# Anthropometric Computer Workstation Design To Reduce Perceived Musculoskeletal Discomfort

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# ABSTRACT

Numerous office employees who work with desktop computer workstations endure various musculoskeletal disorders every day. The objective of this study is to determine the most ergonomic desktop workstation for office workers.

A survey was prepared and distributed to 42 participants from Eastern Mediterranean University who use desktop computer workstations for at least 6 hours per day. Specific anthropometric measurements of the all of 42 subjects were then collected and amongst the contributors, 10 were randomly selected participate in a surface electromyogram experiment to determine muscular impulse differences between standard desktop computer workstations and optimized desktop computer workstations. This is aimed to compare stations due to research.

This research's main focus is seeking and providing the evidence of the symptoms those cause, musculoskeletal system and those symptoms' frequencies are significant in the development of work-related musculoskeletal disorders (WRMSDs). Discomforts in shoulder, neck, lower and upper back and hand-wrist region are more pronounced. Therefore 6 of those regions were recorded. Factorial analysis and records of the EMG's controls and tests group respondents proves risk factors which are determined in results part of thesis with help of ANOVA. Each test group respondents' determined data indicated, musculoskeletal strain's mean differs in time, but it is not true for the control group from experienced.

This study intends to reduce possible WRMSDs caused by desktop computer workstations. One other aim is eliminating psychological and financial losses for workers, minimize decrease in job performance for companies, monetary loss for businesses and reduce social security expenses for citizens.

**Keywords:** Work Related Musculoskeletal Disorders, Surface Electromyograph, sEMG, Anthropometry

# ÖZ


Masaüstü bilgisayar iş istasyonları ile çalışan birçok ofis elemanları, son zamanlarda çeşitli kas-iskelet bozuklukları yaşamaktadırlar.

Bu araştırmanın amacı, ofis çalışanları için en ergonomik masaüstü iş istasyonu belirlemektir.

Bir anket hazırlanarak, Doğu Akdeniz Üniversiteside günde en az 6 saat masaüstü bilgisayar iş istasyonu kullanan 42 katılımcıya dağıtıldı. Katılımcıların belirli antropometrik ölçümler alındıktan sonra, katkıda bulunanlar arasından 10 iştirakçi rastgele seçilerek, standart masaüstü bilgisayar iş istasyonları ve optimize edilmiş masaüstü bilgisayar iş istasyonları arasında kas dürtü farklılıklarını belirlemek için bir yüzey elektromiyogram deneyi uygulandı.

Tezin yazılmasındaki amaç, iskelet-kas sisteminde oluşan rahatsızlıkların belirtileri ve bu belirtilerin oluşum sıklığının kişilerin mesleki hayatlarında oluşturduğu etkileri araştırmak ve bulunan kanıtları sunmaktır. Çalışma hayatındaki bilgisayar başında harcanılan zaman diliminde kişilerin oturma ve bilgisayar kullanma şekillerinden oluşan rahatsızlıkların en yaygın olanları ağrı ve sızlama rahatsızlıkları olduğunu ortaya koyan bu araştırmada görülmüştür ki, rahatsızlıkların en falza omuz, üst sırt, boyun, el ve bilekle birlikte alt sırt bölgelerinde karşılaşılmaktadır. Risk faktörleri, test ve kontrol gruplarına ait yüzeysel EMG ölçüm değerleri, risk değerlendirme modeli tarafından belirlenmiş olup, ANOVA ve faktöryel çözümleme yöntemleri uygulanılarak doğrulanmıştır.

Çalışmaların sonuçunda ulaşılan veriler göstermektedir ki; ortalama iskelet-kas gerilimi test grubu katılımcılarında zamanla değişkenlikler gösterirken bu değişkenlikler kontrol grubu içerisinde görülmemiştir.

Bu çalışma, masaüstü bilgisayar iş istasyonlarının yol açtığı kas-iskelet hastalıklarını azaltmak, işçiler için psikolojik rahatsızlıkları ve finansal kaybı, şirketler için azalmış iş performansını, işletmeler için parasal kaybı, ve vatandaşlar için sosyal güvenlik giderlerini azaltmak veya ortadan kaldırmayı amaçlamaktadır.

**Anahtar Kelimeler:** Mesleki, Kas-iskelet Bozuklukları, sEMG, Yüzey Elektromiyagram, Antropometri

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# GLOSARRY

ANOVA: Analysis of Variance

ANSI: American National Standards Inst

BAuA: The German Federal Institute of Occupational Safety and Health

COP: Center of Pressure

EASHW: European Agency for Safety and Health

EMU: Eastern Mediterranean University

EU: European Union

MSDs: Musculoskeletal Disorders

NIOSH: National Institute for Occupational Safety and Health

NMQ: Nordic Musculoskeletal Questionnaire

RULA: Rapid Upper Limb Assessment

sEMG: Surface Electromyograph

SHARP: The Safety and Health Assessment and Research Prevention

SPSS(Software): Statistical Package for the Social Sciences

VDT: Video Display Terminal

WRMSDs: work-related musculoskeletal disorders

# Chapter 1

# 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. 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) and experience injuries in their bones, tendons, joints, nerves, ligaments, cartilages, spinal discs and even their blood vessels.

Even minor ache and pain cause discomforts and development into more serious medical problems or conditions which need some time interval off work and even medical treatment. Moreover, employees can be permanently disabled and lose their jobs, which may cause them to suffer both psychologically and financially. Apart from the economic burdens the employees would have to tackle, the employers would also face various financial challenges. Duties executed by unsuitable workers would mean reduced job performance for the company, which would bring about monetary loss for the business. Yet, worse off, the employers may have to face unbudgeted expenditures such as medical payments.

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.

The objective of this thesis 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.

A questionnaire had been created in order to determine and analyze the ergonomic risk factors inflicted upon workers. Ten subjects who had participated in a previous anthropometric study had been randomly selected and the muscle activities of critical body regions. Lower and upper backs, neck, wrist, shoulder and forearm, when using standard and optimally designed computer workstations were measured with a surface Electromyograph (sEMG) whilst respondents were typing on standard computer workstation and optimally designed computer workstation. sEMG results were then used to evaluate the survey. With help of data analysis, new designed computer workstation designed and sEMG tested with same respondent group. Data collection of both results helps to compare and reduce WRMSDs.

This study intends to determine a suitable desktop computer workstation for office workers and as result hopes to reduce and even eliminate WRMSDs.

# Chapter 2

# LITERATURE

## 2.1 Musculoskeletal Disorders

Musculoskeletal disorders (MSDs) occur at tendons , muscles, ligaments, nerves, or/and joints due to motions which are highly repetitive and pain causes characterized chiefly, loss of feelings, and weakness in specific body regions. Various risk factors are associated with MSDs. The most familiar of them are, excessive repeating of a task, frequent heavy lifting, bending, twisting, uncomfortable working position, exerting too much force, working without breaks, high job demands like deadline pressures, and unfavorable working conditions such as the office being too hot or just too cold. The signs of the disorder mainly may appear at lower back, in between the bottom of the ribs and the top of the legs. Although in majority of cases, such pain may disappear rather fast, for considerable amount of individuals this may not be the case.

The most common symptom of MSDs can be described as pain; however, at other times it may surface as joint stiffness, muscle tightness, redness, swelling, numbness, changing color on skin, and even decrease on sweating of hands. MSDs develop in stages, and in its initial stages, aching and tiredness of the affected limb occur only during work hours but disappear at night and during days off work. The employee continues to carry out his or her duties as before, without any reduction of work performance. However, later on along with reduced job performance, the employee starts to experience aching and tiredness both during and after work shift. MSDs are related with work condition of employee. If work of an employee repetitive than work related musculoskeletal disorders appear more often. Further along the advanced stages of the disease the worker may feel fatigue and weakness, and may not be able to sleep and perform light tasks.

## 2.2 Work Related Musculoskeletal Disorders

According to European Agency for Safety and Health at Work (EASHW) published statics about WRMSD claims account for about 53% of the complaints in the Austria, Belgium, Denmark, Finland, France, Germany, United Kingdom, Greece, Italy, Ireland, Luxembourg, the Netherlands, Portugal, Spain and Sweden. The disease does not only burden businesses with productivity loss, workers and their families with personal suffering, but it also encumbers society at large with medical and social security expenses. The problem can be reduced if not completely prevented. Proper risk assessments can guide employers to take preventative measures. (on their official webpage in 2009)

At a more in depth research, the scope of the problem can be observed better. In the Austria, Belgium, Denmark, Poland, Czech Republic, Finland, Cyprus, Latvia, Lithuania, Estonia, Slovakia , Hungary, Malta,, France, Germany, United Kingdom, Greece, Italy, Ireland, Luxembourg, the Netherlands, Portugal, Slovenia, Spain, Sweden, Bulgarian and Romanian regions. 62% of workers are exposed to movements of repetitive hand and arm, 46% to tiring positions or painful, also 35%

to moving or carrying loads which are heavy loads, and as a result suffer from muscle strains, tendinitis, and carpal tunnel syndrome.

Although both men and women experience hand or arm related injuries, men seem to have a higher level of exposure to the involved risk factors. Even today, the most risky occupations like farmers, miners and construction workers are composed primarily of men. As a result more men than women are diagnosed with MSDs.

EU labor safety laws demand all members to evaluate workplace hazards, and take necessary preventative measures to protect the safety and health of workers. To achieve this, all relevant risks must be assessed. EASHW guidelines to evaluate the risks entail, inspecting for hazards, considering potential injuries and their sufferers, finding solutions, monitoring risks, and reviewing preventive measures. For the plan to proceed successfully, both workers and their managers must cooperate and implement the necessary procedures.

## 2.3 Computers and WRMSDs

Today most office workstations possess a desktop. In fact, these computers are amongst the leading office devices which instigate WRMSDs. Repetitive tasks performed by certain input and output peripherals, and incorrectly utilized work surfaces and chairs, generate the causes for computer related WRMSDs. The chief components of desktop computer workstations which instigate discomforts are mouse, keyboard, display, desk and chair. In certain cases, an apparatus may produce discomforts individually, while at other times, they may act collectively. Thus, designing a proper desktop computer workstation requires that all these factors are taken into consideration. Various studies have been conducted to determine such workstations. Their findings are discussed below.

Fogleman and Lewis (2002) studied the various factors of risk associated with musculoskeletal discomforts according to self-report in video display terminal (VDT) operators. They surveyed 292 VDT users and recorded the symptoms of their head and eyes, forearms and upper and lower back parts, shoulders, elbows/wrists, and necks, and hands and wrists injuries, along with the employees' job requirements, demographics, and non-occupational habits. For determining logistic regression and descriptive information, they constructed factor analysis. With help of these information estimating the risk were possible and results indicated that statistically significant increased discomfort risks on each regions of body after hours of keyboard usage increases.

Moreover, their research proved that improper keyboards and monitors position were significantly associated with eye and back, and shoulder and head discomforts, respectively.

By taking individual and work organizational factors, and stress into account, Shuval and Donchin (2005) examined the relationship between ergonomic risk factors and upper extremity musculoskeletal symptoms in VDT workers. While the ergonomic data were collected through two direct observations via rapid upper limb assessment (RULA) method, questionnaire responded by 84 workers derived from the rest of the statistics who were computer programmers, managers, administrators, and marketing specialists. According to the RULA observations, none of the employees had acceptable postures; in fact, they carried excessive postural loads. Furthermore, in a logistic regression model, hand, wrist, and finger symptoms along with working for 7.1 and 9 hours per day with VDTs were found to be related to the RULA arm and wrist scores. Additionally, neck and shoulder symptoms, whose sufferers were observed to mainly compose of females, were observed to be associated with working for more than 10 hours per day, laboring for more than 2 years for a hi-tech company, and using uncomfortable workstations.

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 3D head, neck and upper limb postures of 18 male and 18 female 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. However, Straker's results showed that there was no substantial interaction between display heights and desk designs, yet lower display heights increased head and neck flexion, and spinal asymmetry. Moreover curved desks, designed to provide forearm supports, increased scapula elevation and protraction, and shoulder flexion and abduction.

In his research, Søndergaard et al. (2010) examined the variability of sitting postural movements in relation to the development of perceived discomfort by means of linear and nonlinear analysis. Kinetic and kinematics data of prolonged sitting positions along with discomfort ratings of nine male subjects were recorded. In correlation, a body part discomfort index, and displacement of the center of pressure

(COP) in anterior– posterior and medial–lateral directions as well as lumbar curvatures were calculated. Standard deviation and sample entropy techniques were used to assess the degree of variability and complexity of sitting, and a correlation analysis was formed to determine relationship of each parameter with discomforts. The results did not indicate any link between discomforts and any of the mean values. Therefore sample entropies negatively correlated, directions and lumber curvatures resulted as positively correlated with discomforts according to standard deviations of the COP displacement in entropy samples. Shortly, suggestion of the study proves that there is no boundary in between the increase in degree of variability and the decrease in complexity of sitting postural control. These are interrelated with the increase in perceived discomforts.

In a different intervention study conducted by Taieb-Maimon et al. (2010), the effectiveness of a new method called the training for photo self modeling for reducing risks to have musculoskeletal problems among workers in office whole using computers was examined. Group of sixty workers were assigned randomly either to an office training or a control group that received ergonomically or personal training, and adjustments on workstation, or to a self modeling photo group for training that received both office training and an automatic frequent-feedback system that displayed a photo of the worker's posture for current sitting together with the corrected posture's photo taken earlier during office training on the computer screen. Using the RULA method, musculoskeletal risks were evaluated not only during the investigation, but also six weeks later. The results indicated that both methods of training prove effective short-term posture improvement; however, sustained improvement was only attained photo training method with the self-modeling. While both interventions had better effects on older employees and workers who suffer from musculoskeletal pain, the self-modeling photo training method had more positive effect on women than on men.

To compare the muscle patterns and posture between female and male users of computer with symptoms of musculoskeletal, Yang and Cho (2011) recruited 40 computer users to perform an appointed type of speed chore, and a mouse task of repetition. Significant differences between genders for head and flexion angles of neck region were observed during speed typing, and in the repetitive mouse task, major disparities between genders for upper extremity angles were detected. Yang and Cho concluded that overall postural variations between genders were significant, even when the subjects' table and chairs were adjusted to meet their anthropometry.

An innovative VDT workstation chair with an adjustable keyboard and mouse support to minimize the physical discomforts at work sites was proposed by Park et al. (2000). 3D graphical simulations, a mock-up chair was constructed with a keyboard which is adjustable and support for mouse directly attached to the chair body based upon the result, an experiment was conducted to compare Park's workstation chair to a conventional computer chair without a keyboard and mouse support. After measuring muscle fatigue and subjective discomfort, statistics showed that the new concept VDT chair generally improved subjective comfort level and reduced fatigue in the finger flexor and extensor, and the low back muscles.

## 2.4 Economic Impact of WRMSDs

Determining actual cost that spent for WRMSDs is not easy and it could not be accurate. Insurance methodology and organizational differences affects calculating WRMSDs' actual cost. There are few publishments refers approximate calculations.

SHARP (The Safety and Health Assessment and Research Prevention (Silversten at al., 2002)between 1994-2002, in Washington State workplaces these claim cost was 3.3 billion dollar for medical cost and partial replacements benefits.

According to The German Federal Institute for Occupational Safety and Health (BAuA) announce an estimation about productivity loss due to MSDs as 0.59% og GNP in 2002 and 0.4% in 2006. (Brochure of 2007)

Economical impacts are still a huge question mark about WRDSMs and further researchers and their researches will improve importance of WRDSMs in economical currencies. However some measurements are showing approximate importance of WRDSM such as The Institute of Medicine's; productivity lost and wage lost are estimating between 45 billion and 54 billion dollar per annum (U.S. Department of Labor/2009).

