2

Work-Related Musculoskeletal Discomfort in the Shoulder due to Computer Use

Orhan Korhan
Department of Industrial Engineering, Eastern Mediterranean University, North Cyprus, Mersin
Turkey

1. Introduction

The National Institute for Occupational Safety and Health (NIOSH, 1997) in the USA defines Musculoskeletal Disorder (MSD) as a disorder that affects a part of the body's musculoskeletal system, which includes bones, nerves, tendons, ligaments, joints, cartilage, blood vessels and spinal discs. These are the injuries that result from repeated motions, vibrations and forces placed on human bodies while performing various job actions. The individual factors that can contribute to musculoskeletal symptoms include heredity, physical condition, previous injury, pregnancy, poor diet, and lifestyle.

Work-related musculoskeletal disorders occur when there is a mismatch between the physical requirements of the job and the physical capacity of the human body (Korhan, 2010). Musculoskeletal disorders are work-related when the work activities and work conditions significantly contribute to their occurrence, but not necessarily the sole or significant determinant of causation. Work-related musculoskeletal disorders (WRMSDs) describe a wide range of inflammatory and degenerative conditions affecting the muscles, tendons, ligaments, joint, peripheral nerves, and supporting blood vessels. These conditions result in pain and functional impairment and may affect especially the shoulder (Westgaard, 2000).

The causes of musculoskeletal disorders in the workplace are diverse and poorly understood. The meaning that working has to an individual may help to explain why certain psychological factors are associated with musculoskeletal discomfort and may eventually provide one way to intervene to reduce WRMSD (Mekhora et al., 2000) .

Musculoskeletal disorders have been observed and experienced widely at workplaces where the computers are frequently used. Increase in the number of employees working with computer and mouse coincides with an increase of work-related musculoskeletal disorders (WRMSDs) and sick leave, which affects the physical health of workers and pose financial burdens on the companies, governmental and non-governmental organizations (Korhan and Mackieh, 2010).

WRMSDs cover a wide range of inflammatory and degenerative diseases of the locomotor system, such as inflammations of tendons, pain and functional impairments of muscles, compression of nerves, and degenerative disorders occurring especially in the shoulder region due to occupations with large static work demands [European Agency for Safety and Health at Work (EU-OSHA), 2008].

The multifactorial causation of WRMSDs is commonly acknowledged. Different groups of risk factors including physical and mechanical factors, organizational and psychosocial factors, and individual and personal factors may contribute to the genesis of WRMSDs (EU-OSHA, 2008). Repetitive handling at high frequency, awkward and static postures, demanding and straining work and lack of recreation times, high time pressure, frequently overtime hours, repetitive or monotonous work, reduced physical capacity, obesity, and smoking are all the risk factors that contribute to WRMSDs either each one solely or by interacting each other.

WRMSDs largely affect the back (45%), and upper limb (37%); it is less common to suffer lower limb disorder (18%) (Health and Safety Executive, 2005). Work situations across all industries are implicated, particularly those involving use of the upper limbs, including computer work (Oakley, 2008).

This chapter presents the risk factors that contribute to musculoskeletal disorders in shoulders resulting from intensive use of computers in the workplaces. The risk factors of musculoskeletal disorders were revealed by assessing and analyzing workplace ergonomics, worker attitudes and experiences on the use of the computer keyboard and mouse. This was followed by an experimental data collection of muscle load, muscle force and muscular fatigue from the shoulder by Surface electromyogram (sEMG) to validate and verify the developed mathematical model.

Epidemiological studies in the literature confirmed that the work which is related with computer use brings higher risk for the development of musculoskeletal symptoms. Evans and Patterson (2000) tested the hypothesis that poor typing skill, hours of computer use, tension score and poor workstation setup are associated with neck and shoulder complaints, and they found out that tension score and gender were the only factors to predict neck and shoulder pain.

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.

Moreover, Karlqvist et al. (2002) concluded that for both genders the duration of computer work was associated with the musculoskeletal disorder symptoms, and women are at more risk of exposure to such disorder as they have less variability in work tasks.

Fogleman and Lewis (2002) studied the risk factors associated with the self-reported musculoskeletal discomfort in a population of video display terminal (VDT) operators, where their results indicated that there is a statistically significant increased risk of discomfort on each of the body regions (head and eyes, neck and upper back, lower back, shoulders, elbows and forearms, and hands and wrists) as the number of hour of keyboard use increases.

Blatter and Bongers (2002) studied the association of the effect of the gender differences with physical work factors as well as with the psychosocial factors. However their results showed that psychosocial factors were not related with the duration of computer use, whereas computer work of more than 6 hours per day was associated with musculoskeletal symptoms in all body regions of men, and computer work of more than 4 hours per day entailed the association with musculoskeletal disorders in women. Intensive computer use is associated with an increased risk of neck, shoulder, elbow, wrist and hand pain, paresthesias and numbness. Repetition, forceful exertions, awkward positions and localized contact stress are associated with the development of upper limb cumulative trauma in computer users.

Ming and Zaproudina (2003) showed that the repetitive computer use causes cumulative trauma on neck, shoulder, arm and hand muscles and joints.

In their model, Carayon et al. (1999) stipulated that psychosocial work factors (e.g. difficulty of job, working with deadlines, supervisor's pressure, lack of control), which can cause stress, might also influence or be related to ergonomic factors such as force, repetition, and posture that have been identified as risk factor for WRMSDs.

Peper et al. (2003) reviewed the ergonomic and psychosocial factors that affect musculoskeletal disorders at the workstation, and their results showed that there was a significant difference in right forearm extensor-flexor muscle tension and in right middle trapezius muscle tension between type tasks and rest.

Shuval and Donchin (2005) examined the relationship between ergonomic risk factors and upper extremity musculoskeletal symptoms in VDT workers, by taking into account individual and work organizational factors, and stress. Their results of RULA (Rapid Upper Limb Assessment) observations indicated that there were no acceptable postures of the employees whom were exposed to excessive postural loadings.

