International Journal of Applied Science and Engineering
2015. 13, 2: 163-169

Application of Computer-aided Ergonomic Simulation in Designing Supine Computer Workstation

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Abstract: Seated posture has been considered as potentially one of the major contributing factors for several musculoskeletal disorders such as lower back pain, neck and shoulder disorders. Especially, people with low back pain experience great discomfort related to computer operations in sitting position. When changing posture to lying down, not only can release psychological stress, but also alleviate musculoskeletal burdens. Therefore, the main purpose of this study is to design a new supine computer workstation, allowing people to lie in the bed and operate a computer. This paper presents how to apply computer-aided ergonomic simulation in designing a new supine computer workstation. At first, Taiwanese anthropometric data were referred to build a 3D model of a supine computer workstation. And then, JACK software was used to simulate human-workstation interaction in order to find the problems of the original design. Finally, a physical prototype of the revised supine computer workstation was made for realistic test. The developed supine computer workstation was confirmed to be used successfully for operating computer in lying position. More field studies are required to test if supine computer workstation outpaces the sitting position workstation for musculoskeletal strains, subjective comfort, and operation performance.

Keywords: Office ergonomics; computer simulation; work posture; workstation; design

1. Introduction

The computer plays an important role in modern life, commonly used in daily life, both personal and professional use, and all industries rely on computer technology to enhance productivity and efficiency. As computer users continuously increase, the resulting body discomfort is aggravated gradually. Many studies discovered harmful effects of computer usage on the human body such as visual fatigue, musculoskeletal disorders, and work stress; in addition, work performance and productivity go down as well. Wu et al. [1] have pointed out that, dedicated personnel, performing computer related operations, had much more frequent musculoskeletal discomfort, pain and complaints. These causes include: prolonged operations, improper operation posture or inappropriate workstation design [2].

Many computer-related workstations and aid equipments are developed to assist computer users and reduce musculoskeletal discomfort, such as the ergonomic mouse, ergonomic chair,

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Received 18 November 2014
Revised 10 March 2015
Accepted 17 March 2015

ergonomic workstations, and arm support apparatus. These equipments have only limited effects of alleviating musculoskeletal discomfort, and offer temporary convenience or comfort to users because current computer operations are static and in sitting positions, easily giving rise to musculoskeletal discomfort. As early in the middle of the twentieth century many orthopedists proposed that prolonged bad seating could speed up the deterioration of the discs, resulting in back troubles, for example Andersson and Ortengren [3], Keegan [4] and Yamaguchi et al. [5]. In addition, most computer operations belong to static contractions, and thus it may cause local pains.

Seated posture has been considered as potentially one of the major contributing factors for several musculoskeletal disorders such as lower back pain [6-9], neck and shoulder disorders [1]. When changing posture to lying down, not only can release psychological stress, but also alleviate musculoskeletal burdens. This is because that supine posture can reduce the pressure of lumbar discs [10], and relax and soothe the body most. Further, people with low back pain experience great discomfort related to computer operations in sitting position [11]. Therefore, this study was dedicated to designing a supine computer workstation, allowing people to lie in the bed and operate a computer, feeling comfortable, convenience of operation, and alleviating musculoskeletal discomfort.

This paper presents how to apply ergonomic simulation in designing a new supine computer workstation in order to fit the designed workstation to potential users. The proposed design process has three stages: (1) to build a 3D model of a supine computer workstation based on Taiwanese anthropometric data; (2) to simulate human-workstation interaction in order to find the problems of the original design; (3) to make a prototype of the revised workstation for realistic test. These methods are addressed as the following.

2. To build a 3D model based on Taiwanese anthropometric data

A supine computer workstation should be fitted to most human, body height and abdominal thickness data were collected from Taiwanese anthropometric database. Tables 1 and 2 show Taiwanese male and female abdominal thickness data [12]. The desk height of supine computer workstation was set at 30 cm, which was greater than the 95th% of Taiwanese male abdominal thickness.

Table 1. Taiwanese male abdominal thickness data (Unit: mm)

Age	Mean	STD	5th%ile	95th%ile
18-24	197.41	20.00	164.51	230.31
25-34	212.58	24.16	172.84	252.32
35-44	223.30	26.49	179.93	266.87
45-64	236.61	28.88	188.83	284.29

Table 2. Taiwanese female abdominal thickness data (Unit:mm)

Age	Mean	STD	5th%ile	95th%ile
18-24	196.13	19.31	164.36	227.90
25-34	206.61	24.42	166.44	246.78
35-44	222.18	27.20	177.44	266.92
45-64	240.30	24.35	200.25	280.35

The body height may not directly affect the dimension design of supine computer workstation, but it will affect the angle of a user's sight to the screen. Jaschinski, et al. [13] observed marked individual differences in viewing distance and screen height that subjects found most comfortable during work. Therefore, the workstation screen was designed to be adjustable for various body heights. After determining all the dimensions of the workstation, AutoCAD software was used to draw a 3D model of the original design (Figure 1).

