# Anthropometric Home Office Computer Workstation Setup

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# ABSTRACT

Long hours of computer use causes different types of health issues such as noticeable increase in risk factors of musculoskeletal disorders in long-term.

This study aims to design anthropometric home office computer workstation setup for computer users. For this purpose, anthropometric measurements were collected to design the most suitable home office computer workstation to reduce the perceived musculoskeletal discomfort. Electromyogram experiments on two different computer workstations were conducted to find out the muscle groups exposed to pressure during working with computer activities.

The significance of this study is to provide muscle discomfort reducing furniture and user-friendly interfaces during working with computer. Such proper home office computer workstation is necessary to prevent strain injuries which can lead to long-term disabilities.



**Keywords:** Musculoskeletal discomfort, Computer workstation design, computer users

# ÖZ

Uzun süre bilgisayar kullanımi farklı sağlık sorunlara yol açar örneğin, uzun vadede kas iskelet sistemi hastalıklarında artışlara neden olur.

Bu çalışma, bilgisayar kullanıcıları için antropometrik ev ofis bilgisayarı iş-istasyonu kurulumu tasarlamayı amaçlamaktadır. Bu çalışmada, algılanan kas-iskelet rahatsızlığı azaltmak için en uygun ev ofis bilgisayar iş istasyonu tasarlamak için antropometrik ölçümler toplanmıştır. İki farklı bilgisayar iş-istasyonu üzerinde, bilgisayar faaliyetleri sırasında basınca maruz kalan kas gruplarını tespit etmek için elektromiyogram deneyler yapılmıştır.

Bu çalışmanın önemi bilgisayar ile çalışırken boyunca kas rahatsızlıklarını azaltıcı mobilya ve kullanıcı dostu arayüzleri sağlamaktır. Bu koşullara uygun ev ofis bilgisayar iş-istasyonu uzun dönemli sakatlıklara yol açabilir zorlanma yaralanmaları önlemek için gereklidir.

**Anahtar Kelimeler:** Kas-iskelet ağrısı, Bilgisayar iş istasyonu tasarımı, bilgisayar uygulamaları

I dedicate this thesis to my family for nursing me with affection and love and their dedicated partnership for success in my life.

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# Chapter 1

# INTRODUCTION

Computer applications in human life is very high and many people are working with computers for long hours, therefore, identifying effectual factors in the computer workplace is important.

In this thesis, literature for computer workstation was carefully scanned to provide the designs for a home office computer workstation. This computer workstation setup was arranged in the Ergonomics lab to collect both anthropometric and muscle activity data.

Ten healthy subjects, seven men and three women, participated in this research. Anthropometric data collected from the literature setup were used to design a new computer workstation for the participants. Surface electromyogram (sEMG) was used to record muscle activities on 6 body regions (hand, forearm, neck, and shoulder, upper and lower back) during working with computer.

A new computer workstation for computer users was designed based on the analysis of anthropometric data and this new setup was also arranged in the Ergonomics lab. Having the new design more anthropometric data were collected, and sEMG experiment were also conducted on the same 10 respondents.

Specifically, the musculoskeletal discomforts on two computer workstation designs are investigated for computer users. During using computer process, musculoskeletal activity of respondents on the two workstation designs were compared to find out which workstation design can help to reduce musculoskeletal strain.

Correlation analysis was performed to find out relationships among the collected data from anthropometric measurements and sEMG experiments.

A hypothesis testing was used to analyze the data collected through sEMG. For each body region, Two-Factor Factorial analyses with fixed effects were conducted for the proposed and new computer workstation designs.

Discriminant analysis was conducted to determine difference between the musculoskeletal discomfort before and after the intervention. Classification scores for each design were calculated to provide the evidence that computer users suffer from less musculoskeletal discomfort during working with computer.

Thus, the significance of this study is to provide muscle discomfort reducing furniture and user-friendly interfaces during working with computer. Such proper home office computer workstation is necessary to prevent strain injuries which can lead to long-term disabilities.

# Chapter 2

# LITERATURE REVIEW

## 2.1 Musculoskeletal Disorders

The National Institute for Occupational Safety and Health (NIOSH) defines MSDs as "a group of conditions that involve the nerves, tendons, muscles, and supporting structures such as intervertebral discs". They represent a wide range of disorders, which can differ in severity from mild periodic symptoms to severe chronic and debilitating conditions. Examples include carpal tunnel syndrome, tension neck syndrome, and low back pain.

The International Labor Organization (ILO, 2002) has proposed a new list of occupational diseases that includes occupational MSDs. In this ILO recommendation, MSDs are included in the category of diseases classified by a target organ system, caused by specific work activities or work environment where particular risk factors are present. Examples of such activities or environment include

(a) Rapid or repetitive motion,

(b) Forceful exertion,

(c) Excessive mechanical force concentration,

(d) Awkward or non-neutral posture, and

(e) Vibration.

With this new international list of occupational diseases, MSDs will be included in several national lists of occupational diseases, and more attention will be focused on the ergonomics factors that influence their occurrence.

According to the National Research Council and Institute of Medicine, in studies on the origin of MSDs, it has been established in the scientific literature that there is a number of factors to be considered. (National Research Council & Institute of Medicin, 2001)

These are:

(a) Physical, organizational, and social aspects of work and the workplace;

(b) Physical and social aspects of life outside the workplace (sports, exercise programs, etc.), economic incentives and cultural values; and

(c) The physical and psychological characteristics of the individual.

Different groups of factors may cause MSDs, including physical and biomechanical factors, organizational and psychosocial factors, individual and personal factors. These may act uniquely or in combination.

Physical factors which potentially contributing to the development of MSDs are:

- Force application (lifting, carrying, pulling, pushing, use of tools),
- Repetition of movements
- Awkward and static postures (with hands above shoulder level, or prolonged standing and sitting),
- Local compression of tools and surfaces
- Vibration
- Cold or excessive heat

- Poor lighting,
- High noise levels (causing the body to tense organizational and psychosocial factors),
- Demanding work, lack of control over the tasks performed, and low levels of autonomy,
- Low levels of job satisfaction,
- Repetitive, monotonous work, at a high pace,
- Lack of support from colleagues, supervisors and managers individual factors,
- Prior medical history,
- Physical capacity,
- Age,
- Obesity,
- Smoking. (Introduction to work-related musculoskeletal disorders, 2007)

MSDs and their associated costs represent significant problems in developing countries with consequential impact on both productivity and workers' well-being. They are one of the common work-related health problems. These disorders are usually caused by exposure of the body in an unfavorable condition while working. Every year many of the workers lose their health and efficiency caused by this type of events and MSDs are the major causes of employee absenteeism and loss of working hours.

Revelle et al. (2000) conducted a research of effects of technology on the way we live and work. We are spending more time sitting and using computers, which has greatly increased the occurrence of related musculoskeletal disorders.

Buckle and Devereux (2002) found that work-related musculoskeletal disorders describe a wide range of inflammatory and degenerative diseases and disorders. These conditions result in pain and functional impairment and may affect, besides others, the neck, shoulders, forearms, elbows, wrists and hands. They are work-related when the work activities and work conditions significantly contribute to their development or exacerbation but are not necessarily the sole determinant of causation. These disorders are a significant problem within the European Union with respect to ill health, productivity and associated costs. The path mechanisms of musculoskeletal disorders affecting tendons, ligaments, nerves, muscle, circulation and pain perception are reviewed and conceptual models for the pathogenesis of musculoskeletal disorders affecting the neck and upper limbs are presented.

In 1999, workers took time away from work (nearly 1 million people) to treat and recover from WRMDs pain or impairment of function in the low back or upper extremities (Bernard, 2003)

The estimated cost of medical treatment for all work-related back pain was US $13 billion in 1990 with an estimated growth rate of 7% per year (Straus , 2002).

According to the World Health Organization, work-related musculoskeletal disorders arise when exposed to work activities and work conditions that significantly contribute to their development or exacerbation but not acting as the sole determinant of causation (World Health Organization (WHO), 1985)

The most frequently reported disorders related to health were eyestrain affecting nearly 85% and, upper back and neck pain affecting 70% of computer users. Identifying college students at risk for CTDs and other musculoskeletal discomforts provides a prime opportunity for health education professionals to intervene at an early stage (McMahan & Lutz, Computer Use, Workstation Design Training and Cumulative Trauma Disorders in College Students, 2003).

In France, work-related musculoskeletal disorders of the upper limb (WRMSDs-UL) account for over two-thirds of all occupational disorders recognized. This broad term encompasses a vast array of disorders whose development is facilitated by environmental factors present at the workplace. Numerous epidemiological studies have established the key role of occupational activities in the genesis of WRMSDs-UL. (Aptel, Aublet-Cuvelier, & Cnockaert, 2002)

Aptel et al. (2002) found that this role is mediated by biomechanical factors (repetitive motion, strenuous effort, extreme joint postures) and/or psychosocial factors. Biological plausibility supports the epidemiological data. The high incidence of WRMSDs-UL indicates a need for greater emphasis on prevention.

Early intervention educators who serve children with special needs often suffer from physical strains.

Cheng and Ju (2012) investigate the prevalence of work-related musculoskeletal disorders in this population, and to evaluate the relationship between work-related musculoskeletal disorders and personal/ergonomic risk factors. A self-designed questionnaire consisting three domains (demographics/prevalence of work-related musculoskeletal disorders/ergonomic risk factors) was delivered to educators who work in early intervention institutions. Ninety-four percent of early intervention educators suffered from musculoskeletal disorders. Logistic regression revealed that some work-related ergonomic factors were highly associated with symptoms on lower back, shoulder and neck, with odds ratios ranging from 0.321 to 4.256. High prevalence of work-related musculoskeletal disorders impacts this occupation negatively. Further regulations to the institutions regarding workplace health promotion and environment modification, as well as training to the employees for body mechanics, should be implemented to prevent injury occurrence.

## 2.2 Work-Related Musculoskeletal Disorders

The World Health Organization has defined “work-related” diseases as multifactorial to represent that a number of risk factors (e.g., physical, psychosocial, work organizational, individual, and sociocultural) contribute to causing these diseases.

Work-related musculoskeletal disorders (WRMSDs) are considered as an occupational disease. They affect body structures such as muscles, joints, tendons, ligaments, nerves, bones or a localized blood circulation system. Most work related MSDs are cumulative disorders, resulting from repeated exposures to high- or low-intensity loads over a long period of time.

The symptoms may vary from discomfort and pain to decreased body function and invalidity. Although it is not clear to what extent MSDs are caused by work, their impact on working life is huge. WRMSDs can interfere with activities at work and can lead to reduced productivity, sickness absence and chronic occupational disability. WRMSDs are reducing companies' profitability and increasing the government's social costs (Podniece, 2008)

Several studies have been done about the prevalence of pain and musculoskeletal disorders and associated factors in occupational environments that all of them confirm the effects of workplace.

Podniece (2008) stated that MSDs cause harm and suffering to the worker as well as financial loss owing to invalidity, treatment costs and lost income. According to him, they also have negative impact on society as a whole. At the workplace level, the disorders result in costs due to reduced human capacity and disturbances to production. Moreover, he mentioned that the costs to society are increased due to the need for treatment and rehabilitation, in addition to the compensation costs paid through social insurance.

In general, occupational diseases and specifically work-related musculoskeletal disorders (MSDs) impose a significant cost burden on health care systems. Traditionally, this cost is evaluated in two ways: human and social cost for the workers and their families, and financial cost for the employers and for the society as a whole (Piedrahita, 2006).

## 2.3 Computer Ergonomics

Ergonomics or human factors engineering is the scientific combination that has been designed tools, equipment, work environment and jobs according to the ability of some physical - and mental limitations and human interests. This knowledge is formed to increase productivity, with respect to the health, safety and welfare of humans. This science is trying to fit environment to the human instead of fitting human to the environment. In this regard, the International Labor Organization has defined ergonomics to fit work to human.

Many of us have to work with computers motionless and without interrupting for hours. We should do many detailed activities, but our bodies are not designed for these kinds of operations. Long-term abnormal conditions and repetitive movements are associated with neck pain, arm and leg and back pains.

Office workers are spending more time sitting and using computers. With increasing use of computers, musculoskeletal illnesses and injuries have been greatly increased. this can occur at work or at home. With ever changing technology we need to take into account how we set up this technology. The risk of musculoskeletal discomfort increases by using the computer as little as one hour a day (Revelle, Working Painlessly, 2000).

Working with computer can cause health problems for users. Musculoskeletal disorders (MSDs can affect the body's muscles, joints, tendons, ligaments and nerves. Using computers cause symptoms such as vision problems, joint problems, seizures caused by sensitivity to light, skin allergies and stress, for users. Despite the passage of four decades of emergence of computers, these technologies are the most obvious tools as part of people's lives.

RULA (rapid upper limb assessment) is a survey method developed for use in ergonomics investigations of workplaces where work-related upper limb disorders are reported. This tool requires no special equipment in providing a quick assessment of the postures of the neck, trunk and upper limbs along with muscle function and the external loads experienced by the body (McAtamney & Corlett, 1993).

The RULA method evaluates the ergonomics risk factor by observation the posture of employees while they are working at their workstation directly. Postural and biomechanical loading on the upper limbs are assessed by valid RULA method.

Jensen et al. (2002) found that the duration of computer work is associated with neck and shoulder symptoms in women, and hand symptoms in men. Additionally, the use of mouse was observed to have an increase in hand/wrist and shoulder region symptoms among the intensive users of computers.

Regular variation between sitting, standing and walking is vital for back injury management and prevention. Gentle and regular mobilization of the head, neck, shoulders, arms, hands and upper trunk is also a key injury prevention and management strategy. Working at a computer workstation for prolonged periods is considered to be a risk factor for musculoskeletal injury. This is commonly due to the fixed position of the screen, keyboard and mouse in relation to each other, and the awkward postures that result. It is important that workstation design and adjustment is coupled with regular movement of the body in order to offset the static loading effect on musculature and compressive forces on the spine. (Computer Workstations: Design & Adjustment, 2009)

Extended work with computers can lead to muscular fatigue and discomfort, usually in the back, arms, shoulders and neck. As well, if the computer is used for prolonged periods in awkward postures, there is a risk of musculoskeletal injuries. This risk increases as the intensity of computer work increases. Frequently, the source of muscular fatigue and discomfort is the operator's posture while working at the terminal, and this posture is due in turn to the layout of the computer workstation and the furniture provided. The specific task and the intensity of the work are also factors (Computer Workstations: Design & Adjustment, 2009).

Anthropometry is focused on the measurement of physical dimensions and using of the data in physical condition of work stations. One of the reasons for pressures on the body organs is the mismatch of the work place with the characteristics of workers or users body. Anthropometric data can be used effectively in designing equipment, work stations, tools and product.

Sweere (2002) stated that the anthropometric data can be used to create a user friendly, ergonomically correct Computer work environment.

Many factors are involved in the design of a computer workstation such as:

- VDT adjustability
- Keyboard placement/adjustability
- Work surface adjustability
- Chair design/adjustability

- Foot rests
- Wrist rests
- Glare screens
- Lighting, task lighting
- Ease of adjustability
- Accessibility to components
- Human Computer Interfaces (HCI’s)
- Space savings

All of the above issues concern themselves with the reduction or elimination of a class of physical disorders associated with poor ergonomic design known as Musculoskeletal Stress Disorders (MSD’s), which result in:

- Eye, neck and back strain
- Fatigue, headache
- Wrist, hand, elbow and shoulder diseases
- Carpal Tunnel Syndrome
- Tenosynovitis
- Tendonitis
- Synovitis

## 2.4 Computer Workstations

Computer applications in human life is very high and many people are working with computers for long hours, therefore, identifying effectual factors in the computer workplace is important. Unfavorable conditions in the working environment and lack of attention to safety issues can be the cause of long-term diseases and abnormalities during working with computers. Most of users work in small spaces and indoors places. Inactivity during working with computers, staring at the screen a long time and the smooth movements of the wrist may be cause of a variety of abnormalities.

Computer desk is important. Easy and professional installation of computer's physical components is the first reeves of using a specific desk. Computer desk can be divided into three parts:

- First area: an area that is rarely used (the rear surface of desk)
- Second area: an area that sometimes it is used (middle-level desktop)
- The third area: an area that can always be used (the front surface of the desktop)

The first area is the desktop terminal level and it is rarely used, a place that is just for showing. Objects such as monitors, pictures, clocks, vases, pencil and pen, instead, loudspeaker or speaker, are in this area.

Second area, is a mid-level of desktop. In this area, the objects are exposure that they are occasionally used; accessories such as telephone, calculator, etc...

Third area is the initial level or the desktop front. In this region, instruments are stood that are always used such as keyboard, mouse and mouse pad (Principles of work with computer, 2010).

The computer desk should have some properties such as:

1-The heights of that should be adjustable

2-the space has been considered for the legs under table should be appropriate.

3- Table surface should be large enough to replace the existing equipment and all objects.

4- Desks surfaces should not be white or very dark. (Principles of work with computer, 2010).

The chair should be moveable and rotating with wheeled base. Also seat height should be adjustable based on height and length of your body to be set in such a way that working with a keyboard and watching the screen will be easily. Seat cushion must be designed to prevent the occurrence of back pain and joint pain and the seat should be adjustable forward and backward. The seat should be made from a material which does not allowed slipping.

Overall, the monitor may create two types of injuries for people:

- The brightness of the reflected light or reflecting of surroundings light to the eyes (Glare).
- The radiation risk.

Monitors should be located to the first area of table, and exactly the opposite of face. During work with it, the highest point of monitor would be seen. Or in other words, the user’s eye should be along of the highest part of the monitor and the distance from monitor should be among 40 to 70 cm (Principles of work with computer, 2010).

Complaints related to posture and visions are frequently voiced by computer operators. The postural problem appears to be largely caused by improperly designed and ill arranged workstation furniture. Another inherited problem is the habit of putting the computer screen at or slightly below eye height. The third inherited problem is the conventional keyboard, now usually containing about a hundred or more keys, located in a essentially flat (horizontal) board, traditionally placed on a support table. Many operators arrange components of their workstation in various unconventional configurations. The monitor is placed high atop a tower of CPU unit and swivel stand, or placed flat on a support surface to the side of the keyboard. Workstations at home have become rather popular and might become more so with increasing Tele-commuting, where the home office replaces the space required in the employer's building. In the home office, the person is free to use any workstation design—good or bad in the traditional sense—that suits the individual. Proper design and use of furniture assume flexibility in work organization and management attitudes. Indeed, providing freedom for individual variations from the conventional norm requires considering that persons working with computers differ in their physiques and work preferences. The ergonomic design of video display terminal workstations, their adjustability and proper use can determine, via many and subtle interactions, the person's well-being and the related work performance (Kroemer, 1997).

Designers of workplaces and products have three major tasks: one, integrating information about processes, tools, machines, parts, tasks, and human operators; two, satisfying design constraints which often conflict; and three, generating a design acceptable to all parties involved. (Feyen, Liu, Chaffin, Jimmerson, & Joseph, 2000)

Moffet , Hagberg, & Hansson-Risberg (2002) evaluated the impact of two laptop designs (with or without palm rest) and two work situations (on desk or lap) on neck and upper limb posture, muscle activity and productivity. Eight healthy subjects performed a standardized typing task of 15 min duration. During the last 5 min of each test, the neck, upper arm and trunk postures were captured by a three-dimensional video system, wrist motion was measured by a biaxial electro-goniometer and muscle activity of four neck and upper limb muscles was recorded. Only minor differences in postures, wrist positions and productivity were observed when comparing the two laptop designs in the same situation. Larger differences were found when comparing the two situations (desk or lap). In the desk situation, the subjects bent their heads forward less, had less backward trunk inclination and wrist extension, but more elevation of the upper arm. Higher electromyography (EMG) levels in the trapezius and deltoid muscles and lower EMG levels in the wrist extensors were also found in the desk situation. Our findings do not favor one particular laptop design because only small differences in physical exposure were found. However, the workstation set up influenced the physical exposure variables, and was pinpointed as the main determinant to be considered when doing laptop work even-though no ideal situation was found. Greater physical (muscular and articular) constraints seem to be imposed to the shoulder region in the desk situation whereas the head-neck and wrist segments appear to be more stressed in the lap situation.

Repetitive movements for computer users can result in complaints caused by extreme hand posture, finger movements, and force when using the computer, which is known as Work Related Upper Extremity Disorder (WRUED). Machado and Villaverde (2011) investigated construction of electronic instrumentation for monitoring and quantifying these movements and forces, using sensors to register wrist posture and fingertip force with software developed to collect and process the data. Tests evaluated the performance of the instrumentation with seventeen subjects participating in this study. The maximum extension observed for the first test was 41 degree; however after training the subject decreased this value to 33 degree. Six subjects had a wrist extension of between 15 and 41 degree for the first test; five reduced their wrist extension (between 3 and 33degree) during the second test ($p = 0.08$) while one subject increased instead of decreased it. No subject performed fingertip force greater than 0.77N during the first test; this was reduced to 0.57N during the second test ($p = 0.04$). The average typing frequency in the group decreased from 3.2Hz to 2.5Hz during the second test ($p = 0.01$). Results confirm that this solution may potentially contribute to hand movement reeducation, thereby reducing the risk of WRUED for computer users. Relevance to industry: Knowledge of repetitive movements during computer use and associated WRUED is essential for prevention. This electronic instrumentation aids the correction of hand movements, which reduces the risk of injury due to inappropriate posture, extreme range of movement, or force during computer use.

Laptop computers may be used in a variety of postures not coupled to the office workstation. Gold and Driban used passive motion analysis, and examined mean joint angles during a short typing/editing task in college students ($n = 20$), in up to seven positions. Comfort was assessed after task execution through a body map. For three required postures, joint angles in a prone posture were different than those while seated at a couch with feet either on floor or on ottoman. Specifically, the prone posture was characterized by comparatively non-neutral shoulders, elbows and wrists, and pronounced neck extension. Significantly greater intensity and more regions of discomfort were marked for the prone posture than for the seated postures. It is recommended that the prone posture only be assumed briefly during laptop use.

Exposure to laptops outside of the office setting should be assessed in future epidemiologic studies of musculoskeletal complaints and computer use (Gold, Driban, Yingling, & Komaroff, 2012).

The available data for the education sector reveals very low rates of musculoskeletal disorders (MSDs). Education workers have low exposure to repetitive hand and arm movements, and very few are at risk from carrying heavy loads. Typically, the tasks performed by employees, the majority of whom are teachers, are neither repetitive nor static. Employees can freely change their posture and generally carry light loads. The European Union has not passed any specific health and safety legislation covering education, but some general directives and standards can be applied to the sector (Work-related musculoskeletal disorders (MSDs) in education).

# Chapter 3

# METHODOLOGY

## 3.1 Subjects

Ten healthy subjects seven men and three women, aged between 19 and 29 years (median 25.9 years) with a height ranging from 158 to 192 cm (median 172.9 cm) participated voluntarily in one laboratory session. All of subjects were students in Eastern Mediterranean University who are actively using computer for learning/teaching purposes. Participants had no history of significant chronic musculoskeletal disorder in the neck and upper limb, no current neck and/or upper limb pain and no diagnosed rheumatic or acute or chronic musculoskeletal condition.

