JJMIE

Volume 13, Number 2, July. 2019
ISSN 1995-6665
Pages 91 - 103

Jordan Journal of Mechanical and Industrial Engineering

Ergonomic Computer Workstation Design for University Teachers in Bangladesh

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Received 18 May. 2019

Abstract

The ever-growing use of computer in universities due to instructional, administrative, research and study is noticed among the teachers. Prolong sitting-work on the computer workstation causes various pains, discomforts and health related problems. The aim of this study is to design an ergonomic computer workstation to reduce the health-related problems. A Self-reported Nordic questionnaire was developed for conducting ergonomic assessment among 265 participants to evaluate heath conditions. Moreover, to determine the potential mismatch, 12 anthropometric measurements and existing furniture dimensions was measured and evaluated. Results showed that most of the teachers were suffered from different types of musculoskeletal disorders (MSDs), particularly, lower back pain and neck pain. Significant numbers of mismatches were found between furniture dimensions and anthropometric measurements. It can be concluded, presence of the musculoskeletal disorders would be the reason of inappropriate furniture dimensions. Finally, an ergonomic computer workstation was proposed by considering anthropometric measurements and guidelines to reduce the musculoskeletal disorders among the teachers. This research can contribute a lot for ergonomic furniture design to the university as well as other organizations and create a sense to overcome the ergonomic problems.

Keywords: Anthropometry, Ergonomics, Musculoskeletal Disorders, Computer Workstation;

1. Introduction

Ergonomics is a holistic and human–systems approach for work systems design by considering cognitive, organizational, physical, environmental and other factors [1]. Applications of ergonomic principles improve human-computer interaction and enhance comfort, health and safety of the users [2]. Basically productivity, performance improvement prevention of injuries and fatigue reduction are the main concern of the ergonomics [3]. These objectives are achieved by changing the worker job interface such as work process, work environment, work management and tools [4]. Therefore, it is essential to design an ergonomically adjustable workstation to prevent repetitive body movements, awkward postures and static forces in both sitting and viewing position. Ergonomically designed workstation refers to the proper seat height, desk height, proper placement of monitor, and consider environmental factors, such as proper lighting intensity and noise level [5]. Chair is the vital element that needed to design ergonomically which is adjusted as required to the user intension, comfortable and able to maintain natural postures. Principles of ergonomics suggests working with natural postures, keep work element within easy reach, work at proper heights, minimizing pressure points, provide clearance, work with comfortable weather [6]. Ergonomic design can be achieved through anthropometric measurements. Anthropometry refers to the scientific measurements of different body parts of the human [7]. It is not feasible to design a work system or equipment that suitable for everyone. Generally, it is targeted that about 90% user can suit with this system. Therefore, to accommodate 90% of the targeted population, it is required to consider 5th percentile of female and 95th percentile of male anthropometry data. Anthropometry is not universal; it is varied among nations, ethnicities and regions. For example, a design of a product for a certain targeted nation may not match with other nations. Anthropometry is vital element to design and modify of product and service [8]. Three basic ergonomics design principles are design for extreme individual, design for average and design for adjustability. Design for extreme individual principle based on 95th percentile of male (maximum population), or 5th percentile of female (minimum population) anthropometric data [9]. Most of the researchers use design for adjustability principle for furniture design [10, 11] and it is based on 5th percentile of female and 95th percentile of male anthropometric data covers 90% of the population[12, 13]. Third principle is design for average whenever adjustability is impractically not possible though it is widely used [14]. Workstation furniture is the vital element that needed to design ergonomically which is adjusted as required to the user

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intension, comfortable and able maintain natural postures. Design for adjustability principle play vital role for designing ergonomic adjustable furniture that ensures users to work with natural postures, keep work element within easy reach, work at proper heights, minimizing pressure points, provide clearance, and work with comfortably without any discomforts [6]. So, adjustability principle was recommended to design workstation furniture in the current study. Previous studies showed that most of the researchers used adjustability principle to design [10, 11, 14, 15].

In modern world, computer is an integral part of the office. Due to advanced technology and software, computer use in official work is continually increasing. Poor designed workstation and its use are responsible for MSDs and safety problems. Not only visual discomforts and disturbances, but also MSDs problems in neck and shoulders are key problems experienced by the computer users [16]. Moreover, bad postures are the main reason of Musculoskeletal Disorders [17]. Researchers investigated the design parameters of workstation found health related problems among the users. A study was carried out to assess the risks associated with musculoskeletal discomforts by conducting survey among the 292 VDT (Video Display Terminal) users [18]. Results show that MSDs symptoms were observed among different body regions associated with participants. Moreover, researchers concluded improper setting of monitors and keyboards were associated with eye, head, shoulders and back discomforts [18]. Another investigation was carried out to compare postures and muscles patterns among the 40 males and female computer users and found significant differences in both speed typing and repetitive mouse tasking among male and female participants [19]. Furthermore, significant postural variations were observed between genders though chairs and desks of anthropometrically and ergonomically adjusted for both male and female participants. Park et al. (2000) compared discomfort level between adjustable demo chair and conventional chair and concluded that adjustable VDT workstation reduces the discomforts [20]. Straker et al. (2008) investigated neck and upper limb postures of young male and female participants and concluded that no consistent evidence was found between forearm support and posture [21]. Researchers showed that inappropriate design workstation and its use were responsible for shoulder and neck pain [2]. In addition, placement of keyboard above or below the user's elbow height was introduced arm discomfort. Sauter et al.(1991) investigated neck and shoulder pain and suggested the necessity for controlling cervicobrachial pain syndromes in VDT users [22]. The cross-sectional study was conducted by Xue et. al (2013) to evaluate ergonomic hazards of computer workstations among 90 two groups: office and cubicle workers. Neck, shoulders, hands/wrists, upper and lower back discomforts were reported by the workers. It also concluded that the office workers suffered much more neck pain than the cubicle workers, due to an association between longer working computer usages and the frequency of experiencing discomfort [23]. Another research was conducted by lale et. al (2013) to investigate the impact of musculoskeletal discomforts on office workers. They proposed ergonomic computer workstation based on user's anthropometric measurement to solve the costly health related problems and lost productivity due to perceived musculoskeletal discomfort and relieving the imposed economic burden [24].

