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Impact of Different Lifting Height and Load Mass on Muscle Performance using Periodogram

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ABSTRACT

Musculoskeletal disorders (MSDs) caused by muscle fatigue have been a major problem for industry which needs to be resolved to save costs related to human resource development (extra training and compensation). Detailed fatigue monitoring researches aimed at finding the best fatigue indices is not new although studies on the causes of fatigue can be explored further. Identification analysis is required to monitor the factors that influence muscle performance characteristic of surface electromyography (sEMG) signal. Periodogram monitoring technique applies a frequency domain signal and represents the distribution of the signal power over the frequency. It is a technique that allows the tracing of small changes in the behaviour of sEMG signal when external parameters are varied. This technique is used in this paper to monitor the sEMG signal changes in muscle performance when the lifting height and load mass are varied. The periodogram amplitude, which represents the power, increases with the rise in lifting height and load mass. From the frequency representation of the periodogram, the root mean square voltage (V_{rms}) is calculated where the muscle performance characteristic could be further identified. The V_{rms} also shows a similar trend when the lifting height and load mass are varied proving the periodogram technique is useful to monitor changes in the muscle performance during manual lifting.

Keywords: Periodogram, electromyography, frequency representation, manual lifting

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INTRODUCTION

Musculoskeletal disorders (MSDs) due to manual lifting are viewed as one of the main source of occupational injury, influencing the quality of life of industrial laborers worldwide.

Since most of the MSDs are caused by muscle fatigue, studies have concentrated on finding the best fatigue indices (González-Izal et al., 2010). For sometime now, surface electromyography (sEMG) has been perceived as a solid instrument to assess muscle condition in biomechanics applications. The sEMG signal is a measure of the electrical activity in human body produced by skeletal muscles (Merlo & Campanini, 2010). sEMG is commonly utilized in research due to the fact that it is non-invasive and convenient to use (Shair, Zawawi, Abdullah, & Shamsudin, 2015). Since the characteristics of the sEMG signal itself is complicated and non-stationary, accurate analysis and scrutinizing of sEMG signal has been greatly valued.

Generally, there are three types of methods to analyse the sEMG signals: time domain, frequency domain and time-frequency domain. Even though the trend now is to use time-frequency domain the time domain and frequency domain continue to be popular (Tkach, Huang, & Kuiken, 2010). Different techniques have been used to identify the effects of outside factors such as lifting height and load mass in manual lifting on muscle performance. Kamarudin (Kamarudin, Ahmad, Hassan, Yusoff, & Dawal, 2014) in her paper presented the effects of different lifting height, load mass and twist angle to the biceps and triceps muscles, and to the subject's heart rate based on the time representation. Roy, Bonato, & Knaflitz, 1998 have experimentally assessed the differences in back muscle function for static and dynamic lifting based on the instantaneous median frequency.

Identification analysis is required to monitor the factors that play a part in performance characteristics. The periodogram changes waveform information from time domain into frequency domain and represents the dissemination of the signal power over frequency. Time domain signal would only demonstrate the time for any changes in phenomena that are likely to occur in the signal, whereas frequency domain signal able to distinguish and clarify the magnitude (power) behaviour of the signal based on the individual or band of frequency.

Previous studies were mostly concerned with the utilization of periodogram technique on fault detection, leakage current and power quality (Dhahbi-Megriche & Beroual, 2015). This despite several researches having applied the periodogram for bio-signal processing.

Performance monitoring of muscle signal using periodogram is used in this study. The muscle signals, scientifically known as EMG signals from right biceps branchii are captured to assess the effects of varying the lifting height and load mass during manual lifting tasks using periodogram. The analytical domain is limited to assess the effects on various lifting conditions without focusing on muscle fatigue monitoring as a platform for future in-depth monitoring.

EXPERIMENTAL SETUP

Subjects

Five healthy male volunteers and five women volunteers were chosen for the study. None of them had a history of injury, either upper-limb disorder, lower-limb disorder or back disorder.

