IoT Based EMG Monitoring System

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Abstract- Electromyogram (*EMG*) is a technique to record, evaluate and analyse the electrical activity produced by muscles. This technique is used to detect the issues that harm the nerves, muscle tissues and spot the location where they are joining .In manufacturing industries, manual lifting is regularly performed task to move or change thing's position to a desired place even with the availability of mechanized material handling equipment. Heavy weight or over weight lifting with high repetition will affect the soft tissues and muscle that may results in low productivity and low performance of workers. The aim is to develop a IoT based EMG monitoring device, which will analysis the EMG signal, generated from biceps branchii to check the performance of fatigue in that muscle. In addition, the generated raw EMG signal are saved and send over internet via WiFi module ESP8266 using TCP/IP protocol making it a IoT device. Therefore an innovative EMG generating methodology is proposed in this study which shows that repetitive manual lifting will leads to fatigue in muscles of all phases discribed in the study. This study concludes that among all the phases, phase 2 experience maximum muscle fatigue by doing lifting task as compared to phase 1, 2 and 3 but other phases also experience the muscle fatigue.

Key Words: Electromyography, Internet of things, fatigue, Manual lifting, Bicep branchii, WiFi module.

1. INTRODUCTION

EMG ia a technique for measuring the electrical activity of the muscles. EMG is done by using a tool known as an electromyograph which will provide a record known as electromyogram . The EMG signals is used to examine the cause of muscle weakness, numbness, several types of limb pain, cramping, muscle disorder such as polymyositis or biomechanics of living beings movement [1] and can be used to find the weakness and strength level of muscles for recovery purpose. [2].
In manual lifting task, an object of definable dimensions is grabbed with both hands and move the objects with both hand without the use of any automated device vertically [3]. Workers in manufacturing industries regularly perform lifting task manually to move objects to desired place. Even though there are so many mechanized and automated equipments are available but manually lifting task is a common choice and a key method to operate material handling task [4]. Incorrect lifting skills can leads to injuries like back pain [5]. Back pain is a common problem in industries and which cause many loses such as increase in medical cost, low productivity and absenteeism.

Many research work has been done to analyze EMG signal and many techniques have been proposed. Some used fast fourier transform (FFT). However, magnitude and frequency of EMG signal is variable and FFT is appropriate for stationary signal. Also, it provides spectral information only [6]. The short time fourier transform (STFT) technique was used to overcome the limitation of FFT, which provides spectral and temporal information that represents signal with time-frequency representation (TFR) [7] .Apart from that, some used wavelet transform in the analysis of EMG signal [8].WT has some advantage as well as disadvantages like it needs lots of computational analysis, noise level sensitivity and reliance of its own accuracy on selected wavelet.

In this study, EMG signals are analysed to identify fatigue in muscles by locating the phase and characteristic of muscle fatigue activity. The raw EMG signals are generated from right biceps branchii of four healthy male. The raw signal is divided into four phase and AcqKnowledge 4.1 is used to analyse the recorded data to get the mean power frequency (MPF).The muscle activity in different phases can be evaluated to detect the muscle fatigue based on peak voltage of phase.

2. METHODS

2.1 Participants

Raw EMG signal were recorded from four sound subjects who has no history of muscloskeletal difficulty. The participants selected were of the age group between 22-26. All the subjects were right handed. The entire study procedure was explained to participants individually. The demographic of the participants are displayed in table 1.

Table 1: The demographic of the participants

Criteria	Maximum	Mean	Maximum
Age(year)	22	23.75	26
Weight(kg)	50	62.75	81
Height(cm)	156	166	179

2.2 Experimental Setup

So many equipments are used in the experiment to measure the parameters like sEMG cicuit board, adjustable shelf, loads, weight scale and lifting box. EMG cicuit board is the main equipment by which recording of signal is done for each lifting. Electrical activity produced by the muscle contraction are recorded and response of biceps branchii muscle are collected.

2.3 Tasks

The participants were instructed to lift the 10 (kg) weight to 140 cm height and they need to twist 0^0 to get the fatigue of biceps muscle during lifting task. They have to lift the weight to the shelf continuously until they reached the maximum limit of attempts. At that point, participants were considered attain muscle fatigue and recording will be stopped at that point. With the each lifting, contraction muscle signals will be produced and each signal will be divided into four phase as shown in figure.The phase details are as below:

Phase 1: Participant holding the load
Phase 2: Lifting the weight into the shelf
Phase 3: Placing load onto the shelf
Phase 4: Put the load.