When the body dimensions and furniture dimensions are not matched, user feels uncomfortable while sitting, this phenomenon is term as mismatch [25]. Castellucci et al. (2010) conducted a study to evaluate the mismatch between furniture dimension and student anthropometry and found potential mismatch in different dimensions of furniture [26]. Another study conducted in Greece and found high degree of mismatch for seat height and desk height dimensions [27]. The study of Kane et al. (2006) revealed 96% mismatch between furniture dimensions and student's anthropometry [28]. Another study was conducted by Rosyidi et al. (2016) to investigate the mismatch between furniture dimension and student anthropometry and found high percentages of mismatch in three chair and two desk dimensions [29].

On the other hand, researchers recommended ergonomic guidelines and suggestions to solve the ergonomic problems. Workstation furniture is the vital element that needed to design ergonomically which is adjusted as required to the user intension, comfortable and able maintain natural postures. Ergonomically furniture (Chair and Desk) design means design the seat parameters like seat height, seat depth, seat width, backrest, armrest and desk height by considering users anthropometric measurements and ergonomic principles. Haque et. al (2014) considered eleven anthropometric measurements to design ergonomic workstation furniture and these measurements were stature, sitting height, sitting shoulder height, politeal height, sitting elbow height, hip breadth, buttock politeal length, knee height, shoulder breadth and sitting eye height [30]. Design nature of Seat parameters affects the sitting postures of user while sitting [31]. Postural dynamics of users is important element of workstation design that significantly affected by human-computer interface [17][17]. A proper workstation setup is necessary due to use of prolong hours of deskbound computer and routine works [32]. Work postures are affected different parameters like Seat height, Seat depth, Keyboard-to user distance, Monitor height, Monitor-to-user distance, thigh clearance, task lighting etc[33]. Researcher showed that the pressure on legs were greatly reduced by using well height adjusted, rounded edged seat pan [34]. Seat height should be determined in such way that feet freely touch on the floor. However, most of the guidelines suggested that knee bent would be 90 degree with lower leg while seating[35].Haworth (2008) suggested that seat height and seat depth should be adjusted to accommodate large population from 5% female to 95% male user [31]. Seat pan angle is also play a vital role and to reduce MSDs. Researchers found that 10 degree forwarded seat pan angle reduces 30 % intra-disc pressure and concluded that more than 15% inclination of seat pan angle increases muscular tension [36]. Naqv (1994) recommended15°forward slope of seat pan angle to reduce the intra-disc pressure [37]. Researchers suggested that backrest should be tall and wide sufficiently [38]. Grandjean (1984) recommended 50 cm height and 48 cm width of the backrest to compatible with male anthropometry [39]. Researchers suggested backrest inclination angle from 90° to 110° are reduce the disc pressure. Another study recommended that backrest inclination angle should be 90° to 120° [40]. Armrest is also an important parameter of chair and it should be appropriately adjusted and well-padded that will support the forearms and elbows to reduce extra pressure exerted on undersides both forearms and elbows [15]. Another study recommended that the length of armrest will be 25.5 cm from the back of the chair [34]. Other researcher Tijerina (1984) suggested that length, width and height should be 44 cm, 6-9 cm, and 18-23 cm (above from the seat pan) respectively [41]. Desk height and seat height should be adjustable in relation to suitable keyboard-forearm relation and adequate leg room [42]. Proper position of display is essential to prevent neck and visual problems. One study recommended that preferable viewing distance should be 63 to 85 cm[40]. Sommerich et al. (2001) investigated the trade-off between visual and musculoskeletal strain and proposed a u-shaped model to maintain viewing angle from 0° to 45° while using computer [43]. Another study suggested the viewing angle range from 15° to 25° below gaze inclination [44].

Ever growing use of computer in everyday life increases the risks of musculoskeletal disorders and visual problems. Various national and international standards and guidelines for computer workstation design have developed around the world to counter these problems[45]. International Organization for Standardization ISO-9241[46] and Occupational Safety and Health Administration, OSHA (2008) [47] are the two international standards. The prominent national standards are Canadian Standard Can/CSA Z412-M89 (Canada) [48], American Standard ANSI/HFES-100 (United States), and Australian Standard AS-3590.2 (Australia) [49], whereas national guidelines are Australian National Code of Practice for the Prevention of Occupational Overuse Syndrome and A Guide to Work with Computers published by the Labor Department (Hong Kong). Europe, Australia, America and other developed countries continuously active in endorsing and participating in ergonomics standards development. Unfortunately, there are no established ergonomic standards in Bangladesh. In the current study, worldwide prominent computer workstation guidelines were followed to design the proposed computer workstation.

The common and widely recognized guideline for furniture design is BIFMA (The Business and Institutional Furniture Manufacturer's Association) (BIFMA). BIFMA is a group that addresses common concerns in the furniture industry and provides office furniture design guidelines for fit and function [50]. Some furniture design standards have been recognized in various countries, for instance Colombia (ICONTEC 1999), Chile (INN 2002), the European Union (CEN 2012), Japan (JIS 2011) and the United Kingdom (BSI 2006) [25]. Yet not much has been done on office furniture and moreover, there are no established standards for Bangladeshi office furniture.

In Bangladesh, computer is an integral part of office used for different purposes such as, for internet browsing, emailing, chatting and other communicating purposes, especially for the university teachers. So, prolonged period (average more than 6 hours per day) is spend in front of computer with inappropriate sitting postures to do research and other academic activities. They are associated with the risks of MSDs due to continuous computer usages. The furniture used by the teachers are manufactured by local producers and suppliers [30]. Suppliers mainly follow "one-size-fits-all" approach for making Most of the teachers are unaware about their sitting postures and surrounding environmental factors, and they do not take any institutional training on ergonomics and safety related issues furniture without considering user anthropometry. Thus, all users are not compatible with the furniture dimensions. This fixed and unadjusted furniture can lead to awkward postures. As a result, awkward postures lead to fatigue and discomfort in the different body parts of the furniture users [51]. A pilot study of Bangladesh heath profession institution reported that 53% computer users are affected by lower back problems, and more than 30% of the users are affected by rest of form of MSDs problems due to absence of ergonomic intervention [52]. Users are affected not only by health risks, but also by financial losses [53]. A report of US labor department in 2013 showed that 20 billion of US dollars were spent as direct cost, and 100 billion US dollar on indirect cost for MSDs incidents (OSHA, 2014). There is no existence of cost related data and enough researches on MSDs in Bangladesh. So, all these incidents and information about their workstation is an alarming for the teachers and signifies the necessity of redesigning the existing workstation setup.