Their ages are between 21 to 25 years, and mean height and weight are 163 cm and 61.5 kg respectively. The complete demographic data of the subjects are shown in Table 1.

Table 1
Subject's demographic data

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

Fatigue Exercise Protocol

Subjects were requested to stand straight 0° in front of the shelf and were required to lift the load (5 kg and 10 kg) onto the 75 cm shelf repetitively until experiencing muscle fatigue. This is when the simulation time stopped. The lifting height is then changed to 140 cm. The movement of the forearm makes eccentric contraction in biceps branchii muscle. Every contraction was partitioned into four phases as in Figure 1. Details of the phases are shown as follows:

Phase 1: Subject takes the load

Phase 2: Travelling the load onto the shelf

Phase 3: Place the load onto the shelf

Phase 4: Release the load

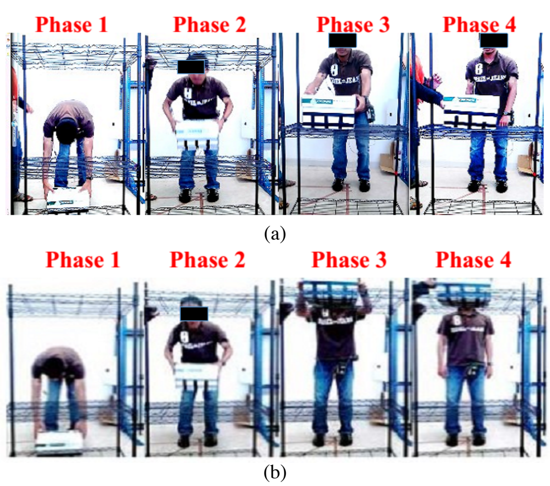


Figure 1. (a) Phases involved in each lifting for 75 cm lifting height; (b) phases involved in each lifting for 140 cm

sEMG Data Collection

The sEMG signals from the right biceps branchii were recorded, sampled at 1500 Hz and filtered by a low pass filter of 500 Hz using Noraxon TeleMyo 2400T G2 and MyoResearch XP Master Research software. The location of Ag/AgCl electrodes (diameter 10mm) was aligned parallel to the fibres of the biceps branchii. To secure the electrodes, the electrodes are fixed onto the skin surface with an anti-allergic tape. Before attaching the electrodes, skin surface is cleansed using BD Alcohol Swabs of 70% Isorophyl Alcohol, and leave to dry before rubbing with the Signa Gel which is highly conductive, then only the electrodes are attached. The electrode placement is shown in Figure 2, where the biceps branchii label as (A) and the reference electrode is (B).

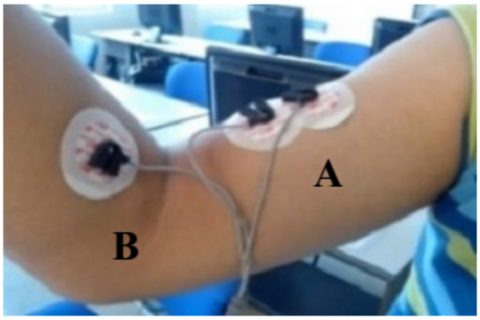


Figure 2. sEMG electrode placement on right biceps branchii

The Non-Invasive Assessment of Muscle (SENIAM) guideline was referred to obtain maximum pickup area of the EMG signals and to ensure that the signal from each subject is stable. The data of the signal were then processed by usingMatlabR2011a.

Periodogram Analytical Model

Raw data of the EMG signals were post-processed using periodogram. The periodogram changes waveform information from the time space into the frequency space and represents the dissemination of the signal power over frequency, which is called the power spectrum. The periodogram can be defined as

$$S_v(f) = \left| \frac{1}{T} \int_{-\frac{T}{2}}^{\frac{T}{2}} v(t) e^{-j2\pi ft} dt \right|^2 \quad (1)$$

where S_v (f) is the periodogram in frequency domain and *v(t)* is the voltage waveform of the raw sEMG signal.

