The Impact of Laptop and Desktop Computer Workstation on Human Performance

Amir Hossein Habibi Onsorodi

Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the Degree of

Master of Science
in
Industrial Engineering

Eastern Mediterranean University
September 2011
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

____

Prof. Dr. Elvan Yılmaz
Director

I certify that this thesis satisfies the requirements as a thesis for the degree of Master of Science in Industrial Engineering.

____

Asst. Prof. Dr. Gökhan Izbirak
Chair, Department of Industrial Engineering

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Industrial Engineering.

____

Asst. Prof. Dr. Orhan Korhan
Supervisor

Examining Committee

1. Asst. Prof. Dr. Emine Atasoylu _______________________________________
2. Asst. Prof. Dr. Gökhan Izbirak _______________________________________
3. Asst. Prof. Dr. Orhan Korhan _______________________________________

ABSTRACT

The goal of this study was to define the differences between desktop computer users and laptop computer users. Also define the affection of working with computer on different body regions.

A questionnaire prepared and published on a web site. 100 people filled it. The information of the questionnaire give important data about the work related musculoskeletal disorders. The questionnaire result showed that women have more disorders in their muscles. Also ache and pain is two important type of discomforts that most of the people fill them on their body regions.

Neck, shoulder, upper back, lower back and hands recognized as a region with maximum risk for suffering to muscles disorders and elbows, hips\thighs\buttocks, knees and ankles\feet have been reported as a region with minimum pain.

Electromyography tests have been done on 5 respondents. The experiments have been done on 6 different body regions for each of the respondents when they are working with a desk type computer and a laptop computer.

Electromyography chart draw for each position. The chart analysis shows that desktop computer user and laptop computer user burden pressure when they are using computer. In some position showed that desktop computer respondents have more pressure than laptop computer respondents. Also sometimes the result for each of the respondent in a same position was different. But totally a significant pressure observed when the respondents working with laptop, especially in neck muscles.

For analyzing of electromyography data used a hypothesis test. For each respondent for all of the body regions an ANOVA table prepared per working with desktop computer and laptop computer. In all of the tests, hypothesis test rejected and it shows that working with computer and laptop cause discomforts for all of the respondents in all of the body regions.

In another ANOVA analysis, we studied the affection of using of desktop computer and laptop computer on each of the body regions for all of the respondents. The result shows that just in shoulder region when the respondents working with desktop computer we cannot say that it has affection, in other region for both of computer we ham significant disorders.

Also we studied the interaction between type of computer and body regions. The ANOVA result showed that each of them did not have any affection on respondents but the interaction between them has a significant difference.

Keywords: Musculoskeletal discomfort, Desktop computer and laptop computer use

ÖZ

Bu çalışmanın amacı, masaüstü bilgisayar kullanıcıları ve dizüstü bilgisayar kullanıcıları arasındaki farklılıkları tanımlamaktır. Ayrıca, bu çalışmanın bir digger amacı; vücudun farklı bölgelerini bilgisayar ile çalışma etkisini ortaya koymaktır.

Bu çalışma için bir anket hazırlanmıştır ve bu anket bir web sitesinde yayınlanarak 100 kişi tarafından doldurulmuştur. Anket sonuçları; bilgisayar kullanımı esnaasındaki kas-iskelet bozuklukları ile ilgili önemli bilgiler vermektedir. Anket sonuçları, kadınlarda kas rahatsızlıklaırnın daha yaygın olduğunu göstermiştir. Ayrıca ağrı ve sızlamanın, değişik vücut noktalarında rastlanan en sık rahatsızlıklar olduğu saptanmıştır.

Boyun, omuz, üst sırt, alt sırt ve dirseklerde kas rahatsızlıkları yaygın bir şekilde saptanırken, eller, kalça, diz ve ayak bileklerinde bu tür rahatsızlıklara pek de sık rastanılmamaktadır.

5 katılımcıya elektromiyografi testi yapılmıştır. Bu testler; masaüstü ve dizüstü bilgisayarlar kullanılarak, 6 değişik vücut bölgesinden kas hareketleri izlenerek gerçekleştirilmiştir.

Her bir bölge için elektromiyografik grafik çizilmiştir. Grafik analizleri, masaüstü ve dizüstü bilgisayar kullanıcılarında ortaya çıkan baskıyı göstermektedir. Genellikle dizüstü kullanıcılarında kaslara daha çok yük yapıldığı ortaya konmuştur. Ayrıca bazen aynı pozisyonda her bir katılımcı için farklı sonuçlar elde edilmiştir.

Katılımcılarda özellikle dizüstü bilgisayar ile çalışırken boyun kaslarında basınç gözlemlenmiştir.

Elektromiyografik verilerin analiz edilmesi için bir hipotez testi kullanılmıştır. Her katılımcı için; masaüstü ve dizüstü bilgisayar kullanımında tüm vücut bölgeleri için bir ANOVA tablosu hazırlanmıştır. Tüm testlerde, hipotez reddedilmiştir. Bu da tüm katılımcılarda, tüm vücut noktalarında her hem masaüstü hem de dizüstü bilgisasyarın rahatsızlıklara yolaçtığı göstermektedir.

Ayrıca bilgisayar ve vücut bölgeleri türü arasındaki etkileşim incelenmiştir. ANOVA sonucu her biri katılımcıda bilgisayar tipinin (masaüstü/dizüstü) ve vücut bölgesinin etkileşerek kas-iskelet sistemi rahatsızlıklarına yol açtığı ortaya konmuştur.

Anahtar Kelimeler: Kas-iskelet rahatsızlıkları, masaüstü bilgisayar ve dizüstü bilgisayar

I would like to dedicate my dissertation to my dear grandparents who have left me but the memories of them will always remain in my heart. Although they have left me alone so soon but they will always be my guide in my life.

Besides, I inscribe this dissertation to my family specially my dear mother who has always been a great supporter of mine through my life time.

A devoted mother who dedicated her life to me without expectation and lost her most valuable moments of her life due to my success.

I know I can never respond to any of her kind efforts she did for me. I just want her to know that I will always be thankful and appreciative. “I kiss your hand mom”

And finally I like to thank my dear friend Setareh. She was my best friend in these years and was always beside me through all tough times.

ACKNOWLEDGMENTS

I would like to express my gratitude to my supervisor, Dr. Orhan Korhan, whose expertise, understanding, and patience, added considerably to my graduate experience. Undoubtedly I would not be able to accomplish this job without help and guidance of my supervisor who supported and encouraged me with no hesitation all the time. I express my sincere gratitude to his friendly responsiveness.

Foremost, I would like to thank to anyone who assisted me in this job and also my deep appreciation to my honorable jury members Dr. Gökhan Izbirak, Dr. Bela Vizvari and Dr. Emine Atasoylu for dedicating their time and undertaking the judgment of my thesis.

I wish I can attract their favorable point of view by presenting this topic.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

Use of computers in the offices has become a necessity for business purposes. Thus, computers are available almost in every office. Many people spend a significant amount of time working with computers for business and work purposes. Occupational injuries pose a major problem in workplaces where computers are widely used. Increase in the number of employees working with computer coincides with an increase of work-related musculoskeletal disorders. Work-related musculoskeletal symptoms occur when there is a mismatch between the physical requirements of the job and the physical capacity of the human body. These are the injuries that result from repeated motions, vibrations and forces placed on human bodies while performing various job actions.

The causes of musculoskeletal disorders in the workplace are diverse and poorly understood. Moreover, intensive, repetitive and long period computer use results in costly health problems (direct cost), and lost productivity (indirect cost).

Today, portable computers (laptops) are used not only by professionals who need to travel and work in different places with a computer system, but due to that they offer high technology performance in a compact, light, self-sufficient (battery provided), and occupying less space; laptop computers are preferred in the office workstations as well. In spite of increasing popularity of the laptop computers, desktop computers still dominate in the office workstations.

The aim of this dissertation is to investigate the development of the work-related musculoskeletal disorders and their effect on performance of office workers in laptop computer workstations and desktop computer workstations. Thus, we have studied the ergonomic differences of the laptop/desktop computer workstations and their impact on human performance.

In this study, we have developed a questionnaire to analyze and understand the ergonomic risk factors which affect the human performance. Surface electromyogram (sEMG) was also used to measure the muscle activities of office workers at their critical body regions; neck, shoulders, upper back, lower back, forearm, and wrist. These sEMG records were also analyzed to verify the risk factors identified by the questionnaire.

The significance of this study to the industry is to provide guidance by designing an optimal computer workstation setup for solving costly health problems and lost performance in offices where computers are frequently used.

Chapter 2

LITERATURE

2.1. Definition of Musculoskeletal Disorders

A musculoskeletal disorder definition is a condition where a part of musculoskeletal system is injured over time. The disorders occurs when the body part is called on to work harder, stretch farther, impact more directly or otherwise function at a greater level then it is prepared for. The immediate impact may be minute, but when it occurs repeatedly the constant trauma cause damage.

The term musculoskeletal disorder identifies a large group of conditions that result from traumatizing the body in either a minute or major way over a period of time. It is the buildup of trauma that causes the disorder. These conditions are often focused on a joint and affect the muscle and bone. However other areas can be strained and their response to that trauma can be an injury.

The federal Bureau of labor statistics (BLS) has defined musculoskeletal disorders (MSDs) as injuries and disorders to muscle, nerves, tendons, ligaments, joint, cartilage and spinal discs. MSDs don’t include injuries resulting from slip, trips, falls or similar accident.

According to the U.S. Bureau of labor statistics, U.S. Department of labor, November 2005 data analyses showed that sprains, strains and tears were the most common disorders also in figure 2.1 shows other statistically disorders percentage.

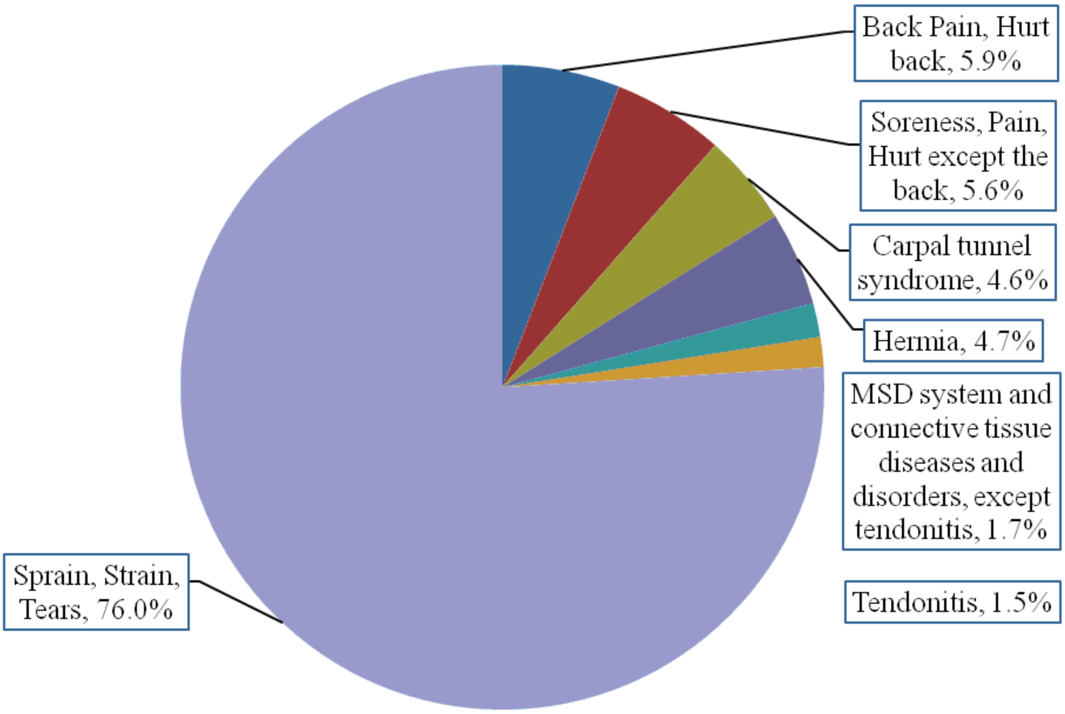

Figure 2.1: Nature of injury or illness, U.S. Bureau of Labor Statistics (2004)

MSDs have many various signs and symptoms. The most commonly noticed signs and symptoms are as follows:

- Inflammation
- Redness, dry, Itchy
- Decreased range of motion in the shoulder, neck or back
- Loss of function
- Tingling or aching
- Numbness or a burning sensation in the hand
- Stiffness or swelling in the joint

- Pain in wrists, forearms, elbows, neck, or back followed by discomfort
- Muscle weakness
- Fatigue
- Decreased grip strength in the hand
- Blurred or double vision
- Cramping
- Loos of color in affected regions
- Tension stress, hardness and related ailments

If you feel any of these signs or symptoms is better to improve which activity that you do frequently.

2.2. Work-Related of Musculoskeletal Disorders (WRMSDs)

Work-Related of Musculoskeletal Disorders are disorders of the musculoskeletal (e.g. muscles, tendons, joint, ligament, etc.) that caused by a work place activity.

Work station condition and human work posture are two important factors. The reason that a worker doesn't have enough attention to their work posture or work condition is that WRMSDs does not appears suddenly. It means that the effect of disorders appear after a period of time.

According to Eurostat figures on recognized occupational diseases (EODS), (Schnider et al., 2010) musculoskeletal disorders are also the most common occupational disease. Musculoskeletal disorders are the most common work-related health in Europe. Across the EU 27, 25% of workers complain of backache and 23% report muscular pain.

In 2005, 35.4% of workers in the EU15 and in the newer Member State consider that their work affects their health.

European Survey on Working Conditions (ESWC) 2005, 24.7% of the European workers complain of backache, 22.8% of muscular pain, 45.5% report working in painful or tiring position while 35% are required to handle heavy loads in their work.

Analysis the data collection showed that, 8.1% to 72.9% of workers report exposure to risk factors of musculoskeletal diseases. In detail, 8.1% of European workers report lifting or moving people for at least one quarter of their working time. Similarly 24.2% of workers in the EU27 are exposed to painful or tiring positions, 35% to carrying or moving heavy loads, 62.3% to repeated hand or arm movements and 72.9% are standing or walking at least one quarter of their working time.

The Safety and Health Assessment and Research for Prevention (SHARP) (Silverstein et al., 2002) studied the impact of work-related musculoskeletal disorders in Washington state work places. WRMSDs accounted for 27 percent of all accepted state fund workers compensation claims. State fund means the workers compensation program operated by the department of labor and industries. Some large employers are self-insured between 1994 and 2002, the state fund accepted 365,760 claims for WRMSDs (About 27%). These claims are 35% of all compensable claims.

Musculoskeletal disorders account for nearly 70 million physician office visits in the United States annually, and an estimated 130 million total health care encounters including outpatient, hospital, and emergency room visits.

Musculoskeletal disorders and carpal tunnel syndrome increased by 32% from 2002 to 2005 (by 39%among women) and also accounted for 59% of all recognized disease covered by European Occupational Disease Statistics (EODS) in 2005 (about 85% of all ODs among women).But all in all, the number of accepted cases of occupational disease is much smaller than the number of self-assessed work-related cases described in the previous section would suggest. Also the Bureau of Labor Statistics reported 26,794 Carpal tunnel syndrome cases involving days away from work in 2001.

The result showed that every day increase the number of workers whom surf to the Work-Related Musculoskeletal Disorders and it is an alarm for the workers and employers to have more attention to the work station design and work posture.

2.3. Computer use and WRMSDs

The number of people who use of computer as a business tools are increased every day. Growing industrial technology caused to human need to use of computer more and more. The number of personal computer in use worldwide exceeded 900 million in 2005. U.S.A has more personal computers in use than people in five to six years (Computer Industry Almanac, 2006). In Australia 89% of businesses used computer in the year to June 2005 (Australian Bureau of Statistics, 2006) and in the U.K. approximately 13.9 million households could access the internet from home in early 2006 (National Statistics UK, 2006). Computer users spend hours of a day for using computer. Computer users are as same as all of the jobs surf to musculoskeletal disorders. Because most of computer users sit on the chair and use of computer on the table, their upper body have more risk for muscle disorders. These disorders can be including neck, shoulder, elbow, forearm, finger, upper back, lower back and etc.

2.4. Economic Impact of WRMSDs

The cost of WRMSDs divided to two parts: Direct cost and indirect cost. Direct cost or visible cost includes insurance, compensation, medical and administrative cost. Indirect cost (hidden cost) include hiring and training of new employees, the reduce performance levels, the effects on production and quality of work.

Actual cost that spent for WRMSDs cannot be determine correctly or accurate. This can be due to the different organization of insurances system. But every year various data publish by different companies that show the cost of WRMSDs approximately.

The safety and Health Assessment and Research for Prevention (SHARP) (Silverstein et al., 2002) between 1994 to 2002, in Washington state workplaces these claim cost was $3.3 billion in medical cost and partial wage-replacement benefit.

The German Federal Institute for Occupational Safety and Health (BAuA) estimated the productivity loss due to MSDs at 0.59% of the GNP in 2002 and 0.4% in 2004 and 2006

In France in 2006, MSDs have led to seven million workdays lost, about 70 million EUR of enterprises contributions.

Sicherhit und Gesundheit bei der Arbit 2006 (SUGA) costs of musculoskeletal diseases about 23.7% of days lost (95 million days lost) , and 23.9 billion EUR or 1.1% of the GNP in lost productivity and gross value added.

In another researched by bureau of Labor Statistics, November 2009, the result shown at the table 2.1.

Table 2.1: Lost productivity, U.S. Department of Labor (2009)

Number of days away from work	Percentage of workers
Cases involving 1 day	11.1%
Cases involving 2 days	9.3%
Cases involving 3-5 days	18.3%
Cases involving 6-10 days	12.8%
Cases involving 11-20 days	13.1%
Cases involving 21-30 days	7.2%
Cases involving 31 or more days	28.1%

Days away from work cases include those that result in days away from work with or without job transfer or restriction. Days away from work caused to direct cost and indirect cost. Companies burden indirect cost because they loss their workers and decrease productivity levels also Insurance company and medical centers burden direct cost.

The Institute of Medicine estimate of economic burden of WRMSDs as measured by compensation costs, lost wages and lost productivity are between $45 and $54 billion annually.

2.5. Mouse

Cook et al. (2000) emphasized that no relationship was found between hours of mouse use per day and symptoms. The result of their research suggests that mouse

use constitutes an additional risk factor for musculoskeletal symptoms, particularly related to the arm posture adopted. The result also suggest that mouse use may contribute to neck and wrist discomfort.

In another research, the effects of duration of mouse use have been reviewed by Blatter and Bongers (2002). The result showed that duration of mouse use was not statistically significant on Work Related Upper limb Disorders (WRULDs) and only for arm, elbow or wrist or hand problem a moderately increased odds ratio among the mouse users was observed.

Although duration of mouse use have not any significant disorders but the size of external notebook mice have different effects on posture and muscle activity (Hengel et al., 2008). Their studies indicated that there were differences in biomechanical exposure across notebook mice. In general, the smallest mouse designs and participants with smaller hands had less neutral postures and higher muscle activities. Surprisingly, participants with smaller hands did not benefit from using the smaller mice; however participants with larger hands had more difficulty with smaller mice than with larger mice. Self-reported rating showed that while participants preferred smaller mice for portability; larger mice scored higher on comfort and usability.

Also Blatter and Bonger (2002) studied the differences between men and woman depend on duration of computer use, it showed that in men, only moderate association were seen for computer use more than 6h/day but in woman, moderately increases odds ratio were observed for a duration of computer use of more than 4h/day and strongly increased risk for computer use more than 6h/day.

2.6. Keyboard

Another device that use for every computer or laptop is keyboard, nowadays too many different types of keyboards are available in the market that each of them have a different shape and different size. The different shapes of keyboard have different influence on wrist and forearm postures. One of the optimal keyboard shapes is the keyboard with an opening angle of 12˚, a gable angle of 14˚, and a slope of 0˚ appears to provide the most neutral posture among the keyboard tested (Rempel et al., 2007). Their subjects most preferred this keyboard or similar keyboard with a gable angle of 8 and their subjects least preferred the keyboard on a conventional laptop computer. When using a computer, wrist and forearm are influenced by a number of factors. This study found that when all factor except keyboard are held constant, wrist and forearm postures are strongly influenced by keyboard design.

2.7. Accessories

2.7.1. Laptop Station

The number of people using support apparatus like palm rest, laptop station, etc. to reduce the work-related musculoskeletal symptoms is increasing significantly. Different studies have been done to investigate the impact of these instruments. Berkhout et al. (2004) studied the effect of using a laptop position (Figure 2.2).

Figure 2.2: Laptopstation

They showed that laptop station allows for adjustability of a separate keyboard and screen height and distance. The instrument caused:

1. Decreasing the impact of the torque (Flexion moment) on the cervical spine(c7.TH1 segment)
2. Decreasing the perceived strain on the neck
3. Increasing the performance

Their statistical analysis showed significant differences ($p<0.05$) between laptop station and laptop pc use in the torque at C7.Th1, the perceived strain on the neck and in the performance score. The use of laptop station produced an average 24% decrease in the mechanical load (torque) on the C7.Th1 cervical segment, an average 17% smaller discomfort score and an average 17% higher performance score when compared to result from the laptop pc.

2.7.2. Palm rest

Another support apparatus that studied by Moffet et al. (2002) was palm rest for laptop computer. The object of this study was to determine the differences between uses of each of these laptops (with or without palm rest) in two computer workstations (Desktop/ Laptop computer).

The result showed that use laptop with palm rest or without palm rest didn't have large differences and only minor differences were found in posture, wrist position and performance.

2.8. Display

There are various designs of displays in desktop and laptop computers which have several effects on posture and muscle activity. Screen is not detachable from laptop computers. Therefore users can not adjust laptop computer display as same as desktop computer display (except for screen inclination).

In modern day offices and homes, it is common to find the computer display screen placed at angle to the user. The effects of different angled positions of the display screen on neck-shoulder muscle activity studied by Szeto et al. (2008). They selected a group of 20 persons (10 male and 10 female) and examined their muscle activities in the cervical erector spine (CES) and upper trapezius (UT). Each subject performed typing tasks for 20 min with central position (CP), angled left position (ALP), and angled right position (ARP). (Figure.3)

Figure 2.3: CP, ALP, ARP. (Szeto et al., 2008)

They found significant increases in ipsilateral CES and contralateral UT muscles in both ALP and ARP. There were also significant increases in subjective discomfort scores in ALP and ARP compared to CP. This result showed that higher muscle activities with angled screen positions may indicate greater biomechanical exposure that may in turn contribute to musculoskeletal disorders, especially with prolonged computer use.

Straker et al. (2008) conducted a research on the effects of height of computer displays. Lower display heights increased head and neck flexion with more spinal asymmetry when working with paper. The results showed that high display would be recommended over the mid display. The high and mid displays were found to be equivalent in posture and muscle activity, except for head flexion.

2.9. Desk

The desk of a working place especially for those who use computer in their office has significant influence on body posture and muscle forces. Too many different types of desks with different height and widths are available in the market. It is very difficult to fit a human operator into a computer workstation due to anthropometric differences. Also the width of desk can be different depend on the number of devices that user want to use. (E.g. printer, telephone, fax …).

Moffet et al. (2002) studied the effect of using desk/lap situation workstation. They selected eight healthy subjects (4 men and 4 women) for this test and the methodology they used for this test was: The subject performed a standardized typewrite test with two different laptops for 15 min, without correction any key mistake.

During test, muscle activity (EMG) from four muscles of the subject right side was picked up by surface electrodes.

In desk situation observed that shoulder were more in the pressure whereas in lap situation head and neck and wrist segments appear to be more stressed. Higher muscles load levels in the trapezius and deltoid muscles and lower muscle load level in the wrist extensors were found in the desk situation as compared to lap situation.

Rectangular shape is the common shape for most of the desk that use for computer. A research has been done to compare traditional desk and curved desk by Straker et al. (2009). The curved desk resulted in greater postural and muscle activity variation, suggesting an advantage of this supportive surface over the straight desk. An analysis of the video record confirmed that the curved desk provide support. Full forearm support was used for 84% of the time with the curved desk. In contrast, wrist support (42%) was the primary form of support for the straight support (22%).(Figure 2.4)

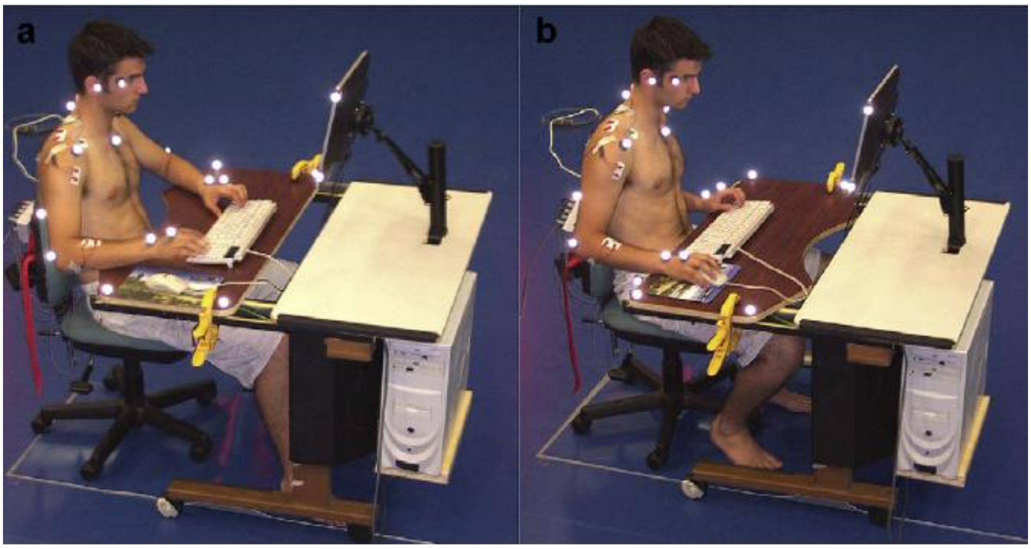

Figure 2.4: Subject working with curved (a) and straight desk (b).(straker et al., 2009)

2.10. Discomforts in computer use

Jensen et al. (2002) emphasized that neck, shoulder and hand/wrist ache were the prevalence ache for computer users. They found that neck and shoulder ache were common among women but hand/wrist ache observed among men. They studied the mouse use among intensive computer users was associated with symptoms in both hand/wrist and shoulder region.

