Performances Comparison of EMG Signal Analysis for Manual Lifting using Spectrogram

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***Abstract*—Electromyography (EMG) signal is non-stationary signal and highly complex time and frequency characteristics. Fast-Fourier transform common technique in signal processing involving EMG signal. However, this technique has a limitation to provide the time-frequency information for EMG signals. This paper presents the analysis of EMG signal of the variable lifting height and mass of load between the four subjects selected in manual lifting by using spectrogram. Spectrogram is one of the time-frequency representation (TFR) that represents the three-dimensional of the signal with respect to time and frequency in magnitude presentations. The manual lifting tasks is based on manual lifting of 5 kg and 10 kg load that performed by the right biceps brachii at lifting height of 75 cm and 140 cm. Four from ten healthy volunteers in fresh condition is selected into this comparison of subject performance tasks with their raw data collections. The raw data of EMG signals were then analyzed using MATLAB 2011 to obtain the voltage in time and frequency information. This study obtained the mean instantaneous RMS Voltage (Vrms(t)) to visualize the strength of the subjects produced during the manual lifting tasks. Results of this study evince the physical details of the subjects would able to effect the performance of the lifting. Higher lifting height and the number of contraction, the better performance of the subjects. It concluded that the application of spectrogram is able to providing the performance of the subjects by time-frequency information for EMG signals.**

***Index Terms*—Electromyography (EMG) Signal; Manual Lifting; Spectrogram.**

I. Introduction

Today, from the worldometers info, there are 7.3 billion population in the world is estimated, with 3.1 billion number of workers working in more than 55 major industrial sectors [1]. In order providing job opportunities, a large number of workplaces in the industrial sectors may lead to occupational injuries if there is no awareness or concern regarding occupational health and safety [1] and [2]. The National Institute for Occupational Safety and Health (NIOSH) recognized the growing problem of work-related back injuries and published Work Practices Guide for Manual Lifting [3].

Manual lifting is commonly practiced by workers in industrial workplace to move or transport good to a desired place. In manual lifting, skeletal muscles perform a crucial function to execute the task [4]. It is important to handle a suitable load mass and lifting height to ensure the muscles work in good experienced fatigue. Muscle performance is the muscle's endurance capability before the muscle experienced fatigue [4].

Electromyography (EMG) signal have been widely used and applied as a control signal in numerous man-machine interface applications. It also been deployed in many clinical and industrial applications [5]. The EMG is known as biomedical signal that consist of electrical current that generated during contraction and relaxation phase of muscles [6] and [7].

EMG signal is complicated and non-stationary signal with highly complex time and frequency characteristics which is controlled by nervous signal because it always responsible the muscle activity [7] and [8]. This signal acquires noise and distorts the signal while travelling through different tissues during collection and recording process [6] and [9].

A lot of studies have been done based on EMG signal investigation especially in extraction of EMG signal [10]. Previous researchers used fast Fourier transform (FFT) to analyze the EMG signal, but it has the limitation to cater non-stationary signals whose spectral characteristics change in time [11]. It is no appropriate to use for non-stationary signal as EMG. It only give the frequency information. Wavelet also is common used in EMG, however it required more time to analyze and required to find mother wavelet for each data. It is also sensitive to noise while EMG produced noise while travelling to each tissue [8], [9] and [12]. Besides that, to extract the features, it involved high computational burden. By artificial Intelligence (AI), it is higher complexity compared to fast-Fourier transform and Wavelet [13]. Between all of this common techniques in EMG signal processing, it is show that Spectrogram with less complexity, better time and frequency resolution and higher accuracy in order to get the information from manual lifting activities.

In this research work, time frequency distributions (TFDs) which are spectrogram employed to analyze the performance of EMG signal for contraction of muscle activities. This technique is one of the time-frequency representations (TFR) that represent a three dimensional of the signal energy with respect to time and frequency [14]. It is able to have superior accuracy in challenging task colour modeling [15]. An optimum frequency resolution is useful for extracting features of any signals for further analysis included Electromyography (EMG) signals [16]. From spectrogram, the overall performance of the different mass of load, height and phase angle would be known.

II. METHODOLOGY

A. *Flow of data processing*

Figure 1 shows the flow of the data collection and how the data is processed to get the performance of EMG signal for the contraction of muscle activity.

