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ERGONOMIC INTERVENTION FOR IMPROVING WORK POSTURES DURING NOTEBOOK COMPUTER OPERATION

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This paper discusses the application of analytical algorithms to determine necessary adjustments for operating notebook computers (NBCs) and workstations so that NBC users can assume correct work postures during NBC operation. Twenty-two NBC users (eleven males and eleven females) were asked to operate their NBCs according to their normal work practice. Photographs of their work postures were taken and analyzed using the Rapid Upper Limb Assessment (RULA) technique. The algorithms were then employed to determine recommended adjustments for their NBCs and workstations. After implementing the necessary adjustments, the NBC users were then re-seated at their workstations, and photographs of their work postures were re-taken, to perform the posture analysis. The results show that the NBC users' work postures are improved when their NBCs and workstations are adjusted according to the recommendations. The effectiveness of ergonomic intervention is verified both visually and objectively.
Key words: notebook computer; ergonomic intervention; work posture; RULA

INTRODUCTION

Prolonged visual display terminal (VDT) operation is a leading cause of musculoskeletal disorders (MSD) and cumulative trauma disorders (CTD) such as low back pain, carpal tunnel syndrome (CTS), stiff shoulders, and sore neck among office employees. The problems are intensified by awkward work postures, e.g., bent neck, bent wrists, or excessively flexed forearms. Numerous research studies were conducted to give recommendations about VDT operation and seated postures, resulting in the ANSI/HFS 100-1988 Standard (HFS, 1988). Mekhora et al. (2000) reported that neck and shoulder pain is prevalent in office employees especially those who work with VDTs. Rurkhamet and Nanthavanij (2004a) developed an analytical design method for computing workstation settings and positioning computer accessories so as to help VDT users sit with a correct posture. Later, Rurkhamet and Nanthavanij (2004b) developed EQ-DeX, a rule-based decision support system, based on their analytical algorithm. The EQ-DeX provides quantitative adjustment recommendations and displays line figures to illustrate the resulting workstation settings and computer accessories layout.

During the recent years, the use of notebook computers (NBCs) has quickly become very popular among computer users due to their light weight, small size, portability, and battery power option. However, limited information about ergonomic recommendations is available for workers who work with notebook computers (Cossey, 2005). At present, very little research (when compared with that related to VDT operation) has been conducted on health and safety issues associated with NBC operation. Given the current research results relating computer use to MSD symptoms and syndromes in office employees, it is reasonable to suspect that NBC operation is likely to induce MSD risks. With the increasing growth in its popularity among office employees, health and safety problems caused

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by NBCs can be expected to accelerate progressively.

Physical implications of NBC operation on body postures have been reported (Harbison and Forrester, 1995; Diederich and Stewart, 1997; Straker et al., 1997a; Price and Dowell, 1998). Straker et al. (1997a) presented a comparison of body postures during desktop computer and NBC operations. The results revealed that in terms of postural constraints and discomforts, desktop computer users felt better even after 20 minutes of computer use. Horikawa (2001) did a quantitative examination on the relation between screen height and trapezius muscle hardness on subjects using desktop computers and NBCs. The results showed that with 15 minutes of data entry work on NBCs, the hardness of the trapezius muscle is increased.

Ergonomic research suggests that VDT workstations which promote awkward or constrained work postures predispose users towards musculoskeletal injuries, and that persistent musculoskeletal problems relate to poor workstation design including the lack of adjustability (Harbison and Forrester, 1995). Adjustable workstations are generally recommended for proper seating during VDT operation so as to minimize discomfort. At least, the workstation should allow the keyboard and monitor to be adjusted independently. Unfortunately, due to its hinge design, the heights of NBC base and screen units cannot be adjusted independently. This design could lead to a body posture with excessive stresses at the neck and wrist regions. Straker et al. (1997a) suggested that an NBC user would assume a posture that would compromise their typing posture either by increased neck flexion in order to view a lower screen, or by increased shoulder and elbow flexion to reach a higher keyboard. Harbison and Forrester (1995) also found that NBC users required an increased forward head inclination to adequately operate the NBC due to its lack of adjustability. In their study, all NBC users adopted the neck flexion of more than 30° greater than the neck posture recommended in the Australian Standard 3590.2.

Sommerick et al. (2002) conducted a detailed study to evaluate the effects of NBC on body postures when being operated in a stand-alone condition and with inexpensive ordinary peripheral input devices such as external keyboard, mouse, and numeric pads. They investigated how head and neck angles, trunk angle and thoracic bend, shoulder and elbow angles, and wrist posture of NBC users are influenced. The results showed that in the stand-alone condition, the body postures are more deviated from the neutral positions. They concluded that the use of external peripheral devices (such as keyboard) can reduce stress on the neck.