2. Methodology

2.1 Objectives

This research addresses worker perception and attitudes towards computer use, and their experiences with musculoskeletal symptoms in the shoulder and their diagnoses. The primary aim of this chapter is to present an in-debt assessment of the relationship between work-related musculoskeletal disorders in the shoulder and computer use. This study illustrates the idea of understanding how demographic structure (gender, age, height, and weight) physical and psychosocial job characteristics, office ergonomics, perceived musculoskeletal discomfort types and their frequencies may affect formation of musculoskeletal disorders in the shoulder. It then provides the evidence on the symptoms of musculoskeletal discomfort types and the frequency of these discomforts which are significant in the development of WRMSDs in the shoulder due to computer use.

The relevance of this study to the industry is to reduce the work-related musculoskeletal disorders associated with the intensive, repetitive and long period computer use that affect the shoulder. The developed risk assessment model also provides guidance for solving problems related to costly health problems (direct cost), lost productivity (indirect cost), and relieving the imposed economic burden.

As a summary, the research objectives of this study are:

- To assess and analyze workplace ergonomics, worker attitudes and experiences on computer use, and musculoskeletal symptoms in the shoulder developed by computer use,

- To determine a meaningful and statistically significant relationship between work-related musculoskeletal disorders in the shoulder and computer use, and develop a risk assessment model,
- To validate and verify the developed mathematical model through analysis of the data collected by the sEMG recordings.

2.2 Questionnaire

A questionnaire (see appendix) was developed based on the U.S. *National Institute for Occupational Safety and Health* (NIOSH) Symptoms Survey (NIOSH, 2011) and the Nordic Musculoskeletal Questionnaire (Dickinson et al., 1992). The questionnaire included questions in 7 modules according to the type of the questions. The questions were related with the demographic structure of the participant, physical job characteristics, psychosocial job characteristics, office ergonomics (workstation setup), types of musculoskeletal discomforts experienced at the shoulder, frequency of the musculoskeletal discomforts in the shoulder, and personal medical history.

The instrument was designed specifically for the current work. We are not aware of such an instrument being used for this purpose. In order to prevent any misunderstanding, the respondents were assisted at the time of answering the questionnaire.

2.3 Risk assessment model

In order to determine a meaningful and statistically significant relationship between work-related musculoskeletal disorders and computer use, a risk assessment model needs to be developed.

Logistic Regression Analysis was used to determine a meaningful and statistically significant relationship between shoulder discomfort and computer use, as a risk assessment model. The Logistic Regression was used since many of the independent variables were qualitative and the normality of residuals could not be guaranteed.

Our dependent variable was the WRMSD diagnosis made by a medical doctor (dichotomous dependent variable), and the independent variables were the rest of the variables in the questionnaire.

2.4 Experimentation

The respondents of the questionnaire, who have experienced musculoskeletal symptoms, were invited to a lab experiment, where surface electromyogram (sEMG) was used to record muscle load, muscle force and muscular fatigue. This test took place in two phases;

i. interrupting the work and performing test contractions of known force in a predetermined body posture and,
ii. comparing situations connected with a certain reference activity.

Before conducting the sEMG experiment, those respondents who were under high risk of having WRMSDs in the shoulder were identified using logistic regression. The significance level in logistic regression analysis was chosen to be 5% in order to minimize the possibility of making a Type I error. An independent variable with a regression coefficient not significantly different from 0 ($p>0.05$) can be removed from the regression model. If $p<0.05$ then the variable contributes significantly to the prediction of the outcome variable (Pampel, 2000).

Odd ratios of the significant factors for each respondent were calculated to find out respondents who were at the risk of having WRMSDs in the shoulder, as given below:

If χ_i's (i= 1,2,…) are independent variables, then the odds ratio is defined as

$$log\left[\frac{Prob\left(diagnosis\ of\ WRMSD\right)}{Prob\left(NOT\ diagnosis\ of\ WRMSD\right)}\right] = \beta_0 + \beta_1\chi_1 + \beta_2\chi_2 + ...$$

Where β_0 is the intercept, and $\beta_1, \beta_2, ...$ are the regression coefficients. Thus, we have $\text{Odds Ratio} = e^{(\beta_0 + \beta_1\chi_1 + \beta_2\chi_2 + ...)}$

In order to determine the respondents under high risk of having WRMSDs in the shoulder, the odds ratios of the significant factors for each respondent were calculated and those respondents who reflected maximum levels of odds ratios for each significant factor were invited for further investigation through electromyography.

Surface electromyogram was used to collect data from the shoulder. The procedure for the experimentation was as follows; twenty minutes typing exercise was given to each respondent at a time. Each respondent was asked to type a given standard text. Data were collected at 5th, 10th, 15th, and 20th minutes of the experiment. The mean value of the data collected for 30 seconds was then calculated and taken into consideration.

Analysis of Variance (ANOVA) and Factorial Analysis were applied at the end to the data collected by sEMG recordings, to validate and verify the significant risk factors of WRMSDs in the shoulder which were determined by logistic regression.

2.5 Respondents

A questionnaire was given to 130 people, who worked intensively with the computers for work/business purposes, such as; staff, research assistants and faculty members of Eastern Mediterranean University (EMU), web page designers, computer programmers, engineers, government officers, public relation officers, marketing officers, bank officers, customer representatives, commissioners, consultants, travel agents and translators. The reason for targeting such diverse disciplines was that the target population is expected to use computers intensively especially for work/business purposes and several other auxiliary purposes including personal and communication. Thus, the results were guaranteed not to be task-related, instead work-related.

3. Results

3.1 Descriptive statistics

Seventy male respondents (53.85%) attended this research. Males appeared to be dominating the female respondents (60, 46.15%). 107 (82.31%) of the 130 participants were between 20 to 35 years old.