Figure 1: Different phases involved during lifting task

2.4 Lifting Procedure

The lifting procedure is shown below.

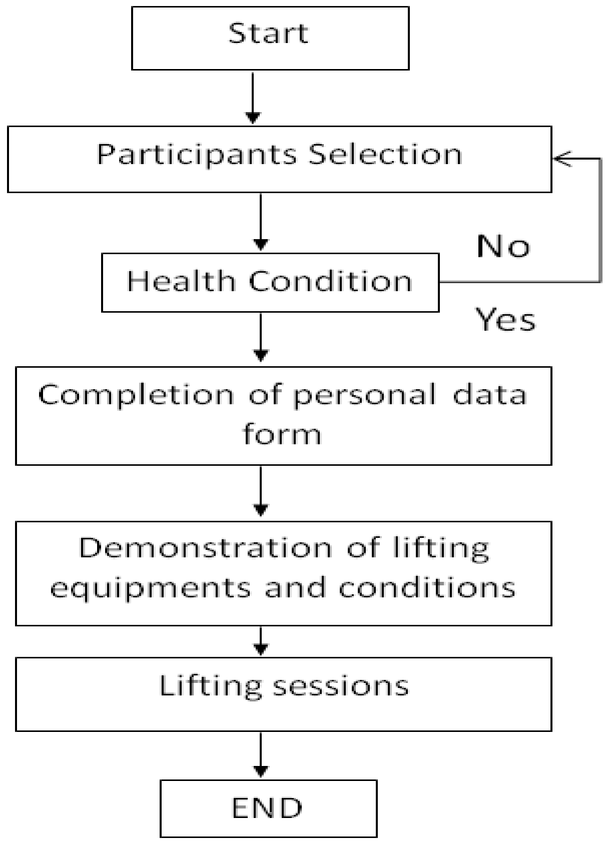


Figure 2: Flowchart of lifting procedure

2.6 Data Collection

The EMG signal generated through muscle movements were recorded, stored and analyzed by self designed EMG circuit, Backyard brains spike recorder and Biopac Acqlnowledge 4.1 software. The participants biceps branchii was cleaned with alcohol. The surface EMG for non-invasive assessment of muscle (SENIAM) guideline were mentioned to make sure every sEMG procedures were followed. The electrodes placed to biceps branchii as input A and reference electrode B.

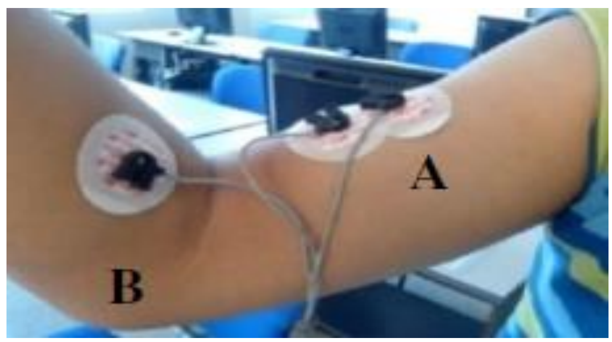


Figure 3: Surface EMG electrodes placed at biceps branchii

The EMG signal was recorded on spike recorder software. Then recorded signal was divided in four experiment sets and each set was further divided into four phase. After this, the values of each phase was find out. After getting values of each phase of every participants, mean power frequency (MPF) is calculated by Acqknowledge 4.1. This will provide best result for analysis. The Minitab verison 18 was used to compare the signals. Depending on the scale of the signals, this study can recognize the muscle fatigue in manual lifting.

2.7 WiFi Module

After completing the First phase of work, that is recording data from spike recorder, you can record data by wifi module also. Wifi module Connect the EMG system with online/Ethernet features using TCP/IP protocol.
This is done using Addition of ESP8266 Wif Module. Wifi Module having capabilities of full TCP/IP protocol is added to our EMG system. It interface with System using AT command.

The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor. Each ESP8266 module comes pre-programmed with an AT command set firmware, meaning, you can simply hook this up to your Arduino device and get about as much WiFi-ability as a WiFi Shield offers.
Algorithm Used: In first step Wi-Fi module is selected for Both server and Client Mode, then any previous Wi-Fi connection is disconnected, then Wi-Fi module is reset, then Wi-Fi module try to connect to access point, after connecting to Wi-Fi server port number and IP address is generated, and now Arduino flash message "Refresh the Page", now user has to type the IP address in web browser and refresh the page, then you will see data on webpage in analog form.