## 3.2 Workstations dimensions

Two typical work situations were simulated: the standard computer workstation and L-shape computer workstation designs. Standard computer workstation with non-adjustable desk and chair were used considering that those are commonly used in places where adjustable furniture is not available. The desk and seat heights were determined for fixed office tables and chairs. The seat height was 46 cm and a backrest slightly tilted backwards (about 10 degree). The desk height was 75 cm and keyboard and mouse was on the desk.

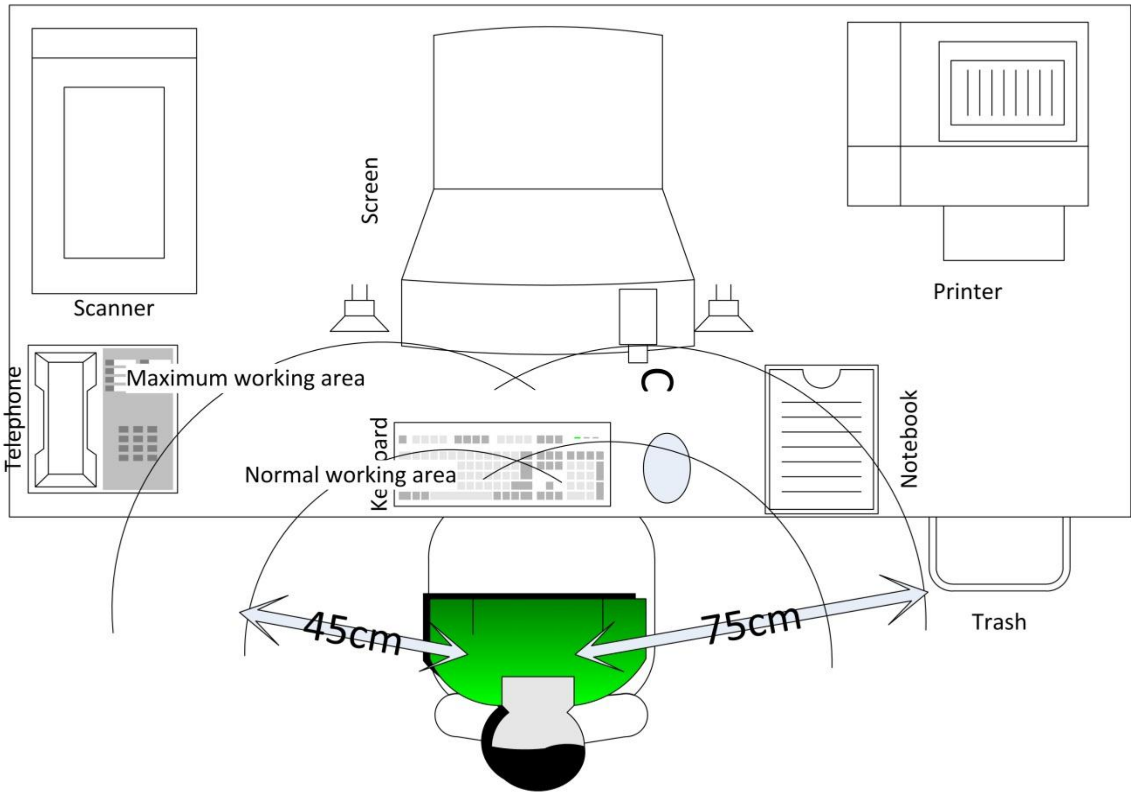



Figure 3.1: Standard normal computer workstation design

New workstation (L-shape desk) was designed based on analysis of the anthropometric data collected from the standard computer workstation. In this design three components were adjusted by the subjects before of each test:

(1) Position of the monitor,

(2) Inclination of the screen,

(3) Height of the chair and chair's position on the floor.

The height of the L-shape desk was fix (75 cm) and the seat height was between 45-60 cm and keyboard and mouse tray was 67 and the height of the placement of monitor position was 95 cm.

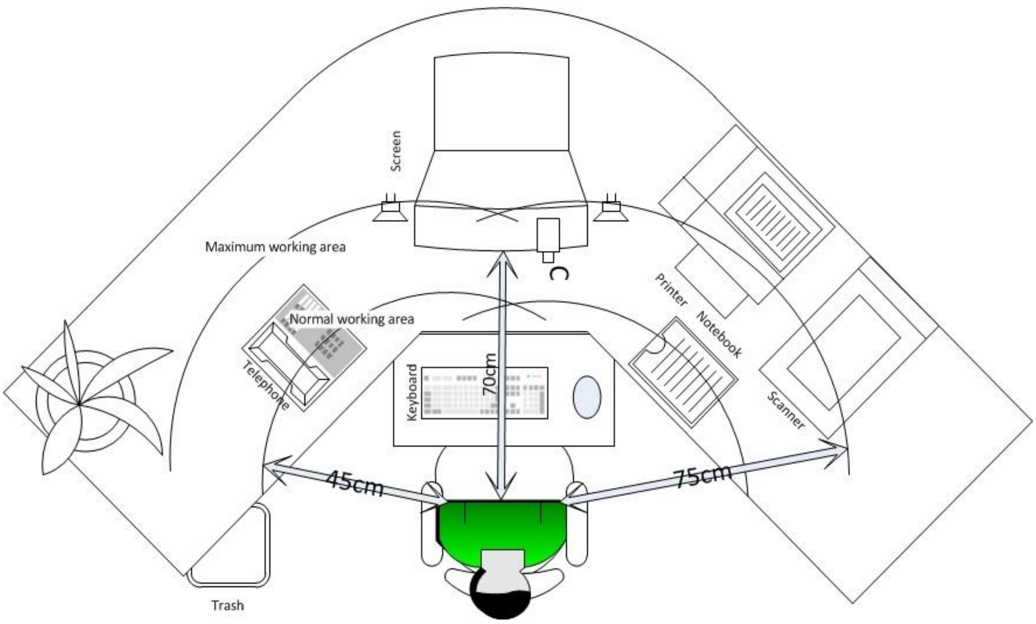



Figure 3.2: New workstation design

Both workstations' computer equipment was similar when considering the screen (17"), keyboard (27 cm _ 9 cm) and key (1.2 cm _ 1.4 cm) sizes, and the screen readability. Main differences in workstations design were how to take place of the needed equipment and the height of keyboard position.

## 3.3 Equipment

The sEMG device was used to recording the muscles activities of the participants on 6 body regions (hand, forearm, neck, and shoulder, upper and lower back) in each workstation.

The subjects performed a standardized typewriting test (typing test Q) on two different workstations. This software was used to provide standard computers tasks and functions to the participants.

The sEMG device has two channels and we can record just two muscle groups' data at a time. For each participant, the test was repeated 3 times in each workstation using the sEMG.

The sequence of the 20 experimental tests (2 workstations x 10 participants) was systematically alternated among subjects. Before each test, the subjects were asked to adjust at their own convenience some components of the workstation. Each test lasted 10 min and consisted of typing a new written text with a comparable degree of difficulty at a free work place without correcting any keying mistakes. The subjects were asked to type continuously for the last 10 min without modifying the workstation setting. The sample of subjects was restricted to non-experienced computer ergonomic users to ensure the same baseline experience with both workstation designs. This choice was considered the best alternative in the context of the present study even though it has some implications for the generalization of the results in other populations. As muscles contract, microvolt level electrical signals are created within the muscle that may be measured from the surface of the body. A procedure that measures muscle activity from the skin is referred to as surface electromyography (sEMG).  Six body region (hand, forearm, neck and shoulder, upper and lower back) motions were measured by a biaxial electromyography and muscle activity of six body region muscles was recorded. Subjects completed 10 minutes typing test in each computer workstation.

## 3.4 Data Analysis

Descriptive statistics were calculated to understand the differences in the data collected from different design. Charts were used to compare and illustrate these differences in the data between the old and the new designs of the computer workstations.

Correlation analysis was performed to find out relationships among the collected data from anthropometric measurements and sEMG experiments.

A hypothesis testing was used to analyze the data collected through sEMG. For each body region, single-factor analyses were conducted for Old and new computer workstation designs. Analysis of variance (ANOVA) was used to confirm and validate the impact of significant changes in the design of computer work stations on risk factors of WRMSDs.

Discriminant analysis was conducted to determine difference between the musculoskeletal discomfort before and after the intervention. Classification scores for each design were calculated to provide the evidence that computer users suffer from less musculoskeletal discomfort during working with computer workstations.

## 3.5 Objective

This study aims to evaluate the impact of two workstation designs on hand, arm, neck; upper and lower limb posture, muscle activity and productivity. Thus, the contribution of this research to the industry is to provide muscle discomfort reducing furniture and user-friendly interfaces during working with computer. Such proper home office computer workstation is necessary to prevent strain injuries which can lead to long-term disabilities.

# Chapter 4

# RESULTS

## 4.1 Anthropometric Data

### 4.1.1 Seated body dimensions of respondents

The dimensions of respondent’s bodies as shown in Figure 4.1 have been measured and the data are shown in table 4.1.

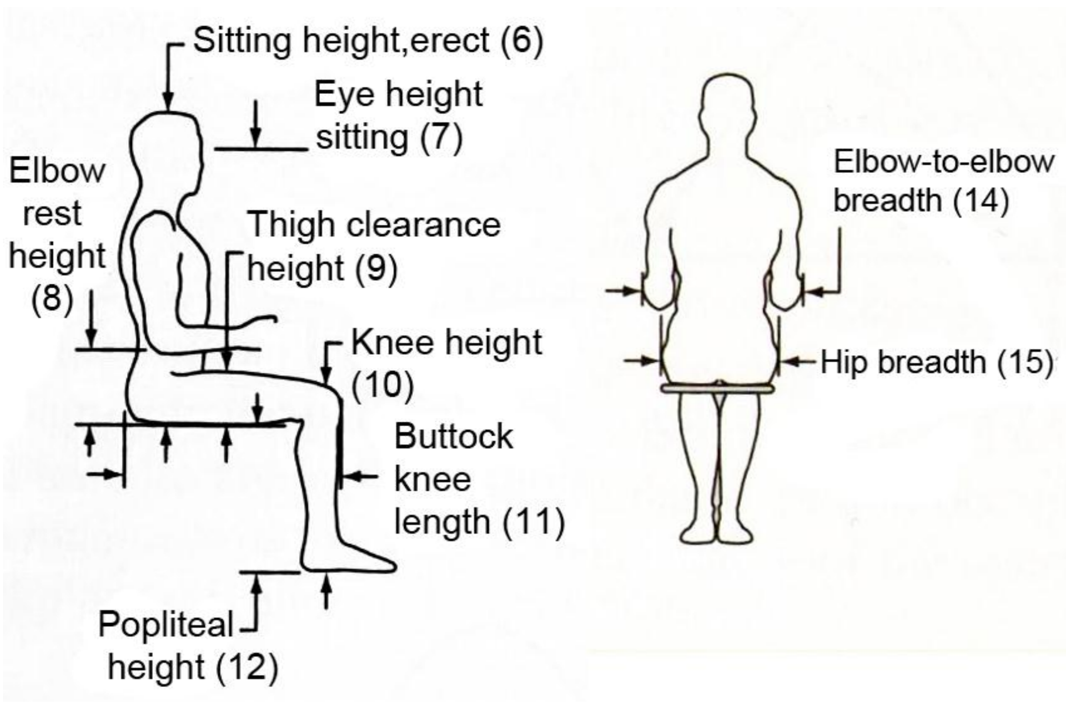



Figure 4.1: Seated body dimensions of respondents

Table 4.1: Seated body dimensions of Respondents data

| Anthropometric measures | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Person | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 14 | 15 |
| Men | 1 | 90 | 81 | 27 | 17 | 54 | 59 | 44 | 54 | 39 |
| | 2 | 89 | 78 | 27 | 17 | 53 | 58 | 43 | 52 | 39 |
| | 3 | 95 | 84 | 28 | 18 | 58 | 61 | 45 | 57 | 43 |
| | 4 | 96 | 85 | 29 | 18 | 58 | 64 | 47 | 59 | 44 |
| | 5 | 87 | 78 | 24 | 17 | 52 | 56 | 43 | 51 | 38 |
| | 6 | 86 | 77 | 22 | 16 | 50 | 56 | 42 | 50 | 37 |
| | 7 | 94 | 84 | 28 | 17 | 55 | 63 | 44 | 54 | 41 |
| Women | 8 | 81 | 70 | 21 | 16 | 47 | 52 | 38 | 44 | 39 |
| | 9 | 88 | 79 | 26 | 17 | 50 | 56 | 40 | 53 | 46 |
| | 10 | 83 | 76 | 23 | 15 | 47 | 53 | 39 | 49 | 43 |

The mean and the standard deviation of the body dimensions of respondents (7 male and 3 female) are shown in table 4.2.

Table 4.2: Mean and standard deviation of body dimensions

| Body Dimension (cm) | | Mean | | Std.dev. | |
|---|---|---|---|---|---|
| | | Male | Female | Male | Female |
| 6 | Sitting height, erect | 91.00 | 84.00 | 4.00 | 3.61 |
| 7 | Eye height, sitting | 81.00 | 75.00 | 3.37 | 4.58 |
| 8 | Elbow rest height | 24.71 | 23.33 | 4.54 | 2.52 |
| 9 | Thigh clearance height | 17.14 | 16.00 | 0.69 | 1.00 |
| 10 | Knee height | 54.29 | 48.00 | 2.98 | 1.73 |
| 11 | Buttock knee length | 59.57 | 53.67 | 3.21 | 2.08 |
| 12 | Popliteal height | 44.00 | 39.00 | 1.63 | 1.00 |
| 14 | Elbow-to-elbow breadth | 53.86 | 48.67 | 3.24 | 4.51 |
| 15 | Hip breadth | 40.14 | 42.67 | 2.61 | 3.51 |

Table 4.3 shows the percentile of body dimensions of respondents. The 5$^{th}$ percentile column indicates that 5 percent of populations are smaller than the sizes given. The 95$^{th}$ percentile column indicates that 95 percent of people are smaller than the sizes given. The 50$^{th}$ column values are simply the mean of these two values.

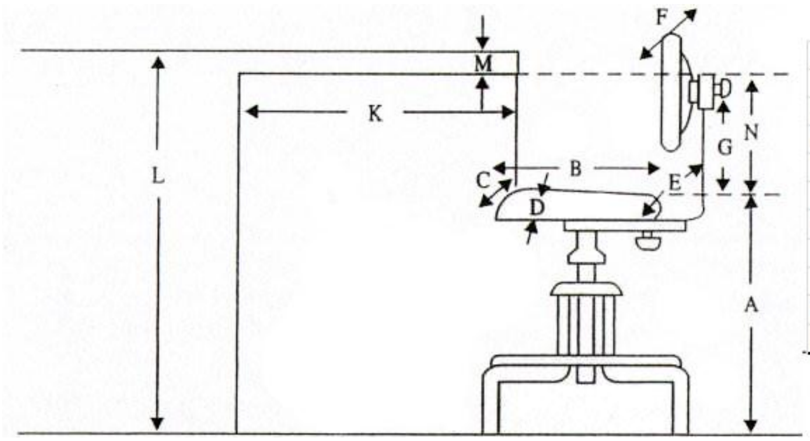
Table 4.3: Percentile of body dimensions

| body dimensions (cm) | | Male (n=7) | | | Female (n=3) | | |
|---|---|---|---|---|---|---|---|
| | | 5th | 50th | 95th | 5th | 50th | 90th |
| 6 | Sitting height, erect | 84.42 | 91.00 | 97.58 | 78.07 | 84.00 | 89.93 |
| 7 | Eye height, sitting | 75.46 | 81.00 | 86.54 | 67.46 | 75.00 | 82.54 |
| 8 | Elbow rest height | 17.25 | 24.71 | 32.18 | 19.19 | 23.33 | 27.47 |
| 9 | Thigh clearance height | 16.01 | 17.14 | 18.28 | 14.36 | 16.00 | 17.65 |
| 10 | Knee height | 49.38 | 54.29 | 59.19 | 45.15 | 48.00 | 50.85 |
| 11 | Buttock knee length | 54.30 | 59.57 | 64.85 | 50.24 | 53.67 | 57.09 |
| 12 | Popliteal height | 41.31 | 44.00 | 46.69 | 37.36 | 39.00 | 40.65 |
| 14 | Elbow-to-elbow breadth | 48.53 | 53.86 | 59.18 | 41.25 | 48.67 | 56.08 |
| 15 | Hip breadth | 35.85 | 40.14 | 44.44 | 36.89 | 42.67 | 48.44 |

### 4.1.2 Seat parameters

A new workstation was designed based on the anthropometric analysis of the above data and the functional ability of the learners (Figure 3.2).

The seat parameters has been measured for both workstations based on Figure 4.2 and the seat parameters data are shown in table 4.4 and 4.5.




| | |
|---|---|
| A | Seat height |
| B | Seat depth |
| C | Seat width |
| D | Seat pan angle |
| E | Seat back to pan angle |
| F | Seat back width |
| G | Lumbar support |
| K | Leg clearance |
| L | Work surface height |
| M | Work surface thickness |
| N | Thigh clearance |

Figure 4.2: Seat parameters

Table 4.4: Seat Parameters - Before Intervention

| | A | B | C | D | E | F | G | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Respondents | Seat height | Seat depth | Seat width | Seat pan angle | Seat back to pan angle | Seat back width | Lumbar support | Leg clearance | Work surface height | Work surface thickness | Thigh clearance |
| 1 | 46 | 43 | 43 | 10 | 100 | 44 | 25 | 66 | 75 | 3.5 | 25.5 |
| 2 | 46 | 43 | 43 | 10 | 100 | 44 | 25 | 66 | 75 | 3.5 | 25.5 |
| 3 | 46 | 43 | 43 | 10 | 100 | 44 | 25 | 66 | 75 | 3.5 | 25.5 |
| 4 | 46 | 43 | 43 | 10 | 100 | 44 | 25 | 66 | 75 | 3.5 | 25.5 |
| 5 | 46 | 43 | 43 | 10 | 100 | 44 | 25 | 66 | 75 | 3.5 | 25.5 |
| 6 | 46 | 43 | 43 | 10 | 100 | 44 | 25 | 66 | 75 | 3.5 | 25.5 |
| 7 | 46 | 43 | 43 | 10 | 100 | 44 | 25 | 66 | 75 | 3.5 | 25.5 |
| 8 | 46 | 43 | 43 | 10 | 100 | 44 | 25 | 66 | 75 | 3.5 | 25.5 |
| 9 | 46 | 43 | 43 | 10 | 100 | 44 | 25 | 66 | 75 | 3.5 | 25.5 |
| 10 | 46 | 43 | 43 | 10 | 100 | 44 | 25 | 66 | 75 | 3.5 | 25.5 |

Table 4.4 shows seat parameters of old workstation design when the respondents were working with that.

Table 4.5: Seat Parameters - After Intervention

| | A | B | C | D | E | F | G | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Respondents | Seat height | Seat depth | Seat width | Seat pan angle | Seat back to pan angle | Seat back width | Lumbar support | Leg clearance | Work surface height | Work surface thickness | Thigh clearance |
| 1 | 53 | 43 | 43 | 14 | 117 | 44 | 25 | 60 | 75 | 3.5 | 18.5 |
| 2 | 52 | 43 | 43 | 16 | 120 | 44 | 25 | 60 | 75 | 3.5 | 19.5 |
| 3 | 54 | 43 | 43 | 14 | 127 | 44 | 25 | 60 | 75 | 3.5 | 17.5 |
| 4 | 55 | 43 | 43 | 17 | 130 | 44 | 25 | 60 | 75 | 3.5 | 16.5 |
| 5 | 52 | 43 | 43 | 13 | 119 | 44 | 25 | 60 | 75 | 3.5 | 19.5 |
| 6 | 47 | 43 | 43 | 10 | 115 | 44 | 25 | 60 | 75 | 3.5 | 24.5 |
| 7 | 48 | 43 | 43 | 12 | 111 | 44 | 25 | 60 | 75 | 3.5 | 23.5 |
| 8 | 45 | 43 | 43 | 10 | 109 | 44 | 25 | 60 | 75 | 3.5 | 26.5 |
| 9 | 46 | 43 | 43 | 7 | 109 | 44 | 25 | 60 | 75 | 3.5 | 25.5 |
| 10 | 45 | 43 | 43 | 8 | 107 | 44 | 25 | 60 | 75 | 3.5 | 26.5 |

Seat parameters after Intervention are shown in Table 4.5. Five seat parameters are changed after intervention (seat height, seat pan angle, seat back to pan angle, leg clearance and thigh clearance) and six parameters have not been changed. All parameters were constant before intervention. Four parameters were variable in new workstation design and seven of them were constant.

## 4.2 Analysis of variance

The sEMG provides the information about muscles activity over time. During of the recording data on time by sEMG, after 2, 4, 6, 8, 10 minutes the mean value was read. The Unit of measurement for muscles activities is microvolts. In order to test the hypothesis ($H_0$ = there is no significant difference between mean of the musculoskeletal discomfort in 2 types of computer workstation). The mean of sEMG results during the time for workstation designs are provided.

Table 4.6 shows mean of Hand musculoskeletal activities for ten respondents during working with two workstations.

Table 4.6: pressure on the hand in different workstations design

| | Hand | |
|---|---|---|
| subjects | Old design | New design |
| 1 | 1104.45 | 1366.62 |
| 2 | 1067.07 | 1111.05 |
| 3 | 125.84 | 761.89 |
| 4 | 589.64 | 845.66 |
| 5 | 3720.92 | 61.00 |
| 6 | 218.83 | 921.35 |
| 7 | 109.43 | 158.97 |
| 8 | 20.46 | 12.67 |
| 9 | 282.27 | 64.02 |
| 10 | 91.62 | 89.33 |

We compared pressures on different body regions for two computer workstation designs.

Hand: we can see from table 4.6 that mean of pressure for new workstation design is lower than old one. We tested this difference with ANOVA analysis.

Table 4.7: ANOVA result for testing pressure on the hand in different workstations design

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 187786.4 | 1 | 187786.4 | 0.246336 | 0.625673 | 4.413873 |
| Within Groups | 13721735 | 18 | 762318.6 | | | |
| | | | | | | |
| Total | 13909521 | 19 | | | | |

Because of $F_0$ is lower than $F_{critical}$ we can say there is no significant differences between pressure on hand during working with 2 designs.

Forearm: The mean of sEMG activities for all respondents on forearm region is shown in Table 4.8 and the Analyze of variance is summarized in Table 4.9.

Table 4.8: pressure on the forearm in different workstations design

| | Forearm | |
|---|---|---|
| Subjects | Old design | New design |
| 1 | 2714.56 | 876.70 |
| 2 | 1505.53 | 1442.14 |
| 3 | 1777.24 | 809.47 |
| 4 | 3708.4 | 1658.19 |
| 5 | 3729.2 | 1624.34 |
| 6 | 3103.17 | 1667.60 |
| 7 | 647.75 | 456.12 |
| 8 | 572.85 | 701.00 |
| 9 | 2140.84 | 797.44 |
| 10 | 1527.29 | 835.97 |

Table 4.9: ANOVA result for testing pressure on the forearm in different workstations design

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 5573420 | 1 | 5573420 | 7.30736 | 0.014552 | 4.413873 |
| Within Groups | 13728838 | 18 | 762713.2 | | | |
| | | | | | | |
| Total | 19302258 | 19 | | | | |

As the table mentioned the $F_0$ ratio (7.3) is greater than $F_{critical}$. Therefore the hypothesis is rejected and we can say there is a significant difference between two workstations and new design improves ergonomics standards.

