Force Prediction Of The Biceps Brachii Muscle Using EMG Analysis

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ABSTRACT

Reduction of range of motion in the elbow joint is common with such conditions as contracture, osteoarthritis, bone fracture, connective tissue tearing. These conditions can be debilitating and make it difficult for an individual to perform simple activities of daily life. Proper rehabilitation requires the use of predetermined loads placed upon the joint, as well as restriction against high loads at mechanically stressful joint angles. The purpose of this experiment is to use measured EMG values to accurately predict the amount of force that can be generated at any given joint angle. This was accomplished by testing the EMG values of the muscle using known joint angles and force values imparted upon the palm of the hand. Using the data points collected, a correlation curve was created. A MATLAB program was used to estimate the possible force production output using the inputs of the EMG value and a given joint angle. This program will be an effective tool that will allow athletes, physicians, and occupational therapists to rehabilitate injuries as well as prevent future injuries.

INTRODUCTION

The movement of elbow joint is very simple in that it only has one degree of freedom and is primarily flexed by the biceps brachii. However, there are many situations in which the amount of force that can be produced at one angle of the joint cannot or should not be produced at another. According to an article in the Oxford academic neurology journal, "Brain", many stroke patients have weakness in a selective range of motion in a muscle.

This study aims to analyze and predict the magnitude of myoelectric activation that occurs in the muscle unit with respect the amount of force that is physically transferred through the joint, to the point of application. This has applications in diagnosis and treatment of orthopedic and neurological conditions. It also has the potential to serve as a useful training tool for athletes. A physician may use this to determine that a stroke patient has weakness in a specific angle that is not present in the rest of the range of motion. It could also help diagnose physiological conditions that prevent force from being transmitted through the joint, such as a torn biceps tendon. Alternatively, an athlete may find that their production of force at a specific range of motion is not equivalent to the amount of force they would be expected to produce with their tested EMG values, this would indicate an increase in training at the weaker joint angles to further develop motor recruitment patterns.

METHODS

An EMG sensor placed on the muscle belly of the biceps brachii of the right arm was used to collect biodata. A strain gauge was used to collect mechanical data on the amount of force being exerted at the palm of the hand.

EMG Sensor:

EMG signals are the electric currents that pass through a muscle when it is contracted. When a muscle is contracted, the brain sends electrical impulses through the nervous system via motor neurons. These signals arrive at the muscle and cause depolarization; the more motor units that are recruited, the greater the electric current that flows through the muscle. The amplitude of the current, and therefore the magnitude of muscle fiber activation, is measured through the skin by the EMG sensor in millivolts (mV). From the data, the RMS value was obtained at an interval of 1 second after target force was reached.

Strain Gauge Setup:

The strain gauge setup consisted of a Bluetooth sensor, upon which 2 carabiners were attached at either end. One was connected to a wooden bar against which the subject would provide resistance with the palm of their hand. The other was connected to a looped length of rope that was anchored to the floor by the subject's foot. The subject took hold of the wooden bar in the palm of their fully supinated hand while keeping their upper arm against their body parallel. The looped rope that anchored the setup was at such a length that the subject's elbow joint would be at an angle of either 45, 90, or 140 degrees of flexion.

Data collection Procedure:

The subject was instructed to pull using 5, 10, 20, and 30 lbs. of force in addition to a final MVC effort, using the strain gauge for reference. The maximum EMG values of each force were then input into the MATLAB code. A line of best fit was then created to produce a correlation. A graph was then plotted and returned to the user; it displayed all of the data points input, as well as the line of best fit (polynomial fit) that can predict the amount of force from any EMG value, or vice versa.

Figure 1: A single EMG sensor was placed on the muscle belly of the biceps Brachii

Figure 2: The rope that anchored the setup was adjusted to allow for overcoming isometric contractions at variable joint angles.