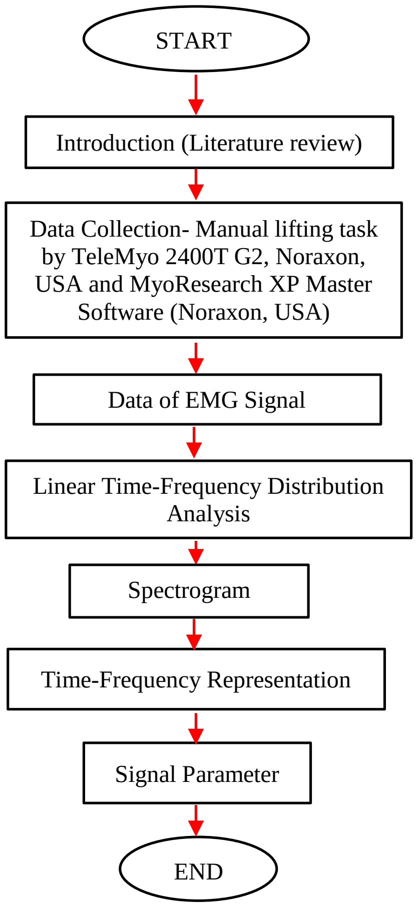


Figure 1: Flow of the data process

B. *Subject Selection*

Ten volunteers, five male and five female in healthy conditions with no previous injuries participated in the experimental work. G power application is an important technical assumption for normality assumption for good estimate the size of sample [17] and [18]. The number of subjects was calculated using G power analysis software to determine sufficient EMG raw signals for the analysis process. Tens subjects selected based on the number of G Power proposed between the age range of 22 to 25 years was selected because this age range is commonly available in the industries[1]. All subjects are right handed. The demographics of the subjects is shown in [19]

C. *Data Collection and Electrode Placement*

The raw EMG data collection is measured by using surface EMG (TeleMyo 2400T G2, Noraxon, USA) and MyoResearch XP Master Software (Noraxon, USA). The electrode positioning is at the right biceps. The details of the data collection and electrodes placement is based on the previous paper [20].

D. *Manual Lifting Experiment*

The subjects have to lift a 5 kg and 10kg load with a neutral body twist (0º) – symmetric lifting with the lifting height 75cm. The subject must repeat the lifting until achieve the muscle fatigue for five times of repetition. Each lifting produced EMG signals of contracted muscle, and each EMG signal was divided into four phases as illustrated in the paper [19] and [21]. At the Phase 1, the subject holds the load (located on the floor). At Phase 2, subject lifts the load and put it on the shelf, then Phase 3, subject arranges the load properly on the shelf. Lastly, subject release the load at Phase 4.

III. EMG SIGNAL ANALYSIS TECHNIQUES

Spectrogram is used in this EMG signal processing because it acquire to display the required information in EMG signal. This is because FFT would not able to display the information needed because of the limitation to non-stationary signals [22]. The details about spectrogram are already discussed in [19] and [20]. The equation of the spectrogram is as followed:

$$S_x(t,f) = \left| \int_{-\infty}^{\infty} h(\tau) w(\tau - t) e^{-j2\pi f \tau} d\tau \right|^2 \qquad (1)$$

Instantaneous RMS voltage is extracted from spectrogram to display the pattern of the signal of instantaneous value $V_{rms}(t)$ for the contraction of muscle activities behavioral. $V_{rms}(t)$ can be calculated using Equation (2) below [11]:

$$V_{rms}(t) = \sqrt{\int_0^{fmax} S_x(t,f) dt} \qquad (2)$$

where $S_x(t,f)$ is the time-frequency distribution and f_{max} is the maximum frequency of interest.

IV. RESULTS AND DISCUSSION

The results of the EMG signal analysis are divided into some parts to make it clearer presentation to know the relationship between the different subjects and the performance of the manual lifts.

A. *EMG Signal of Manual Lifting*

There are four parameters is considered in this experiment for four subjects. Figure 2 until Figure 5 shows the example of raw data for 75 cm and 140 cm lifting height with 5 kg and 10 kg load of mass. The maximum voltage for 5 kg 75 cm is $0.8x10^{-3}$ V and the minimum is $0.4x10^{-3}$ V with 36 times of liftings. It is increasing peak voltage due to the increasing of height with$1.3x10^{-3}$ V maximum and minimum $0.6x10^{-3}$ V at 5 kg, 140 cm for 23 times of lifting.