It is therefore suggested that the NBC user is likely to assume an awkward or constrained posture when typing due to the poor design of NBC itself. Jalil and Nanthavanij (2007) proposed two analytical algorithms to give adjustment recommendations such as adding a footrest, a seat support, a base support, etc. so that the correct work posture can be obtained while operating NBCs. Accessories are utilized to adjust the height and tilt angle of NBC, and the user's seat height. The required adjustments depend on the user's body height, size of NBC, and workstation dimensions (seat and work surface heights).

In this paper, we discuss the ergonomic intervention for improving the work posture during NBC operation using the algorithms developed by Jalil and Nanthanvanij (2007). The Rapid Upper Limb Assessment (RULA) technique is utilized to evaluate work postures both before and after the ergonomic intervention.

NOTEBOOK COMPUTER OPERATION

Generally speaking, NBC operation is similar to VDT operation. Computers are used as a tool to assist users in accomplishing their tasks, such as document preparation, graphics design, numeric data entry, or information search. When scrutinizing the two operations from an ergonomic perspective, their differences are clearly distinguishable and can be discussed from the following two aspects.

Workstation

A typical VDT workstation consists of a computer table and a chair. The computer table is usually a bi-level table in which a keyboard and a mouse are normally placed on the lower level, sliding drawer while a monitor is placed on the top level. The chair is a 5-pronged, wheeled, adjustable chair, similar to any ordinary office chair.

The NBC workstation is however less well-defined than the VDT workstation. Since the NBC is designed to be a portable device, the use of NBC is not restricted to any specific workplace or workstation. Figure 1 shows six examples of unconventional workplaces where NBC operations can be found. The pictures are taken from the university campus and dormitory where NBC uses are common among university students. Readers can see that students can use practically every seated place to operate their NBCs.

(a) Student dormitory room

(b) Student dormitory room

(c) Graduate student office

(d) Common recreation area

(e) Common recreation area

(f) University canteen

Fig. 1. Common places where NBCs are used at the university.

Recommended work posture

As recommended in the ANSI/HFS 100-1988 Standard, the VDT user should sit with the back at an upright (or slightly reclined) position; the upper arms should hang naturally along the side of the trunk; the elbows are fixed at 90° while keeping the lower arms horizontal; the lower arms and hands should form a straight line; the lower legs should form the right angle (90°) with the upper legs; both feet should rest comfortably on the floor. The monitor should be placed such that the user can view the screen comfortably without bending the neck. Since the keyboard and monitor of modern desktop computers come as separate units, it is possible to adjust the partially or fully adjustable VDT workstation so that the above described posture can be obtained.

The NBC has its base and screen units connected by hinges. This design prohibits the heights of the base (or keyboard) and screen (or monitor) from being adjusted independently; thus, imposing conflicting constraints on the work posture. More specifically, if the screen is positioned such that the user's neck is in an ergonomic position, the forearms must be raised to reach the keyboard, causing both wrists to flex excessively. On the other hand, if the keyboard is ergonomically positioned, the wrists will be fine but the neck must be flexed extensively to view the screen.

From the general recommendations given in the ANSI/HFS 100-1988 Standard and those from ergonomic researchers (Lueder, 1996; Straker et al., 1997a; Straker et al., 1997b; Harris and Straker, 2000; Moffet et al., 2002), Jalil and Nanthavanij (2007) summarized that the NBC user should sit with the back at an upright (or slightly reclined) position; neck flexion should not be more than 10°;

shoulder flexion should not be more than 20°; elbow flexion should be about 90°; the lower arms and hands should form a straight line; the lower legs should form the right angle (90°) with the upper legs; both feet should rest comfortably on the floor. Additionally, the viewing distance should be between 38 and 62 cm.

ADJUSTMENT ALGORITHMS

Jalil and Nanthavanij (2007) developed analytical algorithms to recommend NBC and workstation adjustments so that NBC users can assume a correct work posture during NBC operation. In this section, we briefly describe the required inputs for the algorithms, adjustment procedures and their outputs.

Inputs

The adjustment algorithms require the following inputs.