# Chapter 3

# METHODOLOGY

When designing an ergonomically proper desktop computer workstation, the use of anthropometric data, the work envelope, the work surface, and their dynamic with certain input and output devices should be clearly rooted in the model.

Based on the National Institute for Occupational Safety and Health (NIOSH) Symptoms Survey and the Nordic Musculoskeletal Questionnaire (NMQ), a questionnaire (Appendix A, page 60) 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 from Monday to Friday period for work purpose. 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.

Questionnaire was aiming to determine WRMSDs in short term, long term and possibility of chronicle troubles. Questionnaire has 3 columns and every column defines a specific time period.

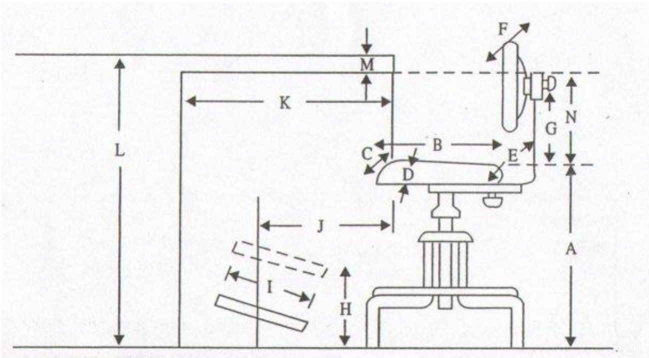
First column’s questions were “Have you had any trouble experienced at any time during 12 months period (such as pain, aches, discomfort, numbness) in Upper and lower backs, neck, shoulder, elbow, wrist parts” (Questions 1, 4, 7, 10, 13, 16, 19, 22 and 25).

Second column helps to realize if there was a trouble, was it chronicle or not. Question of second column about having any trouble in one week period in muscle groups defined in first column (Questions 2, 5, 8, 11, 14, 17, 20, 23 and 26).

Third column of questionnaire aim to determine if there were troubles, were those troubles affect participants daily life like prevent from hobbies, job or any other normal activities (Questions 3, 6, 9, 12, 15, 18, 21, 24 and 27).

After those 3 columns, with help of another 6 of questions were 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, swelling etc. (Question 28, 29 and 30) than medical help received by participants due to their problem were asked in questionnaire. At the end of the questionnaire, the day lost days because of problem asked (Questions 32 and 33).

The anthropometric data of participants were obtained as subjects worked on their existing workstations. Seat parameters shown in Figure 1 and seated body dimensions shown in Figure 2 were recorded (Figure 1 and 2 by Niebel and Freivalds, 2003). Signal amplitude percentiles ranging in between 5 to 95 were incorporate into body posture statistics. Through the logistic regression method, a meaningful and statistically significant relationship between work related musculoskeletal disorders and desktop computer use was determined. Subsequently, the results were analyzed to establish the criteria for the most ergonomic desktop computer workstation.




A- Height of seat
B- Depth of seat
C- Width of seat
D- Pan angle of seat
E- Seat back to pan angle
F- Seat back width
G- Support of lumbar
H- Footrest height
İ- Footrest depth
J- Footrest distance
K- Leg clearance
L- Work surface height
M- Work surface thickness
N- Thigh clearance

Figure 1: Seat Parameters (by Niebel and Freivalds, 2003)

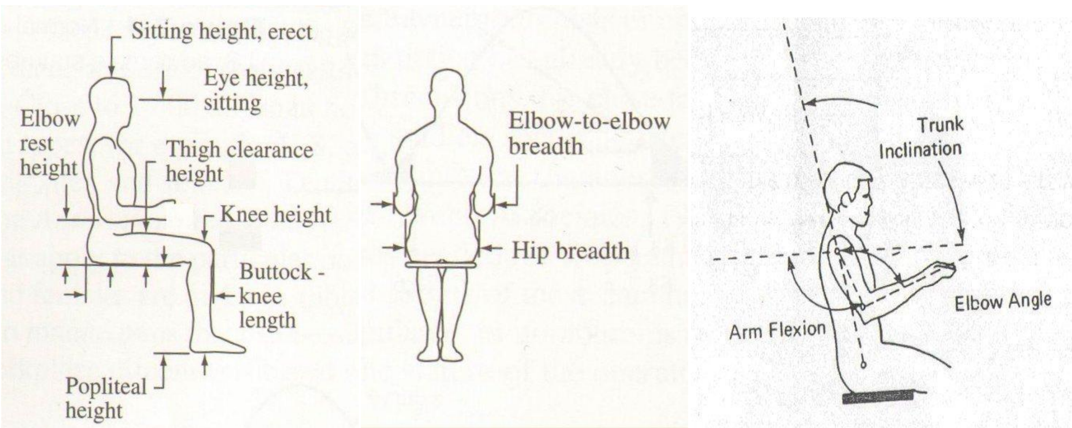



Figure 2: Seated Body Dimensions of Computer Users (by Niebel and Freivalds, 2003)

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 were selected randomly to partake in a surface electromyogram experiment designed to investigate the impact of musculoskeletal discomforts caused by desktop computer workstations. Using a MyoTrac Infiniti SA9800 surface electromyography, muscle force, the load of muscle and the muscular fatigue of six body regions; elbow, hand/wrist and forearm, neck, shoulder, upper and lower backs, were measured. As the sEMG device allowed the collection of data from two muscle groups at a time, the test was repeated three times.

## 3.1 Electromyography Recording for Old and New Workstations

Respondents randomly selected from people who participate to questionnaire. 10 of respondents who work in front of desktop computer were invited sEMG experiment. Data collection regions were 6 of body regions. Those 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). Appendix B page 62 have detailed body muscles figures. Aim of sEMG experiment was estimating amount of pressure put on muscle groups of computer users. Therefore a sEMG experiment was designed which measures the pressure on muscles during their work with desktop computer usage.

Ten participants; 8 male and 2 female with having no background of previous MSDs attended to the experiment. Experiments were conducted in standard condition of temperature and light. Experiments had been taken in EMU, Dept. of IE Ergonomics laboratory.

MyoTrac Infiniti, model SA9800 (sEMG device) had 2 channels, Therefore 6 muscle measurements divided 3 sections by 2 muscle groups at a time. Each muscle's pressure recorded 10 minutes periods. Experiment for collect one respondent's all muscles repeated 3 times (Total of 30 minutes) and every parts have 10 minute break in between sections for old workstation and than 1 day resting, same respondent spend again 3 sections with same timing on new workstations. Placements of sEMG electrodes on 6 of muscle groups are on Figure 3, 4 and 5.

Figure 3: Placement of sEMG Electrodes on Wrist (flexor retinaculum) and Elbow (extensor digitorum)

Figure 4: Placement of sEMG Electrodes on Shoulder (posterior upper deltoid) and Neck (posterior trapezius)

Figure 5: Placement of sEMG Electrodes on Upper Back (rhomboideus major) and Lower Back (sacropinalis)

The respondents had been typing for certain duration while their muscles were recording the muscles activities. Typing test software (Typing test Q) was used for both of new and old workstations.

Old workstation had standard keyboard, 17 inch monitor and a standard mouse also fix table and adjustable chair. Respondents adjust their table due to their daily office habits. This means how they feel they are sitting comfortable, adjust chair as they wants, distance in between table and chair as they want to set were their choices without any interruption. Old version of workstation is available on Figure 6.

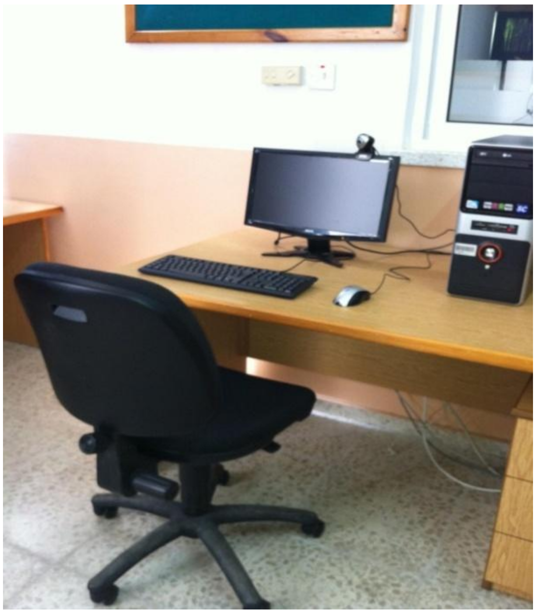


Figure 6: Design of Old Workstation

According to anthropometric measurements, new workstation with standard keyboard, 17 inch monitor and a standard mouse and keyboard was optimized by using 50$^{th}$ percentile according to anthropometric data set observed by help of total 42 respondents. Figure 7 shows new workstation.

Figure 7: Design of New Workstation

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 is having any medical treatment for the WRMSDs. The independent variables were selected to be the variables from the rest of the questions in the questionnaire.

Analysis of variance (ANOVA) was used to test the mean musculoskeletal strain in time for 10 respondents (those attended sEMG experiment). Time consumption for every 6 body regions was same, first for the old workstation. Later, ANOVA was also applied to test the same hypothesis on the 6 body regions, but this time for the sEMG data collected from new anthropometrically designed optimal workstation.

# Chapter4

# RESULTS

## 4.1. Questionnaire Results

Age interval is in between 22 to 54 and mean of age is 36.6. Age distributions are in Figure 8.

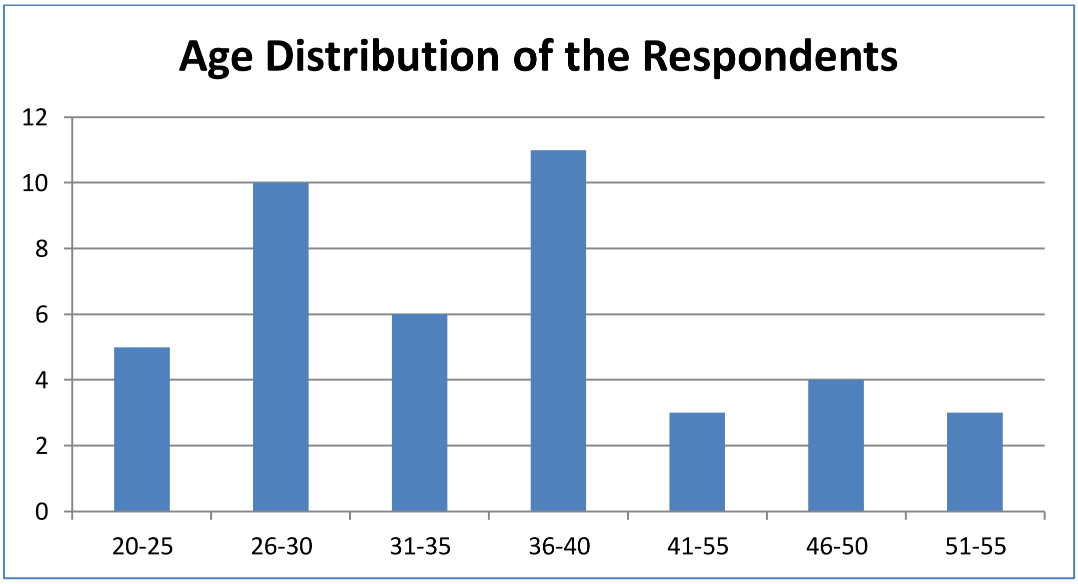



Figure 8: Age Distribution of the Respondents

22 of 42 participants were female (52%) and 20 of participants were male (48%). There were 19 direct yes/no questions. There are 9 multiple selection questions and participants answers 3 questions with essays. Sample of questionnaire on (appendices A) page 60 is available. Table 1 shows the answers given by the respondents.

Table 1:' Respondents' Answers in percent

| | 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 prevent 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 prevent 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 prevent 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 prevent 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 prevent 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 prevent 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 prevent 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 prevent 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 prevent from normal life due to ankles/feet problems in last 12 month | 11.9 | 88.1 |

According to Table 1, there are several results which are proving significant problems in specific body parts of respondents. 57% of the respondents reported that they had experienced trouble (ache, pain, discomfort, numbness) in their neck during the last 12 months. Also 31% of respondent had neck trouble in last 7 days that they filled up questionnaire.

47.6% of respondent reported that they had shoulder problem in last 12 months Indeed, 33.3% of respondent had shoulder problem even in last 7 days that they filled up questionnaire.

Having lower back problem has one of the highest rates in participants. 47.6% respondent reported they had experienced trouble in their lower back in last 12 months. Compared to upper back, lower back problems have higher value. 38.1% of respondent reported upper back trouble in same time interval of their life.
One other result obtained from Table 1, more than 95% of respondent reported that they had no trouble in their elbows part of body.

Knees, ankles, hips, thighs and buttocks reported healthy more than 82% of respondent in 7days and 12 months period.

Some of questions have multiple selections. If participant- had trouble in shoulder, elbow or wrist they need to define which one of those or both of those section of their bodies are in trouble. Shoulders, elbows or wrists/hands related questions have sub answers therefore their percent are on pie chart.

Shoulders related questions focus on having any trouble experienced at any time during 12 months period (such as pain, aches, discomfort, numbness). Participants could answer that question with replying" No" and "Yes". However if answer was "Yes" than, there were sub answers "left", "right" or "both" because human body own 2 shoulders. Figure 9 shows the answers given by the participants.

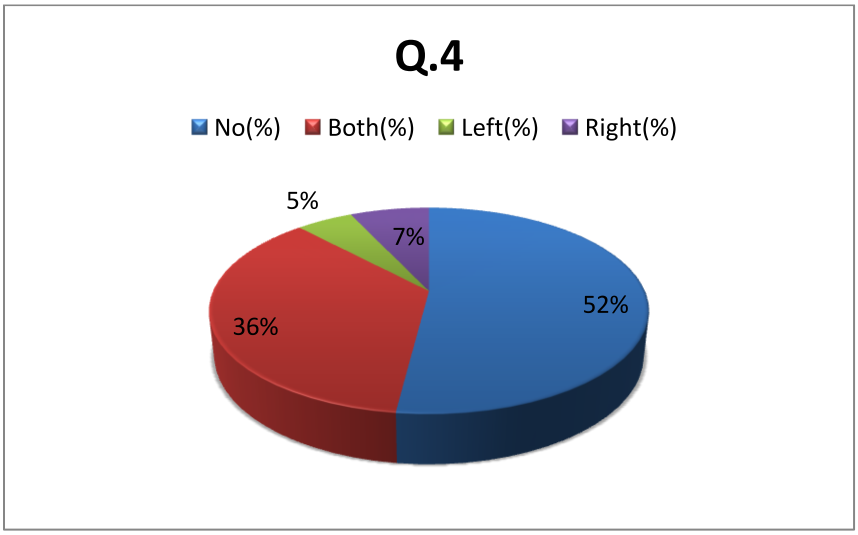



Figure 9: Pie Chart of Question 4

There were 42 participants and 52% of them were answered “No”, 36% of them were answered “Both”, 5% of them were answered “Left” and 7% of them were answered “Right”.

Participants had trouble during the last 7 days in their shoulders question could answer with replying” No” and “Yes”. However if answer was “Yes” than, there were sub answers “left”, “right” or “both” because human body own 2 shoulders. Figure 10 shows the answers given by the participants.