Due to the Figure 4 (21 times lifting) and 5 (13 times lifting), it is shown the raw data of manual lifting of 10 kg 75 cm and 10 kg 140 cm. Their maximum for both parameters is $1.2\text{x}10^{-3}$ V and 1.4 $\text{x}10^{-3}$ V while the minimum peak voltage is $1.1\text{x}10^{-3}$ V. Based on all the figures, it validates that the mass of the load and the height of the lifting would able to affect the peak value produced by the subjects.

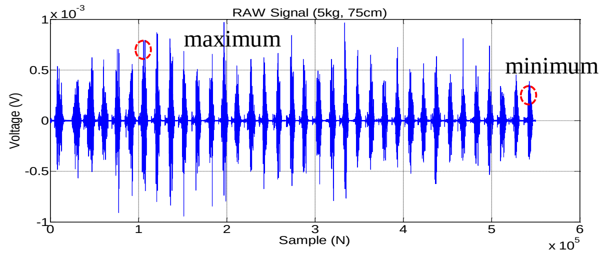


Figure 2: Raw EMG signal for 5 kg, 75 cm

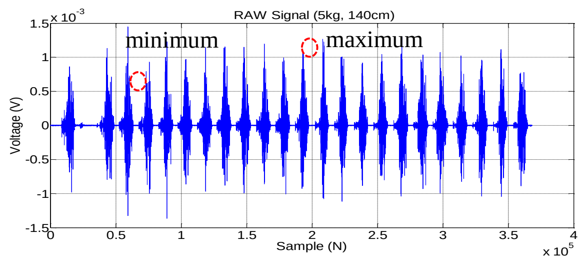


Figure 3: Raw EMG signal for 5 kg, 140 cm

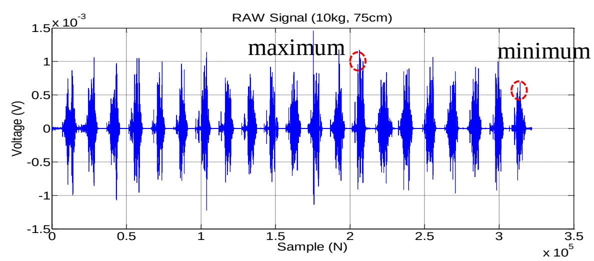


Figure 4: Raw EMG signal for 10kg, 75cm

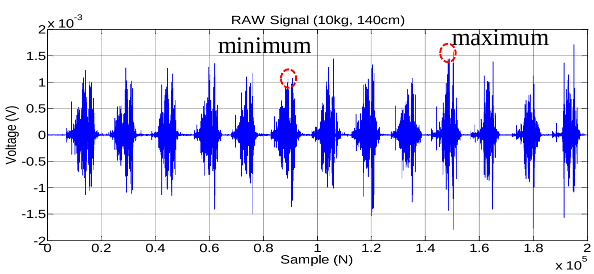


Figure 5: Raw EMG signal for 10 kg, 140 cm

B. *Time-Frequency Representations of EMG*

Spectrogram is used in order to get the important information in EMG signal processing analysis procedures. The details about the spectrogram is discussed in the paper [19] and [21]. Figure 6 show the time frequency representation of spectrogram method in order to display the frequency, time and amplitude for the EMG signals. Instantaneous RMS Voltage ($V_{rms}(t)$) is extracted from spectrogram the displayed the performance of the signals. It indicated the four phases stated in the manual lifting experiments as shown in Figure 7.