Although a lot of research work was done on computer workstation by considering postural, psychological and environmental factors which affect the musculoskeletal system of the user working in office, there were few of the studies solely address teacher's ergonomic problems around the world. As far the author's knowledge, very few studies were conducted on University teacher's ergonomic problems especially in developing country like Bangladesh. Therefore, aim of the research is to find out ergonomic problems among the university teachers, and design an ergonomic computer workstation by considering anthropometric measurements and following various ergonomic guidelines and suggestions to reduce the health-related problems.

2. Methodology

2.1. Participants

A Total of 265 university teachers from different engineering universities of Bangladesh with their demographical information shown in Table 1 participated in this research. Sample size was calculated by using one source [54].

$$n = N/(1 + Ne^2) \tag{1}$$

Where n is the sample size and N is the total population of the group and e is the degree of accuracy at 95% confidence level.

2.2. Ergonomic Assessment (Health Survey)

Ergonomic assessment was conducted among the teachers to evaluate the risk of WMSD (Work Related Musculoskeletal Disorder) Symptoms working as because of prolong sitting on their desk. A set of self-reported

Nordic questionnaire was developed by extensive literature review shown in the Appendices A. Musculoskeletal pain frequency was classified in the three categories, such as: “constantly” (most of time of the day) “occasionally” (two to four times a month) and “frequently” (more than four times a month). Prevalence of pain was measured with percentages of “Yes” and “No” reported by the participants.

Table 1.Demographical information of the participants

Biographical characteristics	Frequency, n	Percentage (%)
Age(years)		
23-30	158	59.62
31-40	63	23.77
41-60	44	16.60
Gender		
Male	200	65.33
Female	65	34.67
Employment Status		
Lecturer	122	32
Assistant Professor	65	30
Associate Professor	36	21.33
Professor	42	16.67

2.3. Anthropometric Measurements, Equipment and Procedures

Harpenden Anthropometer was used to measure the anthropometric dimensions of the participants. Consent of the participants was taken before the data collection process and participants were chosen had no physical disabilities. Standard sitting posture was maintained during measurements. Moreover, subjects were wearing less clothes without shoes. The measurements were taken with help of two research assistants, and they were trained for using measurements, tools and techniques. To ensure the accuracy and consistency of the recorded data, each dimension was taken three times and average value was recorded. Flowing anthropometric measurements were considered to design ergonomic furniture (chair, desk) shown in table 2. Fig.1 shows the anthropometric measurements and definitions of those dimensions were adopted from one source [55].

2.4. Furniture dimensions

Furniture dimensions such seat height, seat width, seat depth, backrest height, and seat to desk clearance, desk height were considered to evaluation in the current study and the definitions of the dimensions were adopted from one source [56].

Seat Height (SH: The vertically distance measured from front edge of seat to surface of the floor.

Seat Depth (SD): The horizontal distance measured from back of the seating surface to seat front.

Seat Width (SW): Distance measured horizontally from outer left side to the outer right side.

Backrest Height (BH): The vertical distance from the top side of the seat surface to the highest point of the backrest.

Desk Height (DH): The distance measured vertically from the front top edge of the desk to floor.

Seat to Desk Clearance (SDC): The distance measured vertically from top edge of the seat surface to underneath surface of the desk.

2.5. Furniture and body dimensions mismatch

Equations (2) to (7) were used to evaluate the potential mismatch between furniture dimension and user’s anthropometric measurements. Six furniture dimensions were check against the anthropometric measurements shown in the Table 2.

Table 2. Anthropometric dimensions

S/N.	Anthropometric dimensions	Definition
1	Sitting height	It is the vertical distance measured from vertex to the sitting surface.
2	Sitting Shoulder Height	The distance measured vertically distance from the sitting surface to top of the shoulder.
3	Popliteal Height	Distance measured vertically with 90° knee flexion from footrest to popliteal surface of the knee.
4	Hip Breadth	It is the maximum horizontal distance across the hips when subjects in sitting position.
5	Sitting Elbow Height	It is the vertical distance from the sitting surface to bottom of the elbow.
6	Buttock-Popliteal Length	Distance measured horizontally With 90° knee flexion from posterior surface to buttock.
7	Buttock-Knee Depth	Distance measured horizontally With 90° knee flexion from knee cap to uncompressed buttock.
8	Thigh Clearance	Distance measured vertically from highest point on the top of the right thigh to sitting surface.
9	Sitting eye height	It is distance measured vertically from the sitting surface to the inner canthus (corner) of the eye.
10	Shoulder (bideltoid) breadth	It is the maximum distance between two deltoid muscles.
11	Sitting Knee Height	Distance measured vertically With 90° knee flexion from knee quadriceps muscles to footrest.

2.6. level of compatibility

To compare furniture dimensions with participants’ anthropometric measurements, there are two types of equations i.e. one-way limit and two-way limits equations. Match and mismatch classifications were defined to measure compatibility by using one-way limit equation. For two-way relationships, three classifications were defined: (a) high mismatch (lowest limit of the relationship is greater than anthropometric measurement); (b) low mismatch (highest limit of the relationship is lower than anthropometric measurement); and (c) match (anthropometric measurement is between the limits).

2.7. Data analysis

The software SPSS 16.0 was used analysis the data. Therefore, different percentile values (5^{th}, 50^{th}, 95^{th}), mean, standard deviation (SD), maximum (Max), minimum (Min) were calculated shown Table 6.