40 respondents (30.77%) reported that their height were between 1.61-1.70 meters, which is followed by the height intervals 1.81-1.90 meters (35 respondents, 26.95%), and 1.71-1.80 meters (34 respondents, 26.15%).

The keyboard and mouse were reported to be the most popular (90.77%) input devices, whereas only 12 (9.23%) of the 130 respondents were using touchpad, keypad and trackball as primary input devices. Moreover, 88.43% of the respondents were using regular (Q-type) keyboards, 3.31% were using F-type keyboards, and 4.96% were using ergonomic (with wrist support) keyboards. Additionally, 72.31% of the respondents were using desktop and 27.69% of the respondents were using laptop computers.

Regarding the keyboard use, it was found that 55.04% of the respondents have been using keyboard for 10 or more years, and 37.98% have been using keyboard for at least 5 years.

Around 24.62% of the respondents reported their daily keyboard use as 5-6 hours per day, 23.85% of them as 7-8 hours per day, and 36.15% of them as more than 8 hours per day.

The results of the questionnaire indicated that 79.84% of the respondents found their job interesting, where 20.16% of the respondents indicated that they did not find their job interesting. Additionally, 74.42% of the respondents mentioned that their job gives them personal satisfaction; however 25.58% of the respondents mentioned that they were not having personal satisfaction from their job. A very high majority of the respondents (90.62%) reported that they have “good” relationship with their supervisor/advisor, where 9.38% reported that they have “not good” relationship with their supervisor/advisor.

More than two thirds of the respondents indicated that they share their office, where 35.66% share the office with more than three people, and 33.33% share the office with three or less people. On the other hand, 31.01% reported that they have their own office.

Majority of the respondents (84.38%) reported that they like their office environment, whereas 15.62% of the respondents reported that they do not like their office environment. Addition to this, a very high majority (94.57%) of the respondents indicated that they like working with computers, however only 5.43% of the respondents indicated that they do not like working with computers.

Most of the respondents (64.04%) reported that they have a stressful job, but 35.94% of the respondents reported that they do not have a stressful job. It was observed that, 48.84% of the respondents think that they have enough rest breaks, and 51.16% of the respondents do not think that they have enough rest breaks. Additionally, 46.88% of the respondents have repetitive (static) jobs, whereas 53.12% of the respondents have non-repetitive (dynamic) jobs.

Only 18.60% of the respondents were smokers when they answered the questionnaire, and 81.40% of the respondents were not smokers. More than half of the smoker respondents (63.41%) reported that they were smokers during the previous year, and 36.59% of the respondents were not smokers during the previous year.

Table 2 shows the results obtained on the workstation ergonomics. The results show that 56.92% of the respondents lean back to support their vertebrae, 67.69% reported that their feet were comfortable in the front, 81.54% stated that their seat and hands were centered on the keyboard, more than half (50.77%) of the respondents sit symmetrically, 79.23% use keyboard at the fingertips, 77.69% have the keyboard and the mouse at the same level, 80.62% of the respondents' screens were about arm length away from their eyes, 65.38% had the monitors at the eye level, 72.87% had sufficient lighting without glare, 78.46% had neutral wrist position, and 64.62% had neutral head and neck position.

However, the majority of the respondents didn't take into consideration of having 90^0 angle between the shoulders and the elbows. They did not care about sitting symmetrically at all, and they usually (73.64%) talked on the phone by having the handset between the head and the shoulder. Elbow, arm or leg supports also were not available in the respondents' workstations. Moreover, the majority of the respondents (78.46%) were not trained in posture (table 1).

Office Ergonomics	**Yes (%)**	**No (%)**
Lean back to support vertebrae	56.92	43.08
Elbows form 90 degrees flexion from shoulder	41.54	**58.46**
Feet are comfortable in the front of the chair	67.69	32.31
Seat and hands are centered on the keyboard	81.54	18.46
Sit symmetrically	50.77	49.23
Keyboard are at the fingertips	79.23	20.77
Keyboard and mouse are at the same level	77.69	22.31
Screen is arm length away from the eyes	80.62	19.38
Monitor is at the eye level	65.38	34.62
Sufficient lighting available, no glare	72.87	27.13
Talk on phone between head and shoulder	26.36	**73.64**
Neutral wrist position	78.46	21.54
Neutral head and neck position	64.62	35.38
Elbow and arm support available	48.84	**51.16**
Leg support available	25.58	**74.42**
Change sitting position every 15 min	57.69	42.21
Take active breaks	55.38	44.62
Take frequent microbreaks	45.38	**54.62**
Trained in posture	21.54	**78.46**

Table 1. Office ergonomics (n = 130).

Table 2 shows that the most prevalent discomfort experienced was having ache in the shoulder (46.15%). Discomfort (feeling of pain) was observed to be the next prevalent discomfort after ache. It was reported by the respondents that 34.62% of them were experiencing pain in the shoulder. Heaviness was reported by 17.69% of the respondents in the shoulder, and 9.23% of the respondents stated that they have a tightness in their shoulder. Having weakness was reported by 8.46% of the respondents in the shoulder, and having cramp in the shoulder was reported by 6.15%. Feeling of numbness was reported by 3.85% of the respondents and 3.08% of them reported tingling in their shoulder. Feeling hot and cold in the shoulder was reported by 2.31% of the respondents, and only 1.54% reported swelling in their shoulder.

	Percent Occurrence
Ache	46,15
Pain	34,62
Cramp	6,15
Tingling	3,08
Numbness	3,85
Heaviness	17,69
Weakness	8,46
Tightness	9,23
Feeling Hot and Cold	2,31
Swelling	1,54

Table 2. Type of discomfort and percent occurrence in the shoulder.

Therefore, the discomfort feelings of ache and pain were the most common types of discomforts which are experienced at the shoulder.