The total mean of pressure on forearm region during working with old workstation is 2142.68 and new workstation design is 1086.89. The Fisher Least Significant Difference (LSD) Method was used to pair means of old workstation and new workstation.

To use the Fisher LSD procedure, we compare the observed difference between pair of averages to the corresponding LSD.

$\bar{Y}_{old} - \bar{Y}_{new} = 2142.683-1086.897= 1055.786$

And the LSD= $t_{0.1,\ 18}\sqrt{}$ (2MSE)/10=677.231

Because the $\bar{Y}_{old} - \bar{Y}_{new}$>LSD we conclude that the means of pressure on forearm during working with workstations differ. The pressure on forearm during work with new workstation design is less than old workstation.

Neck: Table 4.10 shows mean of Neck musculoskeletal activities for ten respondents during working with two workstations.

Table 4.10: pressure on the neck in different workstations design

| | Neck | |
|---|---|---|
| Subjects | Old desing | New design |
| 1 | 1383.03 | 580.22 |
| 2 | 1150.66 | 312.77 |
| 3 | 106.03 | 983.57 |
| 4 | 157.55 | 700.42 |
| 5 | 3723.94 | 944.68 |
| 6 | 10.53 | 1238.46 |
| 7 | 195.96 | 865.38 |
| 8 | 1177.26 | 579.34 |
| 9 | 680.97 | 739.00 |
| 10 | 569.65 | 601.36 |

Table 4.11: ANOVA result for testing pressure on the neck in different workstations design

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 129666.2 | 1 | 129666.2 | 0.201402 | 0.658948 | 4.413873 |
| Within Groups | 11588743 | 18 | 643819 | | | |
| | | | | | | |
| Total | 11718409 | 19 | | | | |

Table 4.11 shows that the $F_0$ is lower than $F_{critical}$ (0.2<4.41), therefore the hypothesis is rejected and we can say there is no significant difference pressure on neck between two design.

Shoulder: The mean of pressure on shoulder of ten subjects during working with two workstations is shown in table 4.12.

Table 4.12: pressure on the shoulder in different workstations design

| | Shoulder | |
|---|---|---|
| Subjects | Old design | New design |
| 1 | 98.08 | 1251.526 |
| 2 | 8.32 | 1071.17 |
| 3 | 1350.81 | 1697.38 |
| 4 | 1416.96 | 1668.64 |
| 5 | 3744.94 | 1207.452 |
| 6 | 476.96 | 1517 |
| 7 | 773.78 | 1245.90 |
| 8 | 12.67 | 44.87 |
| 9 | 12.78 | 11.13 |
| 10 | 11.76 | 12.33 |

Table 4.13: ANOVA result for testing pressure on the shoulder in different workstations design

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 165681.5 | 1 | 165681.5 | 0.178879 | 0.677348 | 4.413873 |
| Within Groups | 16671996 | 18 | 926222 | | | |
| | | | | | | |
| Total | 16837677 | 19 | | | | |

ANOVA result (Table 4.13) shows that $F_0$ is less that $F_{Critical}$ (0.17<4.41), so the hypothesis failed to reject and it means there is no significant differences between pressure on the shoulder of respondent during working with workstations.

Upper back: Table 4.14 shows the mean of pressure on upper back during working with 2 workstation designs.

Table 4.14: pressure on the upper back in different workstations design

| | Upper Back | |
|---|---|---|
| Subjects | Old design | New design |
| 1 | 39.95 | 13.35 |
| 2 | 456.08 | 15.09 |
| 3 | 82.52 | 1158.73 |
| 4 | 53.38 | 1122.96 |
| 5 | 3804.18 | 107.02 |
| 6 | 11.26 | 223.02 |
| 7 | 184.32 | 877.90 |
| 8 | 3917.1 | 872.08 |
| 9 | 16.37 | 17.84 |
| 10 | 19.71 | 19.49 |

Table 4.15: ANOVA result for testing pressure on the upper back in different workstations design

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 864194.6 | 1 | 864194.6 | 0.623806 | 0.439918 | 4.413873 |
| Within Groups | 24936443 | 18 | 1385358 | | | |
| | | | | | | |
| Total | 25800638 | 19 | | | | |

Analyze of variance is summarized in table 4.15. Note that the $F_0$ ratio is less than $F_{0.05,\ 1,\ 18}$=4.41. Therefore, $H_0$ failed to reject and mean of musculoskeletal strain on upper back between 2 workstation designs does not differ.

Table 4.16: pressure on the lower back in different workstations design

| | Lower back | |
|---|---|---|
| Subjects | Old design | New design |
| 1 | 922.24 | 1083.41 |
| 2 | 3110.82 | 754.35 |
| 3 | 1202.91 | 1913.38 |
| 4 | 1776.22 | 1239.99 |
| 5 | 3776.76 | 828.80 |
| 6 | 3911 | 519.24 |
| 7 | 2054.54 | 1654.75 |
| 8 | 3918.68 | 781.44 |
| 9 | 872.46 | 694.50 |
| 10 | 900.27 | 946.09 |

Lower back: The pressure on lower back during working with two workstation designs is shown in Table 4.16.

Table 4.17: ANOVA result for testing pressure on the lower back in different workstations design

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 7235985 | 1 | 7235985 | 7.558685 | 0.013192 | 4.413873 |
| Within Groups | 17231532 | 18 | 957307.3 | | | |
| | | | | | | |
| Total | 24467517 | 19 | | | | |

The result of ANOVA shows that there is a significant difference between two workstation designs and new design improved ergonomic standards.

The total mean of pressure on lower back region during working with old workstation is 2142.68 and new workstation design is 1086.89. The Fisher Least Significant Difference (LSD) Method was used to pair means of old workstation and new workstation.

To use the Fisher LSD procedure, we compare the observed difference between pair of averages to the corresponding LSD.

$\bar{Y}_{old} - \bar{Y}_{new}$ = 2244.59-1041.595= 1202.995

And the LSD= $t_{0.1, 18}\sqrt{}$ (2MSE)/10=758.73

Because the $\bar{Y}_{old} - \bar{Y}_{new}$>LSD we conclude that the means of pressure on lower back during working with workstations differ. The pressure on lower back during work with new workstation design is less than old workstation.

Neck: Table 4.10 shows mean of Neck musculoskeletal activities for ten respondents during working with two workstations.

Table 4.18: Summary information for comparing workstation design

| Regions | $F_0$ | F crit |
|---|---|---|
| Hand | 0.246 | 4.41 |
| Forearm | 7.30 | 4.41 |
| Neck | 0.201 | 4.41 |
| Shoulder | 0.17 | 4.41 |
| Upper back | 0.623 | 4.41 |
| Lower back | 7.55 | 4.41 |

Table 4.18 is the summary of $F_0$ ratio for workstation designs and it shows that for two regions (forearm, Lower back) $H_0$ is rejected and the mean of musculoskeletal strain differ in two workstation designs.

## 4.3 EMG Experiment Result

In this part pressure on all of body region that had been tested are compared based on region in two workstation designs.

### 4.4.1 Hand

Typing activities for respondent 1 to 10 during 10 minutes on both workstations (new and old) for hand as a region of body that had been tested are coming in Figure 4.3 to 4.12. The vertical axis is the pressure on respondent's hand (μV) and the horizontal axis is time (min).


Figure 4.3: EMG activity at the hand of respondent 1

Figure 4.3 shows that the pressure on hand of respondent 1 when he was working with new workstation is lower than when he was working with old workstation. But during time 4 to 6 min on new workstation the pressure is increasing and during time 6 to 8 min the pressure has decreased again.

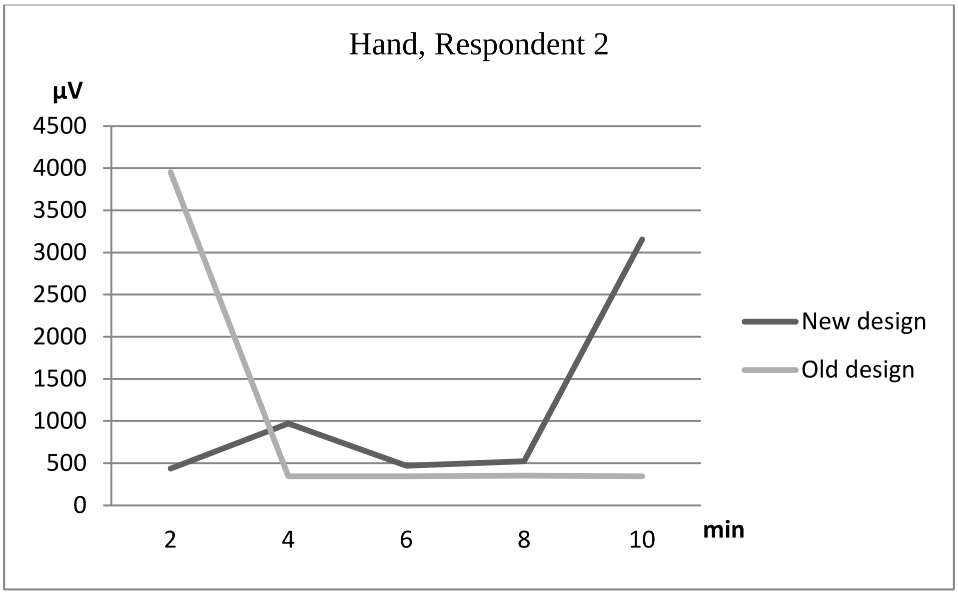



Figure 4.4: EMG activity at the hand of respondent 2

Figure 4.4 shows pressure on respondent 2's hand in the old workstation design until the fourth minutes has decrease sharply and after that there is an increasing slope. The pressure in new workstation design is higher than old one.

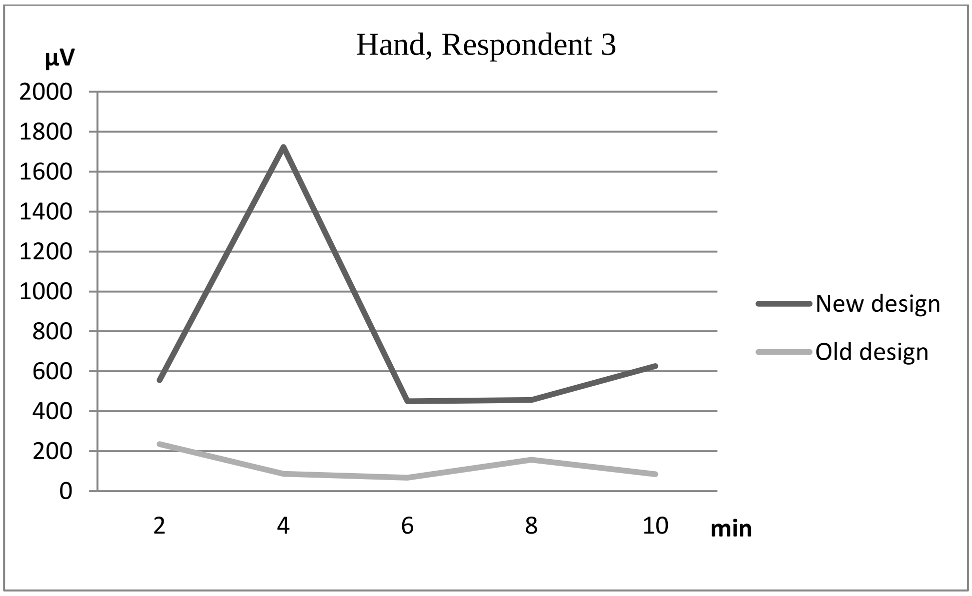



Figure 4.5: EMG activity at the hand of respondent 3

The pressure on hand of respondent 3 in new workstation design is higher than pressure in old workstation. (Figure 4.5)

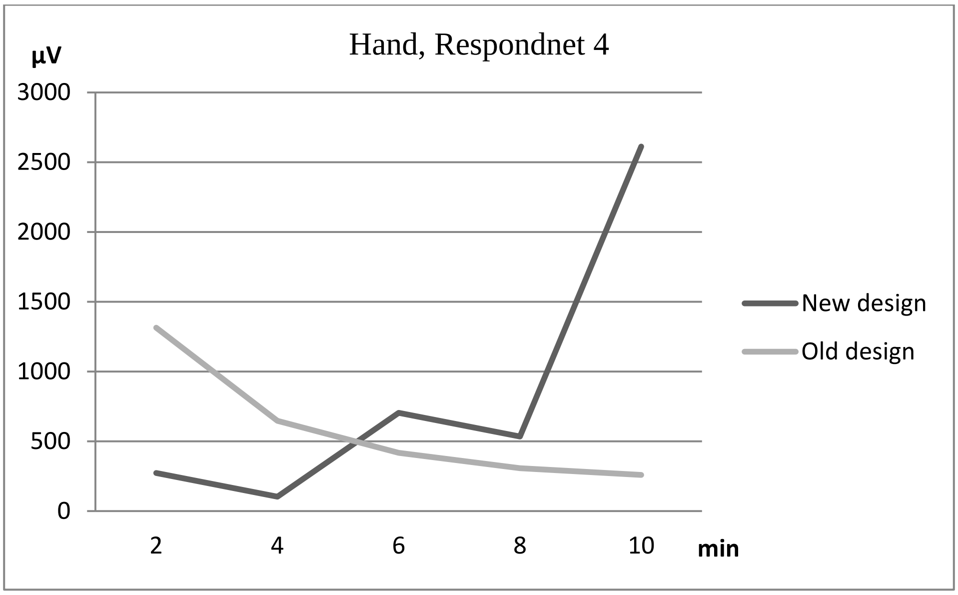



Figure 4.6: EMG activity at the hand of respondent 4

For respondent 4's hand, the pressure in the new workstation is increasing, and in the old one, the pressure has decreasing slope (figure 4.6).

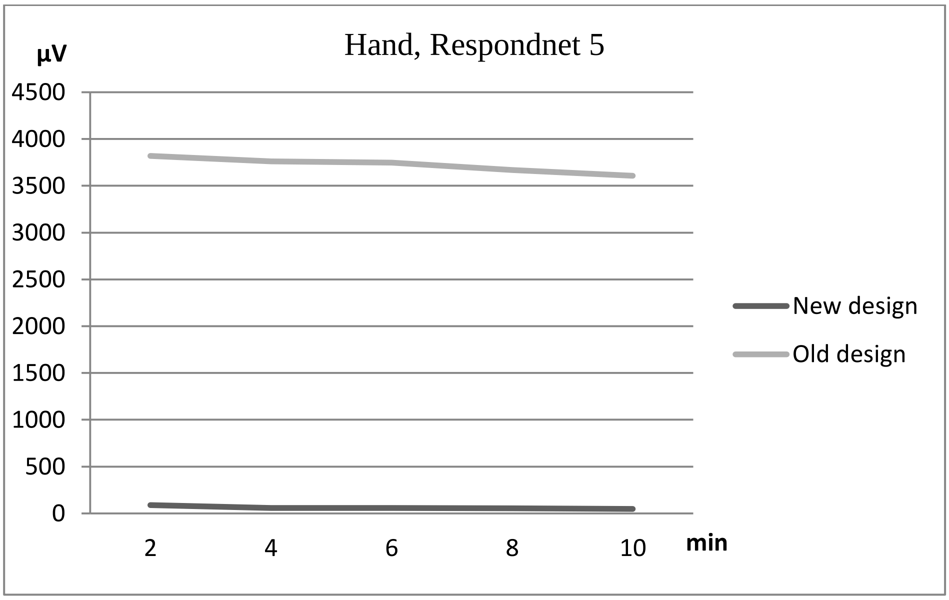



Figure 4.7: EMG activity at the hand of respondent 5

Figure 4.7 shows typing activities of the respondent 5 in the new workstation design is significantly lower than old workstation activities. A line with a negative slope shows an overall decrease on hand for respondent 5 in new workstation design.

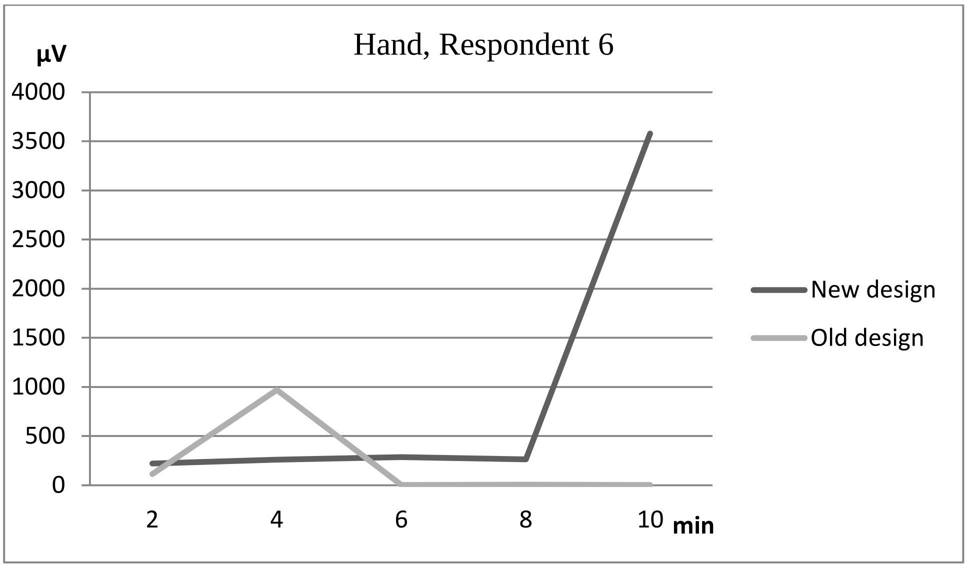



Figure 4.8: EMG activity at the hand of respondent 6

Figure 4.8 shows EMG activities at the hand of respondent 6. During first 8 minutes there is a positive slope in new design and after that there is a sharply increase. In old workstation from 2th to 4th minutes there is increasing slope and between 4th to 6th minutes there is decreasing slope and After 6th minutes the pressure is decreasing.

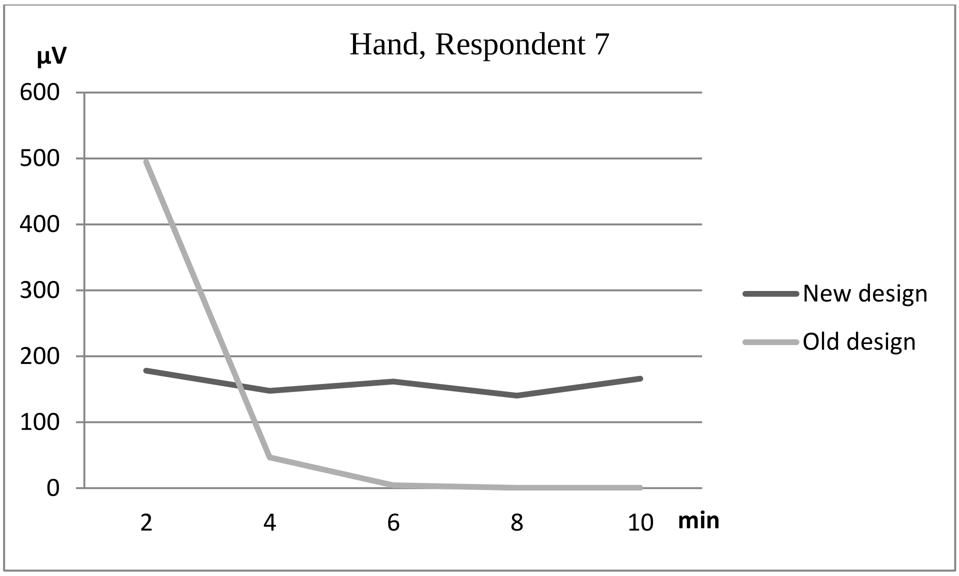



Figure 4.9: EMG activity at the hand of respondent 7

Figure 4.9 shows that at the first pressure on hand for respondent 7 in old workstation design is higher than new workstation design but in 4th minute it is decreased and after 4th min the pressure on hand in old workstation is lower than new one.

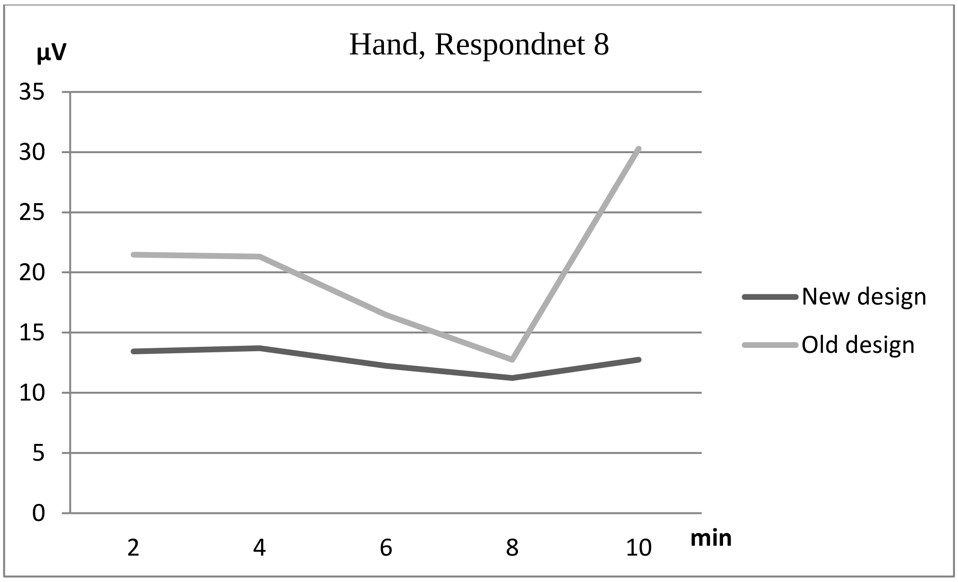



Figure 4.10: EMG activity at the hand of respondent 8

For respondent8, pressure on hand region in new workstation design is lower than old workstation. Until 8th minute the pressure has negative slope in both workstation but after 8th min the pressure is increasing. (Figure 4.10)

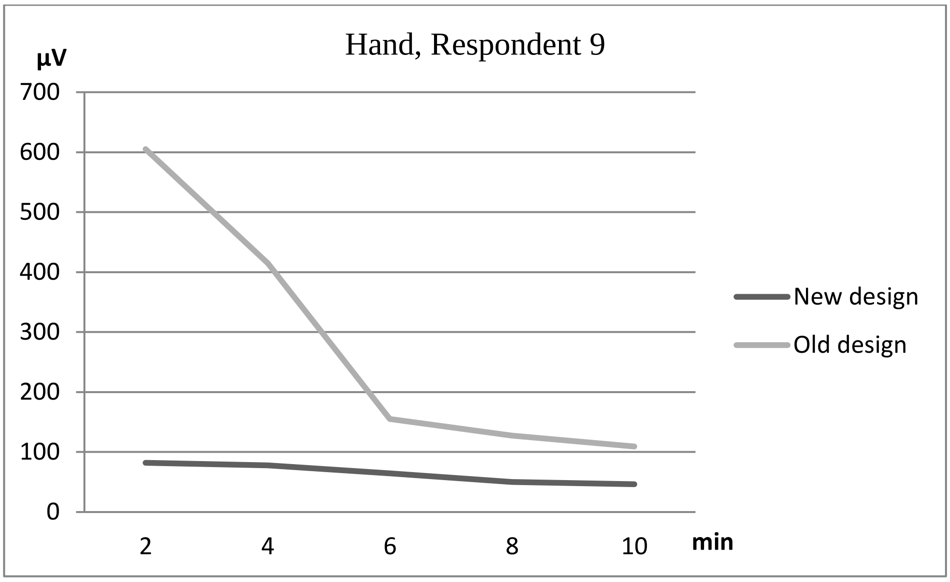



Figure 4.11: EMG activity at the hand of respondent 9

Pressure in new workstation design is lower than old workstation for respondent 9's hand. In both workstations the pressure is decreasing during time (Figure 4.11).