1. The user's body part dimensions
2. NBC dimensions
3. Workstation constraints (seat and work surface heights)

For practical usage, the algorithms use anthropometric formulas to estimate the user's body part dimensions from the body height and gender. Based on the anthropometric data of the Thai population (Thai Industrial Standards Institute, 2001), the following body part dimensions can be estimated: (1) eye height (sitting), (2) shoulder height (sitting), (3) length of the upper arm, (4) length of the lower arm, (5) length of the hand, (6) popliteal height (sitting), (7) length of the upper leg, and (8) length of the lower leg. From the estimated body part dimensions, selected body reference points are defined. They are: (1) eye, (2) shoulder joint, (3) elbow joint, (4) wrist joint, (5) fingertip at the middle finger, (6) hip joint, (7) knee joint, and (8) ankle joint.

Similarly, it is necessary to know some physical dimensions of the NBC in order to define the coordinates of its reference points. The required dimensions can be estimated from the screen size (measured diagonally). Firstly, the three physical dimensions are determined (either from direct measurement or estimation): (1) distance between the front edge of the base unit and the keyboard's home row, (2) distance between the front and rear edges of the base unit, and (3) distance between the top and bottom edges of the screen unit. Next, selected reference points of the NBC are defined as follows: (1) keyboard's home row, (2) front edge of the base unit, (3) rear edge of the base unit, (4) bottom edge of the screen unit, and top edge of the screen unit.

The NBC user's work posture is strongly constrained by the workstation. Two workstation data are required by the algorithms. They are: (1) seat height and (2) work surface height.

Adjustment procedures

Two adjustment algorithms are developed. In the first algorithm, it is assumed that there are no workstation constraints. That is, the algorithm freely positions the body and the NBC to form the work posture recommended for NBC operation, and provides the coordinates of all reference points and body joint angles as the outputs.

The second algorithm considers two constraints of the workstation, namely, seat height and work surface height. Firstly, the algorithm imports the resulting reference point coordinates and joint angles from the first algorithm. From the recommended and actual seat and work surface heights, nine possible adjustment scenarios can be defined. The algorithm determines which scenario exists and recommends the footrest, seat support, and NBC base support for assuming the recommended work posture.

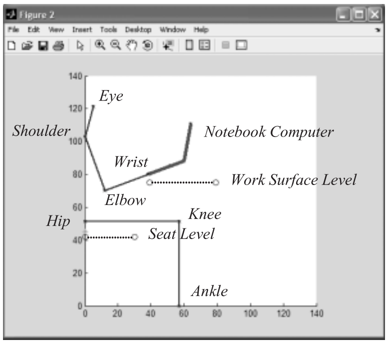
For more details on the adjustment algorithms, see Jalil and Nanthavanij (2007).

Outputs

To assume the recommended work posture, the algorithms determine the required (x, y) coordinates of body and NBC reference points, including body joint angles. However, such recommendations will be useless for NBC users since they will not be able to measure their joint coordinates and angles. Thus, the adjustment recommendations are translated into necessary NBC and workstation adjustments, from which if adjusted accordingly, the correct work posture can be assumed. The recommended NBC and workstation adjustments are as follows.

1. Seat support
2. Base support
3. Footrest
4. Distance between the user's body and NBC
4. Tilt angle of NBC base
5. Screen angle

As an example, consider a male NBC user whose body height is 168 cm. Suppose that he is using a 13.3" NBC and is seated at a workstation where the seat and work surface heights are 45 and 75 cm, respectively. From the inputs, the algorithms (coded as a MATLAB program) gives the adjustment recommendations as summarized in Figure 2. Note that all adjustments are rounded to the nearest integer value for practicality.



User:	Gender = male
	Body height = 168 cm
NBC:	13.3î screen size
Workstation:	Seat height = 42 cm
	Work surface height = 78 cm

Recommended Work Posture

Viewing angle:	10°
Shoulder flexion:	20°
Elbow flexion:	89°
Wrist deviation:	0°
Viewing distance:	60 cm
Seat height:	45 cm
Work surface height:	78 cm

Recommended Adjustments

Seat support:	3 cm
NBC Base Support:	3 cm
Footrest:	-
Distance between body and NBC:	29 cm
NBC tilt angle:	21°
Screen angle:	121°

Fig. 2. Recommended adjustments given by the algorithms.

EXPERIMENT

Subjects

Twenty-two Thai office employees (eleven males and eleven females) voluntarily participated in the experiment to evaluate the effectiveness of the ergonomic intervention. None of them received monetary compensation for their involvement in this study. All subjects are employees in Thai government agencies and business organizations who use NBCs regularly. Table 1 shows the averages, standard deviations, maximums, and minimums of ages and body heights of the twenty-two subjects. From the anthropometric data of the Thai population (Thai Industrial Standards Institute, 2001) and following the body height classification guidelines used in Jalil and Nanthavanij (2007), the subjects'

Table 1. Statistics of ages and body heights of the twenty-two subjects.

