.00	2.00	1.50
3. Data acquisition and/or analysis	2.00	6.00	1.00
4. Computer graphics and/or design	1.38	5.75	3.00
5. Document preparation	2.17	1.50	2.17
6. Multiple tasks	2.14	1.88	3.05

e) Perceived *shoulder* discomfort data

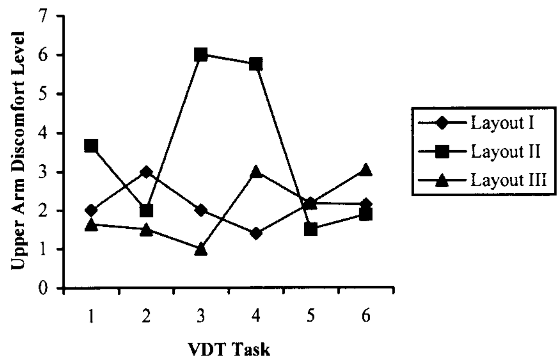
VDT Task	Keyboard-Mouse Layout		
	Layout I	Layout II	Layout III
1. Programming	2.00	3.67	1.63
2. Data entry	3.86	2.90	4.50
3. Data acquisition and/or analysis	4.00	7.00	3.00
4. Computer graphics and/or design	2.00	6.50	5.00
5. Document preparation	2.78	3.50	2.67
6. Multiple tasks	3.00	3.31	5.05



(a) Elbow discomfort



(b) Shoulder discomfort



(c) Upper arm discomfort

Figure 2: Physical discomforts associated with VDT task and keyboard-mouse layout style (VDT task: 1 = programming, 2 = data entry, 3 = data acquisition and/or analysis, 4 = computer graphics and/or design, 5 = document preparation, and 6 = multiple tasks)

Table 5. Number of subjects separately grouped according to the VDT task and dominant input device

VDT Task	Dominant Input Device*		
	Keyboard	Mouse	Multiple Devices
Programming	4	1	7
Data entry	14	-	14
Data acquisition and/or analysis	3	1	9
Computer graphics and/or design	1	9	5
Document preparation	16	1	11
Multiple tasks	21	4	32

**Based on percent utilization of input device*

Figure 3 shows mean response plots (a, b, and c) of average discomfort levels for all combinations of dominant input device and keyboard-mouse layout style for the wrist, lower arm, and upper arm data, respectively. In all plots, the extensive use of the mouse seems to be a major factor that causes high physical discomforts among "*mouse*" users especially when the mouse is placed far from the body (i.e., Layout II). Additionally, the users who use both the keyboard and mouse relatively equally show high physical discomforts when the mouse is placed according to Layout III.

5. Conclusion

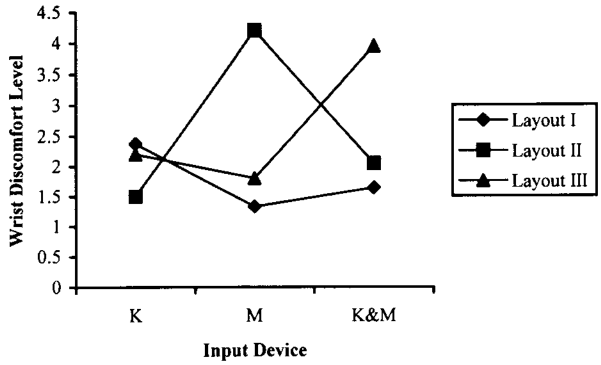
When grouping VDT users according to the dominant VDT task, it is seen that users who were mostly involved in the "*data acquisition and/or analysis*" or "*computer graphics and/or design*" task reported high elbow, upper arm, and shoulder discomforts when the keyboard and mouse were arranged according to Layout II. With this layout style, it is noted that the mouse is placed on the work surface of the computer table (in which its level height is higher than that of the keyboard) and is far from the user. This mouse location requires users to extend their arm forward in the direction that is midway between the front and the right of the body (i.e., shoulder abduction).

