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Reducing Perceived Musculoskeletal Discomfort in Office Employees through Anthropometric Computer Workstation Design

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ABSTRACT Numerous office employees who work with computer workstations endure various musculoskeletal discomforts every day. This study intends to reduce musculoskeletal discomfort caused by desktop computer workstations, which causes productivity losses and several medical costs. A survey was distributed to 42 participants who use desktop computer workstations for at least 6 hours per day. Specific anthropometric measurements were collected to design an optimized computer workstation. Ten respondents were randomly selected to participate in an electromyogram (EMG) experiment to determine muscular impulse differences between standard and optimized desktop computer workstations. The EMG results indicated that discomforts are pronounced in shoulder, neck, lower and upper back and hand-wrist regions. The risk assessment model showed that experiencing troubles in the neck (p=0.022), shoulder (p=0.023), and wrist/hands (p=0.020) within 12 months were the significant factors. ANOVA results proved that the optimized design of a computer workstation causes less muscular pressure on the muscles at each measured body region.

INTRODUCTION

Working with computers has become a constant in today's world of business. As useful as these devices are, they can also be significantly damaging for those who continuously utilize them. Often, employers mismatch the capacities of their employees and the tasks in hand. As incompatible users perform repetitive tasks for extensive hours, they impair their musculoskeletal system. The employees' erroneous daily life practices such as, eating habits and seating routines established within their working environments further stimulate and agitate injuries. As a result, numerous workers develop various work-related musculoskeletal disorders (WRMSDs).

Companies may choose to supply their workstations either with desktops or with laptops. Ordinarily, the price, portability and the technological functionalities of computers affect the employers' preference. Although laptops have been outselling desktops for the past several years, desktops certainly still dominate the modern office workstations.

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Improper use of computers can cause serious physical injury to the user even if the duration of use is less trivial. Finding correct exposure while using a computer can dramatically help prevent such injuries.

The objective of this research is to study the grounds and the consequences of WRMSDs caused by desktop computer workstations. The research investigates the ergonomic discrepancies of such workstations and their effects on office employees.

Literature Review

Economic impacts are still a huge question mark regarding WRDSMs and further researches will improve importance of WRDSMs in economical currencies. However, some measurements are showing the approximate importance of WRDSM such as,the Institute of Medicine's productivity lost and wage lost are estimating between USD 45 billion and 54 billion per annum (U.S. Department of Labor/2009). EU-OSHA provided that seventy-five percent of all the occupational diseases in 2005 were musculoskeletal disorders. In the UK, 8.3 million days were lost due to MSDs in 2013-2014 (Health and Safety Executive 2014).

One of the first researches in the literature was carried by Hagberg et al. (2002), where they conducted a study to evaluate whether self-reported productivity occurred in computer users due to MSD and their association to workplace and individual factors. Their results indicated that eight point four percent of men and eight percent of women reported reduced productivity due to MSD symptoms, and the mean reduction in productivity for men was thirteen percent and fifteen percent for women.

Ergonomic interventions are applied to improve the worker productivity and overcome health related problems. Taieb-Maimon et al. (2012) examined the effectiveness of a new method to reduce the risks to have musculoskeletal problems among office workers who use computers. Their results indicated that interventions had better effects on older employees and workers who suffer from musculoskeletal pain, and also the new method had more positive effect on women than on men.

Not only physical interventions, but also organizational interventions are significant in offices. Kirk et al. (2013) invested the impact of training methods on levels of WRMSD illustrating how the application of new training strategies may improve WRMSD outcomes. Their findings suggested that designing training to develop multidisciplinary work skills or competencies may be a strategy for the management of occupational musculoskeletal discomfort amongst computer operators.

The effectiveness of workplace-based participatory ergonomic interventions was discussed by several researches in the literature. Davis and Kotowski (2014) studied different interventions aimed at promoting postural changethat could increase body movement throughout the shift and reduce musculoskeletal discomfort. Their results illustrated that there were significant reductions in reported short-term shoulder, upper back, and lower back discomfort, and about a ten percent increase in productivity after intervention.