	Male		Female	
	Age (year)	Height (cm)	Age (year)	Height (cm)
Average	33.82	170.18	31.55	160.55
Standard Deviation	9.10	4.92	6.49	6.33
Maximum	56.00	175.00	43.00	172.00
Minimum	23.00	163.00	22.00	150.00

stature can be described as short, average, and tall. From the eleven male subjects, two are short, five are average, and four are tall persons. In the same manner, the eleven female subjects consist of one short, four average, and six tall persons.

Equipment

The equipment used in this experiment are as follows:

1. Measuring tape
2. Angle-adjustable platform
3. 0.5-cm thick acrylic boards (to be used as seat, base, and footrest supports)
4. Seat cushion
5. Portable goniometer
6. Digital camera
7. Notebook computers (actual NBCs used by the subjects)
8. NBC workstations (actual workstations used in the subjects' workplaces)

Table 2 summarizes the NBCs and workstations that the twenty-two subjects use.

Table 2. Summary of NBCs and workstations used by the subjects.

	Male subjects										
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
NBC screen size (inches)	12.2	15.0	13.3	14.0	12.2	13.3	15.0	15.0	14.0	15.0	13.3
Seat height (cm)	42.0	44.0	43.0	45.5	46.0	44.0	49.0	45.0	43.0	46.0	45.0
Work surface height (cm)	74.5	76.5	75.0	75.0	77.0	77.0	75.0	75.0	77.0	75.0	77.5
	Female subjects										
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
NBC screen size (inches)	13.3	14.0	12.2	14.0	15.0	15.0	14.0	14.0	15.0	15.0	12.2
Seat height (cm)	46.0	47.0	46.0	44.0	44.0	47.0	43.0	43.0	49.0	40.0	39.0
Work surface height (cm)	75.5	75.0	72.0	77.0	76.5	78.0	75.0	75.0	75.5	75.0	75.0

Procedure

The experimental procedure can be described as follows. Initially, the subject was asked to operate his/her notebook computer according to his/her normal work practice. No assistance was provided in positioning the NBC as related to the body or adjusting the seat height. Once the subject was satisfied with the workstation arrangement, a digital photograph was taken to record the subject's work posture.

Next, the information about the subject, NBC, and workstation were entered into the adjustment algorithms to compute necessary adjustments for the subject. Based on the recommendations, the NBC and workstation were adjusted and the subject was re-seated at the workstation. The NBC was positioned on the work surface with its angles and distance (from the user's body) as recommended. Another digital photograph of the subject's work posture was taken for comparison.

The work postures both before and after ergonomic intervention were analyzed using RULA. The RULA scores were then compared to evaluate the effectiveness of ergonomic intervention.

Data analysis

The Rapid Upper Limb Assessment (RULA) was firstly developed by L. McAtamney and N.

Corrett for evaluating individuals' exposures to postures, forces, and muscle activities that have been shown to contribute to repetitive strain injuries (RSI). The use of RULA results in a risk score from one to seven, where higher scores signify greater levels of apparent risk (McAtamney and Corrett, 1993). Later, Lauder (1996) refined the RULA technique by introducing changes to increase its relevance for evaluating computer work.

Briefly, the upper arm, lower arm, and wrists postures are evaluated and scores are given for each body part posture. Then, the scores are combined (using a specially developed scoring table) to generate the upper limb posture score. Similarly, the neck, trunk, and legs postures are evaluated and scores are also given. They are combined to generate the neck-trunk-legs score. For both combined scores, scores for muscle use and force are added. Finally, the grand score is determined and action to be taken is recommended.

Action Level One: *A score of one or two indicates that the posture is acceptable if it is not maintained or repeated for long periods of time.*

Action Level Two: *A score of three or four indicates that further investigation is needed and changes may be required.*

Action Level Three: *A score of five or six indicates that investigation and changes are required soon.*

Action Level Four: *A score of seven or more indicates that investigation and changes are required immediately.*

For more details on the RULA, see Lueder (1996).