The instantaneous root means square voltage (V_{rms} (t)) can be calculated from the periodogram as follows:

$$V_{rms}(t) = \sqrt{\int_{-\frac{f_{max}}{2}}^{\frac{f_{max}}{2}} S_v(f)df} \quad (2)$$

where $f_{max}/2$ is the maximum frequency of interest and S_v (f) is the periodogram.

EXPERIMENTAL RESULTS

Figure 3 shows the raw EMG signal at various lifting height and load mass obtained from the fatigue exercise experiment for 1 subject. These figures show a decreasing trend in the number of repetitions and time taken for the subject to experience muscle fatigue as the lifting height and load mass are increased. Similar trends were also seen for the other 9 subjects. At lifting height of 75 cm and load mass of 5 kg, the number of repetition is 36 liftings with the time

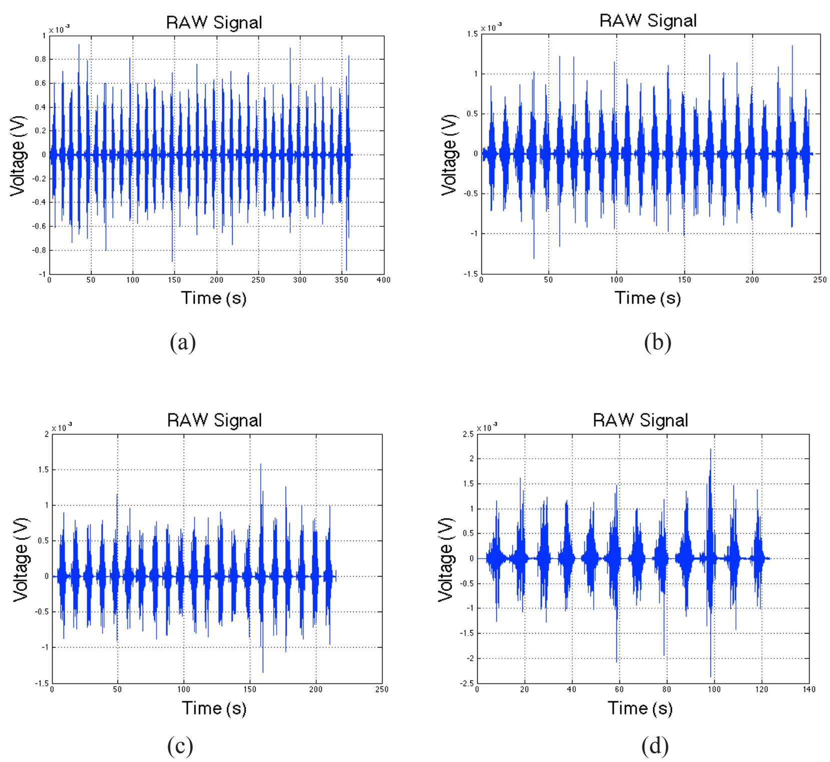
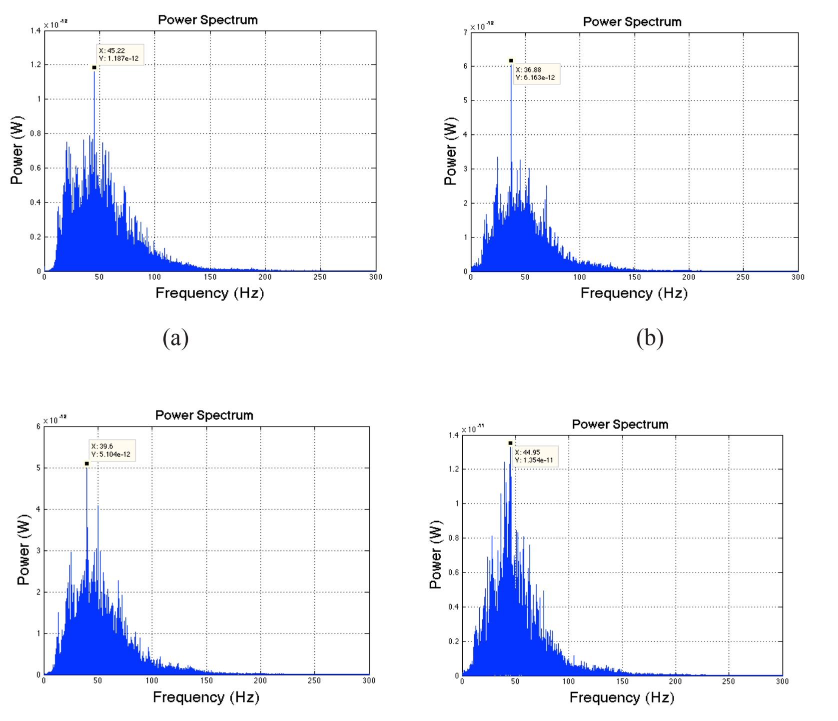


