Investigation of Upper limb Muscle Activity during Repetitive Light Task using Surface Electromyography (SEMG)

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Abstract— **A study was conducted to investigate the effect of upper limb muscles during repetitive task consisted of three hand-arm directions: 30^0, 90^0, and 150^0. The aims of this study were to investigate muscle activity during repetitive task, to compare muscle activity between genders and to determine the correlation between muscles and time. Biceps brachii, anterior deltoid, and upper trapezius muscles were identified as a significant muscle in the repetitive light task experiment. Surface electromyography (SEMG) measurements for each muscle mentioned above were taken from ten subjects in the duration of one hour experiment. The results indicated that anterior deltoid is the highest affected muscle by the tasks. There was a significantly increase of root mean square (RMS) between the beginning and the end of the experiment, that indicated muscle fatigue. However there were no significant differences of RMS between male and female subjects, and between 30^0, 90^0 and 150^0 hand-arm directions.**

Keywords— ***Upper limb muscle; muscle activity; muscle fatigue; repetitive tasks; surface EMG***

I. INTRODUCTION

Worker fatigue is one of the most prevalent root causes of earth-moving equipment accidents in the industry [1]. This fact contributes to the theory that muscle fatigue is an indicator of developing a work-related musculoskeletal disorder (WMSD) and that minimizing fatigue will decrease the risk of developing a WMSD.

It was postulated that fatigue effects were as a result of work (daily or weekly), shift changes, illumination and ventilation, workplace design, and plant layout. It is also widely accepted that night shift work, circadian disruption, sleep loss, long working hours, monotonous and unstimulating tasks lead to lowered alertness, decreased vigilance and a build-up of fatigue [2].

Jensen et al. [3] defined muscle fatigue as failure to maintain the required or expected force or power. Muscle fatigue is associated with physically monotonous or repetitive work but more recent studies also report an association between psychosocial factors at the work place and musculoskeletal disorders [4].

In measuring muscle fatigue, however, most of the studies used subjective measurement methods, or very limited number of subjects was measured with objective methods [5]. Electromyography (EMG) is the most popular objective-measurement tool used in experiments. Study by Cook, et al. [6] also found that EMG collection methods used at the work site were feasible for analysis of changes in muscle effort and hold promise for use in other investigations.

Nowadays, the evidence that chronic musculoskeletal disorders (MSDs) of the upper extremities are rapidly growing [7]. It is remarkable that work-related upper extremity disorders also occur in the absence of high force exertion and awkward body postures [8, 9]. The development of muscle fatigue at repetitive, low-intensity tasks has been studied on the basis of objective measurements (mainly EMG) and subjective rating scales [10].

Sundelin and Hagberg [11] studied a pick and place task with the right arm for one hour in laboratory. An increase in amplitude and a decrease in frequency content of the trapezius muscle EMG were found, while subjective ratings of fatigue in the shoulder muscle significantly increased. In a laboratory study by Mathiassen and Winkel [12], subjects performed the assembly of starters of power saws. They found a trend towards increased muscle fatigue in the trapezius muscle over the course of a simulated six hour working day.

Bennie et al. [13] investigated an isolated repetitive ulnar deviation task at a low intensity level during a simulated eight hour working day. The EMG measurements also showed an increase in muscle fatigue over the course of an eight hour working day.

In summary, repetitive task in modern industry has proved as one of the factors that could cause MSD among workers. And there were many studies investigated about muscle fatigue

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in repetitive task. But there are still a few researchers that determine the time to fatigue during repetitive task. Therefore, this study investigated the effect of task activity on upper limb muscles (Biceps brachii, anterior deltoid, and upper trapezius) during repetitive task consisted of three hand-arm directions: 30^0, 90^0, and 150^0. The study also compared the muscle activities during repetitive process and determined correlation of muscles and time. It is hoped from this study, the ergonomists and industrial engineers will be able to design the job that proper to worker's limitation and capability.

II. Subjects and Methods

A. Subjects

Ten subjects consisted of five males and five females from the university population were recruited to participate in the experiment. These subjects were selected based on age (20-30 year-old) and current health conditions. It was ensured that the subjects have no history of upper extremity complaints or other musculoskeletal problems.

B. Apparatus and Material

Equipment and task used during the experiment:

- Surface Electromyography (SEMG) Telemyo "2400" Gen2 Telemetric Real Time 8 channel SEMG System was used to record electrical activity of muscles
- Lego construction block
- Disposable surface electrodes Ag/AgCl/Solid Adhesive pregelled.

