Biomechanics Instrumentation Design Laboratory II

Electromyography

Minster

Abstract

Patients with peripheral neuropathies, neuromuscular junction disorders, myopathies and motor neuron disease are candidates for an EMG test. The purpose of this lab is to obtain abilities to acquire and analyze biomedical signals and electromyography (EMG) and pressure data are chosen for this lab. The objective is to investigate the correlation of pressure and EMG activity during isometric contraction of the biceps brachia. The EMG measures muscle response in response to a nerve's stimulation of the muscle, which is called motor unit action potential. In this lab, surface electrodes were used to measure both pressure and EMG signals and MS Excel program was used for data analysis. According to the normalized EMG, it explains that motor units are fired before force is exerted to the bench and muscles are relaxed before force is actually released from the bench. Also the distance between the motor unit and the surface of the electrode severely influences the amplitude of the action potential. Pressure vs. linear envelope of rectified EMG graph does not show the linear correlation. The EMG peak voltage at maximum, 75%, 50%, and 25% and pressure data points has a linear correlation. The IEMG (integrated) voltage at pressure data points has a non linear correlation. For the future lab, various muscle groups can be tested to understand duration of motor unit action potential.

Introduction

In biomedical engineering fields, signals are critical for analyzing and helping to decide the conditions and treatment of patients. Thus, biomedical instruments require a signal processing, for example, filtering to get undistorted, free of noise, etc. The purpose of this lab is to obtain abilities to acquire and analyze biomedical signals and electromyography (EMG) and pressure data are chosen for this lab. The objective is to investigate the correlation of pressure and EMG activity during isometric contraction of the biceps brachia. It is important to understand an electrical signal generated in the muscle fibers which is very similar to the way action potentials through axons, this special signal is called motor unit action potential (m.u.a.p). In response to an action potential from the neuron, a muscle fiber depolarizes as the signal propagates along its surface and the fiber twitches (Winter, 235). This depolarization generates an electric field in the vicinity of the muscle fibers which can be detected by a skin surface electrode located near this field. The resulting signal is called the muscle fiber action potential. The combination of the muscle fiber action potentials from all the muscle fibers of a single motor unit is the motor unit action potential. All of the muscle fibers in a motor unit are fired each time a motor unit fires. The summation of electrical activity created by each active motor unit is the myoelectrical signal. There are two main types of electrodes: surface and indwelling. Surface electrodes detect average activity of superficial muscles and give more reproducible results than do indwelling types. Indwelling electrodes are required for the assessment of fine movements or to record from deep muscles. However, indwelling and surface electrodes are influenced not only by waves that actually pass by their conducting surfaces, but also by waves that pass within a few millimeters of the bare conductor (Andreassen and Rosenfalck, 23). An indwelling electrode is a hypodermic needle with an insulated conductor which forms the other conductor. Therefore surface electrode is more preferred than indwelling electrode. Conductive electrode gel is placed between skin and surface electrodes to decrease the impedance of skin. Biomedical engineers should consider each electrode-skin interface has finite impedance that depends on many factors, such as, thickness of the skin, cleaning of the skin prior to the attachment of the electrodes, area of the electrode surface, and temperature of the electrodes. Thus, electrode gel is not necessary for indwelling EMG.

Methods

Before preceding the experiments, there are settings should be selected: for hand dynamometer, gain is 100, filter frequency is 50Hz, and mode is bridge. For EMG, gain is 100, filter frequency is 1000Hz, and mode is BIO2. The subject should be seated near the biopotential amplifier and computer and facing the bench. The EMG leads are placed on elbow (brown color- ground), positive (red color), and negative (black color). The positive electrode should be positioned in line with the belly of the biceps muscle, near the proximal end. The negative electrode should be positioned in a similar fashion at the distal end of the muscle. After placing electrodes, turn the biopotential amplifier on. Then the pressure transducer should be held in the palm of the hand and pressed upward against the underside of the counter. After collecting data, data acquisition and analysis is performed. With the program BioBench, the condition is set with sampling rate as 1000Hz combined for the two channels, the sampling period is 5 seconds. The channel 1 is pressure and channel 2 is EMG signal. After clicking on "Go" button, the subject exert upward against the counter. Check both channels have a zero offset. Before clicking on "Ok" button, the subject press upward on the counter with maximal force. Maintain this force until after the data collection has been initiated. During data acquisition is performed, the subject should gradually decrease the applied force until no force is applied. This procedure records a single contraction over a 5 seconds interval. The acquired data will be displayed on the graphs. If it is necessary, then repeat the procedure. Perform recalculation of power spectrum, adjusting frame size and log/linear option. Then, transfer all collected data to Excel program to perform statistical analysis. Analysis includes rectified voltage, integrated voltage, filtered voltage, running sum of voltage, linear envelope of voltage, normalized voltage, and same as pressure data.

Results

The linear envelope of rectified EMG vs. time graph represents the low pass filtering the EMG power spectrum from BioBench. The data show high voltage at the beginning of the experiment due to apply for upward, and voltage is dropping due to release the force. The high voltage is shown between 1 second and 2 seconds and voltage is decreasing between 2 seconds to 4 seconds.

The raw EMG data vs. time include a lot of noise which is very difficult to distinguish EMG data. With the raw EMG data, the tendency of decreasing voltage between 2 seconds to 4 seconds is not shown which was shown in the graph with filtered data. The highest voltage was 0.75 V, the starting voltage was 0V, the lowest voltage was -3.4V and it contains the constant value, 0.3V during decreasing pressure time.