Work with computer regularly and daily cause to various discomforts in all body regions. Types of discomforts divided to 10 types: Ache, pain, cramp, tingling, numbness, heaviness, weakness, tightness, felling hot and cold and swelling. (Korhan, O., Mackieh, A., 2010). Ache and pain were the most common types of discomforts in all body regions based on their study. Also they studied these types of discomforts on 6 different part of body (neck, shoulder, elbow/forearm, hand/wrist, fingers, upper back and lower back). The result showed that most prevalent discomforts experienced were observed having ache at the shoulder and ache in the neck.

The observation supported where the respondents did not take into consideration of having 90 angles between the shoulder and elbow, sitting symmetrically, having no elbow and leg supports and not being trained in posture.

Most of the computer user have tendency sitting flexed back posture while seated at work (Mork and Westgaard, 2009). Their result showed that aggravating low back pain was not related to duration of sitting, sitting posture or low back muscle activity. Low back muscle activity in upright posture affected strongly pelvic and upper trunk posture while sustained stretch of passive lumbar structures in combination with essentially silent muscles may exacerbate low back pain in sedentary workers.

The National Research Council (NRC) reviewed upper-extremity disorders among computer users. Their result showed that constraint posture, constant force and highly repetitive movements as well as psychosocial factors such as time constraints and high quantitative demand caused to upper extremity disorders.

Most of Work-Related Musculoskeletal Disorders for computer users showed that neck, shoulder and upper limb are different ache point for computer user body. Larson et al (2007) studied all of the criteria that use for diagnosis of disorders neck and upper limbs (table 2.2).

Table 2.2: Criteria used for diagnosis of disorders neck and upper limb

Diagnosis	Criteria
Tension neck syndrome	Neck pain; sense of fatigue or stiffness in the neck; pain radiating from neck to the back of the head of muscles; tender spots in the muscles
Cervical syndrome	Pain radiating from the neck to the upper extremity; limited neck movement radiating pain provoked by test movement; decreased sensibility in

	hands/fingers; muscle weakness of the upper limb
Cervialgia	Neck pain, limited neck movement in at least four of six directions. Diagnosis only if tension neck syndrome or cervical syndrome is not present
Trapezius myalgia	Neck pain, tightness of muscles, tender point in the muscles. Diagnosis only if tension neck syndrome or cervical syndrome is not present
Thoracic outlet syndrome	Pain radiating to upper extremity, in the distribution of the ulnar nerve; paresthesia in the distribution of the ulnar nerves; positive Roos' test (increase of subjective symptoms, not only fatigue); intense tenderness over the brachial plexus. Diagnosis only if tension neck syndrome or cervical syndrome is not present
Frozen shoulder	Shoulder pain; progressive of the shoulder during the last 3-4 months, limited outward rotation, and abduction
Supraspinatus tendinitis	Shoulder pain; local tenderness over the tendon insertion; paint at resisted isometric abduction
Infraspinatus tendinitis	Shoulder pain; local tenderness over tendon insertion; pain at resisted isometric outward rotation
Bicipital tendinitis	Shoulder pain; local tenderness over tendon(s); pain at resisted isometric elevation of the arm (straight and elevated 90 degree) and/or resisted isometric flexion of the elbow (fixe 90 degree hand supinated)
Acromioclavicular syndrome	Shoulder (epaulet pain); palpable tenderness of the joint; pain provoked by horizontal adduction and/or by outward rotation of the arm (90 degree abduction, with flexed elbow)
Lateral and medial epicondylitis	Elbow pain; palpable tenderness of the lateral and/or medial epicondyle; pain at resisted isometric extension or flexion of the wrist; for the diagnosis lateral epicondylitis, pain and/or weakness in gripping
De Quervian's tendinitis	Pain at the wrist, tenderness at palpation of tendons the thumb side of the wrist. Localized swelling, redness and heat
Overused hand syndrome	Wrist pain; palpable tenderness of the wrist capsule of the thenar and hypothenar muscles and of the

	intrinsic muscles of the hand
Peritendinitis/tenosynovitis	Wrist pain; palpable tenderness of the tendon(s); local swelling; redness; or heat
Carpal tunnel syndrome	Nocturnal numbness of the hand; paraesthesia in the distribution of the median nerve, positive Tinle's sign over the carpal tunnel; positive Phalen's test; decreased sensibility in the distribution of the median nerve; decreased strength in opposition of the thumb
Pronator syndrome	Pain of the medial/proximal part of the forearm; local tenderness over the edge of m. pronator teres; pain and decreased flexion strength of the wrist and/or of the distal phalanxes of the fingers I-II
Radial tunnel syndrome	Pain in the elbow during rest; tenderness about 2-3 inches distally of the lateral epicondyle; pain of the proximal, lateral part of the forearm and pain and decreased strength in supination; decreased strength in ulnar deviation
Ulnar nerve entrapment at the elbow	Pain and paraesthesia of numbness in the distribution of the ulnar nerve; decreased sensibility of the fingers IV-V and of the ulnar part of the back of the hand; positive Tinel's sign over the cubital tunnel; decreased strength in spreading the fingers and flexion of the distal phalanx of finger V
Ulnar nerve entrapment the wrist	Pain and paraesthesia or numbness in the distribution of the ulnar nerve; decreased sensibility of the fingers IV-V; positive Tinel's sign over Guyon's tunnel (volar/ulnar at the wrist); decreased strength in spreading the fingers

2.11. Computer Posture

Many different study have been done to show that the relation between posture and muscles disorders.

Gerr et al. (2004) studied the relation between neck disorder with work posture and duration of computer use. Their result showed that duration of computer use did not have any significant influence on neck or shoulder disorders while work posture was a major factor for neck disorders.

Computer users spend hours of a day in front of a computer. This is more important for computer users to seat correctly when they are using a computer. Correct computer posture is a combination of several body placements that work together to ensure that a computer user suffers the least amount of strain while using the computer. It means all of the users body must be in the best position (i.e. eyes, back, neck, knee, foot, etc.). Strongly advise to the computer users when they are using a computer, seat as a below positions:

- Keep arms on the table
- Keep safe distance from the monitor
- Sit with the back straight and in the comfortable chair
- Keep feet either flat on floor or on a foot rest
- Find the time for breaks

Opting for a well-designed chair is one of the crucial consideration keeping the hips as behind as possible in the chair and altering the height of the seat, so that the feet are flat on the ground and the knees in line with or slightly lower than the hips, will prove beneficial.

Samani et al (2010) studied the interactive effects of acute experimental pain in trapezius and sore wrist extensor during computer work.

In another research Straker et al (2009) studied relationships between prolonged neck/shoulder pain and sitting spinal posture in male and female adolescents. Their result showed that prolonged neck/shoulder pain affected 5% of adolescents, and was more common in females than males. Prolonged neck/shoulder pain was weakly associated with more lordotic lumbopelvic postures, but the clinical belief that neck and shoulder pain is related to cervicothoracic postures was not supported when gender was included in model.

Zeidi et al (2010) studied the effect of intervention based on transtheoretical modeling on computer operators postural habits. The result from this study provided that transtheoretical model (TTM) based ergonomic training among computer operators can improve postural risk factors for musculoskeletal disorders.

Chapter 3

METHODOLOGY

3.1. Introduction

This research is divided into two parts; a questionnaire study and an experimental study. The questionnaire utilized for this particular research consisted of a self-administered by a non-probability, convenience sample from people who use computers for work purposes. Since a large statistical society required and also to facilitate the procedure for the users the questionnaires were uploaded on an internet website (www.surveymonkey.com/s/msd_survey). Analysis of the data collected by this questionnaire will be used to assess and understand the user attitudes and differences towards the desktop and laptop computer use.

Work-related musculoskeletal disorders (WRMSDs) associated with the intensive, repetitive and long period computer keyboard and mouse use that affect the low back, neck, shoulders, forearms, hands, and wrists (Korhan and Mackieh, 2010). Surface electromyogram (sEMG) was used to record the muscle activities of the selected respondents of the questionnaire, to further analyze the muscle activities. This analysis would identify and reveal the factors which causes WRMSDs and would determine which computer station provides better performance.

3.2. Questionnaire

In order to design the appropriate questionnaire for this research, different questionnaires in the field of ergonomics were investigated. Two well-known questionnaires, the Nordic Musculoskeletal Questionnaire and the U.S. *National Institute for Occupational Safety and Health* (NIOSH) Symptoms Survey were addressed to develop a new questionnaire on WRMSDs in computer users.

We published the link of questionnaire web page (www.surveymonkey.com/s/msd_survey) in different way. Send link as email to different company such as Barin Choob Company and Ghods Hospital, the computer department of each company distribute the web link to staff of company. Also we published the web link in Industrial Engineering department of Eastern Mediterranean University and also we published it in Elm va Sanat University of Iran. Also we used of social networks such as Facebook and Linkedin for publishing the link of questionnaire.

The questionnaire was distributed to 100 people from different countries and different occupation and working environment. The questionnaire was also uploaded on the Internet at social networks Facebook and Linkedln for making it accessible to everyone in different work environment. Only those users were allowed to fill this questionaries' who were working continuously with the computers in their working environment.

The questionnaire was designed to include 3 sections; a prologue, a series of classification questions, and a core questions of the study.

In the first section, the questions were selected to identify the nature and severity of self-rated musculoskeletal symptoms. Therefore, the questionnaire included items asking about the experience of musculoskeletal problems in nine body areas (neck, shoulder, elbow, wrist, hand, upper back, lower back, hips\tights, knees and ankles\feet) over the past year.

The second section included the detailed information about musculoskeletal disorders (MSD), such as problems have been prevented from carrying out normal activities (e.g. job, house works and hobbies).

The third section of the questionnaire was more focused on symptoms and side effects of muscles activities and investigates the illness symptoms on different area of the body including aching, burning, cramping, loss of color, numbness, pain, swelling, stiffness, tingling, weakness on the above mentioned body regions (neck, shoulder, elbow/forearm, hand/wrist, upper back, and lower back).

Some questions to identify the demographic impact (such as age, weight, height, etc...) and some particular ones in the field of computer (considering the type of used computer, duration of usage and the record and duration of past activities with the computer) were required to be asked for codification of the final used questionnaire, this type of questions added to the original questionnaire.

The significance of this questionnaire is that, it investigated the time of starting the muscular phenomenon and the duration that these MSDs make the person suffering. Moreover, the lost efficiency of each person during the impact of the MSDs was investigated through this questionnaire as well.

The contribution of this research to the industry is that, by analyzing the information obtained from the questionnaire, the high risks areas for getting impacted by muscular disease in computer users will be identified. Moreover, the different regions of disease caused by laptop or desktop computers will be magnified. In the same way it would be possible to evaluate the amount of increase perceived MSDs.

3.3. Experiment

In order to estimate the amount of pressure put on computer users, an experiment was designed which measures the pressure on muscles during their work with computers and laptops.

In the sEMG experiment, data were collected from 6 body regions; hand/wrist (flexor retinaculum), elbow/forearm (flexor carpi radialis), neck (posterior upper trapezius), shoulder (posterior deltoid), upper back (rhomboideus major), and lower back (sacropinalis). The sEMG device (MyoTrac Infiniti, model SA9800) has 2 channels, which means the device allows to collect data from two muscle groups at a time. Therefore, the experiment was repeated three times to collect data for each muscle group.

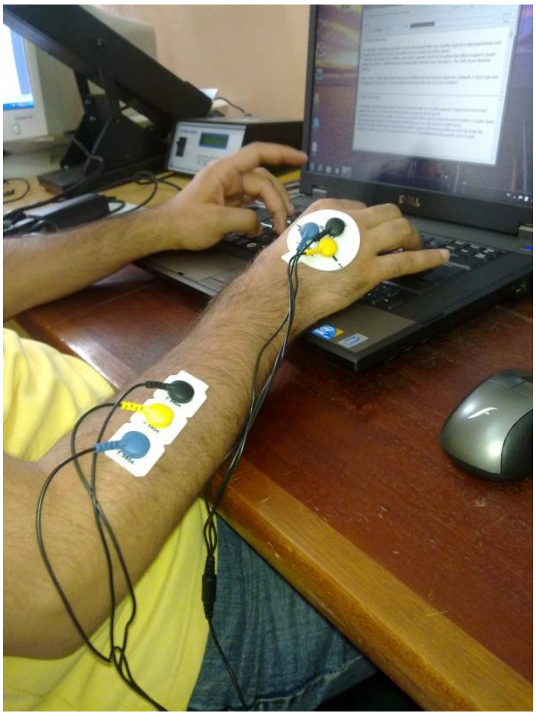

Figure 3.1: Placement of sEMG electrodes on hand (musculi lumbricales manus) and forearm (extensor carpi radialis)

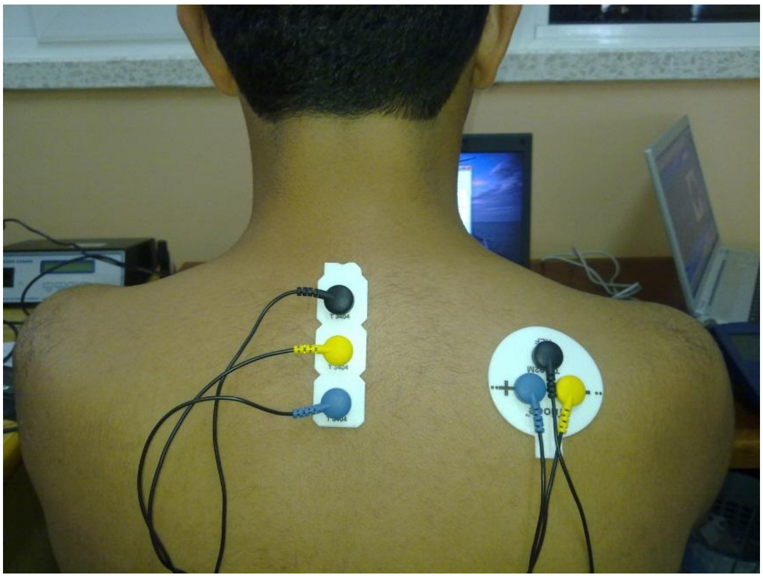

Figure 3.2: Placement of sEMG electrodes on shoulder (posterior deltoid) and neck (posterior upper trapezius)

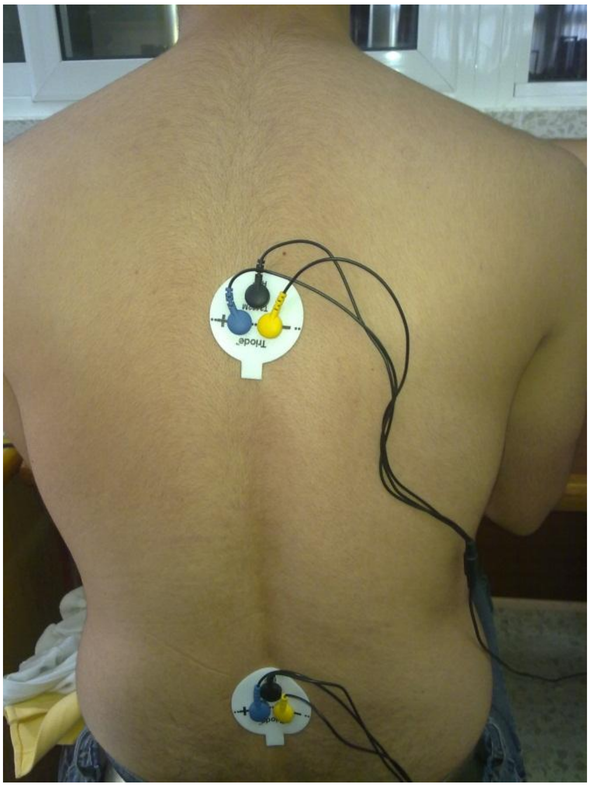

Figure 3.3: Placement of sEMG electrodes on upper back (posterior upper trapezius) and lower back (sacropinalis)

Five people with no background of previous MSDs were invited to take a part in this experiment (3 men and 2 women). All the experiments were taken place at the Ergonomics labs of the Department of Industrial Engineering of the Eastern Mediterranean University.

The experiment was conducted in standard condition of temperature and light and these quantities were tried to be kept constant throughout the experiment. Two different type of computer were used; a desktop computer with standard keyboard, 17 inch monitor and a standard mouse. The other one was a DELL Latitude E5510 laptop 15.6 inch monitor with a standard mouse.

The users were asked to operate only with the mouse (not using the touchpad) with the laptop. They used table has been one of the standard types with normal height and dimension also flexible chair is used for users to enable them to adjust it based on their height and put themselves in a standard position. We asked them sit on the computer desk during experiment as a standard position as follow:

- Hands, wrists, and forearms are straight, in-line and roughly parallel to the floor.
- Head is level or bent slightly forward, forward facing, and balanced.
- Shoulders are relaxed and upper arms hang normally at the side of the body.
- Elbows stay in close to the body and are bent between 90 and 120 degrees.
- Sit far back in with your back touching the back support.
- Push your hips as far back as they can go in the chair.
- Adjust the seat height so your feet are flat on the floor and your knees equal too, or slightly lower than, your hips.

The users were asked to keep typing for certain duration and while the typing was in process the conductors, connected to their muscles was recording the muscles activities.

Typing test software (Typing test Q) was used to standardize the performance of the respondent. The function of this software is to show a text on the monitor so the users are able to type exactly whatever they saw, so there was no need of turning the head or changing the position to see the text which is supposed to be typed.

Because the sEMG device has two channels (it allows collecting data from two muscle groups at a time), the experiment was repeated three times to collect data for each muscle group. Each of respondents did the experiment in two stages. First stage was with a desktop computer and then with a laptop computer. Each stage included 3 sets of typing for duration of 20 minutes. After each set 10 minutes brake was given to them.

In each 20 minutes with interval 5 minute a sample with duration 30 seconds recorded. For analysis the data that collected in each 30 second studied as average in 5^{th}, 10^{th}, 15^{th}, 20^{th}, 25^{th} and 30^{th} second and finally with total average.

3.4. Data Analysis

Correlation analysis was performed to find out relationships among the variables determined form the questionnaire data and the experimental (sEMG) data.

Logistic Regression was constructed to identify a statistically significant factor which contributes formation of the WRMSDs.

Analysis of Variance (ANOVA) was applied at the end to the data collected by sEMG experiment to reveal the factors which causes WRMSDs and would determine which computer station provides better performance.

Chapter 4

RESULTS

4.1. Questionnaire Results

The result showed that from 100 people who filled the questionnaire, 54 percent of them were male and 46 percent of them were female. Figure 4.1 shows that more than half of the respondents (58%) were between 26 and 35 years old.

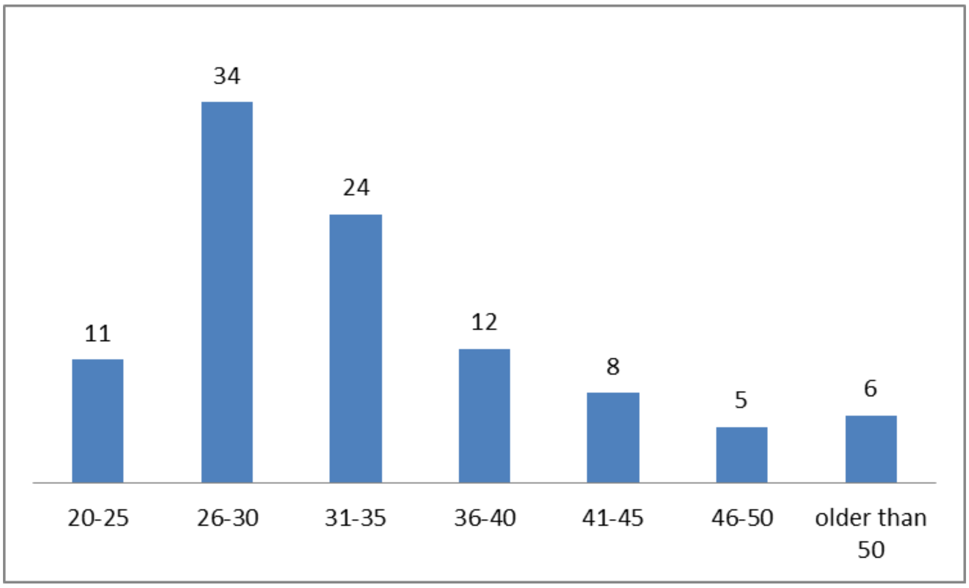

Figure 4.1: Age distribution of the respondents

Most of the male height were between 1.71 cm and 1.90 cm and for the female height were between 1.51cm and 1.70 cm. (figure 4.2)

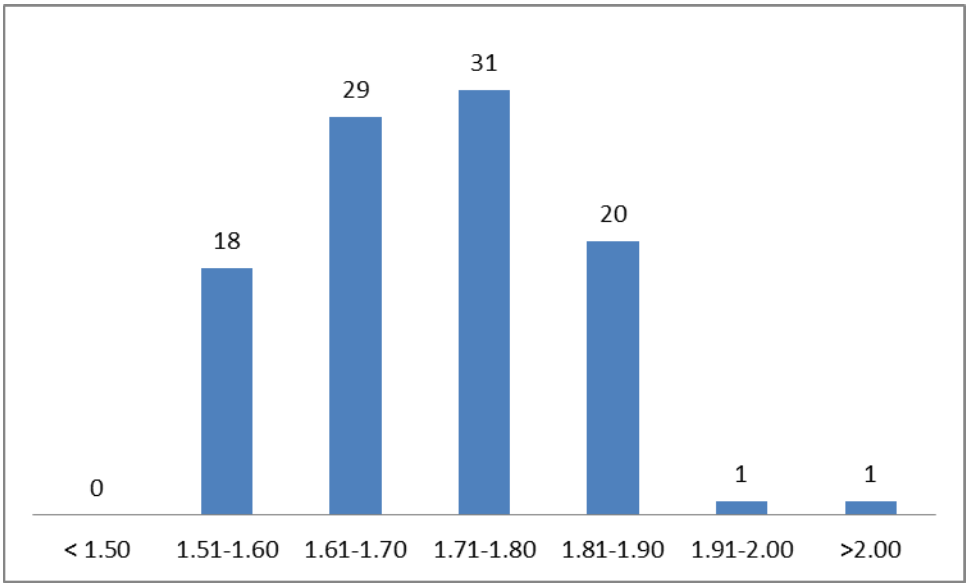

Figure 4.2: Height distribution of the respondents

Figure 4.3 illustrates that most of the respondents were between 51 and 90 kilograms, where only 8 respondents stated that they were more than 90 kilograms and 6 respondents stated that they were less than 50 kilograms.

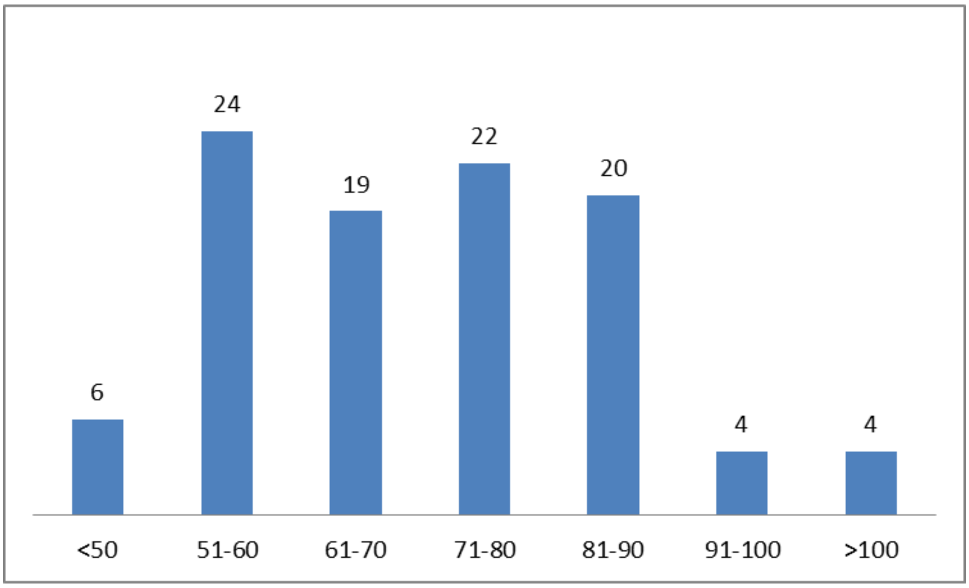

Figure 4.3: Weight distribution of the respondents

24 respondents just used of desktop computer and laptop users were 30 people (30%) whereas the respondents who used of desktop computer and laptop computer together were 46 people (46%).

Regular keyboard (Q-type) used by most of the respondents (90%) and only 9 persons used of ergonomic (with wrist support) keyboard.

