Design of Workstations for Computer Users: A Review

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Abstract- ***In order to facilitate the advancement of computer based technology and prevent health risk associated with computer workstations (non-ergonomics), a modification of the computer workstations is essential. The ergonomics for design of computer workstations leads to motivate the work, higher performance, efficiency and quality of work. Current scenario, our society spends lot of time with computers, thus the computer workstation needs to provide comfort to users. Discomfort position can harmfully affect the overall health and performance of work. In this past, present and future trends of computer workstation designs are discussed. Furthermore this paper offers the suggestions for design of computer workstations and simple exercises to reduce musculoskeletal disorders of prolong time users.***

Index Terms- Computer, Ergonomics, Workstations, Risk Factor.

I.INTRODUCTION

Currently, the computer is an essential element of our lives. Computer users often have health problems associated with musculoskeletal disorders (MSDs). Some of the users are affected by eye fatigue, headaches and mental fatigue. These happen when uncomfortable postures and body movements are often maintained over long period of time. Work behaviour of this kind can increase the risks of neck, shoulder and lower back problems [1]. When one thinks about computers, the computer chair and desk are the most important parts. Addition to that the lighting system and temperature effect in the workstation is also considered. To provide comfort these tools are need with comfort workstation design, since the discomfort can harmfully affect overall health and productivity, especially for long time workers each day [2]. An improper posture for long periods leads to pain around the neck, shoulders, lower back, arms, wrists, legs, other parts of the body and also facilitates repetitive strain injury [3]. The people training with adjustable chair lead to decrease musculoskeletal risk [4]. Similarly, adjustable keyboard and mouse support improved the comfort level of fingers and lower back [5] and the inclination of a keyboard affected the comfort of neck and head [6]. Finally, changing the working position allowed the body parts to stretch and relax before pain developed [7]. Chaiklieng and Krusun [8] found that the desktop computer users more than 4 hours per day during working time are at high risk of work-related shoulder pain. The health problems, causes, symptoms, prevention and remedy of computer-related user's health issues are presented in the table 1.

Table 1. Computer related health issues

Sl. No.	Problem	Cause	Symptoms	Prevention and Remedy
1	Eye Strain	Monitor glare will puts a strain on the eyes. At prolong time eye lens and the muscles, get strained.	• Headache • Blurred vision • Irritated eyes • Burning eyes • Pain and watering of the eyes.	• Take frequent breaks • Take vitamins A and C regularly. • Use anti-glare glasses. • Exercise frequently
2	Cervical and Lumbar Spondylosis	Due to unwanted position of neck and back, pressure on inter-vertebral disc between two vertebrae occurs and the nerves get pressed.	• Pain and Stiffness in neck and shoulder muscles, deadness in hands (Cervical). • Pain, tingling and deadness in lower limbs,	• Keep monitor at eye level • Maintain a proper posture • Exercise daily • Wear the limbo sacral belt • For severe cases, surgical intervention

			inability to bend, stand and sit (Lumbar).	becomes necessary
3	Carpal Tunnel Syndrome	Due to constant handling of the mouse and keyboard, wrist gets hard-pressed	• Pain, stiffness and burning sensation in forearm, palm and finger • Loss of strength in the affected hand.	• Maintain a proper posture • Hold the mouse lightly • Take frequent breaks • Use arm pads
4	Mental stress	Prolong in front of the computer, tension and loneliness develops into depression.	• Difficulty sleeping • Lack of energy	Try to mingle people at work during breaks and talk to friends and family daily.
5	Weight gain	Physical inactivity due to long hours at work. For ladies, it is an additional cause of menopause.	• Headaches • Weight gain, • Depression, • Insomnia • Fatigue	• A low fat, high fiber nutritious diet must be followed. • 30 minutes of exercise daily

An excellent review of Woo et al. [9] discusses the parameters such as sitting posture, monitor position, requirement of seating, back rest, arm rest, leg space and work surface and suggested the standard and guide lines for computer workstation as per International Organization for Standardization (ISO) - 9241. The ergonomic risk factors (awkward postures, dynamic actions, repetitive motions, prolonged duration, contact stresses, temperature and illumination) and other important features for design of computer workstation are shown in figure 1.

