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Full Paper

Novel method of computing recommended settings of notebook computer and office workstation for ergonomic work posture

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Abstract: A method of computing recommended settings of the notebook computer (NBC) and the partially adjustable office workstation is developed. In the first stage relevant anthropometric data of the NBC user is analytically estimated. Next, the selected reference points of the user's body and the NBC are defined and their co-ordinates determined. The ideal settings of the NBC and workstation components (chair seat and work surface) that allow the user to maintain an ergonomic work posture are computed. In the second stage an adjustment procedure for determining the settings of the office workstation is employed. The results are the recommended settings of the NBC (i.e. base tilt angle, screen angle and body-to-NBC distance), the workstation (i.e. seat height and work surface height), and accessories (e.g. NBC platform, seat cushion and footrest).

Keywords: formula-based algorithm, constrained workstation, ergonomic work posture, notebook computer settings, workstation settings

INTRODUCTION

The design of office work systems to miximise occupational health, safety and human comfort can be defined as 'office ergonomics' [1]. Several researchers have studied office ergonomics in different perspectives such as office workstation design, practical implementation and evaluation of impacts of improper workstation design and poor work posture on work performance and visual symptoms among office employees. Mueller and Hassenzahi [2] conducted an experiment to examine the features of ergonomic chairs and concluded that when using ergonomic office chairs, the participants can perceive body comfort. Amick III et al. [3] summarised from their research that in a public sector organisation workers who receive adjustable chairs and office ergonomics training have reduced visual symptoms. Nevertheless, many firms still lack good ergonomic design of their work systems. Shikdar and Al-Kindi [4] identified ergonomic deficiencies in computer workstation design in typical offices. They also concluded that there is a positive and significant correlation between workers' health symptoms and workstation facilities: poor workstation facilities contribute to increased health problems.

Work-related musculoskeletal disorders are common health problems among office workers. For people who spend a great deal of time using computers, body discomfort, especially at the neck, is a common problem [5]. Asundi et al. [6] found that the use of a simple inclined platform as a portable accessory helps to improve head and neck posture when using notebook computers (NBCs) at mobile workstations. Gold et al. [7] characterised postures and comfort in non-desk usage of NBCs. They concluded that compared to the seated posture, using NBCs when lying face down on the stomach significantly increases the intensity of discomfort at shoulders, elbows and wrists. Positioning the NBCs improperly can also be another risk factor. Jonai et al. [8] reported that an improper tilt angle of the computer screen have caused more constrained posture and neck muscle among users of NBCs than those of desktop computers.

There have been many studies on the set-up of desktop and notebook computer workstations. Szeto et al. [9] concluded that a desktop keyboard may be a better choice of a typing instrument than the NBC keyboard. According to their study, participants were not likely to change their chair heights or positions, but instead adjusted their posture to use the computers. Less natural postures and greater levels of muscle activity were observed when working at a computer workstation where the computer mouse was located at a different height than that of the keyboard [10]. Shin and Hedge [11] conducted a desktop computer workstation test to examine effects of the display size and user-preferred position of the display. They found that the participants placed larger display lower and farther away, maintaining the display top at or near eye height.

There are ergonomic standards of adjustment and placement of computer hardware for desktop computers. For example, Standards Australia [12] describes how the work surface and keyboard tray should be adjusted so as to obtain proper elbow, wrist and neck postures. Similar postures for the upper extremities have also been descriptively recommended by the ANSI/HFES 100-2007 Standard [13]. Rurkhamet and Nanthavanij [14] developed an ergonomic and quantitative design methodology that considers relevant ergonomic principles and recommends, in quantitative form, appropriate visual display terminal workstation adjustment settings and arrangement layout of computer peripherals. The key contribution of their methodology is that it provides quantitative design recommendations, not descriptive recommendations.