Figure 3. Raw EMG signal for (a) 5 kg load mass, 75 cm lifting height; (b) 5 kg load mass, 140 cm lifting height; (c) 10 kg load mass, 75 cm lifting height; (d) 10 kg load mass, 140 cm lifting height

taken to experienced fatigue is the highest (362.8 s) compared to the other three liftings. This trend is followed by lifting height of 140 cm and load mass of 5 kg, lifting height of 75 cm and load mass of 10 kg, and lifting height of 140 cm and load mass of 10 kg, with 24 liftings (244.6 s), 21 liftings (215.1 s) and 12 liftings (123.3 s) respectively.

Periodogram algorithm is then applied to the raw EMG signal to obtain the frequency representation of the signal. The periodogram results for different lifting height and load mass are shown in Figure 4. The signal of periodogram shows the distribution of the waveform signal power for the Y-axis over the frequency for the X-axis. Each signal from the periodogram shows similar frequency trend, however the amplitude value of the power spectrum for different lifting has a slight changed. The result indicates that the value of the amplitude (power) increased when the lifting height and load mass increased. The maximum power exists in the power spectrum for different liftings starting from 75 cm lifting height and 5 kg load mass, 140 cm lifting height and 5 kg load mass, 75 cm lifting height and 10 kg load mass, 140 cm lifting height and 10 kg load mass are 1.187×10^{-12} W, 6.153×10^{-12} W, 5.104×10^{-12} W and 1.35×10^{-11} W respectively.



(c) (d)

Figure 4. Power spectrum for (a) 5 kg load mass, 75 cm lifting height; (b) 5 kg load mass, 140 cm lifting height; (c) 10 kg load mass, 75 cm lifting height; (d) 10 kg load mass, 140 cm lifting height

From the power spectrum, muscle strength is estimated by calculating the Vrms values. The periodogram data of V_{rms} and maximum power with various lifting height and load mass is presented in Figure 5. These values are the mean values taken from all of the 10 subjects. It can be seen that V_{rms} are slightly increased from 0.0012 V, 0.0017 V, 0.0018 V and 0.0024 V as the lifting height and load mass are increased. Similar trend also showed by the EMG signal maximum power values. Hence, the overall results for periodogram data of V_{rms} and maximum power at various lifting conditions are presented in Table 2.