It was found that 54 persons (54%) have been using computer more than 10 years and 37 persons of them have been using of computer between 5 and 9 years the others persons reported between 1 and 4 years (Figure 4.4).

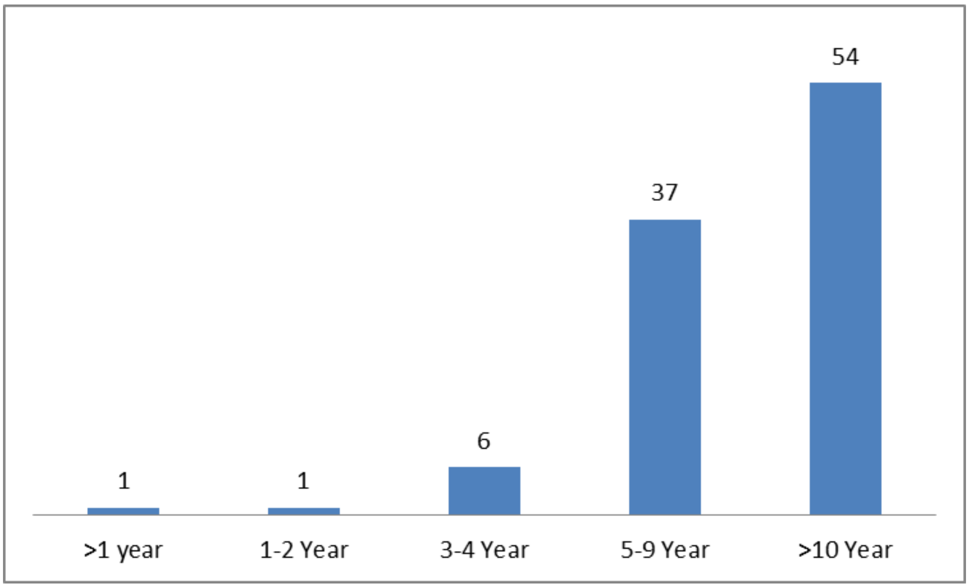

Figure 4.4: Years of Computer Use

Further 20% of the respondents used of computer more than 8 hours per day and most of the respondents (24%) used of computer between 7 and 8 hours daily. About 22 respondents used of computer between 5 and 6 hours per day. The rest of the respondents stated that they used computer less than 5 hours per day.

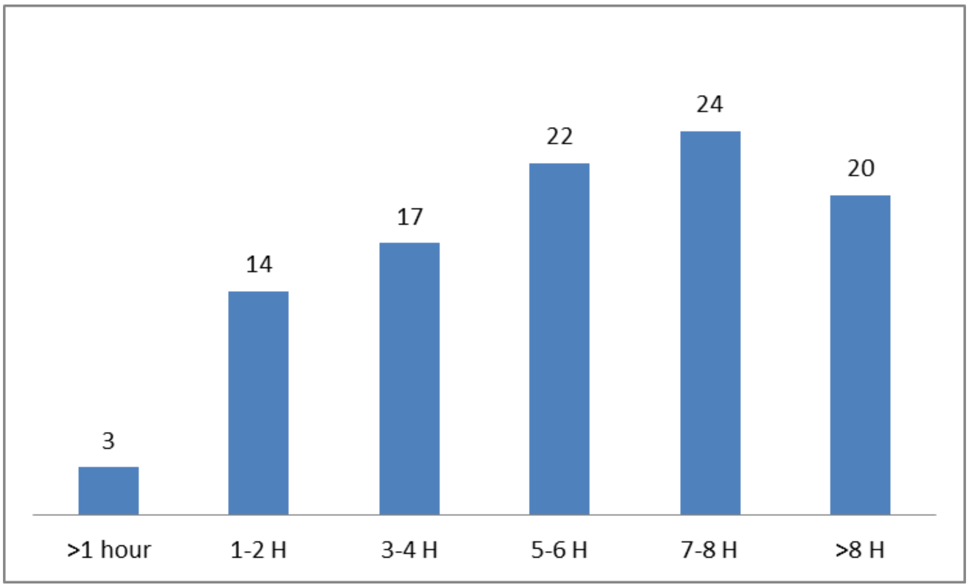

Figure 4.5: Daily computer use

During the last 12 month 54% of the respondents had trouble in neck, 44% of them had trouble in shoulder. Amongst the respondents, 37% had trouble in their hand\wrist, and 29% stated that they experienced discomfort at their fingers. Upper back and lower back trouble reported respectively 37% and 35%. Elbows, hips\thighs\buttocks, knees and ankles\feet have been reported as a region with minimum pain (table 4.1).

Table 4.1 also shows pain was the most prevalent discomfort type, which was followed by aching. Feelings of weakness and numbness were also among the most observed discomforts. On the other hand, swelling and loss of color (lowest) were the least observed discomforts among the respondents.

Table 4.1: Type of Discomfort

Region \ Discomfort		Aching	Burning	Cramping	Loos of Color	Numbness	Pain	Swelling	Stiffness	Tingling	Weakness	Response count
Neck	Total	**23**	6	6	0	1	**24**	0	5	3	7	54
	Percent	**43%**	11%	11%	0%	2%	**44%**	0%	9%	6%	13%	
Shoulder	Total	**12**	5	6	1	2	**23**	2	1	2	10	44
	Percent	**27%**	11%	14%	2%	5%	**52%**	5%	2%	5%	23%	
Elbows	Total	5	1	0	0	**6**	**8**	0	1	1	**18**	21
	Percent	24%	5%	0%	0%	**29%**	**38%**	0%	5%	5%	**38%**	
Wrist\Hands	Total	12	4	3	1	7	**18**	0	4	2	**13**	37
	Percent	32%	11%	8%	3%	19%	**49%**	0%	11%	5%	**35%**	
Finger	Total	**8**	2	1	0	**8**	**10**	0	4	1	6	29
	Percent	**28%**	7%	3%	0%	**28%**	**34%**	0%	14%	3%	21%	
Upper Back	Total	**12**	8	3	0	2	**19**	0	3	1	6	37
	Percent	**32%**	22%	8%	0%	5%	**51%**	0%	8%	3%	16%	
Lower Back	Total	**12**	5	4	0	3	**25**	0	6	0	8	35
	Percent	**34%**	14%	11%	0%	9%	**71%**	0%	17%	0%	23%	
Hips\Tights\Buttocks	Total	**5**	2	4	0	**8**	**8**	1	1	0	4	22
	Percent	**23%**	9%	18%	0%	**36%**	**36%**	5%	5%	0%	18%	
Knees	Total	**8**	4	4	2	3	**17**	4	2	3	**8**	30
	Percent	**27%**	13%	13%	7%	10%	**57%**	13%	7%	10%	**27%**	
Ankles\Feet	Total	5	3	5	0	3	**9**	4	4	3	**6**	27
	Percent	19%	11%	19%	0%	11%	**33%**	15%	15%	11%	**22%**	

The users were asked to indicate the number of the day that they have been experience restriction or light duties during the last year. On an average, each person has been encounter to small muscular problems for almost 7 days. The maximum number reported working days was 90 days and the minimum one has been zero.

Also the number day ask by users as medical care permission has been reported 5 days on an average, the most number it has been 20 days and the least number of it has been zero days.

Among the studied group, it is claimed by some of them that have not been able to use the permission because of not being able to get that permission or because of the special situation of their job.

Generally the result shows the women are more highly to be affected by muscular diseases; the reason could be researched in physiological differences between men and women, since women have competitively weaker muscles than the men.

There is a higher chance that they can be affected by muscular disorders analyzing the researches results which are done on different bodies region of men and women bodies, it is claimed that that women's hand muscles has the most probability of being affected by muscular diseases than the man hands. The proposed reason of this issue, other than physiological differences, could be found in that fact that women are taking more share in household activities such as washing the dishes, cooking, cleaning and etc. than men, and all of this activities are considered as hand working.

Also it was found that neck, shoulder, upper back and lower back of the women are in higher risk of experiencing muscular problem than the other muscles comparing to the men.

4.2 Correlation Analysis

All the 100 respondents provided complete responses, resulting in 100 observations available for analysis. There were 129 variable in the study (Appendix B). In order to avoid the multicollinearity between independent variable that is used to fit the risk assessment models in this research, a correlation analysis was performed to determine relationships among independent variables. As a result variable which are highly correlated (with a correlation coefficient greater than r=0.5) are found.

Table 4.2: Positive Correlation

Variable 1	Variable 2	Correlation Coefficient
Height	Weight	0.694856
Lower Back Trouble	Lower Back Problem	0.503558
Lower Back Trouble	Lower Back Pain	0.583641
Knee Trouble	Knee Pain	0.502850
Neck Problem	Shoulder Problem	0.764706
Neck Problem	Elbow Trouble	0.558142
Neck Problem	Hand Problem	0.528470
Neck Problem	Upper Back Problem	0.608798
Neck Problem	Feet Problem	0.599432
Shoulder Problem	Elbow Trouble	0.639032
Shoulder Problem	Hand Problem	0.528470
Shoulder Problem	Upper Back Problem	0.608798
Shoulder Problem	Lower Back Problem	0.548521
Shoulder Problem	Hip Problem	0.558142
Shoulder Problem	Feet Problem	0.599433
Elbow Trouble	Hand Problem	0.606764
Elbow Trouble	Upper Back Problem	0.572763
Elbow Trouble	Lower Back Problem	0.572763
Elbow Trouble	Hip Problem	0.777531
Elbow Trouble	Knee Problem	0.536413
Elbow Trouble	Feet Problem	0.631963
Hand Problem	Upper Back Problem	0.544610
Hand Problem	Hip Problem	0.606764
Hand Problem	Feet Problem	0.570638
Upper Back Problem	Knee Problem	0.636591
Upper Back Problem	Feet Problem	0.615820
Lower Back Problem	Hip Problem	0.655652
Lower Back Problem	Feet Problem	0.615820
Hip Problem	Knee Problem	0.536413
Hip Problem	Feet Problem	0.631963
Knee Problem	Feet Problem	0.590271
Hip Aching	Hip Burning	0.622700
Knee Aching	Knee Burning	0.559209

Neck Burning	Wrist Burning	0.593067
Neck Burning	Lower Back Burning	0.521648
Neck Burning	Feet Burning	0.696086
Neck Burning	Wrist Tingling	0.565445
Shoulder Burning	Knee Loos of Color	0.622700
Elbow Burning	Knee Burning	0.571489
Elbow Burning	Feet Burning	0.571489
Elbow Burning	Wrist Cramping	0.571489
Elbow Burning	Neck Tingling	0.571489
Elbow Burning	Wrist Tingling	0.703527
Elbow Burning	Feet Tingling	0.571488
Wrist Burning	Feet Burning	0.562401
Wrist Burning	Wrist Numbness	0.504116
Wrist Burning	Feet Numbness	0.562401
Wrist Burning	Wrist Tingling	0.699854
Wrist Burning	Feet Tingling	0.562401
Finger Burning	Elbow Stiffness	0.703527
Lower Back Burning	Feet Tingling	0.766570
Lower Back Burning	Lower Back Weakness	0.608859
Hip Burning	Finger Tingling	0.703527
Hip Burning	Upper Back Tingling	0.703527
Knee Burning	Knee Cramping	0.562401
Knee Burning	Shoulder Loos of Color	0.571489
Knee Burning	Elbow Tingling	0.571489
Feet Burning	Wrist Loos of Color	0.571489
Feet Burning	Elbow Tingling	0.571489
Feet Burning	Wrist Tingling	0.812320
Neck Cramping	Elbow Weakness	0.546342
Shoulder Cramping	Knee Cramping	0.593067
Wrist Cramping	Finger Cramping	0.571489
Wrist Cramping	Knee Cramping	0.562401
Wrist Cramping	Wrist Stiffness	0.562401
Wrist Cramping	Elbow Tingling	0.571489
finger Cramping	Shoulder Swelling	0.703527
Hip Cramping	Hip Numbness	0.504116
Hip Cramping	Feet Tingling	0.562401
Shoulder Loss of color	Knee Loos of Color	0.703527
Shoulder Loss of color	Shoulder Numbness	0.703527
Shoulder Loss of color	Knee Numbness	0.571489
Shoulder Loss of color	Knee Stiffness	0.703527
Shoulder Loss of color	Shoulder Tingling	0.703527
Shoulder Loss of color	Knee Tingling	0.571489
Neck Numbness	Upper Back Numbness	0.703527

Shoulder Numbness	Knee Numbness	0.812320
Upper Back Numbness	Hip Swelling	0.703527
Lower Back Numbness	Finger Tingling	0.571489
Lower Back Numbness	Upper Back Tingling	0.571489
Feet Numbness	Finger Tingling	0.571489
Feet Numbness	Upper Back Tingling	0.571489
Shoulder Pain	Upper Back Pain	0.604274
Wrist Pain	Lower Back Pain	0.529010
Upper Back Pain	Lower Back Pain	0.563430
Elbow Stiffness	Feet Stiffness	0.571489
Knee Stiffness	Knee Tingling	0.812320
Neck Tingling	Elbow Tingling	0.571489
Elbow Tingling	Wrist Tingling	0.703527
Elbow Tingling	Feet Tingling	0.571489
fingerer Tingling	Feet Tingling	0.571489
Upper Back Tingling	Feet Tingling	0.571489
Feet Tingling	Lower Back Weakness	0.596381
Neck Weakness	Upper Back Weakness	0.546342
Neck Weakness	Feet Weakness	0.546342
Shoulder Weakness	Knee Weakness	0.638915
Elbow Weakness	Upper Back Weakness	0.546342
Elbow Weakness	Lower Back Weakness	0.728261
Elbow Weakness	Hip Weakness	0.728261
Elbow Weakness	Knee Weakness	0.592391
Elbow Weakness	Feet Weakness	0.701552
Wrist Weakness	Upper Back Weakness	0.684168
Wrist Weakness	Lower Back Weakness	0.685119
Upper Back Weakness	Lower Back Weakness	0.701552
Upper Back Weakness	Knee Weakness	0.546342
Upper Back Weakness	Feet Weakness	0.645390
Lower Back Weakness	Hip Weakness	0.504116
Lower Back Weakness	Knee Weakness	0.592391
Lower Back Weakness	Feet Weakness	0.546342
Knee Weakness	Feet Weakness	0.546342
Restrict Day	Lost Day	0.609550

Table 4.3: Negative Correlation

Variable 1	Variable 2	Correlation Coefficient
Gender	Height	-0.676027
Gender	Weight	-0.689475

In each module, the variable could be related to other variables. Correlation analysis was constructed using Microsoft Office Excel 2007 in order to determine any relationship between the variables. It was observed that 111 positive correlation (r>0.05), and 2 negative correlation (r<-0.5) at level 0.5. (Tables 4.2, 4.3)

Also we prepared a correlation analysis for the electromyography respondents from their questionnaire results. As a result the variable which are highly correlated (with correlation coefficient greater than r=0.5) are found. Table 4.4 shows that positive correlation and table 4.5 shows that negative correlation.

Table4.4: Positive Correlation for EMG respondents

Variable 1	Variable 2	Correlation Coefficient
Age	Shoulder Desktop	0.855010
Age	Neck Laptop	0.648061
Height	Lower Back Desktop	0.970454
Weight	Lower Back Desktop	0.842757
Computer Type	Forearm Desktop	0.511625
Computer Type	Lower Back Desktop	0.565900
Keyboard	Lower Back Desktop	0.970454
Forearm Laptop	Neck Laptop	0.880145
Forearm Laptop	Shoulder Laptop	0.680120
Neck Laptop	Shoulder Laptop	0.713541

Table 4.5: Negative Correlation for EMG Respondents

Variable 1	Variable 2	Correlation Coefficient
Gender	Hand Laptop	-0.512736
Gender	Forearm Laptop	-0.766548
Gender	Neck Laptop	-0.954229
Gender	Shoulder Laptop	-0.505797
Age	Lower Back Desktop	-0.970454
Height	Shoulder Desktop	-0.855010
Height	Neck Laptop	-0.648061
Weight	Shoulder Desktop	-0.844765
Weight	Upper Back Desktop	-0.595945
Computer Type	Upper Back Laptop	-0.846447

Daily Use	Forearm Desktop	-0.574849
Daily Use	Neck Desktop	-0.720321
Daily Use	Shoulder Desktop	-0.651647
Daily Use	Forearm Laptop	-0.523720
Daily Use	Neck Laptop	-0.721557
Daily Use	Lower Back Laptop	-0.625615
Year Use	Hand Desktop	-0.976033
Year Use	Hand Laptop	-0.990894
Year Use	Forearm Laptop	-0.609837
Year Use	Neck Laptop	-0.633947
Year Use	Shoulder Laptop	-0.993229
Key Board	Shoulder Desktop	-0.855010
Key Board	Neck Laptop	-0.648061
Shoulder Trouble	Neck Laptop	-0.520626
Shoulder Trouble	Lower Back Laptop	-0.613561
Forearm Laptop	Upper Back Laptop	-0.546025

The correlation result shows that 10 positive correlation (r>0.5), where the correlation greater than 0.95 was found between keyboard and lower back desktop (r=0.97) and there are 26 negative correlation (r<-0.5) at level 0.5.

4.3. Logistic Regression Analysis

Logistic regression analysis was used to develop and to determine a meaningful and statistically significant relationship exists between work-related musculoskeletal disorders and computer use as a risk assessment model. The logistic regression was used because many of independent variables were qualitative and the normality of residuals cannot be guaranteed.

The dependent variable is Medical treatment, and the independent variables were selected from 129 variable factors.

Logistic regression analysis has been conducted by using Minitab 14 software.

Table 4.6: Logistic Regression Analysis Demographic Factors

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	-1.04789	2.38971	-0.44	0.661			
[Q1]Gender	0.0684713	0.776579	0.09	0.930	1.07	0.23	4.91
[Q2] Age	0.355468	0.160060	2.22	**0.026**	1.43	1.04	1.95
[Q3] Height	-0.338359	0.370365	-0.91	0.361	0.71	0.34	1.47
[Q4] Weight	0.0254397	0.258834	0.10	0.922	1.03	0.62	1.70

Table 4.6 shows that only age ($p=0.026<0.05$) is the sole demographic factor found to be significant predictors of medical treatment for the collected data.

Table 4.7: Logistic Regression Analysis of Physical Work Environments

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	1.32928	1.25499	1.06	0.290			
[Q5] CompType	-0.0958550	0.278369	-0.34	0.731	0.91	0.53	1.57
[Q6] DailyUse	-0.0666952	0.160821	-0.41	0.678	0.94	0.68	1.28
[Q7] YearUse	-0.417952	0.259583	-1.61	0.107	0.66	0.40	1.10
[Q8] Keyboard	0.0556801	0.205271	0.27	0.786	1.06	0.71	1.58

Table 4.7 shows that none of the physical work environment factors were found to be significant predictors of medical treatment for collect data.

Table 4.8: Logistic Regression Analysis of Trouble disorders

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	-2.27747	1.28151	-1.78	0.076			
[Q9] NeckTr	0.324995	0.531670	0.61	0.541	1.38	0.49	3.92
[Q10] ShoulTr	0.0391938	0.554816	0.07	0.944	1.04	0.35	3.09
[Q11] ElbowTr	-0.862450	0.699933	-1.23	0.218	0.42	0.11	1.66
[Q12] HandTr	0.310398	0.542938	0.57	0.568	1.36	0.47	3.95
[Q13] UBTr	-0.216664	0.552193	-0.39	0.695	0.81	0.27	2.38
[Q14] LBTr	0.305058	0.565408	0.54	0.590	1.36	0.45	4.11
[Q15] HipTr	-1.21439	0.753910	-1.61	0.107	0.30	0.07	1.30
[Q16] KneeTr	2.38946	0.710613	3.36	**0.001**	10.91	2.71	43.92
[Q17] FeetTr	-0.312645	0.708510	-0.44	0.659	0.73	0.18	2.93

Table 4.8 shows that only knee trouble (p=0.001<0.05) is the sole trouble factor found to be significant predictors of medical treatment for the collected data.

Table 4.9: Logistic Regression Analysis of Problem disorders

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	Upper
Constant	-0.200708	0.882939	-0.23	0.820			
[Q18] NeckPr	-0.991172	1.21196	-0.82	0.413	0.37	0.03	3.99
[Q19] ShoulPr	2.94134	1.28132	2.30	**0.022**	18.94	1.54	233.39
[Q20] ElbowTr	-1.07884	2.00905	-0.54	0.591	0.34	0.01	17.44
[Q21] HandPr	0.319948	0.962389	0.33	0.740	1.38	0.21	9.08
[Q22] UBPr	-2.80397	1.25915	-2.23	**0.026**	0.06	0.01	0.71
[Q23] LBPr	0.797022	0.895027	0.89	0.373	2.22	0.38	12.82
[Q24] HipPr	-1.89830	2.08422	-0.91	0.362	0.15	0.00	8.91
[Q25] KneePr	1.66451	0.977995	1.70	0.089	5.28	0.78	35.92
[Q26] FeetPr	0.127038	1.23214	0.10	0.918	1.14	0.10	12.71

Table 4.9 shows that shoulder problem (p=0.022<0.05) and Upper back problem (p=0.026<0.05) are problem factors found to be significant predictors of medical treatment for the collected data.

Table 4.10: Logistic Regression Analysis of Discomfort of Ache

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	Upper
Constant	-0.990101	0.286164	-3.46	0.001			
NeckAche	-0.153607	0.652066	-0.24	0.814	0.86	0.24	3.08
ShoulAche	-1.06199	1.08936	-0.97	0.330	0.35	0.04	2.92
ElbowAche	-20.5761	12160.9	-0.00	0.999	0.00	0.00	*
WristAche	0.264587	0.923141	0.29	0.774	1.30	0.21	7.96
FingerAche	-0.100065	0.966851	-0.10	0.918	0.90	0.14	6.02
UBAche	0.923514	0.855575	1.08	0.280	2.52	0.47	13.47
LBAche	0.176958	0.914426	0.19	0.847	1.19	0.20	7.17
HipAche	-0.542867	1.32988	-0.41	0.683	0.58	0.04	7.87
KneeAche	0.612857	0.926163	0.66	0.508	1.85	0.30	11.34
FeetAche	2.36702	1.22905	1.93	0.054	10.67	0.96	118.62

Table 4.10 shows that none of the ache factors were found to be significant predictors of medical treatment for collect data.

Table 4.11: Logistic Regression Analysis of Discomfort of Burn

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	-0.916291	0.241523	-3.79	0.000			
NeckBurn	-81.1683	20170.0	-0.00	0.997	0.00	0.00	*
ShoulBurn	-40.3984	14044.7	-0.00	0.998	0.00	0.00	*
ElbowBurn	-64.6669	42024.9	-0.00	0.999	0.00	0.00	*
WristBurn	-18.8091	11648.4	-0.00	0.999	0.00	0.00	*
FingerBurn	20.4112	10382.2	0.00	0.998	7.31957E+08	0.00	*
UBBurn	1.60944	1.24833	1.29	0.197	5.00	0.43	57.75
LBBurn	20.1545	9130.29	0.00	0.998	5.66222E+08	0.00	*
HipBurn	-19.1092	13534.6	-0.00	0.999	0.00	0.00	*
KneeBurn	60.8097	17463.7	0.00	0.997	2.56627E+26	0.00	*
FeetBurn	61.5314	26779.9	0.00	0.998	5.28129E+26	0.00	*

Table 4.11 shows that none of the burn factors are found to be significant predictors of medical treatment for collect data.

Table 4.12: Logistic Regression Analysis of Discomfort of Cramp

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	-0.916843	0.244690	-3.75	0.000			
NeckCramp	-20.0791	10443.6	-0.00	0.998	0.00	0.00	*
ShoulCramp	0.888348	1.60915	0.55	0.581	2.43	0.10	56.96
WristCramp	20.2976	9804.06	0.00	0.998	6.53310E+08	0.00	*
FingerCramp	-81.3177	32385.9	-0.00	0.998	0.00	0.00	*
UBCramp	0.0569894	1.49851	0.04	0.970	1.06	0.06	19.97
LBCramp	-0.554763	1.37849	-0.40	0.687	0.57	0.04	8.56
HipCramp	-58.8395	16399.5	-0.00	0.997	0.00	0.00	*
KneeCramp	39.2872	13698.1	0.00	0.998	1.15402E+17	0.00	*
FeetCramp	1.19422	1.59219	0.75	0.453	3.30	0.15	74.81

Table 4.12 shows that none of the cramp factors are found to be significant predictors of medical treatment for collect data.

Table 4.13: Logistic Regression Analysis of Discomfort of loss of color

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	-0.901902	0.224069	-4.03	0.000			
ShoulColor	43.1278	41417.0	0.00	0.999	5.37229E+18	0.00	*
WristColor	-20.5537	27661.4	-0.00	0.999	0.00	0.00	*
KneeColor	-20.5537	27661.4	-0.00	0.999	0.00	0.00	*

Table 4.13 shows that none of the loos of color factors are found to be significant predictors of medical treatment for collect data.

Table 4.14: Logistic Regression Analysis of Discomfort of Numbness

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	Upper
Constant	-0.980423	0.252885	-3.88	0.000			
NeckNumb	22.6307	44953.9	0.00	1.000	6.73561E+09	0.00	*
ShoulNumb	44.0906	35217.3	0.00	0.999	1.40698E+19	0.00	*
ElbowNumb	-0.399867	1.26420	-0.32	0.752	0.67	0.06	7.99
WristNumb	0.481390	0.987336	0.49	0.626	1.62	0.23	11.21
FingerNumb	0.377218	0.977762	0.39	0.700	1.46	0.21	9.91
UBNumb	0.0219498	32720.5	0.00	1.000	1.02	0.00	*
LBNumb	-20.4971	17478.1	-0.00	0.999	0.00	0.00	*
HipNumb	0.481390	0.987336	0.49	0.626	1.62	0.23	11.21
KneeNumb	-21.4379	27661.4	-0.00	0.999	0.00	0.00	*
FeetNumb	-20.1340	14875.6	-0.00	0.999	0.00	0.00	*

Table 4.14 shows that none of the numbness factors are found to be significant predictors of medical treatment for collect data.