For NBC users, the recommended work posture was described by Jalil and Nanthavanij [15]. A quantitative NBC and workstation adjustment procedure was also developed. Specifically, two analytical algorithms, one without and the other with workstation constraints, were sequentially utilised to recommend how to adjust the NBC and workstation [15]. Klangsin et al. [16] reported that the recommended work posture for NBC users resulted in low muscle activity in the cervical paravertebral, upper trapezius, deltoid and lumbar paravertebral muscles. They also concluded that this posture is suitable for prolonged usage of NBCs. However, a slanted NBC platform is an essential workstation accessory that helps the user to sit with a correct work posture since it enables the wrists to be in line with the forearms. Saito et al. [17] provided ergonomic tips for NBC users: 'Avoid unnatural postures and change the posture occasionally.'

This study extends previous research on the NBC and workstation settings by Jalil and Nanthavanij [15] by improving on its shortcomings and expanding its applicability.

COMPUTATION OF IDEAL NBC AND WORKSTATION SETTINGS

In the first stage the ideal NBC and workstation settings are determined based on an assumption that the seat height and work surface height are fully adjustable with unlimited adjustment ranges. The ideal settings are thus computed without any consideration of the workstation constraints, which enables the NBC user to assume the recommended work posture that is shown in Figure 1. The computation consists of three steps: 1) estimating relevant anthropometric data of the NBC user; 2) computing the coordinates of selected body reference points; and 3) computing the ideal NBC and workstation settings.

To estimate the relevant anthropometric data of the NBC user, two sets of regression models, one for male and the other for female NBC users, are developed from the relations between body height and relevant anthropometric data. Specifically, the anthropometric data set, which is required for the computation of ideal NBC and workstation settings, consists of body height (*BH*), sitting eye height (*IH*), sitting shoulder height (*SH*), length of upper arm (*UA*), length of lower arm (*LA*), length of hand (*HA*), popliteal height (*HH*) and length of lower leg (*LL*) (Figure 1).

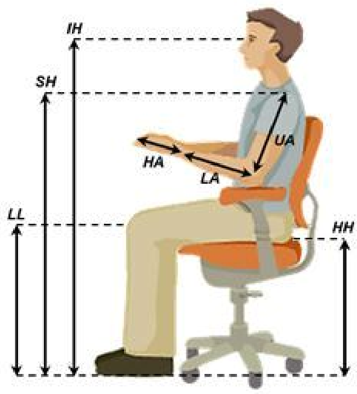


Figure 1. Relevant anthropometric data

According to the Handbook of Anthropometric Data of the Thai Population [18], the anthropometric data is categorised into four age ranges, i.e. 17-19, 20-29, 30-39, and 40-49 years. In each age range, seven percentile values are shown: the 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th} percentiles. Thus, for each body part dimension, twenty-eight values are presented. A linear regression analysis is applied to analysing the relationships between the body height and the body part dimensions. The predictive formulas for estimating individual body part dimensions from the body height are listed in Table 1.

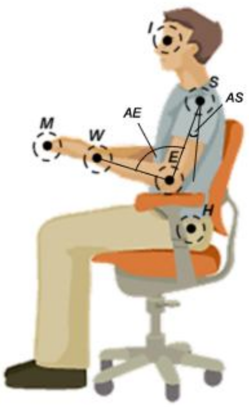
In the second step of computation, the selected body reference points are eye (*I*), shoulder (*S*), elbow (*E*), wrist (*W*), fingertip (*M*) and hip (*H*). Assuming that the reference vertical axis (where $x = 0$) is the line passing through the shoulder and hip joints, the x, y co-ordinates (in cm) of the body reference points can be determined (Figure 2). For convenience, it is assumed that the eye is located 5 cm from the reference vertical axis. Note that *AS* and *AE* are shoulder (extension) angle and elbow angle respectively.

Figure 3 shows NBC reference points and parts for the computation of ideal settings. Note that the bottom edge of the screen unit and the rear edge of the keyboard unit are the same point. Table 2 summarises the average *RL*, *BL* and *SL* for five different NBC sizes. Note that the NBC size is represented by the diagonal width of the screen in inches.