RESULTS AND DISCUSSION

Prior to the ergonomic intervention, it is found that none of the twenty-two subjects assumed the correct work posture during NBC operation. Surprisingly, these subjects shared several commonalities in their work postures. Their neck, trunk, and wrist postures are found to range from somewhat awkward to extremely awkward. By observation, it is clear that neck, shoulder, and elbow flexions exceed the recommended angles. Some subjects assumed relaxed body postures during NBC operation by leaning their trunk backward against the backrest while typing (see subjects M8 and F11). Nearly all subjects were provided with height-adjustable chairs. Nevertheless, very few, if any, subjects attempted to adjust the seat height.

From the subjects' body heights and the NBC and workstation data (see Table 2), the required adjustments were determined. Table 3 shows the summary of recommended adjustments for all twen-

Table 3. Summary of recommended adjustments for all twenty-two subjects.

Male subjects											
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
Seat support (cm)	4	2	5	3	-	1	1	3	5	-	1
Footrest (cm)	-	1	-	-	-	-	9	-	-	-	2
Distance (body – NBC) (cm)	30	26	30	28	30	29	25	25	25	26	28
Base tilt angle (degree)	24	17	20	19	21	21	16	16	16	17	20
Screen angle (degree)	124	117	120	119	121	121	116	116	116	117	120
Base support (cm)	7	-	10	9	2	2	-	6	5	1	-
Female subjects											
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
Seat support (cm)	-	-	-	2	1	4	3	1	-	6	5
Footrest (cm)	6	8	10	4	-	15	7	2	6	5	-
Distance (body – NBC) (cm)	26	26	25	26	26	24	26	26	26	25	28
Base tilt angle (degree)	21	18	21	19	19	14	18	19	16	15	26
Screen angle (degree)	121	118	121	119	119	114	118	119	116	115	126
Base support (cm)	1	1	3	-	1	-	-	-	4	-	6

Note: All adjustments are rounded to the nearest integer value.

ty-two subjects. It should be noted that for any two subjects who have the same body height, but operate the NBCs with different sizes or sit at the workstations with different seat and work surface heights, their required adjustments are different. Vice versa, the two subjects who use identical NBCs and sit at the same workstation may require different adjustments if their body heights are different. Figure 3 provides visual comparisons of work postures both before and after the ergonomic

Fig. 3. Work postures before and after ergonomic intervention of male and female subjects.

intervention of the twenty-two subjects.

Neck flexion

As reported in several studies, NBC users tend to flex their neck far too much when working with NBCs in order to get a clear view of the screen which is normally positioned too low. Some subjects even bent their back while operating the keyboard in order to reduce neck flexion (see subject M4). Tall subjects who use a small NBC will suffer more than others. Improper seat and work surface heights also worsen the subjects' neck posture.

When using the foot, seat, and base supports, the screen can be positioned at the level where it can be viewed comfortably (i.e., neck flexion is not greater than 10°). The adjustments also help to improve the subjects' trunk postures by straightening them (see subject M4).

Shoulder flexion

Most subjects positioned their NBCs too far from their body as seen in subjects M2, F4, F5, F7, F8, F10, and F11. This action forces them to extensively flex their shoulders in order to reach the keyboard. It also increases the viewing distance which causes several subjects to lean forward in order to view the screen. Several subjects placed their lower arms on the work surface (see subjects M2, M4, M6, M9, M10, M11, F1, F4, F5, F6, F7, F9, and F10). As a result, their lower arms tend to press against the edge of the work surface which can cause blood flow occlusion and even pain (see subjects M1, M4, M6, F1, F2, F4, F5, F6, F9, and F10).

For each subject, the adjustment algorithms recommend the distance between the subject's body and NBC (see Table 3). To help prevent the subject from pressing the lower arms against the edge of the work surface, the NBC was positioned at or very near the edge of the work surface. Although this may raise an argument that since there is no armrest provided, this posture can cause fatigue in the upper arms. However, it should be noted that most NBCs come with a large area for a palm rest. The subject can then use it to help support the lower arms. Additionally, the recommended distance between the subject's body and NBC will help to keep the shoulder flexion from exceeding 20° in order to minimize discomfort.

There is one subject (see subject M7) who initially positioned the NBC too close to his body. For him, the NBC had to be placed further away than its usual position.

Wrist deviation

It is noticed that all wrist deviations observed from the twenty-two subjects are palmar flexion. This is due to the fact that the NBCs were placed on the work surfaces that were rather high as compared to the subjects' body. All subjects chose to horizontally place their NBCs on the work surface. Since the subjects' elbow joints were lower than the work surface, they had to flex their palms downward for typing. For those subjects who chose to place the lower arms on the work surface, they were able to maintain a straight wrist posture. However, it is suspected that ulnar deviation is still likely to exist.