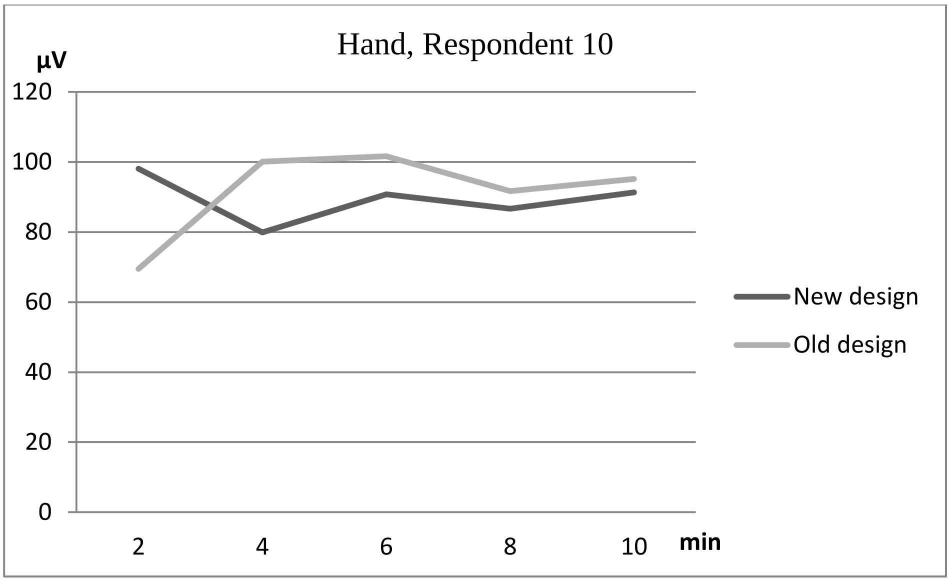



Figure 4.12: EMG activity at the hand of respondent 10

For respondent 10, the pressure on hand in both workstations is close to each other but in the new workstation is lower (Figure 4.12).

### 4.4.2 Forearm

sEMG activities at the forearm of all respondents on both workstations are came in the Figure 4.13 to 4.22.

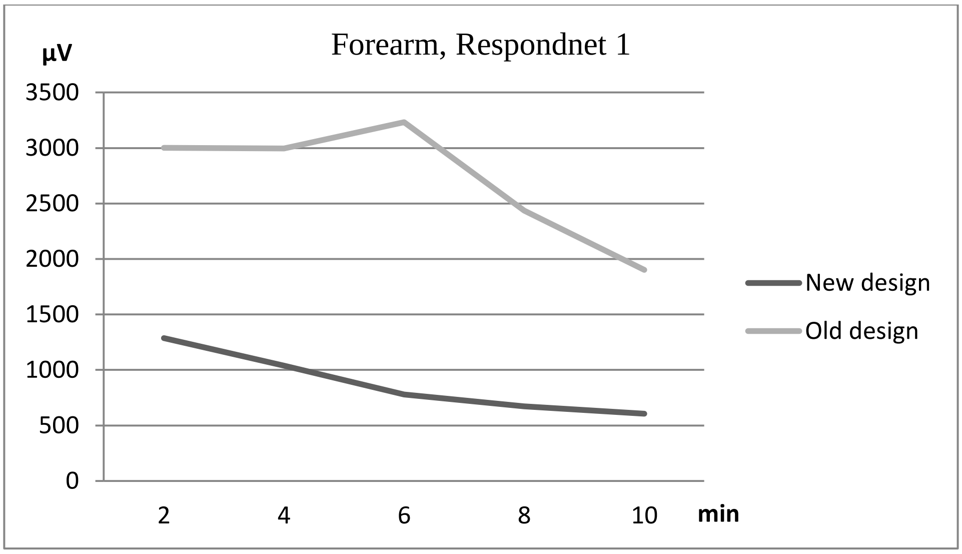



Figure 4.13: EMG activity at the forearm of respondent 1

Pressure on forearm of respondent 1 has negative slope and it shows an overall decrease in new workstation design. Pressure in new workstation design is lower than old workstation design (Figure 4.13).

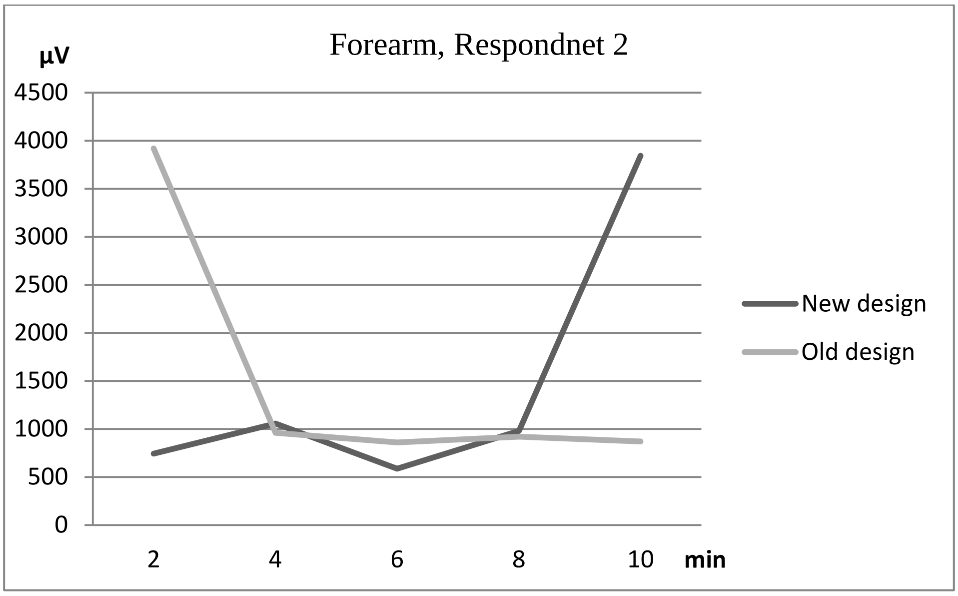



Figure 4.14: EMG activity at the forearm of respondent 2

For the first eight minutes, the pressure on forearm of respondent2 in new workstation design is almost lower than old one. After 8$^{th}$ min it is increased (Figure 4.14).

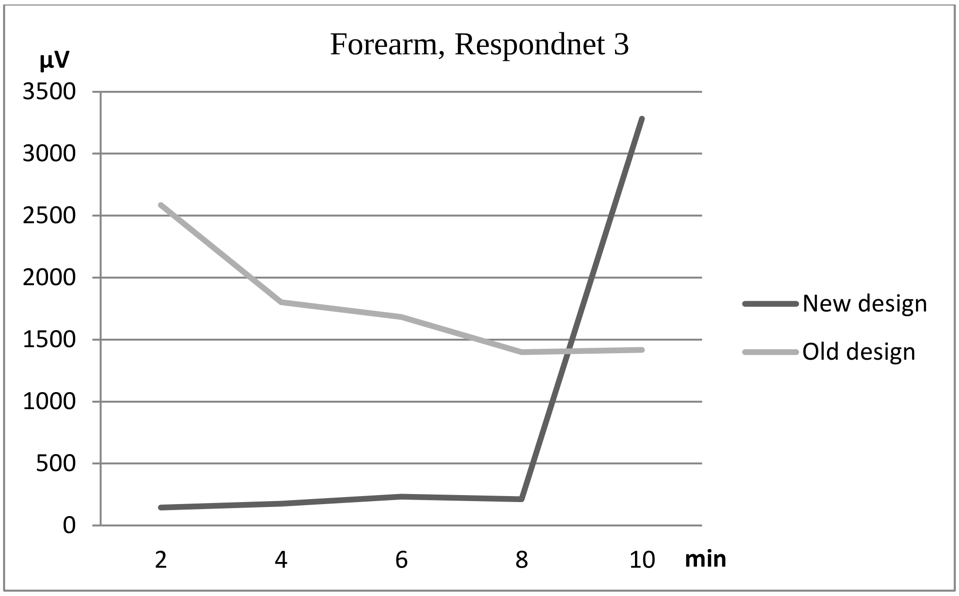



Figure 4.15: EMG activity at the forearm of respondent 3

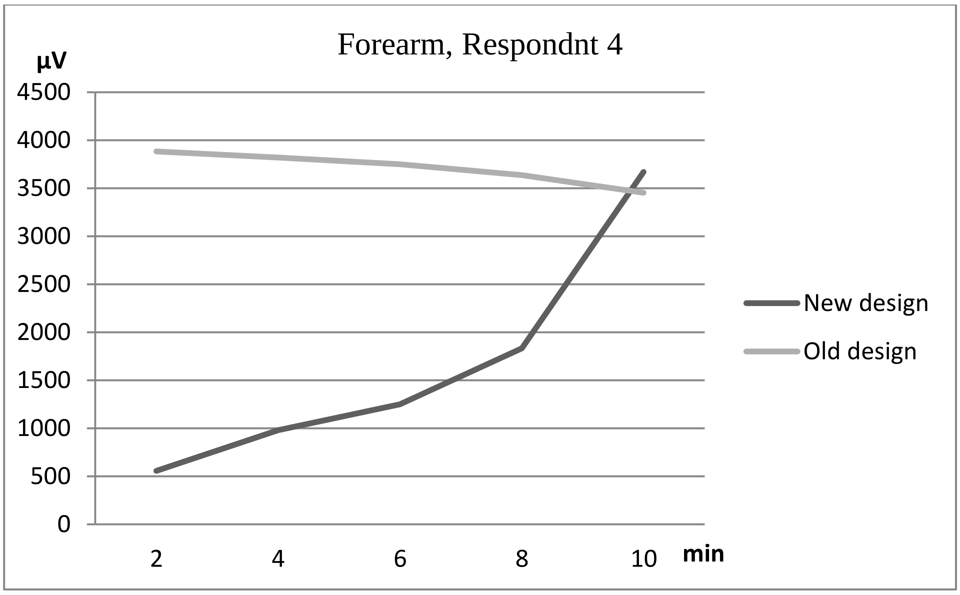



Figure 4.16: EMG activity at the forearm of respondent 4

In Figure 4.15 and 4.16 the pressure on forearm for respondent 3 and 4 is shown. The EMG activities for both respondents in old workstation design have a negative slope and in new workstation have a positive slope. However the pressure in new workstation is lower than old workstation for respondent 3 and 4.

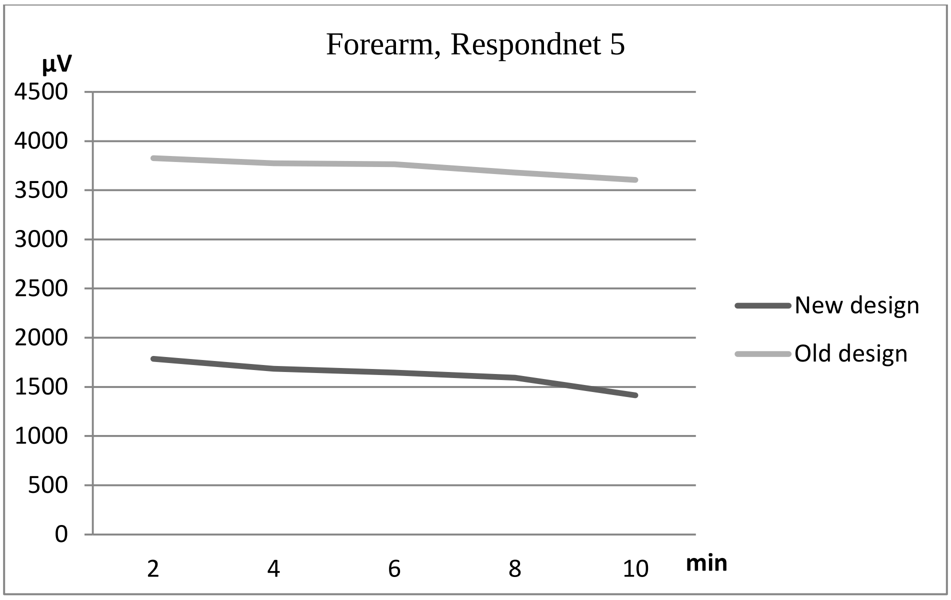



Figure 4.17: EMG activity at the forearm of respondent 5

For respondent 5 the pressure on forearm in both workstations has a negative slope but the pressure in the new workstation is significantly lower than old workstation design (Figure 4.17).

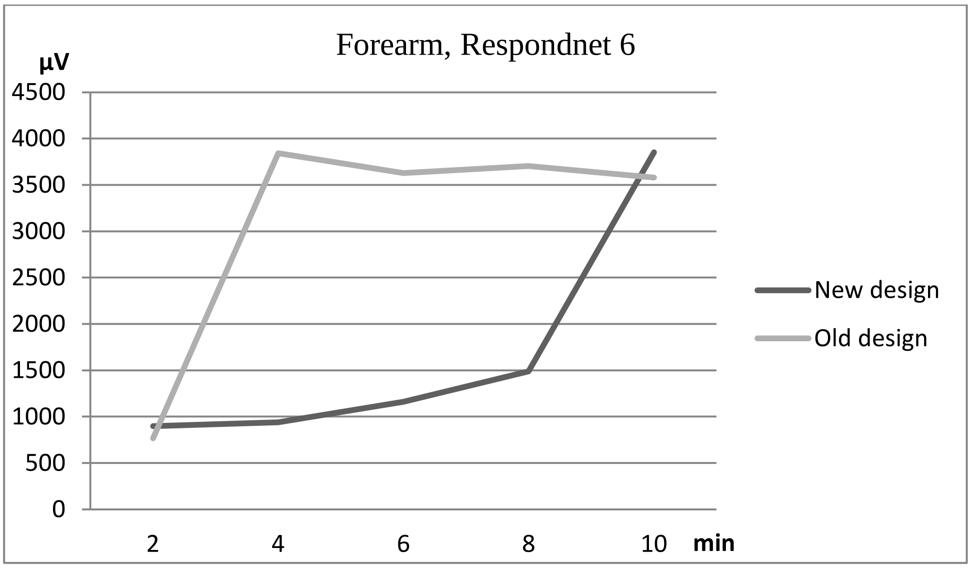



Figure 4.18: EMG activity at the forearm of respondent 6

Figure 4.18 shows that pressure on forearm for respondent 6 in new workstation is lower than old workstation. In new workstation the pressure has a positive slope during time.

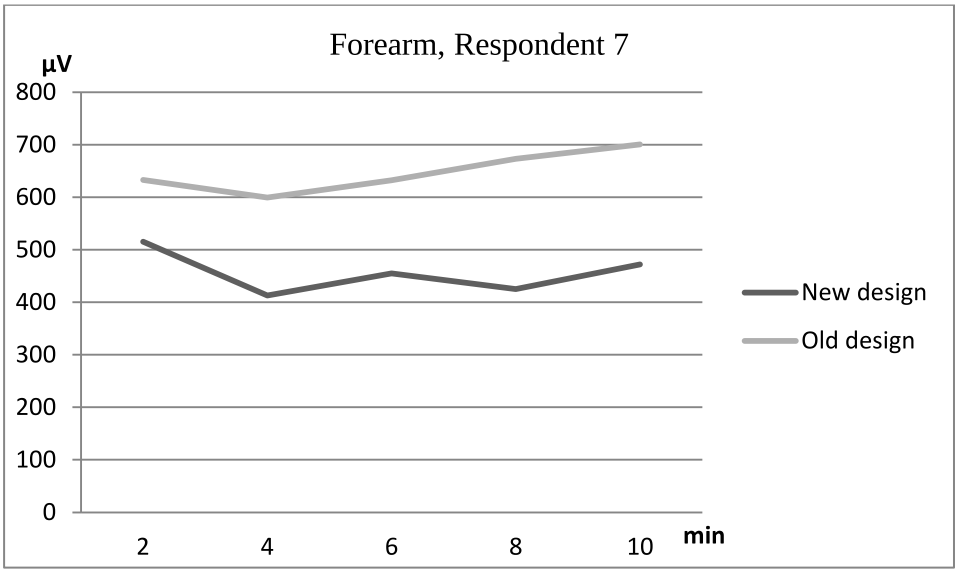



Figure 4.19: EMG activity at the forearm of respondent 7

sEMG activity for respondent 7 at the forearm region shows that the pressure in new workstation is lower than old workstation (Figure 4.19).

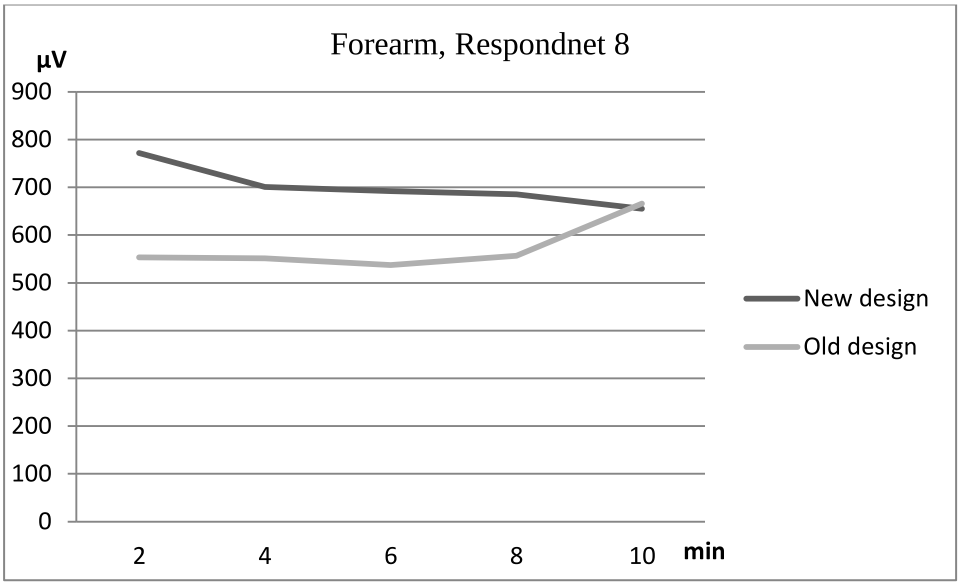



Figure 4.20: EMG activity at the forearm of respondent 8

For respondent 8 at the forearm region the pressure in new workstation is higher than old one but in new workstation there is a negative slope and in old workstation there is positive slope during time (Figure 4.20).

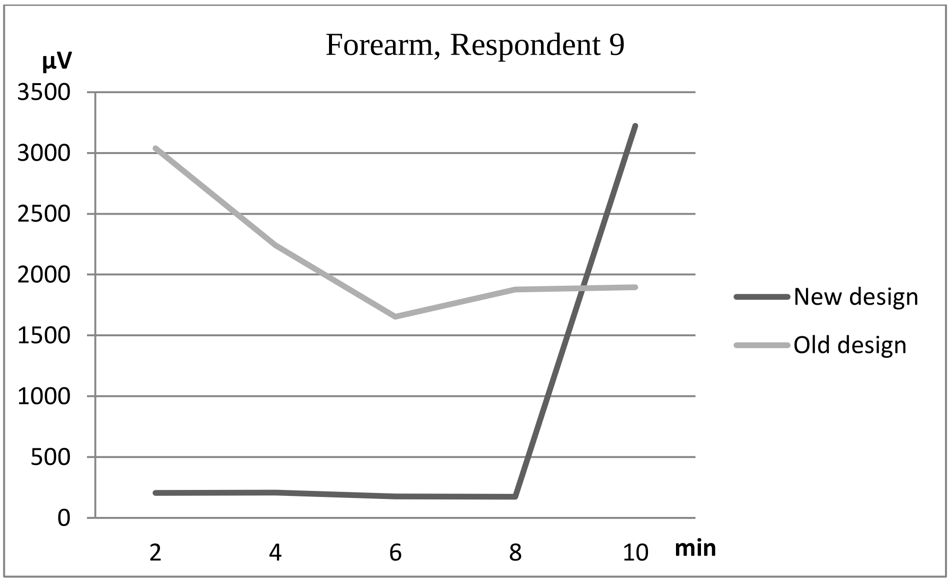



Figure 4.21: EMG activity at the forearm of respondent 9

The pressure on forearm of respondent 9 in new workstation is lower than old workstation. At 8th minute the pressure is increasing up sharply in new workstation (Figure 4.21).

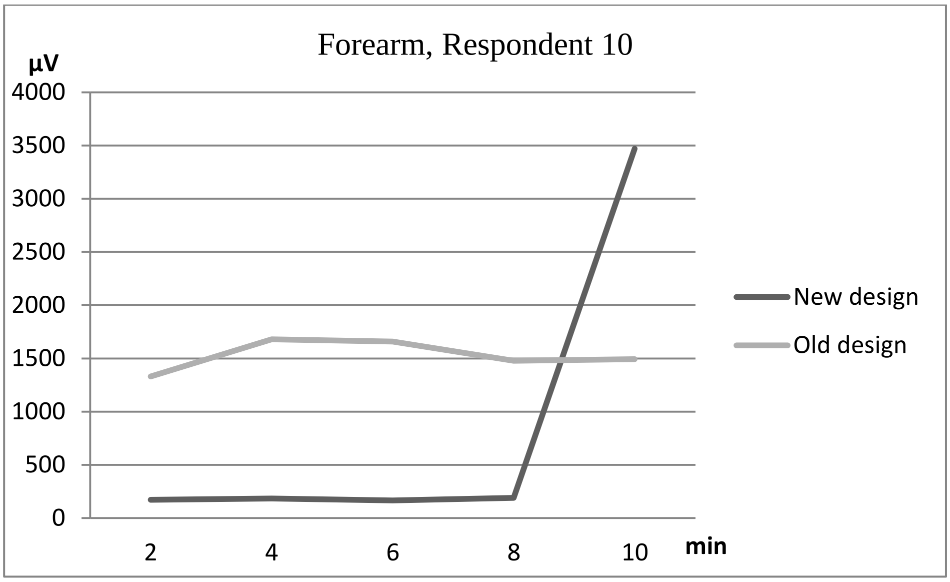



Figure 4.22: EMG activity at the forearm of respondent 10

Same as respondent 9, for respondent 10 the pressure on forearm in new workstation design is lower than old workstation design and again at 8th min there is a sharply increasing in new workstation (Figure 4.22).

### 4.4.3 Neck

The pressure on the neck of respondents will be shown in the Figure 4.23 to 4.32 in both workstations.