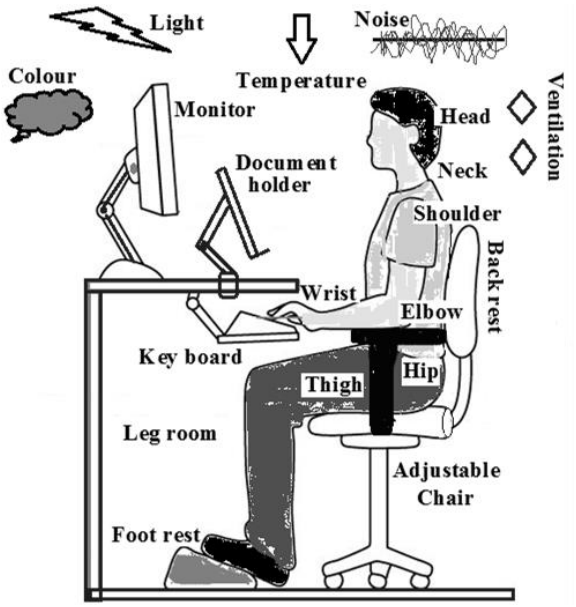

Figure 1. Factors involved in design of computer workstation

II. WORKSTATION DESIGN – PAST AND PRESENT

In this review the following parameters are discussed in the past and present scenario.

- Posture
- Seating
- Back rest
- Arm rest
- Monitor and its viewing parameters
- Leg space, Work area includes position of keyboard and mouse
- Temperature and lighting.

A. Posture

Most of the guidelines and research the standard work postures for seat and work height adjustment. The correct sitting posture is essential for preventing musculoskeletal disorders (MSD) at computer related work. According to the conventional seating, a standard computer chair encourages a straight or upright sitting posture that maintaining right angles at the ankles, knees, hips and elbows. But, working in the same

posture for long periods may be causes MSD problems. Therefore, the researchers proposed alternative sitting postures for computer workers. Grandjean [10] suggested that people preferred reclined sitting posture rather than upright posture and Mandal [11] suggested declined sitting posture.

B. Seat

Optimum design of computer chairs is an ongoing process with much work yet to be done. However, the basic requirements for a chair do not change. It should provide adequate support for the user while working should not place unnecessary stress on any part on the user's body and should positively encourage optimum posture while allowing for comfort and efficiency and minimum muscle fatigue. The following features have to be considered while sitting on a chair.

- Posture of the spine
- Muscle work required to maintain work posture
- Individual fatigue tolerance level
- Compression of blood vessels and nerves

In this section seat pan height, width and depth and also seat pan tilt angle are discussed. Several studies have been carried out to examine the different types of computer chairs on musculoskeletal discomfort and postural changes. Suitable design of the work chair is essential for preventing musculoskeletal disorders of the back, legs, buttocks and arms. The seat height of the chair will allow the feet to be able to rest flat on a footrest. The knees should be bent at least to 90° with the feet slightly forward. Lueder [12] states that, the pressure on the backs of the user's legs can greatly reduced by the chairs with suitable height adjustments and rounded edges on the front of the seat. The seat height and depth of the chair should be adjustable to accommodate a range of people from the lowermost setting) to the uppermost setting. The work chair with a seat pan is too high will lead to a concentration of pressure on the back of the knee and too low will lead to concentration of pressure on a small area of the buttocks. Similarly, if the seat pan of the chair is too wide and deep, it will prevent the user from taking advantage of the armrests and the backrest. The recommended seat height is adjustable between 38 and 56 cm and depth is adjustable between 33 and 48 cm [9].

A seat pan angle of 10° forward slope decreases 30% of intra-disc pressure compared to a horizontal seat [13] and more than 15° of pan angle resulted in increased muscular tension. Anderson and Helander [14] showed that an increase in forward slope angle up to 15° decreases spinal load, but the results depend on the presence of a backrest and it is verified by Naqv [15]. Kayis and Hoang [16] studied that the tilting of the seat pan either forwards or backwards has an effect of reducing the intervertebral disc loading. The seat pan angle of 15° didn't influence significantly muscle activity, but higher back leaning may result in unsupported foot position and trunk support is required [17].

C. Backrest

Backrests will be supposed to provide sufficient lumbar support and buttocks clearance. The height and inclination angle should be adaptable and able to support the back of users in a range of sitting postures. Most of the studies are exposed that backrests must be adequately tall and wide [18, 19, 20]. Grandjean [10] recommended a backrest height of 50 cm and a width of 48 cm, which is compatible with the upper back width obtained from the analysis of large-male anthropometry. However, review article of Woo et al. [9] recommended height of the backrest is between 45 and 53 cm, with width between 36 and 48 cm.