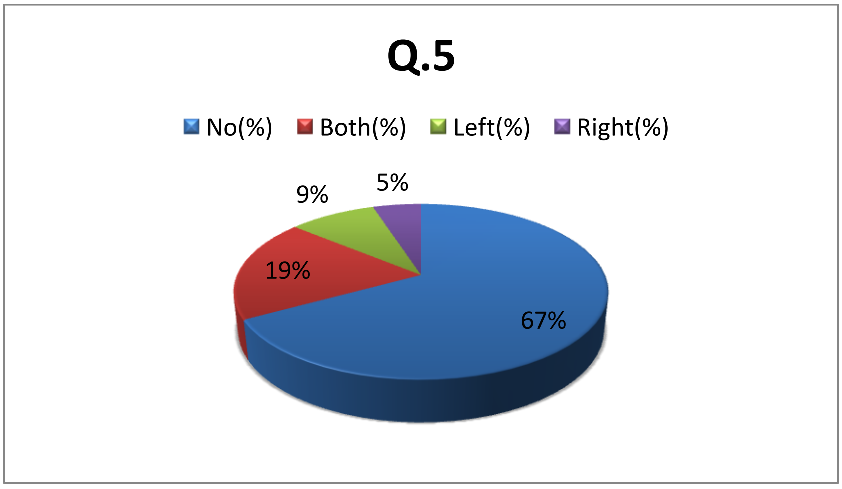



Figure 10: Pie Chart of Question 5

There were 42 participants and 67% of them were answered “No”, 19% of them were answered “Both”, 9% of them were answered “Left” and 5% of them were answered “Right”.

Elbows related questions focus on having any trouble experienced at any time during 12 months period (such as pain, aches, discomfort, numbness). Participants could answer that question with replying” No” and “Yes”. However if answer was “Yes” than, there were sub answers “left”, “right” or “both” because human body own 2 elbows. Figure 11 shows the answers given by the participants.

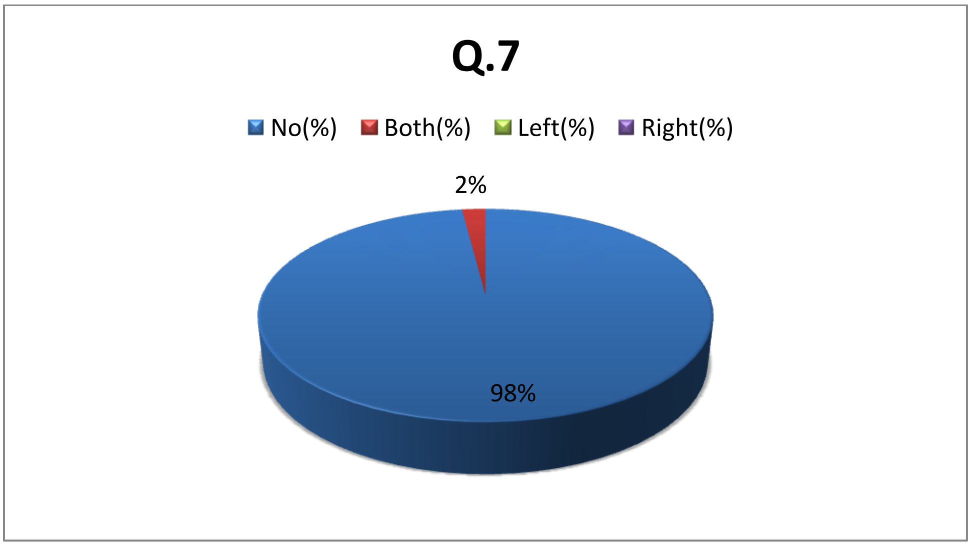



Figure 11: Pie Chart of Question 7

There were 42 participants and 98% of them were answered “No”, 2% of them were answered “Both”, 0% of them were answered “Left” and 0% of them were answered “Right”.

Participants had trouble during the last 7 days in their elbows question could answer with replying” No” and “Yes”. However if answer was “Yes” than, there were sub answers “left”, “right” or “both” because human body own 2 elbows. Figure 12 shows the answers given by the participants.

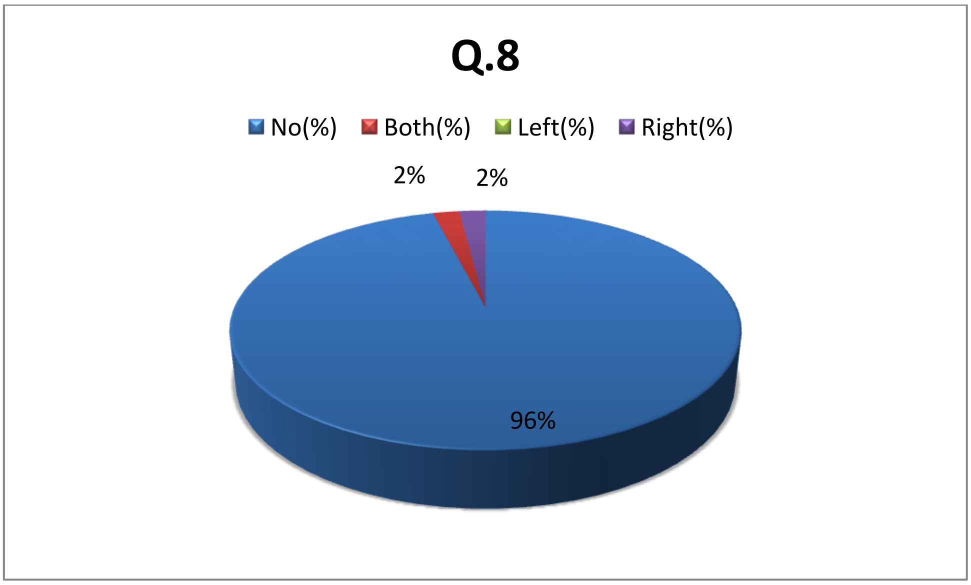



Figure 12: Pie Chart of Question 8

There were 42 participants and 96% of them were answered “No”, 2% of them were answered “Both”, 0% of them were answered “Left” and 2% of them were answered “Right”.

Wrists/Hands related questions focus on having any trouble experienced at any time during 12 months period (such as pain, aches, discomfort, numbness). Participants could answer that question with replying” No” and “Yes”. However if answer was “Yes” than, there were sub answers “left”, “right” or “both” because human body own 2 wrists and 2 hands. Figure 13 shows the answers given by the participants.

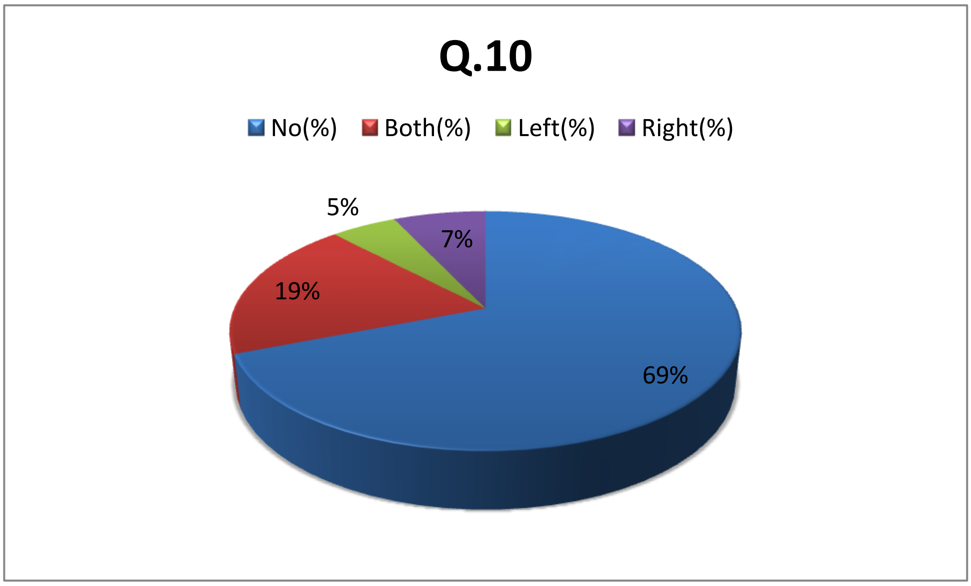



Figure 13: Pie Chart of Question 10

There were 42 participants and 69% of them were answered “No”, 19% of them were answered “Both”, 5% of them were answered “Left” and 7% of them were answered “Right”.

Participants had trouble during the last 7 days in their hands/hrists question could answer with replying” No” and “Yes”. However if answer was “Yes” than, there were sub answers “left”, “right” or “both” because human body own 2 hands/wrists. Figure 14 shows the answers given by the participants.

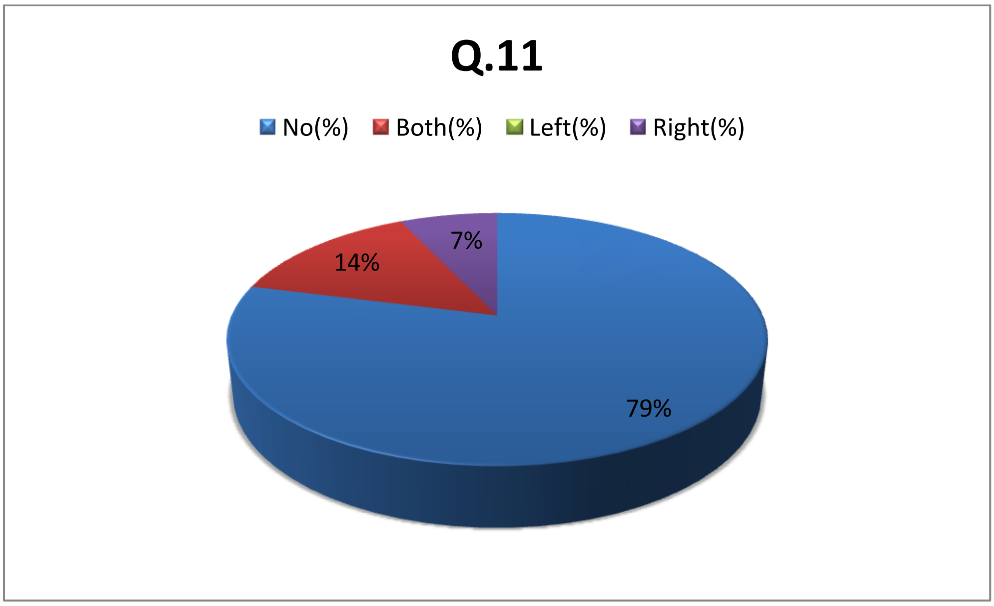



Figure 14: Pie Chart of Question 11

There were 42 participants and 79% of them were answered “No”, 14% of them were answered “Both”, 0% of them were answered “Left” and 7% of them were answered “Right”.

## 4.2 Logistic Regression Analysis

In order to determine a relationship between computer use as a risk assessment model and WRMSDs, logistic regression analysis was performed. Logistic Regression was preffered because dataset of questionnaire had many of the independent variables.

Respondents answered some essay questions such as their medical backround, first 27 questions were multiple choice and also specific information of participants such as their age, sex and position of work were also analyst.

By help of using SPSS and Minitab (ver.14), Logistic Regression Analysis had been conducted. SPSS and Minitab conducted together because p-ratio check function were only available on SPSS. Predictors and coefficients and p values on tables are below.

Table 2: P Values Predictors and Coefficients due to Age, Sex, Position

| Predictor | Coef | SE Coef | Z | P | Ratio | Lower | Upper |
|---|---|---|---|---|---|---|---|
| Constant | 4.84893 | 2.50012 | 1.94 | 0.052 | | | |
| position | -1.31060 | 0.699071 | -1.87 | 0.061 | 0.27 | 0.07 | 1.06 |
| Age | 0.0413191 | 0.0531858 | 0.78 | 0.437 | 1.04 | 0.94 | 1.16 |
| Sex | -1.19604 | 0.769751 | -1.55 | 0.120 | 0.30 | 0.07 | 1.37 |

Table 3: Predictors and Coefficients and p Values of Q1, Q2, Q3

| | | | | | Odds | 95% CI | |
|---|---|---|---|---|---|---|---|
| Predictor | Coef | SE Coef | Z | P | Ratio | Lower | Upper |
| Constant | -3.83809 | 1.54193 | -2.49 | 0.013 | | | |
| Q1 | 1.41494 | 1.10887 | 1.28 | **0.022** | 4.12 | 0.47 | 36.17 |
| Q2 | -0.0574977 | 1.12673 | -0.05 | 0.959 | 0.94 | 0.10 | 8.59 |
| Q3 | 1.51017 | 1.06136 | 1.42 | 0.155 | 4.53 | 0.57 | 36.25 |

Table 3 shows that "having trouble in the neck within 12 months" was a significant factor (p=0.022) in the development of WRMSDs due to desktop computer use (Question 1). However, neck trouble in 7 days and preventing from carrying out normal activities are not showing any significant p value (Question 2 and 3).

Table 4: Predictors and Coefficients and p Values of Q4, Q5, Q6

| | | | | | Odds | 95% CI | |
|---|---|---|---|---|---|---|---|
| Predictor | Coef | SE Coef | Z | P | Ratio | Lower | Upper |
| Constant | 1.66466 | 2.11082 | 0.79 | 0.430 | | | |
| Q4 | -0.813675 | 0.357907 | -2.27 | **0.023** | 0.44 | 0.22 | 0.89 |
| Q5 | -0.128174 | 0.370024 | -0.35 | 0.729 | 0.88 | 0.43 | 1.82 |
| Q6 | 1.38802 | 0.875967 | 1.58 | 0.113 | 4.01 | 0.72 | 22.31 |

Table 4 shows that “having trouble in the shoulders within 12 months” was a significant factor (p=0.023) in the development of WRMSDs due to desktop computer use (Question 4). However, shoulders trouble in 7 days and preventing from carrying out normal activities are not showing any significant p value (Question 5 and 6).

Table 5: Predictors and Coefficients and p Values of Q7, Q8, Q9

| Predictor | Coef | SE Coef | Z | P | Odds Ratio | 95% CI Lower | Upper |
|---|---|---|---|---|---|---|---|
| Constant | 25.6311 | 22191.8 | 0.00 | 0.999 | | | |
| Q7 | -4.95677 | 9731.75 | -0.00 | 1.000 | 0.01 | 0.00 | * |
| Q8 | -7.43515 | 9232.35 | -0.00 | 0.999 | 0.00 | 0.00 | * |
| Q9 | 22.2254 | 27697.0 | 0.00 | 0.999 | 4.49E+9 | 0.00 | * |

According to regression analysis, having troubles in elbows are not showing any significant p value (Question 7, 8 and 9).

Table 6: Predictors and Coefficients and p Values of Q10, Q11, Q12

| Predictor | Coef | SE Coef | Z | P | Odds Ratio | 95% CI Lower | Upper |
|---|---|---|---|---|---|---|---|
| Constant | -2.45890 | 2.91292 | -0.84 | 0.399 | | | |
| Q10 | 0.504641 | 0.625901 | 0.81 | **0.020** | 1.66 | 0.49 | 5.65 |
| Q11 | -0.867735 | 0.639109 | -1.36 | 0.175 | 0.42 | 0.12 | 1.47 |
| Q12 | 2.23044 | 1.25206 | 1.78 | 0.075 | 9.30 | 0.80 | 108.25 |

Table 6 shows that “having trouble in the wrists/elbows within 12 months” was a significant factor (p=0.020) in the development of WRMSDs due to desktop computer use (Question 10). However, wrists/elbows trouble in 7 days and preventing from carrying out normal activities are not showing any significant p value (Question 11 and 12).