Table 3 shows the frequency of the discomforts experienced by the respondents.

	Never (%)	Rarely (%)	Sometimes (%)	Often (%)	Very Often (%)
Shoulder	8.46	10.77	26.92	17.69	12.31

Table 3. Frequency of discomfort.

Among the 130 respondents, 17 had a recent accident and 6 of those had this accident within 12 months (4.62% of the whole population). Also, 23 respondents reported that they had diagnosed with a work-related musculoskeletal disorder by a medical doctor, and 11 (8.46% of the whole respondents) of the sufferers reported this diagnosis had been made within the last 12 months.

Additionally, 4 respondents (3.08%) reported that they were diagnosed with rheumatoid arthritis, 1 respondent (0.77%) with diabetes, 4 respondents (3.08%) with thyroid disease, 8 respondents (6.15%) with pinched nerve. Moreover, 3 respondents were pregnant and 14 respondents with other medical symptoms and none of the respondents reported that they were diagnosed with hemophilia.

It was reported by the respondents that, 41 (31.54%) of them exercise never/rarely, 57 (43.85%) sometimes, 25 (19.23%) often, and only 7 (5.38%) of them exercise very often. Moreover, 91 of the respondents (70%) stated that they were involved in sport activities, and 39 of them (30%) reported that they were not involved in any kind of sport activities. More than half of the respondents (76, 58.46%) reported that they were involved in walking as sport activity, 17 of the respondents (13.08%) did jogging, 15 (11.54%) of them played football, 4 (3.08%) of them played basketball, 5 (3.85%) of them played volleyball, 10 (7.69%)

of them played tennis, 26 (20.00%) did swimming, and 27 (20.77%) involved in other sport activities.

3.2 Data analysis

Table 4 shows that only one of the above ergonomics factors, using keyboard and mouse at the same level (p=0.038<0.05) was found to be significant predictors of WRMSDs in the shoulder for the collected data.

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	7.02755	2.19910	3.20	0.001			
Elbow for 90^0	-0.720072	0.584639	-1.23	0.218	0.49	0.15	1.53
Sit symmetrically	0.0280327	0.594662	0.05	0.962	1.03	0.32	3.30
Centered hands	-0.513098	0.635498	-0.81	0.419	0.60	0.17	2.08
Monitor at eye level	-0.600702	0.524867	-1.14	0.252	0.20	0.55	1.53
Same level	-1.12705	0.544516	-2.07	0.038	0.11	0.32	0.94
Fingertips	-0.598543	0.542812	-1.10	0.270	0.55	0.19	1.59
Change sitting position	-0.421873	0.513102	-0.82	0.411	0.66	0.24	1.79
Elbow/arm support	0.271838	0.521752	0.52	0.602	1.31	0.47	3.65
Awkward tel use	-0.288873	0.600352	-0.48	0.630	0.75	0.23	2.43

Table 4. Logistic Regression of Ergonomic Factors that affects the Shoulder.

Table 5 shows that ache in the shoulder (p=0.024<0.05), pain in the shoulder (p=0.019<0.05), and having tightness in the shoulder (p=0.038<0.05) were found to be significant predictors of WRMSDs in the shoulder for the collected data.

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	2.16707	0.407966	5.31	0.000			
Ache	-0.473919	0.532888	-0.89	0.024	0.62	0.22	1.77
Pain	-0.673783	0.547809	-1.23	0.019	0.51	0.17	1.49
Cramp	0.137425	1.24328	0.11	0.912	1.15	0.10	13.12
Tingling	17.9883	14439.0	0.00	0.999	64896260.75	0.00	*
Numbness	19.9041	13118.6	0.00	0.999	4.40812E+08	0.00	*
Heaviness	-0.472714	0.631196	-0.75	0.454	0.62	0.18	2.15
Weakness	0.313680	1.04407	0.30	0.764	1.37	0.18	10.59
Tightness	-0.721157	0.752196	-0.96	0.038	0.49	0.11	2.12
Felling Hot&Cold	-0.609979	1.52017	-0.40	0.688	0.54	0.03	10.69
Swelling	-0.522971	1.66041	-0.31	0.753	0.59	0.02	15.35

Table 5. Logistic Regression of Feelings of Discomforts in the Shoulder.

Table 6 shows that often in the shoulder (p=0.022<0.05) was found to be significant predictors of WRMSDs for the collected data.

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	2.23359	0.607493	3.68	0.000			
Neck Never	-0.729515	0.990030	-0.74	0.461	0.48	0.07	3.36
Neck Rarely	-1.31730	0.847967	-1.55	0.120	0.27	0.05	1.41
Neck Sometimes	-0.185899	0.807035	-0.23	0.818	0.83	0.17	4.04
Neck Often	-1.19214	0.771063	-1.55	0.022	0.30	0.07	1.38
Neck Very Often	-1.13498	0.838082	-1.35	0.176	0.32	0.06	1.66

Table 6. Logistic Regression of Frequency of Discomforts in the Shoulder.

3.3 Experimental results

After developing the risk assessment model, the model should be validated and be verified. Towards this end, we have to first identify those respondents under risk. Then, the data analysis of the surface EMG recordings is supposed to provide the validation and verification.

Odds ratios for each significant factor determined by the logistic regression analysis were calculated and those respondents who have higher odds ratios for each factor were identified.

It was observed that fifteen respondents were under risk of having WRMSDs according to the results of odds ratio analysis. However, only six of the fifteen respondents were able to be contacted and invited to the sEMG data collection experiment. That group of six respondents formed the test group, and among the non-risk respondent group, six more respondents were invited to form the control group.

In the sEMG experiment, muscular activity in the shoulder (posterior deltoid) was recorded by using sEMG device (MyoTrac Infiniti, model SA9800). The procedure for the experimentation is as follows; 20 minutes typing exercise was given to each respondent at a time. Data were collected at 5th, 10th, 15th, and 20th minutes of the experimentation. The mean value of the collected data for 30 seconds is then calculated and taken into consideration.