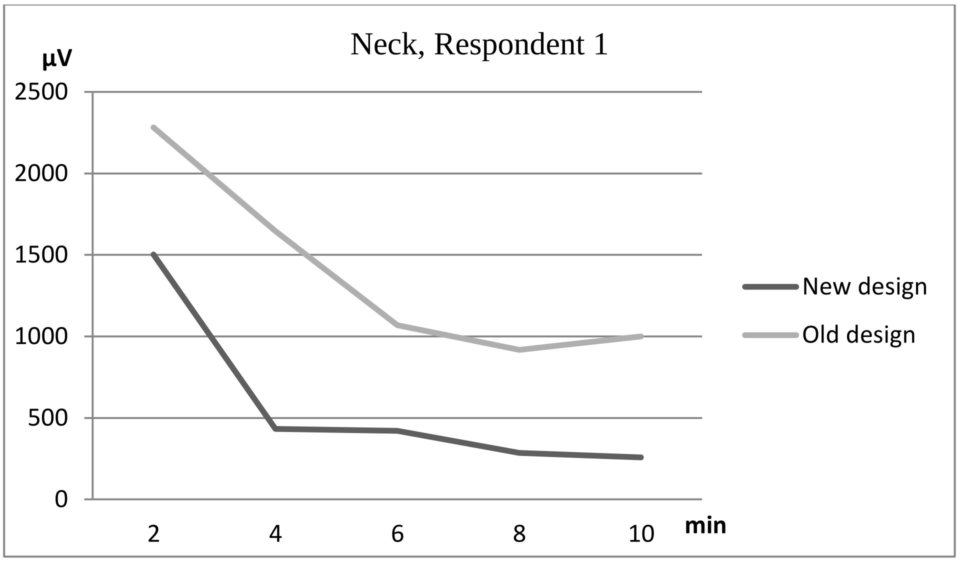



Figure 4.23: EMG activity at the neck of respondent 1

There is negative slope of pressure at the neck of respondent 1 in both workstations but the pressure in the new workstation is lower than old workstation (Figure 4.23).

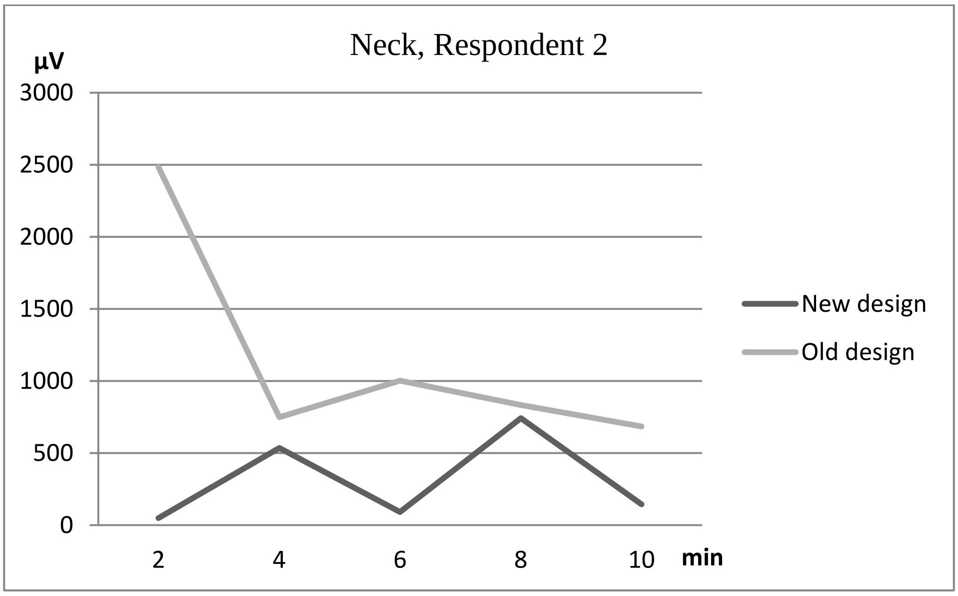



Figure 4.24: EMG activity at the neck of respondent 2

Figure 4.24 shows that the sEMG activity at the neck of respondent 2 in new workstation is lower than old workstation during time.

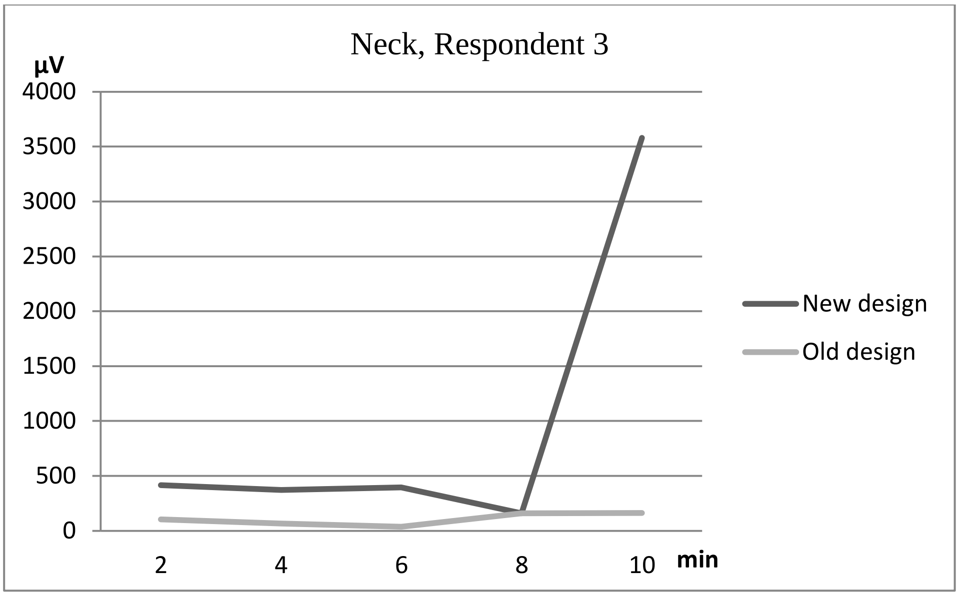



Figure 4.25: EMG activity at the neck of respondent 3

The pressure on neck of respondent 3 in old workstation is lower than new one. In new workstation design there is a negative slope until 8th min and after that the pressure is increasing sharply (Figure 4.25).

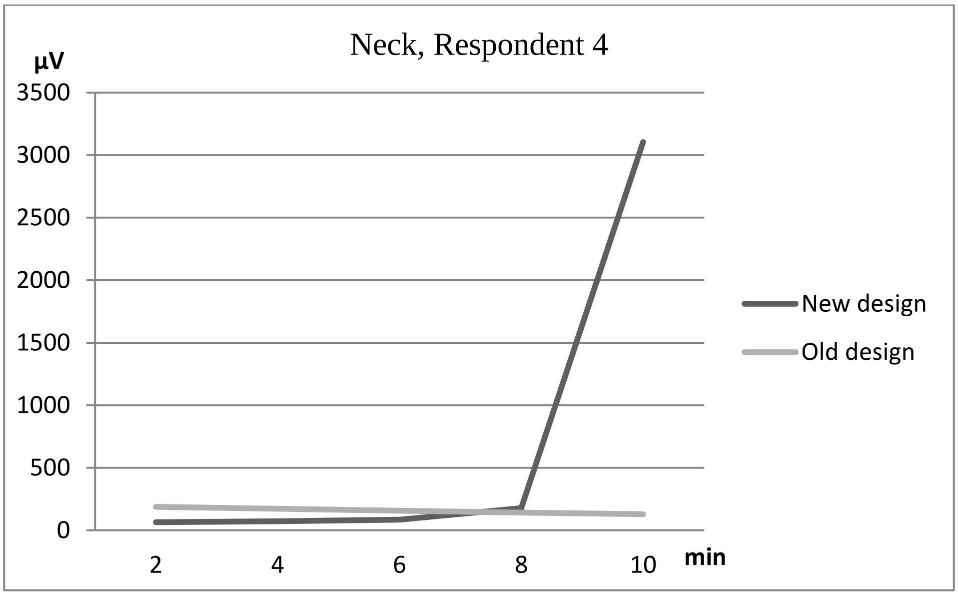



Figure 4.26: EMG activity at the neck of respondent 4

The sEMG activities at the neck of respondent 4 based on Figure 4.26 in both workstations are too close. But after the 8th min the pressure is increased sharply in new workstation design.

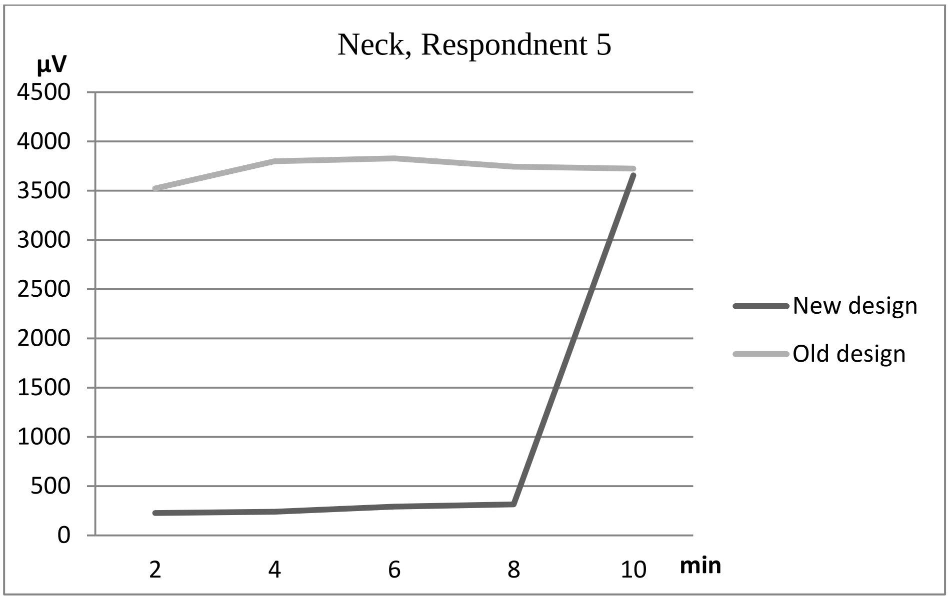



Figure 4.27: EMG activity at the neck of respondent 5

Figure 4.27 shows that the pressure on the neck of respondent 5 in new workstation design is lower than old workstation.

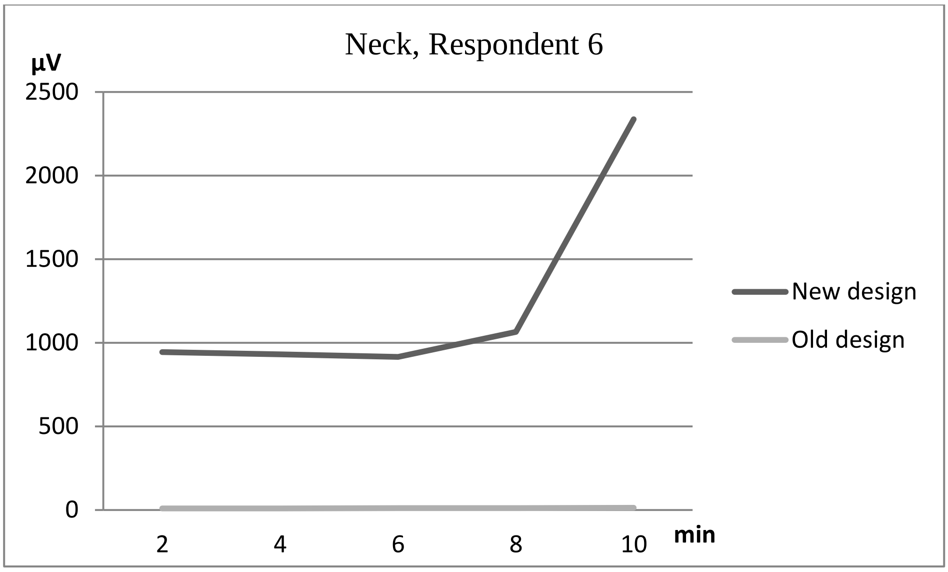



Figure 4.28: EMG activity at the neck of respondent 6

sEMG activities show that the pressure on the neck of respondent 6 in new workstation design is higher than old one. (Figure 4.28)

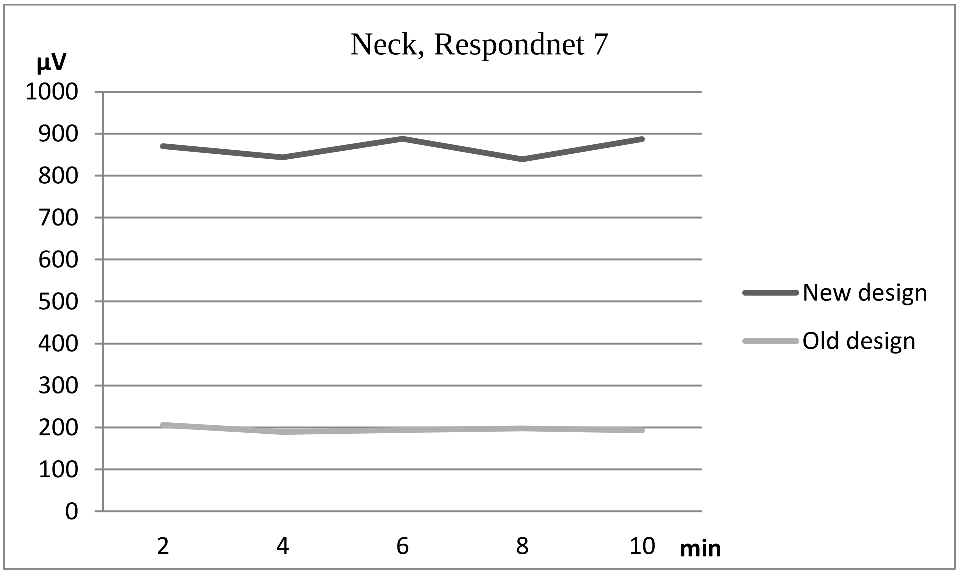



Figure 4.29: EMG activity at the neck of respondent 7

During 10 minutes working with two workstations, the sEMG result shows that the pressure on the neck of respondent 7 in new workstation design is higher than old workstation design (Figure 4.29).

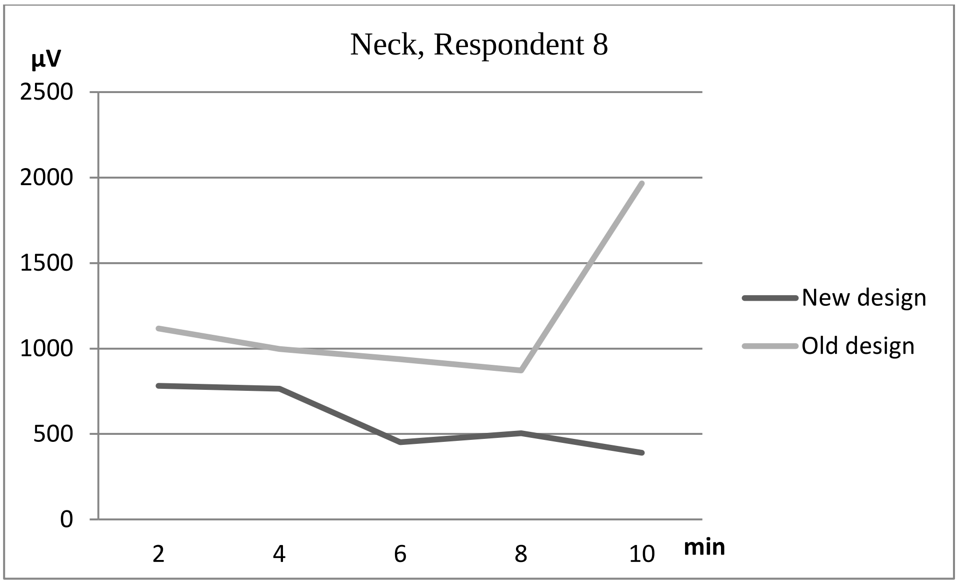



Figure 4.30: EMG activity at the neck of respondent 8

Pressure on neck of respondent 8 in new workstation design has a negative slope and it is lower than pressure in old workstation design (Figure 4.30).

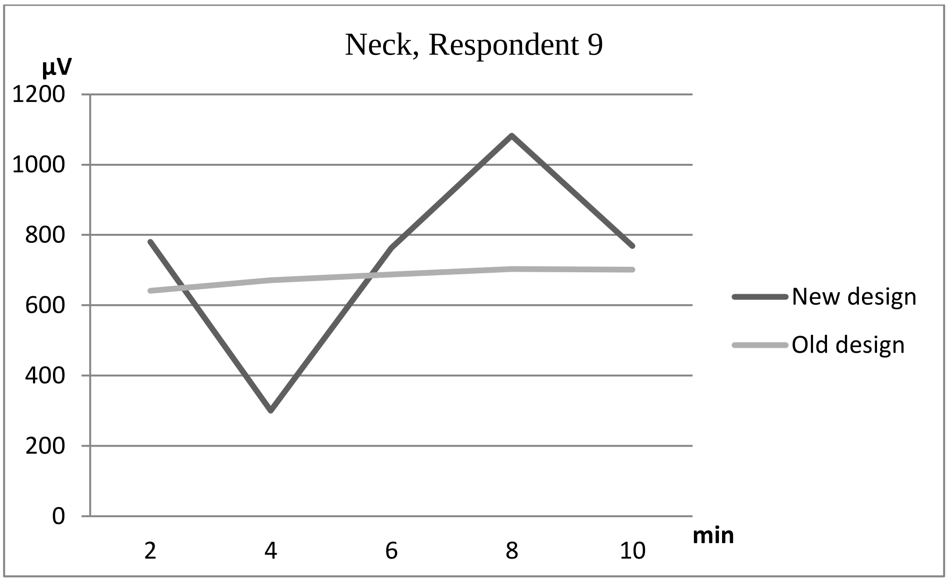



Figure 4.31: EMG activity at the neck of respondent 9

Figure 4.31 shows pressure on neck for respondent 9 when she was using new and old workstation design during 10 minutes. The chart shows that pressure on her neck while using the old workstation design is higher than when she was working new workstation design before the 6th min. after 6 min the pressure on neck when she worked with new workstation design was increasing and it came higher than when she was working with old workstation design.

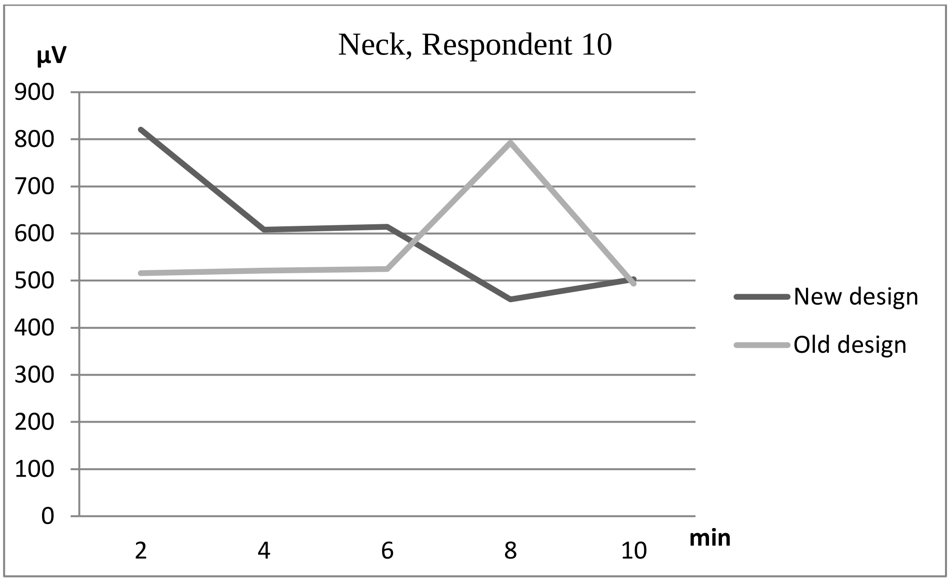



Figure 4.32: EMG activity at the neck of respondent 10

Figure 4.32 shows that the pressure on the neck of the respondent 10. When she was working with new workstation design has a negative slope and before 6th min it is higher than pressure in the old workstation design and after 6th min it is lower than pressure in the old workstation design.

### 4.4.4 Shoulder

In the next 10 Figure (4.33 to 4.42) the shoulder muscle activities of all respondent will be illustrated.

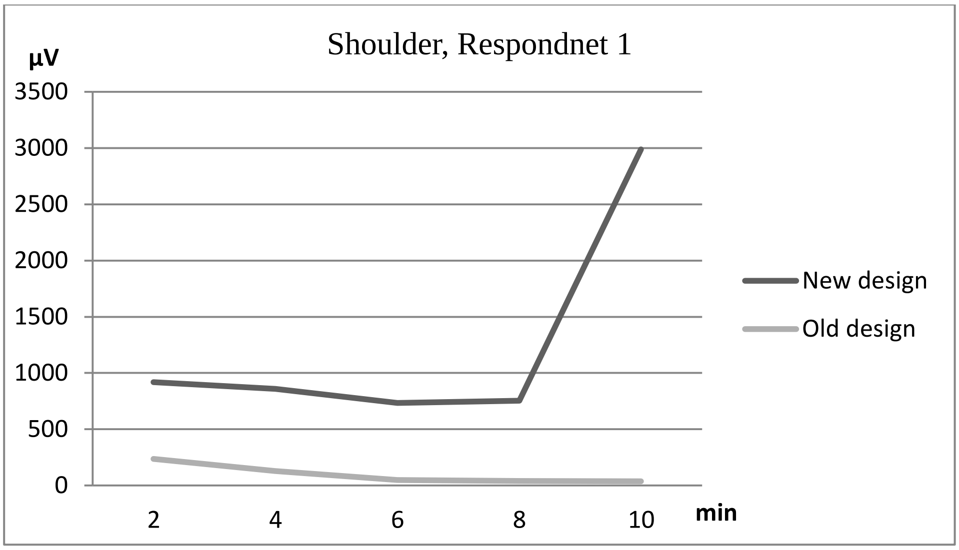



Figure 4.33: EMG activity at the shoulder of respondent 1

The EMG activity at the shoulder of respondent is shown in figure 4.33. In this case, the pressure on shoulder of respondent 1 when he was working with old workstation design is lower than when he was working with new workstation design.