Maejo Int. J. Sci. Technol. **2016**, *10*(01), 13-24

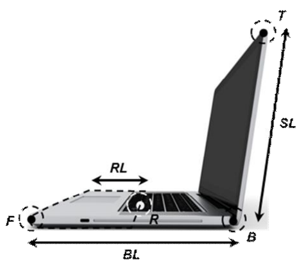
Table 1. Predictive formulas for estimating relevant anthropometric data

Thai male population		Thai female population	
$IH = (0.953 \times BH) - 38.698$	$(r^2 = 0.993)$	$IH = (0.958 \times BH) - 38.305$	$(r^2 = 0.993)$
$SH = (1.133 \times BH) - 86.939$	$(r^2 = 0.981)$	$SH = (0.872 \times BH) - 41.728$	$(r^2 = 0.991)$
$UA = (0.283 \times BH) - 12.551$	$(r^2 = 0.984)$	$UA = (0.306 \times BH) - 14.830$	$(r^2 = 0.978)$
$LA = (0.276 \times BH) - 18.246$	$(r^2 = 0.989)$	$LA = (0.230 \times BH) - 11.648$	$(r^2 = 0.978)$
$HA = (0.162 \times BH) - 7.527$	$(r^2 = 0.971)$	$HA = (0.155 \times BH) - 6.010$	$(r^2 = 0.985)$
$HH = (0.400 \times BH) - 21.927$	$(r^2 = 0.996)$	$HH = (0.413 \times BH) - 24.964$	$(r^2 = 0.997)$
$LL = (0.426 \times \mathrm{BH}) - 20.177$	$(r^2 = 0.995)$	$LL = (0.407 \times \mathrm{BH}) - 13.302$	$(r^2 = 0.993)$



$$I_x = 5$$
$$I_y = IH$$
$$S_x = 0$$
$$S_y = SH$$
$$E_x = S_x + (UA \times \sin AS)$$
$$E_y = S_y - (UA \times \cos AS)$$
$$W_x = E_x + (LA \times \cos|AE - 90°|)$$
$$W_y = E_y + (LA \times \sin|AE - 90°|)$$
$$M_x = E_x + [\{(0.75 \times HA) + LA\} \times \cos|AE - 90°|]$$
$$M_y = E_y + [\{(0.75 \times HA) + LA\} \times \sin|AE - 90°|]$$
$$H_x = 0$$
$$H_y = LL$$

Figure 2. Formulas for computing *x*, *y* co-ordinates of body reference points



R Keyboard's home row
F Front edge of NBC base unit
B Rear edge of NBC base unit
T Top edge of NBC screen unit
RL Front edge – home row distance
BL Front edge – rear edge distance
SL Top edge – bottom edge distance

Figure 3. Selected reference points and parts of NBC

Table 2. Average dimensions (in cm) of selected NBC parts

NBC Part	NBC Size*				
	11-inch	12-inch	13-inch	14-inch	15-inch
Front edge – home row (*RL*)	9.80	12.35	13.53	13.71	15.22
Front edge – rear edge (*BL*)	17.90	20.85	22.31	23.63	26.35
Top edge – bottom edge (*SL*)	18.10	20.78	22.77	23.55	26.35

* Diagonal width of NBC screen

Maejo Int. J. Sci. Technol. **2016**, *10*(01), 13-24

The ideal settings of NBC and workstation components can be computed using the following 12 steps. Firstly, the following variables are defined: *AB* = tilt angle of the NBC keyboard unit, *AV* = viewing angle (or angle between the horizontal axis and line of sight), *AS* = angle of the NBC screen unit (from the horizontal axis), *BS* = angle between the NBC keyboard unit and NBC screen unit, *ES* = incidence angle (or angle between the line of sight and the surface of the NBC screen unit), and *VD* = viewing distance (distance between the eye and the NBC screen unit).

1. Initially, set *AS* = 0°, *AE* = 90°, *AB* = 90° + *AS* – *AE* = 0°, and *BS* = 120°.
2. Determine the *x*, *y* co-ordinates of NBC reference points.