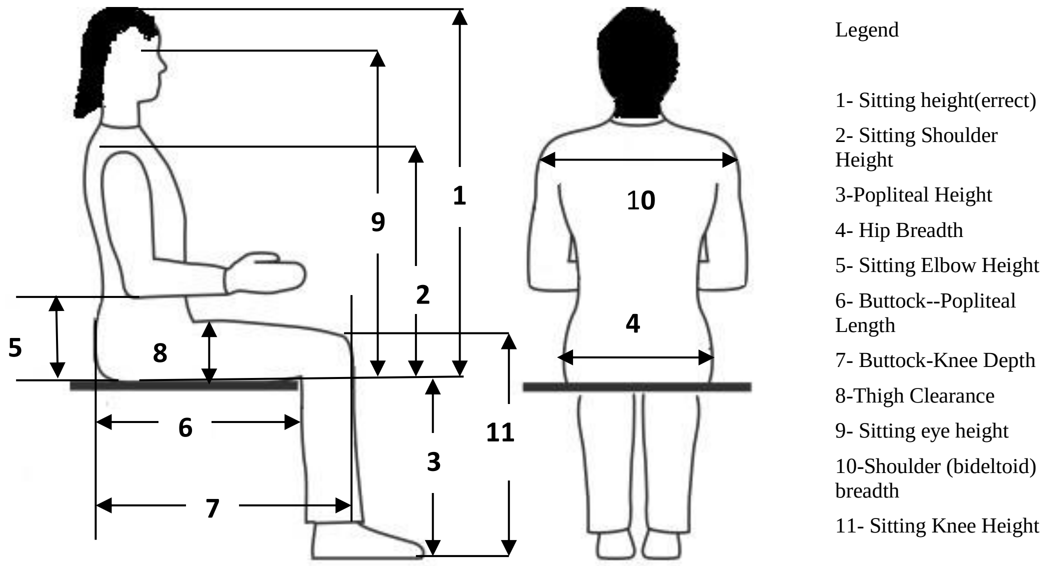

Figure 1. Anthropometric measurements

3. Results and Discussion

3.1. Ergonomic assessment (Health Survey) report

Table 4 shows MSDs frequency percentages among different body parts such as shoulder, wrist, neck, and ankle elbow regions reported by participants. No common presence of MSDs is found when it is observed in three separate categories. But the combination of occasional and frequent category shows the high frequencies percentage of pain. Majority of the participants (65.28%) experienced lower back pain. 58.49% participants suffered from neck pain whereas 48.3% participants reported that they were suffered by Hips/Buttocks/Thighs pain. 47.16%, 41.88%, 27.55%, 37.35% and 30.19% participants suffered from different kinds of pain on the body, such as shoulder/upper arm body, such as Shoulders/Upper arm, Upper back, Elbow/forearm, Knees and legs, and Feet/Ankles respectively. A few percentages of participants suffered from lower and upper back pains constantly. Frequently occurring pain in lower back, hips and neck were reported 33.20%, 33.321% and 30.56% respectively by the participants. This MSDs Prevalence is slightly higher compared to other study[57], and nearly similar to another study conducted in Bangladesh[52].

Prevalence of MSDs indicates that there were large percentages of incompatibility between user anthropometry and furniture dimensions. As a result, most of the users did not maintain the appropriate sitting postures while sitting and workstations setup were inappropriate and unadjusted for the users. However, incompatible furniture and unadjusted workstation setup leads to user discomfort for working activities it introduces to Musculoskeletal Disorders (MSDs) among different body parts. In the current study, 58.49% participants worked on their computer workstation more than 5 hours and 13.58% were spent their time more than 8 hours per day in computer related work (shown in Table 1). Many participants (155) did their regular computer related activities by spending 5-8 hours or more time per day. This pronged sitting work, incorrect postures, and inappropriate workstation setup would be the reason of high frequency of MSDs. Other studies showed that discomforts are the main reason of poor ergonomic workstation design, excessive hours of computer usage, continuous awkward sitting Postures, psychosocial environmental factors and longer work load [58, 57]. These findings were congruent with the current study. After the critical literature review, authors reached a conclusion that incorrect postures and inappropriate workstation setup were significantly associated with MSDs (shown in Table 5).

3.2. Anthropometric data analysis

Anthropometric data were analyzed in the form of different percentiles values (5th, 50th and 95th), average (Mean), standard deviation (SD), maximum (Max), minimum (Min), and shown in Table 6. From Table 6, average sitting height of the male participants was 85.21cm and 90% of the male participants cover the stature rage from 79cm to 92.05cm (standard deviation 4.24cm). Similarly rest of the dimensions, Shoulder height(44.00-65.005 cm), popliteal height(42-52 cm), Hip breadth(29-47.47 cm), Elbow height(20-29.55 cm), Buttock-popliteal length(39.00-49.05 cm), Buttock-knee length(47-61 cm), Thigh clearance(11-25 cm), Eye height(58-81.16 cm), Shoulder (bideltoid) breadth(36-51.05 cm) , Knee height(47-63.69 cm), covers the mentioned range . The highest standard deviations were found in case of sitting shoulder height and eye height that are respectively 7.37 cm and 6.69 cm respectively. In case of female data, sitting height (76.26-85.40 cm), Shoulder height(49.20-59.08 cm), popliteal height(32.68-46.18 cm), Hip breadth(, 30.72-48.21 cm), Elbow height(17.20-30.92 cm), Buttock-popliteal length(38.02-49.48 cm), Buttock-knee length(, 48.20-58.40 cm), Thigh clearance(9.76-15 cm), Eye height(64.06-73.32 cm), Shoulder (bideltoid) breadth(34.60-50.80 cm) , Knee height(44.92-54.24) covers the mentioned range. The highest standard deviations were found in case of hip breadth and shoulder breadth that are 4.83 cm and 4.45 cm respectively. Finally, it can be concluded that all dimensions of male were higher than female except hip breadth. All data (male and female) statistically checked and found normally distributed with strong nature of normal curve (shown in figure 3). As anthropometric regional variability is absence in Bangladesh, therefore collected data represents the whole country's anthropometric image of ages from 23-60.

3.3. Participant's Match and Mismatch History with Furniture

Table 7 shows the match and mismatch percentages between existing furniture dimensions, and participant anthropometry. High percentages of mismatches were found particularly on seat height, backrest height, desk height, seat to desk clearance. 74% female participants were mismatched on seat whereas male participants were less. About 50% both male and female participants were mismatched on seat depth. Almost all participants were matched on seat width and very few of them were mismatched. Backrest was totally inappropriate for all participants. 87.7 % female participants were mismatched on seat to desk height that was slightly higher than male. 100% of the female participants had not enough desk clearance. Seat height and desk height were so taller for the female participants. The potential mismatch found between furniture dimensions and participant anthropometry measurements indicated the high frequency of MSDs problems existence among the participants (shown in Table 4). This mismatch history will be alarming for the participants and this situation will be overcome by redesigning the workstation for better welfare of participants and organization.