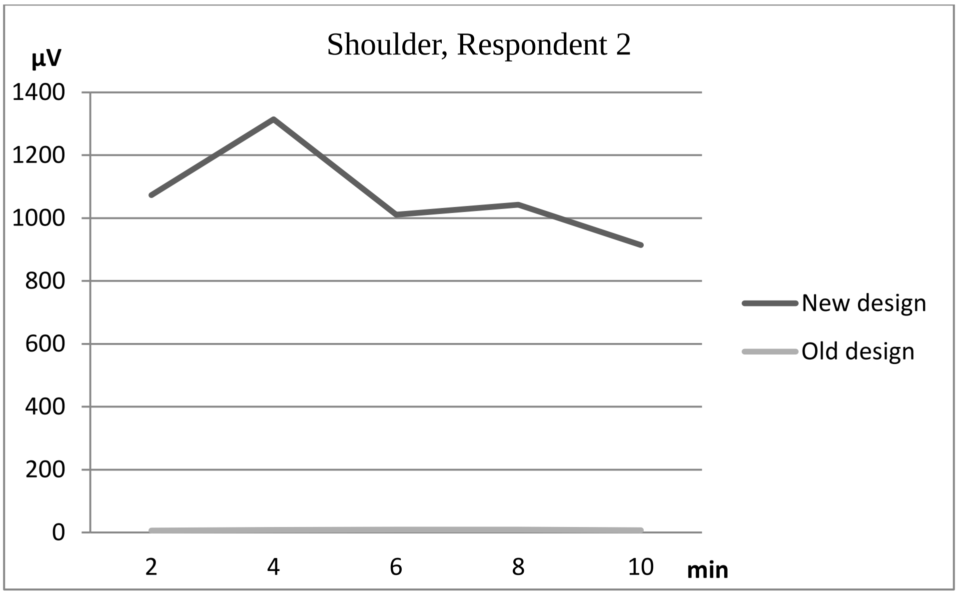



Figure 4.34: EMG activity at the shoulder of respondent 2

Figure 4.34 shows the EMG activity at the shoulder of respondent 2 while he was working with two workstation design. The pressure on his shoulder when he worked with old workstation design is lower than when he worked with new workstation design.

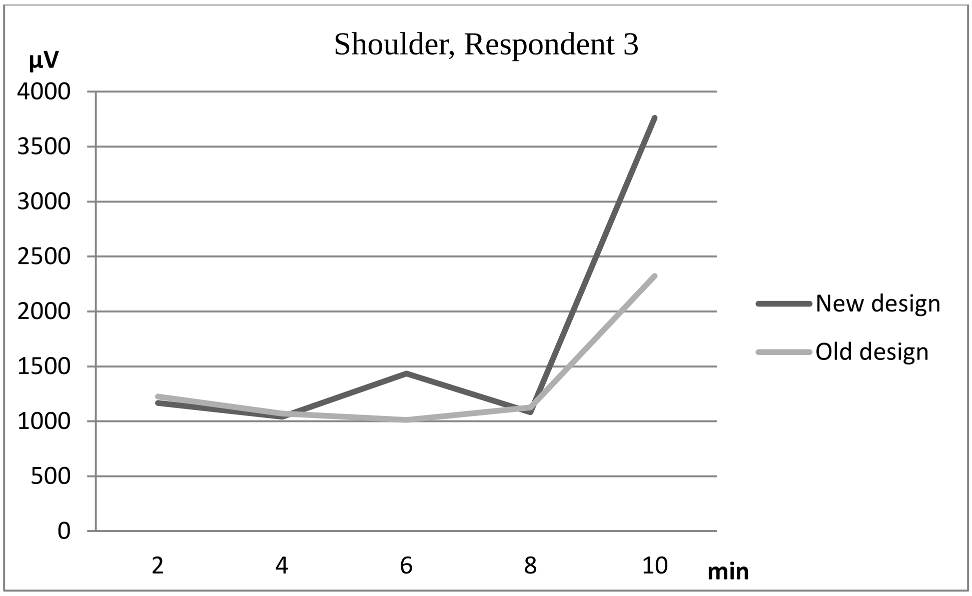



Figure 4.35: EMG activity at the shoulder of respondent 3

The pressures on shoulder for respondent 3 are close in both workstations design (Figure 4.35).

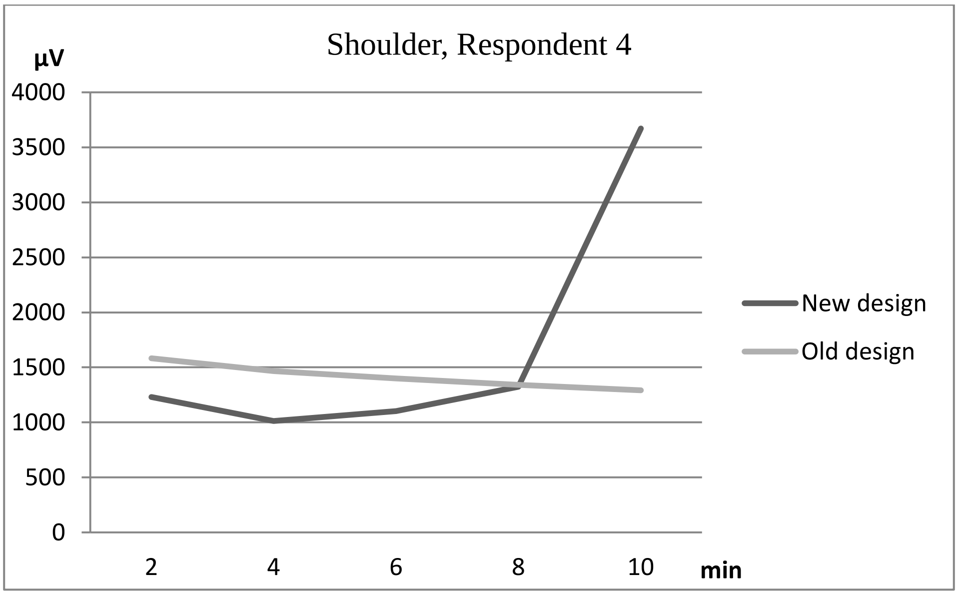



Figure 4.36: EMG activity at the shoulder of respondent 4

Figure 4.36 shows that before 8$^{th}$ minute, the pressure on shoulder of respondent 4 when he was working with new workstation design is lower than when he was working with old workstation design, but after 8th minute the pressure in new workstation is became higher than old one.

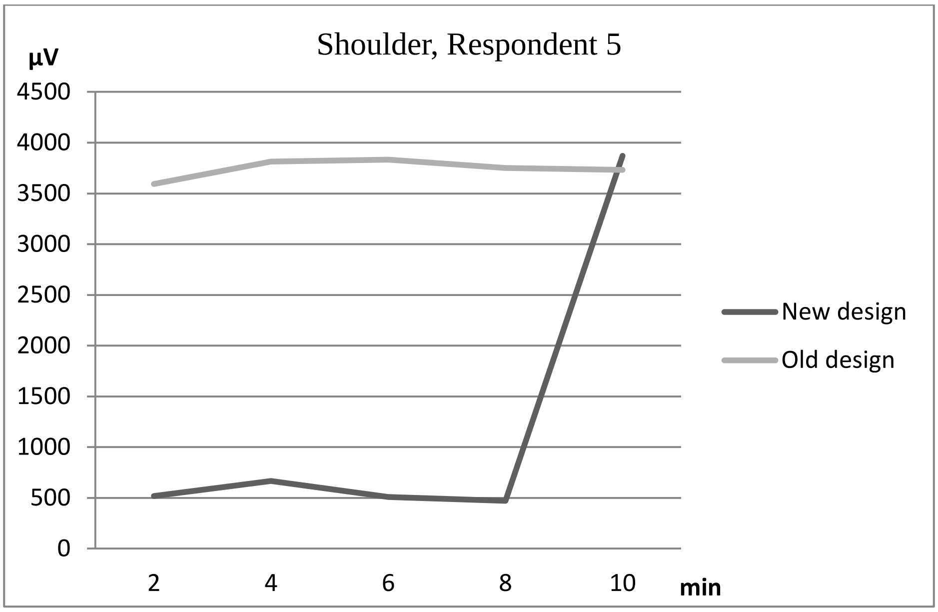



Figure 4.37: EMG activity at the shoulder of respondent 5

Figure 4.37 shows that pressure on shoulder of respondent 5 during 10 minutes typing test. The pressure when he was working with new workstation design was significantly lower than when he was working with old workstation.

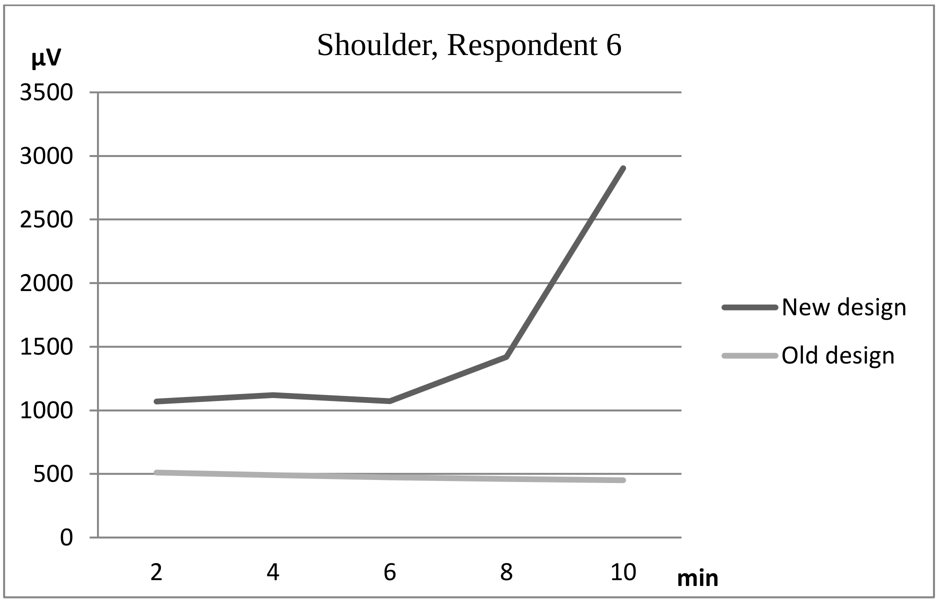



Figure 4.38: EMG activity at the shoulder of respondent 6

The pressure on shoulder of respondent 6 when he used old workstation design is lower than when he was working with new workstation design (Figure 4.38).

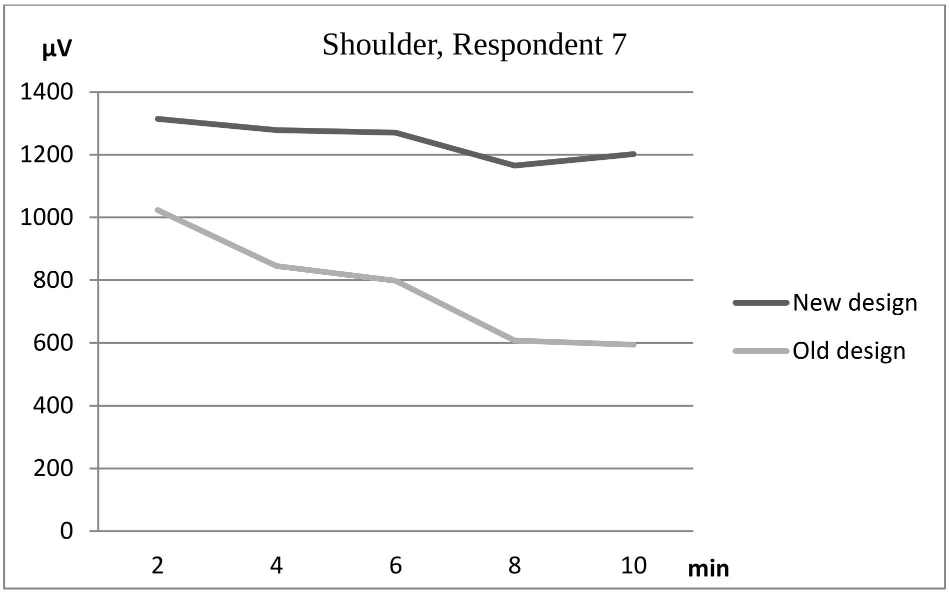



Figure 4.39: EMG activity at the shoulder of respondent 7

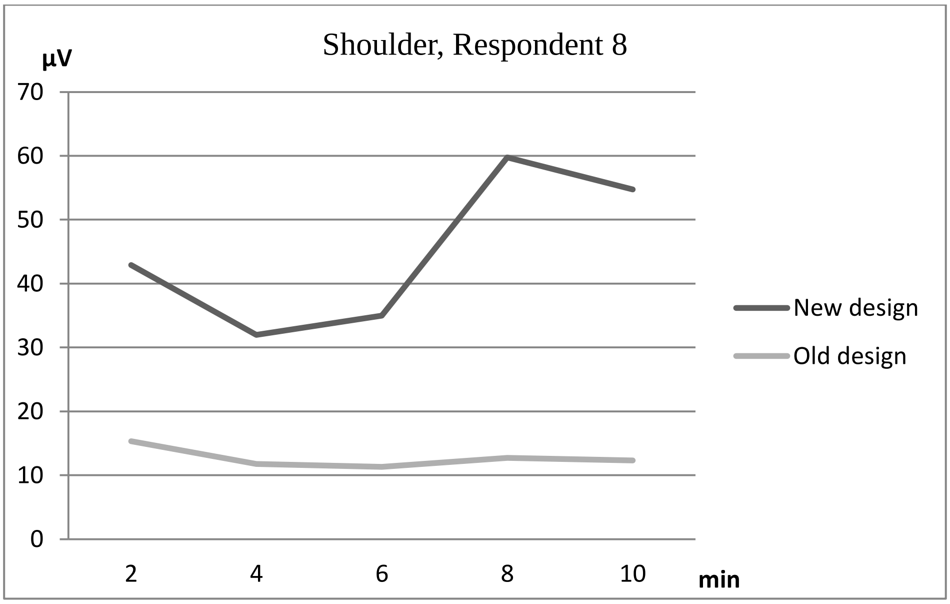



Figure 4.40: EMG activity at the shoulder of respondent 8

Figure 4.39 and 4.40 show shoulder muscle activity during 10 minutes of respondent 7 and 8. For both respondents the pressure when they working with old workstation design is lower than when they worked with new workstation design.


Figure 4.41: EMG activity at the shoulder of respondent 9

Figure 4.41 shows that pressure on the shoulder of the respondent 9 during 10 minutes working with new and old workstation design. The pressure on shoulder of respondent 9 when she was working with new workstation design is almost lower than when she was working with old workstation design.

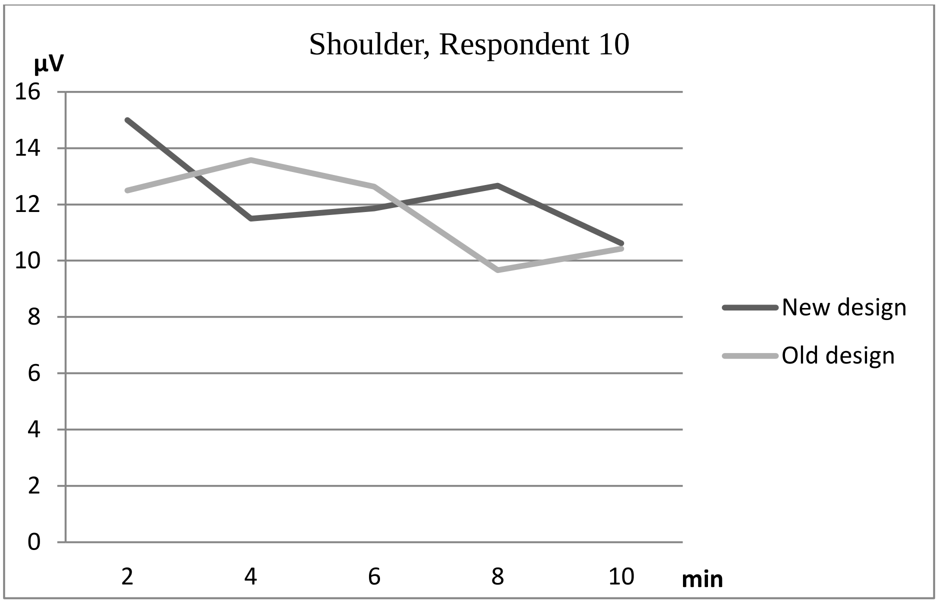



Figure 4.42: EMG activity at the shoulder of respondent 10

Figure 4.42 shows that the pressure on shoulder for respondent 10 was approximately same, sometimes pressure on shoulder of respondent 10 in new workstation is higher and sometimes the pressure on shoulder in old workstation design is higher but there is a negative slope of pressure in both workstations at all.

### 4.4.5 Upper back

The upper back muscle activities, which were recorded with EMG for all 10 respondents, have been illustrated in next 10 figures (figure 4.43 to 4.52).

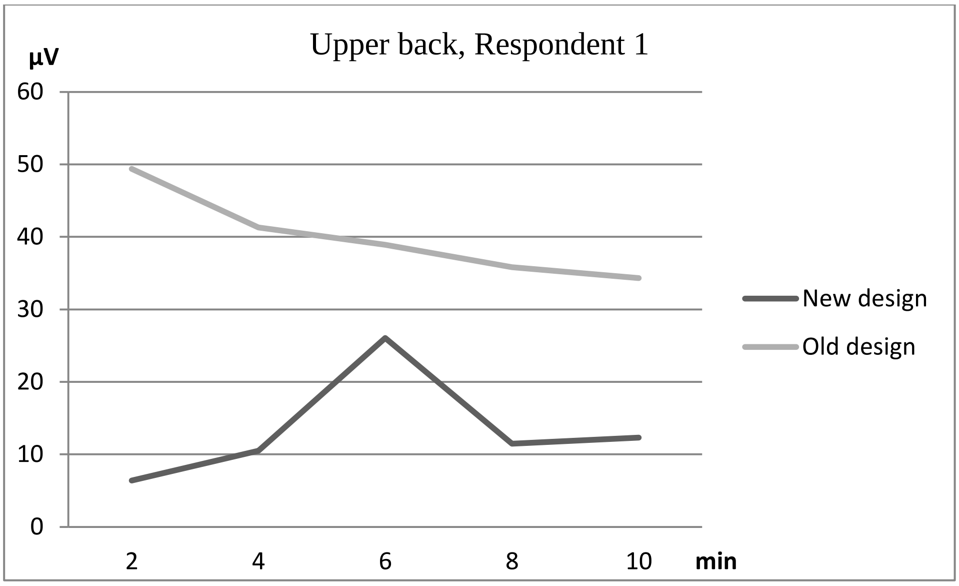



Figure 4.43: EMG activity at the upper back of respondent 1

Figure 4.43 shows that the pressure on the upper back of the respondent 1. The pressure when he was working with new workstation design is lower than when he was working with old workstation design. The pressure on upper back in old workstation design has a negative slope at all.

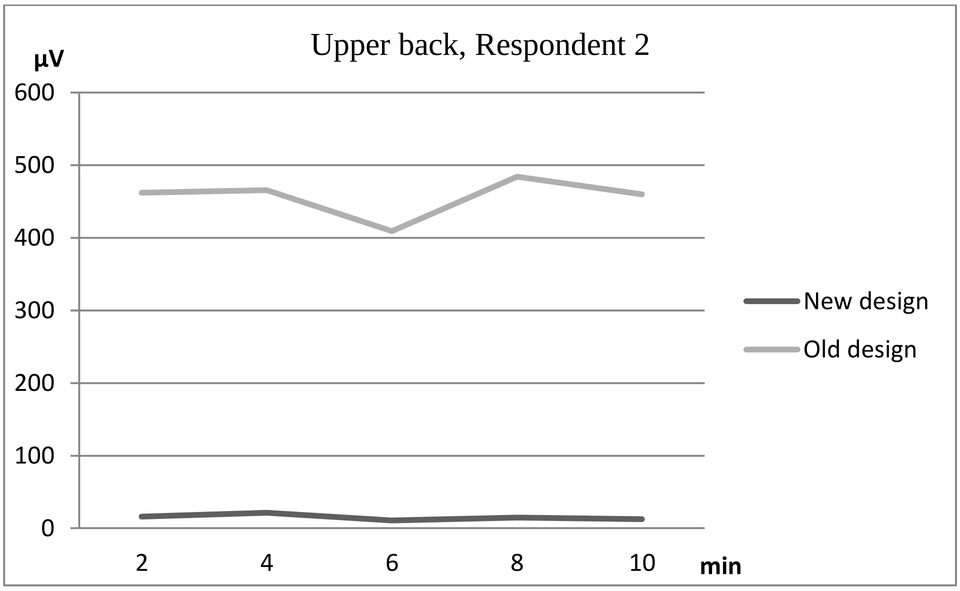



Figure 4.44: EMG activity at the upper back of respondent 2

Figure 4.44 show the upper back muscle activity for respondent 2 during 10 minutes typing test. The pressure when he was working with old workstation design is significantly higher than when he was working with new workstation design.

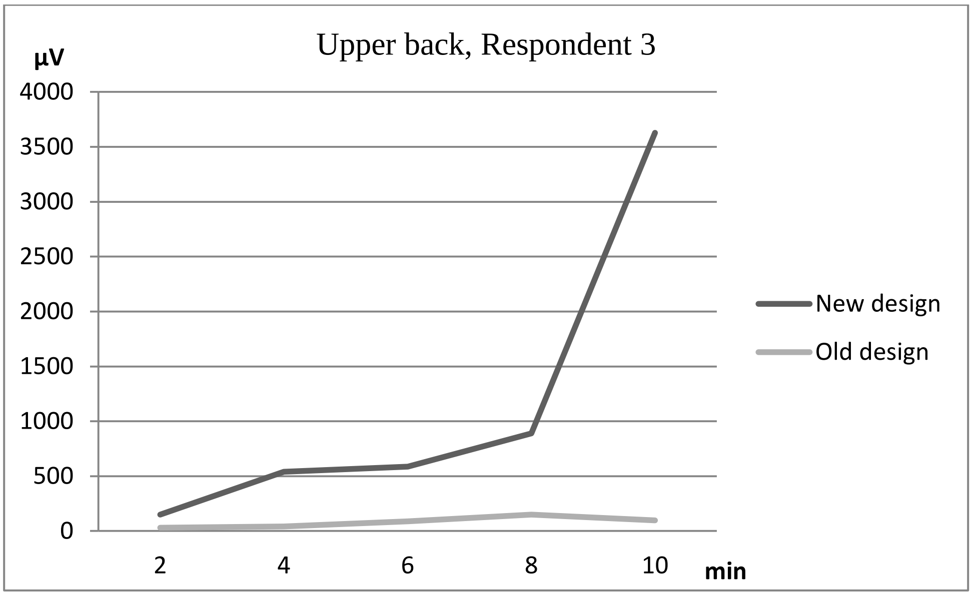



Figure 4.45: EMG activity at the upper back of respondent 3

Figure 4.45 shows that the pressure on upper back muscle of respondent 3 when he was working with new workstation design has a positive slope, and it is higher than pressure when he was working with old workstation.

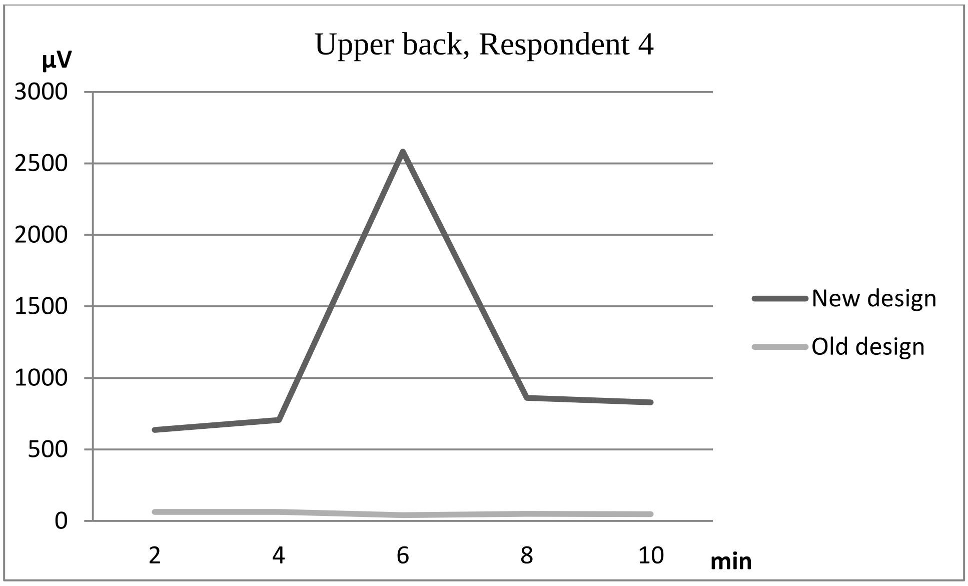



Figure 4.46: EMG activity at the upper back of respondent 4

EMG activity at the upper back of respondent 4 is shown in figure 4.46. The pressure on upper back muscle when respondent 4 was working with new workstation design is higher than when he was working with old workstation design.