3. RESULT AND DISCUSSION

The EMG signal was measured from the fatigue muscle activity during manual lifting task. All the participants will repeat the lifting process until they experience the muscle fatigue state. AcqKnowledge 4.1 is used to analyze the recorded data and we can find different parameters like average rectified EMG, integrated EMG, root mean square EMG, EMG power and frequency analysis and also locate muscle activation but we used V_{rms} to identify the muscle fatigue and four phase.
The raw EMG signal recorded during the lifting task is shown in the figure 4(a).
Figure 4 (b) displays the contraction muscle which is separated from overall EMG data to be analysed and this will further divide into four phase

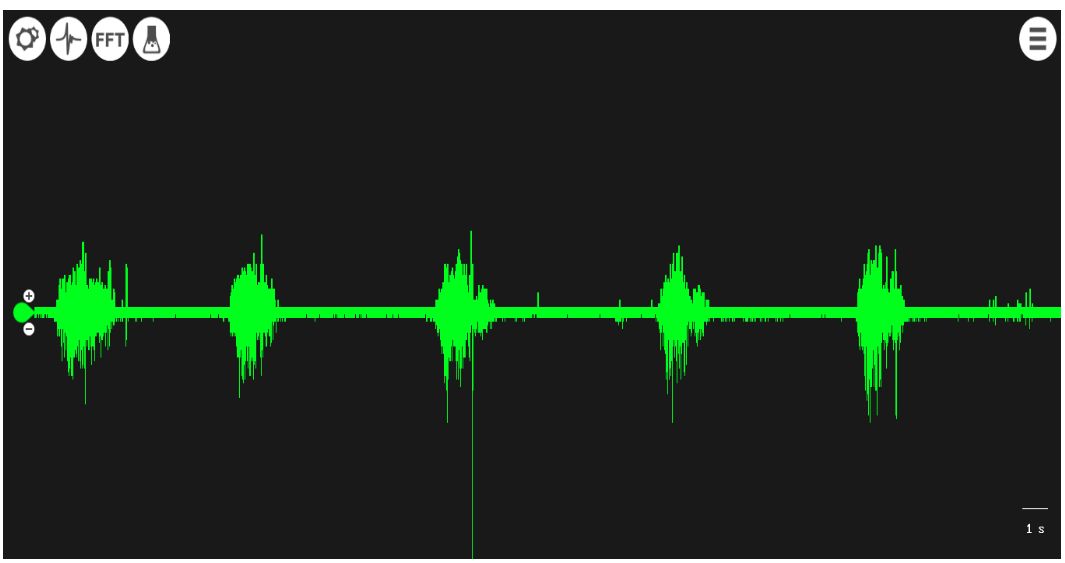


Figure 4(a): Raw signal recorded during manual lifting task to identify muscle fatigue (amplitude vs time)

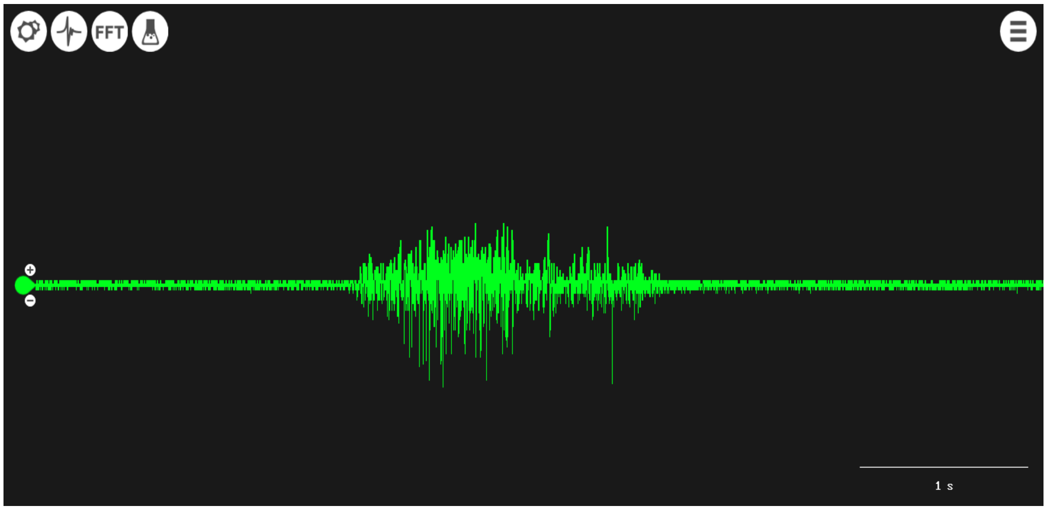


Figure 4(b): Separated signal to analyse

Further, the separated signal which is selected is sub-divided into 4 phases. Similarly all the contraction muscles data will be separated one by one and sub-divided into 4 phase and then analysed by Minitab before presented by V_{rms} to get the muscle fatigue information.