Table 4.15: Logistic Regression Analysis of Discomfort of Pain

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	Upper
Constant	-0.943700	0.308552	-3.06	0.002			
NeckPain	0.674394	0.648115	1.04	0.298	1.96	0.55	6.99
ShoulPain	-0.516947	0.933827	-0.55	0.580	0.60	0.10	3.72
ElbowPain	0.431466	1.38484	0.31	0.755	1.54	0.10	23.24
WristPain	0.0434442	0.922049	0.05	0.962	1.04	0.17	6.36
FingerPain	-21.4856	8173.55	-0.00	0.998	0.00	0.00	*
UBPain	-1.16900	1.02620	-1.14	0.255	0.31	0.04	2.32
LBPain	0.764646	0.750881	1.02	0.309	2.15	0.49	9.36
HipPain	-1.87219	1.31930	-1.42	0.156	0.15	0.01	2.04
KneePain	2.03349	0.843428	2.41	**0.016**	7.64	1.46	39.91
FeetPain	-1.07871	1.29151	-0.84	0.404	0.34	0.03	4.27

Table 4.15 shows that only pain in knee ($p=0.016<0.05$) is the sole numbness factor found to be significant predictors of medical treatment for the collected data.

Table 4.16: Logistic Regression Analysis of Discomfort of Stiffness

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	Upper
Constant	-1.21379	0.261671	-4.64	0.000			
NeckStiff	1.20946	1.08467	1.12	0.265	3.35	0.40	28.09
ElbowStiff	24.3595	30825.6	0.00	0.999	3.79488E+10	0.00	*
WristStiff	-0.765581	1.75729	-0.44	0.663	0.47	0.01	14.57
FingerStiff	1.26168	1.10667	1.14	0.254	3.53	0.40	30.90
UBStiff	-1.46695	1.83261	-0.80	0.423	0.23	0.01	8.37
LBStiff	2.17147	1.64681	1.32	0.187	8.77	0.35	221.24
HipStiff	0.967444	2.32840	0.42	0.678	2.63	0.03	252.42
KneeStiff	22.3538	20732.8	0.00	0.999	5.10679E+09	0.00	*
FeetStiff	-0.707935	2.31712	-0.31	0.760	0.49	0.01	46.23

Table 4.16 shows that none of the stiffness factors are found to be significant predictors of medical treatment for collect data.

Table 4.17: Logistic Regression Analysis of Discomfort of Swelling

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	Upper
Constant	-0.962028	0.233344	-4.12	0.000			
ShoulSwell	-20.8363	19283.0	-0.00	0.999	0.00	0.00	*
HipSwell	22.6342	30825.6	0.00	0.999	6.75960E+09	0.00	*
KneeSwell	0.641352	1.17988	0.54	0.587	1.90	0.19	19.18
FeetSwell	0.641352	1.17988	0.54	0.587	1.90	0.19	19.18

Table 4.17 shows that none of the swelling factors are found to be significant predictors of medical treatment for collect data.

Table 4.18: Logistic Regression Analysis of Discomfort of Tingling

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	Upper
Constant	-0.931558	0.231545	-4.02	0.000			
NeckTing	-40.9732	24306.7	-0.00	0.999	0.00	0.00	*
ShoulTing	17.9391	99090.5	0.00	1.000	61778425.41	0.00	*
ElbowTing	18.3694	55419.6	0.00	1.000	95004467.05	0.00	*
WristTing	-20.5240	27661.4	-0.00	0.999	0.00	0.00	*
FingerTing	-43.1278	41417.0	-0.00	0.999	0.00	0.00	*
KneeTing	21.2277	15488.2	0.00	0.999	1.65605E+09	0.00	*
FeetTing	22.6038	30825.6	0.00	0.999	6.55674E+09	0.00	*

Table 4.18 shows that none of the tingling factors are found to be significant predictors of medical treatment for collect data.

Table 4.19: Logistic Regression Analysis of Discomfort of Weakness

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	Upper
Constant	-0.944462	0.257172	-3.67	0.000			
NeckWeak	29.5899	8655.72	0.00	0.997	7.09144E+12	0.00	*
ShoulWeak	1.63761	1.25145	1.31	0.191	5.14	0.44	59.77
ElbowWeak	-9.08192	8657.24	-0.00	0.999	0.00	0.00	*
WristWeak	-47.7945	12291.6	-0.00	0.997	0.00	0.00	*
FingerWeak	-19.1382	9846.44	-0.00	0.998	0.00	0.00	*
UBWeak	-27.0352	44483.0	-0.00	1.000	0.00	0.00	*
LBWeak	23.1458	40049.2	0.00	1.000	1.12745E+10	0.00	*
HipWeak	-18.5698	10480.8	-0.00	0.999	0.00	0.00	*
KneeWeak	20.9040	11765.3	0.00	0.999	1.19809E+09	0.00	*
FeetWeak	-9.50979	8657.90	-0.00	0.999	0.00	0.00	*

Table 4.19 shows that none of the weakness factors are found to be significant predictors of medical treatment for collect data.

4.4. EMG Experiment Results

4.4.1. Hand

Figure 4.6 shows typing activities for respondent 1 during 20 min of typing with desktop computer keyboard and laptop computer keyboard. The pressure on respondent’s hand (vertical axis, in µV) when he was typing with desktop computer keyboard was observed to decrease but the pressure was higher than when he was typing with laptop computer keyboard.

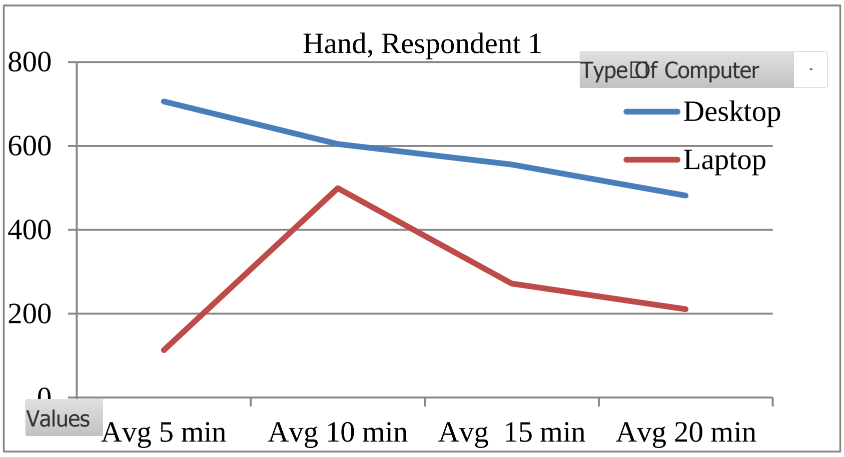

Figure 4.6: EMG activity at the hand of respondent 1

Figure 4.7 shows typing activities of the respondent 2 with desktop computer keyboard and laptop computer keyboard. In this case, the pressure on his hands when he was typing with laptop computer keyboard was higher than when he was typing with desktop computer keyboard. In both of them the pressure during the 20 min was decreasing. Moreover, the hand muscle activities reflected a similar pattern in both cases.

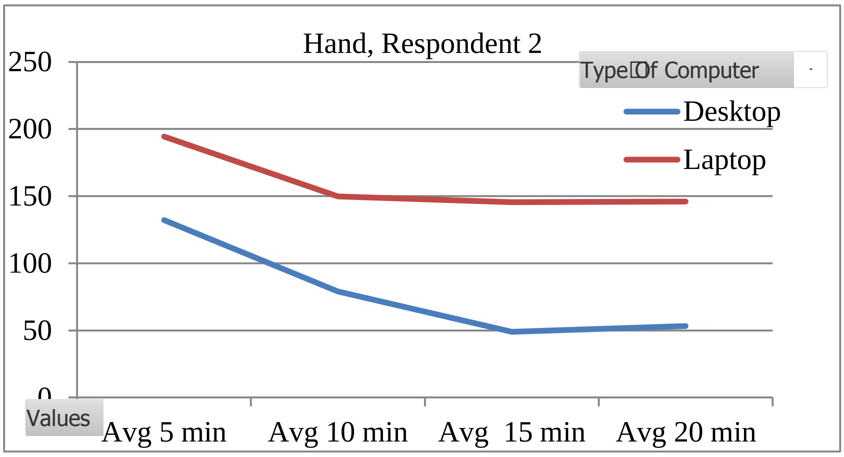

Figure 4.7: EMG activity at the hand of respondent 2

Figure 4.8 shows the pressure on hands of respondent 3. Form the figure 4.8, it is observed that the pressure on desktop computer keyboard is higher than laptop computer keyboard. Also when the respondent 3 was typing with desktop computer keyboard, the pressure increased but when the respondent 3 was typing with laptop computer desktop the pressure decreased.

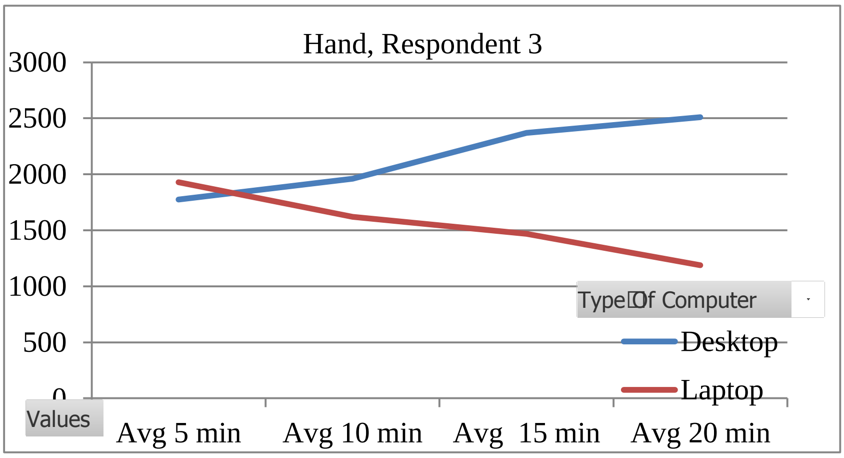

Figure 4.8: EMG activity at the hand of respondent 3

Figure 4.9 shows that pressure on desktop computer keyboard is higher than laptop computer keyboard. During 20 min the average pressure for both of them is decreased. At 10th min the pressure on desktop computer respondent increased but after that it goes down. Opposite for laptop computer, at 10th min the pressure decrease and after that it goes up, but the pressure during 10th minute to 20th minute is less than 5th minute.

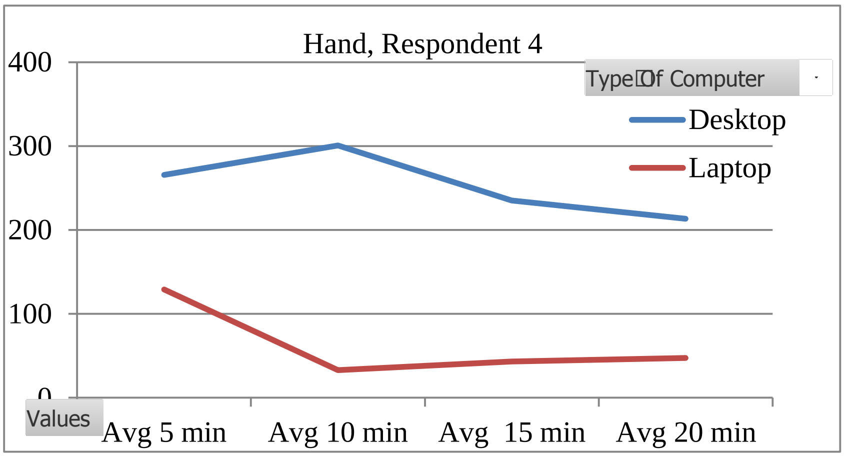

Figure 4.9: EMG activity at the hand of respondent 4

Figure 4.10 shows the pressure on desktop computer respondent's hand is higher than when she was typing with laptop computer. The amount of pressure on her hand when she was typing with laptop computer was constant approximately but when she was typing with desktop the pressure is increased. Just between 15th minute to 20 minute a little pressure is decreased but finally the pressure is higher than when she started typing with desktop computer keyboard.

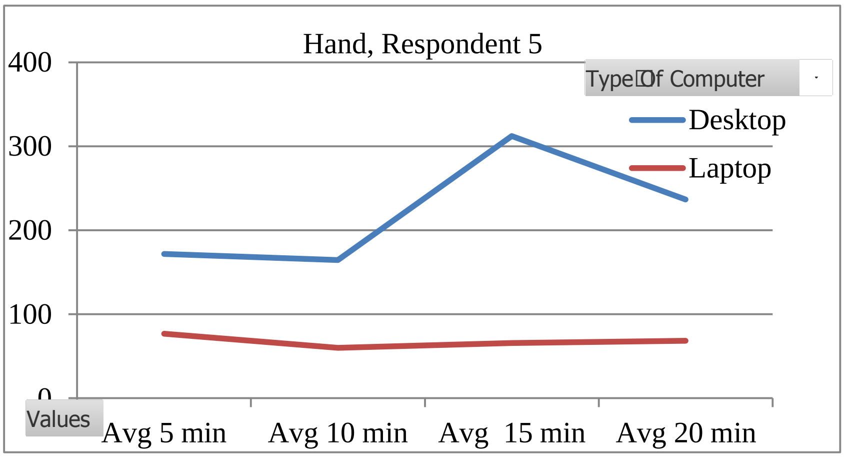

Figure 4.10: EMG activity at the hand of respondent 5

The EMG activities shown in figures 4.6-4.10 illustrates that the pressure on respondents hands during typing with the desktop keyboard is more than when the respondent typing with laptops keyboards.

Also pressures on laptop user's hands have been reducing in time, but it is not exactly the same about the desktop users. One of the effective factor in increasing the pressure during using the laptop keyboard could be the existence of palm rest on laptops, which provides a chance of rest for user's hands put their hands in relax (neutral) position. Also since the laptops' keyboards are smaller than desktop keyboards, less hand movement were observed to result in less typing pressure. However, the advantage of using the desktop keyboards is the ability to adjust the angle of desktop keyboards while there is no such a chance in keyboards of laptops.

Normally the laptops are using a flat plane of keyboard with the angle of zero degree and they are not adjustable.

4.4.2. Elbow

Figure 4.11 is a chart per pressure per time on respondent 1's elbow. The force on respondent 1 elbow when he was typing with laptop computer is higher than when he was typing with desktop computer. During 20 minutes, the pressure on his elbow was increasing when he was typing with laptop computer. On the other hand, when he was typing with desktop computer, the pressure on his elbow was decreasing and approximately was constant between from the 10th minute until the end of the experiment.

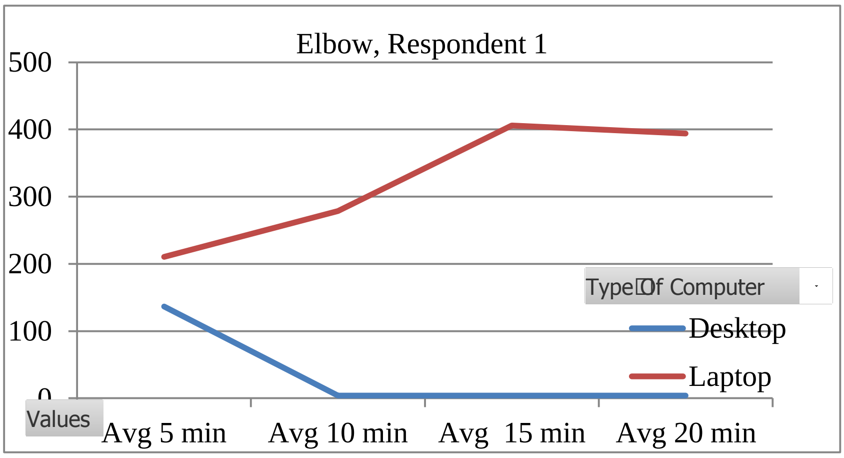

Figure 4.11: EMG activity at the elbow of respondent 1

Figure 4.12 shows that pressure on the elbow during the 20 minutes per laptop computer and desktop computer for respondent 2. As it is shown, the respondent burdened more force on elbow when he was working with laptop computer. The amount of force was increasing when he was typing with laptop. This amount was decreasing when he was working with desktop computer. When he worked with laptop computer between 5th minute to 10th minute the forces grow up suddenly and after that the force decreased but again between 15th min and 20th minute the force was increased.

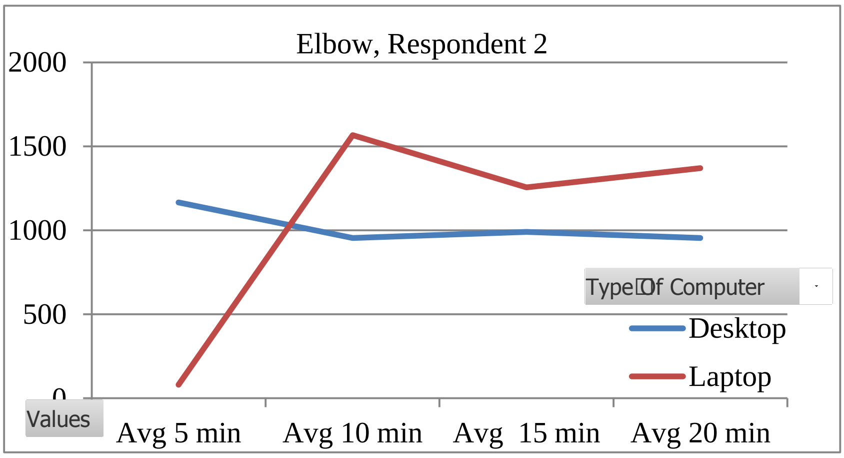

Figure 4.12: EMG activity at the elbow of respondent 2

Figure 4.13 shows the amount of pressure on the elbow of the respondent 3 when he was working with laptop computer and desktop computer for 20 minutes. The amount of pressure when he was working with laptop was significantly higher than when he was typing with desktop computer. Whereas, the amount of pressure on elbow when he was working with desktop was too much less than when he was working with laptop computer. Although the elbow pressure activity seems to be constant in time while using the desktop computer, it actually was increasing slightly in time The reason is that, the discomfort experienced while using laptop computer was very high for the respondent 3 and had a range between 1000 to 1200 µV.

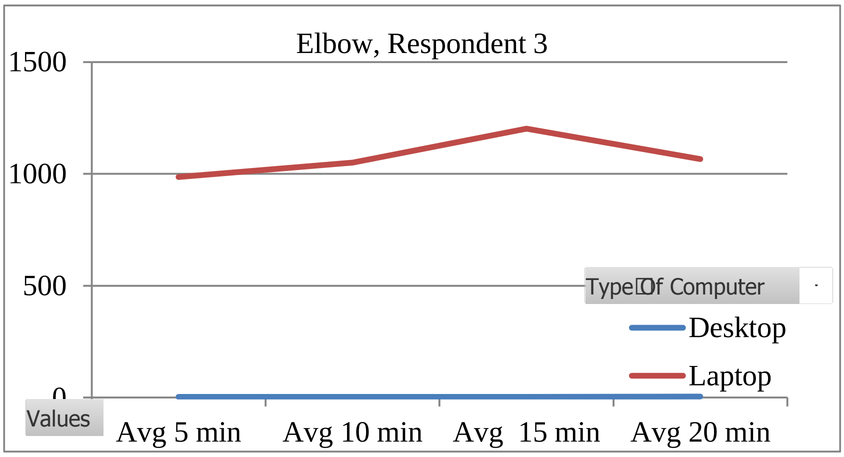

Figure 4.13: EMG activity at the elbow of respondent 3

Figure 4.14 shows that the pressure on elbow during 20 minutes for respondent 4. The pressure when the respondent was working with laptop was higher than the pressure when the respondent was working with desktop. But the pressure was increased during the 20 min when she used the laptop computer. A slight decrease in time was also observed while the respondent was using the desktop computer..

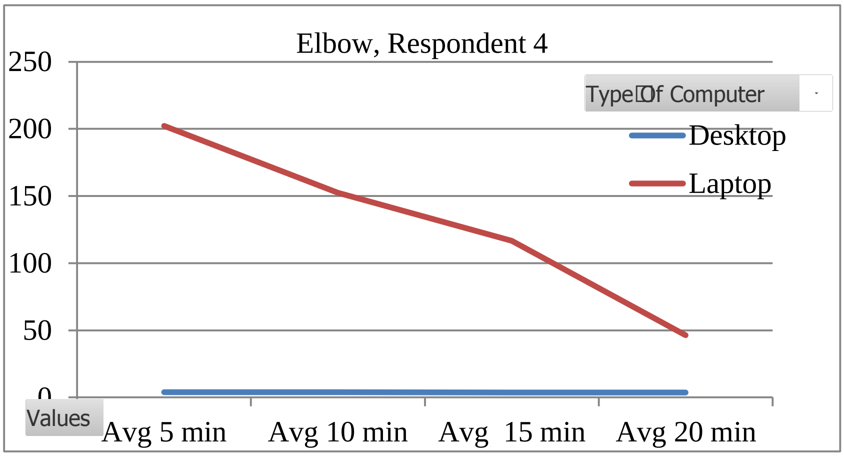

Figure 4.14: EMG activity at the elbow of respondent 4

Figure 4.15 shows that pressure on elbow for respondent 5 was approximately same up to 15th minute. Just the amount of desktop computer force was a little more than laptop computer. After the 15th minute, the pressure on the elbow when she used laptop suddenly grew up. However there was no change in the pressure when she used desktop computer.

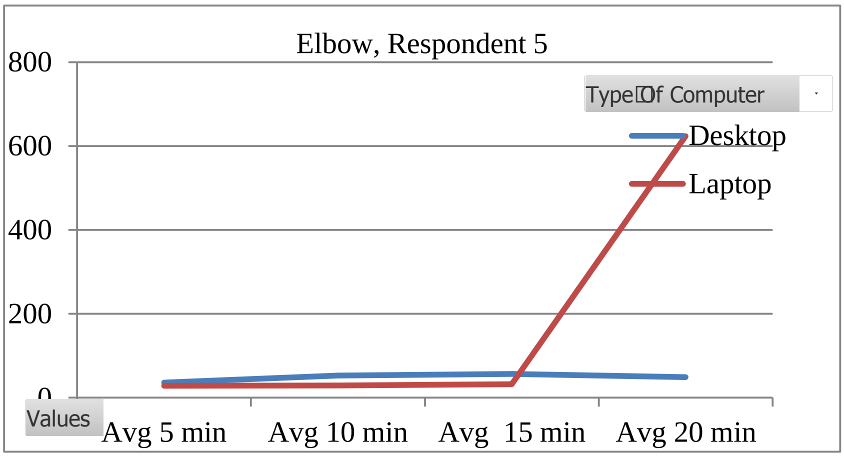

Figure 4.15: EMG activity at the elbow of respondent 5

Unlike the output result of studding the amount of pressure on desktop computer users hands, the studies shows the amount of pressure on elbow muscles in laptop users were more than desktop users. It is shown in all of the users that the amount of pressure on elbow muscles in laptop users has been significantly more than computer users (Figures 4.11-4.15)

Since the palm rest area on laptop is an area to put the wrist, it cause the rest of the hand (elbows) to be places in a lower position than the wrist, so the wrist and elbow will not be at the same level of height, but usually desktop user hands (the elbows and the wrists) are at the same level of height and it causes increase in pressure on elbow muscles.

Also by considering the time factor, it was show that passing the time has not significant effect on desktop users and the amount of pressure stays almost constant, but it is not the same about the laptop users, on their case, the amount of pressure follows an increasing pattern during the time.

4.4.3. Neck

Figure 4.16 shows neck pressure on respondent 1 when he was working with laptop computer and desktop computer for 20 minutes. The measurement showed that when laptop use burdened more pressure on the respondent. During the 20 minutes the amount of pressure did not change significantly in bot cases. When he was working with laptop the amount of pressure was between 2200 and 2500 µV and when he was working with desktop the amount of pressure range is 700 to 1000 µV.

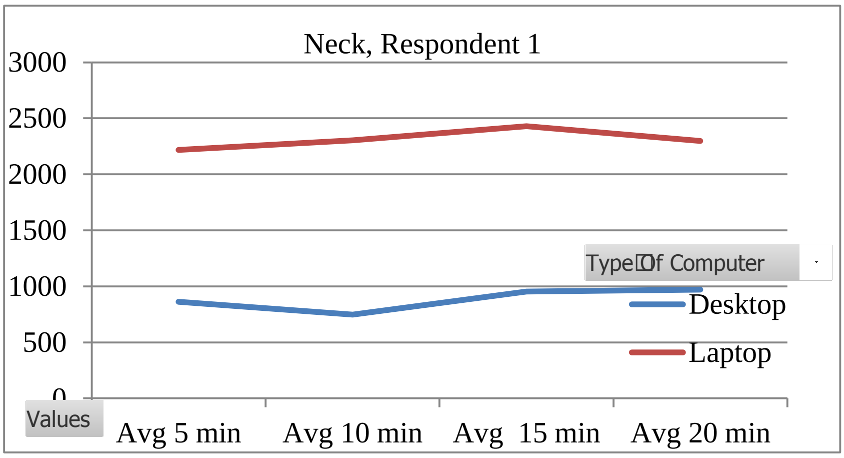

Figure 4.16: EMG activity at the neck of respondent 1

Figure 4.17 shows that during the 20 minutes the amount of pressure on respondent 2 when he was working with laptop computer or desktop computer was approximately the same. In both of two types of computers the value of pressure was observed to be decreasing in time.

