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EMG Signal Analysis of Fatigue Muscle Activity in Manual Lifting

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In manufacturing industries, manual lifting is commonly practiced by workers in their routine to move or transport the objects to a desired place. Manual lifting with high repetition and loading on the arm will contribute the effects of soft tissues and muscle fatigue that will affect the performance of the worker to work with efficient. This paper presents the analysis of EMG signal from muscle activity to see the performance of muscle fatigue. Various researchers have proposed fast Fourier transforms (FFT) in analysing the EMG signal. However, this technique only gives spectral information but does not provide temporal information. Thus, the technique is not suitable for EMG analysis that consists of magnitude and frequency variation. To overcome the limitation, spectrogram is proposed to analyse the signal because it can represent the signal in jointly time-frequency representation (TFR). In fatigue muscle activities, ten volunteers in fresh condition and no previous of history injury are used as the subjects. Data is taken from right Biceps Branchii with lifting height of 140 cm and load mass of 5 kg. This research shows that the repeatability of manual lifting will contribute to the muscle fatigue for all the phases stated in this paper. This study concludes that phase 2 contribute highest effort by doing manual lifting task, compared to phase 1, 3 and 4, but all phases experienced the muscle fatigue.

Keywords: Electromyography (EMG) signal; fatigue muscle activity; spectrogram; manual lifting, phases.

1. Introduction

The Electromyography (EMG) was originally developed for investigating muscular disorder. The EMG recording is used to study the functional state of the muscle during various motions (1). Its application to control prosthetic limbs that can restore some or all of lost motor functions of amputees has presented a great challenge due to the complexity of the EMG signal (1, 2). Manual lifting is an action of manually grasping an object of definable size and mass with one or two hands and vertically moving the objects without the use of mechanical device. Manual lifting is commonly practiced by workers in industrial workplace to move or transport good to a desired place. (3, 4). In industrial workplaces, manual lifting is a prevalent choice and an essential way to perform material handling task even though mechanized and automated equipment are provided. Improper lifting techniques can contribute to occupational injuries such as back pain (4). Back pain was recorded as a common complaint in Malaysia (5) which cause absenteeism at work and lead to direct loses like the increasing of medical and compensation cost and indirect loses for example low productivity due to sickness and absenteeism (6).

Most of researches use fast Fourier transform (FFT) to analyse the EMG signal. However, FFT does not provide temporal information and is not appropriate for non-stationary signal as EMG has variable magnitude and frequency. The short time Fourier transforms (STFT) which provide temporal and spectral information that represent signal

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with time-frequency representation (TFR) can overcome the FFT limitation (7, 8). Besides that, there are some researchers used wavelet transform to analyse EMG signal. However, it is found that the wavelet is sensitive to noise level and suitable selection of mother wavelet and the level of decomposition need to be chosen based on the disturbance (9). Additionally, the features extracted from the wavelet multi resolution analysis requires neural network and this procedure needs high computational.

This paper represents the analysis of EMG signal to detect the muscle fatigue by identifying the phases and characteristics of fatigue muscle activity. The EMG signals are acquired from the right Biceps Brachii (upper arms) of ten subjects based on body position of 0º. Spectrogram is used to analyse the data of the signal to get the frequency and time, before represents it in V_{rms} to form the TFR. The signal can be estimated to identify the fatigue muscle based on the peak voltage from the identified phases.

2. Notation

The notation used throughout the paper is stated below.

Indexes:

V_{rms} Instantaneous voltage

3. Experiment Setup

3.1. Subjects

Five healthy male and five female in fresh condition with no previous history of musculoskeletal injuries participated in this study. The subjects were selected between the ages range of 21 to 25 years. The entire subjects are right handed. The demographics of the subjects are shown in Table 1.

Table 1. The demographics of the subjects.