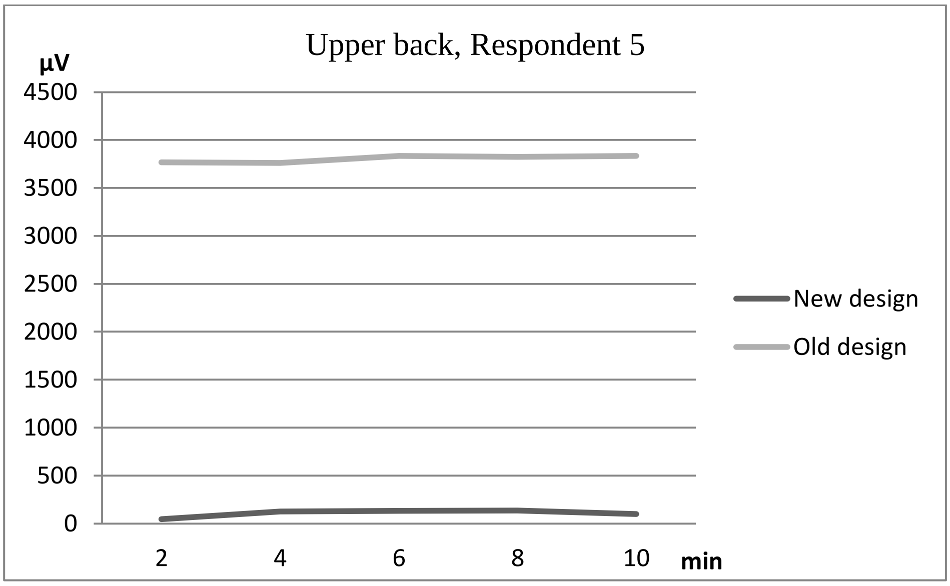



Figure 4.47: EMG activity at the upper back of respondent 5

Figure 4.47 shows that the pressure on upper back of respondent 5 during 10 minutes when he was working with two workstation. The pressure on upper back in new workstation design is significantly lower than old workstation design.

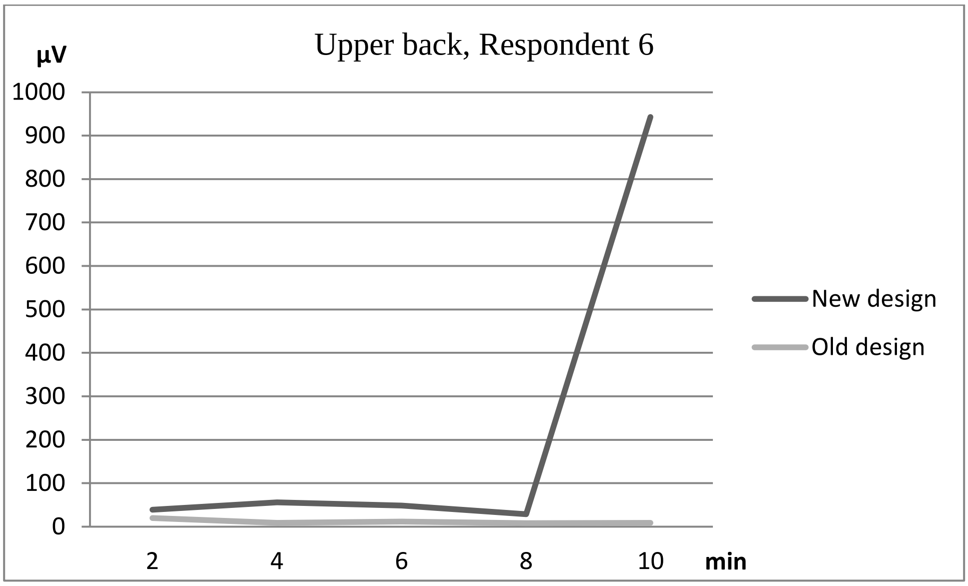



Figure 4.48: EMG activity at the upper back of respondent 6

Figure 4.48 shows that the pressure on upper back of respondent 6 when he was working with both workstations is almost same before 8th minute. After 8th minutes the pressure is increasing when the respondent 6 work with new workstation design.

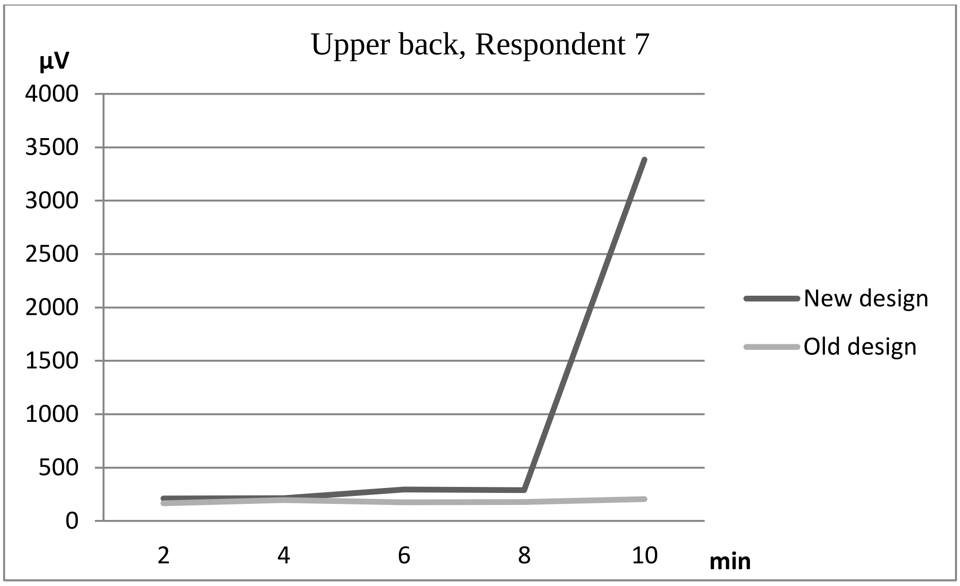



Figure 4.49: EMG activity at the upper back of respondent 7

Figure 4.49 shows the sEMG activity at the upper back of respondent 7 during ten minutes. The pressure in both workstations before 8$^{th}$ minute is same but after the 8$^{th}$ minute the pressure is increasing sharply when the respondent was working with new workstation design.

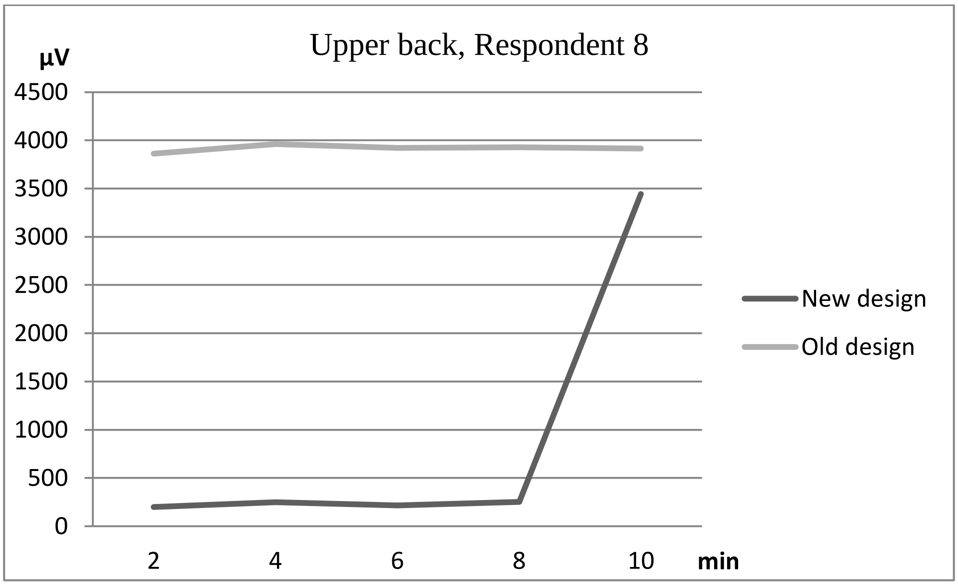



Figure 4.50: EMG activity at the upper back of respondent 8

The pressure on upper back muscle of respondent 8, when he was using new workstation design is significantly lower than when he was using old workstation design (Figure 4.50).

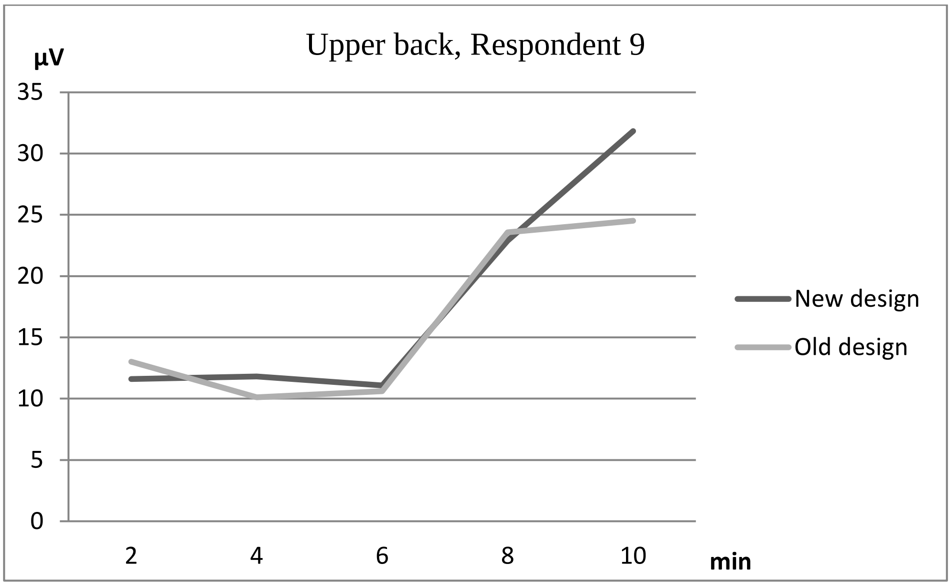



Figure 4.51: EMG activity at the upper back of respondent 9

Figure 4.50 shows that the pressure on upper back of respondent 9 when he was working with both workstations is approximately same. During time the pressure is increasing at all in both workstations.

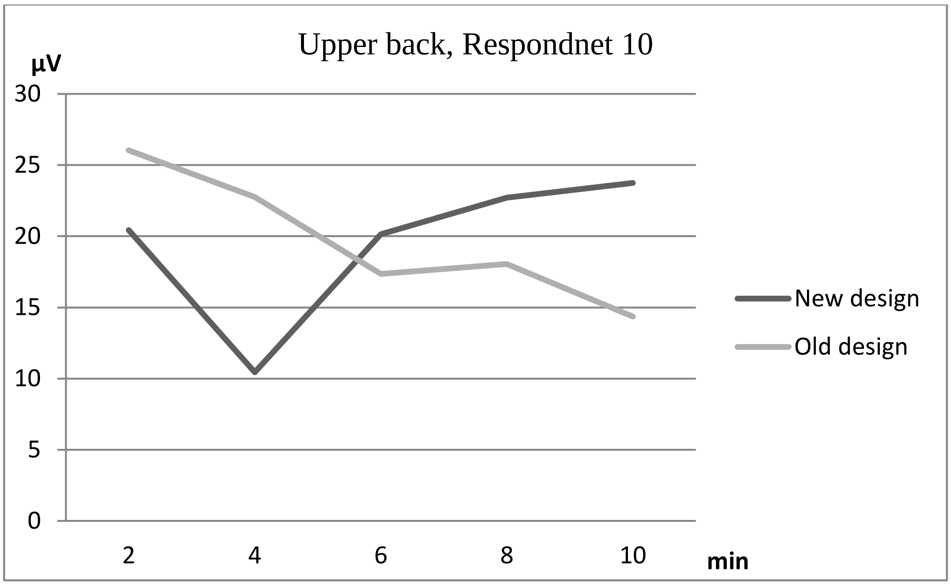



Figure 4.52: EMG activity at the upper back of respondent 10

Figure 4.52 shows that the pressure on upper back of the respondent 10 while she was working with new workstation design before 4$^{th}$ min was decreasing but after 4$^{th}$ minutes it has positive slope and it increased. During ten minutes the pressure on upper back of respondent 10 when she was working with old workstation design has a negative slope and it decreased during time. Before 6$^{th}$ minute the pressure in new workstation was lower than old workstation and after 6$^{th}$ minute the pressure on upper back in old workstation is lower than new workstation.

### 4.4.6 Lower back

The amounts of pressure on lower back of all respondents when they were working with both workstations are shown in figure 4.53 to 4.62.

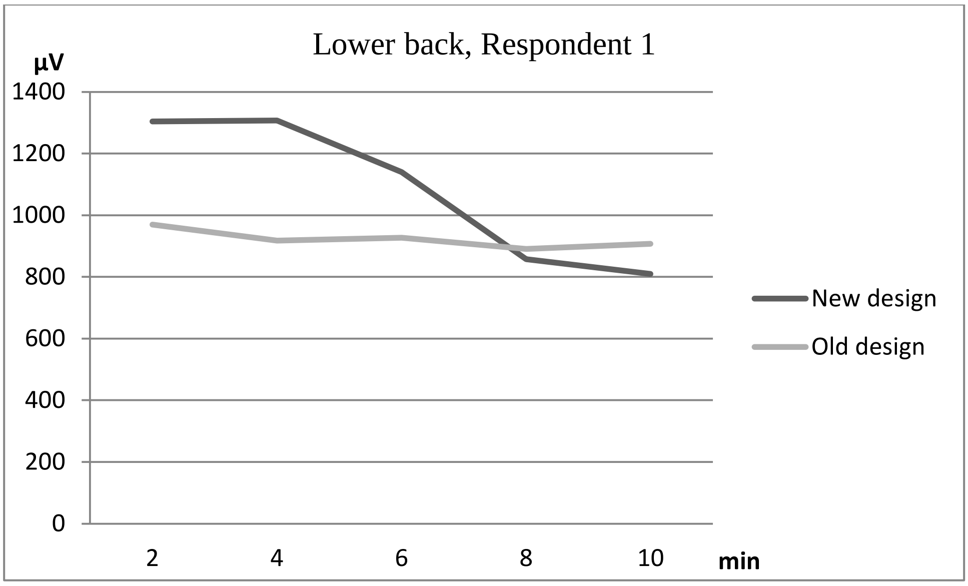



Figure 4.53: EMG activity at the lower back of respondent 1

Figure 4.53 shows that the pressure on lower back of respondent 1 during 10 minutes when he was working with old workstation design is lower than when he was working with new one. But the negative slope of the pressure during working with new workstation design is more than old workstation design to the extent that after 8$^{th}$ minute the pressure on lower back of respondent 1 when he was working with new workstation design had become lower than when he was working with old workstation design.

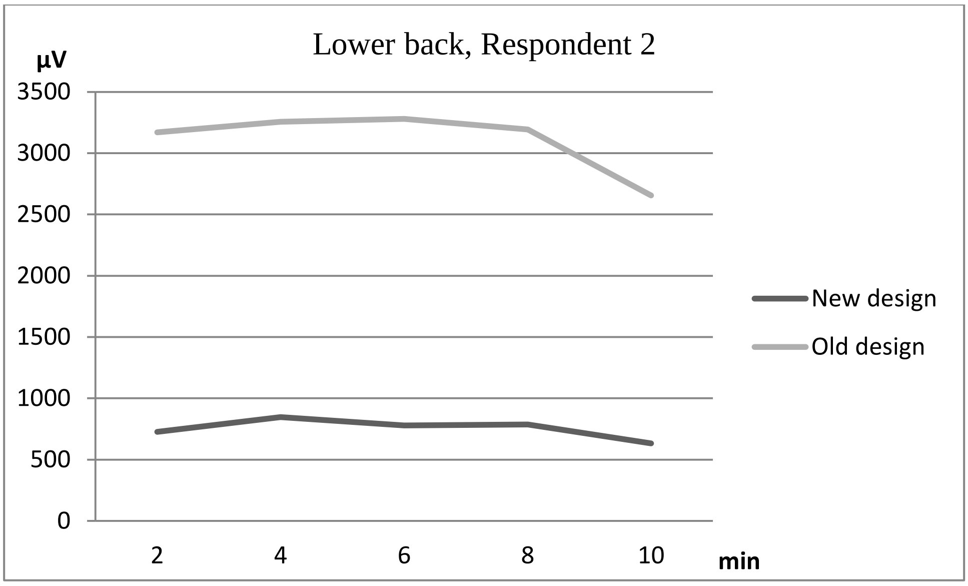



Figure 4.54: EMG activity at the lower back of respondent 2

Figure 4.54 shows that the pressure on lower back of respondent 2, when he was working with new workstation design is significantly lower than when he was working with old workstation.

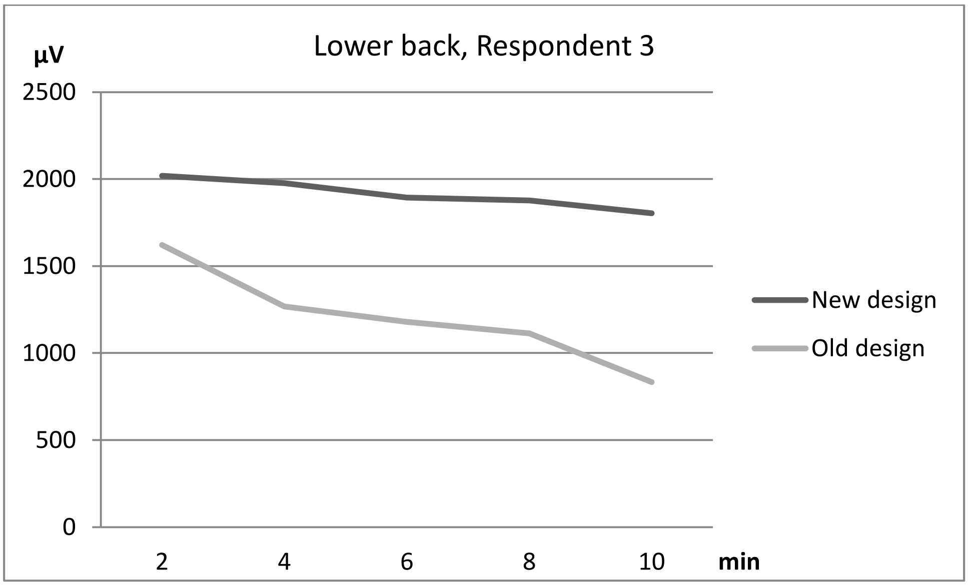



Figure 4.55: EMG activity at the lower back of respondent 3

The pressure on lower back of respondent 3 has a negative slope during ten min in both workstations, but the pressure in old workstation is lower than new workstation design (Figure 4.55).

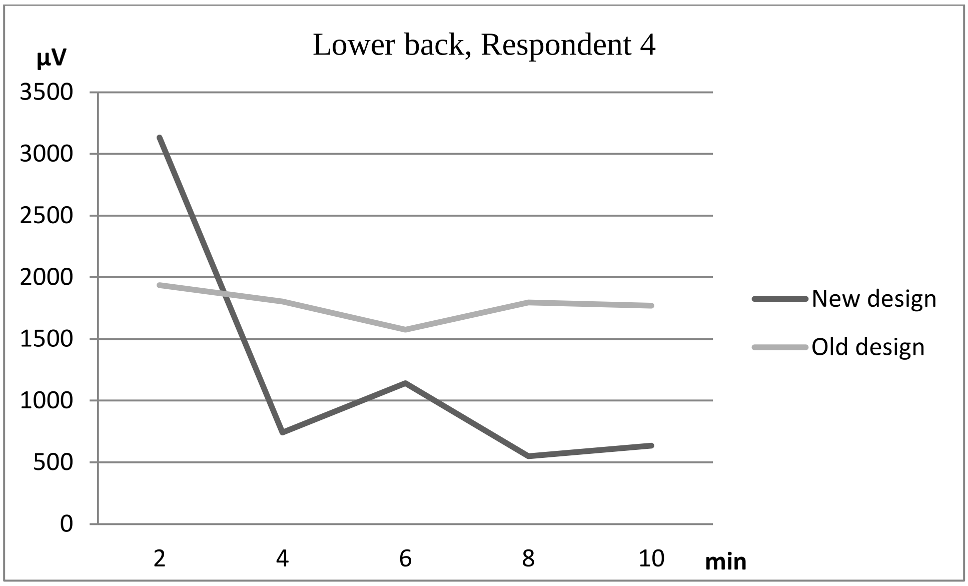



Figure 4.56: EMG activity at the lower back of respondent 4

Figure 4.56 shows that the pressure on lower back muscle of respondent 4 when he was working with new workstation design is lower than when he was working with old workstation design. During time the pressure is declining in new workstation design at all.

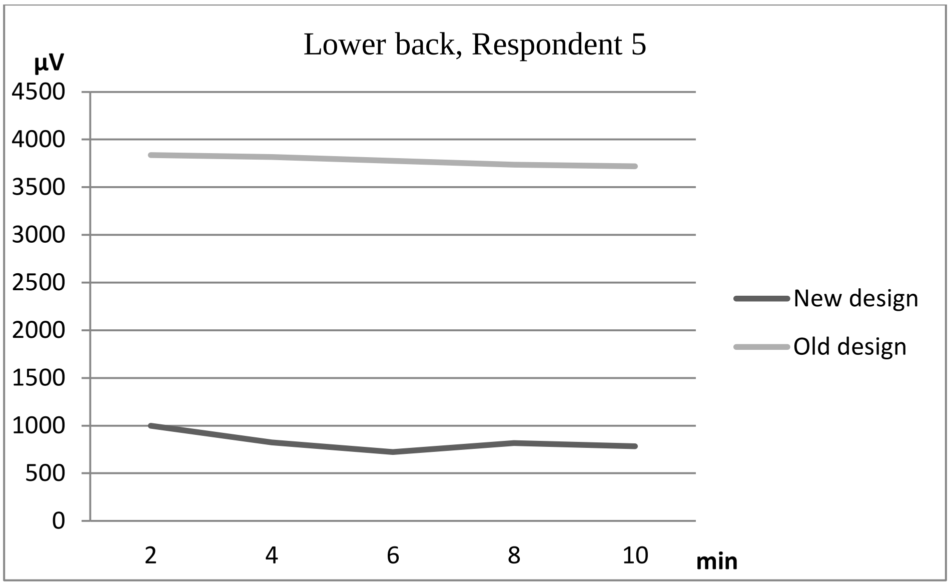



Figure 4.57: EMG activity at the lower back of respondent 5

Figure 4.57 shows the EMG activity at lower back of respondent 5 when he was working with both workstations. The pressure on lower back muscle of respondent 5 when he was working new workstation design is significantly lower than when he was working with old workstation design.