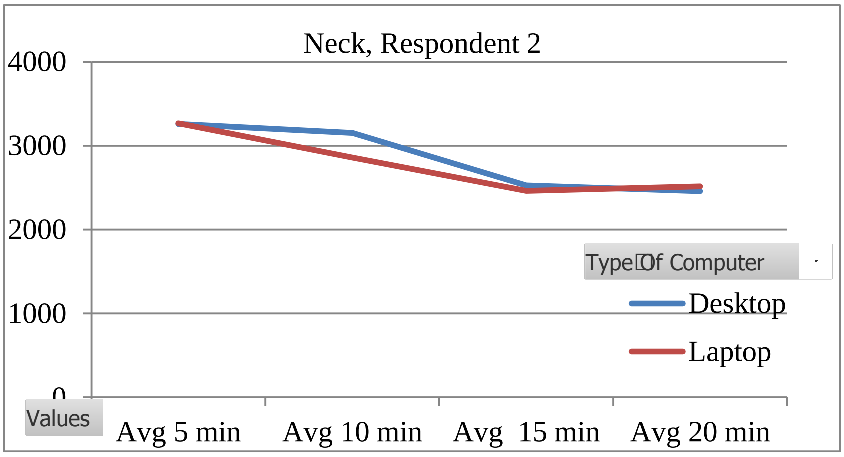

Figure 4.17: EMG activity at the neck of respondent 2

Figure 4.18 shows that the pressure on the neck of respondent 3 when he was working with laptop computer was significantly higher than when he was working with desktop computer. In both of the computers, respondent 3 experienced constant pressure on neck muscles during 20 minutes.

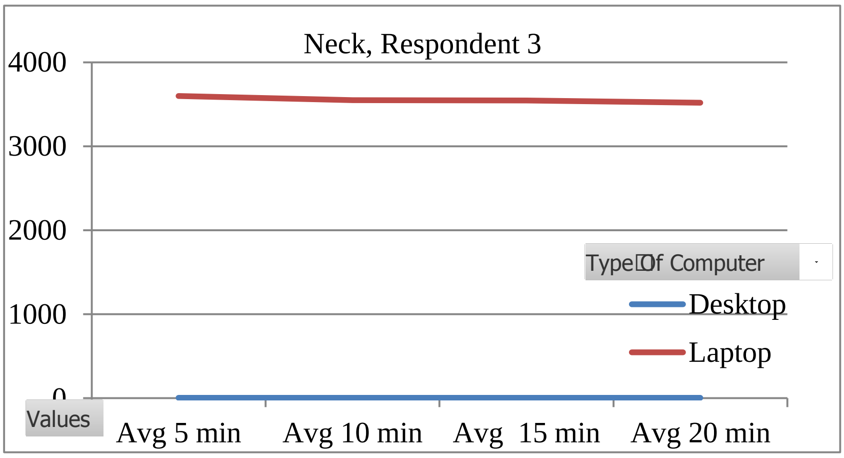

Figure 4.18: EMG activity at the neck of respondent 3

Figure 4.19 shows the pressure on neck muscles while the respondent 4 was working desktop computer and laptop computer. When she was working with desktop computer, there was a significant discomfort on her neck. The pressure was increasing when respondent 4 was working with laptop computer and when he was working with desktop computer; the pressure was almost constant throughout the experiment.

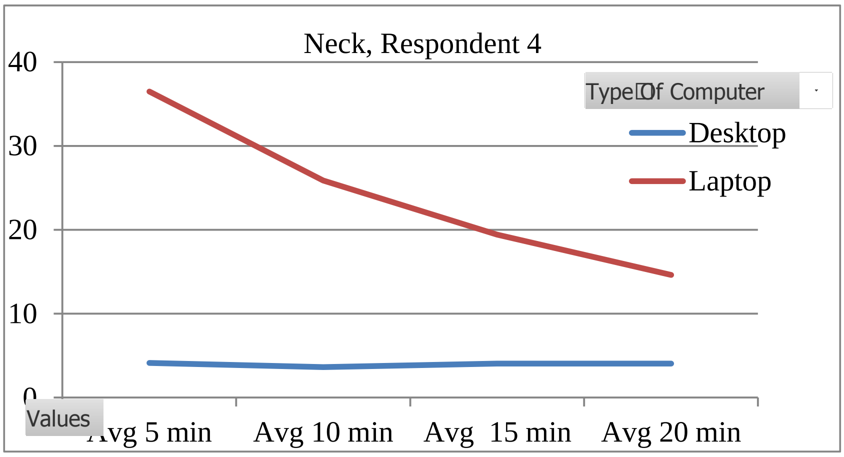

Figure 4.19: EMG activity at the neck of respondent 4

Figure 4.20 shows the pressure on neck muscles for respondent 5 during 20 minute of experiment. The pressure on neck muscle when she used of desktop computer is higher in all of the experiment. Both diagrams have a frequency value and during the 20 min the pressure has a different value.

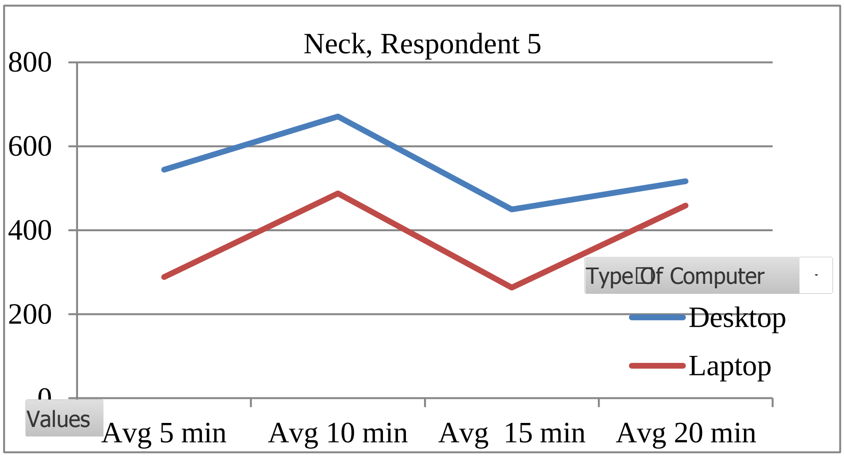

Figure 4.20: EMG activity at the neck of respondent 5

The EMG experiment, until now, provides the fact that; the main problem of using laptop is that the inability to take the monitor apart from the base, since the users were unable to adjust the height of the laptop's monitor. They usually had to bend their neck more than the standard to be able to get a suitable view of the monitor. This issue is significantly showed in the charts. (Figures 4.16-4.20)

The pressure on the neck was observed to be more in laptop computer users than the desktop computer users.

Nowadays a lot of accessories created to decrease the pressure on neck during the working with laptops (as in shown in figure 2.2), but these accessories usually cause the changes in standard 90 degree users elbows position and as a result there would be more pressure on user hands.

4.4.4. Shoulder

Figure 4.21 is related to the shoulder pressure when the respondent 1 used of desktop computer and laptop computer. The total pressure that burden on respondent 1 shoulder when he was working with desktop was higher than when he was using the laptop computer. When he used of laptop computer pressure was constant throughout the experiment. However, the pressure was varying when he was working with the desktop computer. Between 5^{th} min and 10^{th} min, the pressure had a sharp increase, and it decreased later towards the end of the experiment. When he used the desktop computer, the value of pressure in 5^{th} and 10^{th} minute was higher than when he was using laptop computer. In fact, this amount was opposite at the 5^{th} and 20^{th} minutes.

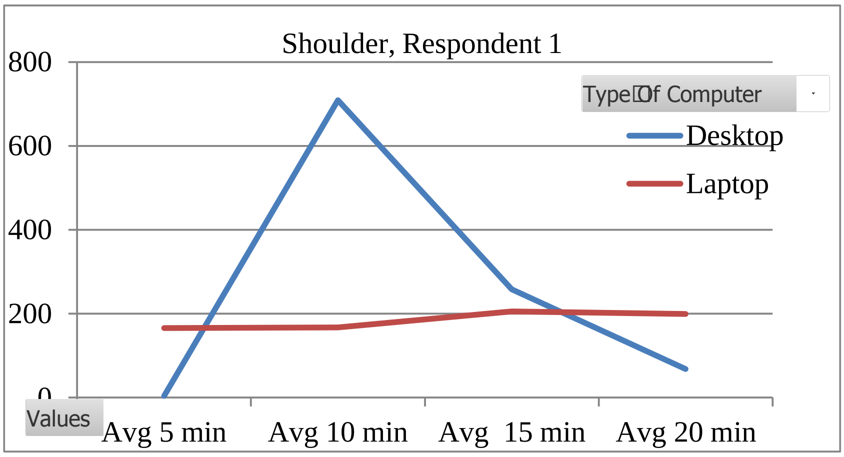

Figure 4.21: EMG activity at the shoulder of respondent 1

Figure 4.22 shows pressure on shoulder for respondent 2 when he was using laptop computer and desktop computer during 20 minutes. The chart shows that pressure on his shoulder while using the desktop computer was higher than when he was working the laptop computer. The pressure on shoulder when he worked with desktop computer was decreasing in time, but it was observed that there was an increase in the discomfort when he used the laptop computer.

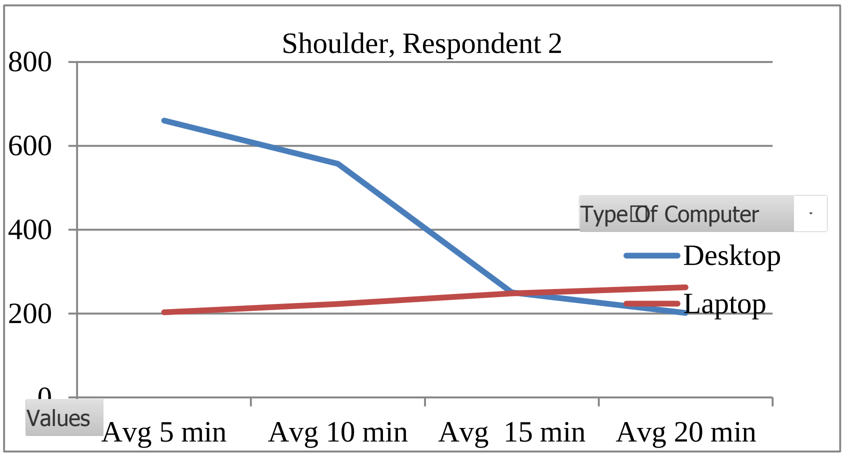

Figure 4.22: EMG activity at the shoulder of respondent 2

Figure 4.23 shows that the pressure on the shoulder of the respondent 3 was significantly higher when he was working with a laptop computer than the desktop computer. The pressure was observed to increase between 5th and 10th minute when he used a laptop computer, and it because almost constant after the 10th minute. Also when he used a desktop computer the pressure decreased a little in time.

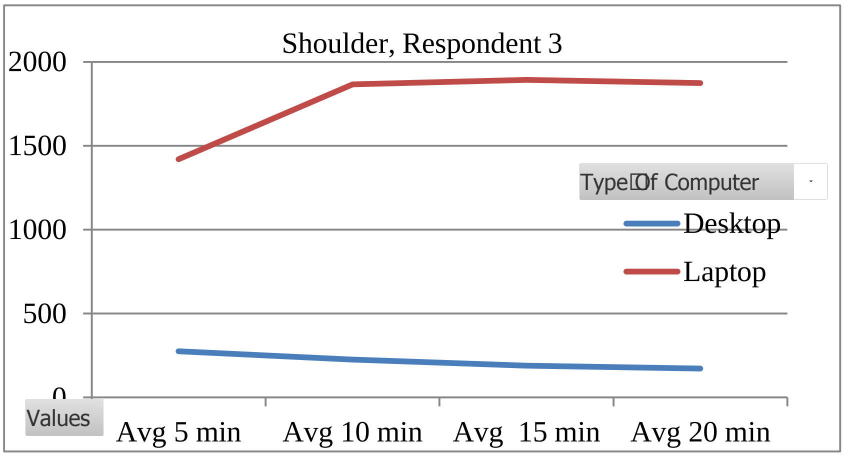

Figure 4.23: EMG activity at the shoulder of respondent 3

Figure 4.24 illustrates the shoulder muscle activities of the respondent 4 while working with a desktop and a laptop computer. It was observed that the pressure on shoulder when he used the laptop computer was higher than when he used a desktop computer. Between 5th minute to 10th minute the amount of pressure was approximately same but after that pressure on shoulder when he used a laptop increased suddenly.

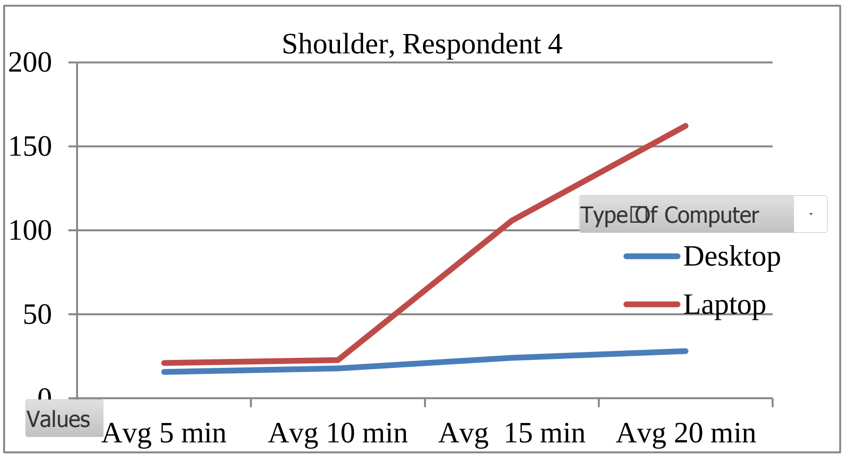

Figure 4.24: EMG activity at the shoulder of respondent 4

Figure 4.25 shows the pressure on shoulder muscle for respondent 5. When she was using a desktop computer, she has more pressure on her shoulder. The amount of pressure increased in both of computers during the 20 minute experiment. However, it was observed that the discomfort in the shoulder fluctuated (first decreased, then increased, and again decreased again) in time, but there was an overall increase at the end of 20 minutes.

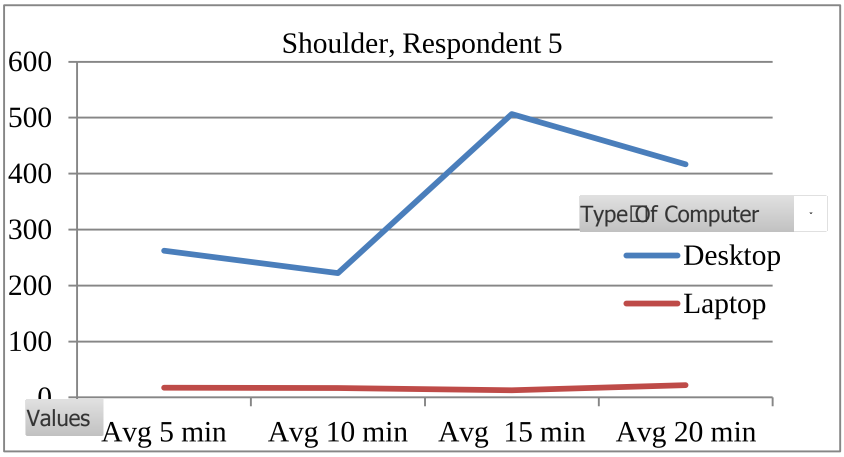

Figure 4.25: EMG activity at the shoulder of respondent 5

In studding the shoulder muscles it is not possible to determine significant which type of computer use takes more pressure. Generally both groups suffer pressure on shoulder region (figures 4.21-4.25).

Time factor was also an important factor in increasing the pressure on shoulders, as it is shown that the pressure have been increased in time on both group shoulders. Also, this increase was more significant on laptop users.

4.4.5. Lower Back

Figure 4.26 shows pressure on lower back muscles on respondent 1 while working with the two types of computers. Pressure on lower back was higher when working with laptop than using a desktop computer. Also, figure 4.26 illustrates that, there was an increase in the lower back discomfort in time among the laptop computer users. Contrary, there was a decrease in the lower back discomfort among the desktop computer users in time. It means that time causes a decrease in pressure on lower back muscles when respondent 1 used a desktop computer and the pressure increases when he used a laptop computer throughout the experiment.

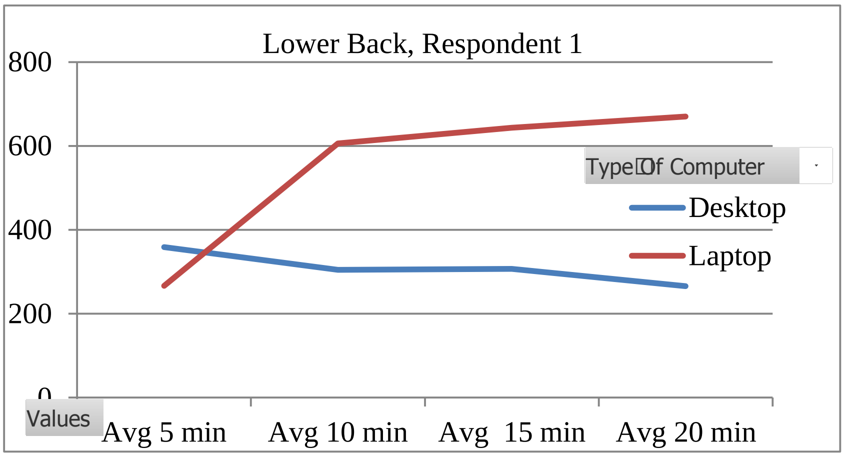

Figure 4.26: EMG activity at the lower back of respondent 1

Figure 4.27 shows pressure on lower back for respondent 2, when he was using a laptop computer and desktop computer. During 20 minute of experiment the amount of pressure when he used of a desktop was higher than when he used of a laptop computer. Between 5th and 15th minutes, the pressure was increased while using the laptop computer but after that a decreasing trend was observed. Also the pressure was decreased a little when he used the desktop computer.

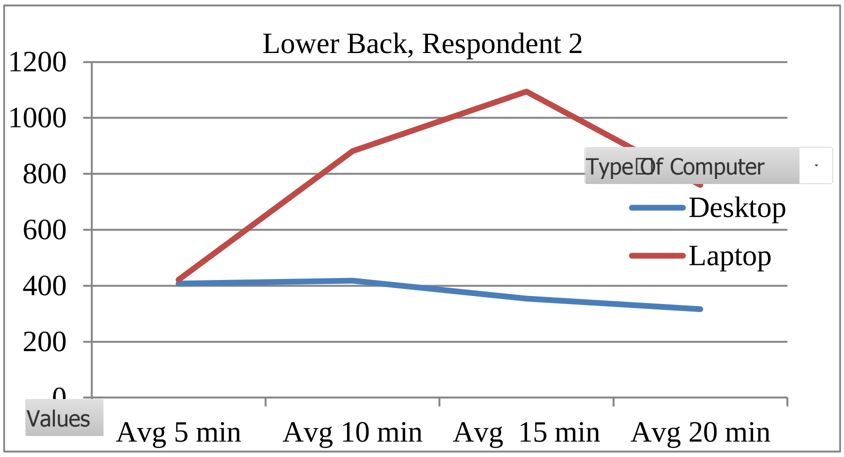

Figure 4.27: EMG activity at the lower back of respondent 2

Figure 4.28 illustrates the pressure of lower back on respondent 3. It was observed that when the respondent 3 was working with the laptop computer, more pressure was burdened on his lower back muscle. When he used the laptop computer between 10th and 15th minutes, the pressure was observed to decrease. However, in the rest of the experiment, the pressure was observed to be constant. Also when he was using a desktop computer the pressure had a constant level.

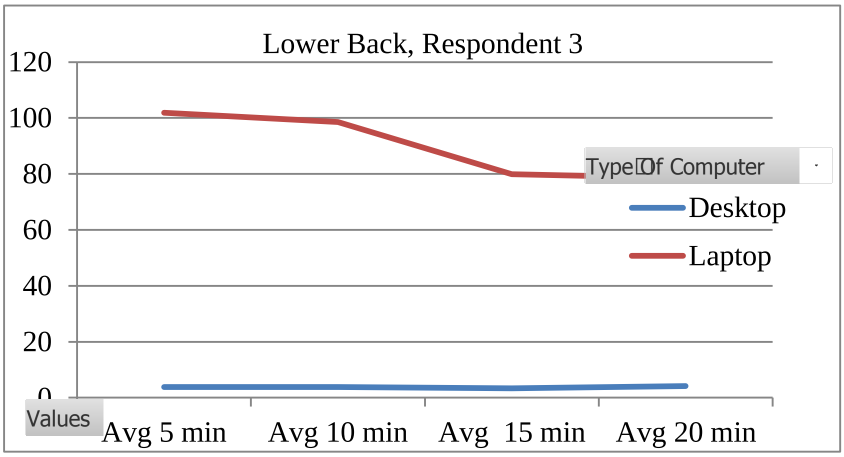

Figure 4.28: EMG activity at the lower back of respondent 3

Figure 4.29 shows lower back pressure in time when the respondent 4 was using a desktop computer and a laptop computer. The lower back pressure was significantly higher while she was working on laptop computer. The lower back pressure was observed to increase in time when she was using a laptop computer. However, when she was using the desktop computer, there was almost a constant pressure throughout the experiment.

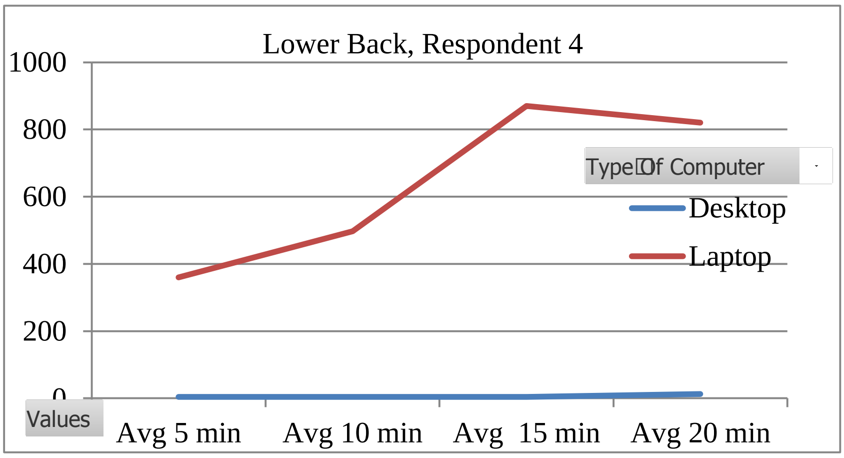

Figure 4.29: EMG activity at the lower back of respondent 4

Figure 4.30 illustrates the amount of pressure on lower back on respondent 5. It was observed that when she used the desktop computer, she experienced more pressure on her lower back muscles. Use of laptop computer increased pressure on her lower back muscle. When she used a desktop computer between 5th and 10th minutes, the pressure was decreased and after that it had almost a constant level.

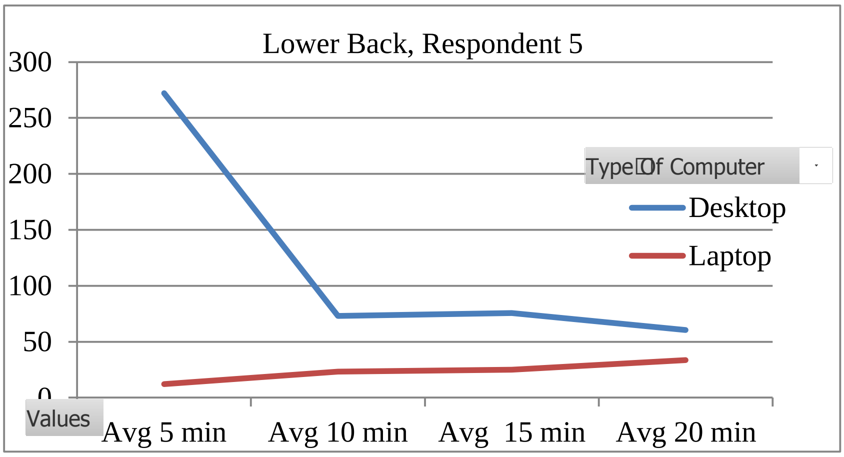

Figure 4.30: EMG activity at the lower back of respondent 5

As the related charts to lower back muscles shows (figure 4.26-4.30), except one respondent, it was shown that the pressure on lower back while working with laptop computer was significantly more than that the lower back discomfort while working with desktop computer. Even about that exceptional case after a period of time, the pressure on the lower back during the work with desktop computer and laptop computer approached to a close level.

During the study, it was observed that the pressure in lower back muscles increases in laptop computer users in time, while it decreases in desktop computer users, which means normally after a period of time the pressure decreases or not changes on desktop computer users.

4.4.6. Upper Back

Figure 4.31 illustrates pressure on upper back on respondent 1 when he was using a desktop computer and laptop computer. It was observed that the pressure on upper back when he was using the laptop was too much higher than he was using the desktop computer. The pressure during the 20 minute experiment was constant when he was using the laptop computer, while it had increasing trend when he was working with desktop computer (it looks like constant line, because laptop computer discomfort at upper back was too much for the respondent 1).