Home row:	$R_x = M_x$	$R_y = M_y$
Front edge:	$F_x = R_x - (RL \times \cos AB)$	$F_y = R_y - (RL \times \sin AB)$
Rear edge:	$B_x = F_x + (BL \times \cos AB)$	$B_y = F_y + (BL \times \sin AB)$
Top edge:	$T_x = B_x + \{SL \times \sin(BS - 90°)\}$	$T_y = B_y + \{SL \times \cos(BS - 90°)\}$

3. Determine the incidence angle *ES*.

$$ES = \cos^{-1}\left[\frac{(I_x - T_x)(B_x - T_x) + (I_y - T_y)(B_y - T_y)}{\left(\sqrt{(I_x - T_x)^2 + (I_y - T_y)^2}\right)\left(\sqrt{(T_x - B_x)^2 + (T_y - B_y)^2}\right)}\right]$$

4. Check if *ES* = 90°.

If *ES* = 90°, go to Step 5.

If *ES* < 90°, set *BS* = *BS* – 1°. Check *BS*.

If *BS* > 90°:

$$T_x = B_x + \{SL \times \sin(BS - 90°)\}$$
$$T_y = B_y + \{SL \times \cos(BS - 90°)\}$$
$$ES = \cos^{-1}\left[\frac{(I_x - T_x)(B_x - T_x) + (I_y - T_y)(B_y - T_y)}{\left(\sqrt{(I_x - T_x)^2 + (I_y - T_y)^2}\right)\left(\sqrt{(T_x - B_x)^2 + (T_y - B_y)^2}\right)}\right]$$

Repeat Step 4.

If *BS* = 90°:

$$T_x = B_x + \{SL \times \sin(BS - 90°)\}$$
$$T_y = B_y + \{SL \times \cos(BS - 90°)\}$$
$$ES = \cos^{-1}\left[\frac{(I_x - T_x)(B_x - T_x) + (I_y - T_y)(B_y - T_y)}{\left(\sqrt{(I_x - T_x)^2 + (I_y - T_y)^2}\right)\left(\sqrt{(T_x - B_x)^2 + (T_y - B_y)^2}\right)}\right]$$

If *ES* = 90°, go to Step 5.

If *ES* > 90°, set *BS* = *BS* + 1°.

If *BS* < 180°:

$$T_x = B_x + \{SL \times \sin(BS - 90°)\}$$
$$T_y = B_y + \{SL \times \cos(BS - 90°)\}$$

$$ES = \cos^{-1}\left[\frac{(I_x - T_x)(B_x - T_x) + (I_y - T_y)(B_y - T_y)}{\left(\sqrt{(I_x - T_x)^2 + (I_y - T_y)^2}\right)\left(\sqrt{(T_x - B_x)^2 + (T_y - B_y)^2}\right)}\right]$$

Repeat Step 4.

If $BS = 180°$:

$$T_x = B_x + \{SL \times \sin(BS - 90°)\}$$
$$T_y = B_y + \{SL \times \cos(BS - 90°)\}$$

$$ES = \cos^{-1}\left[\frac{(I_x - T_x)(B_x - T_x) + (I_y - T_y)(B_y - T_y)}{\left(\sqrt{(I_x - T_x)^2 + (I_y - T_y)^2}\right)\left(\sqrt{(T_x - B_x)^2 + (T_y - B_y)^2}\right)}\right]$$

If $ES = 90°$, go to Step 5.

5. Determine the viewing angle AV.

$$AV = \cos^{-1}\left[\frac{|T_x - I_x|}{\sqrt{(I_x - T_x)^2 + (I_y - T_y)^2}}\right]$$

6. Check AV.

If $AV \leq 10°$, determine the viewing distance VD.

$$VD = \sqrt{(I_x - T_x)^2 + (I_y - T_y)^2}$$

If 38 cm $\leq VD \leq$ 62 cm, go to Step 12.

If $AV > 10°$, go to Step 7.