3.3.1 Test group experimental results

The readings from sEMG provides the information about the muscle activity in the shoulder over time. Table 7 illustrates the mean value for each 30 seconds interval readings for each test group respondent.

The muscle activity is converted to μV by sEMG and is shown on the vertical axis, and time is shown on the horizontal axis in minutes (figure 1). Figure 1 illustrates that test group respondents have significantly high levels of muscle activities. There was a very significant

Muscle Activity Test Group	minutes			
	5	10	15	20
Respondent 1	319,8833	322,0783	333,4917	317,1383
Respondent 2	53,21833	51,12833	47,17	44,79333
Respondent 3	65,14167	277,8717	494,045	824,7967
Respondent 4	22,12667	21,44167	21,48833	23,85333
Respondent 5	510,13	346,92	571,84	232,0767
Respondent 6	135,7283	89,59	78,91833	53,97667

Table 7. Muscle activities (μV) of the test group respondents at the shoulder.

increase in the shoulder muscle activity of the test group respondent 3 throughout the experiment. Test group respondent 5 has been suffering from discomforts at the shoulder very significantly more than that of the other 5 respondents. Test group respondent 1 was experiencing almost a constant shoulder muscle activity during the experiment. The test group respondent 6 was observed to have a decreasing muscle activity during the experiment.

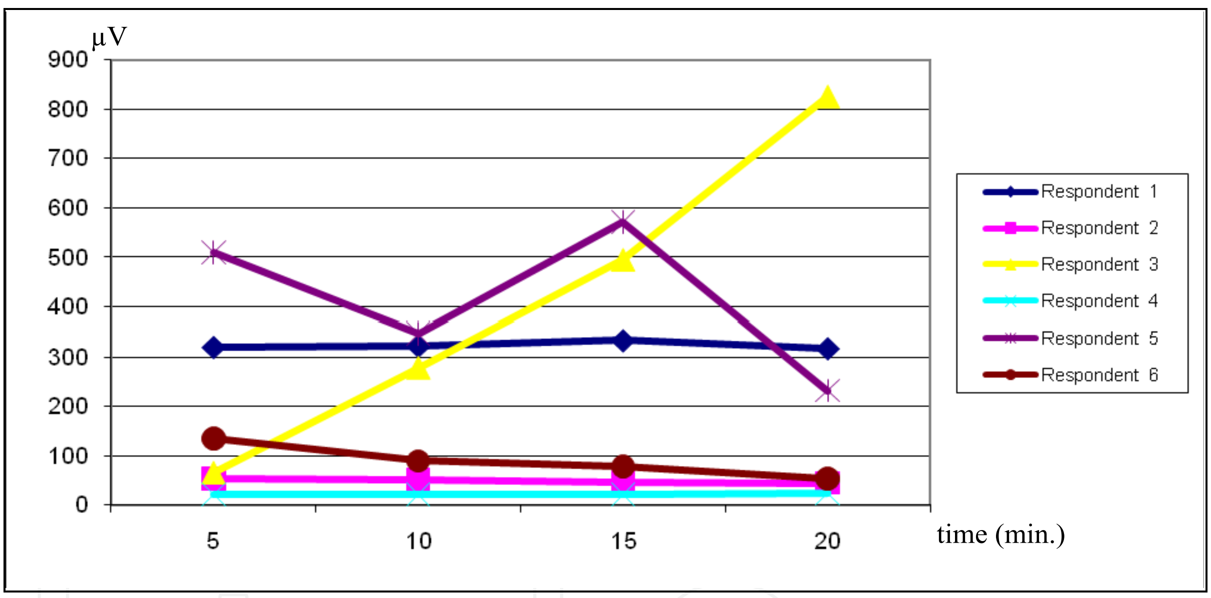


Fig. 1. Muscle activity recordings in the shoulder of test group respondents.

Table 8 shows the ANOVA results for the test group respondents.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	689220,1	5	137844	6,348314	0,001455	2,772853
Within Groups	390842,7	18	21713,48			
Total	1080063	23				

Table 8. ANOVA results for the test group respondents.

$F_0 = 6.348314 > F_{0.05,5,18} = 2.77$; therefore, reject H_o.

Where;
H_0 = mean musculoskeletal strain (in time) of the 6 respondents does not differ, and
H_1 = mean musculoskeletal strain (in time) of the 6 respondents does not differs.

The results obtained by ANOVA indicate that, the risk assessment model developed has been validated and verified with the data collected through sEMG recordings.

3.3.2 Control group experimental results

The control group respondents were selected among the group of respondents who were not under risk according to the odds ratios.

Table 9 illustrates the mean value for each 30 seconds interval sEMG readings for each control group respondent.

Muscle Activity Control Group	**minutes**			
	5	**10**	**15**	**20**
Respondent 1	27,472	50,831	56,273	47,397
Respondent 2	19,11096	40,57785	62,46581	52,06078
Respondent 3	21,88277	58,33066	46,04155	81,68634
Respondent 4	25,374	33,002	176,6562	134,322
Respondent 5	22,978	89,7946	94,56764	162,2307
Respondent 6	19,69543	28,87675	28,62042	74,83737

Table 9. Muscle activities (µV) of the control group respondents at the shoulder.

Figure 2 illustrates that control group respondents' muscle activities do not significantly differ from each other and these readings were not at high levels. Moreover, the muscle activities of the control group respondents 4 and 5 showed slight but not significant increase throughout the experiment.