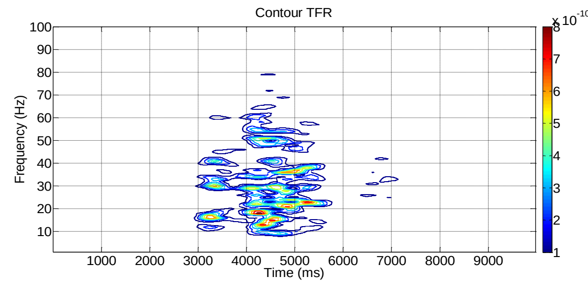


Figure 6: Example of spectrogram analysis

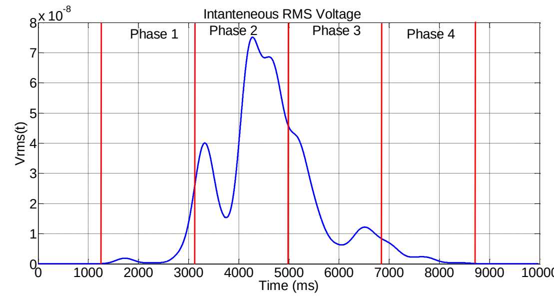


Figure 7: Example of Instantaneous RMS Voltage ($V_{rms}(t)$)

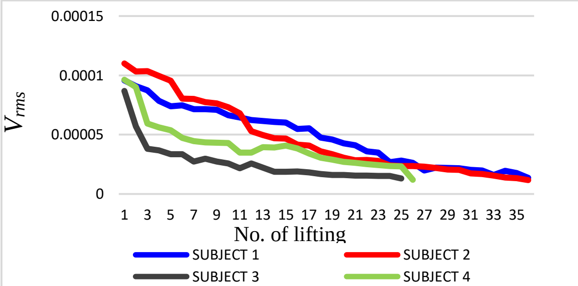
C. *Performance Comparison of Manual Lifting Task*

Mean is the parameter to tell the strength used of the muscle for the EMG signal analysis [7]. Mean data are taken from the mean Instantaneous Root Mean Square (RMS) Voltage ($V_{rms}(t)$). The comparing is divided into four cases which are 5 kg 75 cm, 5 kg 140 cm, 10 kg, 75 cm and 10 kg 140 cm. Subject 1 is sport man with the 174 cm height and thin, Subject 2 is sport women with the 169 cm high thin, Subject 3 is sport man with the 166 cm high and fatter, last Subject 4 is normal tough man 167cm fatter. In this result section, just two phase is selected to be shown the example pattern of the subject's performance.

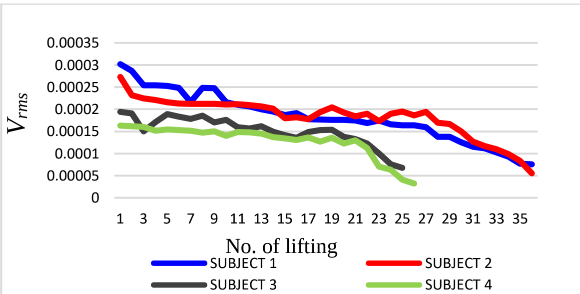
a. *Manual Lifting of 5kg mass of load, 75cm lifting height*

Figure 8(a), (b), represent the comparison from two from four phase which is Phase 1 and Phase 2 to know the performance of four subjects from ten involved in the manual lifting tasks. In this tasks, it show that subject 1 and subject 2 more perform with the higher voltage and longer time to fatigue (no of contractions) compared to subject 3 and 4. It is increasing of mean ($V_{rms}(t)$) which is the strength when the mass of load and lifting height in bigger.

In comparing this two selected phases, it show Phase 2 (Figure 8(b)) give higher strength compared to Phase 1(Figure 8(a)) because the subject have to lift the load that acquire more strength compared to located the load at 5 kg and 75 cm.



(a)

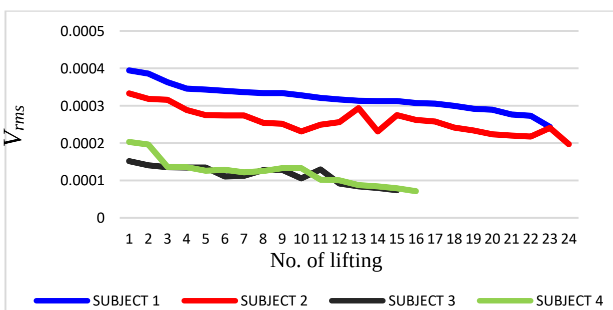


(b)

