

***ErgoCom*: A COMPUTER-BASED TOOL FOR WORK POSTURE ADJUSTMENT DURING DESKTOP COMPUTER USE**

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Abstract

This paper discusses the design and development of *ErgoCom*, a spreadsheet-based computer program for recommending ergonomic adjustment settings for a desktop computer workstation. *ErgoCom* requires input data about the computer user and his/her workstation. It utilizes one of several built-in algorithms based on the computer workstation constraints to generate recommended settings for both the workstation components and any necessary accessories. With *ErgoCom*, computer users will be able to adjust their workstations so that they can sit with a correct work posture during desktop computer use. An experiment to test the effectiveness of *ErgoCom* in providing valid recommendations was conducted using four university students. The results show that the postures based on the recommendations of *ErgoCom* were ergonomically appropriate and are in accordance with the ergonomic recommendations.

Keywords: Office ergonomics, Workstation settings, Work posture, Spreadsheet-based computer program, Video display terminal

1. INTRODUCTION

In this day and age, most, if not all, business office works are performed with the assistance of either desktop computer or notebook computer. The office workstations where computer tasks are performed can range from a non-adjustable (or fixed) workstation to a fully adjustable workstation. While it is known that the non-adjustable workstation imposes restriction on work posture, the fully adjustable workstation might not be of much help if computer users are not aware of the correct work posture or cannot adjust the workstation effectively. Thus, not surprisingly, the number of office employees with work-related musculoskeletal disorders (WMSDs) tends to increase even though the recommendations on correct work posture have been publicized for years.

Shikdar and Al-Kindi (2007) studied the prevalence of WMSDs among office employees of an oil company. The results indicated that the use of improperly designed office workstation and long working hours are the main causes of body discomforts and musculoskeletal disorders. Singh and Wadhwa (2007) reported that 90% of office workstation designs fall in the average category based on the scoring of various ergonomic parameters. Furthermore, they found that the body posture of most computer users is not static. Every 15 minutes, computer users change their work postures 2-5 times.

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In order to help prevent WMSDs, the visual display terminal (VDT) workstation must be properly adjusted to allow VDT users to sit with the correct work posture. Gerr et al. (2000) reported that the workstation dimensions are only partly determinants of some postures. The much stronger correlation was observed between elbow height and keyboard than between eye height and monitor height. This suggests that it is preferential to locate the height of elbow at or near keyboard height in comparison to the height of the eyes with respect to monitor height that may result in preventable of neck disorders. Seghers et al. (2003) investigated the effect of prolonged VDT work at four different screen heights on head and neck posture, muscle activity, and the development of muscle fatigue. They concluded that the height of the VDT screen has an influence on viewing angle, ear-eye angle, and muscle activity over the test session. Despite the occurrence of some postural changes with time, the increase in electromyography (EMG) activity can be interpreted as a sign of muscle fatigue.

Since most recommendations on the correct work posture during desktop computer use tend to be descriptive, most office employees are likely to find them unclear and rather difficult to implement. It is thus the objective of this research to develop a computer program based on Microsoft Excel, called *ErgoCom*, to help suggest quantitative recommendations regarding the settings of chair seat, keyboard tray, and monitor to facilitate the correct work posture. If necessary, workstation accessories such as extra seat cushion, keyboard support, and monitor support will be recommended. An experiment to validate the effectiveness of *ErgoCom* is also conducted. The paper is organized as follows. Firstly, the design of *ErgoCom*, computation algorithm, and adjustment procedures are briefly described. Next, the validation experiment, including the equipment, subjects, and procedure, is explained. Finally, its results are reported and discussed.

2. RECOMMENDED WORK POSTURE DURING COMPUTER USE

The recommended work posture during desktop computer use can be described as follows:

- The neck should be upright or slightly bent downward (between 0-10°).
- The upper arms should hang naturally along the side of the trunk.
- The lower arms should flex about 90 degrees at the elbow joint.
- The wrists should not bend vertically either upward or downward.
- The wrists should not bend horizontally either inward or outward.
- The trunk should be upright or lean on the backrest that is slightly reclined (between 0-10°).
- The upper legs should be parallel to the floor.
- The lower legs should form a right angle (90 degrees) with the upper legs at the knee joints, and should be vertical to the floor.
- The feet should rest comfortably on the floor.