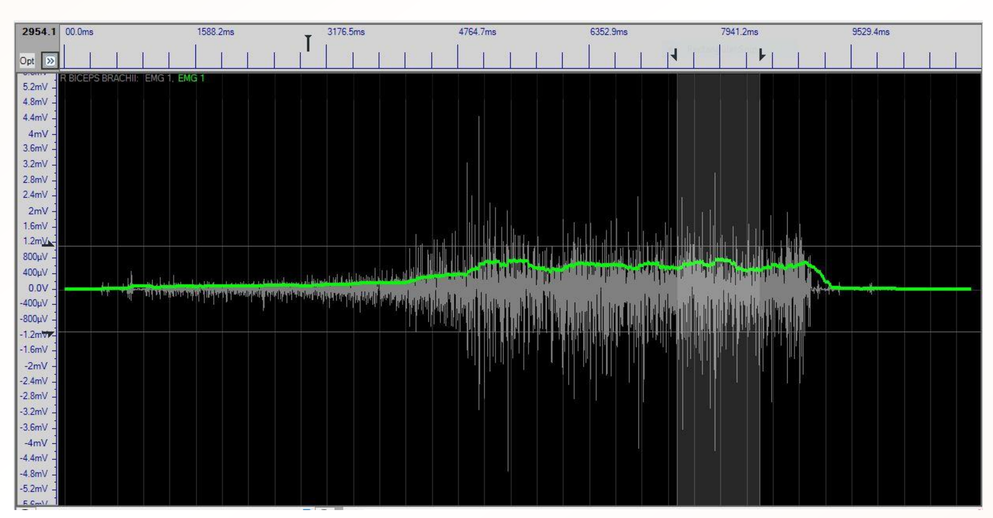

Figure 3 demonstrates the raw EMG data that is used in the MATLAB code.

Figures 4-6 demonstrate the graphical plots created by the data input into MATLAB