For other layout styles in which the mouse is located close to the user (Layout I) or can be conveniently reached (Layout III), the above two VDT tasks do not show any apparent influence on the physical discomforts. Other dominant VDT tasks, for example, "*programming*" and "*document preparation*," do not seem to have any significant influence on the physical discomforts, irrespective of the layout style.

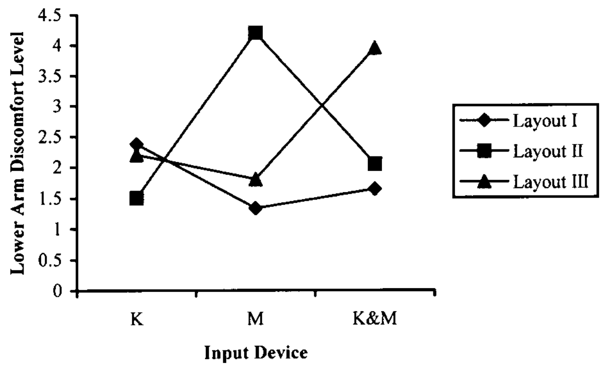
When considering the operational requirements of VDT tasks, it is noticed that the "*data acquisition and/or analysis*" and "*computer graphics and/or design*" tasks require extensive use of the mouse while the "*programming*" and "*document preparation*" tasks do not. It is thus reasonable to suspect that the degree of utilization of the mouse may partially contribute to high upper extremity discomforts. Furthermore, the influence of the mouse on the physical discomforts could even be more pronounced when VDT users place the mouse far from the body (i.e., according to Layout II).

The influence of the mouse on the physical discomforts is statistically confirmed when VDT users are regrouped according to the dominant input device. The results show that "*mouse*" users who place the mouse far from the body are likely to show high discomforts in several upper body parts. Furthermore, "*multi-device*" users whose keyboard and mouse are both placed on the work surface of the computer table also show high levels of discomfort at the wrist and lower arm. These discomforts are believed to result, in part, from the abduction of the upper extremity when operating the mouse. "*Keyboard*" users do not show any apparent discomforts at the upper extremity in all cases.

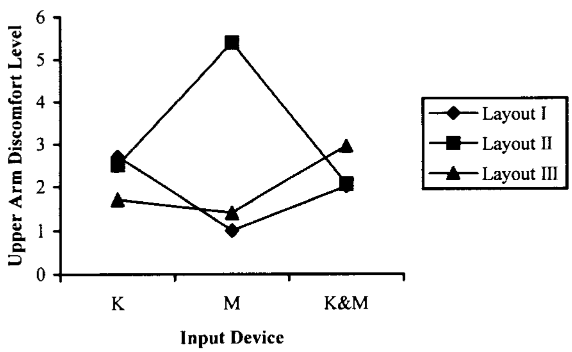
This study shows that not only the height and distance settings of the VDT workstation as traditionally recommended but also the type and location of the input device dominantly used could have a significant impact on the upper extremity discomforts. Comparing between the keyboard and mouse, the latter has greater tendency to cause high upper extremity discomforts especially when its location is not appropriate. More specifically, placing the mouse far from the body (according to Layouts II and III) or on the work surface of the table (according to Layout III) is likely to cause high physical discomforts.



(a) Wrist discomfort



(b) Lower arm discomfort



(c) Upper arm discomfort

Figure 3: Physical discomforts associated with dominant input device and device location as indicated by the layout style (Input device: K = keyboard, M = mouse, K&M = keyboard and mouse)

In summary, in addition to the keyboard height and distance, monitor height and distance, and seat height, it is necessary to consider the following points when recommending ergonomic VDT workstation settings:

1. Dominant VDT task that the user performs
2. Input devices that the user uses and the degree of utilization of individual input devices
3. Combined effect of the VDT task and the keyboard-mouse layout style
4. Appropriate location of dominant input device

To accommodate VDT users with different body sizes, task requirements, and typing skill levels, it is recommended that the VDT workstation be fully adjustable. The VDT workstation components that should be adjustable can be grouped according to the adjustment directions as follows:

1. Up-down, left-right, and forward-rearward directions: monitor platform, keyboard tray, mouse tray, document holder
2. Up-down and forward-rearward directions: chair seat

The adjustment ranges of the above mentioned components are based on key body parts of VDT users and should accommodate users between the 5^{th} percentile of female population to the 95^{th} percentile of male population. Additionally, VDT users need to be educated regarding a proper seated posture during prolonged VDT operations.