3. DESIGN OF *ErgoCom*

ErgoCom is a spreadsheet-based computer program which provides the recommendations on the adjustment settings of desktop computer workstation components (i.e., chair and table) and necessary accessories (e.g., seat cushion, footrest). All recommendations are quantitative in nature to make it easy for the user to follow. *ErgoCom* was developed using Microsoft Excel 2013 on a personal computer with the Microsoft Windows 8 operating system. Initially, the user needs to enable a “Macro” option of the Microsoft Excel program. *ErgoCom* was written in two languages, Thai and English, and the preferred language can be chosen by the user. The language option will appear on the first screen page, or Welcome page, after starting the program. Figure 1 shows the Welcome page of *ErgoCom*. The “Exit” button for terminating the program is located on the lower-left corner of the page.



Figure 1: Welcome page of *ErgoCom*

3.1 Input Data

After choosing the preferred language, the Input Data page will appear. The user is required to enter data into the shown fill-in boxes. The Input Data page is divided into two sections: (1) User data (name, body height, and gender), and (2) workstation data (chair seat, keyboard, and monitor heights). See Figure 2. When entering the data of individual workstation components, the user can choose whether the workstation components are fixed or adjustable. For a fixed component, its actual height is then entered. In case of adjustable

component, the minimum and maximum height boxes will appear so that the user can enter the corresponding data. Note that all heights must be in centimeters. Once all data has been entered, the user can choose to proceed with the computation by clicking at the “Calculate” button (at the lower-right corner of the page). Alternatively, the user can click at the “Back” button (at the lower-left corner of the page) to return to the program’s Welcome page.

The screenshot shows a web-based input form for the ErgoCom application. The form is titled "Input" and is divided into four main sections, each with a distinct background color: yellow for User Information, orange for Seat Height, light blue for Keyboard Height, and light green for Monitor Height. Each section contains radio buttons for "Non-Adjustable" and "Adjustable" settings, and a text input field for "Actual Height" in centimeters. To the right of the form is a silhouette diagram of a person sitting at a desk, with vertical dimension lines labeled TM (top of screen), FT (floor to table), AKH (actual keyboard height), and ASH (actual seat height). At the bottom of the form are two buttons: "Back" on the left and "Calculate" on the right.

Figure 2: Input Data page of *ErgoCom*

3.1.1 User Data

The user is asked to enter the user’s name, gender, and body height (in centimeters). *ErgoCom* will then use the gender and body height to estimate the relevant anthropometric data of the user. Subsequently, it will determine the recommended seat height, keyboard height, and monitor height for the correct work posture during desktop computer use.

3.1.2 Workstation Data

The workstation data include the seat height, keyboard height, and monitor height of the workstation, all in centimeters. The height of the seat is measured from the floor to the upper surface of the seat pan. The seat will be categorized as fixed (non-adjustable) or adjustable. For the fixed seat, its seat height is not adjustable and the user needs to enter only one value (i.e., the actual seat height). For the adjustable seat, the user needs to enter

the minimum seat height (when the seat pan is lowered to its lowest level) and maximum seat height (when the seat pan is raised to its highest level).

The keyboard height is measured from the floor to the surface of the keyboard's home row. Note that the keyboard should be placed on the keyboard tray if there is any. Otherwise, it will be placed on the top surface of the workstation (table). If the keyboard tray or work surface is fixed, the actual height of the keyboard is required. For the keyboard tray or work surface which is height adjustable, the minimum and maximum heights need to be entered.

The height of the monitor is measured from the floor to the top edge of the monitor screen. In the same fashion, if its height is not adjustable, the actual height is entered. If the monitor height is adjustable, the minimum and maximum heights are required.

3.2 Computation Algorithms

ErgoCom has two sets of regression models for estimating the relevant anthropometric data of computer users based on the gender and body height. One set is for male users and the other set is for female users. From the popliteal height, sitting elbow height, and sitting eye height, the program determines the recommended seat height, keyboard height, and monitor height, respectively. Next, *ErgoCom* utilizes one of its built-in adjustment algorithms to evaluate the constraints of the workstation and recommended the adjustment settings of the workstation components and necessary accessories.

Specifically, *ErgoCom* has eight adjustment algorithms as listed below.

1. Workstation with fixed seat height, fixed keyboard height, and fixed monitor height
2. Workstation with fixed seat height, fixed keyboard height, and adjustable monitor height
3. Workstation with fixed seat height, adjustable keyboard height, and fixed monitor height
4. Workstation with fixed seat height, adjustable keyboard height, and adjustable monitor height
5. Workstation with adjustable seat height, fixed keyboard height, and fixed monitor height
6. Workstation with adjustable seat height, fixed keyboard height, and adjustable monitor height
7. Workstation with adjustable seat height, adjustable keyboard height, and fixed monitor height
8. Workstation with adjustable seat height, adjustable keyboard height, and adjustable monitor height

3.3 Output

The results from *ErgoCom* are separated into three sections. Firstly, the user and workstation data is summarized and presented for reference. The second part shows the recommended seat height, keyboard height, and monitor height that are determined from the user’s anthropometric data. The final part shows the final settings of the workstation components and, if necessary, recommended accessories. All numbers are rounded to their nearest integer to enhance the practicality. To help adjust the user’s work posture especially when the adjustability of the workstation is restricted, *ErgoCom* generally recommends the extra use of seat cushion, footrest, keyboard support, and monitor support.