3.4. Computer Workstation Design

From Table 4 and Table 6, research found the mismatch between furniture dimensions and participant anthropometry, and large frequency of MSDs among different body parts of participants. So, the only solution will be the redesign of workstation's furniture and setup. Workstation furniture (Chair and Desk) was designed on user's anthropometric measurements and following various ergonomic guidelines and suggestions (shown in figure 4). Placement of monitor and other accessories were adjusted maintaining postural guidelines following worldwide prominent ergonomic standard and guidelines for computer workstation setup (shown in figure 5).

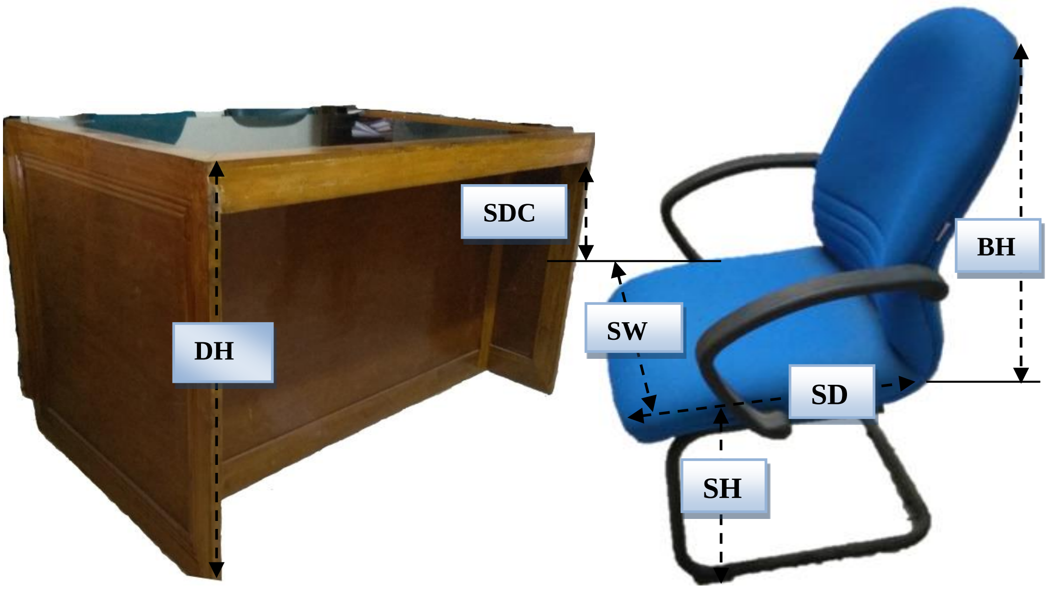

Figure 2. Furniture dimensions

Table 3. Match Criteria equations

Seat dimensions against anthropometric dimensions	Equations		References
Sitting Height (SH) against popliteal height :	$(PH + 3)\cos 30 \leq SH \leq (PH + 3)\cos 5$	2	[70]
Seat depth (SD) against buttock popliteal length (BPL):	$0.80BPL \leq SD \leq 0.95BPL$	3	[71]
Seat Width (SW) against Hip breadth(HB):	$1.10HB \leq SW \leq 1.30HB$	4	[72]
Desk Height (DH) against Sitting Elbow Height(SEH):	$SEH \leq DH \leq SEH + 5$	5	[27]
Backrest Height (BH) against Sitting Shoulder Height(SSH):	$0.60SSH \leq BH \leq 0.80SSH$	6	[73]
Seat to Desk Clearance (SDC) against Thigh clearance(TC):	$(TC + 2) < SDC$	7	[71]