Beyond the interventions, some studies aimed to provide the significant risk factors of MSDs among computer users. Calik et al. (2014) investigated the effects of computer usage on the musculoskeletal system discomforts (MSD), the possible risk factors and study implications. Their results showed that neck, lower back and upper back areas were determined to be the most affected areas.

In a recent study by Dockrell et al. (2015), the prevalence of computer-related musculoskeletal symptoms was studied among laptop computer users. Their results showed that although the reported duration of computer use was quite low, the prevalence of computer-related musculoskeletal symptom was high (52.8%).

Acedo et al. (2015), using EMG, compared the muscle relaxation of the upper trapezius induced by the application of transcutaneous electrical nerve stimulation (TENS) and interferential current (IFC) in females with chronic nonspecific neck discomfort. Their results indicated that IFC induced the upper trapezius relaxation after three sessions in females with neck discomfort, but the TENS application did not change the muscular tension.

In the literature, there has been no study, which focused the anthropometric intervention, which was later evaluated by EMG analysis. Thus, this study fills the gap in the literature by measuring the muscular activities (using EMG) after an anthropometric intervention. As a contribution to the industry, this study intends to reduce musculoskeletal discomfort caused by desktop computer workstations, and therefore, to diminish psychological and financial demises for workers, decreased job performance for companies, monetary loss for businesses, and social security expenses for citizens.

METHODOLOGY

Based on the National Institute for Occupational Safety and Health (NIOSH) Symptoms Survey and the Nordic Musculoskeletal Questionnaire (NMQ), a questionnaire was compiled to gather data on upper limb symptoms, and given to 42 participants from Eastern Mediterranean University who use desktop computer workstations for at least 6 hours per day for work purposes.

The participants were questioned about their personal information such as age, sex and gender, occupational background, current job description, the nature of their symptoms, the areas of discomfort, the duration and the notification period of the disorder, and the existence of any prior medical treatment regarding the matter.

The questionnaire aimed to determine WRMSDs in short term, long term and possibility of chronicle troubles. It had three columns and every column defines a specific time period.

The first column's questions were, "Have you had experienced any trouble at any time during the past 12-month period (such as pain, aches, discomfort, numbness) in upper and lower back, neck, shoulder, elbow, wrist parts?"

The second column helped realize that if there was trouble, was it chronic or not. The question in the second column is about having any trouble in the one-week period in muscle groups defined in first column.

The third column of the questionnaire aimed to determine if there were troubles, did those troubles affect the participants in their daily life, like preventing hobbies, jobs or any other normal activities.

Another set of questions wasalso introduced to classify troubles. If there were relations to WRMSDs, trying to determine duration of problems and episodes repetition, trying to sort of troubles like aching, burning, loss color, pain, and swelling, then medical help received by participants due to their problem were asked in questionnaire. Finally, the lost days because of problem were asked for.

The anthropometric data of participants was obtained as subjects worked on their existing workstations. Seat parameters and seated body dimensions were recorded. Signal amplitude percentiles ranging between 5 and 95 were incorporated into body posture statistics. Subsequently, the results were analyzed to establish the criteria for the most ergonomic desktop computer workstation.

As a result, two desktop computer workstations, one based on anthropometric measurements, and the other on standard desktop computer workstations with fixed office furniture, were constructed.

Amongst 42 contributors, 10 people who have no background of previous musculoskeletal disorder were selected randomly to partake in a surface electromyogram experiment designed to investigate the impact of musculoskeletal discomforts caused by desktop computer workstations. Data collection regions were six of body regions. The regions are, extensor digitorum (elbow/forearm), flexor retinaculum (hand/wrist), posterior trapezius (neck), rhomboideus major (upper back), posterior upper deltoid (shoulder) and sacropinalis (lower back).

MyoTrac Infiniti, model SA9800 (surface EMG device) had two channels, therefore six muscle measurements were divided into three sections with two muscle groups at a time. Each muscle's pressure was recordedat 10-minute periods, which were repeated thrice (total of 30 minutes) and given a 10-minute break in between sections for old workstations.Aftera day's rest, thedata collection continued for the same respondent on the optimized desktop computer workstation.