Figure 3 presents the Results page of *ErgoCom*. For ease of understanding, a graphic depicting the correct work posture is shown for reference. At the bottom of the page, *ErgoCom* provides several action buttons. The “Back” button allows the user to go back to the previous page (i.e., the Input Data page) to correct/change some data. The “New” button allows the user to clear all input data and enter a new data set all over again. The “Print” button generates a PDF file of the results and shows the print preview of a hard copy printout. The “Export” button allows the user to save the recommended settings for future reference. Finally, the “Exit” button will terminate the operation of *ErgoCom*.

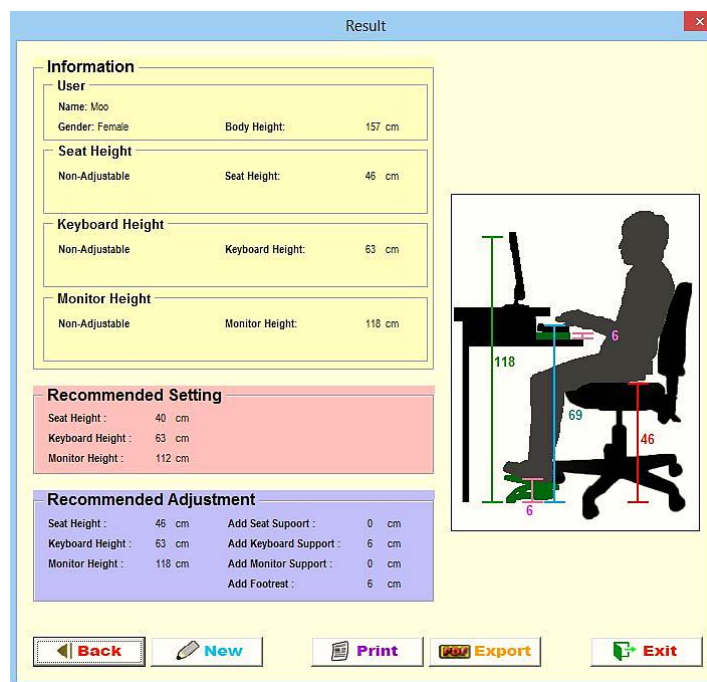


Figure 3: Results page of *ErgoCom*

4. EXPERIMENT

An experiment to test the effectiveness of *ErgoCom* in providing valid recommendations regarding the adjustment of workstation components and the use of accessories for helping to obtain the correct work posture during desktop computer use was conducted. This section briefly describes the equipment, subjects, and test procedure of the experiment.

4.1 Equipment

The workstation used in this experiment is a fully adjustable workstation. The seat height can be adjusted from the lowest level of 40 cm to the highest level of 52 cm. The keyboard tray is attached to the underneath of the top surface of the table. Its minimum height is 65 cm and its maximum height is 79 cm. When not in use, the keyboard tray can be hidden under the table through its retractable shaft.

The monitor is an LCD monitor and is attached to an adjustable monitor arm. This monitor arm enables the monitor height to be set at 112 cm (as the lowest level) or 132 cm (as the highest level).

4.2 Subjects

Four university students, two males and two females, voluntarily participated in this experiment without receiving any monetary compensation. The subjects were explained about the objective and procedure of the experiment prior to their participation. All subjects are experienced desktop computer users, but they have minimum or no knowledge of ergonomics and the correct work posture during desktop computer use. Table 1 summarizes the subjects' biographical data.

Table 1: Biographical data of the four subjects

Subject	Gender	Age (year)	Body Height (cm)	Body Weight (kg)
S1	Female	20	153	45
S2	Female	20	166	50
S3	Male	20	170	59
S4	Male	20	180	75

4.3 Procedure

Initially, *ErgoCom* was utilized to determine the recommended adjustment settings of workstation components and accessories for all four subjects. The results from *ErgoCom* are presented in Table 2.