7. Set VD = 62 cm and $AV = 10°$. Then, re-compute the x, y co-ordinates of T, B, R, and F.

Top edge: $T_x = I_x + (\cos AV \times VD)$ $\quad T_y = I_y - (\sin AV \times VD)$

Rear edge: $B_x = T_x - (\sin AV \times SL)$ $\quad B_y = T_y - (\cos AV \times SL)$

Home row: $R_x = B_x - \{\cos(BS - 100°) \times (BL - RL)\}$

$R_y = B_y - \{\sin(BS - 100°) \times (BL - RL)\}$

Front edge: $F_x = B_x - \{\cos(BS - 100°) \times BL\}$

$F_y = B_y - \{\sin(BS - 100°) \times BL\}$

8. Find the new x, y co-ordinates of E.

$$E_x = \frac{B_x + S_x}{2} + \frac{(B_x - S_x)(r_A^2 - r_B^2)}{2d^2} + \frac{B_y - S_y}{2d^2}\sqrt{\{(r_A + r_B)^2 - d^2\}\{d^2 - (r_A - r_B)^2\}}$$

$$E_y = \frac{B_y + S_y}{2} + \frac{(B_y - S_y)(r_A^2 - r_B^2)}{2d^2} + \frac{B_x - S_x}{2d^2}\sqrt{\{(r_A + r_B)^2 - d^2\}\{d^2 - (r_A - r_B)^2\}}$$

where $d = \sqrt{(B_x - S_x)^2 + (B_y - S_y)^2}$

$r_A = UA$

$r_B = LA + (0.75 \times HA) + (BL - RL)$

9. Determine the tilt angle of NBC keyboard unit *AB*.

$$AB = \cos^{-1}\left[\frac{|B_x - E_x|}{\sqrt{(B_x - E_x)^2 + (B_y - E_y)^2}}\right]$$

10. Determine the angle of NBC screen unit *AS*.

$$AS = \cos^{-1}\left[\frac{(H_x - S_x)(E_x - S_x) + (H_y - S_y)(E_y - S_y)}{\left(\sqrt{(H_x - S_x)^2 + (H_y - S_y)^2}\right)\left(\sqrt{(S_x - E_x)^2 + (S_y - E_y)^2}\right)}\right]$$

11. Check *AS*.
    If $AS > 20°$, set $VD = VD - 1$ cm.
        If $VD \geq 38$ cm, repeat Steps 7-10.
    If $AS \leq 20°$, go to Step 12.
12. Obtain *AB*, *BS*, and *HH*. Also, recalculate F_x and F_y.

The results obtained in Step 12 are the ideal settings of NBC and workstation components for the given NBC user. They are summarised as follows:

Ideal NBC settings:

- Tilt angle of NBC keyboard unit: *AB*
- Angle between NBC keyboard unit and screen unit: *BS*
- Body-to-NBC distance: F_x

(Note that the body-to-NBC distance is the distance between the NBC user's body (as measured from the vertical midline of the body) and the front edge of the NBC.)

Ideal workstation settings:

- Seat height: *HH* (popliteal height)
- Work surface height: F_y

ADJUSTMENT PROCEDURE FOR PARTIALLY ADJUSTABLE WORKSTATIONS

Most NBC workstations in business offices are partially adjustable. While the seat height is adjustable, the work surface height is fixed since the NBC is usually placed on the office desk. In the second stage, therefore, it is necessary for the individual user to follow an appropriate adjustment procedure to obtain the final NBC and workstation settings or to use suggested workstation accessories, which include an NBC platform (a platform that raises the level of the NBC keyboard unit and adjusts its tilt angle), seat cushion (a soft pad or cushion placed on the seat to increase the seat height) and footrest (a footstool placed underneath both feet to prevent them from dangling).

The following procedure yields the recommended seat height and settings of the necessary workstation accessories. Initially, the settings of all workstation accessories are set to zero (i.e. NBC platform = 0 cm, seat cushion = 0 cm and footrest = 0 cm). The minimum level (*MnSH*) and maximum level (*MxSH*) of the adjustable seat height are obtained. Let *ASH* be the actual (recommended) seat height.

1. Compare the ideal seat height to the minimum and maximum levels.
   If $HH > MxSH$:

Maejo Int. J. Sci. Technol. **2016**, *10*(01), 13-24

Set $ASH = MxSH$;
Set seat cushion = seat cushion + ($HH – MxSH$);
Go to Step 2.
If $HH < MnSH$:
Set $ASH = MnSH$;
Set footrest = footrest + ($MnSH – HH$);
Set $F_y = F_y + (MnSH – HH)$;
Go to Step 2.
If $MnSH \leq HH \leq MxSH$:
Set $ASH = HH$;
Go to Step 2.