Table 7: Predictors and Coefficients and p Values of Q1,3 Q14, Q15

| Predictor | Coef | SE Coef | Z | P | Odds Ratio | 95% CI Lower | Upper |
|---|---|---|---|---|---|---|---|
| Constant | -2.91877 | 1.37199 | -2.13 | 0.033 | | | |
| Q13 | 0.176911 | 1.24079 | 0.14 | 0.887 | 1.19 | 0.10 | 13.58 |
| Q14 | -20.3035 | 15366.3 | -0.00 | 0.999 | 0.00 | 0.00 | * |
| Q15 | 22.3371 | 15366.3 | 0.00 | 0.999 | 5.02209E+09 | 0.00 | * |

On Table 7, upper back region is not showing any significant p value. (Question 13, 14 and 15)

Table 8: Predictors and Coefficients and p Values of Q16, Q17, Q18

| Predictor | Coef | SE Coef | Z | P | Odds Ratio | 95% CI Lower | Upper |
|---|---|---|---|---|---|---|---|
| Constant | -2.29440 | 1.35045 | -1.70 | 0.089 | | | |
| Q16 | 0.773561 | 1.15782 | 0.67 | 0.504 | 2.17 | 0.22 | 20.97 |
| Q17 | -0.335356 | 1.07213 | -0.31 | 0.754 | 0.72 | 0.09 | 5.85 |
| Q18 | 1.46103 | 1.04950 | 1.39 | 0.164 | 4.31 | 0.55 | 33.72 |

According to regression analysis, having troubles in lower back is not showing any significant p value (Question 16, 17 and 18).

Table 9: Predictors and Coefficients and p Values of Q19, Q20, Q21

| Predictor | Coef | SE Coef | Z | P | Odds Ratio | 95% CI Lower | Upper |
|---|---|---|---|---|---|---|---|
| Constant | -43.7765 | 39169.5 | -0.00 | 0.999 | | | |
| Q19 | -20.5017 | 18664.5 | -0.00 | 0.999 | 0.00 | 0.00 | * |
| Q20 | 42.8201 | 33398.9 | 0.00 | 0.999 | 3.94928E+18 | 0.00 | * |
| Q21 | 0.0000000 | 33921.8 | 0.00 | 1.000 | 1.00 | 0.00 | * |

On Table 9, hips/thighs/buttocks regions are not showing any significant p value according to regression analysis. (Question 19, 20 and 21)

Table 10: Predictors and Coefficients and p Values of Q22, Q23, Q24

| Predictor | Coef | SE Coef | Z | P | Odds Ratio | 95% CI Lower | Upper |
|---|---|---|---|---|---|---|---|
| Constant | -0.737599 | 2.85208 | -0.26 | 0.796 | | | |
| Q22 | -21.2877 | 14791.7 | -0.00 | 0.999 | 0.00 | 0.00 | * |
| Q23 | 0.693147 | 1.87083 | 0.37 | 0.711 | 2.00 | 0.05 | 78.25 |
| Q24 | 21.3321 | 14791.7 | 0.00 | 0.999 | 1.83830E+09 | 0.00 | * |

On Table 10, knees are not showing any significant p value according to regression analysis. (Question 22, 23 and 24)

Table 11: Predictors and Coefficients and p Values of Q25, Q26, Q27

| Predictor | Coef | SE Coef | Z | P | Odds Ratio | 95% CI Lower | Upper |
|---|---|---|---|---|---|---|---|
| Constant | -2.10284 | 2.03020 | -1.04 | 0.300 | | | |
| Q25 | 0.322128 | 1.02403 | 0.31 | 0.753 | 1.38 | 0.19 | 10.27 |
| Q26 | 0.593572 | 1.55903 | 0.38 | 0.703 | 1.81 | 0.09 | 38.45 |
| Q27 | 0.593572 | 1.55903 | 0.38 | 0.703 | 1.81 | 0.09 | 38.45 |

On Table 11, ankles are not showing any significant p value according to regression analysis. (Question 25, 26 and 27)

## 4.3 Anthropometric Results

Participants filled questionnaires while anthropometric measurments had been collected. According to their workstations and sitting posture, optimized work station had been analyzed by using of $5^{th}$, $50^{th}$, $95^{th}$ percentiles.

Optimum values with respect to 5, 50 and 95 percentile of Elbow to elbow breadth and hip breadth  are on Table 12. Optimized sitting posture on $5^{th}$, $50^{th}$, $95^{th}$ percentiles are on Table 13. Optimized workstation on $5^{th}$, $50^{th}$, $95^{th}$ percentiles are on Table 14 and you  Arm Flexion, Elbow Angle and Trunk Inclination on $5^{th}$, $50^{th}$, $95^{th}$ percentiles are also on Table 15.

Table 12: 5th, 50th and 95th Percentiles of Elbow to Elbow Breadth and Hip Breadth

| **Seated Body Dimension** | **Percentile (cm)** | | |
|---|---|---|---|
| | **5th** | **50th** | **95th** |
| Elbow to Elbow Breadth | 39,09 | 50,39 | 61,69 |
| Hip Breadth | 26,74 | 34,80 | 42,87 |

According to desktop computer usage, width of elbow to elbow and hip measured for every participants of questionnaire were optimized on Table 12.

Table 13: Optimized Sitting Posture on 5th, 50th and 95th Percentiles

| **Seated Body Dimension** | **Percentile (cm)** | | |
|---|---|---|---|
| | **50th** | **95th** | **5th** |
| Sitting height, erect | 70,35 | 82,22 | 94,09 |
| Eye height, sitting | 104,90 | 116,32 | 127,73 |
| Thigh clearance | 9,54 | 14,12 | 18,70 |
| Knee height | 49,50 | 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 |

Posture of participants defined in 7 measurements which are sitting height, elbow rest height, eye height, thigh clearance, knee height, buttock knee height and popliteal height. Optimization of those 7 posture measurements are on Table 13.

Table 14: Optimized Workstation on 5th, 50th and 95th Percentiles

| Workstation's Diameters | Percentile (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 |

Workstation of every participant measured on their own office and optimization of workstation is on Table 14.

Table 15: Flexion, Elbow Angle and Trunk Inclination on $5^{th}$, $50^{th}$, $95^{th}$ Percentiles

| **Seated Body Angles** | **Percentile (°)** | | |
|---|---|---|---|
| | **$5^{th}$** | **$50^{th}$** | **$95^{th}$** |
| Arm Flexion | 100,65 | 114,71 | 128,77 |
| Trunk Inclination | 101,54 | 118,46 | 135,38 |
| Elbow Angle | 81,66 | 98,22 | 114,78 |

Participants have different distance between keyboard and mouse, their arm angles were measured in their own workstations than optimized. Table 15 had optimized elbow angles and trunk inclination.

With help of anthropomethric results, optimized work station designed and 10 of participant selected randomly from 42 of participants of questionnaire. At the end of all measurements, new workstation designed due to $50^{th}$ percentile. Therefore height of table depth of table and every other details which are related with workstation designed. With help of those 10 participant, standard and optimally designed computer workstations had been measured with a surface Electromyograph (sEMG) New and improved workstation designed for reducing pressures on muscles groups that tested by sEMG. With this new workstation's help, aim is reducing pressures on muscle groups. Long run, this reduction improves work rate and employee's health condition.

## 4.4. Electromyography Results

Respondent names were hidden to provide unbiased data and to maintain anonymithy of the results

### 4.4.1 Wrist Region

Figure 15 shows EMG activity on respondents' wrists while they are using standard computer workstation during 10 min of typing. The pressure on respondents wrists are on Figure 15 when they were typing with standard computer work station. “Respondent 5” having highest pressure and “Respondent 1” have first reducing but with time, increasing in wrist muscle pressure occurs. “Respondent 1, 4, 5” are remaining more than 2000 µV end of 10minute time. Rest of respondents concludes test under 500 µV.

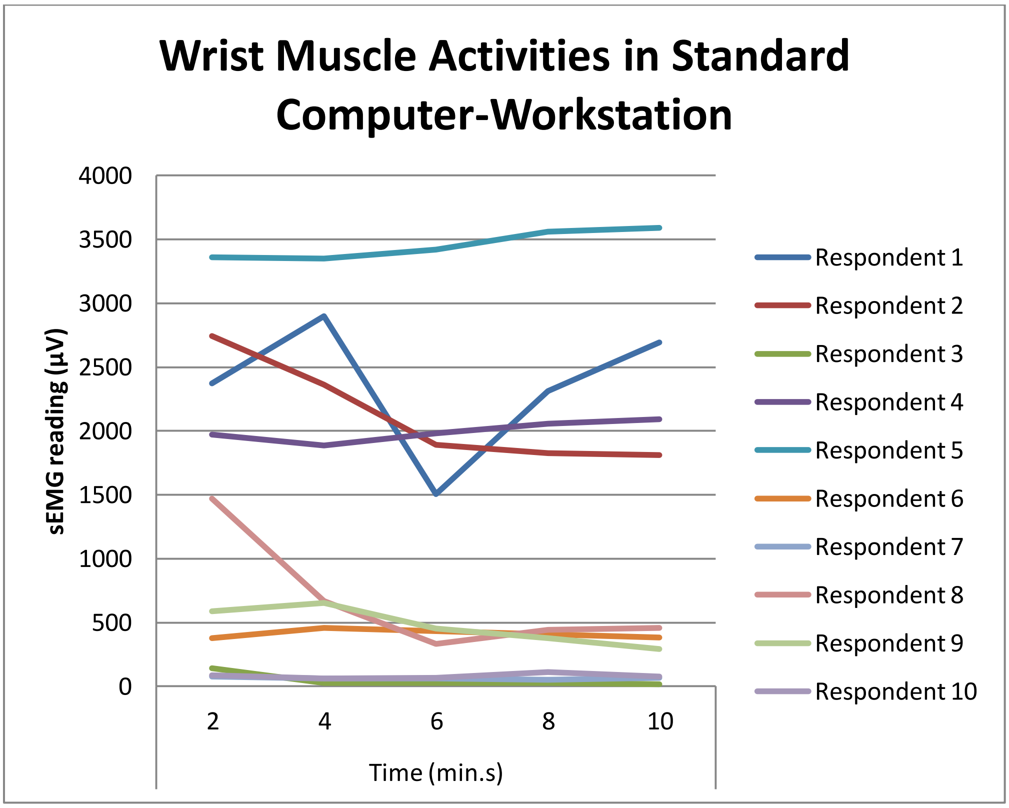



Figure 15**:** Wrist Muscle Activities in Standard Computer-Workstation

Figure 16 shows EMG activity on respondents' wrists while they were using modified computer workstation during 10 min of typing. The pressures on wrists are on Figure 16 when they were typing with modified computer workstation.

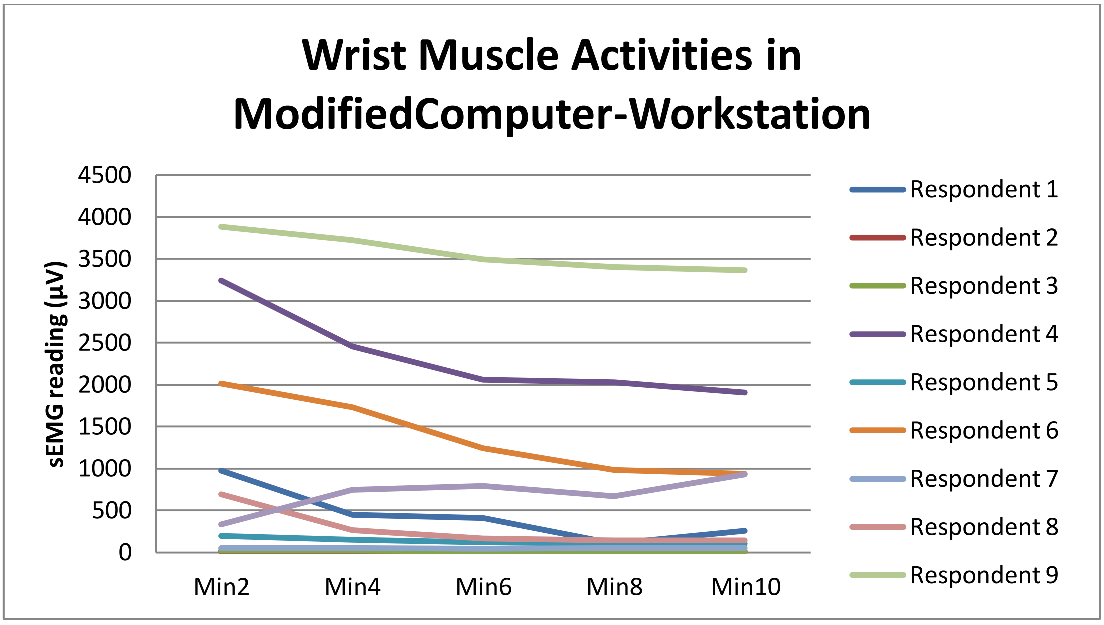



Figure 16: Wrist Muscle Activities in Modified Computer-Workstation

According to modified computer workstation data, pressures on respondents' wrists are decreasing in time period compared to standard computer workstation. Standard computer workstation causes higher pressures or stable pressures. There were not any decrease sign in any respondents' data. With working of modified workstation, 9 over 10 respondents finish their test less than 2000 µV on their wrist. "Respondent 10" has highest value however pressure on "Respondent 10" shows decrease while time passing.

### 4.4.2 Elbow Region

Figure 17 shows EMG activity on respondents' wrists while they are using standard computer workstation during 10 min of typing.

When they were typing with standard computer work station, end of 10 minutes period, “Responded 8” has highest pressure level on Elbow with using standard workstation. 4 of respondents’ reading value are more than 2000 µV. 3 of respondent’s pressure shows reducing pressure level on elbow in 10 min. (Respondents 6, 7 and 9)

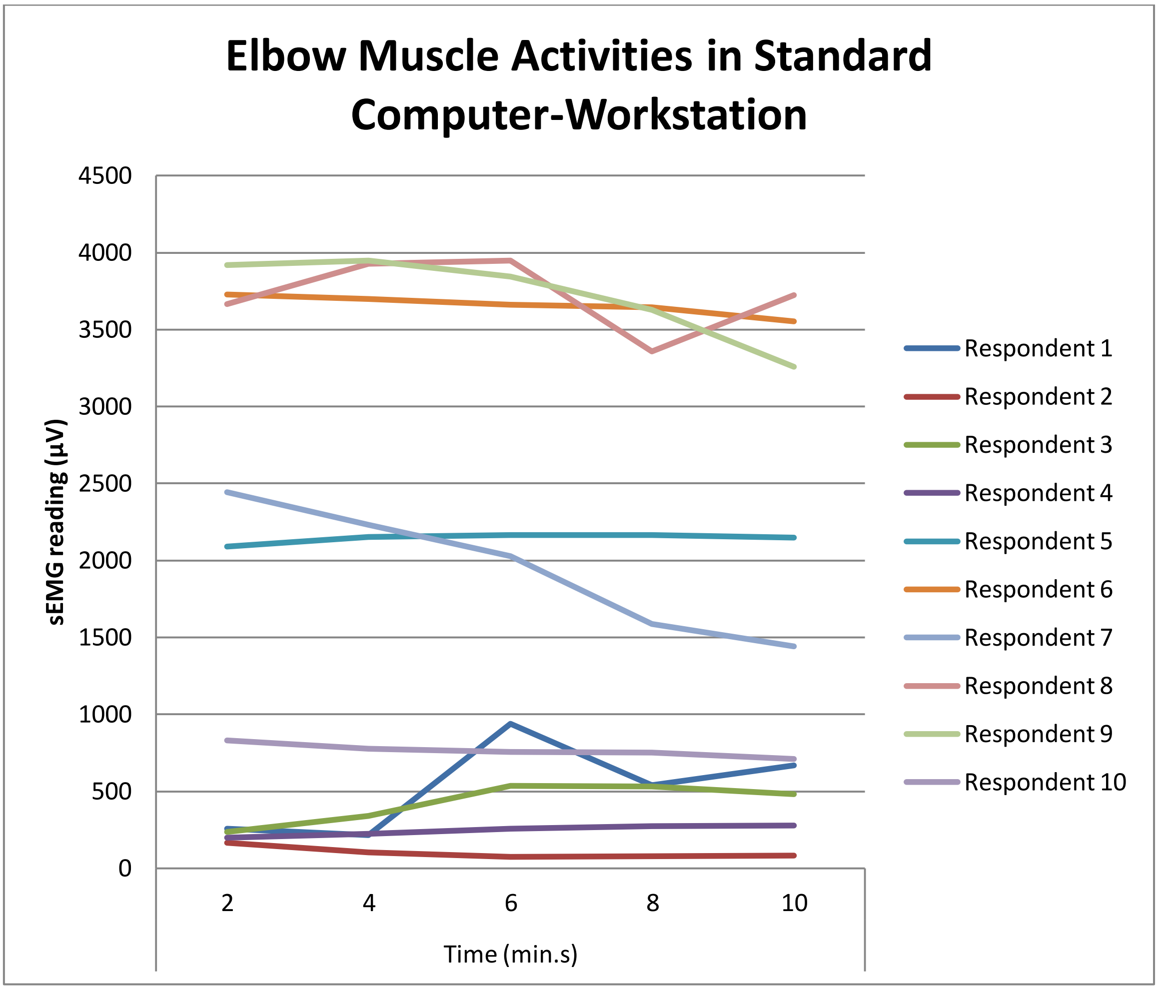



Figure 17: Elbow Muscle Activities in Standard Computer-Workstation

Figure 18 shows EMG activity on respondents' elbow while they were using modified computer workstation during 10 min of typing.