For all subjects, the NBC had to be tilted by lifting the back of the NBC up. (From Table 3, it is seen that the tilt angle of NBC can be as large as 26°.) This adjustment enables the subjects to keep their hands in line with their lower arms; thus, maintaining the straight wrist posture. In addition, the algorithms also recommend the screen angle which will allow the subject to view the screen comfortably.

RULA scores

The RULA technique was applied to evaluate the subjects' work postures both before and after implementing recommended adjustments to improve their postures. It is seen that the average RULA scores drop from 6.09 to 3.18 and from 5.91 to 3.09 in the male and female groups, respectively. For some subjects (M2, M4, F1, F5, and F7), the RULA scores decrease from 7 to 3. Decreased RULA scores observed in the work postures after ergonomic intervention clearly indicate that the adjustment algorithms are effective in helping to improve the NBC users' work postures. When evaluating the RULA scores given to individual body parts, the largest improvement in work postures is seen at the neck and wrist regions. This result has been expected since the algorithms are intended to yield the work posture that improves both the neck and wrist postures.

Table 4 shows the RULA scores of work postures during NBC operation for all twenty-two subjects. From paired t-tests, the differences of RULA scores between *before* and *after* ergonomic intervention are found to be significant for both male and female groups ($p < 0.0005$).

Table 4. Summary of RULA scores of work postures.

Male				Female			
Subject	Before	After	Difference[a]	Subject	Before	After	Difference[a]
M1	5	4	-1	F1	7	3	-3
M2	7	3	-4	F2	6	3	-3
M3	6	4	-2	F3	5	3	-2
M4	7	3	-4	F4	6	3	-3
M5	6	3	-3	F5	7	3	-4
M6	6	3	-3	F6	6	3	-3
M7	6	3	-3	F7	7	3	-4
M8	6	3	-3	F8	6	3	-3
M9	6	3	-3	F9	5	3	-2
M10	6	3	-3	F10	5	4	-1
M11	6	3	-3	F11	5	3	-2
Average (Std Dev)	6.09 (0.54)	3.18 (0.40)		Average (Std Dev)	5.91 (0.83)	3.09 (0.30)	

[a]Difference = RULA score (after) – RULA score (before)

Subjective opinions about the ergonomic intervention

After implementing the necessary NBC and workstation adjustments, the subjects were asked to operate their NBCs and give their opinions about the adjustments. The list below summarizes the subjective opinions.

- The keyboard can be viewed more clearly.
- The subject feels more comfortable at both wrists while typing.
- The texts on the screen can be clearly seen without having to bend the trunk.
- There is no need to excessively flex the neck.
- The keyboard and screen can be both viewed easily.
- The tilted base support helps to reduce wrist flexion (palmar flexion).

CONCLUSIONS

Twenty-two Thai office employees (eleven males and eleven females) participated in the experiment to evaluate whether the analytical adjustment algorithms help to improve work posture of the NBC user. The subjects work in the Thai government agencies and business organizations. All of them use notebook computers on a regular basis for document preparation and numeric data entry. Digital photographs of the subjects' work postures were taken twice, (1) when they set the NBC at the workstation according to their usual practice and (2) when they set the NBC according to the recommended adjustments. Furthermore, the RULA technique was employed to evaluate the work postures. The results show that the subjects' work postures can be significantly improved if the NBC and workstation are adjusted appropriately. The recommended adjustments include footrest, seat support, base support, distance between the body and NBC, tilt angle of NBC, and screen angle.

Although assuming an awkward posture is known to put computer users at high risk of MSDs, there are other task factors which must also be avoided, such as working with the computer over a prolonged period, having insufficient rests between work sessions, and maintaining a static work posture. It is necessary to conduct a task analysis and study the NBC user's work habit. Changes should be introduced to improve the way computer tasks have to be performed and the user's work habit, in conjunction with implementing the NBC and workstation adjustments.

As seen in Table 3, NBC and workstation adjustments require accessories to help increase the seat and work surface height, and the tilt angle of NBC. Simple devices can be fabricated (or even purchased) to achieve these purposes. Management should be encouraged to consider this workstation improvement seriously, especially if their employees are engaged in computer work intensively. The cost of providing these accessories is believed to be small when compared with what is expected to gain in return, namely, decreased work time loss due to MSDs and RSIs, decreased medical and rehabilitation expenses, increased job satisfaction, improved work quality, reduced absenteeism, and reduced employee complaints.

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