Criteria	**Minimum**	**Mean**	**Maximum**
Age (year)	21	23	25
Body mass (kg)	48	61.5	75
Body height (cm)	156	163	170

3.2. Data Collections

The surface EMG (TeleMyo 2400T G2, Noraxon, USA) and MyoResearch XP Master Software (Noraxon, USA) are used for recording and analysing the EMG data. The subject's arm (biceps brachii) are shaved as shown Figure 1. The BD Alcohol Swabs of 70 % Isorophyl Alcohol is used in skin preparation cleanser process, then hand would leave to dry before rubbed with the Signa Gel, 250g tube which is highly conductive multi-purpose and attaching with electrodes (Ag/AgCL, 10 mm diameter). The Non-Invasive Assessment of Muscle (SENIAM) guideline is referred to ensure all the surface EMG protocols were compiled (4). Surface EMG electrodes attached at the biceps as input (A) and reference electrode location (B). Software MATLAB 2011 (MathWorkInc, USA) is used in the analysis of the signal and it is familiar for those using mathematical processing in the analysis data process. The sampling frequency (fs) used is 1500 Hz and a low pass filter with the range of 0-500 Hz is used to filter the EMG signal. New algorithm from the mathematical calculation is written in the program to produce FFT (Power Spectrum), Spectrogram and instantaneous voltage, Vrms. The Hanning window 512 was used to compare the EMG signal. This window produces the best results for the EMG signal to be analysed. Each subject was tested and analyse using the spectrogram and represent with Vrms. Based on pattern of the signals, this study can identify the fatigue of the muscles involved in manual lifting.

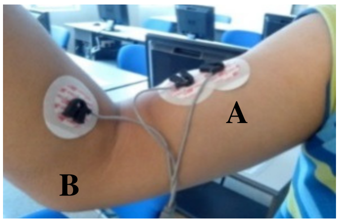


Fig. 1, Surface EMG electrode's placement at the biceps.

3.3. Tasks

Subjects have to lift the 10 kg load mass with 140cm of height for symmetric angle (0°) to get the time fatigue of right biceps during the manual lifting task. The subjects are required to lift the load onto the shelf repetitively until achieved the limit of their effort. At this time, the subjects would be considered achieve fatigue muscle, and data measured would be stop at this time. Each lifting will produce the signal of contraction muscle, and each contraction signal was divided into four phases as in the Figure 2. The details for the phases are shown as follow:

Phase 1: Subject takes the load
Phase 2: Traveling the load onto the shelf
Phase 3: Place the load onto the shelf
Phase 4: Release the load

Phase 1 Phase 2 Phase 3 Phase 4

Fig. 2, Four phases involved in each lifting

4. Methods

Spectrogram is one of the TFR that represents the three-dimensional of the signal with respect to time and frequency in magnitude. The FFT have the limitation which is not able to cater non-stationary signal whose spectral characteristic changes in time and frequency.

It is the result of calculating the frequency spectrum of window frames of compound signal (7, 10). Spectrogram provides high frequency resolution and it is calculated as Equation 1 below:

$$S(t,f) = \left| \int_{-\infty}^{\infty} x(\tau)w(\tau - t)e^{-j2\pi f} dt \right|^2 \tag{1}$$

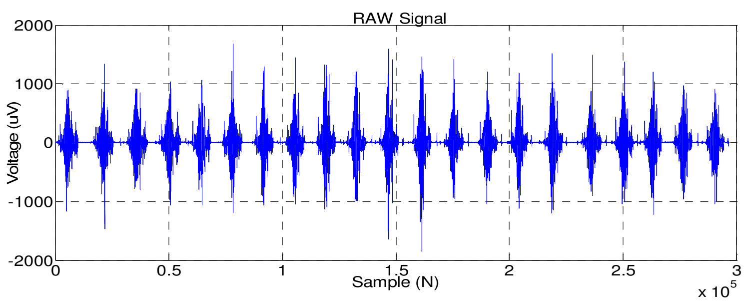
Where $x(\tau)$ is the input and $w(t)$ is the observation window. Hanning window is used in this task because it have lower peak side slope. The parameter used to analyse the pattern of signal from spectrogram is instantaneous RMS voltage, $V_{rms}(t)$. $V_{rms}(t)$ can be calculated as Equation 2 below (7):