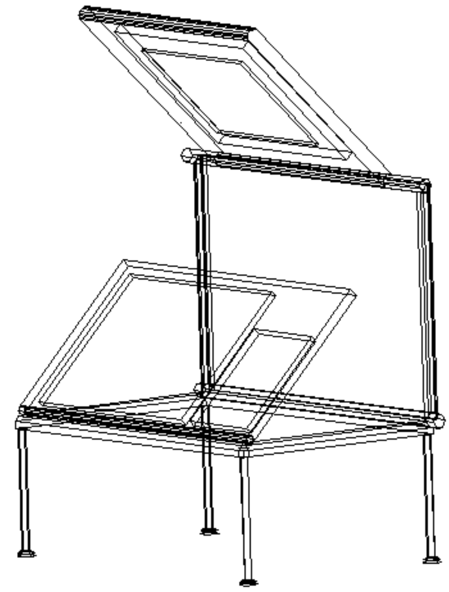


Figure 1. The original design of a supine computer workstation

3. To simulate human-workstation interaction

This study utilized JACK software to simulate human-workstation interaction, including three steps as follows:

(1) Setup of simulation environment

In addition to putting the 3D model of supine computer workstation into JACK environment, a simple bed was also plot here.

(2) Setup of virtual human model

In this step, we use the 95th% of Taiwanese body height and weight to build a human model in JACK environment. And then the human model was properly adjusted to supine condition forusing a computer.

(3) To put human model in workstation for ergonomic simulation

The ergonomic simulation functions applied by this study include: access convenience, reaching, watching, and typing keyboard, as well as computer screen visibility, so as to facilitate efficient computer operation. Figure 2 illustrates the situation of the simulation.

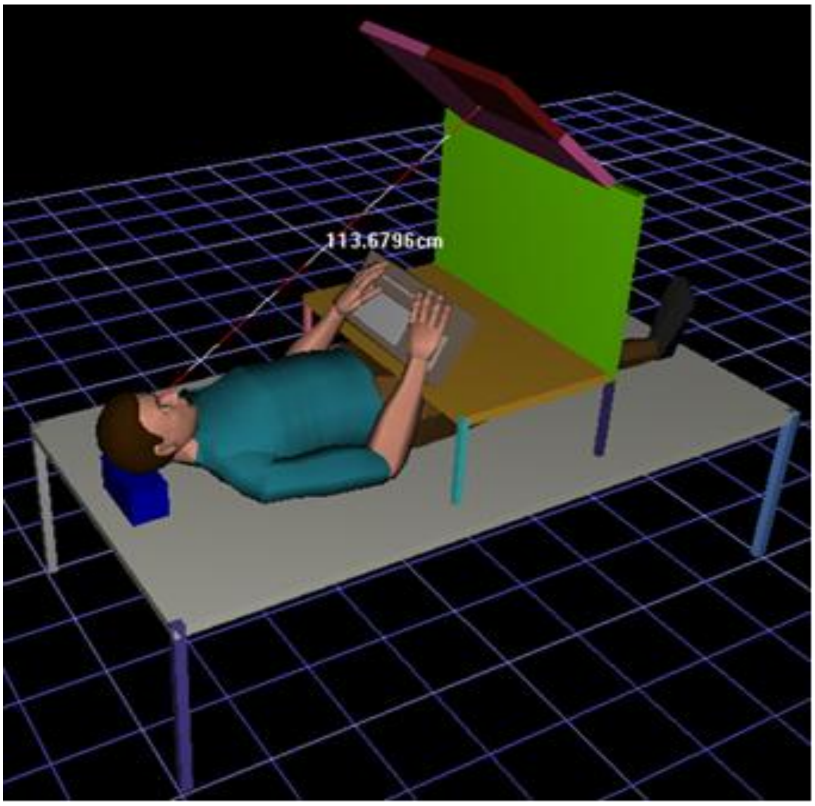


Figure 2. Example of ergonomic simulation for the original design

The human model can be manipulated to operate a computer, and thus, test whether or not the human model can complete computer operation successfully. In terms of access convenience, the collision detection function in JACK software was used to determine user placement at computer workstation for possible collision. In terms of reaching, JACK software has the function of maximal reaching scope, which can be used to find if the human model can reach computer peripheral equipment by hand [14]. In terms of watching, vision window can be used to observe the human model’s sight.

After ergonomic simulation, three problems were found as follows:

(1) The viewing distance between eyes and screen was 113 cm, which was much greater than the recommended viewing distance for visual display terminal (50~70 cm).

(2) The operator was too far from keyboard, as a result, arms and elbows were overhung, elbow angle was much greater than 90 degrees.