In addition the backrest tilt angle and lumbar support of computer chair is also plays vital role in case of backrest design. An angle of less than 90° between trunk and thighs may lead to fatigue or discomfort. The greatest reduction in disc pressure occurs by increasing backrest inclination from 90° to 110° [9]. Harrison et al. [21] expressed the best option for reducing muscle activity at the back is at 120° backrest inclination and they also found that an inclination angle of 130° resulted in more back muscle activity. Recently, Groenesteijn et al. [22] suggested that, 120° backrest inclination is the optimal angle for computing and reading in a computer monitor. On the whole, in order to reduce loading on the spine of users, the backrest angle is in the range of 90–120° [23.] The fat people prefer sitting on an office chair with a higher lumbar support and slimmer people prefer sitting on an office chair with a lower lumbar support and also height is not a constraint [24].

D. Arm rests

Arm rest supporting the arms during keyboard and mouse use is a preferable working posture for most computer users [25, 26, 27]. Suitably designed armrests can reduce muscle loads on the arm, shoulders and neck [28], reduce pressure on the spine and support task-related movements [29]. Van Veen et al. [30] recommended that a chair with adjustable armrests is needed to support smart phone or tablet use. The armrests should be an optional feature. In fact, many national standards accept chairs with detachable armrests [9]. If the armrest is too high or too low, then the user raising or leaning the shoulders and it will lead to discomfort [31]. Similarly, armrest length that is too long then the user sits far away from the monitor, resulting in awkward postures [32]. Appropriate height

adjustment and sufficient padding of the armrests can reduce pressure on the undersides of the forearms and elbows [9].

E. Monitor

In the design of computer workstation, monitor viewing angle and viewing distance of monitor is major parameters. Suitable positioning of the computer monitor is essential to prevent neck and eye strain. Current ergonomics standards specify a certain range of viewing angles and distances. However, there is conflict over which settings and locations may have different standards for viewing angle [9]. The discrepancy may be due to differences in monitor heights and positions with respect to the effect on the neck and eye [33]. The monitor is either too low or too high, it can lead to an increase in either flexion or extension or bending of the head relative to the neck [34, 35, 36] and an increase in muscle activity [37, 38, 39]. Sommerich, et al. [40] states that, muscle activity is generally greater for the low viewing angle for the standard 14 inch monitor and proposed a conceptual U-shaped model to depict the conflict, and suggested the viewing angle at a range of 0° to approximately 45° below eye level. However, most of the researchers suggest a mid position ranging from 15° to 25° below gaze inclination [41]. Recently the researchers suggested that computer displays should be positioned to suit individual needs within a reasonable height and for a favourable head inclination [42, 43]. Therefore, the complete visual area of the display screen should be located between 0° and 60° below eye level when the user assumes the upright sitting, declined sitting or standing reference posture [9]. In case of smart phones and tablets, the viewing angle of display should be between 30° and 35° below horizontal eye level, which is greater than conventional monitors [44].

The people with normal visual capabilities report greater visual fatigue for viewing distances of 50 cm rather than for 100 cm and it is observed that 50 cm is too close when performing computer tasks [45, 46, 47, 48]. Some of the researchers observed that most of the computer users are prefer viewing distances ranges from 63 to 85 cm [23, 49, 50]. The users of smaller sized computers have to bend forward and adopt with decreased viewing distances [51, 52]). In case of notebook the average viewing distance is 42.3 cm [53] and it is shorter than the recommended minimum distance of 63.5 cm for the desktop computer [54]. The average preferred viewing distance for reading English text is 50 cm and for Chinese text is 49.8 cm in the same tablet [44, 55]. Wu [56] states that, the viewing distances and character sizes for electronic displays are also influenced by age of the users. Therefore, the viewing distances should be determined in context and may vary depending upon the task requirements, computer screen characteristics and individual visual capabilities. The preferred viewing distance of a typical user is greater than 40 cm with a preferred character size range of 20 – 22 arcmin [9].