Ergonomically designed furniture can reduce pain and injury, increase productivity, improve morale, and decrease complaints by accommodating different physical dimensions and requirements of the job. In order to design new computer workstations, from 42 respondents, anthropometric measurements were collected based on seated body and workstation dimensions, and arm flexion, trunk inclination and elbow angles were collected.

Logistic Regression was used to determine a risk assessment model for WRMSDs due to computer workstation. The dependent variable was question 31 in the questionnaire, which was regarding any medical treatment for the WRMSDs. The independent variables were selected to be the variables from the rest of the questions in the questionnaire.

An analysis of variance (ANOVA) was used to test the mean musculoskeletal strain in time for ten respondents (those attended EMG experiment). Time consumption for the six body regions was the same, first for the old workstation. Later, ANOVA was also applied to test the same hypothesis on the six body regions, but this time for the EMG data collected from new anthropometrically designed optimal workstation.

RESULTS

The age interval of the respondents who attended to the questionnaire was found to be between 22 and 54years, with a mean of 36.6. 22 of 42 participants were female (52%) and 20 of participants were male (48%).

There are several findings, which provide significant problems in specific body parts of respondents. Table 1 shows that the neck, lower back, shoulders and upper back troubles were the most common discomforts suffered by the respondents.

Table 1: Respondent answers to questionnaire (*n*=42)

	Question	*Yes (%)*	*No (%)*
1	Trouble in neck during last 12 month	57	43
2	Trouble in neck during last 7 days	31	69
3	Any prevention from normal life due to neck problem in last 12 month	26.2	73.8
4	Trouble in shoulder during last 12 month	47.6	52.4
5	Trouble in shoulder during last 7 days	33.3	66.7
6	Any prevention from normal life due to shoulder problems in last 12 month	28.6	71.4
7	Trouble in elbows during last 12 month	2.4	97.6
8	Trouble in elbows during last 7 days	4.8	95.2
9	Any prevention from normal life due to elbows problems in last 12 month	2.4	97.6
10	Trouble in wrists/hands during last 12 month	31	69
11	Trouble in wrists/hands during last 7 days	21.4	78.6
12	Any prevention from normal life due to wrists/hands problems in last 12 month	19	81
13	Trouble in upper back during last 12 month	38.1	61.9
14	Trouble in upper back during last 7 days	33.3	66.7
15	Any prevention from normal life due to upper back problems in last 12 month	31	69
16	Trouble in lower back during last 12 month	47.6	52.4
17	Trouble in lower back during last 7 days	33.3	66.7
18	Any prevention from normal life due to lower back problems in last 12 month	31	69
19	Trouble in hips/thighs/buttocks during last 12 month	12	88
20	Trouble in hips/thighs/buttocks during last 7 days	7.1	92.9
21	Any prevention from normal life due to hips/thighs problems in last 12 month	4.8	95.2
22	Trouble in knees during last 12 month	16.7	83.3
23	Trouble in knees during last 7 days	4.8	95.2
24	Any prevention from normal life due to knees problems in last 12 month	14.3	85.7
25	Trouble in ankles/feet during last 12 month	19	81
26	Trouble in ankles/feet during last 7 days	11.9	88.1
27	Any prevention from normal life due to ankles/feet problems in last 12 month	11.9	88.1

During the last 12 months, fifty-seven percent of the respondents provided that they suffered from neck troubles, 47.6 percent provided that they suffered from lower back and shoulder troubles, and 38.1 percent stated that they suffered from upper back troubles.

During the last 7 days, 33.3 percent of the respondents provided that they suffered from shoulder, upper back, and lower back troubles. Also, thirty-one percent of the respondents stated that they suffered from neck troubles.

Table 1, moreover, illustrates that one-third of the respondents (33%) were prevented from daily activities during the last 12 months, due to the discomforts experienced in the lower back and upper back regions. Having shoulder problems prevented 28.6 percent, and neck problems prevented 26.2 percent of the respondents from living a normal life within the 12 months.

The respondents stated elbow, wrists/hand, hips/thigh/buttocks, knees, and ankles/feet problems as not significant during the last 7 days and 12 months.

Table 2 illustrates that in the questionnaire, a total of forty-eight percent of the respondents experienced shoulder problems within the previous 12 months. Moreover, thirty-one percent of the respondents reported that they had muscular discomfort in their wrist/hand regions. However, muscular discomfort in the elbows was not significant among the respondents.

