An Anthropometric Computer Workstation Design to Reduce Perceived Musculoskeletal Discomfort

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Abstract

Musculoskeletal disorders have been observed and experienced widely at workplaces where the computers are frequently used. Increase in the number of employees working with computer and mouse coincides with an increase of work-related musculoskeletal disorders (WRMSDs) and sick leave, which affects the physical health of workers and pose financial burdens on the companies, governmental and non-governmental organizations. This study investigates the impact of musculoskeletal discomfort on computer workstations used by office workers. Anthropometric measurements were collected to design the most suitable computer workstation to reduce the perceived musculoskeletal discomfort. The significance of this study is to provide guidance for solving problems related with costly health problems (direct cost) and lost productivity(indirect cost) due to perceived musculoskeletal discomfort , and relieving the imposed economic burden.

Keywords
Work-related musculoskeletal disorders, computer design, anthropometry

1. Introduction
According to The National Institute for Occupational Safety and Health (NIOSH) in the USA , Musculoskeletal Disorders (MSD) are defined as; "a disorder which affects one or multiple body parts of the human musculoskeletal system which covers bones, tendons, joints, nerves, ligaments, cartilage, spinal discs and blood vessels. These parts of human body be can affected by performing repetitive activities during various job actions. Other catalyzers are the conditions which would result in MSDs such as eating habits, local injuries, pregnancy, physical condition and daily life routines.

Each person has unique physical capacity and certain job positions need high level of physcial activity. However, during work period, jobs can be classified according to different physical requirements. Appointing correct person in/to correct position should be the primary focus. Therefore generalizing jobs according to their physical requirements significantly contribute to work related muscular discomfort. Incorrect appointment of a worker in a position could cause Work Related Musculoskeletal Disorders (WRMSDs). These can affect employee's overall performance significantly and in the long run, these can result in permanent serious injuries. Researches on WRMSDs proved that there are many possible body part can feel pain as like as; shoulders, wrists, neck, elbows and hands (Korhan and Mackieh, 2010).

Musculoskeletal disorders have been observed and experienced widely at workplaces where the computers are frequently used. Increase in the number of employees working with computer and mouse coincides with an increase of work-related musculoskeletal disorders (WRMSDs) and sick leave, which affects the physical health of workers and pose financial burdens on the companies, governmental and non-governmental organizations. This study aims to investigate the impact of musculoskeletal discomfort on computer workstations used by office workers. Diagnoses of WRMSDs in work environment are not easy and researchers may need to observe employees individually. Moreover, discomforts in working environment can cause psychological complicacies as well.

Increased hours of computer use, perceived stress levels and workstation factors have also been found to be associated with upper extremity musculoskeletal pain. Evans and Patterson (2000) conducted an epidemiological field study on 170 subjects from Hong Kong workplaces in order to determine the incidence of neck and shoulder pain in a non-secretarial population of computer users. They tested the hypothesis that poor typing skill, hours of computer use, tension score and poor workstation setup are associated with neck and shoulder complaints. Sixty five percent of subjects recorded pain. Through regression analysis, they found that tension score and gender were the only factors to predict neck and shoulder pain.

Park et al. (2000) proposed a new concept VDT workstation chair with an adjustable keyboard and mouse support to minimize the physical discomfort and the risk of CDTs at work sites. Based upon the result of 3-D graphical simulations, a mock-up chair was constructed with an adjustable keyboard/mouse support directly attached to the chair body. They constructed an experiment to compare the new workstation chair to a conventional computer chair without a keyboard and mouse support by measuring muscle fatigue and subjective discomfort. Their statistical results indicated that the new concept VDT chair generally improved subjective comfort level and reduced fatigue in the finger flexor/extensor and the low back muscles.