$$Vrms(t) = \sqrt{\int_0^{fmax} S(t,f)dt} \tag{2}$$

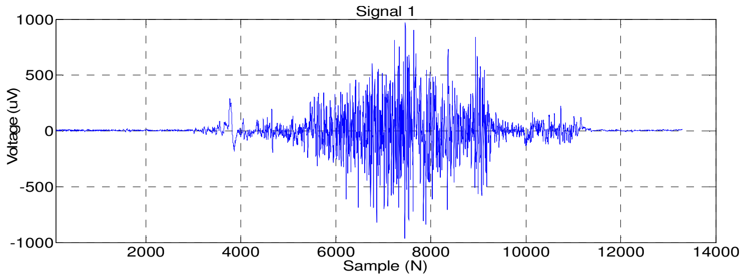
Where $S_x(t,f)$ is the time-frequency distribution and f_{max} is the maximum frequency of interest.

5. Result and Discussion

The raw EMG signal data is captured from the fatigue muscle activity. The signals measured are processed and filtered with low and high frequencies of 0 Hz and 500 Hz, correspondingly. All the subjects will repeat the lifting load process until achieve the fatigue muscle condition. Sampling frequency of 1500 Hz is used in the analysis by using TFR. The recorded EMG data is analysed by using TFD and it shows that the amplitude and frequency of the signal and V_{rms} will show the parameter V_{rms} to identify the muscle fatigue and four phases. Figure 3(a) shows the raw EMG signal for overall fatigue muscle activity involved and Figure 3(b) shows the contraction muscle separated from the overall contraction muscle to be analysed. From the RAW signal, it is shown the amplitude of the EMG signal (Voltage (μV)) is decreasing to the number of samples. From RAW signal, the data would be separated and analyse one by one to transform the data from time domain to frequency domain through FFT and then analysed by using Spectrogram before represent by V_{rms} to get the information of fatigue muscle and pattern of the signal.



(a)



(b)

Fig. 3, (a) RAW signal captured from the fatigue muscle activity to identified muscle fatigue, (b) separated signal to analyse

Figure 4(a) shows the previous technique of power spectrum which is display in bar mode of the signal. However this technique is not appropriate to use because it just give the temporal information of voltage (amplitude) and frequency only, not in time. V_{rms} used as the parameter of the signal to identify the EMG signal. It can't generate the signal without time information. As the result, power spectrum technique cannot be used to identify muscle fatigue and the pattern of the EMG signal.

Based on Figure 4(b), it shows the analysis process by using spectrogram that provides information in terms of frequency and time to know the information of fatigue muscle. It indicates that the highest amplitude for each contraction is at 50Hz and 3200ms. Then, Vrms is estimated to from the TFR to obtain clearer information of voltage, and phases in the contraction.

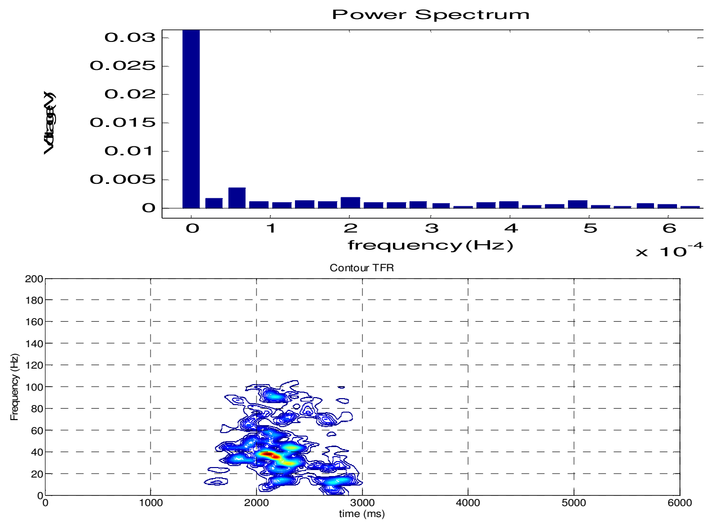


Fig.4 (a), power spectrum in bar of the signal and Fig. 4(b), result for spectrogram

By referring to Figure 5, it shows the peak value at each classified phases from V_{rms} for each contraction. It is based on the duration in fatigue muscle activity to get the peak value for each phases.