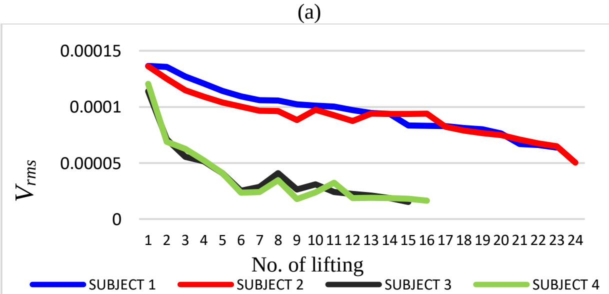
Figure 8 (a) and (b) The performance of Mean ($V_{rms}(t)$) by the Subject 1, Subject 2, Subject 3 and Subject 4

b. Manual Lifting of 5 kg mass of load, 75 cm lifting height

The performance of four subjects involved is presented in Figures 9(a) and (b). It show that Subject 1 and 2 still better performance with higher strength and longer time to achieve fatigue muscle. In this task, it is difference performance of strength higher because at 140 cm lifting height, it acquire more afford and harder for the subject with the lower high to arrange the load onto the shelf, but for the taller subjects, it not give much problem to them with 5 kg mass of load.



(a)



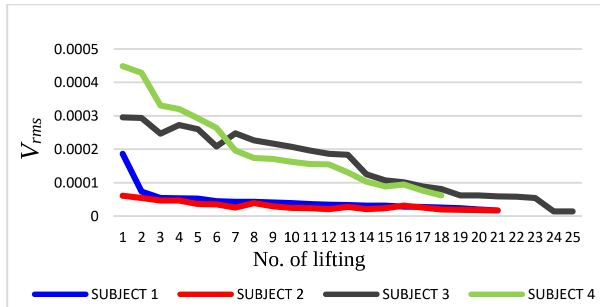
(b)

Figure 9 (a) and (b) The performance of Mean ($V_{rms}(t)$) of 5 kg 140 cm by the Subject 1, Subject 2, Subject 3 and Subject 4

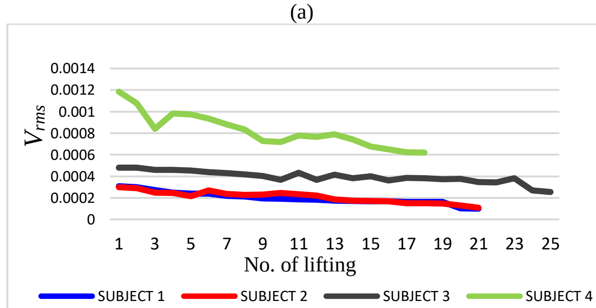
c. Manual Lifting of 10kg mass of load, 75cm lifting height

Based on Figures 10(a) and (b), the subject's performance become different situation compared to the previous results. From the subjects performances, it show that in heavier mass of load, Subject 3 and 4 are higher performance compared to Subject 1 and 2.

In this task, Subject 3 produced the second higher of strength but longest time to achieve fatigue muscle. Subject 2 with highest strength but less the number of liftings. Subject 1 and 2 almost similar performance. The performance of the subject almost similar the strength and although still difference the time to fatigue muscle (number of lifting).



(a)



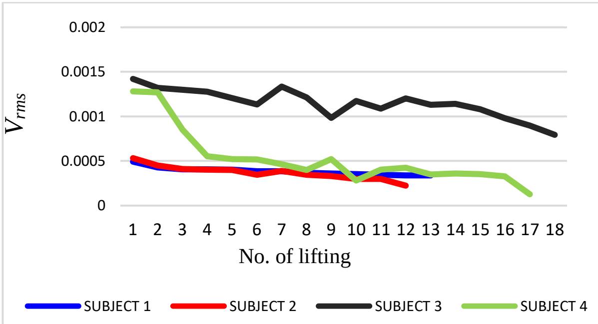
(b)

Figure 10 (a) and (b): The performance of Mean ($V_{rms}(t)$) of 10kg 75cm by the Subject 1, Subject 2, Subject 3 and Subject 4

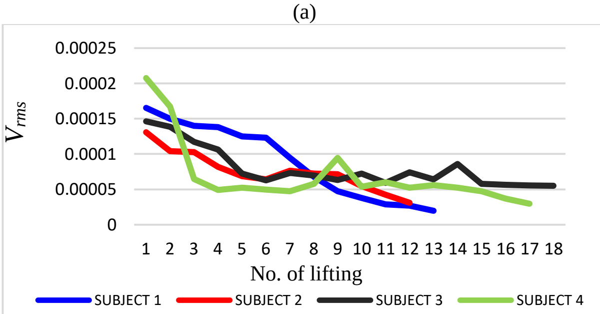
d. Manual Lifting of 10kg mass of load, 140cm lifting height

In this task, it present the Subject 3 have used the highest strength and longest time to fatigue compared to Subject 4, Subject 2 and Subject 1. Subject 4 also quit higher strength have used at the beginning of the manual lifting but drastically decrease as same like the performance of Subject 1 and 2.