In their study, Fogleman and Lewis (2002) studied the risk factors associated with the self-reported musculoskeletal discomfort in a population of video display terminal (VDT) operators. They collected data via a survey from 292 VDT users, and asked to report on symptoms for six body regions, as well as job requirement information, demographic information, and non-occupational hobbies. They constructed factor analysis to determine descriptive information and logistic regression to estimate the risk. Their results indicated that there is a statistically significant increased risk of discomfort on each of the body regions (head and eyes, neck and upper back, lower back, shoulders, elbows and forearms, and hands and wrists) as the number of hour of keyboard use increases. Moreover, their results showed that improper monitor and keyboard position were significantly associated with head/eye and shoulder/back discomfort, respectively.

Shuval and Donchin (2005) examined the relationship between ergonomic risk factors and upper extremity musculoskeletal symptoms in VDT workers, by taking into account individual and work organizational factors, and stress. Their data was derived from a questionnaire responded by 84 workers from computer programmers, managers, administrators, and marketing specialists, while ergonomic data were collected through two direct observations via rapid upper limb assessment (RULA) method. Their results of RULA observations indicated that excessive postural loading with no employee in acceptable postures. Hand/wrist/finger symptoms were related to the RULA arm/wrist score (in a logistic regression model) as well as working with a VDT between 7.1 and 9 hours per day. Neck/shoulder symptoms were related to: gender (female), working more than 10 hours per day, working for more than 2 years in a hi-tech company, and being uncomfortable at the workstation.

Computer display height and desk design to allow forearm support are two critical design features of workstations for information technology tasks. There is inconsistent evidence on the effect of forearm support on posture and no evidence on whether these features interact. In their study, Straker et al. (2008) compared the 3D head, neck and upper limb postures of 18 male and 18 female young adults whilst working with different display and desk design conditions. Their results show that there was no substantial interaction between display height and desk design, and lower display heights increased head and neck flexion with more spinal asymmetry when working with paper. Furthermore the curved desk, designed to provide forearm support, increased scapula elevation / protraction and shoulder flexion / abduction.

Søndergaard et al. (2010) examined the variability of sitting postural movement in relation to the development of perceived discomfort by means of linear and nonlinear analysis. Nine male subjects participated in this study. They recorded discomfort ratings, kinetic and kinematics data during prolonged sitting. They calculated body part discomfort index, displacement of the center of pressure (COP) in anterior– posterior and medial–lateral directions as well as lumbar curvature. They used standard deviation and sample entropy to assess the degree of variability and complexity of sitting. They performed a correlation analysis to determine the correlation of each parameter with discomfort. Their results showed that were no correlations between discomfort and any of the mean values. On the contrary, the standard deviations of the COP displacement in both directions and lumbar curvature were found to be positively correlated to discomfort, whereas sample entropies were negatively correlated. Their study suggested that the increase in degree of variability and the decrease in complexity of sitting postural control were interrelated with the increase in perceived discomfort.

Taieb-Maimon et al. (2010) conducted an intervention study to examine the effectiveness of an innovative self-modeling photo training method for reducing musculoskeletal risk among office workers using computers. They randomly assigned sixty workers were randomly assigned to either: 1) a control group; 2) an office training group that received personal, ergonomic training and workstation adjustments or 3) a photo-training group that received both office training and an automatic frequent-feedback system that displayed on the computer screen a photo of the worker's current sitting posture together with the correct posture photo taken earlier during office training. They evaluated musculoskeletal risk by using the Rapid Upper Limb Assessment (RULA) method before, during and after the six weeks intervention. Both training methods provided effective short-term posture improvement; however, sustained improvement was only attained with the photo-training method. Both of their interventions had a greater effect on older workers and on workers suffering more musculoskeletal pain. Their results provided that the photo-training method had a greater positive effect on women than on men.

Yang and Cho (2011) compared the posture and muscle patterns between male and female computer users with musculoskeletal symptoms. They recruited forty computer users to perform a preferred speed typing, a fast speed typing, and a repetitive mouse task. They found that there were significant differences between genders for head and neck flexion angles when they were performing the preferred speed typing task. They also found that significant differences between genders for upper extremity angles when they were performing the repetitive mouse task. According to them, in general, postural differences were significant between genders, even when the subjects' table and chairs were adjusted to meet their anthropometry.