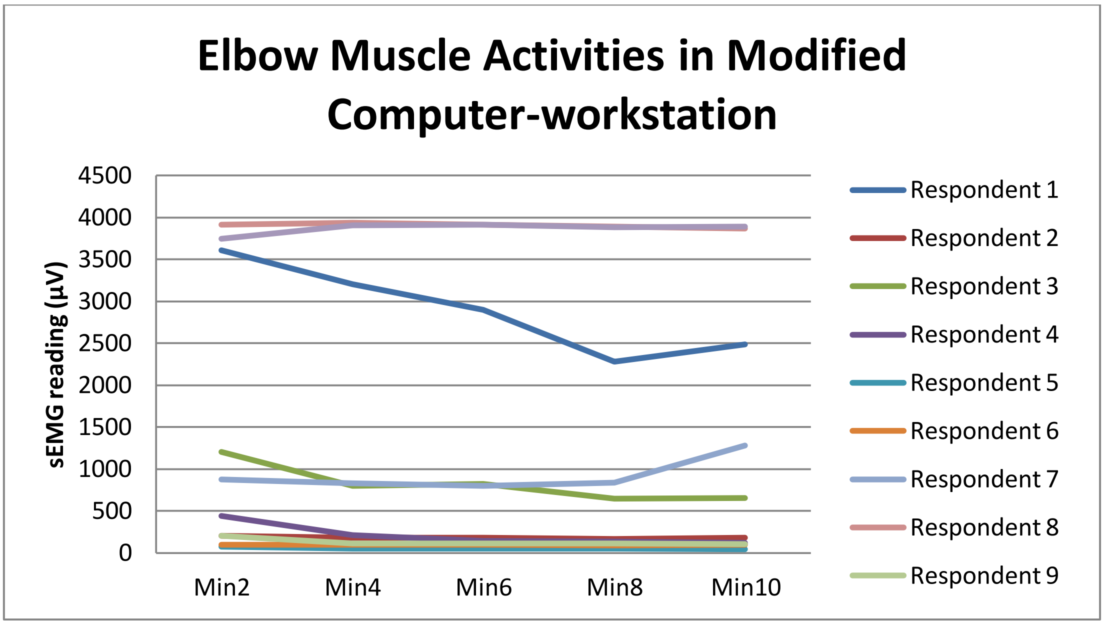



Figure 18: Elbow Muscle Activities in Mod Computer-Workstation

Data show that there were 5 respondents which are typing under 1400 µV or more pressure in standard computer workstation. However, in modified computer workstation, there are 7 of respondents concludes their typing less than 1400 µV pressure. Only 2 respondents shows increase on pressure level in the end of 10 minutes period (Respondent 1 and 7)

### 4.4.3 Neck Region

Figure 19 shows EMG activity on respondents' neck while they are using standard computer workstation during 10 min of typing. The pressures on neck are on Figure 19 when they were typing with standard computer work station. 5 of respondents finalize sEMG around 2000 µV or more pressure on their neck. (Respondent 3, 5, 6, 7 and 9)

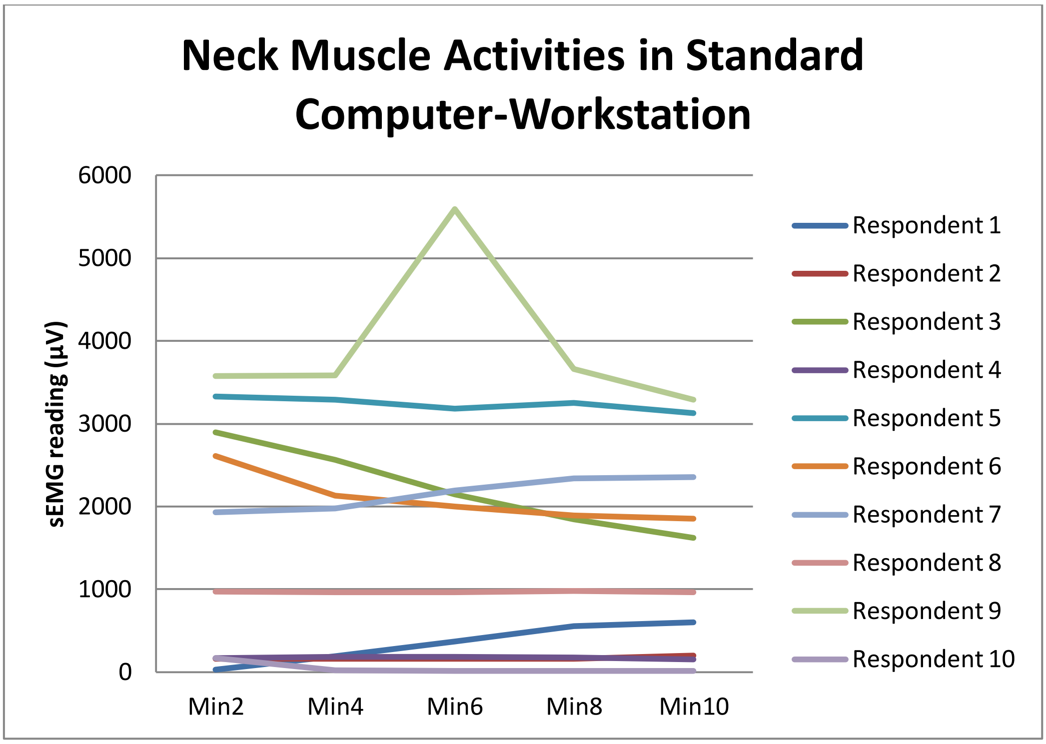



Figure 19: Neck Muscle Activities in Standard Computer-Workstation

Figure 20 shows EMG activity on respondents' neck while they were using modified computer workstation during 10 min of typing.

The pressures on neck are on Figure 20 when they were typing with modified computer work station.

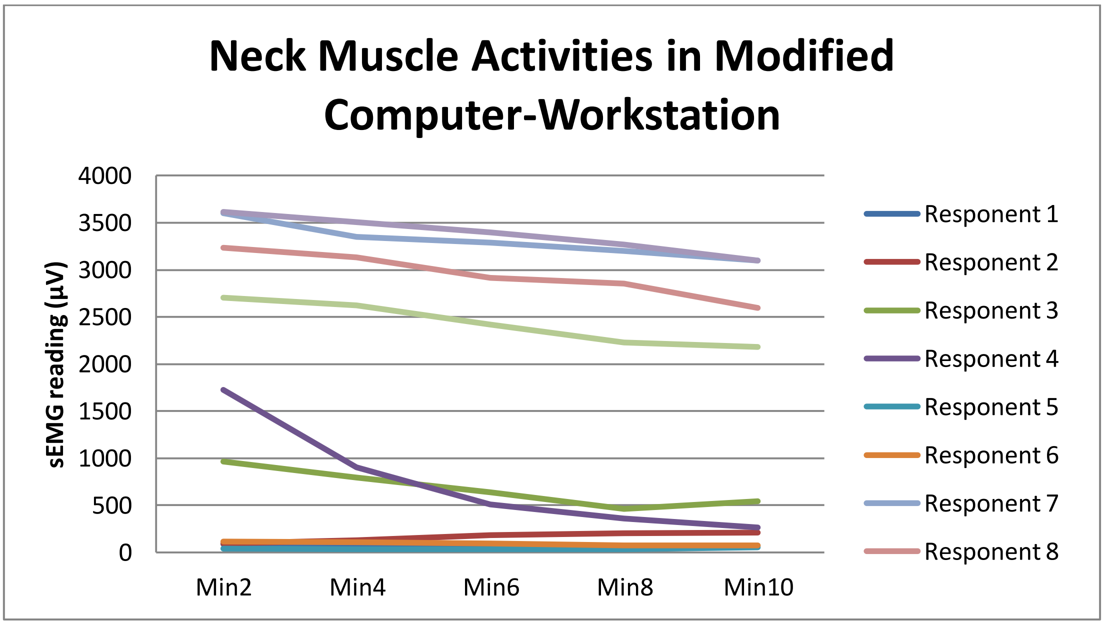



Figure 20: Neck Muscle activities in Modified Computer-Workstation

Modified computer workstation helps to pressure reduction on neck of respondents significantly. This decreasing provides better and more comfortable computer usage when compared to standard computer work station. “Respondent 2 and 3” are only two that shows increase on pressure by time consume. However rest of respondents shows slightly decrease or highly decrease with time change.

### 4.4.4 Shoulder Region

Figure 21 shows EMG activity on respondents' shoulder while they are using standard computer workstation during 10 min of typing. The pressures on respondents' shoulders when they were typing with standard computer work station. 6 of respondents finish their test with a higher pressure than 500 µV (Respondent 1, 2, 4, 5, 9 and 10). 3 of respondent remain more than 2000 µV. (30% of respondent)

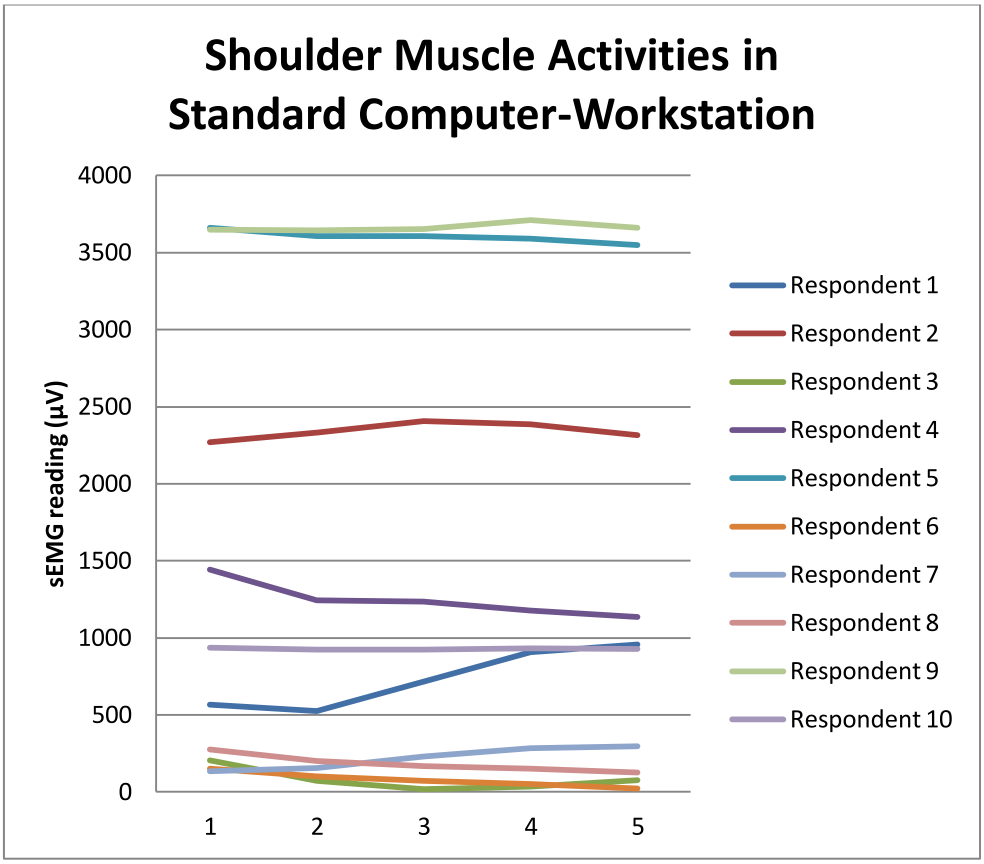



Figure 21: Shoulder Muscle Activities in Standard Computer-Workstation

Figure 22 shows EMG activity on respondents' shoulder while they were using modified computer workstation during 10 min of typing. The pressures on shoulder are on Figure 22 when they were typing with modified computer work station.

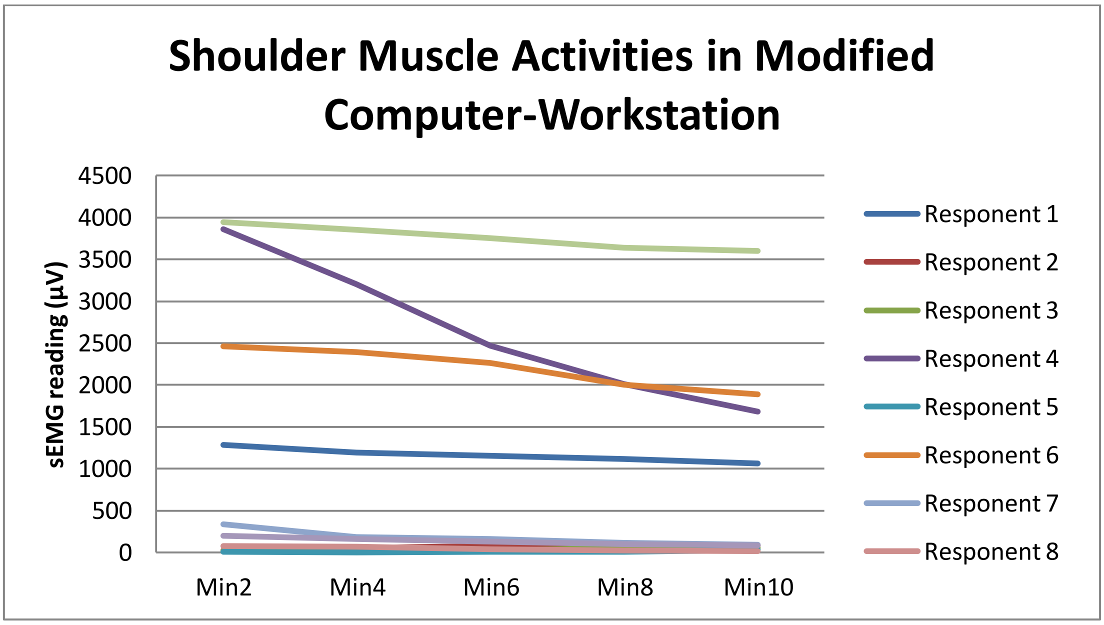



Figure 22: Shoulder Muscle Activities in Modified Computer-Workstation

Pressures on shoulders are significantly reduced on modified computer work station. 90% of respondent’s data are staying under 2000 µV in modified computer work station usage chart. However in standard computer work station usage, 70% were staying under 2000 µV.

### 4.4.5 Lower Back Region

Figure 23 shows EMG activity on respondents' lower back while they are using standard computer workstation during 10 min of typing. The pressures on lower back are on Figure 23 when they were typing with standard computer work station.