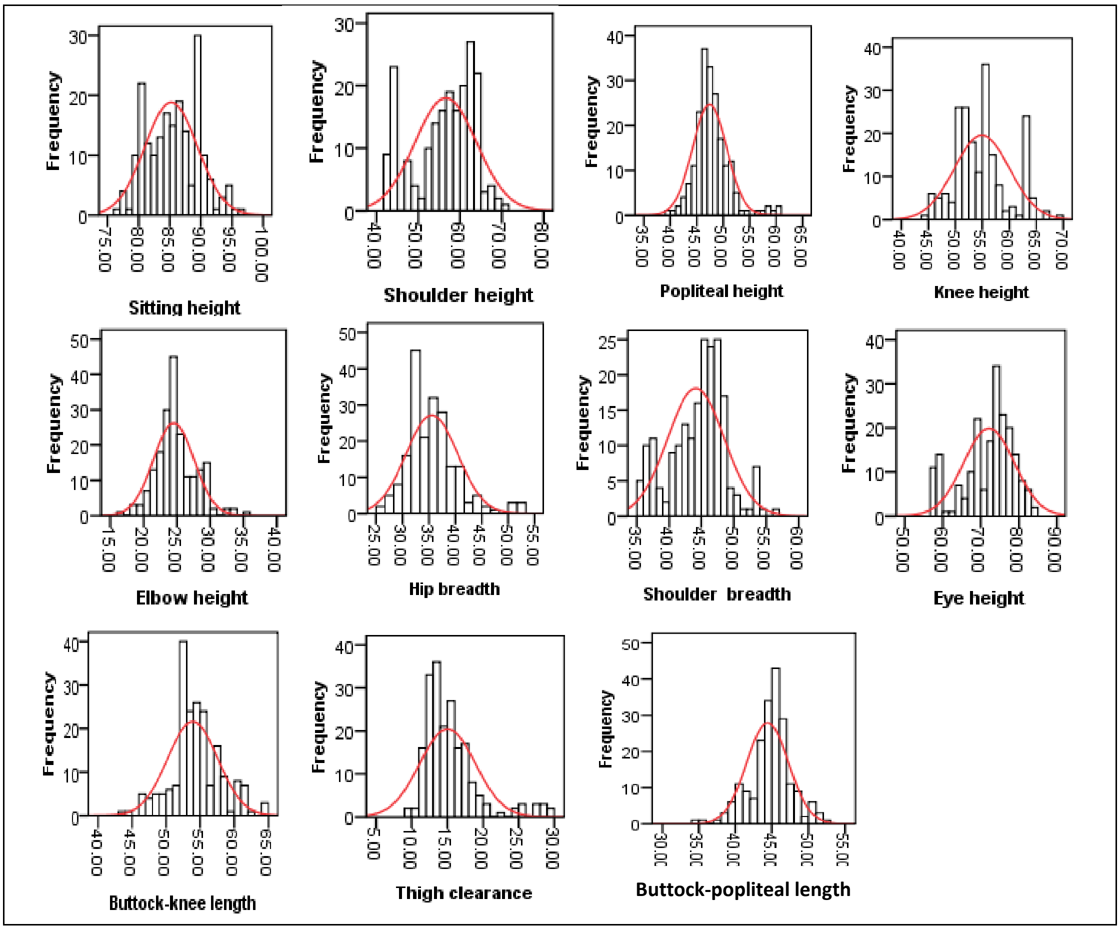

Figure 3. Normality distribution curves of anthropometric data (male)

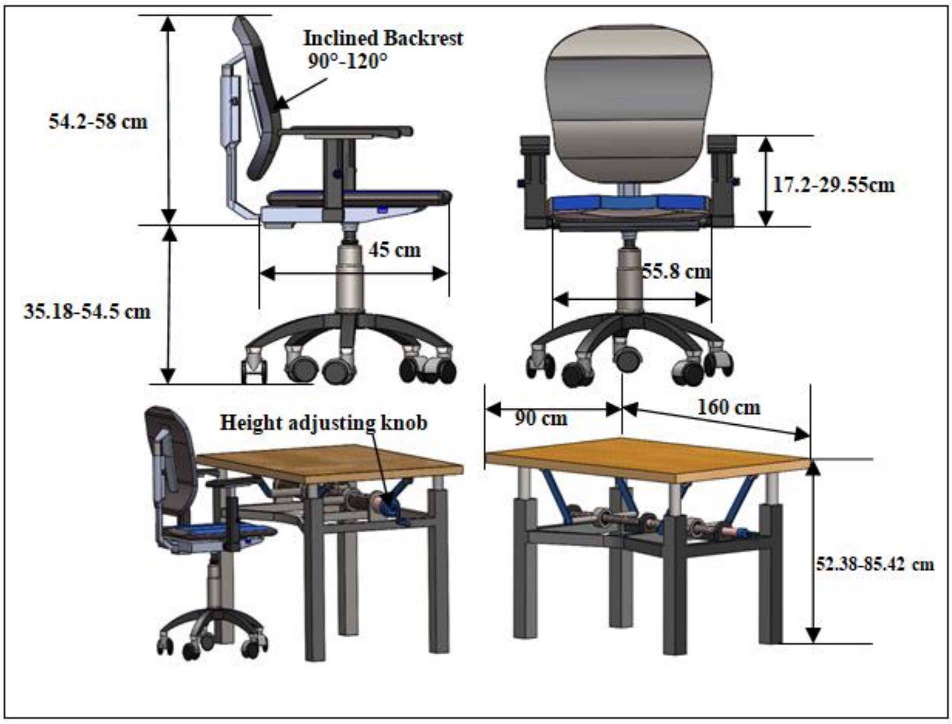

Figure 4. Proposed workstation design (chair and desk)

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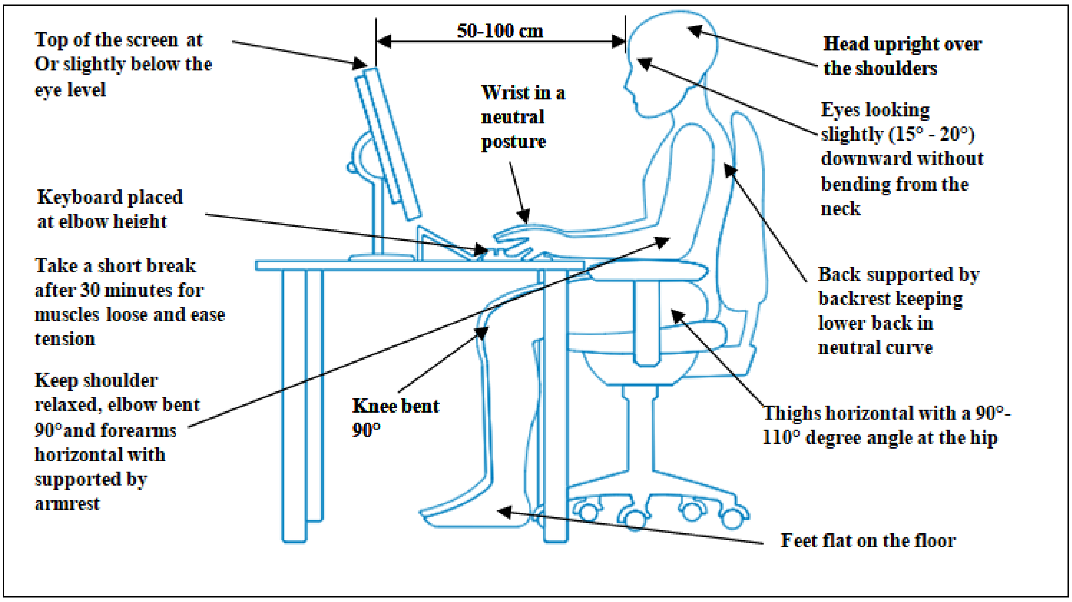

Figure 5. Recommended ergonomic guidelines for monitor, keyboard, mouse placement and sitting postures

Table 4. Frequency distribution of musculoskeletal pain

Pain in the following body regions	Constantly, (%)	Frequently, (%)	Occasionally, (%)	Total, (%)
Neck	3.39	30.56	24.52	58.49
Shoulders/Upper arm	2.26	28.67	16.22	47.16
Upper back	6.79	24.52	10.57	41.88
Lower back	7.92	33.20	24.15	65.28
Elbow/forearm	1.51	9.81	16.22	27.55
Wrist/Hand	0	9.81	30.19	40
Hips/Buttocks/Thighs	5.28	33.21	9.81	48.3
Knees and legs	0	17.35	20	37.35
Feet/Ankles	0	10.19	20	30.19