2. Methodology

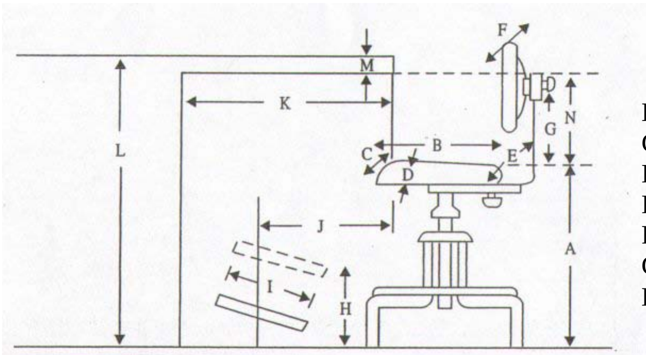
Designing a computer workstation requires more than just putting a computer on a standard office desk and providing an adjustable chair. The design of computer workstation includes the work envelope (range of movement), work surfaces (such as desks, tables, etc.), and seats as well as the design and location of computer screen, keyboard, and mouse. The design of the computer workstation should clearly be rooted in the use of anthropometric data.

In this study, we have specifically developed a questionnaire based on the U.S. National Institute for Occupational Safety and Health (NIOSH) Symptoms Survey and the Nordic Musculoskeletal Questionnaire to gather data on upper limb symptoms. The questionnaire covers the usual background information (age, sex, occupational history), the present job position, the nature of symptoms (ache, numbness, tingling, burning, pain, weakness, cramping, swelling, loss of color, stiffness), trouble and discomfort areas (neck, shoulders, elbows, wrists/hands, upper back, lower back, hips/thighs/buttocks, knees, ankles/feet), the notification and duration of the problems, plus medical history asking about any medical treatment for the problem.

The questionnaire was given to twenty staff, research assistants and faculty members from Eastern Mediterranean University (EMU) who work intensively with the computers. Anthropometric data were collected from each participant they were working on their computer workstations. No previously set-up workstation has been used for this particular study. The anthropometric data included seat parameters from a workstation (Fig. 1), as well as seated body dimensions (Fig. 2). Anthropometric measurements were collected to design the most suitable computer workstation to reduce the perceived musculoskeletal discomfort.

Descriptive statistics were used for anthropometric data, as well as the results from the questionnaire. Summary statistics for body postures included the mean and the signal amplitude percentiles ranging from 5 to 95. The difference between 5 and 95 percentile provides a measure of range of motion (Johnson, 1988).

Logistic regression was used to develop a meaningful and statistically significant relationship between work-related musculoskeletal disorders and computer use. Our dependent variable was the "medical treatment for WRMSDs" by a medical doctor (dichotomous dependent variable), and the independent variables were the rest of the variables in the questionnaire.



B-	Seat height	H-	Footrest height
C-	Seat depth	I-	Footrest depth
D-	Seat width	J-	Footrest distance
E-	Seat pan angle	K-	Leg clearance
F-	Seat back to pan angle	L-	Work surface height
G-	Seat back width	M-	Work surface thickness
H-	Lumbar support	N-	Thigh clearance