(3) Because of being too far from supine keyboard, when user operates while lying down, radial deviation, ulnar deviation, flexion, or extension of wrists easily occur.

4. To make a prototype of the revised workstation

We should modify the original design based on the findings from ergonomic simulation. After discussion, two modifications were made:

(1) In order to comply with the recommended viewing distance for visual display terminal (50~70 cm), the support stand shall be changed from 50 cm to 20 cm, so as to shorten the viewing distance relative to the screen.

(2) In order that user elbow angle be kept at about 90 degrees, a 30 cm radius slot shall be designed on the desk top in order that a user can support himself/herself at the desk edge by hand, and push upper half of body nearer the desk, facilitating operation.

To confirm the effects of the above-mentioned modifications, poly-foam was used to fabricate a simple prototype of the revised workstation, as shown in Figure 3. It is obvious that the viewing distance has been shortened and the user elbow angle is about 90 degrees. Finally, a physical prototype of the revised supine computer workstation was made by wood and steel. The screen can be fixed on the top frame (with a rectangular hole) of the workstation, and the keyboard and mouse can be placed into the adjustable tray on the desk of the workstation, as shown in Figure 4. The user can easily adjust the tilt angle of the screen frame and keyboard tray of the physical prototype. Figure 4 shows that the user could type words easily with the prototype of supine computer workstation.

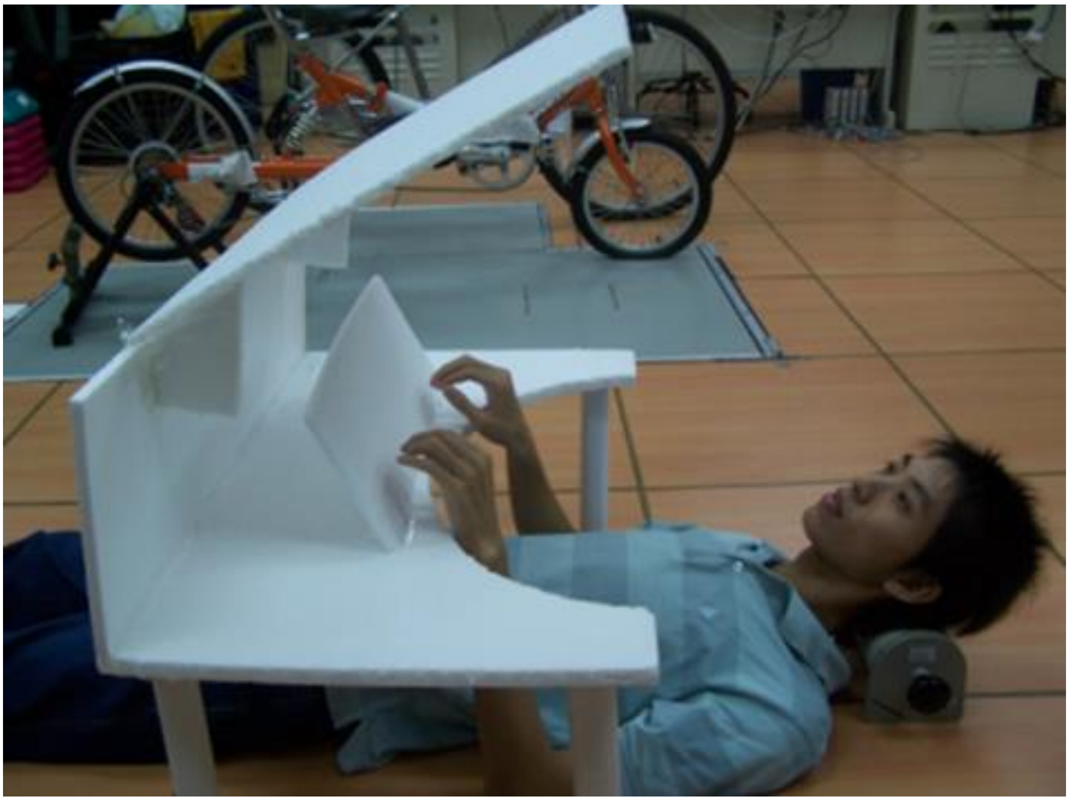
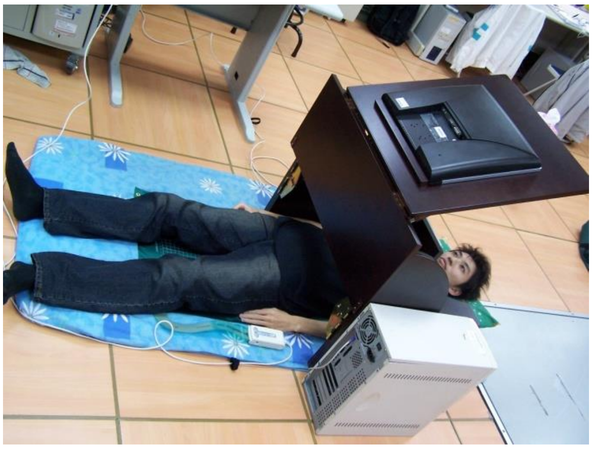