C. Experimental Design

The task performed during the experiment consisted of building a lego construction toys while sitting for one hour of job duration in laboratory. The subjects seated upright in a rigid chair at a desk. The desk was adjusted to elbow height so that the upper arm and forearm formed 90^0 angle when the hand was positioned at the middle of the desk and the upper arm was vertical.

The construction of the lego was based on manual that given in the experiment. The small lego blocks were put in three boxes. The boxes were placed in normal reach area in 30^0, 90^0 and 150^0 hand-arm directions. The amounts of the lego blocks are the same in each box. The subjects picked and placed the lego block from the box to the assembly part every three second-cycle time using their right hands (see Figure 1).

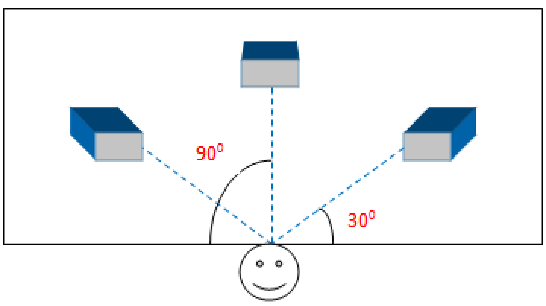

Figure 1. The Place of Lego Blocks for Experiment Task Design

SEMG signals were recorded from three muscles: biceps brachii, anterior deltoid, and upper trapezius on the right hand. Bipolar Ag/AgCl surface electrodes were placed with an inter electrode distance of 20 mm at the belly of muscles. The electrode positions were located according to Hermens et al. [14]. A reference electrode was placed on the piciform bone. The skin was shaved, scrubbed and cleaned with alcohol before the electrodes were applied. Raw SEMG signals were sampled during the test contraction with a sample frequency of 1500 Hz and band-pass filtered (20–400 Hz). The amplitude values were normalized to the SEMG values measured during the task.

Before commencing the task, the Maximum Voluntary Contraction (MVC) was measured from the subjects. After getting MVC data, subjects practiced building a lego construction toys based on instruction book. Then, the experiment was begun for one hour without break.

D. Statistical Analysis

Normalized Root Mean Square (RMS) SEMG data were analysed by using SPSS. While for processing and filtering the signal, the software available together with the hardware was fully used. Saphiro-Wilk test was used to analysis the normality of the data. It was found that the data was normally distributed. One-way ANOVA was used to investigate the RMS of SEMG differences between muscles because of the task.

Paired-samples t-test was used to find the difference of mean RMS between the beginning and the end of the task. While for comparison of mean RMS between 30^0, 90^0, and 150^0 hand-arm directions, one-way ANOVA was used to find their differences. Significance was accepted at $p<0.05$. Independent-samples t-test was also used for investigating the influence of gender factor on RMS value. Correlation analysis was carried out to examine the relationship between mean RMS of SEMG with time.

III. Results

A. Normalized-RMS

The Figure 2 below showed the normalized RMS of SEMG data for all subjects in one hour experiment. The data divided into 21 interval time. Analysis using one-way ANOVA found that normalized RMS between biceps brachii, anterior deltoid, and upper trapezius were significantly difference. Anterior deltoid had the highest normalized RMS compared to upper trapezius and biceps brachii muscles.

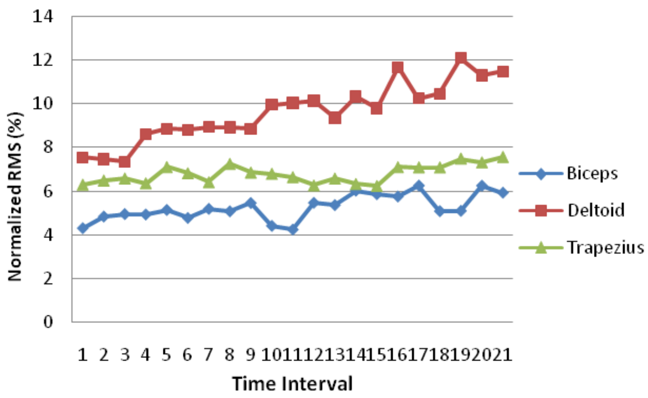

Figure 2. Mean Normalized RMS for All Subjects

B. *Paired-samples T-Test*

Paired-samples t-test found that mean RMS of subjects for all muscles were significantly difference between the beginning and the end of the task, since their p-value<0.05. These results indicated that mean RMS increased with time that reflects the fatigue pattern for the task under study (Table 1).