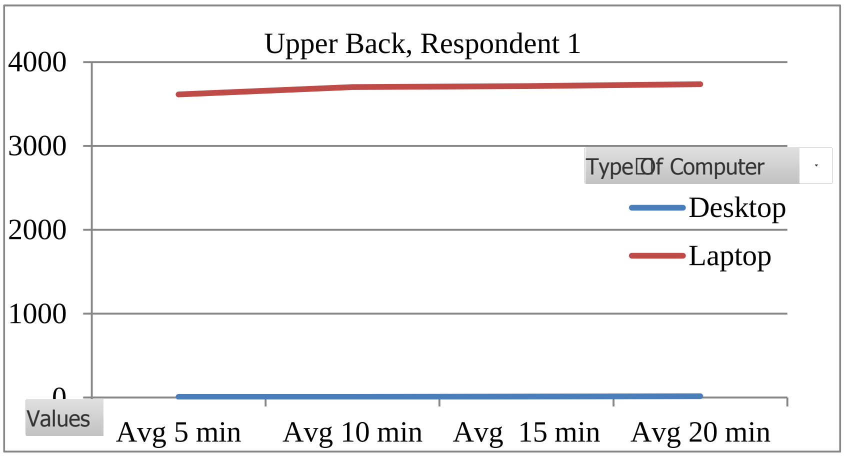

Figure 4.31: EMG activity at the upper back of respondent 1

Figure 4.32 shows the pressure on upper back when the respondent 2 was using laptop and desktop computers. Between 5th and 10th minutes, the respondent experienced more pressure while using the desktop computer. The amount of pressure when he was using the laptop computer was higher than when he was using a desktop computer. When he was using a desktop computer between 5th and 15th minutes, the pressure decreased and it was observed to increase slightly again.

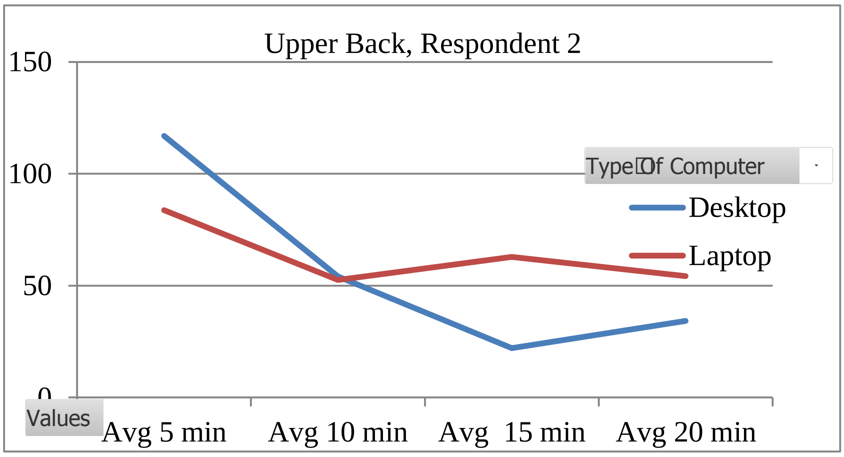

Figure 4.32: EMG activity at the upper back of respondent 2

Figure 4.33 shows pressure on upper back muscles for respondent 3. The lower back pressure was higher when he was working with the laptop computer than she was using the desktop computer. Pressure had a constant level while she was using the desktop computer but while using the laptop computer, the pressure fluctuated throughout the experiment.

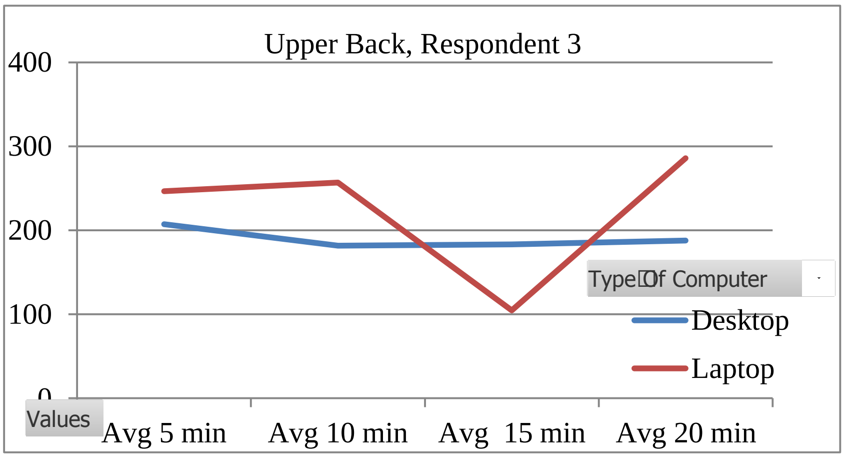

Figure 4.33: EMG activity at the upper back of respondent 3

Figure 4.34 shows that the amount of pressure on upper back muscles for respondent 4. The pressure on the lower back was higher than when she was using the desktop computer than that while working with the laptop computer. When she used the laptop computer, the pressure on the lower back was observed to increase between 5th and 15th minutes, and decrease slightly towards the end of the experiment. However, when she was using the desktop computer; the lower back pressure first increased between 5th and 10th minutes, decreased between 10th and 15th minutes, and later increased again between 15th and 20th minutes.

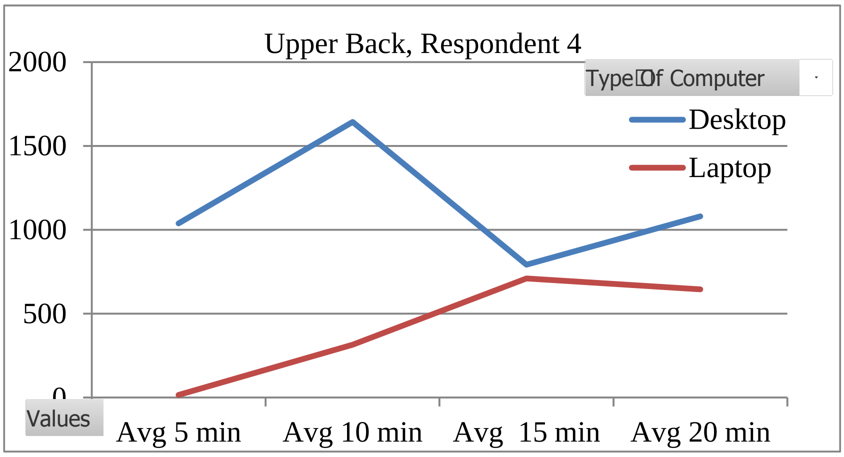

Figure 4.34: EMG activity at the upper back of respondent 4

Figure 4.35 illustrates the amount of pressure on upper back for respondent 5 when she was using desktop and laptop computers. The pressure on the upper back muscle when she was using a laptop computer had significantly differed in time. The amount of pressure at the upper back was much higher when she was using a desktop computer. When she was using a laptop computer between 5th and 10th minutes, the pressure was decreased, but toward the end of the experiment, it increased again.

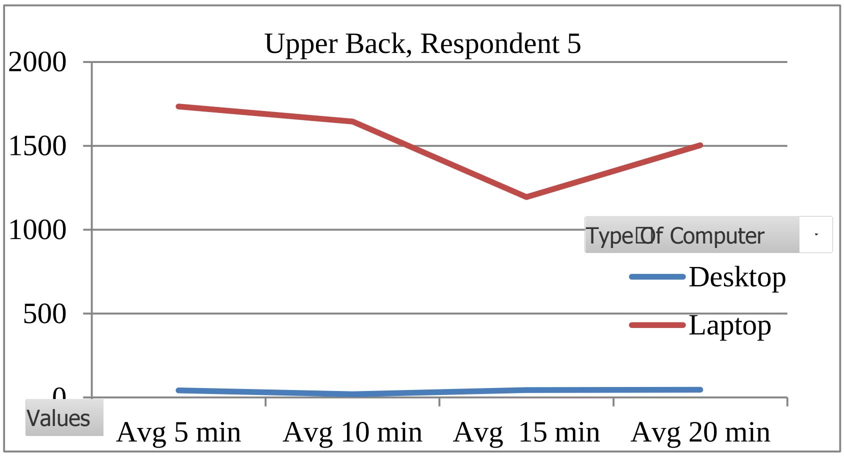

Figure 4.35: EMG activity at the upper back of respondent 3

Similarly as in the neck discomfort, the pressure on upper back of laptop users was observed to be more than that in desktop users.

Significantly by studying the time factor and the effect of time on upper back muscles, it was found that the diagram of the activities and pressure on upper back muscles of the laptop users shows more fluctuation comparing to desktop users. This is because the laptop users were not able to keep their head fixed in the standard position and they have to move their neck in order to rest and decrease the pressure on their neck muscles. The upper back muscles are strictly under influence of neck muscles and this issue causes the affection on these muscles too.

4.5. ANOVA Results

4.5.1 Respondent based on musculoskeletal strain on desktop computer and laptop computer workstation

The reading from sEMG provides the information about the muscle activity over time. After calculating the mean value for each 30 seconds interval reading, the table 4.20 had been prepared.

Table 4.20: EMG recordings for respondent 1 on desktop computer

Body Region	minutes			
	5	10	15	20
Hand	705,730	604,695	555,693	481,522
Forearm	136,542	3,817	3,783	3,807
Neck	862,810	748,120	954,367	969,590
Shoulder	3,910	709,287	258,310	67,800
Upper back	8,702	7,385	10,740	14,752
Lower back	358,437	304,275	306,993	266,068

In order to test the hypothesis (H_o = mean musculoskeletal strain [in time] of the 6 body region does not differ) ANOVA is applied for each respondent's readings.

The result of ANOVA table for respondent 1 shows that respondent is under forces for working with desktop. (Table 4.21)

Table 4.21: ANOVA result for respondent 1, Desktop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2256327	5	451265.5	21.39553	5.34E-07	2.772853
Within Groups	379648.3	18	21091.57			
Total	2635976	23				

The result studied on six different region of respondent's body (hand, elbow, neck, shoulder, upper back, lower back). The hypothesis (H_0) is rejected because the value of F_0 is greater than $F_{critical}$ (144.6 > 2.77). Whereas the hypothesis test is rejected, it shows that working with desktop computer cause discomfort in all 6 body region of desktop respondent.

Table 4.22: EMG recordings for respondent 2 on desktop computer

Body Region	**minutes**			
	5	**10**	**15**	**20**
Hand	132,230	78,995	48,985	53,130
Forearm	1164,933	953,318	990,380	953,727
Neck	3259,467	3151,217	2526,417	2456,133
Shoulder	660,450	556,750	250,138	201,810
Upper back	116,840	54,183	22,058	34,188
Lower back	407,247	417,632	353,632	316,265

Table 4.23: ANOVA result for respondent 2, Desktop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	22573425	5	4514685	113.1343	5.97E-13	2.772853
Within Groups	718299.7	18	39905.54			
Total	23291724	23				

F_0=113.1343 > $F_{critical}$=2.77

Therefore, (H_0) is rejected again for the second respondent as well (table 4.23).

Table 4.24: EMG recordings for respondent 3 on desktop computer

Body Region	**minutes**			
	5	**10**	**15**	**20**
Hand	1775,350	1960,767	2369,350	2510,150
Forearm	3,840	3,917	3,983	4,043
Neck	4,085	4,133	4,132	4,090
Shoulder	274,857	224,720	190,208	172,308
Upper back	3,802	3,815	3,383	4,135
Lower back	207,243	181,643	183,218	187,915

Table 4.25: ANOVA result for respondent 3, Desktop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	14479982	5	2895996	144.6132	7.02E-14	2.772853
Within Groups	360464.6	18	20025.81			
Total	14840446	23				

Hypothesis testing for third respondent 3 shows that F_0 is 144.6 and $F_{critical}$ is 2.77, So, as the cause the F_0 is greater than $F_{critical}$ the H_0 should be rejected and again it shows that working with computer suffer discomfort for respondent 3 (table 4.25).

Table 4.26: EMG recordings for respondent 4 on desktop computer

Body Region	**minutes**			
	5	**10**	**15**	**20**
Hand	265,490	300,618	235,168	213,242
Forearm	3,815	3,853	3,663	3,677
Neck	4,128	3,627	4,043	4,058
Shoulder	15,753	17,868	24,145	28,052
Upper back	3,720	4,020	3,690	12,592
Lower back	1037,823	1643,433	792,155	1079,798

Table 4.27: ANOVA result for respondent 4, Desktop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4084588	5	816917.6	37.41904	6.74E-09	2.772853
Within Groups	392968.9	18	21831.6			
Total	4477557	23				

Respondent 4 was a female and the hypothesis done for his sEMG as same as other respondents, also the result is same. The F_0 is 37.4 and it is greater than $F_{critical}$ (=2.77). The hypothesis rejected and shows that working with computer also has discomfort on respondent 4 (table 4.27).

Table 4.28: EMG recordings for respondent 5 on desktop computer

Body Region	**minutes**			
	5	**10**	**15**	**20**
Hand	171,867	164,522	312,273	236,440
Forearm	35,893	53,025	56,968	49,235
Neck	543,852	671,132	449,242	516,453
Shoulder	262,032	221,908	506,395	416,658
Upper back	42,997	19,323	45,112	46,980
Lower back	272,087	73,017	75,658	60,512

Table 4.29: ANOVA result for respondent 5, Desktop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	780984.8	5	156197	22.5462	3.6E-07	2.772853
Within Groups	124701.5	18	6927.861			
Total	905686.3	23				

The last respondent, respondent 5, was a female too. Comparison between F_0 and $F_{critical}$ showed that the F_0 is again greater than $F_{critical}$. As same as other respondents, the hypothesis is rejected again. The result shows that working with computer has significantly disorder on 6 different body regions for respondent 5 when she was working with desktop computer (Table 4.29).

In addition, the entire respondent's hypothesis (all 5 respondents) showed that when they worked with desktop computer the F_0 value was greater than the $F_{critical}$. The result informs that working with computer has significantly discomfort on 6 different region bodies and gender differences do not affect this result.

In another hypothesis test, we studied the affection of laptop computer when the respondents were working with a laptop computer.

Same hypothesis (H_o = mean musculoskeletal strain [in time] of the 6 body region does not differ) is tested for the respondent, but this time it is tested on the sEMG data were collected while they were using laptop computers.

Table 4.30: EMG recordings for respondent 1 on laptop computer

Body Region	minutes			
	5	10	15	20
Hand	113,322	499,467	271,988	210,548
Forearm	210,405	278,765	405,825	394,163
Neck	2217,567	2303,917	2429,883	2298,900
Shoulder	165,642	167,665	205,393	199,240
Upper back	3612,983	3701,633	3714,317	3735,617
Lower back	266,397	606,072	643,362	669,980

Table 4.31: ANOVA result for respondent 1, Laptop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	42109120	5	8421824	613.8553	1.91E-19	2.772853
Within Groups	246952	18	13719.56			
Total	42356072	23				

The result for the first respondent shows that working with laptop computer causes discomfort on 6 different body regions. As shown on the table 4.31 the F_0 is 613.8 and the $F_{critical}$ is 2.77. Because $F_0 > F_{critical}$, the hypothesis test rejected and it a show that working with laptop computer has discomfort for firs respondent.

Table 4.32: EMG recordings for respondent 2 on laptop computer

Body Region	**minutes**			
	5	**10**	**15**	**20**
Hand	194,290	149,843	145,535	146,087
Forearm	81,527	1566,950	1256,200	1370,600
Neck	3266,317	2857,033	2459,900	2516,050
Shoulder	202,833	222,798	248,195	262,545
Upper back	83,672	52,605	62,893	54,262
Lower back	421,862	882,037	1094,417	760,350

Table 4.33: ANOVA result for respondent 2, Laptop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	20928674	5	4185735	37.56877	6.52E-09	2.772853
Within Groups	2005475	18	111415.3			
Total	22934149	23				

For the second respondent, the F_0 is 37.56 and it is greater than $F_{critical}$(=2.77). The assumption is same, thus the hypothesis is rejected. The result shows that working with laptop has discomfort on different body region for respondent 2. Recommended that the result for respondent 2 when he worked with desktop is same as when he worked with desktop computer. It shows that both of computers cause disorder on muscles for respondent 2 (table 4.33).

Table 4.34: EMG recordings for respondent 3 on laptop computer

Body Region	**minutes**			
	5	**10**	**15**	**20**
Hand	1930,300	1619,650	1468,100	1186,750
Forearm	985,335	1050,017	1202,567	1066,450
Neck	3597,467	3547,900	3545,733	3519,483
Shoulder	1418,817	1866,367	1893,217	1873,000
Upper back	246,453	256,747	104,737	285,845
Lower back	101,870	98,507	79,900	78,515

Table 4.35: ANOVA result for respondent 3, Laptop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	31964140	5	6392828	232.6592	1.07E-15	2.772853
Within Groups	494589.9	18	27477.22			
Total	32458730	23				

The F_0 for the third respondent is 232.6 (table 4.35), and it is more than $F_{critical}$(=2.77). Therefore, the H_0 is rejected, and thus the result shows that working with laptop cause discomfort on different 6 body region for respondent 3.

Table 4.36: EMG recordings for respondent 4 on laptop computer

Body Region	**minutes**			
	5	**10**	**15**	**20**
Hand	128,995	33,033	43,320	47,452
Forearm	202,137	152,527	116,683	46,238
Neck	36,472	25,878	19,437	14,638
Shoulder	21,093	22,805	105,797	162,178
Upper back	359,882	497,533	870,362	820,808
Lower back	16,678	315,592	710,323	645,250

Table 4.37: ANOVA result for respondent 4, Laptop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1223807	5	244761.3	8.371658	0.000309	2.772853
Within Groups	526264.2	18	29236.9			
Total	1750071	23				

As explained above, the respondent 4 is a female. The ANOVA table for the respondent 4 shows the F_0 is 8.37 (Table 4.37). The hypothesis (H_0) is rejected and it expresses that working with laptop affected on respondent 4.

Table 4.38: EMG recordings for respondent 5 on laptop computer

Body Region	**minutes**			
	5	**10**	**15**	**20**
Hand	76,967	60,133	65,650	68,428
Forearm	28,607	28,980	32,215	623,747
Neck	288,683	487,873	263,748	459,098
Shoulder	17,357	16,517	12,915	21,767
Upper back	1734,750	1644,733	1194,417	1502,767
Lower back	12,192	23,293	25,018	33,547

Table 4.39: ANOVA result for respondent 5, Laptop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6771842	5	1354368	51.59479	4.81E-10	2.772853
Within Groups	472501.8	18	26250.1			
Total	7244343	23				

The last respondent, respondent 5 has similar result. The F_0 for the respondent 5 is 51.59. It is clearly that $F_0 > F_{critical}$(=2.77). For this reason the hypothesis is rejected and again we can say that working with laptop has discomfort in 6 body region for respondent 5 (table 4.39).

Completely in all of the result for all of the users when they are working with desktop computer or laptop computer we can say definitely working with computer cause disorder on 6 different body regions and it is included male and female.

In another analysis studied two factors at the same time. The interaction between desktop computer and laptop computer studied on 6 different body regions for 5 respondents. At the first step calculated total average. As followed that for each type of computers 5 respondents did the test, which for each of them recorded sEMG data for 6 body regions. For each region we have 5 data, which they recorded in 5th, 10th, 15th and 20th minute during the test. Total average is the average of the value during the 20 minutes. The count of total average is 60. 2 type of computer (desktop computer and laptop computer), 6 body regions (hand, elbow, neck, shoulder, upper back and lower back) and 5 respondents.

Table 4.40: Overall sEMG averages for the body regions in both desktop and laptop

	Hand	Forearm	Neck	Shoulder	U. Back	L. Back
Desktop	586,910	36,987	883,722	259,827	10,395	308,943
	78,335	1015,590	2848,308	417,287	56,818	373,694
	2153,904	3,946	4,110	215,523	3,784	190,005
	253,630	3,752	3,964	21,455	6,005	1138,303
	221,275	48,780	545,170	351,748	38,603	120,318
Laptop	273,831	322,290	2312,567	184,485	3691,138	546,4525
	158,939	1068,819	2774,825	234,0929	63,35792	789,6663
	1551,200	1076,092	3552,646	1762,85	223,4454	89,69792
	63,200	129,3963	24,10625	77,96833	637,1463	421,9608
	67,795	178,3871	374,8508	17,13875	1519,167	23,5125

Table 4.41: ANOVA result for interaction of computer type and body region on 6 respondents

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*
Computer Type	$SS_{ComputerType}$	1	2403974.48	3.4495	4.048
Body Region	$SS_{BodyRegion}$	5	1370705.88	1.9669	2.418
Interaction	$SS_{Interaction}$	5	4003692.23	5.7450	2.418
Error	SS_{Error}	48	696900.88		
Total	SS_T	59	791736.246		

Table 4.40 is the ANOVA table with two factors, where the computer type (desktop and laptop) and the effect of the body region is tested. Table 4.41 shows that only the interaction effect is significant. This means that, when the computer type interacts with the body region, musculoskeletal strain occurs.

4.5.2 Body region based on musculoskeletal strain on desktop and laptop workstation

In another hypothesis tests, we studied the affection of working with desktop computer on each of the body region separately.

First we studied the affection of working with a desktop computer on hand for all of 5 respondents.

Hypothesis (H_0 =mean musculoskeletal strain [in time] on hand does not differ on desktop computer) is tested on 5 respondent’s hand.

Table 4.42 shows data per each respondent for hand region during 20 minutes of experiment.

Table 4.42: EMG recordings for hand region per respondents on desktop computer

Body Region	minutes			
	5	10	15	20
Resp. 1	705.730	604.695	555.693	481.522
Resp. 2	132.230	78.995	48.985	53.130
Resp. 3	1775.350	1960.767	2369.350	2510.150
Resp. 4	265.490	300.618	235.168	213.242
Resp. 5	171.867	164.522	312.273	236.440

Table 4.43: ANOVA result for hand, Desktop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	11732140	4	2933035	109.0769	6.74E11	3.055568
Within Groups	403344.3	15	26889.62			
Total	12135485	19				

The result from table 4.43 shows that whereas the F_0 value is greater than $F_{critical}$ the hypothesis test rejected and it means that working with desktop computer has significant disorders on all of the hand's respondents.

Table 4.44: EMG recordings for forearm region per respondents on desktop computer

Body Region	minutes			
	5	10	15	20
Resp. 1	136.542	3.817	3.783	3.807
Resp. 2	1164.933	953.318	990.380	953.727
Resp. 3	3.840	3.917	3.983	4.043
Resp. 4	3.815	3.853	3.663	3.677
Resp. 5	35.893	53.025	56.968	49.235

Table 4.45: ANOVA result for forearm, Desktop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3156795	4	789198.8	268.374	9.3E-14	3.055568
Within Groups	44110.02	15	2940.668			
Total	3200905	19				

Table 4.44 shows EMG data for forearm region for the entire respondent in duration 20 minutes when they working with desktop computer. The ANOVA table (table 4.45) shows that the F_0 value is greater than $F_{critical}$. In this case hypothesis test is mean musculoskeletal strain [in time] on forearm does not differ on desktop computer rejected and it means that working with desktop computer cause disorders on forearm muscles for all of the respondents.

Table 4.46: EMG recordings for neck region per respondents on desktop computer

Body Region	minutes			
	5	10	15	20
Resp. 1	862.810	748.120	954.367	969.590
Resp. 2	3259.467	3151.217	2526.417	2456.133
Resp. 3	4.085	4.133	4.132	4.090
Resp. 4	4.128	3.627	4.043	4.058
Resp. 5	543.852	671.132	449.242	516.453

Table 4.47: ANOVA result for neck, Desktop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	22073410	4	5518353	143.8808	9.04E-12	3.055568
Within Groups	575304.4	15	38353.63			
Total	22648715	19				

Table 4.46 shows that data that collected from EMG test for neck muscles for each of the respondents. The result from ANOVA table (table 4.47) inform that working with desktop computer has significant disorders on neck muscle respondents because assumption was mean musculoskeletal strain [in time] on neck does not differ on desktop computer, the F_0 value is greater than $F_{critical}$, and hypothesis test is rejected.

Table 4.48: EMG recordings for shoulder region per respondents on desktop computer

Body Region	minutes			
	5	10	15	20
Resp. 1	3.910	709.287	258.310	67.800
Resp. 2	660.450	556.750	250.138	201.810
Resp. 3	274.857	224.720	190.208	172.308
Resp. 4	15.753	17.868	24.145	28.052
Resp. 5	262.032	221.908	506.395	416.658

Table 4.49: ANOVA result for shoulder, Desktop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	367222.9	4	91805.72	2.665789	0.073344	3.055568
Within Groups	516577.3	15	34438.49			
Total	883800.2	19				

Table 4.48 shows that EMG data that collected from EMG test for shoulder muscles when the respondents working with a desktop computer. The ANOVA result for shoulder muscle regions when the respondent working with a desktop computer prepared on table 4.49. Assumed that hypothesis test is meaning musculoskeletal strain [in time] on shoulder does not differ on desktop computer. Comparison between F_0 and $F_{critical}$ showed that F_0 is smaller than $F_{critical}$. Hypothesis test dose not rejected and it means that we cannot say that working with desktop computer has significant affection on respondent's shoulder muscles.