2. Let AWH be the actual work surface height. Compare the ideal work surface height to the actual height.
If $F_y > AWH$:
Set NBC platform = NBC platform + ($F_y – AWH$);
Go to Step 4.
If $F_y < AWH$, go to Step 3.
If $F_y = AWH$, go to Step 4.

3. Let $NASH$ be the new actual seat height. Check if it is necessary to readjust the seat height.
Set $NASH = ASH + (AWH – F_y)$.
If $NASH > MxSH$:
Set $ASH = MxSH$;
Set seat cushion = seat cushion + ($NASH – MxSH$);
Set footrest = footrest + ($AWH–F_y$);
Go to Step 4.
If $NASH \leq MxSH$:
Set $ASH = NASH$;
Set footrest = footrest + ($AWH – F_y$);
Go to Step 4.

4. Summarise the settings of seat height and the recommended workstation accessories.
   - Set recommended setting of seat height = ASH.
   - Set recommended setting of NBC platform = NBC platform.
   - Set recommended setting of seat cushion = seat cushion.
   - Set recommended setting of footrest = footrest.

NUMERICAL EXAMPLE

Suppose that an NBC user is a Thai male whose body height is 172 cm. Furthermore, suppose that he is operating a 13-inch NBC at a workstation that consists of an adjustable chair and a fixed-height table. The adjustment range of seat height is 40-52 cm and the table height is 72 cm.

In Step 1 the relevant anthropometric data (in cm) are computed using the predictive formulas (for Thai male population) that are shown in Table 1:

$IH = (0.953\times172) – 38.698 = 125.22$
$SH = (1.133\times172) – 86.939 = 107.94$
$UA = (0.283\times172) – 12.551 = 36.13$
$LA = (0.276\times172) – 18.246 = 29.23$

HA	=	(0.162×172) – 7.527	=	20.34
HH	=	(0.400×172) – 21.927	=	46.87
LL	=	(0.426×172) – 20.177	=	53.10

In Step 2 the x, y co-ordinates of the body reference points are computed using the formulas given in Figure 3:

I_x = 5

I_y = 125.22

S_x = 0

S_y = 107.94

E_x = 0 + (36.13 × sin0°) = 0

E_y = 107.94 – (36.13 × cos0°) = 71.81

W_x = 0 + (29.23 × cos|90°–90°|) = 29.23

W_y = 70.81 + (29.23 × sin|90°–90°|) = 71.81

M_x = 0 + [{(0.75 × 20.34) + 29.23} × cos|90° – 90°|] = 44.49

M_y = 71.81 + [{(0.75 × 20.34) + 29.23} × sin|90° – 90°|] = 71.81

H_x = 0

H_y = 53.10

In Step 3 the dimensions of the selected NBC parts are determined from Table 2. For the 13-inch NBC, RL, BL and SL are 13.53 cm, 22.31 cm and 22.77 cm respectively.

After obtaining the above data, the computation algorithm is employed to compute the ideal settings of NBC and workstation components. The final step yields the following results: AB = 20°, BS = 119°, F_x = 40.80 cm, HH = 46.87 cm and F_y = 84.47 cm.

In summary, the computation algorithm yields the following ideal settings (by rounding to the nearest integer):

Ideal NBC settings:

- Tilt angle of NBC keyboard unit: 20°
- Angle between NBC keyboard unit and screen unit: 119°
- Body-to-NBC distance: 41 cm

Ideal workstation settings:

- Seat height: 47 cm
- Work surface height: 84 cm

An adjustable NBC platform is used to adjust the tilt angle of the NBC keyboard unit to 20°. The thickness of the NBC platform is 4 cm. Hence this extra 4 cm is added to the actual work surface height to obtain the correct final height of the NBC platform. Thus, the actual work surface height becomes 76 cm. Next, set the heights of the NBC platform, seat cushion and footrest to zero.