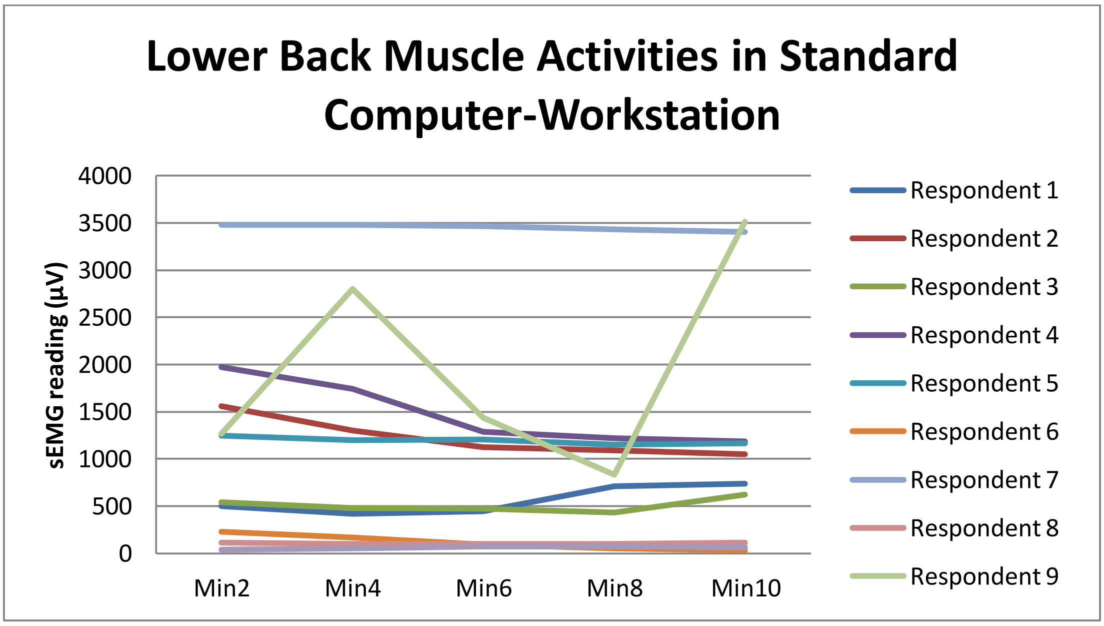



Figure 23: Lower Back Muscle Activities in Standard Computer-Workstation

Figure 24 shows EMG activity on respondents' lower back while they were using modified computer workstation during 10 min of typing. Pressures on lower back are on Figure 24 when they were typing with modified computer work station.

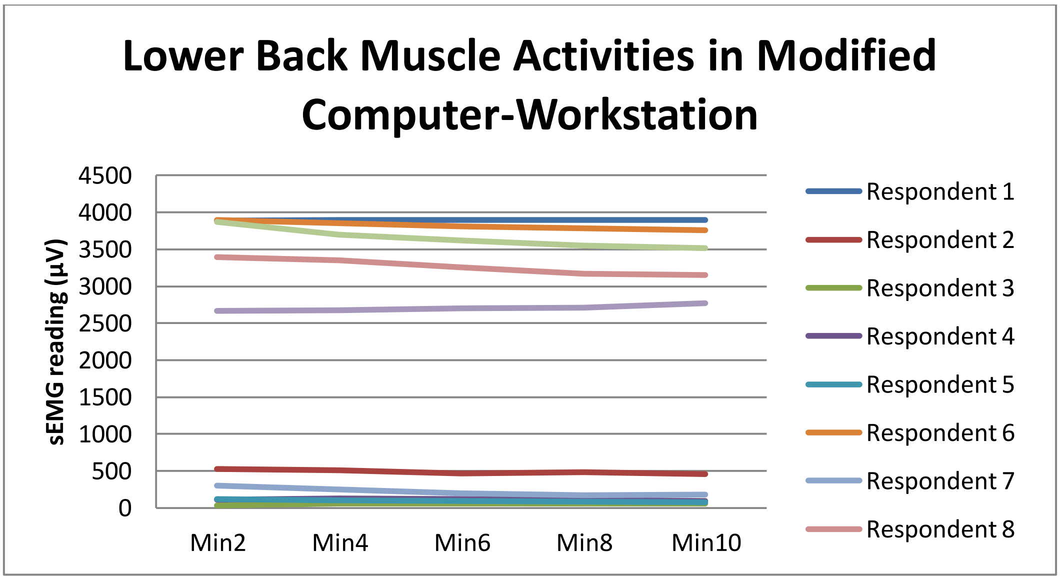



Figure 24: Lower Back Muscle Activities in Modified Computer-Workstation

Usage of modified computer work station stabilizes pressure constantly instead of changing frequency. Usage of standard work station may cause difference in pressure rate.

### 4.4.6. Upper Back Region

Figure 25 shows EMG activity on respondents' upper back while they are using standard computer workstation during 10 min of typing. Pressures on upper back are on Figure 25 when they were typing standard computer work station.

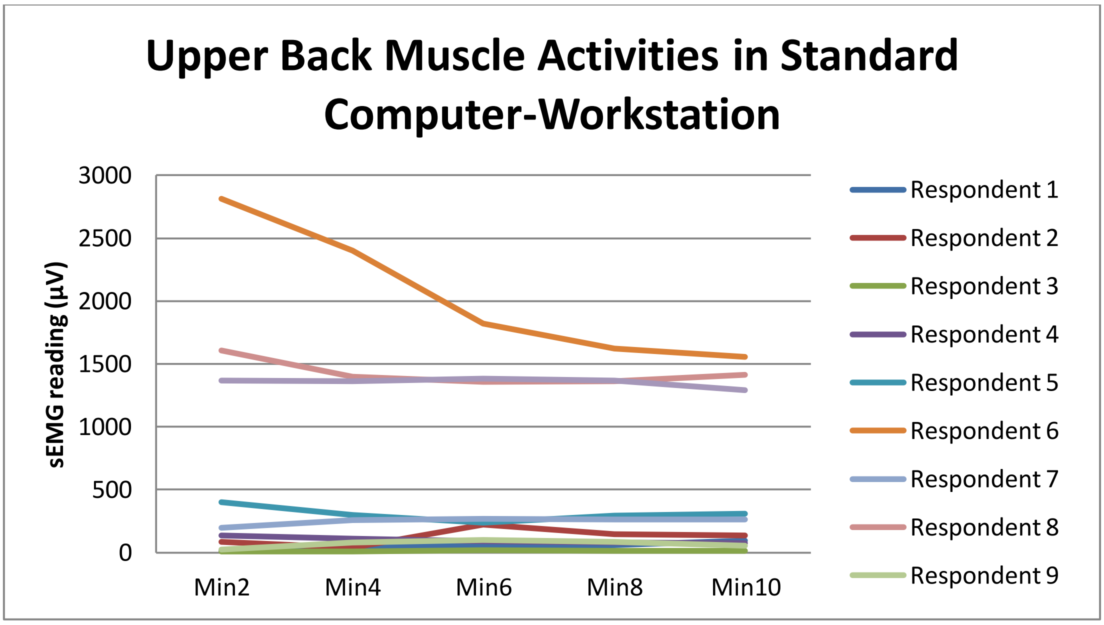



Figure 25: Upper Back Muscle Activities in Standard Computer-Workstation

Figure 26 shows EMG activity on respondents' upper back while they were using modified computer workstation during 10 min of typing. Pressures on upper back are on Figure 26 when they were typing modified computer work station.

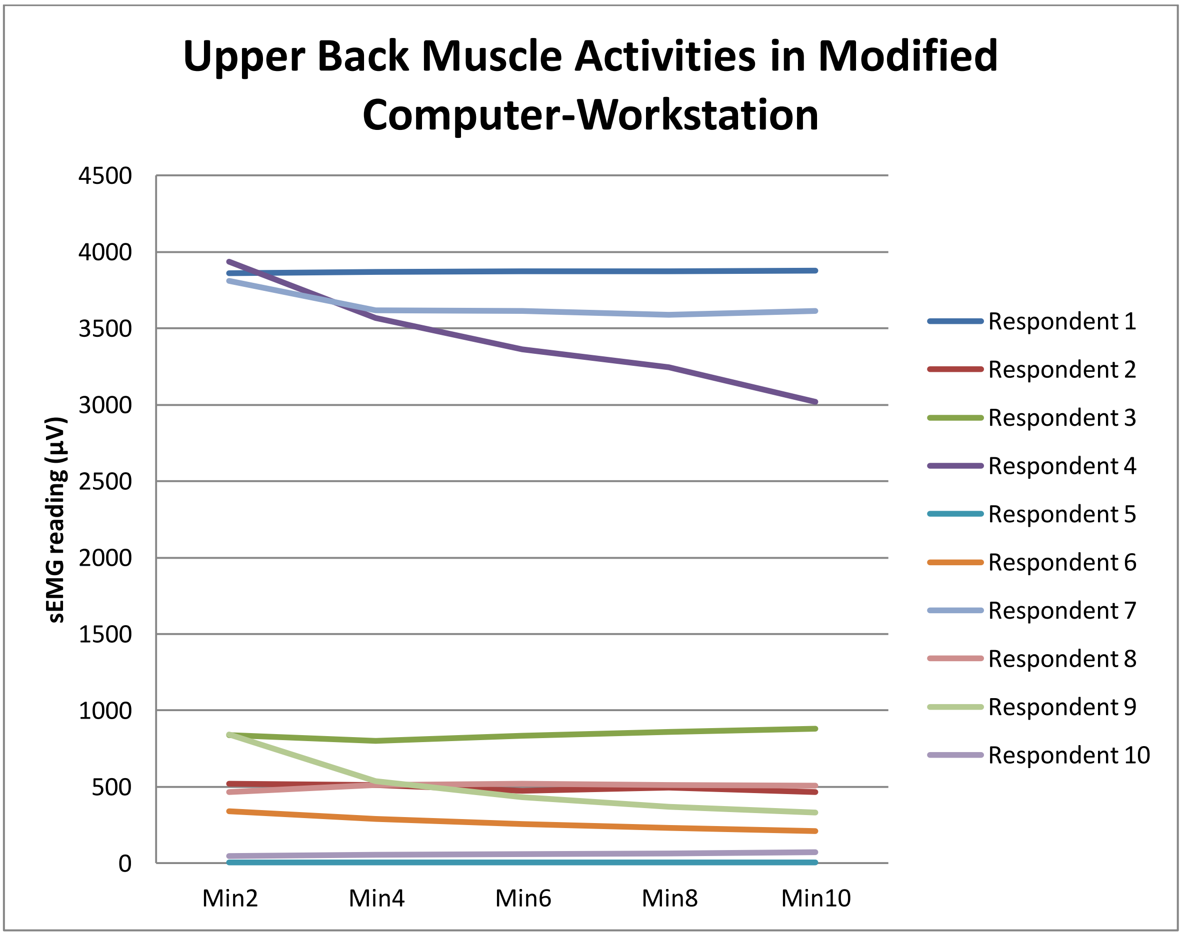



Figure 26: Upper Back Muscle Activities in Modified Computer-Workstation

Standard computer workstation produces less amounts of pressures on participants upper backs when compared to to modified computer workstation.

### 4.4.7 Analysis of Variance (ANOVA)

The reading from sEMG provides the information about the muscle activity over time. After calculating the mean value, for 10 respondents on their 6 of body regions for Standard computer workstation, and modified computer workstation. In order to test the hypothesis ($H_0$ = mean of musculoskeletal strain in time of the 6 body region does not differ) ANOVA is applied for each respondent.

#### 4.4.7.1 Standard Computer Station's Wrist Factors

Table 16 shows the ANOVA results of the muscle activities for standard computer workstation users.

Table 16: ANOVA Results for Standard Computer Workstation Users' Wrists

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 539821.8 | 4 | 134955.5 | 8.8825 | 0.985493 | 2.578739 |
| Within Groups | 68370716 | 45 | 1519349 | | | |
| | | | | | | |
| Total | 68910538 | 49 | | | | |

Hypothesis ($H_0$) is rejected because the value of $F_0$ is greater than $F_{critical}$. This means the old workstation design is not appropriate for muscle activities of the wrist.

#### 4.4.7.2 Modified Computer Station's Wrist Factors

Table 17shows the ANOVA results of the muscle activities for modified computer workstation users.

Table 17: ANOVA Results for Modified Computer Workstation Users' Wrists

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 1048556 | 4 | 262139.1 | 0.176048 | 0.949582 | 2.578739 |
| Within Groups | 67005938 | 45 | 1489021 | | | |
| | | | | | | |
| Total | 68054494 | 49 | | | | |

Hypothesis ($H_0$) is failed to be rejected because the value of $F_0$ is smaller than $F_{critical}$. This means that new anthropometrically designed workstation is preferred for the muscle activities at the wrist.

#### 4.4.7.3 Standard Computer Station's Elbow Factors

Table 18 illustrates the ANOVA results of the muscle activities for standard computer workstation users.

Table 18: ANOVA results for Standard Computer Workstation Users' Elbows

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 245681.8 | 4 | 61420.44 | 2.6174 | 0.998622 | 2.578739 |
| Within Groups | 1.06E+08 | 45 | 2346608 | | | |
| Total | 1.06E+08 | 49 | | | | |

Hypothesis ($H_0$) is rejected because the value of $F_0$ is greater than $F_{critical}$. Again, old workstation was proved for not being preferred for elbow muscle activities.

#### 4.4.7.4 Modified Computer Station's Elbow Factors

Table 19 shows the ANOVA results of the muscle activities for modified computer workstation users.

Table 19: ANOVA results for Modified Computer Workstation Users' Elbows

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 280238.2 | 4 | 70059.56 | 0.026966 | 0.998539 | 2.578739 |
| Within Groups | 1.17E+08 | 45 | 2598069 | | | |
| | | | | | | |
| Total | 1.17E+08 | 49 | | | | |

Hypothesis ($H_0$) is failed to be rejected because the value of $F_0$ is smaller than $F_{critical}$, which states that new computer workstation design is also preferred for elbow muscle activities.

### 4.4.7.5 Standard Computer Station's Neck Factors

Table 20 illustrates the ANOVA results of the muscle activities for standard computer workstation users.

Table 20: ANOVA results for Standard Computer Workstation Users' Neck

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 404007.3 | 4 | 101001.8 | 4.9069 | 0.995314 | 2.578739 |
| Within Groups | 92626352 | 45 | 2058363 | | | |
| | | | | | | |
| Total | 93030359 | 49 | | | | |

Hypothesis ($H_0$) is rejected because the value of $F_0$ is greater than $F_{critical}$. Thus, Table 20 proves that standard computer workstation design is not preferred for neck muscle activities.

#### 4.4.7.6 Modified Computer Station's Neck Factors

Table 21 shows the ANOVA results of the muscle activities for modified computer workstation users.

Table 21: ANOVA results for Modified Computer Workstation Users' Neck

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 1016010 | 4 | 254002.6 | 0.119925 | 0.974693 | 2.578739 |
| Within Groups | 95310421 | 45 | 2118009 | | | |
| | | | | | | |
| Total | 96326431 | 49 | | | | |

Hypothesis ($H_0$) is failed to be rejected because the value of $F_0$ is smaller than $F_{critical}$. Therefore, Table 21 shows that modified computer workstation is better for neck muscle activities.

#### 4.4.7.7 Standard Computer Station's Shoulder Factors

Table 22 illustrates the ANOVA results of the muscle activities for standard computer workstation users.

Table 22: ANOVA results for Standard Computer Workstation Users' Shoulder

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 14313.4 | 4 | 3578.349 | 0.001802 | 0.999993 | 2.578739 |
| Within Groups | 89352537 | 45 | 1985612 | | | |
| | | | | | | |
| Total | 89366851 | 49 | | | | |

Hypothesis ($H_0$) is failed to be rejected because the value of $F_0$ is smaller than $F_{critical}$. In this case, Table 22 illustrates that standard computer workstation design is appropriate for muscle activities.