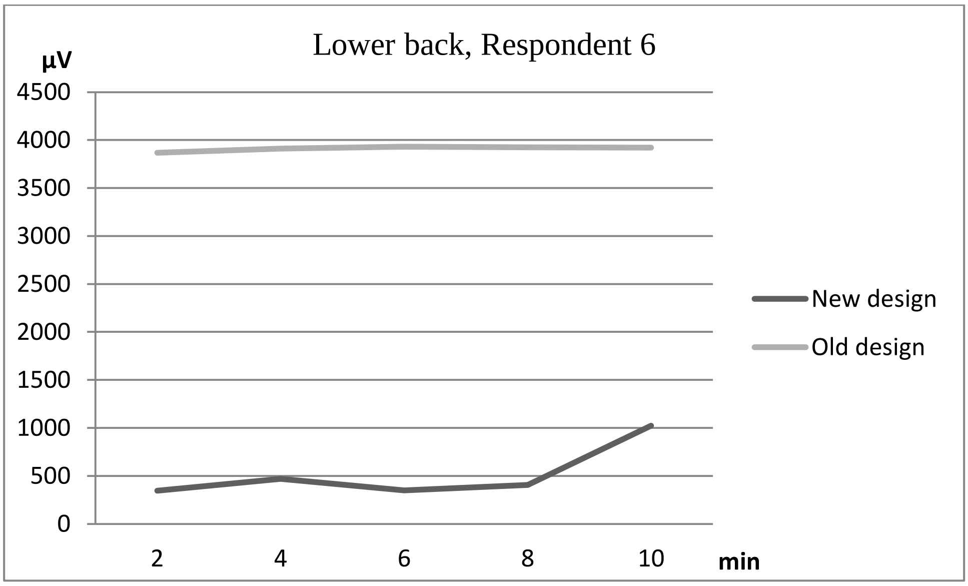



Figure 4.58: EMG activity at the lower back of respondent 6

Figure 4.58 shows that the pressure on lower back of the respondent 6 when he was working with old workstation design is significantly higher than when he was working with new workstation during 10 minutes.

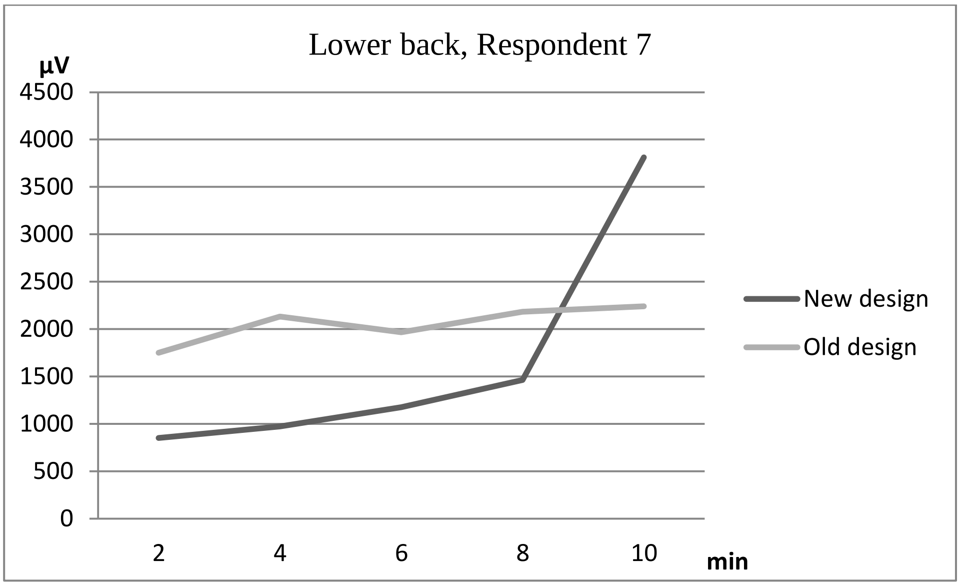



Figure 4.59: EMG activity at the lower back of respondent 7

Figure 4.59 shows the pressure on lower back of respondent 7 in both workstations design. In new workstation design, the pressure has a positive slope and before $8^{th}$ minute is lower than old workstation design.

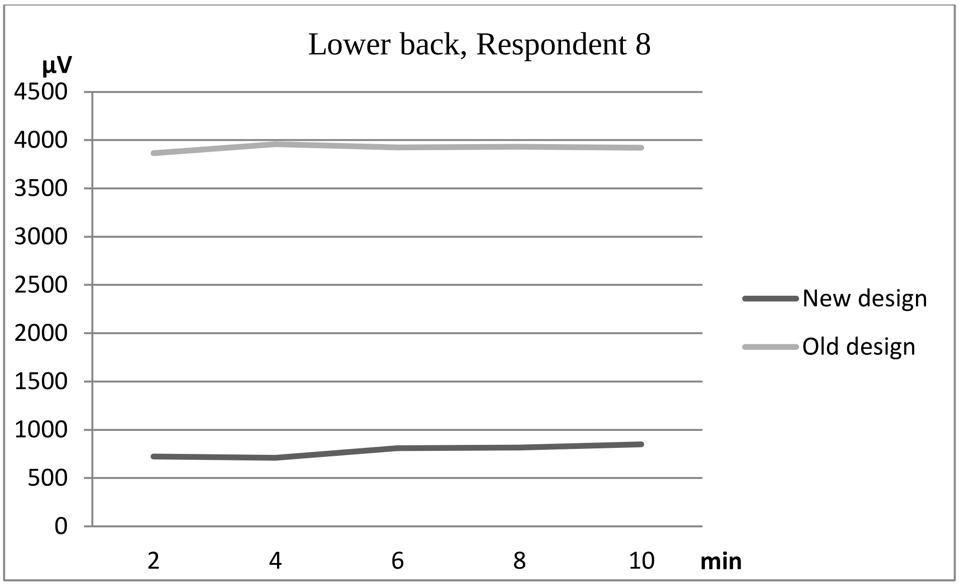



Figure 4.60: EMG activity at the lower back of respondent 8

Figure 4.60 shows that the pressure on lower back of the respondent 8 when he was working with old workstation design is significantly higher than when he was working with new workstation during 10 minutes.

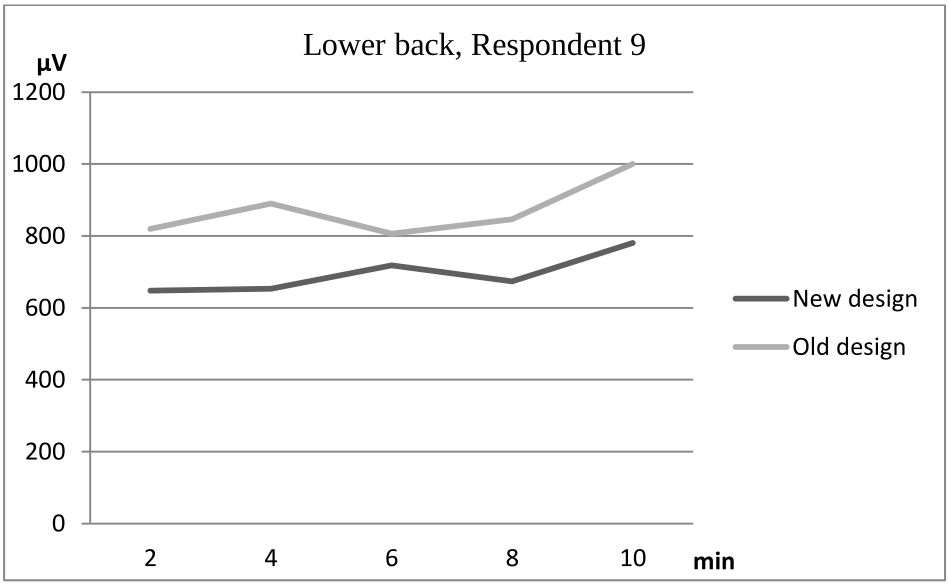



Figure 4.61: EMG activity at the lower back of respondent 9

EMG activity at the lower back of respondent 9 is shown in Figure 4.61. The diagram shows that the pressure when the respondent was working with new workstation design is lower than when he was working with old one.

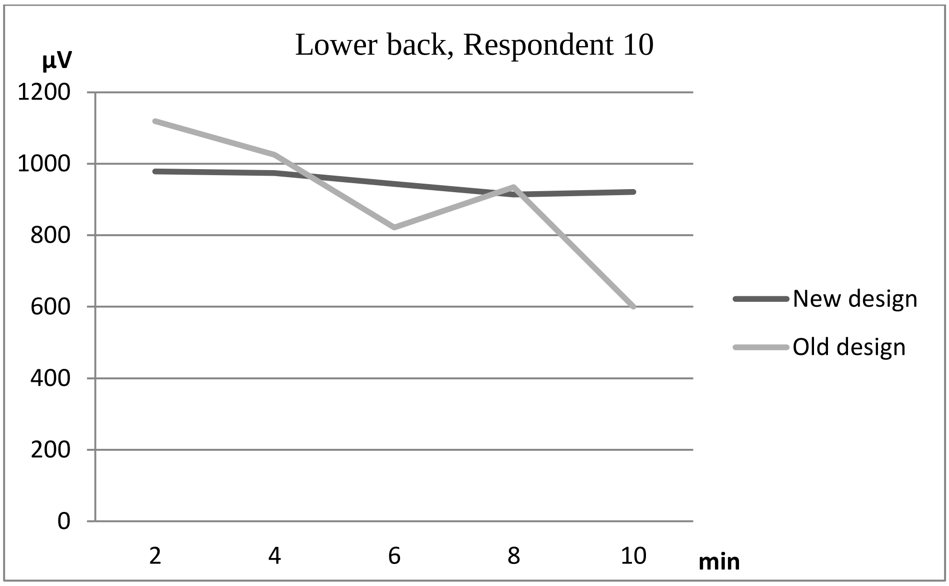



Figure 4.62: EMG activity at the lower back of respondent 10

Figure 4.62 shows typing activities of the respondent 10during 10 minutes. The pressure on lower back in the new workstation design before 5th minute is lower than old workstation activities and after 5th minutes is higher. A line with a negative slope shows an overall decrease on lower back for respondent 5 in new workstation design.

In table 4.19 the summary of charts result is shown. The "New design" column indicates how many times the pressure in new workstation design is lower than old workstation design.  The "Old design" column indicates how many times the pressure in old workstation design is lower than new workstation design and the last column shows that how many times the pressure on body regions are close to each other in both workstations.

Table 4.19: Summery of charts result

| | New design | Older design | Close to each other |
|---|---|---|---|
| **Hand** | 3 | 1 | 6 |
| **Forearm** | 8 | 1 | 1 |
| **Neck** | 4 | 2 | 4 |
| **Shoulder** | 1 | 5 | 4 |
| **Upper back** | 4 | 3 | 3 |
| **Lower back** | 7 | 1 | 2 |

## 4.4 Correlation analysis

Correlation analysis was used to find out relationships among the collected data by sEMG experiments. In the case of positive linear relationship, the correlation is +1 (perfect increasing) and in the case of perfect decreasing (negative) linear relationship the correlation is -1 (anti-correlation) and the values between +1 and -1 indicate the degree of linear dependence between variables. The coefficient which is closer to either -1 or 1 is stronger correlation between variables. Six variables (average of sEMG activities in 10 minutes of hand, forearm, neck, shoulder, upper back and lower back) correlation in new design and old design have been tested. The old design correlation coefficient is shown in table 4.20. In the old design, 14 out of 15 correlations were positive correlation and 1 were negative.

Table 4.20: Correlation coefficient for old design

| Variable 1 | Variable 2 | Correlation Coefficient |
|---|---|---|
| Hand | Forearm | 0.57 |
| Hand | Neck | 0.922 |
| Hand | Shoulder | 0.844 |
| Hand | Upper back | 0.567 |
| Hand | Lower back | 0.421 |
| Forearm | Neck | 0.306 |
| Forearm | Shoulder | 0.636 |
| Forearm | Upper back | -0.005 |
| Forearm | Lower back | 0.136 |
| Neck | Shoulder | 0.687 |
| Neck | Upper back | 0.782 |
| Neck | Lower back | 0.467 |
| Shoulder | Upper back | 0.447 |
| Shoulder | Lower back | 0.249 |
| Upper back | Lower back | 0.659 |

Table 4.21 shows correlation coefficient for new workstation design which has 11 positive correlations and 4 negative.

Table 4.21: Correlation coefficient for new design

| Variable 1 | Variable 2 | Correlation Coefficient |
|---|---|---|
| Hand | Forearm | 0.377 |
| Hand | Neck | -0.117 |
| Hand | Shoulder | .640* |
| Hand | Upper back | -0.067 |
| Hand | Lower back | 0.068 |
| Forearm | Neck | 0.193 |
| Forearm | Shoulder | 0.466 |
| Forearm | Upper back | -0.19 |
| Forearm | Lower back | -0.447 |
| Neck | Shoulder | 0.432 |
| Neck | Upper back | 0.226 |
| Neck | Lower back | 0.142 |
| Shoulder | Upper back | 0.38 |
| Shoulder | Lower back | 0.457 |
| Upper back | Lower back | .699* |

The relations between variables are decreased after intervention except 2 cases (shoulder-upper back and upper back-lower back).

The highly correlated variables in old and new design where the correlation coefficient is greater than r=0.5 are shown in table 4.22 and 4.23 (Correlation is significant at the 0.05 level).

Table 4.22: Highly correlated variables in old design

| Variable 1 | Variable 2 | Correlation Coefficient |
|---|---|---|
| Hand | Neck | .922** |
| Hand | Shoulder | .844** |
| Neck | Shoulder | .687* |
| Neck | Upper back | .782* |

Table 4.23: Highly correlated variables in new design

| Variable 1 | Variable 2 | Correlation Coefficient |
|---|---|---|
| Hand | Shoulder | .640* |
| Upper back | Lower back | .699* |

The number of correlated variables that their correlation coefficients are greater than r=0.5 between six body regions have been decreased after intervention. Before intervention (old design) the relation between variables is more than after intervention (new design). It means that the relation between the pressures on body regions in new design is decreased.

## 4.5 Linear discriminant analysis (LDA)

The ultimate objective in any pattern recognition issues is separating the two sets of samples to several different classes. Also in this research the independent variables separate into two groups (group 1= old design, group 2= new design).

To predict the categorical variables and to find a linear combination of variables and separates into two classes of workstations the LDA method was used.

The independent variables are average of sEMG activities in 10 minutes of hand, forearm, neck, shoulder, upper back and lower back.

The aim of LDA is to create a discriminant function which shows different output data for different rates.

The result of separating of variables into two workstations by using LDA is shown in table 4.24. In this table coefficient of the linear discriminant function for each workstation design are shown.

Table 4.24: Linear discriminant functions

| Classification Function Coefficients | | |
|---|---|---|
| | Group | |
| **Body region** | **Old** | **New** |
| Hand | -0.0040 | -0.0037 |
| Forearm | 0.0042 | 0.0013 |
| Neck | 0.0041 | 0.0042 |
| Shoulder | -0.0008 | 0.0013 |
| Upper | -0.0017 | -0.0020 |
| Lower | 0.0038 | 0.0021 |
| (Constant) | -8.1607 | -2.5886 |

The classification functions are used to determine to which group each case most likely belongs.

The classification score are applied by the formula:

$$C_i = a_i + w_{ij}*x_{ij} + w_{ij}*x_{ij} + ... + w_{im}*x_m$$

In this formula, the subscript i denotes the respective group; the subscripts 1 denotes old design and 2 denotes new design; $a_i$ is a constant for the $i^{th}$ group, the subscript j denotes the respective average of sEMG (1=/Hand, 2=Forearm, 3=Neck, 4=shoulder, 5= upper back and 6= lower back), $w_{ij}$ is the weight for the $j^{th}$ variable in the computation of the classification score for the $i^{th}$ group; $x_j$ is the average of sEMG average for the $j^{th}$ variable, $S_i$ is the resultant classification score for $i^{th}$ group.

The sEMG activities averages of six body regions in both workstations are shown in tables 4.25 and 4.26.

Table 4.25: Average EMG Activity in 10 minutes old design

| | **Hand** | **Forearm** | **Neck** | **Shoulder** | **Upper back** | **Lower back** |
|---|---|---|---|---|---|---|
| Respondent 1 | 1104.45 | 2714.564 | 1383.028 | 98.082 | 39.946 | 922.238 |
| Respondent 2 | 1067.068 | 1505.53 | 1150.66 | 8.322 | 456.08 | 3110.82 |
| Respondent 3 | 125.842 | 1777.24 | 106.026 | 1350.814 | 82.522 | 1202.908 |
| Respondent 4 | 589.636 | 3708.4 | 157.548 | 1416.96 | 53.38 | 1776.22 |
| Respondent 5 | 3720.92 | 3729.2 | 3723.94 | 3744.94 | 3804.18 | 3776.76 |
| Respondent 6 | 218.83 | 3103.166 | 10.526 | 476.96 | 11.256 | 3911 |
| Respondent 7 | 109.43 | 647.754 | 195.956 | 773.78 | 184.322 | 2054.54 |
| Respondent 8 | 20.46 | 572.848 | 1177.258 | 12.668 | 3917.1 | 3918.68 |
| Respondent 9 | 282.268 | 2140.84 | 680.974 | 12.776 | 16.37 | 872.456 |
| Respondent 10 | 91.618 | 1527.292 | 569.654 | 11.756 | 19.71 | 900.268 |

Table 4.26: Average EMG Activity in 10 minutes new design

| | **Hand** | **Forearm** | **Neck** | **Shoulder** | **Upper back** | **Lower back** |
|---|---|---|---|---|---|---|
| Respondent 1 | 1366.62 | 876.7 | 580.218 | 1251.526 | 13.35 | 1083.406 |
| Respondent 2 | 1111.052 | 1442.142 | 312.772 | 1071.166 | 15.092 | 754.346 |
| Respondent 3 | 761.886 | 809.472 | 983.57 | 1697.38 | 1158.732 | 1913.38 |
| Respondent 4 | 845.658 | 1658.186 | 700.42 | 1668.64 | 1122.962 | 1239.988 |
| Respondent 5 | 61.002 | 1624.34 | 944.678 | 1207.452 | 107.02 | 828.798 |
| Respondent 6 | 921.354 | 1667.596 | 1238.456 | 1517 | 223.016 | 519.238 |
| Respondent 7 | 158.968 | 456.122 | 865.38 | 1245.9 | 877.902 | 1654.748 |
| Respondent 8 | 12.672 | 701.002 | 579.34 | 44.87 | 872.084 | 781.438 |
| Respondent 9 | 64.022 | 797.44 | 738.996 | 11.134 | 17.842 | 694.498 |
| Respondent 10 | 89.334 | 835.974 | 601.358 | 12.326 | 19.494 | 946.088 |

The classification scores for all respondent's EMG activity are shown in table 4.54.

Table 4.27: Classification scores

| Respondents | C1 (old) | C2 (new) |
|---|---|---|
| 1 | 7.870 | -0.184 |
| 2 | 9.776 | -0.565 |
| 3 | 2.548 | 3.706 |
| 4 | 11.206 | 1.913 |
| 5 | 12.940 | 6.438 |
| 6 | 18.580 | 4.049 |
| 7 | 1.830 | 4.429 |
| 8 | 7.478 | 0.650 |
| 9 | 5.775 | 2.777 |
| 10 | 3.606 | 2.673 |

Table 4.27 shows that there are significant differences between classification score in computer workstations. We can use the classification functions to directly compute classification scores for some new observations.

# Chapter 5

# CONCLUSION

Given the infectious spread use of computer in the workplaces and daily life, despite the many benefits of this technology, the prevalence of musculoskeletal disorders are increasing and muscles fatigue as an indicator of progression repetitive injuries of work is considered.

The continually pressure on body regions such as hand, forearm, neck, and shoulder, upper and lower back during working with computer can be lead to musculoskeletal disorders. This study has tried to design a workstation to reduce musculoskeletal strain by analyzing signal processing of sEMG during working with computer.

A new workstation has been designed base on anthropometric data and ergonomic standards. Table 5.1 shows the ANOVA test result briefly. The $F_{critical}$ value for all cases was equal 4.41. In two regions the hypothesis was rejected and in four regions failed to reject and it means there is significant difference between mean of the musculoskeletal discomfort on forearm and lower back in the computer workstation designs and the new workstation design improved ergonomic standards.

Table 5.1: Comparing F ratios of ANOVA test

| Regions | $F_0$ | F crit |
|---|---|---|
| Hand | 0.246 | 4.41 |
| Forearm | 7.30 | 4.41 |
| Neck | 0.201 | 4.41 |
| Shoulder | 0.17 | 4.41 |
| Upper back | 0.623 | 4.41 |
| Lower back | 7.55 | 4.41 |

The Analysis of variance (ANOVA) results confirm that significant changes in the design of computer workstation have validated impact on risk factors of WRMSD.

The charts were used to compare sEMG activities in both workstation and result of charts illustrated that the pressure on body regions of respondents has been reduced by working new computer workstation design. In 27 cases the pressures on body regions in new design were lower than old one for sure (table 5.2). In 13 cases the pressures on body regions in old computer workstation design were lower than new design (table 5.3), and in 20 cases the pressures on body regions were close to each other in both computer workstations approximately.

Table 5.2: Pressure on body regions in new design is lower than old design

| **Respondent** | **Body region** |
|---|---|
| **1** | Forearm - Neck - Upper back |
| **2** | Neck - Upper back - Lower back |
| **3** | Forearm |
| **4** | Forearm - Lower back |
| **5** | Hand - Forearm –Neck - Shoulder -Upper back -Lower back |
| **6** | Forearm - Lower back |
| **7** | Forearm - Lower back |
| **8** | Hand - Neck- Upper back- Lower back |
| **9** | Hand - Forearm- Lower back |
| **10** | Forearm |

Table 5.3: Pressure on body regions in old design is lower than new design

| Respondent | Body region |
|---|---|
| **1** | Shoulder |
| **2** | Shoulder |
| **3** | Hand - Upper back- Lower back |
| **4** | Upper back |
| **5** | No significant body region |
| **6** | Neck - Shoulder- Upper back |
| **7** | Neck - Shoulder |
| **8** | Forearm - Shoulder |
| **9** | No significant body region |
| **10** | No significant body region |

The correlation analysis confirms that the relations between sEMG activities in new design are less than old design. After intervention the number of correlated variables with correlation coefficients greater than r=0.5 have been decreased from 4 (hand-neck, hand-shoulder, neck-shoulder and neck upper back) to 2 (hand-shoulder, upper back-lower back) between six body regions. Discriminant analysis shows that the original grouped cases correctly classified and there are significant differences between classification score in computer workstations.

This study is based on scientific anthropometric data and ergonomic rules, which can be used by computer workstation designers to help provide an optimum design for computer users. An engineer who is familiar with efficient anthropometric data and standards of workstation ergonomics should be consulted by workstation designers for corroboration recommendations.

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