Table 2: Recommended and final settings of workstation components and accessories

Subject	Recommended Height (cm)			Final Settings (cm)			Accessory Height (cm)			
	Seat	Keyboard	Monitor	Seat	Keyboard	Monitor	SC	KS	MS	Fr
S1	38	60	108	43	65	113	-	-	-	5
S2	44	71	121	44	71	121	-	-	-	-
S3	46	70	123	46	70	123	-	-	-	-
S4	50	79	133	50	79	132	-	-	1	-

Next, each subject was seated at the computer workstation which was already adjusted according to his/her recommended settings provided by *ErgoCom*. The side-view, front-view, and top-view photographs of the subject's work posture were taken. The same procedure was repeated for all four subjects.

Then, a rapid upper limb analysis (RULA) technique was applied to evaluate the neck, trunk, upper arm, lower arm, wrist, and leg postures of the subjects. RULA is a quick and simple technique for evaluating the body posture. From a snapshot photograph of the body posture, one body part is focused at a time. For any body part, its posture is compared to several given postures. The posture that is the closest to the subject's posture is chosen and its corresponding score is used to represent the RULA score of that body part. It should be noted that the natural posture has the RULA score of 1. The further the posture is deviated from the natural posture, the greater the RULA score becomes.

5. RESULTS

From the workstation component settings and accessories which were recommended by *ErgoCom* (as presented in Table 2), readers can see that subject S1 who is a short female subject (with her body height of 153 cm) would need a 5-cm footrest to help prevent her feet from dangling. The reason for this footrest is that the chair seat has to be raised above the recommended level by 5 cm (from 38 cm to 43 cm). This increase in seat height is required to raise her body up by 5 cm so that she could properly operate the keyboard at the minimum keyboard tray height of 65 cm. Note that the appropriate keyboard height for subject S1 is 60 cm which is below the minimum keyboard tray height. Thus, it is not possible to lower

the keyboard tray to a level height of 60 cm. A feasible alternative is to raise her body up to the keyboard level height.

For subjects S2 and S3, it is seen that the given workstation can be adjusted to allow them to sit with the correct work posture. No extra accessories are required for both of them. Subject S4, a 180-cm tall male subject, would need a 1-cm support for the monitor to raise its level height to 133 cm. Note that the maximum monitor height (without any extra monitor support) is 132 cm.

Figure 4 shows the side-view of work postures of subjects S1-S4.



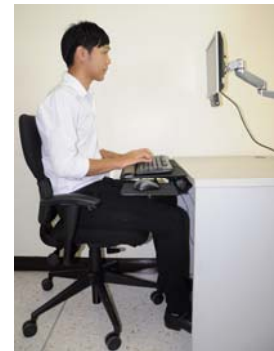
(a) Subject S1



(b) Subject S2



(c) Subject S3



(d) Subject S4

Figure 4: Side-view photographs of body postures

Table 3 shows the RULA scores of six body part postures of all four subjects. Readers can see that the adjustable workstation in conjunction with the recommendations from *ErgoCom* can help the subjects to sit with the correct work posture during desktop computer use. All RULA scores are equal to 1, which indicates that all body part postures are natural. Additionally, it can be easily seen that the work postures of all four subjects in Figure 4 are in accordance with the recommendations described in Section 2.

Table 3: RULA scores of six body part postures

Subject	Neck	Trunk	Upper Arm	Lower Arm	Wrist	Leg
S1	1	1	1	1	1	1
S2	1	1	1	1	1	1
S3	1	1	1	1	1	1
S4	1	1	1	1	1	1

6. CONCLUSION

ErgoCom is a spreadsheet-based computer program that is intended to provide adjustment recommendations for the desktop computer workstation components and necessary accessories. It is developed using the Microsoft Excel 2013 program. *ErgoCom* is user-friendly and easy to use without extensive knowledge on the spreadsheet program. *ErgoCom* requires two groups of data for its computation algorithms. The first group is the user data which consists of the gender and body height of the user. The second group is the computer workstation data. The user has to provide the seat height, keyboard height, and monitor height. For the workstation component which is adjustable, both the minimum and maximum heights must be provided.

From the user's gender and body height, *ErgoCom* is able to estimate the relevant anthropometric data of the user. Subsequently, the recommended settings of workstation components are determined. In case that the workstation components have adjustability constraints, *ErgoCom* uses one of its adjustment algorithms to determine the final adjustment settings of the components and necessary accessories. *ErgoCom* is able to not only display its results on screen but also to generate a hard copy printout for future reference.

The results from the experiment also confirm the effectiveness of *ErgoCom* in providing valid recommendations. All four subjects were able to sit with the correct work posture during desktop computer use. The postures of their neck, trunk, upper arm, lower arm, wrist, and leg are found to be in accordance with the ergonomic recommendations.

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