Figure 1: Seat parameters

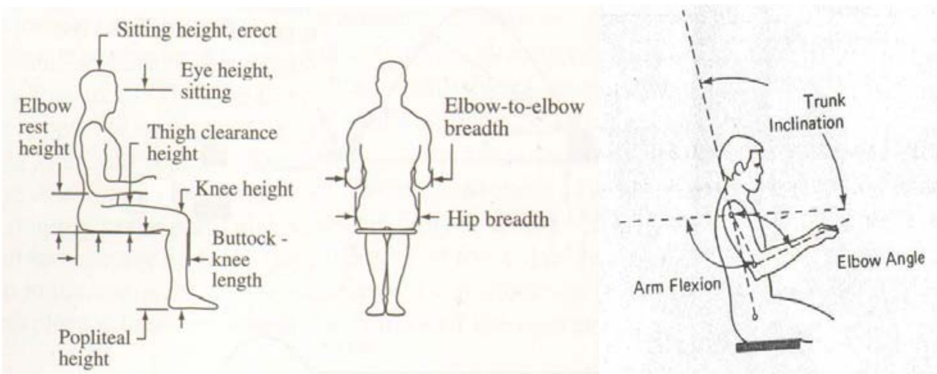


Figure 2: Seated body dimensions computer users

3. Results

The questionnaire was given to 20 staff, research assistants and faculty members from Eastern Mediterranean University (EMU) who work intensively with the computers. The reason for targeting such diverse disciplines is that the target population is expected to use computers intensively especially for work/business purposes and several other auxiliary purposes including personal and communication. Thus the results are guaranteed not to be task-related, instead work-related.

The results showed that 65% of the respondents were male (*n*=13) and 35% of them were female (*n*=7). It was observed that the average age of the respondents were 35.55 ± 9.09 (*n*=20).

Table 1 illustrates the descriptive statistics of the seat parameters, where it was found that seat width (38±2.791), seat pan angle (11.55±3.762), lumbar support (23.55±5.16), footrest distance (22.25±7.34), and leg clearance (54.05±66) used by the participants in their computer workstation did not fit into the acceptable design values determined by ANSI (1988) and Eastman Kodak (1983). Moreover, it was observed that none of the respondents used a footrest.

Table 1. Seat parameters descriptive statistics versus acceptable design values (*n*=20)

Parameter	Mean (cm)	St. Dev. (cm)	Minimum (cm)	Maximum (cm)	Acceptable Value (cm)
Seat height	48.450	4.123	40.000	54.000	40 – 52
Seat depth	38.550	2.373	35.000	44.000	38 – 43
Seat width	38.000	2.791	34.000	47.000	≥ 46.2
Seat pan angle	11.550	3.762	2.000	20.000	$-10^0 - +10^0$
Seat back to pan angle	97.50	9.41	80.00	115.000	$> 90^0$
Seat back width	37.150	4.017	31.00	44.000	> 30.5
Lumbar support	23.55	5.16	12.00	30.00	15 – 23
Footrest height	13.800	3.592	10.00	22.000	2.5 – 23
Footrest depth	0.00	0.00	0.00	0.00	30.5
Footrest distance	22.25	7.34	12.00	43.00	42
Leg clearance	54.05	13.12	30.00	80.00	66
Work surface height	75.350	1.226	74.00	80.000	~81
Work surface thickness	4.050	0.2236	4.00	5.000	< 5
Thigh clearance	26.65	4.55	18.00	33.00	> 20

Correlation analysis was constructed in order to determine any relationship between the variables. It was observed that there were 10 positive correlations (r>0.50), and 5 negative correlations (r<0.50) at 0.05 level. Table 2 and table 3 illustrate the positive correlations and negative correlations, respectively with the corresponding correlation coefficient between the variables. The results showed that the anthropometric measurements were both positively and negatively correlated to the workstation seat parameters.

Table 2. Positive correlations (r>0.50)

Variable 1	Variable 2	Correlation Coefficient
Seat Back Width	Seat Depth	0.5153
Lumbar Support	Thigh Clearance	0.963238
Eye Height	Footrest Height	0.789188
Popliteal height	Seat Height	0.715075
Popliteal height	Eye height	0.513409627
Thigh Clearance Height	Sitting Height	0.736741001
Elbow-to-elbow Height	Eye Height	0.504426948
Elbow-to-elbow Height	Thigh Clearance Height	0.542565901
Hip Breadth	Sitting Height	0.500225509
Hip Breadth	Thigh Clearance Height	0.618827832

Table 3. Negative correlations (r>0.50)

Variable 1	Variable 2	Correlation Coefficient
Hip Breadth	Footrest Height	-0.55314
Hip Breadth	Work Surface Height	-0.51488
Hip Breadth	Eye Height	-0.531328352
Sitting Height	Work Surface Height	-0.57952
Leg Clearance	Work Surface Height	-0.50493

Table 4 illustrates the list of the eleven significant risk factors which contribute to the formation of WRMSDs in computer workstations. The logistic regression was used because many of the independent variables were qualitative and the normality of residuals cannot be guaranteed.