Table 4.50: EMG recordings for upper back region per respondents on desktop computer

Body Region	minutes			
	5	10	15	20
Resp. 1	8.702	7.385	10.740	14.752
Resp. 2	116.840	54.183	22.058	34.188
Resp. 3	3.802	3.815	3.383	4.135
Resp. 4	3.720	4.020	3.690	12.592
Resp. 5	42.997	19.323	45.112	46.980

Table 4.51: ANOVA result for upper back, Desktop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8815.912	4	2203.978	5.581875	0.005885	3.055568
Within Groups	5922.682	15	394.8455			
Total	14738.59	19				

For upper back body regions EMG data collected on table 4.51. The ANOVA result for upper back muscle when the respondents working with a desktop computer showed that whereas the F_0 value is greater than $F_{critical}$, the assumption is mean musculoskeletal strain [in time] on upper back does not differ on desktop computer and rejected and it informs that working with desktop computer suffering disorder on upper back muscles on 5 respondents. (Table 4.51)

Table 4.52: EMG recordings for lower back region per respondents on desktop computer

Body Region	**minutes**			
	5	**10**	**15**	**20**
Resp. 1	358.437	304.275	306.993	266.068
Resp. 2	407.247	417.632	353.632	316.265
Resp. 3	207.243	181.643	183.218	187.915
Resp. 4	1037.823	1643.433	792.155	1079.798
Resp. 5	272.087	73.017	75.658	60.512

Table 4.53: ANOVA result for lower back, Desktop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2691791	4	672947.7	23.43	2.64E-06	3.055568
Within Groups	430824.3	15	28721.62			
Total	3122615	19				

The last body muscle, lower back muscle data show in table 4.53. The comparison between F_0 value and $F_{critical}$ showed that again F_0 is greater than $F_{critical}$. As same as other muscles group (excepted shoulder muscle) the hypothesis test rejected again. (H_0 = mean musculoskeletal strain [in time] on lower back does not differ on desktop computer). The result shows that working with desktop computer has significantly disorder on lower back muscles for all of the respondents.(Table 4.53)

In addition, the result shows that working with desktop computer has significant disorder on hand, forearm, neck, upper back and lower back on all of the respondents. The hypothesis test for shoulder muscles dose not rejected, it means that working with desktop computer is not significant for shoulder muscles when the respondents were working with desk top computer.

Table 4.54: EMG recordings for hand region per respondents on laptop computer

Body Region	minutes			
	5	10	15	20
Resp. 1	113.322	499.467	271.988	210.548
Resp. 2	194.290	149.843	145.535	146.087
Resp. 3	1930.300	1619.650	1468.100	1186.750
Resp. 4	128.995	33.033	43.320	47.452
Resp. 5	76.967	60.133	65.650	68.428

Table 4.55: ANOVA result for hand, Laptop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6481767	4	1620442	64.55571	2.85E-09	3.055568
Within Groups	376521.7	15	25101.45			
Total	6858289	19				

In another hypothesis test, we studied the affection of working with laptop computer on 6 different body rejoins separately.

The EMG data for hand muscles collected on table 4.54. The ANOVA result (Table 4.55) for the hand muscle when the respondents working with a laptop computer shows that F_0 is equal 64.55 and $F_{critical}$ is equal 3.05, in this case the F_0 value is greater than $F_{critical}$. The hypothesis test is meaning musculoskeletal strain [in time] on hand does not differ on laptop computer rejected and it means that working with laptop computer has significant disorders on hand muscles on all of the 5 respondents.

Table 4.56: EMG recordings for forearm region per respondents on laptop computer

Body Region	minutes			
	5	10	15	20
Resp. 1	210.405	278.765	405.825	394.163
Resp. 2	81.527	1566.950	1256.200	1370.600
Resp. 3	985.335	1050.017	1202.567	1066.450
Resp. 4	202.137	152.527	116.683	46.238
Resp. 5	28.607	28.980	32.215	623.747

Table 4.57: ANOVA result for forearm, Laptop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3650708	4	912677.1	8.158628	0.001058	3.055568
Within Groups	1677997	15	111866.5			
Total	5328706	19				

Forearm EMG data shows in table 4.56 for each of respondents in 20 minutes. Supposed that hypothesis test is “mean musculoskeletal strain [in time] on forearm does not differ on laptop computer”. The result of ANOVA table (Table 4.57) shows that F_0 value is greater than $F_{critical}$. In this case again the hypothesis test is rejected and it informs that working with laptop computer has significant disorders on forearm muscles on each of the respondents.

Table 4.58: EMG recordings for neck region per respondents on laptop computer

Body Region	minutes			
	5	10	15	20
Resp. 1	2217.567	2303.917	2429.883	2298.900
Resp. 2	3266.317	2857.033	2459.900	2516.050
Resp. 3	3597.467	3547.900	3545.733	3519.483
Resp. 4	36.472	25.878	19.437	14.638
Resp. 5	288.683	487.873	263.748	459.098

Table 4.59: ANOVA result for neck, Laptop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37877282	4	9469320	295.5461	4.56E-14	3.055568
Within Groups	480601.1	15	32040.07			
Total	38357883	19				

Another muscle group is neck muscles. The EMG data for each of the respondent collected on table 4.58. H_0 is: mean musculoskeletal strain [in time] on neck does not differ on laptop computer. The ANOVA result for neck muscles shows that again F_0 value is greater than $F_{critical}$ and hypothesis test is rejected. It means that working with laptop computer has significant disorders on neck muscles when any of respondents working with laptop computer.(Table 4.59)

Table 4.60: EMG recordings for shoulder region per respondents on laptop computer

Body Region	minutes			
	5	10	15	20
Resp. 1	165.642	167.665	205.393	199.240
Resp. 2	202.833	222.798	248.195	262.545
Resp. 3	1418.817	1866.367	1893.217	1873.000
Resp. 4	21.093	22.805	105.797	162.178
Resp. 5	17.357	16.517	12.915	21.767

Table 4.61: ANOVA result for shoulder, Laptop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8665299	4	2166325	184.8481	1.45E-12	3.055568
Within Groups	175792.3	15	11719.49			
Total	8841092	19				

Table 4.60 shows that EMG data for shoulder muscle per respondents when they were working with a laptop computer. Table 4.61 shows the ANOVA result for shoulder muscles. The assumption is: mean musculoskeletal strain [in time] on shoulder does not differ on laptop computer. Whereas the F_0 value is greater than $F_{critical}$, the assumption failed and the hypothesis test is rejected. The result shows that working with laptop computer has significant disorders on shoulder muscles on 5 respondents. This result is opposite that the result from the same muscle when the respondents work with a desktop computer.

Table 4.62: EMG recordings for upper back region per respondents on laptop computer

Body Region	minutes			
	5	10	15	20
Resp. 1	3612.983	3701.633	3714.317	3735.617
Resp. 2	83.672	52.605	62.893	54.262
Resp. 3	246.453	256.747	104.737	285.845
Resp. 4	359.882	497.533	870.362	820.808
Resp. 5	1734.750	1644.733	1194.417	1502.767

Table 4.63: ANOVA result for upper back, Laptop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	35465788	4	8866447	348.6771	1.34E-14	3.055568
Within Groups	381432.2	15	25428.82			
Total	35847220	19				

EMG data shows in table 4.62 for upper back muscles. ANOVA table (Table 4.63) result shows that F_0 value is greater than $F_{critical}$. We supposed that hypothesis test is: mean musculoskeletal strain [in time] on upper back does not differ on laptop computer". F_0 is greater than $F_{critical}$, hypothesis test is rejected. It means that working with laptop computer has significant disorders on upper back muscles.

Table 4.64: EMG recordings for lower back region per respondents on laptop computer

Body Region	minutes			
	5	10	15	20
Resp. 1	266.397	606.072	643.362	669.980
Resp. 2	421.862	882.037	1094.417	760.350
Resp. 3	101.870	98.507	79.900	78.515
Resp. 4	16.678	315.592	710.323	645.250
Resp. 5	12.192	23.293	25.018	33.547

Table 4.65: ANOVA result for lower back, Laptop Computer

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1633949	4	408487.4	9.377032	0.000528	3.055568
Within Groups	653438.2	15	43562.54			
Total	2287388	19				

Last muscle group, lower back muscle data shows in table 4.64. Mean musculoskeletal strain [in time] on upper back does not differ on laptop computer is assumption. The assumption is rejected because the F_0 value is greater than $F_{critical}$. It means that working with laptop computer has significant disorders on all of 5 respondents during time. (Table 4.65)

Completely in all of the result for 6 regions of respondents body muscles when they are working with a laptop computer, we can say defiantly working with laptop computer has significant disorders in all of 6 different body regions for 5 respondents.

Chapter 5

CONCLUSIONS

The results show that working with computers is a constant cause of muscle problems. Pressures of working with computers on the neck, shoulders and back muscles more than other areas is likely to damage the muscles in the long run.

Our study illustrated that gender difference is not a significant factor of work-related musculoskeletal disorders during computer use.

Our statistics showed that ache and pain are the most common types of discomfort among users.

The ANOVA result for each of the body region for all of the respondents shows that working with desktop computer has significant disorder on hand, elbow, neck, upper back and lower back. But in shoulder region we cannot say it has significant disorders when respondents working with desktop computer.

Also working with laptop computer based on ANOVA result shows that working with laptop computer had significant disorders on all of the body regions for 5 respondents.

From questionnaire results, 129 variable analyzed by correlation analysis, we found that 111 positive correlation and just 2 negative correlation.

Also the correlation analysis for electromyography respondents and their questionnaire shows that 10 positive correlations and 26 negative correlations were found that the correlation between keyboard and lower back was the maximum positive correlation.

The regression analysis shows that age, knee trouble, shoulder problem, upper back problem and knee pain are the factors found to be significant predictors of medical treatment.

Since the laptop users are limited in posture, their muscles take more pressure than the desktop users. Especially the neck muscles would take a heavy pressure during the work. Also it is highly important to mention that using laptop computers at various places in different postures can cause much heavier damage to the muscles.

Studies on 5 users who participated in this thesis showed that working with a laptop computer leaves a significant impact on the area of the hands, elbow, neck, shoulders, upper back, and back. Also combination of working with the computers and laptops are shown to have a significant impact on muscles.

One of the disadvantage of laptops in the inability of separating the monitors, so the user should been his/her neck in order to get the appropriate position and it course more pressure on the neck muscles.

New monitor designs and ideas are required to study the effect of those in human performance. Some samples are designed for laptops with screens of the devices were separated. They are called ergonomic laptops. The models with the ability temperate the monitor is able to solve the problem of non-adjustable height of the laptop without changing the normal algorithm of the laptops.

Today lots of the people are using computers in their work and as the statistics shows, over 46% of them are using desktop and laptop at the same time. Using the computers in long run hurts the muscles and can cause MSDs and it will decrease the efficiency of the person in the work and increase the direct and indirect cost.

As we discussed before, as a result of these problems, each person goes on permit at least 5 working days per year, but sometimes they are not able to use all their permission and have to be at work and take the pain, so his efficiency will decrease significantly. In a long run it can cause unrecoverable problems for the person, and it will hurt both the person and the place that he works for, just imagine as if a very well experienced person had to leave his work in short intervals because of muscular problems and medical treatments.

REFERENCES

[1]Australian Bureau of Statistics, 2006. 8129.0 Business use of information technology. Available from: http://www.abs.gov.au/AUSSTATS/ [Accessed 08 January 2008].

[2] Blatter, B.M., Bongers, P.M., 2002. Duration of computer use and mouse use in relation to musculoskeletal disorders of neck or upper limb. International journal of Industrial Ergonomics 30, 295-306.

[3] Berkhout, A.L., Larsen, K.H., Bongres, P., 2004. The effect of using a laptop station compared to using a standard laptop PC on the cervical spine torque, perceived strain and productivity. Applied Ergonomics 35, 147-152.

[4]Computer Industry Almanac Inc., 2006. PCs in-use surpassed 900M in 2005. Available from: www. c-i-a.com/pr0605.htm [Accessed 31 October 2006].

[5] Cook, C., Limerick, R.B., Chang, S., 2000. The prevalence of neck and upper extremity musculoskeletal symptoms in computer mouse users. International Journal of Industrial Ergonomic 26, 347-356.

[6] Gerr, f., Marcus, M., Montelih, C., 2004. Epidemiology of musculoskeletal disorders among computer users: Lesson learned from the role of posture and keyboard use. Journal of Electromyography and Kinesiology 14(1), 25-31.

[7] Hengel, K.M.O., Houwink, A., Odell, D., Dieen, J.H.V., Dennerlein, J.T., 2008. Smaller external notebook mice have different effects on posture and muscle activity. Clinical Biomechanics 23, 727-734.

[8] Jensen, C., Finsen, L., Sogaard, K., Christensen, H., 2002. Musculoskeletal symptoms and duration of computer and mouse use. . International Journal of Industrial Ergonomics 30, 265-275.

[9] Korhan, O., Mackieh, A., 2010. A model for occupational injury risk assessment of musculoskeletal discomfort and their frequencies in computer users. Safety Science 48, 868-877.

[10] Larsson, B., Sogaard, K., Rosendal, L., 2007. Work related neck-shoulder pain: a review on magnitude, risk factor, biomchemical characteristic, clinical picture and preventive interventions. Best Practice & Research Clinical Rheunatology Vol21, No 3, pp, 447-463.

[11] Moffet, H., Hagberg, M., Hansson, E., Karlqvist, L., 2004. Influence of Laptop computer design and working position on physical exposure variables. Clinical Biomechanics 17, 368-375.

[12] Mork, P.J., Westgaard, R.H., 2009. Back posture and low back muscle activity in female computer workers: A field study. Clinical Biomechanics 24, 169-175.

[13] National Research Council and the Institute of medicine, Musculoskeletal Disorders and the Workplaces 2001. Washington, D.C: National Academy Press.

[14] National Statistics UK, 2006. Available from:www.statistics.gov.uk (accessed 30.10.06)

[15] Rempel, D., Barr, A., Barfman, D., Young, E., 2007. The effect of six keyboard design on wrist and forearm postures. Applied Ergonomics 38, 293-298.

[16]Samani, A., Carnero, J., Nielsen, L., Madelein, P., 2010. Interactive effects of acute experimental pain in trapezius and sore wrist extensor on the electromyography of the forearm muscles during computer work. Applied Ergonomics xxx, 1-6.

[17] Schneider, E., Irastorza, X., Copsey, S., European Agency for Safety and Health at Work (EU-OSHA), European Agency for Safety and Health at work (EU-OSHA) 2010. OSH in figures: Work-related musculoskeletal disorders in the EU-facts and figures.

[18] Silverstein, B., Adams, D., Kalat, J., 2002. Work-related musculoskeletal disorder in the neck, back and upper extremity in Washington state.

[19] Straker, L., Limerick, R.B., Pollock, C., Maslen, B., 2009. The influence of desk and display design on posture and muscle activity variability whilst performing information technology tasks. Applied Ergonomics 40, 852-859.

[20] Straker, L., Limerick, R.B., Pollock, C., Murray, K., Netto, K., Coleman, J., Skoss, R., 2008. The impact of computer display height and desk design on 3D posture during information technology work by young adults. Journal of Electromyography and Kinesiology 18, 336-349.

[21] Szeto, G.P.Y., Sham, K.S.W., 2008. The effect of angled position of computer display screen on muscle activities of the neck-shoulder stabilizers. International Journal of Industrial Ergonomics 38, 9-17.

[22] U.S Bureau of labor statistics, U.S department of labor, November 2005.

[23] Zeidi, I., Morshedi, H., Zeidi, B., 2010. The effect of interventions based on transtheoretical modeling on computer operator’s postural habits. Clinical Chiroparctic.

APPENDICES

Appendix A: Questionnaire Form

1- What is your gender?
2- What is your age?
3- How tall are you in meters?
4- How much do you weight in kilograms?
5- What type of computer do you use?
6- Typically, how much time daily in total you spend typing on a computer keyboard or using a mouse?
7- Overall, how many years have you been using computers?
8- What type of computer keyboard you mostly use?
9- Have you at any time during the last 12 months had trouble (such as ache, pain, discomfort, numbness) in neck?
10- Have you at any time during the last 12 months had trouble (such as ache, pain, discomfort, numbness) in shoulder?
11- Have you at any time during the last 12 months had trouble (such as ache, pain, discomfort, numbness) in elbow?
12- Have you at any time during the last 12 months had trouble (such as ache, pain, discomfort, numbness) in hand/wrist?
13- Have you at any time during the last 12 months had trouble (such as ache, pain, discomfort, numbness) in upper back?
14- Have you at any time during the last 12 months had trouble (such as ache, pain, discomfort, numbness) in lower back?
15- Have you at any time during the last 12 months had trouble (such as ache, pain, discomfort, numbness) in one or both Hips/Thighs/Buttocks?

16- Have you at any time during the last 12 months had trouble (such as ache, pain, discomfort, numbness) in one or both Knees?
17- Have you at any time during the last 12 months had trouble (such as ache, pain, discomfort, numbness) in one or both Ankles/Feet?
18- During the past 12 months have you been prevented from carrying out normal activities (e.g.. job, housework, hobbies) because of this trouble in neck?
19- During the past 12 months have you been prevented from carrying out normal activities (e.g.. job, housework, hobbies) because of this trouble in shoulder?
20- During the past 12 months have you been prevented from carrying out normal activities (e.g.. job, housework, hobbies) because of this trouble in hands/wrist?
21- During the past 12 months have you been prevented from carrying out normal activities (e.g.. job, housework, hobbies) because of this trouble in elbows?
22- During the past 12 months have you been prevented from carrying out normal activities (e.g.. job, housework, hobbies) because of this trouble in upper back?
23- During the past 12 months have you been prevented from carrying out normal activities (e.g.. job, housework, hobbies) because of this trouble in lower back?
24- During the past 12 months have you been prevented from carrying out normal activities (e.g.. job, housework, hobbies) because of this trouble in Hips/Thighs/Buttocks?
25- During the past 12 months have you been prevented from carrying out normal activities (e.g.. job, housework, hobbies) because of this trouble in knees?

26- During the past 12 months have you been prevented from carrying out normal activities (e.g.. job, housework, hobbies) because of this trouble in ankles/feet?

27- During the last 12 months, have you experienced the following symptoms in the following body regions? (mark all apply)

	Aching	Burning	Cramping	Loos of Color	Numbness	Pain	Swelling	Stifness	Tingling	Weakness
Neck										
Shoulder										
Elbows										
Wrist/Hands										
Finger										
Upper Back										
Lower Back										
Hips\Tighs\Buttocks										
Kness										
Ankles\Feet										

28- Have you had any medical treatment for the problem(s)?

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

30- How much time have you lost in the last year because of this problem(s)? (days)

Appendix B: List of Variables

1 Gender
2 Age
3 Height
4 Weight
5 Computer Type
6 Daily Use
7 Year Use
8 Keyboard
9 Neck Trouble
10 Shoulder Trouble
11 Elbow Trouble
12 Hand Trouble
13 Upper Back Trouble
14 Lower Back Trouble
15 Hip Trouble
16 Knee Trouble
17 Feet Trouble
18 Neck Problem
19 Shoulder Problem
20 Elbow Trouble
21 Hand Problem
22 Upper Back Problem
23 Lower Back Problem
24 Hip Problem
25 Knee Problem
26 Feet Problem
27 Neck Ache
28 Shoulder Ache
29 Elbow Ache
30 Wrist Ache
31 Finger Ache
32 Upper Back Ache
33 Lower Back Ache
34 Hip Ache
35 Knee Ache
36 Feet Ache
37 Neck Burn
38 Shoulder Burn
39 Elbow Burn
40 Wrist Burn
41 Finger Burn
42 Upper Back Burn
43 Lower Back Burn
44 Hip Burn
45 Knee Burn
46 Feet Burn
47 Neck Cramp
48 Shoulder Cramp
49 Elbow Cramp
50 Wrist Cramp
51 Finger Cramp
52 Upper Back Cramp
53 Lower Back Cramp
54 Hip Cramp
55 Knee Cramp
56 Feet Cramp
57 Neck Color
58 Shoulder Color
59 Elbow Color
60 Wrist Color
61 Finger Color
62 Upper Back Color
63 Lower Back Color
64 Hip Color
65 Knee Color
66 Feet Color
67 Neck Numbness
68 Shoulder Numbness
69 Elbow Numbness
70 Wrist Numbness
71 Finger Numbness
72 Upper Back Numbness
73 Lower Back Numbness
74 Hip Numbness
75 Knee Numbness
76 Feet Numbness
77 Neck Pain
78 Shoulder Pain
79 Elbow Pain
80 Wrist Pain

81 Finger Pain
82 Upper Back Pain
83 Lower Back Pain
84 Hip Pain
85 Knee Pain
86 Feet Pain
87 Neck Swelling
88 Shoulder Swelling
89 Elbow Swelling
90 Wrist Swelling
91 Finger Swelling
92 Upper Back Swelling
93 Lower Back Swelling
94 Hip Swelling
95 Knee Swelling
96 Feet Swelling
97 Neck Stiffness
98 Shoulder Stiffness
99 Elbow Stiffness
100 Wrist Stiffness
101 Finger Stiffness
102 Upper Back Stiffness
103 Lower Back Stiffness
104 Hip Stiffness
105 Knee Stiffness
106 Feet Stiffness
107 Neck Tingling
108 Shoulder Tingling
109 Elbow Tingling
110 Wrist Tingling
111 Finger Tingling
112 Upper Back Tingling
113 Lower Back Tingling
114 Hip Tingling
115 Knee Tingling
116 Feet Tingling
117 Neck Weakness
118 Shoulder Weakness
119 Elbow Weakness
120 Wrist Weakness
121 Finger Weakness
122 Upper Back Weakness
123 Lower Back Weakness
124 Hip Weakness
125 Knee Weakness
126 Feet Weakness
127 Med Trouble
128 Restrict Day
129 Lost Day

Appendix C: Logistic Regression

9/7/2011 12:05:25 PM

Welcome to Minitab, press F1 for help.

Binary Logistic Regression: [Q28] MedTre versus [Q1]Gender, [Q2] Age, ...

Link Function: Logit

Response Information

Variable	Value	Count	
[Q28] MedTreat	2	29	(Event)
	1	71	
	Total	100	

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	Upper
Constant	-1.04789	2.38971	-0.44	0.661			
[Q1]Gender	0.0684713	0.776579	0.09	0.930	1.07	0.23	4.91
[Q2] Age	0.355468	0.160060	2.22	**0.026**	1.43	1.04	1.95
[Q3] Height	-0.338359	0.370365	-0.91	0.361	0.71	0.34	1.47
[Q4] Weight	0.0254397	0.258834	0.10	0.922	1.03	0.62	1.70

Log-Likelihood = -54.816
Test that all slopes are zero: G = 10.797, DF = 4, P-Value = 0.029

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	56.8777	58	0.517
Deviance	64.9046	58	0.249
Hosmer-Lemeshow	7.1217	7	0.416

Table of Observed and Expected Frequencies:
(See Hosmer-Lemeshow Test for the Pearson Chi-Square Statistic)

	Group									
Value	1	2	3	4	5	6	7	8	9	Total
2										
Obs	3	3	1	3	4	2	2	3	8	29
Exp	1.9	1.9	2.1	2.6	2.8	3.4	3.6	4.4	6.3	
1										
Obs	12	8	10	8	7	9	8	7	2	71
Exp	13.1	9.1	8.9	8.4	8.2	7.6	6.4	5.6	3.7	
Total	15	11	11	11	11	11	10	10	10	100

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	1309	63.6	Somers' D	0.30
Discordant	689	33.5	Goodman-Kruskal Gamma	0.31
Ties	61	3.0	Kendall's Tau-a	0.13
Total	2059	100.0		

Binary Logistic Regression: [Q28] MedTre versus [Q5] CompTyp, [Q6] DailyUs, ...

Link Function: Logit

Response Information

Variable	Value	Count	
[Q28] MedTreat	2	29	(Event)
	1	71	
	Total	100	

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	1.32928	1.25499	1.06	0.290			
[Q5] CompType	-0.0958550	0.278369	-0.34	0.731	0.91	0.53	1.57
[Q6] DailyUse	-0.0666952	0.160821	-0.41	0.678	0.94	0.68	1.28
[Q7] YearUse	-0.417952	0.259583	-1.61	0.107	0.66	0.40	1.10
[Q8] Keyboard	0.0556801	0.205271	0.27	0.786	1.06	0.71	1.58

Log-Likelihood = -58.367
Test that all slopes are zero: G = 3.696, DF = 4, P-Value = 0.449

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	54.7631	46	0.176
Deviance	67.1144	46	0.023
Hosmer-Lemeshow	7.9949	7	0.333

Table of Observed and Expected Frequencies:
(See Hosmer-Lemeshow Test for the Pearson Chi-Square Statistic)

	Group									
Value	1	2	3	4	5	6	7	8	9	Total
2										
Obs	2	2	5	2	5	2	3	6	2	29
Exp	3.7	2.2	2.8	2.5	3.5	4.2	3.8	4.0	2.3	
1										
Obs	16	8	7	8	7	11	8	4	2	71
Exp	14.3	7.8	9.2	7.5	8.5	8.8	7.2	6.0	1.7	
Total	18	10	12	10	12	13	11	10	4	100

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	1277	62.0	Somers' D	0.26
Discordant	733	35.6	Goodman-Kruskal Gamma	0.27
Ties	49	2.4	Kendall's Tau-a	0.11
Total	2059	100.0		

Binary Logistic Regression: [Q28] MedTre versus [Q9] NeckTr, [Q10] ShoulT, ...