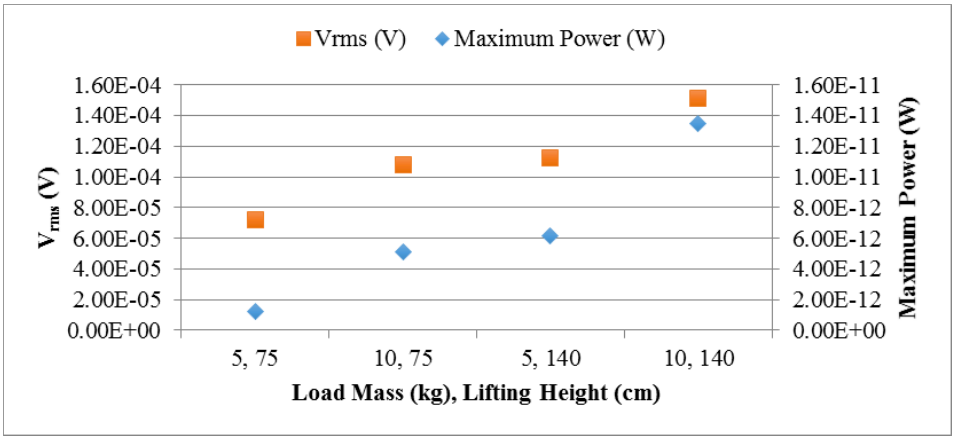


Figure 5. Periodogram data of maximum power and Vrms at various load mass and lifting height

Table 2
Periodogram data of various load mass and lifting height

Lifting Height (cm)	75		140	
Load Mass (kg)	5	10	5	10
Maximum Power (W)	1.19E-12	5.10E-12	6.16E-12	1.35E-11
V_{rms} (V)	7.19E-05	1.08E-04	0.0018	0.0024

CONCLUSION

An experimental study based on analysis of the periodogram power spectrum was performed to monitor the effects of different lifting height and load mass on muscle performance. Results indicate the number of lifting repetitions which could be performed before the subject experiences muscle fatigue. The findings show the relationship between the lifting height and load mass on muscle performance. Apart from that, it indicates that both the amplitude of the periodogram, which represents the power and the Vrms (strength) are increased as the lifting height and load mass are increased. Consequently, the EMG signal characteristic of various lifting height and load mass could be well presented by using periodogram.

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REFERENCES

Dhahbi-Megriche, N., & Beroual, A. (2015). Time–Frequency Analyses of Leakage Current Waveforms of High Voltage Insulators in Uniform and Non-Uniform Polluted Conditions. *IET Science, Measurement and Technology, 9*(8), 945–954. doi:10.1049/iet-smt.2015.0116

González-Izal, M., Malanda, A., Navarro-Amézqueta, I., Gorostiaga, E. M., Mallor, F., Ibañez, J., & Izquierdo, M. (2010). EMG Spectral Indices and Muscle Power Fatigue during Dynamic Contractions. *Journal of Electromyography and Kinesiology, 20*(2), 233–240. doi:10.1016/j.jelekin.2009.03.011

Kamarudin, N. H., Ahmad, S. A., Hassan, M. K., Yusoff, R. M., & Dawal, S. Z. (2014). Muscle Contraction Analysis During Lifting Task. In *IEEE Conference on Biomedical Engineering and Sciences* (pp. 8–10). Miri, Sarawak, Malaysia.

Merlo, A., & Campanini, I. (2010). Technical Aspects of Surface Electromyography for Clinicians. *The Open Rehabilitation Journal, 3*, 98–109. doi:10.2174/1874943701003010098

Roy, S. H., Bonato, P., & Knaflitz, M. (1998). EMG Assessment of Back Muscle Function During Cyclical Lifting. *Journal of Electromyography and Kinesiology, 8*(4), 233–245. doi:10.1016/S1050-6411(98)00010-8

Shair, E. F., Zawawi, T. N. S. T., Abdullah, A. R., & Shamsudin, N. H. (2015). sEMG Signals Analysis Using Time-Frequency Distribution for Symmetric and Asymmetric Lifting. In *2015 International Symposium on Technology Management and Emergent Technologies (ISTMET)* (pp. 233–237).

Tkach, D., Huang, H., & Kuiken, T. a. (2010). Study of Stability of Time-Domain Features for Electromyographic Pattern Recognition. *Journal of Neuroengineering and Rehabilitation, 7*, 1–13. doi:10.1186/1743-0003-7-21