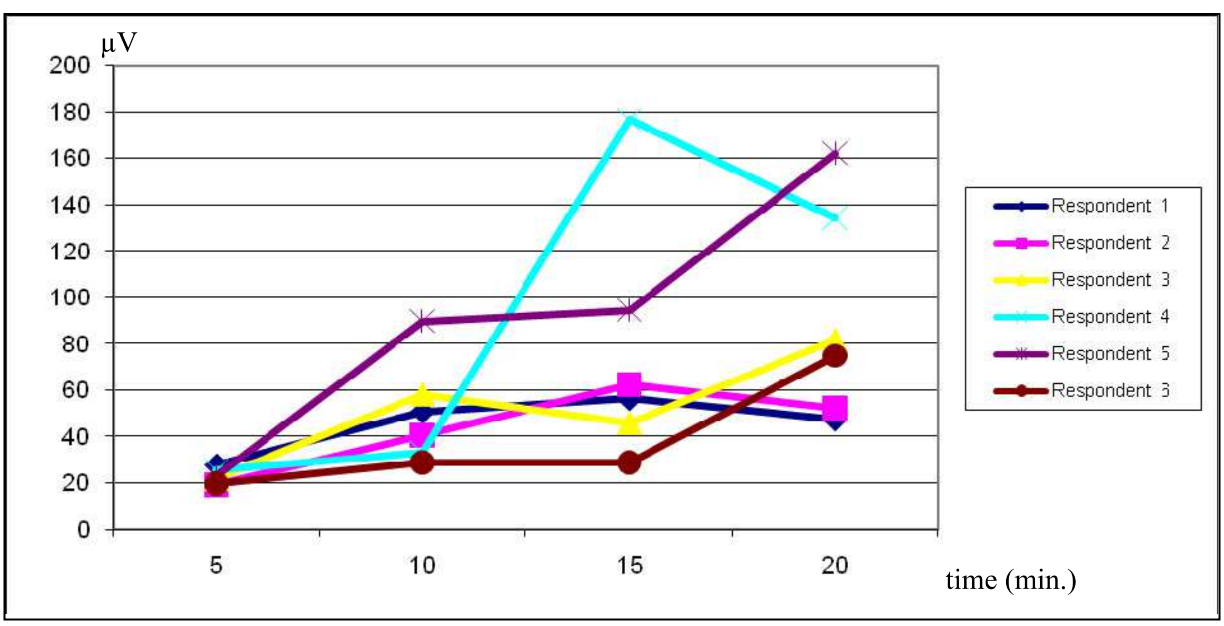


Fig. 2. Muscle activity recordings in the shoulder of control group respondents.

Table 10 shows the ANOVA results for the control group respondents.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	12486,11	5	2497,222	1,41259	0,266916	2,772853
Within Groups	31820,97	18	1767,832			
Total	44307,08	23				

Table 10. ANOVA results for the control group respondents.

$F_0 = 1.\ 12594 < F_{0.05,5,18} = 2.77$; therefore, fail to reject. H_o ,

Where;
H_0 = mean musculoskeletal strain (in time) of the 6 respondents does not differ, and
H_1 = mean musculoskeletal strain (in time) of the 6 respondents does not differs.

The results of the ANOVA for each control group respondent indicate that, the mean musculoskeletal strain that they experience does not differ in time. That is, the musculoskeletal strain at their shoulder do not differ as those in the test group respondents.

ANOVA results for the control group respondents support the risk assessment model developed to determine the risk factors of WRMSDs.

4. Conclusion

Most of the studies on the formation of WRMSDs during computer use have been focused on the gender differences, physical and psychological aspects of the user and have not yet considered extra-rational factors such as the perceived musculoskeletal discomfort types and their frequencies. This study presents the idea of understanding how office ergonomics, perceived musculoskeletal discomfort types and their frequencies may affect formation of musculoskeletal disorders at the shoulder.

After collecting data from 130 respondents, the significant findings related with discomfort in shoulder during computer use were:

- Using keyboard and mouse at the same level [OR=0.11, CI: 0.32-0.94]
- Ache in the shoulder [OR=0.62, CI: 0.22-1.77]
- Pain in the shoulder [OR=0.51, CI: 0.17-1.49]
- Having tightness in the shoulder [OR=0.49, CI: 0.11-2.12]
- Often in the neck [OR=0.30, CI: 0.07-1.38]

This study provided the evidence that, for the study groups tested and for the given computer use activity, ache and pain are the most common types of the discomforts in the shoulder. Also, this study showed that the mean musculoskeletal strain at the shoulder of test group respondents differ in time, whereas for each control group respondent, the mean musculoskeletal strain that they experience, does not differ in time.

5. Appendix: Questionnaire

Name, Surname: Occupation:

Tel no: E-mail:

1. What is your gender?

☐ Male ☐ Female

2. What is your age?

☐ 20-25

☐ 26-30

☐ 31-35

☐ 36-40

☐ 41-45

☐ 46-50

☐ Older than 50

3. How tall are you in meters?

☐ Shorter than or equal to 1.50

☐ 1.51-1.60

☐ 1.61-1.70

☐ 1.71-1.80

☐ 1.81-1.90

☐ 1.91-2.00

☐ Taller than 2.00

4. How much do you weigh in kilograms?

☐ Less than or equal to 50

☐ 51-60

☐ 61-70

☐ 71-80

☐ 81-90

☐ 91-100

☐ More than 100

5. What type of *computer* do you mostly use? (mark only one)

☐ Desktop

☐ Laptop

☐ PDA (Personal Digital Assistant) / Pocket PC

☐ Mainframe

☐ Minicomputer

☐ Server

6. What type of computer input devices do you mostly use? (mark only one)

☐ Keyboard and mouse

☐ Touchpad and keypad

☐ Trackball

☐ Touch pen

☐ Joystick and joypad

7. Typically, how much time daily in total you spend typing on a computer keyboard or using a mouse?

☐ Less than 1 hour

☐ 1-2 hours

☐ 3-4 hours

☐ 5-6 hours

☐ 7-8 hours

☐ More than 8 hours

8. Overall, how many years have you been using computers?

☐ Less than 1 year

☐ 1-2 years

☐ 3-4 years

☐ 5-9 years

☐ More than 10 years

9. What type of computer *keyboard* you mostly use? (mark only one)

☐ Regular (Q-type)