Table 5. Association of MSDs with sitting posture and workstation setup

Body parts with incorrect posture	Part of workstation with inappropriate setup	Body part affected
Torso	Seating	Lower back
Wrist and hands	Input devices	Wrist(left right)
Forearm and elbow	Seating	forearm
Head neck	Monitor	Neck and upper back
Head and neck	Monitor	Right and left shoulder
Shoulder and arm	Monitor	Right and left shoulder

Table 6. Anthropometric data for the teachers

Dimensions	Gender	Min	Max	Mean	SD	5th percentile	50th percentile	95th percentile
Sitting height (erect) (cm)	Male	76.00	96.00	85.21	4.24	79.00	85.05	92.05
	female	73.00	88.90	80.35	3.03	76.26	79.756	85.4
Shoulder height, sitting (cm)	Male	47.00	71.00	56.57	7.37	44.00	58.00	65.05
	female	42.00	64.00	54.22	3.24	47.10	54.20	59.08
Popliteal height (cm)	Male	39.00	60.00	47.43	3.24	43.00	47.00	52.00
	female	28.00	47.00	39.71	4.19	32.68	39.90	46.18
Hip breadth, sitting (cm)	Male	25.00	53.00	35.54	4.89	29.00	35.00	44.47
	female	29.00	52.00	36.17	4.83	30.72	35.00	48.21
Elbow height, sitting (cm)	Male	17.00	35.00	24.52	3.05	20.00	24.00	30.92
	female	16.20	34.00	23.56	4.06	17.2	23.10	29.01
Buttock-popliteal length (cm)	Male	34.00	52.00	44.40	2.86	39.00	45.00	49.48
	female	35.00	52.07	43.43	3.42	38.02	43.60	49.05
Buttock-knee length (cm)	Male	43.00	64.00	53.90	3.69	47.00	54.00	61.00
	female	45.50	60.71	52.90	3.26	48.20	52.70	58.40
Thigh clearance (cm)	Male	9.00	29.21	15.02	3.90	11.00	14.00	25.00
	female	8.70	17.02	12.30	1.76	9.76	12.00	15.00
Eye height, sitting (cm)	Male	57.00	85.00	72.15	6.69	58.00	74.00	81.16
	female	60.20	76.90	68.70	3.22	64.06	68.20	73.32
Shoulder (bideltoid) breadth (cm)	Male	35.00	56.00	44.14	4.41	36.00	45.00	51.05
	female	33.00	55.00	40.43	4.45	34.60	40.00	50.80
Knee height (cm)	Male	44.00	69.00	54.90	5.10	47.00	54.00	63.69
	female	40.60	58.00	49.47	3.18	44.92	49.20	54.24

Table 7. Match and mismatch history

Furniture dimensions	Participants	Match	High mismatch	Low mismatch	Total mismatch
Seat Height	Male	68.5%	32.5%	0%	32.5%
	Female	26%	50%	14%	74%
Seat depth	Male	52%	14%	34%	48%
	Female	46%	28%	26%	54%
Seat width	Male	90%	10%	0%	10%
	Female	98%	2%	0%	2%
Backrest height	Male	00%	100%	0%	100%
	Female	4.6%	95.4%	0%	95.4%
Seat to desk height	Male	32.5%	0%	67.5%	67.5%
	Female	12.3%	0%	87.7%	87.7%
Seat to desk clearance	Male	37%			63%
	Female	0%			100%

3.4.1. General Requirements for Chair Design

Seat height: Seat height is the vital parameter of proper design of office chair and according to OSHA (2008) [60] and BIFMA furniture guidelines [50], it should be adjusted to accommodate a large population for preventing MSDs on back, legs, buttocks and arms. For example, ***ANSI/HFES-100*** specifies the seat height should be adjustable up to 56 cm [61], which has a much higher value than 51 and 52 cm recommended in ***AS-3590.2*** and ***CAN/CSA-Z412-M89,*** respectively. Seat should be adjustable with suitable keyboard-forearm relation and adequate leg room [42]. According to Parvez et al. (2018), seat height is related to popliteal height [25], while another researcher showed that seat height should be lower than popliteal height or else most users will be unable to rest their feet on the floor [62]. Popliteal height is the determinant of seat height [25], and Haworth (2008) suggested adjustable seat height that was ranged from 5th percentile of female and 95th percentile of male popliteal height [31]. So, researchers proposed adjustable seat height considering 5th percentile of female and 95th percentile of male popliteal height with added a shoes allowance of 2.5 cm and it was ranged from 35.18 cm to 54.5 cm (shown in figure 4).

Seat depth: Seat depth dimension should be considered in such way that shortest users cannot exceed their buttock popliteal length [63]. According to OSHA (2008), seat depth should be not too short and not too long to avoid creating pressure on buttock of taller users and knee of shorter users [60]. Taifa et. al proposed 50th percentile of male buttock popliteal length for seat depth [14]. That’s why, 50th percentile of male buttock-popliteal length was taken to determine the seat depth dimension and it was 45 cm (shown in figure 4).

Seat width: Seat width should be designed in such way those users who has wider hip can accommodate with the seat [64] and consider the cloth allowance for easy movement. ISO-9241 proposes to consider large hip breadth for determining dimension of seat width [46]. Taifa et.al (2017) and BIFMA guidelines proposes seat width should be determined considering 95th percentile of female hip breadth added with clothing allowance for easy movement [14, 50]. In this research, 95th of the female hip breadth with cloth and movement allowance was considered to determine the seat width and it was 55.8 cm (shown in figure 4).

Backrest: Backrest should be designed that will support the individual body load and stabilize reclining posture with supporting head/neck when extreme reclining posture [65]. ***CAN/CSA-Z412-M89*** specifies the backrest height should be adjustable [48].OSHA (2008) recommended that backrest should be contoured and adjustable for maintaining neutral posture by the users [47]. It should be enough taller and wider for better supporting of reclining sitting without restricting elbow movement comfortably and impede upper body mobility [24]. Other researchers proposed that backrest should be adjustable from 50th percentile of male and female sitting shoulder height [15] and The inclination angle of 90-120 degree was recommended by Grandjean et.al [40]. Authors recommended the adjustable backrest considering 50th percentile of male and female sitting shoulder height and it was ranged from 54.2 cm to 58 cm and backrest inclination angle was 90 to 105 degree adopted from OSHA(2008)[47] (shown in figure 4).