F. Work surface

In this section the work surface height, Leg room and Work surface area which includes position of mouse and keyboards. A work surface height is more, then the user to raise the arms and shoulders leading to fatigue and discomfort is too low will make the user to lean forward, introduce stress on the arms and back. Suitable height adjustment and curved desk edges can prevent contact stress on the arms and wrists. Most of the researchers recommended that the keyboard height of 5–10 cm above the elbow height which is reduce the neck and shoulder pain compared to lower keyboard height [57, 58, 59]. The pressure on the median nerve at the wrist is least when wrist extension is below 15° [60]). Most of the studies recommend that the computer desk should have sufficient leg space for stretching the legs.

The keyboard and mouse position is also playing vital role in the computer workstation set-up to reduce the musculoskeletal risks. Marcus et al. [61] states that, more than 12 cm distance from the desk edge leads to lower risk of hand arm symptoms and disorders. The mouse position is closer to the centre line of the body is also important to produce more neutral postures and reduce muscle load [62]. Most of the results suggest that keyboards can be placed away from the edge of the work surface, and the mouse can be placed in between keyboard and user. The recommended minimum width for the work surface area is 76 cm, and minimum depth is 90 cm [9]. In addition the document holders should be available for source material and it can be raised and tilted surface of any kind for user's suitable positions.

G. Illumination

Generally there are different types of lighting available in the workstations such as ambient light (overall room lighting), task light (specific task area - bright, flexible and directional), accent light (light specific objects like document holder) and natural light (from a window and door). Hedge et al. [63], presented field studies testing different lighting systems and found that computer workers report fewer complaints of eyestrain and eye focusing problems, and express strong preferences for lensed-indirect up lighting compared with parabolic lensed down lighting. The illumination factor consists of lighting, glare and reflection as shown in figure 2. In the design of visual environment a care must be taken. Lighting should not create glare, bright spots or irritating reflections in the visual field of the computer

users. The reflections from the screen must be avoided and if possible computers should be positioned away from windows. Generally the lighting levels should be lower than is normal for artificially lit rooms and 300-500 lux is recommended as optimum if source documents or reference material are to be read easily. Also the light fittings should be at right angles to the screen and to either side of the user. One centimetre egg crate light filters reduce glare by shielding direct light from the side of lights. The object surface also reflects the light rays as shown in table 2.

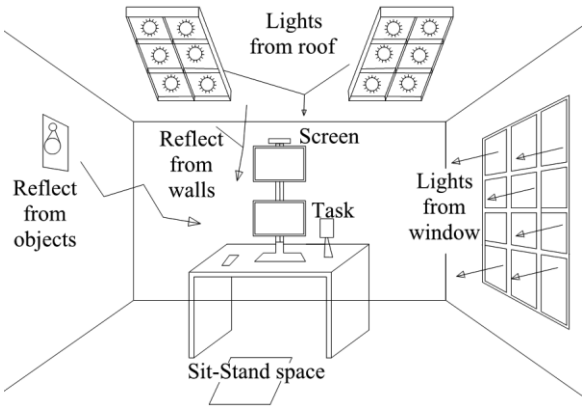

Figure 2. Illumination factors involved in the computer workstations

Table 2. The reflectance of workstation objects

Ceiling	Side Walls	Equipments	Window screen	Furniture	Floor
70-80 %	40-50%	40-50%	40-50%	20-45%	20-40%

III.WORKSTATION DESIGN – FUTURE

Workstations will vary from one job to the other, since a worker may sitting or standing or walking with in the workstation. The workstations have to include a name and key dimensions. The horizontal dimensions are measured with respect to the barriers that determine where the worker will be located. The vertical dimension is measured with respect to the floor, however it may not be constrained for some cases, such as where the lineman that can move up or down the utility pole. The lateral dimension will be measured with respect to the side to side movement of workers. Also the computer workstation deign will indicate the presence of environmental factors (lighting and temperature) that may be affecting the student performance. Figure 3 shows some of the computer workstation layouts of sit-stand work for future technology. Using these workstation layouts immediately converts the work position from sit to stand-up.