#### 4.4.7.8 Modified Computer Station's Shoulder Factors

Table 23 shows the ANOVA results of the muscle activities for modified computer workstation users.

Table 23: ANOVA results for Modified Computer Workstation Users' Shoulder

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 859673.1 | 4 | 214918.3 | 0.110821 | 0.97811 | 2.578739 |
| Within Groups | 87270141 | 45 | 1939336 | | | |
| | | | | | | |
| Total | 88129814 | 49 | | | | |

Hypothesis ($H_0$) is failed to be rejected because the value of $F_0$ is smaller than $F_{critical}$. This means that, Table 23 provides evidence that modified computer workstation is appropriate for shoulder muscle activities as expected.

#### 4.4.7.9 Standard Computer Station's Lower Back Factors

Table 24 illustrates the ANOVA results of the muscle activities for standard computer workstation users.

Table 24: ANOVA Results for Standard Computer Workstation Users' Lower Back

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 615543.3 | 4 | 153885.8 | 12.3584 | 0.973263 | 2.578739 |
| Within Groups | 56033768 | 45 | 1245195 | | | |
| | | | | | | |
| Total | 56649311 | 49 | | | | |

Hypothesis ($H_0$) is rejected because the value of $F_0$ is greater than $F_{critical}$. This provides a similar result that standard computer workstation is also not preferred for lower back muscle activities.

### 4.4.7.10 Modified Computer Station's Lower Back Factors

Table 25 shows the ANOVA results of the muscle activities for modified computer workstation users.

Table 25: ANOVA Results for Modified Computer Workstation Users' Lower Back

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 51548.97 | 4 | 12887.24 | 0.004158 | 0.999964 | 2.578739 |
| Within Groups | 1.39E+08 | 45 | 3099637 | | | |
| | | | | | | |
| Total | 1.4E+08 | 49 | | | | |

Hypothesis ($H_0$) is failed to be rejected because the value of $F_0$ is smaller than $F_{critical}$. Table 25 shows that, once again, modified computer workstation is proved to be better for lower back muscle activities.

#### 4.4.7.11 Standard Computer Station's Upper Back Factors

Table 26 illustrates the ANOVA results of the muscle activities for standard computer workstation users.

Table 26: ANOVA Results for Standard Computer Workstation Users' Upper Back

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 144148.2 | 4 | 36037.05 | 6.2773 | 0.992481 | 2.578739 |
| Within Groups | 25833853 | 45 | 574085.6 | | | |
| Total | 25978001 | 49 | | | | |

Hypothesis ($H_0$) is rejected because the value of $F_0$ is greater than $F_{critical}$. So, standard computer workstation is not preferable for upper back muscle activities.

#### 4.4.7.12 Modified Computer Station's Upper Back Factors

Table 27 shows the ANOVA results of the muscle activities for modified computer workstation users.

Table 27: ANOVA Results for Modified Computer Workstation Users' Upper Back

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 169741.9 | 4 | 42435.48 | 0.016508 | 0.999444 | 2.578739 |
| Within Groups | 1.16E+08 | 45 | 2570622 | | | |
| Total | 1.16E+08 | 49 | | | | |

Hypothesis ($H_0$) is failed to be rejected because the value of $F_0$ is greater than $F_{critical}$. Table 27 also provides proof that modified computer workstation is preferable for muscle activities at the upper back.

# Chapter 5

# CONCLUSION

Based on NIOSH's symptoms survey and NMQ Questionnaire reaching level of suffering WRMSDs in work environment was purpose. WRMSDs are causing costly health problems (define as direct cost) and they also result in losing productivity (define as indirect cost).

Questionnaire results provided that 57% of the 42 respondents stated that they had neck trouble within the last 12 months. Also, 47.6% stated that they had shoulder trouble within the last 12 months. Moreover, again 47.6% stated that they experienced lower back trouble within the last 12 months.

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.

Anthropometric data of participants were obtained as subjects worked on their existing workstation. Then optimal workstation designed.

Collecting data from North Cyprus would provide huge generalizability to this thesis. Moreover, technological background with a wider array and especially level of education may yield results differently. Validating and verifying the improvements made by redesigned new computer workstation required in further research. 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.

EMG Studies on 10 users who had participated in this thesis proved that working with a computer may leave a significant impact on the area of the hands, elbow, neck, shoulders, upper back, and back. With using sEMG recording on old workstation and new workstation were helped to compare strain on muscle regions.

Table 28: sMEG Data Comparison

| **Muscle Region** | **Workstation** | | | | | |
|---|---|---|---|---|---|---|
| | **Old** | | | **New** | | |
| | 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 was used to test the mean musculoskeletal strain in time for those 10 respondents.

Table 29: Comparing F ratios of ANOVA test

| **Muscle Region** | **(New design)$F_0$** | **(Old design)$F_0$** | ***F crit*** |
|---|---|---|---|
| **Wrist** | 0.176048 | 8.8825 | 2.578739 |
| **Elbow** | 0.026966 | 2.6174 | 2.578739 |
| **Neck** | 0.119925 | 4.9069 | 2.578739 |
| **Shoulder** | 0.110821 | 0.001802 | 2.578739 |
| **Lower Back** | 0.004158 | 12.3584 | 2.578739 |
| **Upper Back** | 0.016508 | 6.2773 | 2.578739 |

Thus, it was proved that the new modified design of computer workstation provides less muscular pressure to the muscles at each measured body region. However, only for the shoulder region, old design for the computer workstation provided preferable results for the muscle activities.

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

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# APPENDICES

# Appendix A: Questionnaire

| Have you at any time during the last 12 months had trouble (such as ache, pain, discomfort, numbness) in; | Have you had trouble during the last 7days; | During the last 12 months have you been prevented from carrying out normal activities (eg. Job, housework, hobbies) because of this trouble? |
|---|---|---|
| 1 **Neck**<br>_ No _Yes | 2 **Neck**<br>_ No _Yes | 3 **Neck**<br>_ No _Yes |
| **4** **Shoulder**<br>_ No Yes<br>_ Right Shoulder<br>_ Left Shoulder<br>_ Both | **5** **Shoulder**<br>_ No Yes<br>_ Right Shoulder<br>_ Left Shoulder<br>_ Both | **6** **Shoulder**<br>_ No _Yes |
| **7** **Elbows**<br>_ No Yes<br>_ Right Elbow<br>_ Left Elbow<br>_ Both | **8** **Elbows**<br>_ No Yes<br>_ Right Elbow<br>_ Left Elbow<br>_ Both | **9** **Elbows**<br>_ No _Yes |
| **10** **Wrists/Hands**<br>_ No Yes<br>_ Right Wrists/Hands<br>_ Left Wrists/Hands<br>_ Both | **11** **Wrists/Hands**<br>_ No Yes<br>_ Right Wrists/Hands<br>_ Left Wrists/Hands<br>_ Both | **12** **Wrists/Hands**<br>_ No _Yes |
| **13** **Upper Back**<br>_ No _Yes | **14** **Upper Back**<br>_ No _Yes | **15** **Upper Back**<br>_ No _Yes |
| **16** **Lower Back (small of the back)**<br>_ No _Yes | **17** **Lower Back (small of the back)**<br>_ No _Yes | **18** **Lower Back (small of the back)**<br>_ No _Yes |
| 19 **One or both hips/thighs/buttocks**<br>_ No _Yes | 20 **One or both hips/thighs/buttocks**<br>_ No _Yes | 21 **One or both hips/thighs/buttocks**<br>_ No _Yes |
| 22 **One or both knees**<br>_No _Yes | 23 **One or both knees**<br>_ No _Yes | 24 **One or both knees**<br>_ No _Yes |
| 25 **One or both ankles/feet**<br>_No _Yes | 26 **One or both ankles/feet**<br>_ No _Yes | 27 **One or both ankles/feet**<br>_ No _Yes |

28) Please put a check by the words(s) that best describr your problem

| | | | |
|---|---|---|---|
| _ Aching | _ Burning | _ Cramping | _ Loss of color |
| _ Numbness(asleep) | _ Pain | _ Swelling | _ Stiffness |
| _ Tingling | _ Weakness | _ Other ( ____________________ ) | |

29) How long does each episode last?

_ 1 Hour _ 1 Day _ 1 Week _ 1 Month _ 6 Months

30) How many seperate episodes have you had in the last year?

______________________________________________________________________

31) Have you had medical treatment for this problem?

_ No (if No, why not?)

______________________________________________________________________

_ Yes (if Yes, where did you receive treatment?)

| | |
|---|---|
| _ Company Medical | Times in past year ________ |
| _ Personal Doctor | Times in past year ________ |
| _ Other(___________________) | Times in past year ________ |

32) How much time have you lost in the last year because of this problem?
______ Days

33) How many days in the last year were you on restricted or light duty because of this problem?

______ Days

# Appendix B: Human Body Muscles

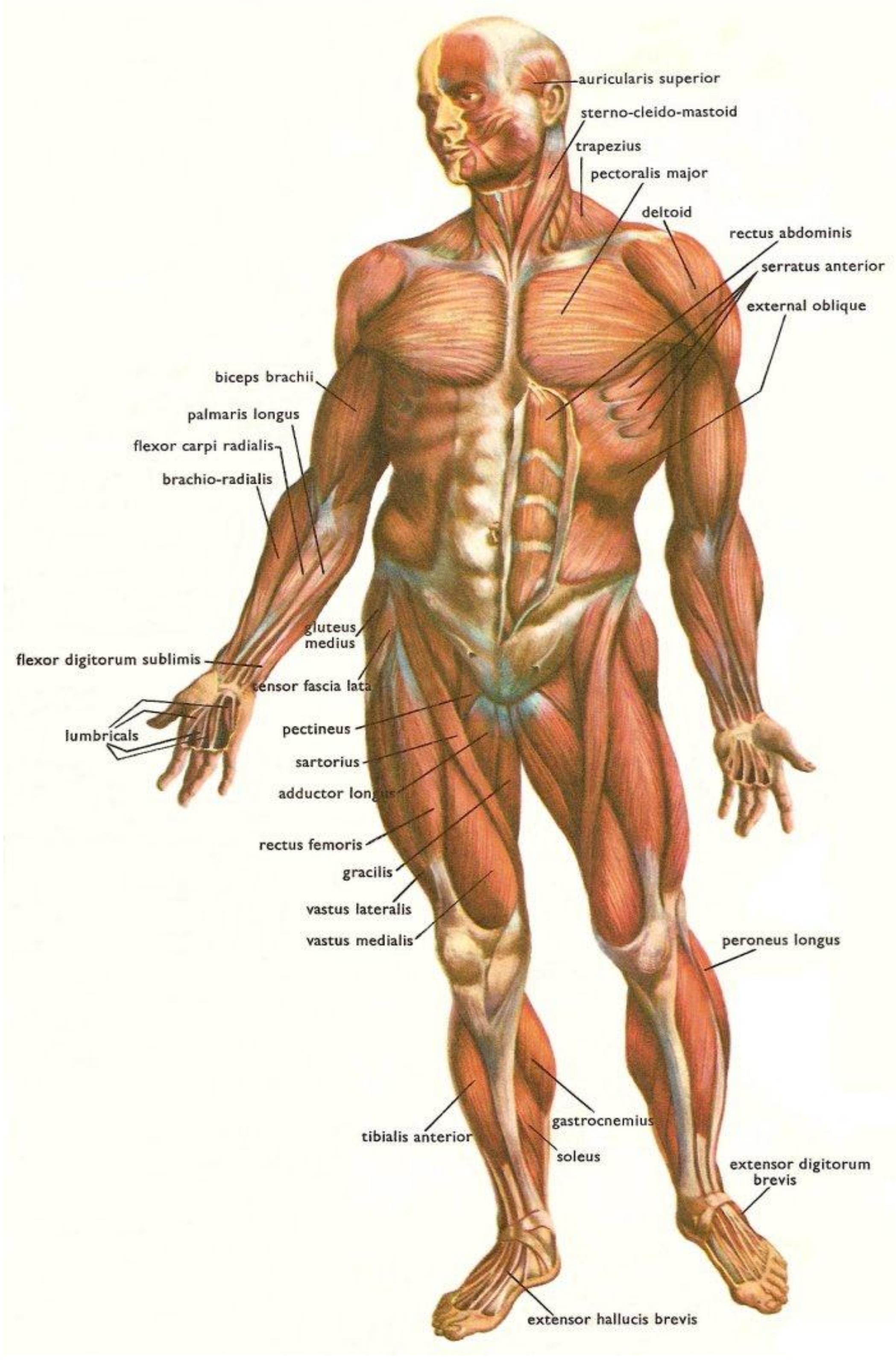


Figure 27: Frontside of Human Body Muscles

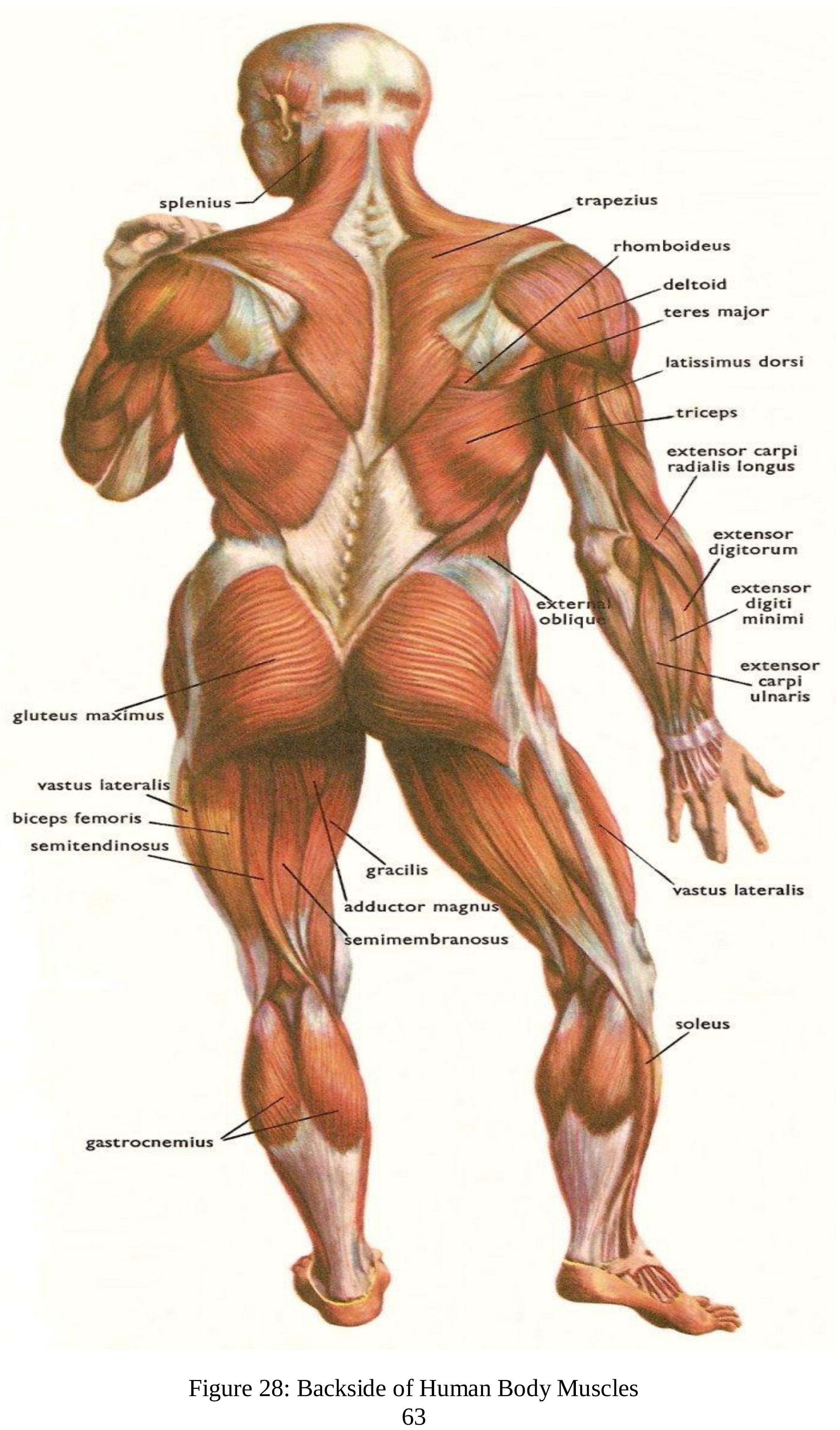


Figure 28: Backside of Human Body Muscles

# Appendix C: sEMG Activity Readings for Regions

Table 30: Standard Workstation' Wrists/Hands

| | | Wrist | | | | |
|---|---|---|---|---|---|---|
| | | Time (min.s) | | | | |
| Respondent | | 2 | 4 | 6 | 8 | 10 |
| Respondent | 1 | 2374.1 | 2897.3 | 1504.9 | 2313.0 | 2696.0 |
| Respondent | 2 | 2743.0 | 2360.7 | 1890.2 | 1827.4 | 1812.8 |
| Respondent | 3 | 140.8 | 27.3 | 26.8 | 27.1 | 15.9 |
| Respondent | 4 | 1969.8 | 1884.9 | 1982.5 | 2057.4 | 2089.7 |
| Respondent | 5 | 3361.3 | 3352.0 | 3422.5 | 3558.6 | 3591.6 |
| Respondent | 6 | 378.1 | 457.8 | 434.9 | 408.3 | 384.4 |
| Respondent | 7 | 76.4 | 63.33 | 61.9 | 51.7 | 65.9 |
| Respondent | 8 | 1469.8 | 668.5 | 330.9 | 443.9 | 455.9 |
| Respondent | 9 | 590.7 | 655.8 | 454.6 | 378.3 | 292.8 |
| Respondent | 10 | 86.8 | 63.3 | 67.4 | 110.8 | 76.2 |