The raw pressure data vs. time graph shows very clear increasing and decreasing pressure range. The pressure increased between 0.7 seconds to 1.3 seconds and decreased between 1.3 seconds to 3.5 seconds. The starting pressure was 1.5 psi and the highest pressure was 2.2 psi.

The full wave rectified EMG signal vs. time shows all positive voltage which is absolute value of raw EMG data. It still has a lot of noise and saturated points. With the raw EMG data, the tendency of decreasing voltage between 2 seconds to 4 seconds is not shown which was shown in the graph with filtered data. The highest voltage was 0.75 V, the starting voltage was 0V, and it contains the constant value, 1V during decreasing pressure time.

Normalized pressure and normalized rectified EMG vs. time graph shows that similar range of increasing and decreasing signals of both pressure and rectified EMG. But normalized EMG explains that motor units are fired before force is exerted to the bench and muscles are relaxed before force is actually released from the bench. Also the distance between the motor unit and the surface of the electrode severely influences the amplitude of the action potential.

Pressure vs. linear envelope of rectified EMG does not show the linear correlation. The regression line is y (Voltage) =2.0992x (Pressure) + 0.411. The r^2 value is 0.555 which does not support usefulness for the clinical setting.

Discussion

1. Discuss the rationale for performing full-wave rectification of EMG data.

The full-wave rectifier generates the absolute value of the EMG, usually with a positive polarity. The original raw EMG has a mean value of the EMG, usually with a positive polarity (Winter, 249). The original raw EMG has a mean value of zero because it is recorded with an amplifier with a low frequency cutoff around 10-15Hz. Thus, the full-wave rectified signal (integrated EMG) does not have a mean value of zero and it helps to perform statistical analysis. However, the full-wave rectified is limited; for example, it serves as an input to the other processing schemes. The main application of the full-wave rectified signal is for various phasic activities of various muscle groups.

2. What does the rectified, integrated EMG tell you about the EMG signal? What would a rectified, integrated EMG look like for a constant magnitude, uniform frequency EMG signal?

An examination of the amplitude changes of the rectified signal gives an indication of the changing contraction level of the muscle. The positive rectified, integrated EMG shows that the area under the raw EMG is increasing. The negative rectified, integrated EMG is shows that the area under the raw EMG is decreasing. For the constant magnitude frequency of EMG signal, the constant rectified, integrated EMG show the constant increment due to the adding same area under the curve.

3. Discuss in what situations are three surface electrodes required from an engineering point of view?

Electrode #1 and #2 should connect to different active input terminal (different point on skin) and electrode #3 should connect to the ground for safety of patients. There are two electrodes instead of one because two detected signals are subtracted prior to being amplified. In this differential configuration, the shape and area of the detection surfaces and the distance between the detection surfaces are important factors. Because the shapes and areas of and the distance between the detection surfaces determine the number of the muscle fibers seen by the electrode.

4. Construct an algorithm that allows prediction of pressure given EMG information as descried: compare EMG peak voltage at maximum. 75%, 50%, and 25% pressure data points, is it linear? Also compare the IEMG voltage values at these pressure data points.

The EMG peak voltage at maximum, 75%, 50%, and 25% and pressure data points has a linear correlation. The regression line equation is y (voltage) =-0.019x (Pressure) + 2.3242, r^2 is 0.9057, the slope is -0.019.
The IEMG voltage at pressure data points has a non linear correlation. The trend line equation is y (voltage) = 0.000002 x (pressure) ^{2} – 0.0003x (pressure) + 0.0067, r^2 is 0.9839, and the slope is 0.000002.

5. Describe the correlation of normalized pressure and normalized linear envelope EMG. How would this be useful in a clinical setting in terms of a pathology?

The pressure vs. linear envelope of rectified EMG shows no correlation. The r^2 value is 0.555 which does not support usefulness for the clinical setting. The regression line equation is Y (Voltage) =2.0992x (Pressure) + 0.411. It is only useful for seeing the normal pattern. It could be used clinically to compare patterns to decide normal and abnormal signals. However, it would not tell accurate analysis results.

Conclusion

This lab was successful because the objective was fulfilled through analyzed signals with Excel program, such as, investigated the correlation of pressure and EMG activity during isometric contraction of the biceps. The EMG measures muscle response in response to a nerve's stimulation of the muscle, which is called motor unit action potential. According to the normalized EMG, it explains that motor units are fired before force is exerted to the bench and muscles are relaxed before force is actually released from the bench. Also the distance between the motor unit and the surface of the electrode severely influences the amplitude of the action potential. Pressure vs. linear envelope of rectified EMG graph does not show the linear correlation. The regression line of the pressure vs. linear envelop graph is y (Voltage) = 2.0992x (Pressure) + 0.411. The r^2 value is 0.555 which does not support usefulness for the clinical setting. In the lab, surface electrodes were used to collect data of biceps. The EMG peak voltage at maximum, 75%, 50%, and 25% and pressure data points has a linear correlation. The regression line equation is y (voltage) =-0.019x (percentile) + 2.3242, r^2 is 0.9057, the slope is -0.019. The IEMG (integrated) voltage at pressure data points has a non linear correlation. The trend line equation is y (Voltage) = 0.000002 x $(\text{percentile})^2$ – 0.0003x (percentile) + 0.0067, r^2 is 0.9839, and the slope is 0.000002. In this lab, students did not have chance to use indwelling electrodes. An opportunity to be exposed to indwelling electrodes will help to compare and contrast between surface and indwelling electrodes. Also, in order to observe the duration of motor unit action potential, it will be helpful to test various muscles.

References

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