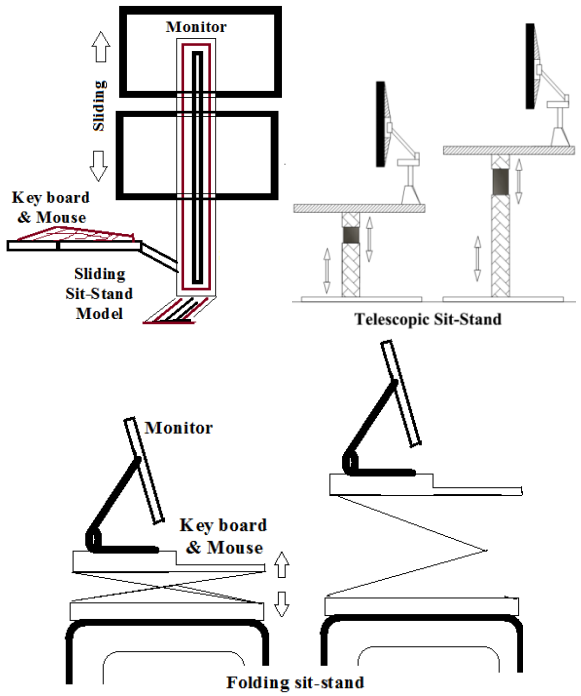

Figure 3. Sit-Stand workstation models

A multiple monitor work environment is also a future technology of computer workstations as shown in figure 4. The following factors are considered for these kinds of workstations.

- Arrange all monitors in an arc
- All monitors should be placed at the same height
- Monitors should be positioned at equal viewing distance
- Position the monitors right next to each other
- Monitors should avoid excess neck rotation.
- Main monitor should be positioned straight and in line with your keyboard and chair.

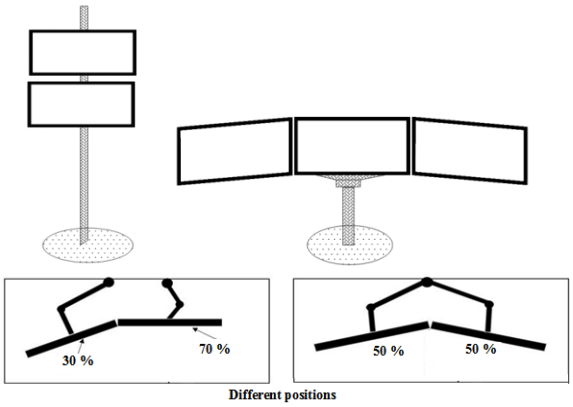

Figure 4. Multiple monitors workstation design

IV.GENERAL GUIDELINES & EXERCISES

A. Guidelines

From the Woo et al. [9] review, it is noted that ISO-9241 does not specify the dimensions of workstation components because of variation in body size among user populations. Another major limitation of ISO-9241 standard as a quality model is that it is too abstract, so manufacturers may not adhere to it. With regard to people of different age, culture and location, practical and universal ergonomics standards and guidelines are in high demand. Since existing standards and guidelines have their own specifications for the design of computer workstations, inconsistencies in ergonomics parameters adopted across different countries are inevitable [9]. From the reviews, more research is required on issues pertaining to a wide range of work postures and design of adjustable workstations. However, the workstations are now designed to be adjustable and most users are still not familiar with the proper adjustments of their furniture. Therefore provide user's training to enable them to adjust their workstation to the comfortable position for their task [64]. From the results and findings of 45 references including research, review and conference papers, chapters of books and other website lectures the standard recommendations for adjustable computer workstations are presented in the table 3.

Table 3. Recommendations for computer workstations

Sl. No	Description	Dimensions	Remarks
1	Posture	Forearm-elbows and Thigh-hip angle are 90° -110°	Shoulders and upper arms relaxed, back and foot supported by rests
2	Screen center from floor (distance)	90-115 cm	Screen is free from glare and shadows
3	Viewing distance	50-75 cm	
4	Screen inclination to vertical plane	2° front - 15° back (88-105° inclination to HP)	
5	Height of keyboard from floor	65-80 cm	Keyboard inclination should be adjustable
6	Keyboard to table distance	10-26 cm	Should be slide
7	Seat height	45-60 cm from floor	Chair has wheels suitable for the floor surface, Chair swivels and adjustable tilt, width and height
8	Seat pan	Width: 35-45 cm, Depth: 35-48 cm	
9	Back rest	Width: 35-40 cm, Height: 16-24 cm and Angle of tilt: 5°-25°	
10	Lumbar support	10-20 cm above seat rest	
11	Armrest height	15-25 cm	Should be adjustable
12	Armrest Width	45-55 cm	Should be adjustable
13	Document Holder	20-45 cm	Should be adjustable
14	Legroom space	Wide: 55- 60 cm, Deep: 60-65 cm from foot, Height: 65-75 cm from floor	Footrests are used in the legroom
15	Footrest	Wide: 50 cm, Deep:30 cm, Height: 5-20	Movable and non-slip surface

		cm and Slope: 10° - 20°	
16	Lighting levels	320-400 lux	-
17	Air Temperature	20°-26°C	-
18	Relative humidity	50-70 %	-