TABLE I.
PAIRED-SAMPLES T-TEST TO FIND THE DIFFERENCE OF MEAN RMS BETWEEN THE BEGINNING AND THE END OF THE TASK

	Mean	**Sig.(2-tailed)**
Biceps_1 - Biceps_end	-2.217	0.019
Deltoid_1 - Deltoid_end	-6.585	0.029
Trapezius_1 - Trapezius_end	-2.966	0.011

C. *One-way ANOVA*

Figure 3 below illustrated the mean RMS for three hand-arm directions, 30^0, 90^0 and 150^0. It was showed that all muscles had the highest contraction when the arm was in the 150^0 direction while doing the task (Figure 3). However, one-way ANOVA test showed that the differences of muscle contraction were not statistically significant while doing the task in different hand-arm directions (Table 2).

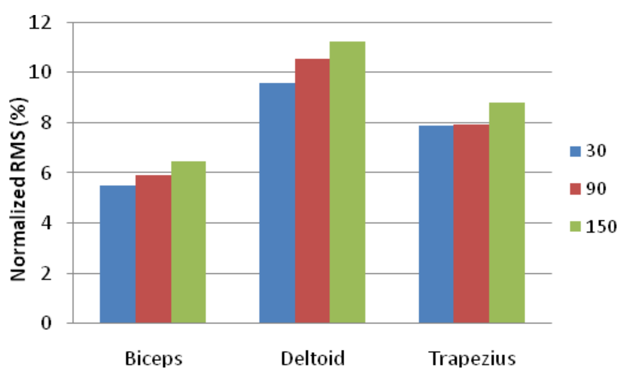

Figure 3. Mean Normalized RMS for 3 hand-arm direction

TABLE II
ONE-WAY ANOVA TO FIND THE DIFFERENCE OF MEAN RMS BETWEEN THREE HAND-ARM DIRECTIONS

	F	**Sig.**
Biceps brachii	0.215	0.808
Anterior deltoid	0.169	0.846
Upper trapezius	0.159	0.853

D. *Independent-samples T-Test*

The differences of muscle contraction between male and female subjects were investigated using independent-samples t-test. The analysis showed that the mean RMS between male and female subjects was not significantly difference (Table 3).

TABLE III
INDEPENDENT-SAMPLES T-TEST TO FIND THE DIFFERENCE OF MEAN RMS BETWEEN MALE AND FEMALE

	Levene's Test	**t-test for Equality of Means**	
	Sig.	***Sig. (2-tailed)***	***Mean Difference***
Biceps brachii	0.680	0.777	-0.629
Anterior deltoid	0.052	0.284	4.434
Upper trapezius	0.399	0.800	0.708

E. *Correlation Analysis*

The time of fatigue was different for each of the involved muscles; therefore, it cannot be defined arbitrarily. It can be determined through an analysis of the correlation coefficient for successive time points (values of EMG parameters) and the regression function [15].

TABLE IV
CORRELATION ANALYSIS BETWEEN MEAN RMS MUSCLES AND TIME

		Time	**Biceps**	**Deltoid**	**Trapezius**
Time	Pearson Correlation	1	0.666	0.929	0.562
	Sig. (2-tailed)		0.001	0.000	0.008
Biceps	Pearson Correlation	0.666	1	0.523	0.273
	Sig. (2-tailed)	0.001		0.015	0.231
Deltoid	Pearson Correlation	0.929	0.523	1	0.583
	Sig. (2-tailed)	0.000	0.015		0.006
Trapezius	Pearson Correlation	0.562	0.273	0.583	1
	Sig. (2-tailed)	0.008	0.231	0.006	

Table 4 above summarized correlation analysis between muscles and time. It showed that the p-value of correlation between muscles and time was less than 0.05. Therefore there were positive and strong correlation between muscles and time. It means that the RMS will increase as the time increase.

IV. Discussion

In the current study, the muscle activity was investigated in the laboratory on subjects while doing repetitive task. The study found the indication of muscle fatigue on subjects while doing the task. Muscle fatigue can be characterized by a feeling of tightening in the muscle, a sustained cramp with a deep and intermittent pain, and a continuous pain with a desire to cease the work or activity. Indications of muscle fatigue include an increase of the EMG amplitude and a decrease of the mean power frequency (MPF) [16].

The findings of this study were accordance to some previous studies which found that the shoulder muscles (trapezius and deltoid) are common site of chronic and work-related disorders in repetitive light tasks. The study found that anterior deltoid has the highest normalized RMS, followed by upper trapezius and biceps brachii during a 1-hour experimental task. Therefore, anterior deltoid can be the reference muscle in detecting muscle fatigue.

Figure 2 has shown that normalized RMS tended to increase with time. It indicated muscle fatigue appeared on the muscles. Even though the study showed signs of fatigue but the differences between three hand-arm directions (30^0, 90^0, and 150^0) were not found. It can be explained because the task was conducted in the same boundary (normal reach area). To be able to detect such differences, the longer time of experiment may be needed.