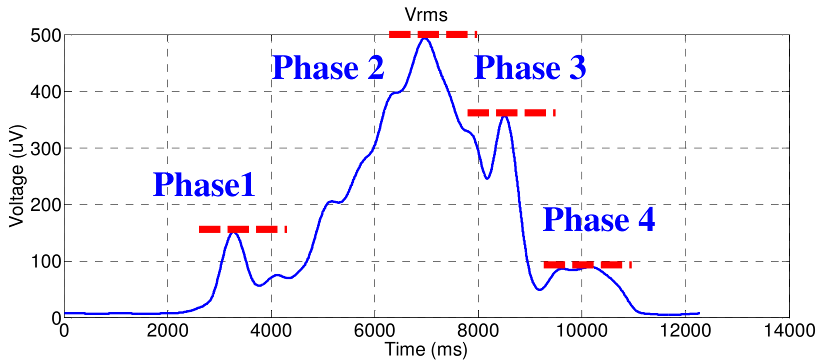


Fig. 6, peak value V_{rms} signal for signal 4

From the Figure 6, it shows the performance of muscle facing fatigue condition. As the increasing of repetition lifting task, it is produced the decreasing of voltage. Muscle fatigue condition is when the ability of the muscle to contract and produce force is reduced. It is typically define the point in time when the subjects can no longer perform task. Muscle fatigue varies from person to person, so the average is taken to get the result in Figure 7. Phase 2 involves the maximum voltage compared to phase 3, phase 1 and phase 2 because at this phase the subject will used all their effort to lift the load.

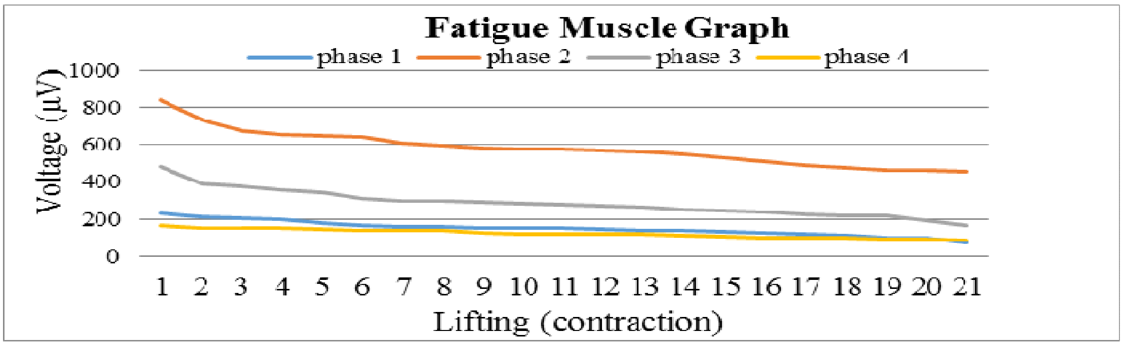


Fig. 7, performance of the fatigue muscle activity

Conclusion

In the nutshell, this study presents that the EMG signal of the fatigue muscle is suitable to be analysed by using spectrogram. The parameters of the EMG signal estimated for the TFR indicates the characteristics of the manual lifting activities. As a conclusion, it shows that phase 2 requires the highest energy used by the subject followed by phase 3, phase 1 and the lowest phase 4. The repetitive lifting in manual task will make the subject expose to lower performance and quality in their work.

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