Armrest: Armrests should be adjusted and made of a soft material and have rounded edges [60]. The armrest must support the forearms. Armrest should be designed in such way that is capable of holding forearms without creating pressure on median curve which leads to carpal tunnel syndrome [34]. Sitting elbow height is the determent of armrest height. So, it was recommended that the adjustable armrest height ranged from 17.2 cm to 29.55 cm considering the elbow height of female 5th percentile to male 95th percentile [15] from the sitting surface (shown in figure 4).

3.4.2. General Requirements for Desk Design

Desk size: ***AS-3590.2*** suggests 120cm length x 90cm wide desk size for solely performed computer working [49]**.** In this research, target users perform computer working and other activities like reading. So, the desk size was recommended by 160 cm length x 90 cm wide as official desk in considering work envelope concept, nature of task and anthropometric dimensions of the target users (shown in figure 4).

Desk height: Most of the computer workstation guidelines such as ***OSHA (2008), CAN/CSA-Z412, ISO-9241, ANSI/HFES-100, AS-3590.2,*** and other researchers recommend the height adjustable desk for easily accommodate the knee without any problems [15, 47-49, 61]. Desk height should be adjustable with suitable keyboard-forearm relation and adequate leg room [42] . Desk height was recommended by considering the summation of popliteal height and sitting elbow height values from female 5th percentile to male 95th percentile with added the shoes allowance 2.5 cm that was ranged from 52.38 cm to 85.42 cm (shown in figure 4).

3.4.3. Placement of Computer Accessories with Postural Guidelines

Keyboard: Placement of keyboard should in such way that it will not create any problem on arms, wrists, neck and shoulders. So, it was recommended to place the keyboard at least at elbow height [66].

Monitor: Computer monitor should be placed in such way that will prevent eyestrain and neck pain. Placement depends on individual's visual capacities, task requirements, screen characteristics, comfortable viewing distance. Recent studies suggested that computer monitor placement should be placed according to the individual's need of user within a moderate height range below the eye level with physiologically favorable head inclination [45, 67]. *OSHA (2008*) proposes to place the monitor 50-100cm away from the users with maintaining viewing angle 15° - 20°[47]. ***AS-3590.2*** proposes a low monitor position that is between 32° and 45° below horizontal eye level [49] while ***ANSI/HFES-100*** proposes a mid-position that is between 15° and 25°[61]. ***AS-3590.2*** specifies viewing distances between 35 and 75 cm which are closer than those recommended in ***CAN/CSA-Z412-M89*** and ***ANSI/HFES-100***[48, 49, 61]. However, user often reports that 50cm viewing distance causes more fatigue than 100 cm [68]. Most of the authors recommended that monitor should be placed 63-85 cm away from users at or below the eye level with comfortable viewing angle [40, 69]. In the current study suggested monitor should be placed 50-100 cm way from the user with maintaining viewing 15° - 20° (shown in figure 5).

Posture: In this research, authors recommended to maintain neutral postures while sitiing (shown in figure 5).

4. Conclusion and Recommendations

4.1. Conclusion

The primary focus of the current study was to investigate the prevalence of ergonomic issues/problems among the teachers and their workstations through a design of an ergonomic workstation to overcome these problems. High prevalence of musculoskeletal pain was observed among the users reported by ergonomic assessment (Health survey). It was also noticed that most of users were mismatched with their workstation furniture compared to their anthropometric measurements. Prevalence of MSDs, in the current study indicates that these problems are directly associated with physical workstation characteristics (office equipment), workload characteristics, human behaviors and perceptions towards ergonomics. An ergonomic computer workstation was designed for the teachers based on their anthropometric dimensions and related ergonomic guidelines. It is expected that implementation of suggestions and ergonomic guidelines in physical workstation designing, will reduce user's discomfort and enhancing their performance and productivity.

It is a common practice nowadays to buying furniture following the concept of "one-size-fits-all" in educational institution rather than adjustable furniture due to excessive cost of furniture that accommodate 90% of the target population. Very few researches have been conducted on cost reduction of ergonomic adjustable furniture. In this regard, the focus will be placed on reducing manufacturing cost. This research can contribute a lot for ergonomic furniture design to the university authorities as well as other organizations and create a sense to overcome the ergonomic problems. All these factors contribute to organizational effectiveness, productivity, health and safety of computer users. Moreover, arrangement of basic ergonomic training like workstation setup, posture practicing and related other issues by the organization is necessary to overcome this threat. Similar study can be conducted to other organization to assess the health condition and ergonomic practices of the computer users which can inspire to manufacturers to design ergonomic furniture.

4.2. Recommendations

Ergonomic problems can be solved to redesign the existing workstation's furniture and its adjustment. As it is difficult to eliminate all critical problems of health survey just collecting anthropometric measurements, all responsible administrations and managements of universities are recommended to consider the following.

1. Anthropometric considerations must be incorporated with furniture procurement process to avoid musculoskeletal symptoms caused by prolonging computer usage.
2. QFD (Quality Function Deployment) and Kano Model with ergonomic integrations should be incorporated with the furniture designing process.
3. It is highly recommended that frequent seminar and workshop should be arranged by the universities creating awareness on negative effect of poor posture and practice neutral posture practicing when working.

Acknowledgement

The authors are very much grateful to Khulna University of Engineering and Technology (KUET), Bangladesh, for providing its lab facility to pursue this research.

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Appendices A

Ergonomic Assessment (Health Survey)

Name:
Designation:
Age:
Date of Assessment:

Question: Do you experience pain or discomfort in any following parts of the body when using your computer? If "yes", mention please which part of your body?

a) Neck b) Shoulders/upper arm c) Upper back d) Lower back e) Elbow/ forearm

f) Wrist/Hand g) Hips/Buttocks/Thighs h) Knees and legs i) Feet/ Ankles

Please mention in which form is affected?

i) Constantly (most time of the day)

ii) Frequently (more than four times a month)

iii) Occasionally (two to four times a month

iv) Never

User Signature