Table 2: Mean values of recorded signal from all four participants.

Lifting Task	Phase	Participant 1	Participant 2	Participant 3	Participant 4
1	1	0.001653	0.001001	0.002613	0.002566
	2	0.003503	0.008666	0.005128	0.005368
	3	0.0016	0.009164	0.004336	0.004
	4	0.000678	0.002874	0.002794	0.002544
2	1	0.002023	0.004845	0.004627	0.0022
	2	0.004176	0.010308	0.007150	0.004645
	3	0.001498	0.0082	0.003769	0.003057
	4	0.000977	0.002073	0.003316	0.002075
3	1	0.002522	0.003546	0.002442	0.001943
	2	0.003719	0.010904	0.003847	0.005301
	3	0.001163	0.00777	0.004726	0.003692
	4	0.000871	0.003854	0.003981	0.002374
4	1	0.001923	0.003106	0.003319	0.001544
	2	0.003701	0.010666	0.00476	0.004708
	3	0.003155	0.007961	0.003706	0.005435
	4	0.001909	0.003369	0.002696	0.003836

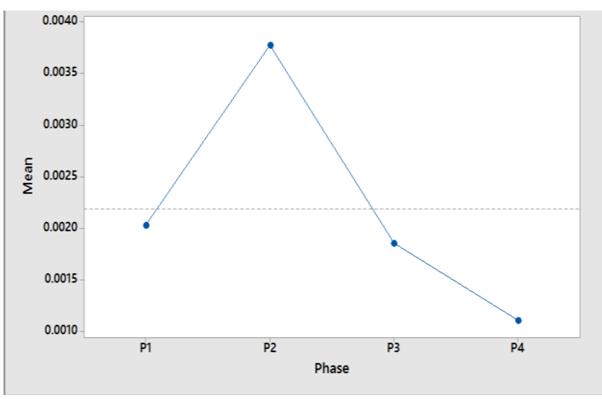
Table 2 displays the mean values of recorded data taken from all the participants are calculated during manual lifting task. V_{rms} is used as the parameter to identify the EMG signal.

Table 3: Analysis of Variance

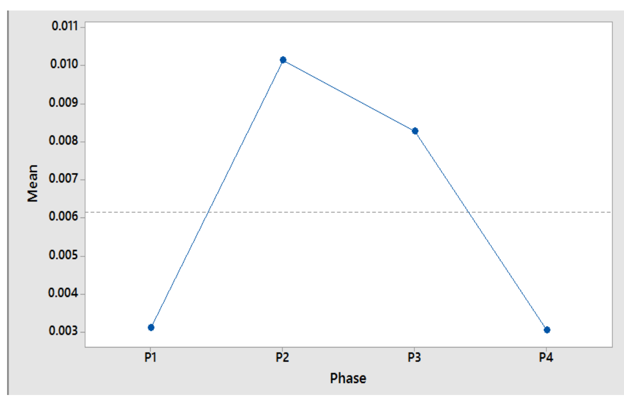
Source	DF	Adj SS	Adj MS	F-Value	P-Value
phase	3	0.000137	0.000046	9.95	0.000
task	3	0.000002	0.000001	0.15	0.932
phase*task	9	0.000008	0.000001	0.20	0.993
Error	48	0.000221	0.000005		
Total	63	0.000368			

The results of the one-way ANOVA test (Table 3) revealed no significant difference ($p>0.05$) in the mean frequency values for all muscles during manual lifting task.

Fig. below displays the graphs of mean values versus phases for muscles when performing manual lifting. The x-axis represents the phase of different experiment task taken when performing the lifting task, while the y-axis shows the mean of the lifting task. The right Biceps Brachii muscle experienced maximum fatigue in phase 2 when performing the lifting task of experiment set 1, 2, 3 and 4 as the MPF of the muscles increased. Meanwhile, the Biceps Brachii muscle experienced fatigue in phase 3 at the experiment set 2, 3 and 4. As phase 1 and 4 apply less force while lifting task so they don't experience muscle fatigue in any experiment tasks. Based on these experimental settings, the muscles experienced fatigue because muscle activity is affected by lifting height and load mass.