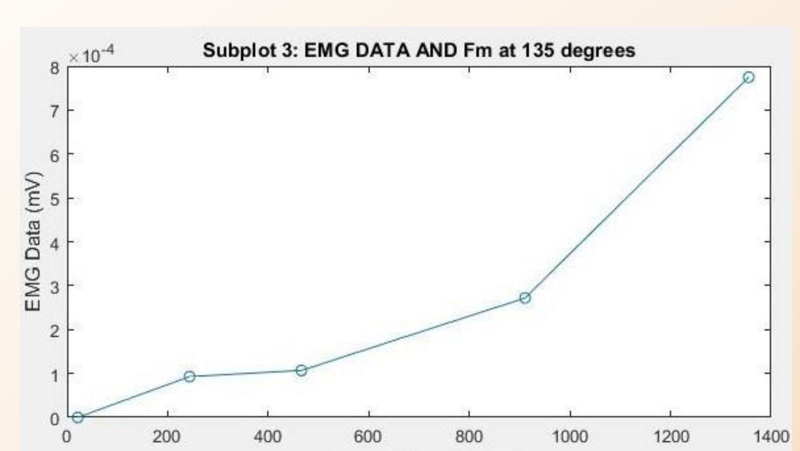

Figure 4

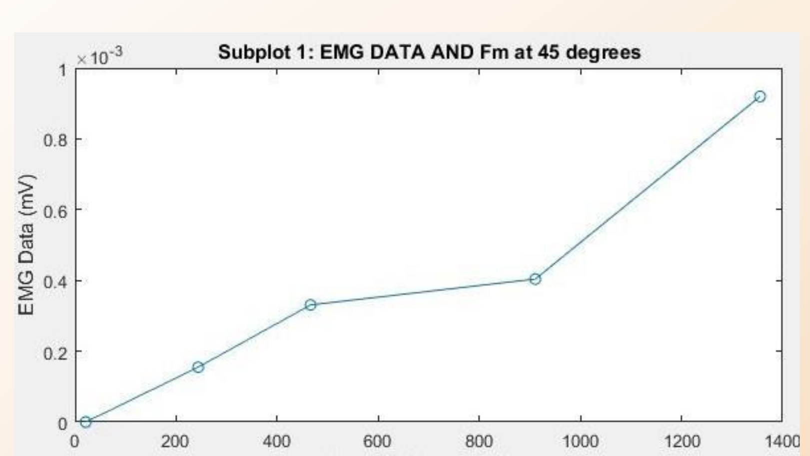

Figure 5

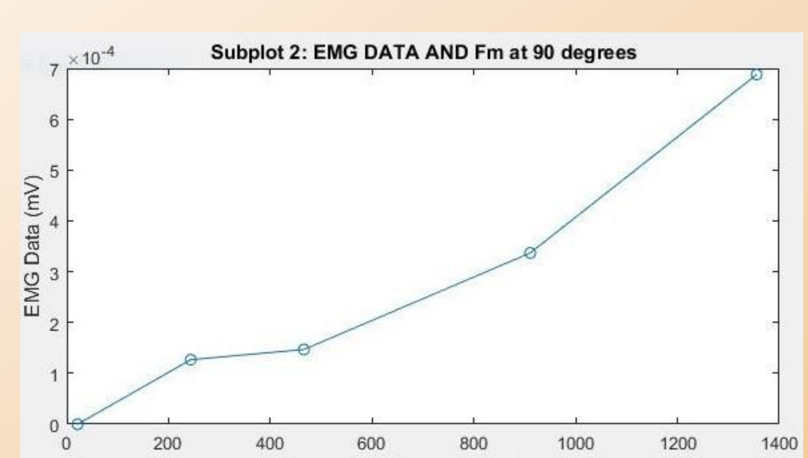

Figure 6

To ensure expeditious and user-friendly data collection, the following tables were used to upload the subject's information and data values into the MATLAB program.

Table 1: EMG values (μV)

	A	B	C	D
1	Force (lbs)	45 Degrees	90 Degrees	135 Degrees
2	0	0	0	0
3	5	0.02	0.102	0.042
4	10	0.105	0.163	0.142
5	20	0.549	0.61	0.59
6	30	0.732	0.813	0.732

Table 2: Subject information

	A	B	C	D	E	F	G	H	I
1	Patient	Gender	Age	Height	Weight	r3	r2	r1	MAX_EMG_V
2	1	M	20	170	70	40	15	4	0.813

DISCUSSION

One major muscle was analyzed for the elbow flexion: the biceps brachii.

The results confirm several hypotheses that had formed prior to conducting the experiment:

1. Increased force of flexion of the elbow positively correlates to increased recruitment of the biceps brachii muscle, evidenced by increased voltage amplitude. Figure 3 demonstrates the EMG output of gradually increasing, then sustained flexion of the muscle.

1. There is a similar, strong positive correlation between the 3 elbow angles tested; the line of best fit that was used to relate the data points shows a similar result in all 3 plots. However, each individual will have different muscle recruitment patterns, meaning that there will be a varying range of amplitudes that can result from the force a muscle exerts. Therefore, it is necessary to collect data from each individual in order to obtain a result that can be used to accurately predict force output.

2. 45 ° is the most mechanically advantageous angle for the biceps brachii to exert force. This was confirmed in figure 6 by the fact that the RMS EMG values are lower at every given force output, meaning that less muscle activation is required to of the muscle at each joint angle. This is because at that joint angle, much of the load placed downward upon the hand is held in static equilibrium through the resistance of the carpals, the radius, and the ulna. The load taken by these joints relieves load from the biceps brachii, meaning that more external force is placed upon the joint, making it more stressful to the connective tissues of the subject.

ACKNOWLEDGEMENTS

University of Wisconsin-Milwaukee BioRobotics Lab, Support for Undergraduate Research Fellows and the Office of Undergraduate Research for supporting this project. Special thanks are given to Mohammed Rahman, who devoted his time and energy to this project.

SOURCES

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