1. Compare the ideal seat height to the minimum and maximum levels.
   Since $MnSH \leq HH \leq MxSH$,
   Set $ASH = HH = 47$
2. Compare the ideal work surface height to the actual height.
   Since $F_y \geq AWH$,
   Set NBC platform = NBC platform + (F_y – AWH) = 0 + (84 – 76) = 8
3. Check if it is necessary to re-adjust the seat height.
   (It is currently not necessary to re-adjust.)
4. Summarise the settings of seat height and the recommended workstation accessories.

Maejo Int. J. Sci. Technol. **2016**, *10*(01), 13-24

- Recommended seat height 47 cm
- Recommended NBC platform 12 cm (8 + 4 = 12)
- Recommended seat cushion 0 cm
- Recommended footrest 0 cm

Note: The recommended height of NBC platform is 8 cm beyond its thickness of 4 cm. Thus, the total NBC platform above the actual work surface height (of 72 cm) is 12 cm.

Table 3 shows the photo of a Thai male whose body height is 172 cm, operating a 13-inch NBC at an NBC workstation similar to the above example. The settings of the NBC, workstation components and accessories are according to the recommendations obtained from the computation algorithm and adjustment procedure. The work surface height shown in Table 3 is based on the original height without adding the thickness of the NBC base support (i.e. 4 cm). Additionally, the height of the NBC platform is that above the actual workstation height. It is inclusive of the thickness of the NBC platform.

Table 3. Summary of recommended settings

Workstation		Recommended settings		Work posture
Partially adjustable workstation		**NBC**		
- Seat height (adjustable):		- Tilt angle of NBC keyboard	20°	
Minimum level	40 cm	- Keyboard-screen angle	119°	
Maximum level	52 cm	- Body-NBC distance	41 cm	
- Work surface height	72 cm	**Workstation and accessories**		
		- Seat height	47 cm	
		- Work surface height	72 cm	
		- NBC platform	12 cm	
		- Seat cushion	-	
		- Footrest	-	

It is clearly seen that the work posture shown in Table 3 is very similar to the correct work posture presented in Jalil and Nanthavanij [15]. This confirms the effectiveness of the proposed computation algorithm and adjustment procedure in computing the recommended settings of the NBC, workstation components and accessories. This allows an NBC user to sit with a correct work posture at a partially adjustable workstation.

It should be noted that the recommended settings for the NBC, workstation and accessories obtained from this analytical method should be considered as initial rather than final settings since they are analytically determined. The NBC user should firstly set the NBC and workstation components according to the recommended settings. Then, if necessary, additional adjustments might be made to give a more appropriate work posture. If the chair is equipped with armrests that are both height- and width-adjustable, the NBC user should adjust the armrests so that the forearms are comfortably supported. The shoulders should neither be raised nor extended outwards. The user's upper arms should hang naturally along the body. In the case of using a chair without adjustable armrests, the NBC user should not rest his/her forearms on the armrests while working with the NBC in order to avoid awkward shoulder and upper arm postures.

Maejo Int. J. Sci. Technol. **2016**, *10*(01), 13-24

CONCLUSIONS

A methodology for computing the recommended settings for the NBC and workstation components is described. It comprises a formula-based algorithm (for computing the ideal settings of the NBC and workstation components) and an adjustment procedure, which can be used to determine the recommended settings for the workstation components and necessary accessories for a partially adjustable workstation. It is an improvement on our previous work [15] in two ways. Firstly, the relevant anthropometric data are estimated from the user's body height using predictive formulas which are developed from anthropometric data of the Thai population using linear regression. From their strong correlations (r^2), the formulas give good estimates of the NBC user's anthropometric data. Secondly, the adjustment procedure for the partially adjustable workstation is developed and presented. It is applicable to NBC workstations with adjustable seat height but fixed work surface height. With the adjustment procedure, the methodology is more realistic and has wider application since it can be applied to NBC workstations in most business offices. Although the predictive formulas in this paper are based on the anthropometric data of the Thai population, they can be replaced by formulas developed from the anthropometric data of any population group. Such flexibility should allow the process described in this paper to be applicable to non-Thai NBC users as well.

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