Table 2: Muscular discomfort experience frequencies within previous12 months (*n*=42)

	No (%)	*Yes (%)*		
		Right	*Left*	*Both*
Shoulder	52	7	5	36
Elbows	98	0	0	2
Wrist / Hands	69	7	5	19

Logistic Regression was used to determine WRMSDs due to computer workstation. Thus, a risk assessment model was created, where experiencing neck trouble within 12 months (p=0.022), having shoulder trouble within 12 months (p=0.023), and experiencing trouble at wrist/hands within 12 months (p=0.020) were found out to be the significant factors (Table 3).

After completing the questionnaire, anthropometric measurements had also been collected from the 42 participants. According to their workstations and sitting posture, 5^{th}, 50^{th}, 95^{th} percen-

Table 3: Significant Predictors of WRMSDs

Significant predictor	*p*	*OR*	*95% CI*
Neck trouble within 12 months	0.22	4.12	0.47–36.17
Shoulder trouble within 12 months	0.023	0.44	0.22–0.89
Wrist/hand trouble within 12 months	0.020	1.66	0.49–5.65

tiles were calculated for the contributed participants (Table 4).

Table 4: 5th, 50th and 95thpercentiles of seated body dimensions (*n*=42)

Seated body dimension	*Percentiles (in cm)*		
	5th	*50th*	*95th*
Sitting height (erect)	70.35	82.22	94.09
Eye height (sitting)	104.9	116.32	127.73
Thigh clearance	9.54	14.12	18.7
Knee height	49.5	55.95	62.41
Elbow rest height	19.98	27.63	35.29
Buttock-knee length	48.77	57.93	67.08
Popliteal height	40.43	47.71	54.98
Elbow to Elbow Breadth	39.09	50.39	61.69
Hip Breadth	26.74	34.8	42.87

Table 5 shows workstation dimensional data (5th, 50th, and 95th percentiles) collected from the respondents.

Arm flexion, trunk inclination and elbow angles during the computer use were also measured for the participants (Table 6).

Ten respondents were randomly selected to participate in an electromyogram (EMG) experiment to determine muscular impulse differences between standard and optimized desktop computer workstations.

Table 7 shows mean, maximum, and minimum of EMG records of muscular activity of the 10 respondents while working on both standard and optimized computer workstations. EMG results revealed that there were significant reductions of the muscular activities in the wrists, elbows, shoulder, and neck regions while working on the optimized computer workstation. However, muscular activities in the lower back and upper back regions were observed to increase at the anthropometrically designed workstation.

Table 5: 5th, 50th and 95thpercentiles of workstation dimesions (*n*=42)

Workstation dimension	*Percentiles (in cm)*		
	5th	*50th*	*95th*
Height of seat	42.27	48.63	55.00
Depth of seat	33.83	39.71	45.58
Width of seat	34.36	40.80	47.25
Pan angle of seat	4.25	10.07	15.89
Seat back to pan angle	55.47	93.66	131.85
Seat back width	30.01	38.15	46.29
Support of lumbar	13.22	24.46	35.71
Footrest height	8.31	13.15	17.98
Footrest depth	-13.49	2.12	17.74
Footrest distance	11.98	25.00	38.02
Leg clearance	38.82	56.41	74.01
Work surface height	73.64	75.29	76.95
Work surface thickness	3.65	4.04	4.42
Thigh clearance	14.54	33.59	52.63

Table 6: 5th, 50th, 95thpercentiles of flexion, elbow angle and trunk inclination (*n*=42)

Seated body angles	*Percentiles (in cm)*		
	5th	*50th*	*95th*
Arm flexion	100.65	114.71	128.77
Trunk inclination	101.54	118.46	135.38
Elbow angle	81.66	98.22	114.78

ANOVA was applied to muscle activity recordings at both computer workstations to test the hypothesis (H_0 = mean of musculoskeletal strain in time of the 6 body region does not differ).