Link Function: Logit

Response Information

Variable	Value	Count	
[Q28] MedTreat	2	29	(Event)
	1	71	
	Total	100	

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	Upper
Constant	-2.27747	1.28151	-1.78	0.076			
[Q9] NeckTr	0.324995	0.531670	0.61	0.541	1.38	0.49	3.92
[Q10] ShoulTr	0.0391938	0.554816	0.07	0.944	1.04	0.35	3.09
[Q11] ElbowTr	-0.862450	0.699933	-1.23	0.218	0.42	0.11	1.66
[Q12] HandTr	0.310398	0.542938	0.57	0.568	1.36	0.47	3.95
[Q13] UBTr	-0.216664	0.552193	-0.39	0.695	0.81	0.27	2.38
[Q14] LBTr	0.305058	0.565408	0.54	0.590	1.36	0.45	4.11
[Q15] HipTr	-1.21439	0.753910	-1.61	0.107	0.30	0.07	1.30
[Q16] KneeTr	2.38946	0.710613	3.36	**0.001**	10.91	2.71	43.92
[Q17] FeetTr	-0.312645	0.708510	-0.44	0.659	0.73	0.18	2.93

Log-Likelihood = -51.075
Test that all slopes are zero: G = 18.279, DF = 9, P-Value = 0.032

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	62.6542	53	0.171
Deviance	69.0541	53	0.068
Hosmer-Lemeshow	6.4747	7	0.486

Table of Observed and Expected Frequencies:
(See Hosmer-Lemeshow Test for the Pearson Chi-Square Statistic)

	Group									
Value	1	2	3	4	5	6	7	8	9	Total
2										
Obs	1	2	0	3	3	4	4	7	5	29
Exp	0.6	1.4	3.2	2.2	2.6	3.4	3.6	5.9	6.1	
1										
Obs	9	8	18	8	8	8	6	3	3	71
Exp	9.4	8.6	14.8	8.8	8.4	8.6	6.4	4.1	1.9	
Total	10	10	18	11	11	12	10	10	8	100

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	1567	76.1	Somers' D	0.54
Discordant	461	22.4	Goodman-Kruskal Gamma	0.55
Ties	31	1.5	Kendall's Tau-a	0.22
Total	2059	100.0		

Binary Logistic Regression: [Q28] MedTre versus [Q18] NeckPr, [Q19] ShoulP, ...

Link Function: Logit

Response Information

Variable	Value	Count	
[Q28] MedTreat	2	29	(Event)
	1	71	
	Total	100	

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	Upper
Constant	-0.200708	0.882939	-0.23	0.820			
[Q18] NeckPr	-0.991172	1.21196	-0.82	0.413	0.37	0.03	3.99
[Q19] ShoulPr	2.94134	1.28132	2.30	**0.022**	18.94	1.54	233.39
[Q20] ElbowTr	-1.07884	2.00905	-0.54	0.591	0.34	0.01	17.44
[Q21] HandPr	0.319948	0.962389	0.33	0.740	1.38	0.21	9.08
[Q22] UBPr	-2.80397	1.25915	-2.23	**0.026**	0.06	0.01	0.71
[Q23] LBPr	0.797022	0.895027	0.89	0.373	2.22	0.38	12.82
[Q24] HipPr	-1.89830	2.08422	-0.91	0.362	0.15	0.00	8.91
[Q25] KneePr	1.66451	0.977995	1.70	0.089	5.28	0.78	35.92
[Q26] FeetPr	0.127038	1.23214	0.10	0.918	1.14	0.10	12.71

Log-Likelihood = -52.655
Test that all slopes are zero: G = 15.120, DF = 9, P-Value = 0.088

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	44.9801	19	0.001
Deviance	32.1847	19	0.030
Hosmer-Lemeshow	9.6819	3	0.021

Table of Observed and Expected Frequencies:
(See Hosmer-Lemeshow Test for the Pearson Chi-Square Statistic)

Value	Group 1	2	3	4	5	Total
2						
Obs	3	11	4	7	4	29
Exp	0.8	15.3	3.4	5.3	4.3	
1						
Obs	8	53	6	3	1	71
Exp	10.2	48.7	6.6	4.7	0.7	
Total	11	64	10	10	5	100

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	1173	57.0	Somers' D	0.41
Discordant	334	16.2	Goodman-Kruskal Gamma	0.56
Ties	552	26.8	Kendall's Tau-a	0.17
Total	2059	100.0		

Binary Logistic Regression: [Q28] MedTre versus NeckAche, ShoulAche, ...

* WARNING * Algorithm has not converged after 20 iterations.
* WARNING * Convergence has not been reached for the parameter estimates criterion.

* WARNING * The results may not be reliable.
* WARNING * Try increasing the maximum number of iterations.

Link Function: Logit

Response Information

Variable	Value	Count	
[Q28] MedTreat	2	29	(Event)
	1	71	
	Total	100	

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	-0.990101	0.286164	-3.46	0.001			
NeckAche	-0.153607	0.652066	-0.24	0.814	0.86	0.24	3.08
ShoulAche	-1.06199	1.08936	-0.97	0.330	0.35	0.04	2.92
ElbowAche	-20.5761	12160.9	-0.00	0.999	0.00	0.00	*
WristAche	0.264587	0.923141	0.29	0.774	1.30	0.21	7.96
FingerAche	-0.100065	0.966851	-0.10	0.918	0.90	0.14	6.02
UBAche	0.923514	0.855575	1.08	0.280	2.52	0.47	13.47
LBAche	0.176958	0.914426	0.19	0.847	1.19	0.20	7.17
HipAche	-0.542867	1.32988	-0.41	0.683	0.58	0.04	7.87
KneeAche	0.612857	0.926163	0.66	0.508	1.85	0.30	11.34
FeetAche	2.36702	1.22905	1.93	0.054	10.67	0.96	118.62

Log-Likelihood = -54.507
Test that all slopes are zero: G = 11.416, DF = 10, P-Value = 0.326

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	31.4531	24	0.141
Deviance	31.1760	24	0.149
Hosmer-Lemeshow	4.7730	4	0.311

Table of Observed and Expected Frequencies:
(See Hosmer-Lemeshow Test for the Pearson Chi-Square Statistic)

	Group						
Value	1	2	3	4	5	6	Total
2							
Obs	2	2	13	3	6	3	29
Exp	0.6	2.5	14.9	3.1	4.7	3.3	
1							
Obs	8	9	42	7	4	1	71
Exp	9.4	8.5	40.1	6.9	5.3	0.7	
Total	10	11	55	10	10	4	100

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	1097	53.3	Somers' D	0.33
Discordant	426	20.7	Goodman-Kruskal Gamma	0.44
Ties	536	26.0	Kendall's Tau-a	0.14
Total	2059	100.0		

Binary Logistic Regression: [Q28] MedTre versus NeckBurn, ShoulBurn, ...

```
* WARNING * Algorithm has not converged after 20 iterations.
* WARNING * Convergence has not been reached for the parameter estimates
            criterion.
* WARNING * The results may not be reliable.
* WARNING * Try increasing the maximum number of iterations.
```

Link Function: Logit

Response Information

Variable	Value	Count	
[Q28] MedTreat	2	29	(Event)
	1	71	
	Total	100	

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	Upper
Constant	-0.916291	0.241523	-3.79	0.000			
NeckBurn	-81.1683	20170.0	-0.00	0.997	0.00	0.00	*
ShoulBurn	-40.3984	14044.7	-0.00	0.998	0.00	0.00	*
ElbowBurn	-64.6669	42024.9	-0.00	0.999	0.00	0.00	*
WristBurn	-18.8091	11648.4	-0.00	0.999	0.00	0.00	*
FingerBurn	20.4112	10382.2	0.00	0.998	7.31957E+08	0.00	*
UBBurn	1.60944	1.24833	1.29	0.197	5.00	0.43	57.75
LBBurn	20.1545	9130.29	0.00	0.998	5.66222E+08	0.00	*
HipBurn	-19.1092	13534.6	-0.00	0.999	0.00	0.00	*
KneeBurn	60.8097	17463.7	0.00	0.997	2.56627E+26	0.00	*
FeetBurn	61.5314	26779.9	0.00	0.998	5.28129E+26	0.00	*

Log-Likelihood = -52.164
Test that all slopes are zero: G = 16.102, DF = 10, P-Value = 0.097

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	0.0000000	4	1.000
Deviance	0.0000000	4	1.000
Hosmer-Lemeshow	0.0000000	1	1.000

Table of Observed and Expected Frequencies:
(See Hosmer-Lemeshow Test for the Pearson Chi-Square Statistic)

Value	Group 1	2	3	Total
2				
Obs	0	24	5	29
Exp	0.0	24.0	5.0	
1				
Obs	10	60	1	71
Exp	10.0	60.0	1.0	
Total	10	84	6	100

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	593	28.8	Somers' D	0.28

Discordant	24	1.2	Goodman-Kruskal Gamma	0.92
Ties	1442	70.0	Kendall's Tau-a	0.11
Total	2059	100.0		

Binary Logistic Regression: [Q28] MedTre versus NeckCramp, ShoulCramp, ...

```
* WARNING * Algorithm has not converged after 20 iterations.
* WARNING * Convergence has not been reached for the parameter estimates
            criterion.
* WARNING * The results may not be reliable.
* WARNING * Try increasing the maximum number of iterations.
```

Link Function: Logit

Response Information

Variable	Value	Count	
[Q28] MedTreat	2	29	(Event)
	1	71	
	Total	100	

Logistic Regression Table

						95% CI	
Predictor	Coef	SE Coef	Z	P	Odds Ratio	Lower	Upper
Constant	-0.916843	0.244690	-3.75	0.000			
NeckCramp	-20.0791	10443.6	-0.00	0.998	0.00	0.00	*
ShoulCramp	0.888348	1.60915	0.55	0.581	2.43	0.10	56.96
WristCramp	20.2976	9804.06	0.00	0.998	6.53310E+08	0.00	*
FingerCramp	-81.3177	32385.9	-0.00	0.998	0.00	0.00	*
UBCramp	0.0569894	1.49851	0.04	0.970	1.06	0.06	19.97
LBCramp	-0.554763	1.37849	-0.40	0.687	0.57	0.04	8.56
HipCramp	-58.8395	16399.5	-0.00	0.997	0.00	0.00	*
KneeCramp	39.2872	13698.1	0.00	0.998	1.15402E+17	0.00	*
FeetCramp	1.19422	1.59219	0.75	0.453	3.30	0.15	74.81

Log-Likelihood = -53.270
Test that all slopes are zero: G = 13.890, DF = 9, P-Value = 0.126

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	7.54984	7	0.374
Deviance	9.02260	7	0.251
Hosmer-Lemeshow	1.47401	1	0.225

Table of Observed and Expected Frequencies:
(See Hosmer-Lemeshow Test for the Pearson Chi-Square Statistic)

		Group		
Value	1	2	3	Total
2				
Obs	1	22	6	29
Exp	0.4	23.3	5.3	
1				
Obs	9	60	2	71
Exp	9.6	58.7	2.7	
Total	10	82	8	100

Measures of Association:

(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	651	31.6	Somers' D	0.26
Discordant	109	5.3	Goodman-Kruskal Gamma	0.71
Ties	1299	63.1	Kendall's Tau-a	0.11
Total	2059	100.0		

Binary Logistic Regression: [Q28] MedTre versus ShoulColor, WristColor, ...

* WARNING * Algorithm has not converged after 20 iterations.
* WARNING * Convergence has not been reached for the parameter estimates criterion.
* WARNING * The results may not be reliable.
* WARNING * Try increasing the maximum number of iterations.

Link Function: Logit

Response Information

Variable	Value	Count	
[Q28] MedTreat	2	29	(Event)
	1	71	
	Total	100	

Logistic Regression Table

						95% CI	
Predictor	Coef	SE Coef	Z	P	Odds Ratio	Lower	Upper
Constant	-0.901902	0.224069	-4.03	0.000			
ShoulColor	43.1278	41417.0	0.00	0.999	5.37229E+18	0.00	*
WristColor	-20.5537	27661.4	-0.00	0.999	0.00	0.00	*
KneeColor	-20.5537	27661.4	-0.00	0.999	0.00	0.00	*

Log-Likelihood = -58.292
Test that all slopes are zero: G = 3.847, DF = 3, P-Value = 0.279

* NOTE * No goodness of fit test performed.
* NOTE * The model uses all degrees of freedom.

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	127	6.2	Somers' D	0.06
Discordant	0	0.0	Goodman-Kruskal Gamma	1.00
Ties	1932	93.8	Kendall's Tau-a	0.03
Total	2059	100.0		

* NOTE * 1 time(s) the standardized Pearson residuals, delta chi-square, delta
deviance, delta beta (standardized) and delta beta could not be computed because leverage (Hi) is equal to 1.

Binary Logistic Regression: [Q28] MedTre versus NeckNumb, ShoulNumb, ...

```
* WARNING * Algorithm has not converged after 20 iterations.
* WARNING * Convergence has not been reached for the parameter estimates
            criterion.
* WARNING * The results may not be reliable.
* WARNING * Try increasing the maximum number of iterations.
```

Link Function: Logit

Response Information

Variable	Value	Count	
[Q28] MedTreat	2	29	(Event)
	1	71	
	Total	100	

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	Upper
Constant	-0.980423	0.252885	-3.88	0.000			
NeckNumb	22.6307	44953.9	0.00	1.000	6.73561E+09	0.00	*
ShoulNumb	44.0906	35217.3	0.00	0.999	1.40698E+19	0.00	*
ElbowNumb	-0.399867	1.26420	-0.32	0.752	0.67	0.06	7.99
WristNumb	0.481390	0.987336	0.49	0.626	1.62	0.23	11.21
FingerNumb	0.377218	0.977762	0.39	0.700	1.46	0.21	9.91
UBNumb	0.0219498	32720.5	0.00	1.000	1.02	0.00	*
LBNumb	-20.4971	17478.1	-0.00	0.999	0.00	0.00	*
HipNumb	0.481390	0.987336	0.49	0.626	1.62	0.23	11.21
KneeNumb	-21.4379	27661.4	-0.00	0.999	0.00	0.00	*
FeetNumb	-20.1340	14875.6	-0.00	0.999	0.00	0.00	*

Log-Likelihood = -54.025
Test that all slopes are zero: G = 12.381, DF = 10, P-Value = 0.260

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	4.94141	5	0.423
Deviance	6.99735	5	0.221
Hosmer-Lemeshow	2.64651	1	0.104

Table of Observed and Expected Frequencies:
(See Hosmer-Lemeshow Test for the Pearson Chi-Square Statistic)

	Group			
Value	1	2	3	Total
2				

Obs	22	2	5	29
Exp	21.3	3.7	3.9	
1				
Obs	63	8	0	71
Exp	63.7	6.3	1.1	
Total	85	10	5	100

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	661	32.1	Somers' D	0.21
Discordant	233	11.3	Goodman-Kruskal Gamma	0.48
Ties	1165	56.6	Kendall's Tau-a	0.09
Total	2059	100.0		

Binary Logistic Regression: [Q28] MedTre versus NeckPain, ShoulPain, ...

* WARNING * Algorithm has not converged after 20 iterations.
* WARNING * Convergence has not been reached for the parameter estimates criterion.
* WARNING * The results may not be reliable.
* WARNING * Try increasing the maximum number of iterations.

Link Function: Logit

Response Information

Variable	Value	Count	
[Q28] MedTreat	2	29	(Event)
	1	71	
	Total	100	

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	Upper
Constant	-0.943700	0.308552	-3.06	0.002			
NeckPain	0.674394	0.648115	1.04	0.298	1.96	0.55	6.99
ShoulPain	-0.516947	0.933827	-0.55	0.580	0.60	0.10	3.72
ElbowPain	0.431466	1.38484	0.31	0.755	1.54	0.10	23.24
WristPain	0.0434442	0.922049	0.05	0.962	1.04	0.17	6.36
FingerPain	-21.4856	8173.55	-0.00	0.998	0.00	0.00	*
UBPain	-1.16900	1.02620	-1.14	0.255	0.31	0.04	2.32
LBPain	0.764646	0.750881	1.02	0.309	2.15	0.49	9.36
HipPain	-1.87219	1.31930	-1.42	0.156	0.15	0.01	2.04
KneePain	2.03349	0.843428	2.41	**0.016**	7.64	1.46	39.91
FeetPain	-1.07871	1.29151	-0.84	0.404	0.34	0.03	4.27

Log-Likelihood = -51.163
Test that all slopes are zero: G = 18.104, DF = 10, P-Value = 0.053

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	21.9422	31	0.885
Deviance	26.7683	31	0.684
Hosmer-Lemeshow	2.7491	5	0.739

Table of Observed and Expected Frequencies:

(See Hosmer-Lemeshow Test for the Pearson Chi-Square Statistic)

	Group							
Value	1	2	3	4	5	6	7	Total
2								
Obs	0	0	3	12	7	6	1	29
Exp	0.1	0.9	2.1	12.6	5.5	7.0	0.9	
1								
Obs	10	10	7	33	6	5	0	71
Exp	9.9	9.1	7.9	32.4	7.5	4.0	0.1	
Total	10	10	10	45	13	11	1	100

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	1312	63.7	Somers' D	0.47
Discordant	337	16.4	Goodman-Kruskal Gamma	0.59
Ties	410	19.9	Kendall's Tau-a	0.20
Total	2059	100.0		

Binary Logistic Regression: [Q28] MedTre versus ShoulSwell, HipSwell, ...

* WARNING * Algorithm has not converged after 20 iterations.
* WARNING * Convergence has not been reached for the parameter estimates criterion.
* WARNING * The results may not be reliable.
* WARNING * Try increasing the maximum number of iterations.

Link Function: Logit

Response Information

Variable	Value	Count	
[Q28] MedTreat	2	29	(Event)
	1	71	
	Total	100	

Logistic Regression Table

						95% CI	
Predictor	Coef	SE Coef	Z	P	Odds Ratio	Lower	Upper
Constant	-0.962028	0.233344	-4.12	0.000			
ShoulSwell	-20.8363	19283.0	-0.00	0.999	0.00	0.00	*
HipSwell	22.6342	30825.6	0.00	0.999	6.75960E+09	0.00	*
KneeSwell	0.641352	1.17988	0.54	0.587	1.90	0.19	19.18
FeetSwell	0.641352	1.17988	0.54	0.587	1.90	0.19	19.18

Log-Likelihood = -57.735
Test that all slopes are zero: G = 4.959, DF = 4, P-Value = 0.291

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	0.156965	2	0.925
Deviance	0.154984	2	0.925
Hosmer-Lemeshow	0.015958	0	*

Table of Observed and Expected Frequencies:
(See Hosmer-Lemeshow Test for the Pearson Chi-Square Statistic)

	Group		
Value	1	2	Total
2			
Obs	25	4	29
Exp	25.2	3.8	
1			
Obs	68	3	71
Exp	67.8	3.2	
Total	93	7	100

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	327	15.9	Somers' D	0.12
Discordant	77	3.7	Goodman-Kruskal Gamma	0.62
Ties	1655	80.4	Kendall's Tau-a	0.05
Total	2059	100.0		

Binary Logistic Regression: [Q28] MedTre versus NeckStiff, ElbowStiff, ...

```
* WARNING * Algorithm has not converged after 20 iterations.
* WARNING * Convergence has not been reached for the parameter estimates
            criterion.
* WARNING * The results may not be reliable.
* WARNING * Try increasing the maximum number of iterations.
```

Link Function: Logit

Response Information

Variable	Value	Count	
[Q28] MedTreat	2	29	(Event)
	1	71	
	Total	100	

Logistic Regression Table

						95% CI	
Predictor	Coef	SE Coef	Z	P	Odds Ratio	Lower	Upper
Constant	-1.21379	0.261671	-4.64	0.000			
NeckStiff	1.20946	1.08467	1.12	0.265	3.35	0.40	28.09
ElbowStiff	24.3595	30825.6	0.00	0.999	3.79488E+10	0.00	*
WristStiff	-0.765581	1.75729	-0.44	0.663	0.47	0.01	14.57
FingerStiff	1.26168	1.10667	1.14	0.254	3.53	0.40	30.90
UBStiff	-1.46695	1.83261	-0.80	0.423	0.23	0.01	8.37
LBStiff	2.17147	1.64681	1.32	0.187	8.77	0.35	221.24
HipStiff	0.967444	2.32840	0.42	0.678	2.63	0.03	252.42
KneeStiff	22.3538	20732.8	0.00	0.999	5.10679E+09	0.00	*
FeetStiff	-0.707935	2.31712	-0.31	0.760	0.49	0.01	46.23

Log-Likelihood = -53.387
Test that all slopes are zero: G = 13.656, DF = 9, P-Value = 0.135

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	8.2704	5	0.142
Deviance	10.3575	5	0.066
Hosmer-Lemeshow	0.0806	1	0.777

Table of Observed and Expected Frequencies:
(See Hosmer-Lemeshow Test for the Pearson Chi-Square Statistic)

	Group			
Value	1	2	3	Total
2				
Obs	19	5	5	29
Exp	19.1	4.7	5.2	
1				
Obs	65	5	1	71
Exp	64.9	5.3	0.8	
Total	84	10	6	100

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	730	35.5	Somers' D	0.29
Discordant	128	6.2	Goodman-Kruskal Gamma	0.70
Ties	1201	58.3	Kendall's Tau-a	0.12
Total	2059	100.0		

Binary Logistic Regression: [Q28] MedTre versus NeckTing, ShoulTing, ...

* WARNING * Algorithm has not converged after 20 iterations.
* WARNING * Convergence has not been reached for the parameter estimates criterion.
* WARNING * The results may not be reliable.
* WARNING * Try increasing the maximum number of iterations.

Link Function: Logit

Response Information

Variable	Value	Count	
[Q28] MedTreat	2	29	(Event)
	1	71	
	Total	100	

Logistic Regression Table

						95% CI	
Predictor	Coef	SE Coef	Z	P	Odds Ratio	Lower	Upper
Constant	-0.931558	0.231545	-4.02	0.000			
NeckTing	-40.9732	24306.7	-0.00	0.999	0.00	0.00	*
ShoulTing	17.9391	99090.5	0.00	1.000	61778425.41	0.00	*
ElbowTing	18.3694	55419.6	0.00	1.000	95004467.05	0.00	*
WristTing	-20.5240	27661.4	-0.00	0.999	0.00	0.00	*
FingerTing	-43.1278	41417.0	-0.00	0.999	0.00	0.00	*
KneeTing	21.2277	15488.2	0.00	0.999	1.65605E+09	0.00	*
FeetTing	22.6038	30825.6	0.00	0.999	6.55674E+09	0.00	*

Log-Likelihood = -54.777
Test that all slopes are zero: G = 10.877, DF = 7, P-Value = 0.144

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	0.0000000	1	1.000

Deviance	0.0000000	1	1.000
Hosmer-Lemeshow	0.0000000	0	*

Table of Observed and Expected Frequencies:
(See Hosmer-Lemeshow Test for the Pearson Chi-Square Statistic)

	Group		
Value	1	2	Total
2			
Obs	26	3	29
Exp	26.0	3.0	
1			
Obs	71	0	71
Exp	71.0	0.0	
Total	97	3	100

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	343	16.7	Somers' D	0.17
Discordant	0	0.0	Goodman-Kruskal Gamma	1.00
Ties	1716	83.3	Kendall's Tau-a	0.07
Total	2059	100.0		

* NOTE * 1 time(s) the standardized Pearson residuals, delta chi-square, delta
deviance, delta beta (standardized) and delta beta could not be computed because leverage (Hi) is equal to 1.

Binary Logistic Regression: [Q28] MedTre versus NeckWeak, ShoulWeak, ...

* WARNING * Algorithm has not converged after 20 iterations.
* WARNING * Convergence has not been reached for the parameter estimates criterion.
* WARNING * The results may not be reliable.
* WARNING * Try increasing the maximum number of iterations.

Link Function: Logit

Response Information

Variable	Value	Count	
[Q28] MedTreat	2	29	(Event)
	1	71	
	Total	100	

Logistic Regression Table

						95% CI	
Predictor	Coef	SE Coef	Z	P	Odds Ratio	Lower	Upper
Constant	-0.944462	0.257172	-3.67	0.000			
NeckWeak	29.5899	8655.72	0.00	0.997	7.09144E+12	0.00	*
ShoulWeak	1.63761	1.25145	1.31	0.191	5.14	0.44	59.77
ElbowWeak	-9.08192	8657.24	-0.00	0.999	0.00	0.00	*
WristWeak	-47.7945	12291.6	-0.00	0.997	0.00	0.00	*
FingerWeak	-19.1382	9846.44	-0.00	0.998	0.00	0.00	*
UBWeak	-27.0352	44483.0	-0.00	1.000	0.00	0.00	*
LBWeak	23.1458	40049.2	0.00	1.000	1.12745E+10	0.00	*
HipWeak	-18.5698	10480.8	-0.00	0.999	0.00	0.00	*
KneeWeak	20.9040	11765.3	0.00	0.999	1.19809E+09	0.00	*
FeetWeak	-9.50979	8657.90	-0.00	0.999	0.00	0.00	*

Log-Likelihood = -46.381
Test that all slopes are zero: G = 27.668, DF = 10, P-Value = 0.002

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	0.0000000	10	1.000
Deviance	0.0000001	10	1.000
Hosmer-Lemeshow	0.0000000	1	1.000

Table of Observed and Expected Frequencies:
(See Hosmer-Lemeshow Test for the Pearson Chi-Square Statistic)

	Group			
Value	1	2	3	Total
2				
Obs	0	21	8	29
Exp	0.0	21.0	8.0	
1				
Obs	10	60	1	71
Exp	10.0	60.0	1.0	
Total	10	81	9	100

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	902	43.8	Somers' D	0.43
Discordant	21	1.0	Goodman-Kruskal Gamma	0.95
Ties	1136	55.2	Kendall's Tau-a	0.18
Total	2059	100.0		