☐ Regular (F-type)

☐ Ergonomic (with wrist support)

☐ Other (Please specify)

10. Do you think you have an interesting job?

☐ Yes ☐ No

11. Does your current job give you *personal* satisfaction?

☐ Yes ☐ No

12. How do you define your relationship with your current supervisor/advisor?

☐ Good ☐ Not good

13. In what kind of office environment you work?

☐ I share the office with more than 3 people

☐ I share the office with 3 or less people

☐ I have my own office

14. Do you like your office environment?

☐ Yes ☐ No

15. Do you like working with computers?

☐ Yes ☐ No

16. Do you think you have a stressful job?

☐ Yes ☐ No

17. What kind of job you have?

☐ Repetitive (Static) ☐ Non-repetitive (Dynamic)

18. Do you think you have enough rest breaks?

☐ Yes ☐ No

19. Do you currently smoke?

☐ Yes ☐ No

If "Yes", have you been smoking in the last year?

☐ Yes ☐ No

The questions in the table below are related with your working posture. Mark with "Yes" if the statement is applicable, mark with "No", if it is not applicable with your working posture.

	YES	NO
20. Lean back in chair to support your vertebrae	☐	☐
21. Elbows form a 90 degree angle while hanging at sides from the shoulders	☐	☐
22. Feet are comfortable on the floor in front of you	☐	☐
23. Your seat and your hands are centered on the keyboard	☐	☐
24. Sit symmetrically (not bending either sides)	☐	☐
25. The keyboard and the mouse are at the fingertips	☐	☐
26. The keyboard and the mouse are on the same level (side by side)	☐	☐
27. The screen is about an arm's length away from the eyes	☐	☐
28. The top of the monitor is at the eye level	☐	☐
29. Sufficient lightening available without glare from lights, windows, surfaces, and etc…	☐	☐
30. Frequent use of telephone between head and shoulder	☐	☐
31. Neutral position of the wrist (straight from fingers to the elbow)	☐	☐
32. Neutral position of the head and the neck	☐	☐
33. Elbow/arm support provided for intensive/long durations	☐	☐
34. Leg support provided for intensive/long durations	☐	☐
35. Change sitting position at least every 15 minutes	☐	☐
36. Take active breaks (phone call, file paper, drink water, etc…) every 30 minutes	☐	☐
37. Take frequent microbreaks (while seated on your workstation)	☐	☐
38. Trained in proper posture	☐	☐

39. During the last 12 months, have you experienced, *while using a keyboard or a mouse*, the following symptoms in the following body regions? (mark all that apply)

	Neck	Shoulder	Elbow/ forearm	Hand/ wrist	Finger	Upper back	Lower back
Ache	☐	☐	☐	☐	☐	☐	☐
Pain	☐	☐	☐	☐	☐	☐	☐
Cramp	☐	☐	☐	☐	☐	☐	☐
Tingling	☐	☐	☐	☐	☐	☐	☐
Numbness	☐	☐	☐	☐	☐	☐	☐
Heaviness	☐	☐	☐	☐	☐	☐	☐
Weakness	☐	☐	☐	☐	☐	☐	☐
Tightness	☐	☐	☐	☐	☐	☐	☐
Feeling Hot & Cold	☐	☐	☐	☐	☐	☐	☐
Swelling	☐	☐	☐	☐	☐	☐	☐

40. How often have you experienced those symptoms? (mark all that apply)

	Never	Rarely	Sometimes	Often	Very Often
Neck	☐	☐	☐	☐	☐
Shoulder	☐	☐	☐	☐	☐
Elbow/forearm	☐	☐	☐	☐	☐
Hand/wrist	☐	☐	☐	☐	☐
Finger	☐	☐	☐	☐	☐
Upper back	☐	☐	☐	☐	☐
Lower back	☐	☐	☐	☐	☐

41. Have you had any recent accident?

☐ Yes ☐ No

If "Yes", when?

☐ Within 1 year

☐ More than 1 year

42. Have you been diagnosed with any of the following medical symptoms? (mark all that apply)

☐ Yes ☐ No

If "Yes", which one(s)?

☐ Rheumatoid *arthritis*

☐ Diabetes

☐ Tyroid disease

☐ Hemophilia

☐ Pinched nerve

☐ Recent pregnancy

☐ Other, please specify

43. Have you been diagnosed by a medical doctor with work-related musculoskeletal disorders (herniated disk, carpal tunnel syndrome, tendonitis, etc…)?

☐ Yes ☐ No

If "Yes", have you been diagnosed within 12 months?

☐ Yes

☐ No

If "No", has a medical doctor ever told you that you are at risk for work-related musculoskeletal disorders?

☐ Yes ☐ No

44. Do you exercise?

☐ Never or rarely ☐ Sometimes ☐ Often ☐ Very often or constantly

45. Are you involved in any of the following sport activities?

☐ Yes ☐ No

If "Yes", which one(s)? (mark all that apply)

☐ Walking ☐ Football ☐ Basketball ☐ Swimming

☐ Jogging ☐ Volleyball ☐ Tennis Other, please specify

6. References

Blatter, B. M., Bongers, P. M. (2002). Duration of computer use and mouse use in relation to musculoskeletal disorders of neck or upper limb. *International Journal of Industrial Ergonomics*, Vol. 30, 295-306, ISSN 0169-8141.

Carayon, P., Smith, M. J., Haims, M. C. (1999). "Work Organization, Job Stress, and Work-Related Musculoskeletal Disorders", *Human Factors*, Vol. 41 (4): 644-663, ISSN 1520-6564.