It is the same situation cross to the number of lifting can produced by the subjects, the higher strength produced while doing the lifting task the longer time of lifting to achieve muscle fatigue.



(a)



(b)

Figure 11(a) and (b) The performance of Mean ($V_{rms}(t)$) of 10kg 140cm by the Subject 1, Subject 2, Subject 3 and Subject

The comparison of all the performances for manual lifting tasks is presented in Appendix A. Four subjects have selected to be shown in the analysis process. The difference of task will produce the different number of liftings. Each task is divided into four phases as stated. Each will have the starting (1st lifting) and ending (the end of lifting) mean $V_{rms}(t)$ voltage (strength). Either all phase, it would be focus on the highest strength Phase 2 and Phase 3 which while travel the load and arrange the load onto the shelf. All the subjects show by increasing the mass of load and lifting height, the number of lifting that would able to handle decreased but the strength increase. At this phase it required more strength to handle the load.

V. Conclusion

Based on the analysis of EMG signals, this study concluded that the application of spectrogram is able give the information of the subject's performance based on the variable lifting height and mass of load from the determining of time-frequency representation (TFR). From the summary of Appendix A, it clearly show the relationship of the parameter and physical condition of the subjects. All of this factors would be affect the strength and time to fatigue. Subject 1 and Subject 2 have the advantage to the higher lifting height, but disadvantage to the higher mass of load. Furthermore, the mean instantaneous RMS voltage (Vrms) which is strength increased when the lifting height and mass of load is increased. However, number of lifting would affected by the strength produced by the subjects.

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APPENDIX

Appendix A shows the comparison of the performance of manual lifting tasks.

	Parameters	Number of liftings	Mean of ($V_{rms}(t)$)							
			Phase 1		Phase 2		Phase 3		Phase 4	
			Start	End	Start	End	Start	End	Start	End
Subject 1	5 kg 75 cm	36	95.7	13.6	301.4	75.6	273.8	85.7	106.4	29.5
	5 kg 140 cm	23	49.2	13.9	290.1	79.1	394.5	243.5	136.6	63.9
	10 kg 75 cm	21	186.0	17.3	309.0	100.2	400.0	151.2	184.3	43.9
	10 kg 140 cm	13	66.1	26.7	323.9	135.8	491.7	337.1	165.2	19.6
Subject 2	5 kg 75 cm	36	110.1	11.8	272.9	55.3	226.2	99.5	103.5	30.8
	5 kg 140 cm	24	83.6	13.2	313.7	37.0	333.0	196.7	136.2	50.5
	10 kg 75 cm	21	61.0	17.1	298.0	110.0	348.2	187.1	134.4	29.5
	10 kg 140 cm	12	85.3	32.0	326.5	165.9	530.7	223.5	130.8	30.9
Subject 3	5 kg 75 cm	25	86.9	13.0	194.0	86.0	238.3	26.0	86.9	13.0
	5 kg 140 cm	18	178.5	20.3	302.2	15.0	151.5	73.9	113.9	15.2
	10 kg 75 cm	25	296.0	14.4	479.1	254.4	628.3	298.4	104.4	27.8
	10 kg 140 cm	18	448.3	61.9	1183.3	619.2	1422.4	793.3	146.2	54.8
Subject 4	5 kg 75 cm	27	96.3	12.0	162.9	32.2	203.0	32.0	88.2	13.0
	5 kg 140 cm	19	138.0	15.4	248.8	46.2	203.0	71.7	121.0	16.5
	10 kg 75 cm	25	448.3	61.9	1183.3	619.2	1422.4	793.3	146.2	54.8
	10 kg 140 cm	17	295.3	15.4	971.8	175.6	1280.8	125.9	207.7	29.6