Age factor of the users is also plays an important role in the computer workstations. The young user, especially those who have used a computer at college or school will have more confidence and understanding of computer systems than older one. Most of the users above 45 years old will need reading glasses to read the screen and source documents. The size and readability of both the font and computer display icons will be important for this age group. The user above the age of 60 is less confident users of computers than younger people. Therefore, the training will be need in a different way for different age groups. A good neutral body postures when working at the computer workstation are listed below will reduce muscle strain and fatigue.

- Relaxed shoulders
- Straight hands, wrists, forearms and approximately parallel to the floor surface
- Elbow close to sides of body
- Adequate leg space
- Straight head position
- Spine supported with 'S – curve' backrest
- Thighs and hips supported by well padded seat and parallel to the floor surface
- Feet support by rest or floor.
- Avoid seating at front edge

B. Exercises

The common body exercises which are easy to do and very effective to keep users energy in the computer workstations listed in table 4. Furthermore some of the simple exercises at sitting position of users are shown in figure 5.

Table 4. List of exercises for prolong time users

Sl. No	Description	Exercise	Cycle
1	Eye	• Blinking and yawning which produces tears to aid lubricate the eyes • Expose eyes to natural light • Close eyes, slowly move eyes up and down as well as left to right.	3-5 times
2	Breathing	• At standing or relaxed position, put one hand on the abdomen and one on the chest, inhale slowly through the nose and hold for 3-5 seconds and exhale slowly through the mouth.	3-5 times
3	Head/Neck	• Tilt head to one side (left or right) hold for 10-15 seconds.	3 times on each side
		• Tilt head to one side (up or down) hold for 10-15 seconds.	3 times on each side
		• Turn head slightly and look down diagonally toward shirt pocket hold for 10-15 seconds.	3 times on each side
		• Bring ear to shoulder and hold for 10 seconds, slowly roll chin to chest and up to other shoulder and hold for 10 seconds.	2-3 times on both directions
4	Shoulder squeeze	• Slowly bring shoulders up to the ears and hold for approx 3 seconds and rotate shoulder	5-10 times.

		forward and backward.	
5	Executive Stretch	• At sitting position, lock hands behind head; bring elbows back as far as possible leaning back and stretching, hold for 15-20 seconds.	1-2 times
6	Whole Hand	• At sitting position, drop arms to the side, shake hands downward gently	Frequently
		• Massage the inside and outside of the hand using the thumb and fingers	Frequently
		• Massage fingers of each hand individually, slowly, and gently Move toward nail gently	Frequently
		• Massage space between fingers	Frequently
7	Wrist/finger	• Hold arm straight out in front of you, pull the hand backwards with the other hand, then pull downward, hold for 15-20 seconds.	3-5 times each
8	Thumb	• Bend thumb to touch the little finger base, keeping tip of thumb joint straight for 5-10 seconds.	5-10 times
		• With palm on the table, lift thumb up and hold 10 seconds • Use index finger to extend tip of thumb and hold 10 seconds	
9	Foot	• At sitting position, slowly rotate each foot from the ankle.	3-5 times in both directions
		• At sitting position, grasp the shin of one leg and pull slowly toward your chest. Hold for five seconds.	Several times for both legs

a. Executive Stretch for shoulder

b. Stretch for Wrist/Finger and Head roll

Figure 5. Simple exercises for computer users

V.CONCLUSION

This In order to deal with the advancements of computer technology and reduce the health risk factor due to non-ergonomics designs for computer workstations, a modification of the existing model is important. Nowadays, the ergonomics standards, guidelines and recommendations for computer workstations are easily available and these are usually not a compulsory requirement. However, a great concentration on the working environment of computer

users and related with their comfort is important. The presented guidelines, recommendations and findings provide a useful support for ergonomics design and may used to improve future research.

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