Dickinson, C.E., Campion, K., Foster, A.F., Newman, S.J., O'Rourke, A.M., Thomas, P.G. (1992). Questionnaire development: an examination of the Nordic Musculoskeletal questionnaire. *Applied Ergonomics* 23(3): 197-201, ISSN 0003-6870.

Evans, O., Patterson, K., (2000). "Predictors of neck and shoulder pain in non-secretarial computer users", *International Journal of Industrial Ergonomics*, Vol. 26: 357-365, ISSN 0169-8141.

EU-OSHA (2008). What are work-related musculoskeletal disorders (WRMSDs)? In: *European Agency for Safety and Health at Work*, 2012, Available from: http://osha.europa.eu/en/faq/frequently-asked-questions/what-are-work-related-musculoskeletal-disorders-msds.

Fogleman M., Lewis, R. J. (2002). Factors associated with self-reported musculoskeletal discomfort in video display terminal (VDT) users. *International Journal of Industrial Ergonomics*, Vol. 29, 311-318, ISSN 0169-8141.

Health and Safety Executive (HSE, 2005). Health and Safety Statistics 2004/05. In: Health and Safety Commission, 2012. Available from: http://www.hse.gov.uk/statistics/overall/hssh0405.pdf

Jensen, C., Finsen, L., Søgaard, K., Christensen, H. (2002). Musculoskeletal symptoms and duration of computer and mouse. *International Journal of Industrial Ergonomics*, Vol. 30 (4-5), 265-275, ISSN 0169-8141.

Karlqvist, L., Tornqvist, E. W., Magberg, M., Hagman, M., Toomingas, A. (2002). Self-reported working conditions of VDU operators and associations with musculoskeletal symptoms: a cross-sectional study focusing on gender differences. *International Journal of Industrial Ergonomics*, Vol. 30, 277-294, ISSN 0169-8141.

Korhan, Orhan. "Work-Related Musculoskeletal Disorders due to Computer Use: A Literature Review". Lambert Academic Publishing, Germany 2010. ISBN: 978-3-8383-6625-8.

Korhan, O., Mackieh A. (2010). A Model for Occupational Injury Risk Assessment of Musculoskeletal Discomfort and Their Frequencies in Computer Users. *Safety Science*, Vol. 48 (7), 868-877, ISSN 0925-7535.

Mekhora K., Liston, C. B., Nanthanvanij, S., Cole, J. H. (2000). The effect of ergonomic intervention on discomfort in computer users with tension neck syndrome. *International Journal of Industrial Ergonomics*, Vol. 26, 367,-379, ISSN 0169-8141.

Ming, Z., Zaproudina, N. (2003). Computer use related upper limb musculoskeletal (ComRULM) disorders. *Pathophysiology*, Vol. 9, 155-160, ISSN 0928-4680.

NIOSH, "Elements of Ergonomics Programs: A Primer Based on Evaluations of Musculoskeletal Disorders," 1997 DHHS (NIOSH) Publication No. 97-117, ISSN 0348-2138.

NIOSH (2011). Elements of Ergonomics Programs. In: *NIOSH Publication No. 97-117*, 2012, Available from: http://www.cdc.gov/niosh/docs/97-117/eptbtr4.html

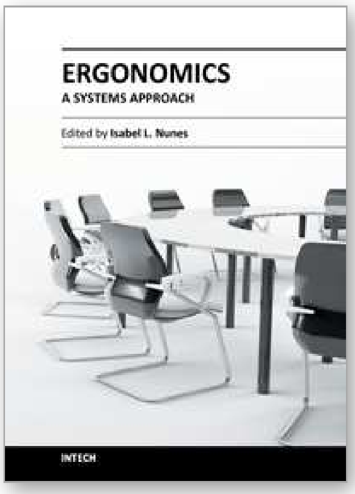
Oakley, Katie. "Occupational Health Nursing". John Wiley & Sons Inc, USA 2008. ISBN: 9780470035335.

Pampel, Fred C. "Logistic Regression, A Primer". SAGE Publications Inc., USA 2000. ISBN: 9780761920106.

Peper, E., Wilson, V. S., Gibney, K. H., Huber, K., Harvey, R., Shumay, D.,M. (2003). "The integration of electromyography (SEMG) at the workstation: assessment, treatment, and prevention of repetitive stain injury (RSI)", *Applied Psychophysiology and Biofeedback*, Vol. 28 (2): 167-182, ISSN 1573-3270.

Shuval, K., Donchin, M. (2005). "Prevalence of upper extremity musculoskeletal symptoms and ergonomic risk factors at a High-Tech company in Israel", *International Journal of Industrial Ergonomics*, Vol. 35: 569-581, ISSN 0169-8141.

Westgaard, R. H. (2000). Work-related musculoskeletal complaints: some ergonomics challenges upon the start of a new century. *Applied* Ergonomics, Vol. 31, 569-580, ISSN 0003-6870.



Ergonomics - A Systems Approach

Edited by Dr. Isabel L. Nunes

ISBN 978-953-51-0601-2
Hard cover, 232 pages
Publisher InTech
Published online 25, April, 2012
Published in print edition April, 2012

This book covers multiple topics of Ergonomics following a systems approach, analysing the relationships between workers and their work environment from different but complementary standpoints. The chapters focused on Physical Ergonomics address the topics upper and lower limbs as well as low back musculoskeletal disorders and some methodologies and tools that can be used to tackle them. The organizational aspects of work are the subject of a chapter that discusses how dynamic, flexible and reconfigurable assembly systems can adequately respond to changes in the market. The chapters focused on Human-Computer Interaction discuss the topics of Usability, User-Centred Design and User Experience Design presenting framework concepts for the usability engineering life cycle aiming to improve the user-system interaction, for instance of automated control systems. Cognitive Ergonomics is addressed in the book discussing the critical thinking skills and how people engage in cognitive work.

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821