The differences of RMS were not found between male and female subjects. Thus, it can be suggested that there is no need to consider different job designs between male and female because there was no evidence to show a significant difference between genders. In relation to correlation analysis, it has been found that there was a strong and positive correlation between RMS of SEMG and time. It indicated that muscles will be fatigue as the time increase. The results signify that fatigue can be predicted.

V. Conclussion

In conclusion, the activities of each muscle were different while doing the repetitive task. The activities of anterior deltoid muscle were higher than the upper trapezius and biceps brachii muscles while doing experiment. The muscles indicated fatigue since the normalized RMS of SEMG increased with time. The study found there was no difference of muscle activity between genders, and there was positive and strong correlation between muscles and time.

Further study will be conducted to determine the validity of model by increasing the samples and comparing with other upper limb muscles using regression analysis. Therefore, jobs can be appropriately designed, by taking into consideration the workers' capacity and capability.

References

[1] Edwards, D. J., Sirois, B., Dawson, T., Aguirre, A., Davis, B., Trutschel, U., "Evaluation of Fatigue Management Technologies using Weighted Feature Matrix Method," in Proceedings of the Fourth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, 2007.

[2] Finkelman, M., "A large database study of the factors associated with work-induced fatigue," *Human factors,* 36(2). 232-243, 1994.

[3] Jensen, B. R., Laursen, B., Sjùgaard, G., "Aspects of shoulder function in relation to exposure demands and fatigue - a mini review," *Clinical Biomechanics,* 15 Supplement No. 1. S17-S20, 2000.

[4] Cohen, S. (2000) Measures of Psychological Stress. John D. and Catherine T. MacArthur Research Network on Socioeconomic Status and Health. [Online]. Available: http://www.macses.ucsf.edu/Research/Psychosocial/notebook/stress.html.

[5] Bao, S., Silverstein, B., and Cohen, M., "An electromyography study in three high risk poultry processing jobs," *International Journal of Industrial Ergonomics,* 27. 375–385, 2001.

[6] Cook, T. M., Ludewig, P. M., Rosecrance, J. C., Zimmermann, C. L., and Gerleman, D. G., "Electromyographic effects of ergonomic modifications in selected meat packing tasks," *Applied Ergonomics,* 30. 229-233, 1999.

[7] Salvendy, G., *Handbook of Human Factors and Ergonomics*, 2nd edition, John Wiley & Sons, 1997.

[8] National Research Council and Institute of Medicine, *Musculoskeletal Disorders and the Workplace: Low Back and Upper Extremities,* Washington DC: National Academic Press, 2001.

[9] Andersen, J.H., Kaergaard, A., Mikkelsen, S., Jensen, U.F., Frost, P., Bonde, J.P., Fallentin, N. And Thomsen, J.F., "Risk factors in the onset of neck/shoulder pain in a prospective study of workers in industrial and service companies," *Occupational and Environmental Medicine*, 60, 649–654, 2003.

[10] Bosch, T., De Looze, M.P., and Van Dieen J.H. "Development of fatigue and discomfort in the upper trapezius muscle during light manual work," *Ergonomics*, Vol. 50, No. 2, 161–177, February 2007.

[11] Sundenlin, G. and Hagberg, M., "Electromyographic signs of shoulder muscle fatigue in repetitive arm work paced by the Methods-Time Measurement system," *Scandinavian Journal of Work, Environment and Health*, 18, 262–268, 1992.

[12] Mathiassen, S.E. and Winkel, J., "Physiological comparison of three interventions in light assembly work: reduced work pace, increased break allowance and shortened working days," *International Archives of Occupational and Environmental Health*, 68, 94–108, 1996.

[13] Bennie, K.J., Ciriello, V.M., Johnson, P.W. and Dennerlein, J.T., "Electromyographic activity of the human extensor carpi ulnaris muscle changes with exposure to repetitive ulnar deviation," European Journal of Applied Physiology, 88, 5–12, 2002.

[14] Hermens, H.J., Freriks, B., Disselhorst-Klug, C. and Rau, G., "Development of recommendations for SEMG sensors and sensor placement procedures," *J. Electromyogr. Kinesiol.* 10, pp. 361–374, 2000.

[15] Liu, D.R., Tokarski, T., and Wojcik, K., "Quantitative Assessment of Upper Limb Muscle Fatigue Depending on the Conditions of Repetitive Task Load," *Journal of Electromyography and Kinesiology,* Vol. 14: 671-682, 2004.

[16] Basmajian, J.V. and DeLuca, C.J., *Muscles Alive: Their Functions Revealed by Electromyography*, 5th ed. Baltimore: Lippincott, Williams and Wilkins, 1985.