6. Acknowledgments

The authors wish to express their gratitude to the Thailand Research Fund (TRF) for providing financial support for this study through research grant No. PHD/00032/2541.

7. References

[1] Bendix, T., Seated Trunk Posture at Various Seat Inclinations, Seat Heights, and Table Heights, Human factors, Vol. 26, No. 6, pp. 695-703, 1984.

[2] Burgess-Limerick, R., Plooy, A., Fraser, K., and Ankrum, D.R., The Influence of Computer Monitor Height on Head and Neck Posture, International Journal of Industrial Ergonomics, Vol. 23, pp. 171-179, 1999.

[3] Carter, J.B. and Banister, E.W., Musculoskeletal Problems in VDT Work: A Review, Ergonomics, Vol. 37, No. 10, pp. 1623-1648, 1994.

[4] de Moraes, A., Design of Workplace: Footrest, In: Kumar, S. (Ed.), Advances in Industrial Ergonomics and Safety IV, Taylor & Francis, London, pp. 545-552, 1992.

[5] Grandjean, E., Hunting, W., and Pidermann, M., VDT Workstation Design: Preferred Settings and Their Effects, Human Factors, Vol. 25, No. 2, pp. 161-175, 1983.

[6] Karlqvist, L., Bernmark, E., Ekenvall, L., Hagberg, M., Isaksson, A, and Rosto, T., Computer Mouse and Track-ball Operation: Similarities and Differences in Posture, Muscular Load and Perceived Exertion, International Journal of Industrial Ergonomics, Vol. 23, pp. 157-169, 1999.

[7] Kim, J.H., Lee, N.S., and Kim, C.J., A Cross-sectional Study on VDT Working Environment and Identification of Relationship between VDT Work Characteristics and Health in Hazards in Korea, In: Kumar, S. (Ed.), Advances in Industrial Ergonomics and Safety IV, Taylor & Francis, London, pp. 1379-1385, 1992.

[8] Lu, H., Aghazadeh, F., 1993. VDT positions: Effect on performance and comfort. Proceedings of Human Factors and Ergonomics Society 37^{th} Annual Meeting, 397-400.

[9] Lu, H. and Aghazadeh, F., The Perceived Discomfort and Musculoskeletal Complaints associated with Varying Positions of VDT and Keyboard, In: Aghazadeh, F. (Ed.), Advances in Industrial Ergonomics and Safety VI, Taylor & Francis, London, pp. 475-481, 1994.

[10] Mekhora, K., Liston, C.B., Nanthavanij, S., and Cole, J.H., The Effect of Ergonomic Intervention on Discomfort in Computer Users with Tension Neck Syndrome, International Journal of Industrial Ergonomics, Vol. 26, No. 3, pp. 367-379, 2000.

[11] Miller, I. and Suther III, T.W., Preferred Height and Angle Settings of CRT and Keyboard, Proceedings of the Human

Factors Society 25th Annual Meeting, pp. 492-496. 1981.

[12] Mohammed, O., Shell, R., and Swanson, N., Investigating the postural stress associated with sedentary work, In: Lee, G.C.H. (Ed.), Advances in Occupational Ergonomics and Safety, IOS Press, pp. 401-406, 1999.

[13] Sauter, S.L., Cheleifer, L.M., and Knutson, S.J., Work Posture, Workstation Design, and Musculoskeletal Discomfort in a VDT Data Entry Task, Human Factors, Vol. 33, No. 2, pp. 151-167, 1991.

[14] Shute, S.J. and Starr, S.J., Effects of Adjustable Furniture on VDT Users, Human Factors, Vol. 26, No. 2, pp. 157-170, 1984.