Table 7: Muscular activity from standard and optimized computer workstations (ìV)

Muscle region	*Workstation*					
	Standard			*Optimized*		
	Mean	*Max*	*Min*	*Mean*	*Max*	*Min*
Wrists	1169.12	1295.10	986.59	891.89	980.02	728.45
Elbows	1725.43	1862.82	1573.65	1309.11	1348.62	1200.21
Shoulders	1308.36	1354.18	1267.80	1023.02	1123.50	850.30
Neck	1535.88	1795.53	1369.57	1386.54	1475.79	1203.88
Lower back	1067.50	1295.50	869.53	1830.34	1861.64	1786.94
Upper back	574.47	633.87	501.08	1362.15	1391.65	1289.14

ANOVA results (Table 8) proved that the new optimized design of computer workstation provides less muscular pressure to the muscles at each measured body region (F_0, $<F_{ciritical}$= 2.578739). However, the findings provide that the standard workstation design imposed significant muscle activities ($F_0 > F_{ciritical}$) except at the shoulder region.

Table 8: ANOVA test results (*n*=10)

Muscle region	*F_0(Optimized Workstation)*	*F_0 (Standard Workstation)*
Wrist	0.176048	8.8825
Elbow	0.026966	2.6174
Neck	0.119925	4.9069
Shoulder	0.110821	0.001802
Lower back	0.004158	12.3584
Upper back	0.016508	6.2773

DISCUSSION

In their research, Fogleman and Lewis (2002) showed that improper keyboards and monitors position were significantly associated with eye and back, and shoulder and head discomforts, respectively. Also, Yang and Cho (2011) provided that overall postural variations between genders were significant, even when the subjects' table and chairs were adjusted to meet their anthropometry.

This study proved that anthropologically designed computer workstations would reduce the muscular pressure on the neck, shoulders, hand/wrist, elbow/forearm, upper back, and lower back regions. Thus, ergonomic interventions would be less required to overcome medical costs and loss of productivity caused by WRMSDs.

In their research, Søndergaard et al. (2010) showed that the variability of sitting postural movements in relation to the development of perceived discomfort are interrelated with the increase in perceived discomforts.

It has been widely accepted that the most critical design features of workstations are display heights and desk designs, as desks support forearms. Until Straker et al. (2008) studied the head, neck and upper limb postures young adults who work with various displays and desk designs, there had not been consistent evidence as to the effect of forearm support on posture and furthermore, there had not been any evidence as to the relationship of these features.

Won et al. (2009) dichotomized their subjects according to large/small shoulder width or arm length, instead of anthropometry, and their finding showed that muscle activity at the wrist and shoulder was more pronounced with smaller subjects. This particular study revealed that there were significant reductions of the muscular activities in the wrists, elbows, shoulder, and neck regions while working on the anthropometrically designed computer workstation

Golebowicz et al. (2015) suggested that the interventions help improve the awareness of body positions at the workstation and thus, pain was observed to decrease in some body parts. In this study, it has been proved that anthropometric interventions help overcome muscular discomfort and provide a convenient work environment for the office employees to be more productive.

In the long term, working with computers on non-ergonomic workstations may cause unrecoverable problems for employees, and it will economically hurt both, the place where employee works and employees themselves may suffer from health problems. That person even may have to leave specific work for long intervals because of musculoskeletal problems and medical treatments.

CONCLUSION

The questionnaire results provided that neck, lower back, shoulders, and upper back problems were the significant discomforts experienced by the respondents during the last 7 days and 12 months. In each type of these discomforts, almost one-third of the respondents were prevented from performing daily life activities.

The risk assessment model revealed that experiencing neck trouble within 12 months (*p*=0.022), having shoulder trouble within 12 months (*p*=0.023), and experiencing trouble in the wrist/hands within 12 months (*p*=0.020) were found out to be the significant factors.

EMG studies on 10 respondents proved that working with a computer imposes a significant impact on the area of the hands, elbow, neck, shoulders, upper back, and back. Thus, after anthropometric intervention and the optimized design of computer workstations, it was proved that there was less muscular pressure at each measured body region.

RECOMMENDATIONS

Collecting data from a greater population would provide huge generalizability to this study. Moreover, technological background with a wider array and especially level of education may yield results differently. Validating and verifying the improvements made by designed computer workstations required in further research.

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