(1)



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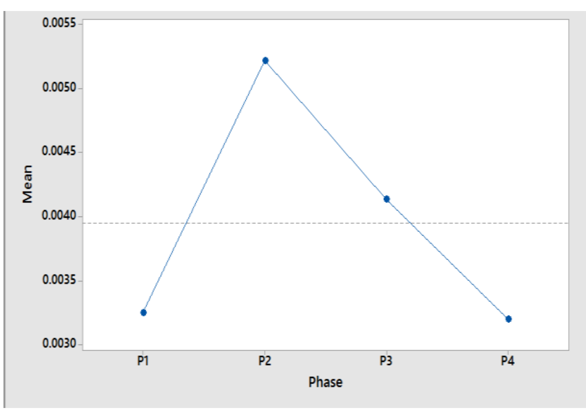

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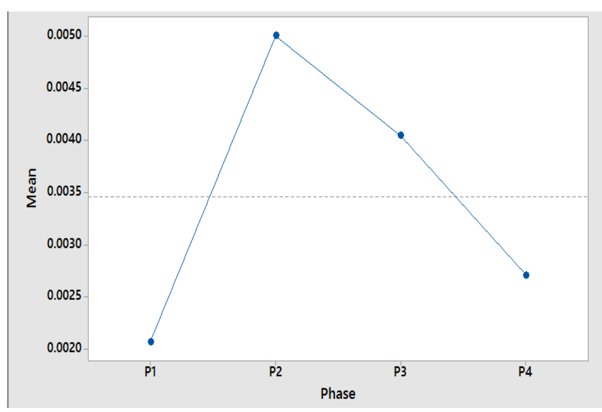

(4)

Figure 5: Muscle fatigue of biceps branchii during four experiment task (1,2,3,4)

Figure 6 displays the performance of muscle facing fatigue state. It shows that with the continuous lifting task, it will result in decreasing of voltage mean. Muscle fatigue state is a state when capability of muscle to contract and generate force is decreased. It is generally describes as a point when the participants can't continue the task further in time. Among all the phases, phase 2 experience maximum muscle fatigue by doing lifting task as compared to phase 1, 2 and 3 but other phases also experience the muscle fatigue because at that point the participants will utilize their all energy to lift the load.

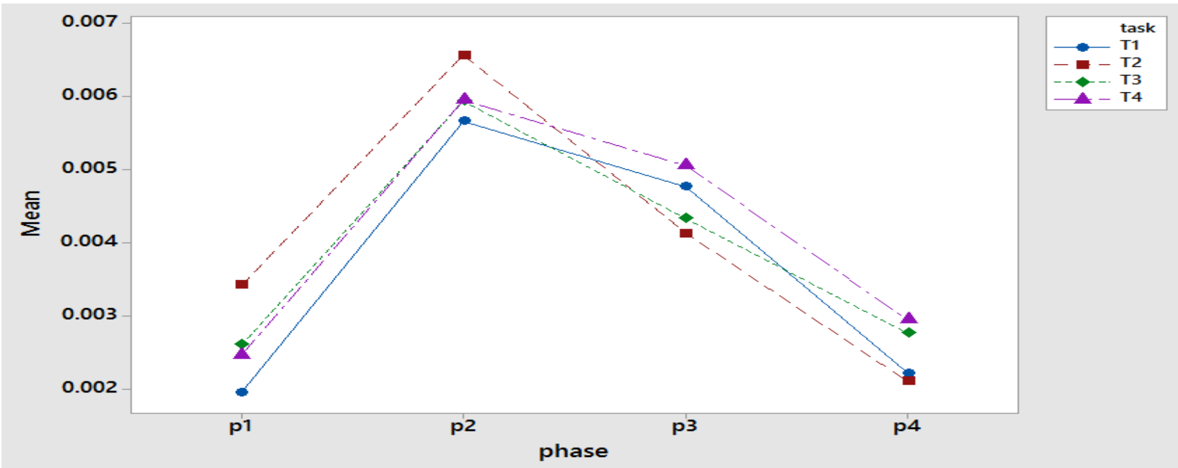

Figure 6: Perfomance of muscle facing fatigue condition of all phases (mean value vs phase)

CONCLUSIONS

This study comes to the conclusion that right biceps branchii faces muscle fatigue condition as the weight load applied was 10 (kg) at the lifting height of 140 cm while performing symmetric lifting task of 0^0 twist angle. This study concludes that among all the phases, phase 2 experience maximum muscle fatigue by doing lifting task as compared to phase 1, 2 and 3 but other phases also experience the muscle fatigue. The continuous manual lifting task will leads to low productivity and low performance in their work. Also this system can be used as IoT monitoring system for recording EMG data and send data wirelessly with online/Ethernet features using TCP/IP protocol.

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