Table 4. Significant predictors of WRMSDs ($p < 0.05$)

Predictor	*p* value	Odds Ratio	95% CI
Neck problem	0.031	0.04	0.00 – 19.58
Shoulder problem	0.035	1.75	0.56 – 5.42
Wrist problem	0.025	5.54	0.29 – 104.26
Upper Back problem	0.028	29.75	0.06 – 15579.27
Lower Back problem	0.040	4.25	0.15 – 123.21
Trunk Inclination	0.046	1.07	0.89 – 1.29
Arm Flexion	0.023	1.15	0.92 – 1.43
Elbow Angle	0.081	0.93	0.76 – 1.14
Thigh clearance height	0.019	0.47	0.15 – 1.45
Popliteal height	0.012	0.61	0.33 – 1.15
Hip breadth	0.029	1.44	0.73 – 2.85

Table 5 illustrates the seated body dimensions of the computer users. Knowing what parameters to design for while the user is seated can help increase the comfort of the user. Therefore applying the below design dimension is expected to increase computer user's comfort during work, thus decrease the perceived musculoskeletal discomfort.

Table 5. Seated body dimensions of computer users (*n* = 20)

	Dimension (cm)					
	Female (*n*=7)			Male (*n*=13)		
Body Dimension	5th	50th	95th	5th	50th	95th
Sitting height	77	82.7	126	78	88.2	128
Eye height	111	119	183	110	120	181
Elbow rest height	21	27.9	34.4	21	29.5	34.6
Thigh clearance height	10	12.9	17.2	11	16	18.7
Knee height	47	52.7	77.5	51	56.7	84.7
Buttock knee length	51	59.3	83.7	46	57.7	76.1
Popliteal height	40	47.4	65.6	39	48.5	64.8
Elbow-to-elbow	39	46.9	64.7	45	53.7	73.8
Hip breadth	27	33.3	44.1	27	35.8	45

4. Discussion

WRMSDs, repetitive strain injuries (RSI) and cumulative trauma disorders (CTD) cause pain, slow responses, increased probabilities of accidents, reduced quality of life and working ability in aging working population (Jensen et al., 2002). Our study provides a self-reported assessment on the perceived musculoskeletal discomfort by computer users from the EMU. This study investigates the anthropometrics of a computer workstation, provides the significant predictors which contributes into the formation of WRMSDs due to computer work, and proposes a computer workstation design dimensions which would reduce the perceived musculoskeletal discomfort in EMU personnel.

Our statistics showed that seat width (38±2.791), seat pan angle (11.55±3.762), lumbar support (23.55±5.16), footrest distance (22.25±7.34), and leg clearance (54.05±66) used by the participants in their computer workstation did not fit into the acceptable seat design parameters values. It was observed that there were 10 positive correlations ($r>0.50$), and 5 negative correlations ($r<0.50$) at 0.05 level between the anthropometric measures and the seat parameters. We have also shown that eleven risk factors were significant predictors of WRMSDs.

5. Conclusion

The significance of this study is that it provides guidance design parameter for solving problems related with perceived musculoskeletal discomfort. WRMSDs are costly health problems (direct cost) and they also result in lost productivity (indirect cost). The proposed new dimensions for a computer workstation are expected to relieve the imposed economic burden.

The collection of data from a wider area of recruitment in North Cyprus would provide greater generalizability to the study. Moreover, a wider array of technological background and especially educational level may yield different results. Further research is also required to validate and verify the improvements made by the new computer workstation design. The respondents of the questionnaire, who have experienced musculoskeletal symptoms, should be invited to a lab experiment, where surface electromyogram (sEMG) used to record muscle load, muscle force and muscular fatigue for validation and verification.

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