Figure 3. A simple prototype of the revised supine computer workstation


(a)The screen can be fixed on the top frame


(b)The user can use keyboard and mouse

Figure 4. Physical prototype of the revised supine computer workstation

5. Discussions

The advantage of a supine computer workstation, as designed in this study, is that people with lower back pain can adopt supine position so that their lower back can be eased, and overall body stress can be evenly distributed. Further, this supine computer workstation can alleviate the inconvenience of the lower extremity-disadvantaged population who cannot use a computer in the sitting position. Besides, four wheels can be attached to the base of the workstation, which make the workstation moving easily.

As known from literatures, the supine position is the most relaxed, and with the smallest stress, among all postures, however, the situation of using a computer while being supine has never been well studied. The workstation designed in this study remains to be evaluated in physiological and subjective aspects, because musculoskeletal strains have to be evaluated for a prolonged period to determine whether it is indeed better than a sitting position. Testing users' subjective opinions should be determined from a prolonged period of practical usage. In addition, the proposed supine workstation in this study was designed to be combined with a personal computer (PC), and consequently a notebook was not suitable to be placed in this workstation.

6. Conclusions

This study shows a systematic method to apply computer-aided ergonomic simulation in designing a new supine computer workstation. The designed workstation mainly enables the people, who cannot use a computer in the sitting position, to use personal computers with the supine posture. Of course, this supine workstation also can be used by general healthy people without difficulty. However, past literatures have less physiological and subjective experimental evaluation on lying down operation, and there is even less literature on supine computer operation, therefore, this study designed the supine computer workstation first, confirmed sizes and functions, and subsequent research shall be field experiments and evaluation to study if supine computer workstation outpaces the sitting position workstation for musculoskeletal strains, subjective comfort, and operation performance.

References

[1] Wu, H.C., Lin, C.Y., Chen, H.C., and Wang, C.H. 2007. Relations between ergonomic risk factors and musculoskeletal disorders in computer operation. *Journal of Ergonomic Study* 9:1-10(in Chinese)

[2] Wu, H.C. and Chen, T. 2006. The development of an electronic tool for diagnosing risk factors in computer operation. *WSEAS Transactions on Computers* 5:1013-1019

[3] Andersson, B.J.G. and Ortengren, R. 1974. Lumbar disc pressure and myoelectric back muscle activity during sitting. 1. Studies on an office chair. *Scandinavian Journal of Rehabilitation Medicine* 3:115-121

[4] Keegan, J.J. 1953. Alterations of lumbar curve related to posture and seating. *Journal of bone and joint Surgery* 35:567-589

[5] Yamaguchi, Y., Umezawa, F., and Jshinada, Y. 1972. Sitting posture: an electromyographic study on healthy and nostalgic people. *Journal of the Japanese orthopedics Association* 46:51-56

[6] Cartas, O., Nordin, M., Frankel, V., Malgady, R., and Sheikhzadeh, A. 1993. Quantification of trunk muscle performance in standing, semistanding and sitting postures in healthy men. *Spine* 18:602-609

[7] Ebe, K., and Griffin, M.J. 2001. Factors affecting static seat cushion comfort. *Ergonomics* 44 10: 901-921.

[8] Lengsfeld, M., Frank, A., van Deursen, D.L., and Griss, P. 2000. Lumbar spine curvature during office chair sitting. *Medical Engineering & Physics* 22:665-669

[9] Videman, T., Nurminen, M., and Troup, J. 1990. Lumbar spinal pathology in cadaveric material in relation to history of back pain. *Spine* 15:728-740

[10] Nachemson, A. and Elfstrom, G. 1970. Intravital dynamic pressure measurements in lumbar discs. S*candinavian Journal of Rehabilitation Medicine*, Suppl. 1.

[11] Haynes, S. and Williams, K. 2007. Product review of alternative computer workstations as possible workplace accommodations for people with chronic low back pain. *Technology and Disability* 19:41-52

[12] Wang, M.J., Wang, M.Y., and Lin, Y.C. 2002. "*Handbook of Taiwanese anthropometric database*", Ergonomics Society of Taiwan, HsinChu, Taiwan.

[13] Jaschinski, W., Heuer, H., and Kylian, H. 1998 The preferred position of visual displays relative to the eyes: a field study of visual strain and individual differences. *Ergonomics* 41:1034-1049

[14] Wu, H.C. and Chang, F.C. 2011. Ergonomic evaluation of computer desks and chairs for children — based on computer simulation. *Journal of Ergonomic Study* 13:41-51 (in Chinese)