Table 30: Standard Workstation' Elbows

| | | Elbow | | | | |
|---|---|---|---|---|---|---|
| | | Time (min.s) | | | | |
| Respondent | | 2 | 4 | 6 | 8 | 10 |
| Respondent | 1 | 257.3 | 215.1 | 938.6 | 538.2 | 669.3 |
| Respondent | 2 | 164.0 | 104.0 | 75.0 | 77.2 | 81.5 |
| Respondent | 3 | 238.1 | 340.9 | 536.7 | 532.8 | 482.1 |
| Respondent | 4 | 199.9 | 222.6 | 257.8 | 272.6 | 275.9 |
| Respondent | 5 | 2090.4 | 2153.9 | 2163.5 | 2165.1 | 2148.9 |
| Respondent | 6 | 3730.0 | 3699.5 | 3660.7 | 3644.1 | 3555.6 |
| Respondent | 7 | 2443.0 | 2233.6 | 2027.3 | 1587.4 | 1440.0 |
| Respondent | 8 | 3666.7 | 3929.1 | 3950.6 | 3357.9 | 3723.1 |
| Respondent | 9 | 3918.4 | 3947.1 | 3845.8 | 3627.2 | 3257.1 |
| Respondent | 10 | 830.2 | 777.1 | 757.6 | 750.1 | 710.9 |

Table 31: Standard Workstation' Neck

| | | Neck | | | | |
|---|---|---|---|---|---|---|
| | | Min2 | Min4 | Min6 | Min8 | Min10 |
| Respondent | 1 | 32.84 | 189.5 | 370.6 | 552.5 | 604.8 |
| Respondent | 2 | 159.4 | 157.4 | 158.2 | 159.5 | 198.6 |
| Respondent | 3 | 2900.0 | 2560.8 | 2147.6 | 1847.7 | 1624.9 |
| Respondent | 4 | 171.4 | 180.9 | 182.9 | 177.0 | 155.9 |
| Respondent | 5 | 3329.1 | 3289.3 | 3181.7 | 3253.9 | 3125.3 |
| Respondent | 6 | 2609.3 | 2134.8 | 1999.1 | 1889.8 | 1850.0 |
| Respondent | 7 | 1929.2 | 1980.3 | 2195.6 | 2339.8 | 2357.9 |
| Respondent | 8 | 974.7 | 961.1 | 961.5 | 981.4 | 961.4 |
| Respondent | 9 | 3579.1 | 3586.0 | 5597.1 | 3661.5 | 3294.2 |
| Respondent | 10 | 169.5 | 19.7 | 16.8 | 15.3 | 17.5 |

Table 32: Standard Workstation' Shoulders

| | | Shoulder | | | | |
|---|---|---|---|---|---|---|
| | | Min2 | Min4 | Min6 | Min8 | Min10 |
| Respondent | 1 | 567.4 | 524.3 | 714.9 | 907.3 | 958.4 |
| Respondent | 2 | 2269.3 | 2332.7 | 2406.3 | 2386.9 | 2314.8 |
| Respondent | 3 | 206.7 | 72.2 | 17.1 | 33.4 | 78.6 |
| Respondent | 4 | 1441.8 | 1242.2 | 1236.7 | 1178.9 | 1133.9 |
| Respondent | 5 | 3661.3 | 3606.5 | 3605.2 | 3591.0 | 3549.7 |
| Respondent | 6 | 149.6 | 101.9 | 74.4 | 51.6 | 24.9 |
| Respondent | 7 | 133.2 | 154.3 | 228.9 | 283.6 | 295.5 |
| Respondent | 8 | 275.4 | 201.4 | 169.8 | 150.5 | 128.4 |
| Respondent | 9 | 3646.7 | 3646.4 | 3651.0 | 3709.6 | 3660.4 |
| Respondent | 10 | 936.0 | 922.3 | 924.3 | 933.8 | 927.4 |

Table 33: Standard Workstation' Upper Back

| | | Upper Back | | | | |
|---|---|---|---|---|---|---|
| | | Min2 | Min4 | Min6 | Min8 | Min10 |
| Respondent | 1 | 14.2 | 56.9 | 51.2 | 58.7 | 97.3 |
| Respondent | 2 | 84.9 | 40.5 | 223.3 | 146.5 | 135.7 |
| Respondent | 3 | 9.3 | 9.2 | 16.5 | 13.5 | 15.4 |
| Respondent | 4 | 138.4 | 111.2 | 89.4 | 79.8 | 74.1 |
| Respondent | 5 | 398.1 | 300.2 | 239.6 | 292.3 | 309.1 |
| Respondent | 6 | 2815.4 | 2401.8 | 1820.7 | 1620.4 | 1558.4 |
| Respondent | 7 | 197.2 | 257.7 | 268.8 | 263.4 | 260.9 |
| Respondent | 8 | 1608.5 | 1396.1 | 1356.6 | 1365.1 | 1416.1 |
| Respondent | 9 | 25.9 | 80.5 | 98.9 | 83.4 | 53.3 |
| Respondent | 10 | 1366.5 | 1363.8 | 1383.4 | 1366.5 | 1289.2 |

Table 34: Standard Workstation' Lower Back

| | | Lower Back | | | | |
|---|---|---|---|---|---|---|
| | | Min2 | Min4 | Min6 | Min8 | Min10 |
| Respondent | 1 | 497.3 | 420.8 | 444.3 | 710.2 | 736.6 |
| Respondent | 2 | 1561.4 | 1300.9 | 1125.7 | 1090.1 | 1048.7 |
| Respondent | 3 | 540.3 | 482.9 | 475.9 | 429.5 | 622.6 |
| Respondent | 4 | 1972.6 | 1740.5 | 1286.8 | 1217.2 | 1185.4 |
| Respondent | 5 | 1246.1 | 1200.1 | 1207.2 | 1153.4 | 1162.0 |
| Respondent | 6 | 228.9 | 170.6 | 93.0 | 51.9 | 33.3 |
| Respondent | 7 | 3479.4 | 3480.2 | 3466.7 | 3433.8 | 3407.0 |
| Respondent | 8 | 112.0 | 100.3 | 100.5 | 99.0 | 112.69 |
| Respondent | 9 | 1263.8 | 2800.7 | 1437.2 | 835.1 | 3514.7 |
| Respondent | 10 | 37.1 | 52.7 | 69.5 | 69.5 | 68.8 |

Table 35: Modified Workstation' Wrists/Hands

| | | Wrist | | | | |
|---|---|---|---|---|---|---|
| | | Min2 | Min4 | Min6 | Min8 | Min10 |
| Respondent | 1 | 974.9 | 445.4 | 410.0 | 101.3 | 256.6 |
| Respondent | 2 | 13.4 | 14.7 | 12.9 | 10.2 | 14.9 |
| Respondent | 3 | 18.6 | 17.6 | 13.5 | 9.9 | 15.1 |
| Respondent | 4 | 3243.8 | 2457.3 | 2059.8 | 2032.4 | 1906.0 |
| Respondent | 5 | 192.9 | 147.2 | 116.9 | 103.9 | 101.2 |
| Respondent | 6 | 2015.9 | 1734.7 | 1245.5 | 983.0 | 935.0 |
| Respondent | 7 | 53.2 | 50.0 | 46.1 | 49.5 | 49.3 |
| Respondent | 8 | 690.4 | 267.9 | 164.2 | 144.9 | 140.1 |
| Respondent | 9 | 3883.3 | 3723.9 | 3495.8 | 3401.9 | 3368.0 |
| Respondent | 10 | 331.9 | 743.7 | 791.7 | 666.7 | 927.6 |

Table 36: Modified Workstation' Elbows

| | | Elbow | | | | |
|---|---|---|---|---|---|---|
| | | Min2 | Min4 | Min6 | Min8 | Min10 |
| Respondent | 1 | 3607.8 | 3205.3 | 2896.5 | 2284.5 | 2485.6 |
| Respondent | 2 | 201.3 | 179.7 | 179.7 | 162.8 | 180.6 |
| Respondent | 3 | 1204.7 | 797.5 | 819.3 | 650.2 | 655.9 |
| Respondent | 4 | 439.6 | 209.9 | 143.5 | 131.6 | 122.1 |
| Respondent | 5 | 74.4 | 54.3 | 49.4 | 51.1 | 44.5 |
| Respondent | 6 | 93.7 | 93.2 | 100.7 | 89.2 | 93.6 |
| Respondent | 7 | 872.0 | 829.3 | 802.2 | 838.8 | 1283.8 |
| Respondent | 8 | 3915.8 | 3937.9 | 3916.2 | 3892.6 | 3870.7 |
| Respondent | 9 | 202.9 | 112.6 | 114.6 | 114.4 | 107.4 |
| Respondent | 10 | 3747.0 | 3905.4 | 3916.9 | 3881.1 | 3890.2 |

Table 37: Modified Workstation' Neck

| | | Neck | | | | |
|---|---|---|---|---|---|---|
| | | Min2 | Min4 | Min6 | Min8 | Min10 |
| Responent | 1 | 90.0 | 71.4 | 64.3 | 64.1 | 64.5 |
| Responent | 2 | 91.7 | 125.6 | 181.8 | 203.2 | 211.8 |
| Responent | 3 | 965.4 | 797.3 | 640.1 | 462.4 | 542.5 |
| Responent | 4 | 1728.8 | 900.3 | 511.2 | 357.4 | 267.9 |
| Responent | 5 | 42.0 | 34.1 | 33.1 | 35.6 | 55.8 |
| Responent | 6 | 113.8 | 109.4 | 94.9 | 77.2 | 71.7 |
| Responent | 7 | 3601.4 | 3350.1 | 3288.8 | 3201.3 | 3100.2 |
| Responent | 8 | 3233.4 | 3132.2 | 2916.4 | 2853.6 | 2593.6 |
| Responent | 9 | 2707.7 | 2624.7 | 2418.2 | 2231.5 | 2183.5 |
| Responent | 10 | 3614.6 | 3504.9 | 3396.9 | 3265.3 | 3099.5 |

Table 38: Modified Workstation' Shoulders

| | | Shoulder | | | | |
|---|---|---|---|---|---|---|
| | | Min2 | Min4 | Min6 | Min8 | Min10 |
| Responent | 1 | 1281.9 | 1194.2 | 1154.3 | 1117.7 | 1066.1 |
| Responent | 2 | 23.7 | 56.1 | 72.4 | 84.3 | 87.5 |
| Responent | 3 | 12.5 | 18.6 | 15.3 | 58.9 | 52.3 |
| Responent | 4 | 3862.5 | 3206.9 | 2471.6 | 2008.5 | 1681.3 |
| Responent | 5 | 7.8 | 3.2 | 3.7 | 4.3 | 33.6 |
| Responent | 6 | 2458.7 | 2393.6 | 2262.1 | 2004.0 | 1886.3 |
| Responent | 7 | 337.8 | 184.1 | 157.9 | 117.8 | 91.9 |
| Responent | 8 | 78.9 | 64.8 | 41.6 | 22.7 | 12.5 |
| Responent | 9 | 3946.2 | 3849.4 | 3755.8 | 3641.1 | 3597.3 |
| Responent | 10 | 198.9 | 161.9 | 127.2 | 95.7 | 83.7 |

Table 39: Modified Workstation' Upper Back

| | | Upper Back | | | | |
|---|---|---|---|---|---|---|
| | | Min2 | Min4 | Min6 | Min8 | Min10 |
| Respondent | 1 | 3860.0 | 3869.1 | 3873.9 | 3874.0 | 3878.2 |
| Respondent | 2 | 520.3 | 512.5 | 473.8 | 494.6 | 466.8 |
| Respondent | 3 | 837.6 | 799.4 | 833.7 | 859.8 | 881.3 |
| Respondent | 4 | 3937.3 | 3568.6 | 3363.2 | 3244.3 | 3020.5 |
| Respondent | 5 | 4.79 | 4.5 | 4.5 | 4.5 | 4.7 |
| Respondent | 6 | 341.0 | 288.7 | 256.9 | 233.7 | 212.8 |
| Respondent | 7 | 3811.2 | 3619.8 | 3615.3 | 3588.8 | 3614.3 |
| Respondent | 8 | 467.2 | 511.1 | 521.6 | 510.5 | 506.7 |
| Respondent | 9 | 842.8 | 536.0 | 431.9 | 370.7 | 331.6 |
| Respondent | 10 | 48.8 | 58.1 | 58.2 | 62.7 | 74.8 |

Table 40: Modified Workstation' Lower Back

| | | Lower Back | | | | |
|---|---|---|---|---|---|---|
| | | Min2 | Min4 | Min6 | Min8 | Min10 |
| Respondent | 1 | 3892.4 | 3896.8 | 3897.5 | 3897.3 | 3898.8 |
| Respondent | 2 | 525.4 | 509.9 | 463.5 | 484.7 | 454.3 |
| Respondent | 3 | 33.7 | 58.6 | 59.1 | 56.8 | 56.2 |
| Respondent | 4 | 114.7 | 126.2 | 122.6 | 108.2 | 93.9 |
| Respondent | 5 | 118.3 | 100.1 | 89.9 | 81.7 | 79.4 |
| Respondent | 6 | 3897.0 | 3855.3 | 3807.8 | 3786.1 | 3754.9 |
| Respondent | 7 | 303.9 | 246.1 | 200.0 | 175.1 | 181.3 |
| Respondent | 8 | 3391.9 | 3348.1 | 3253.2 | 3168.2 | 3149.4 |
| Respondent | 9 | 3870.0 | 3700.7 | 3621.3 | 3552.6 | 3512.6 |
| Respondent | 10 | 2667.0 | 2671.6 | 2700.3 | 2710.0 | 2772.2 |