Studying Muscle Contractile Force, Coactivation and Nerve Conduction Velocity using Electromyography.

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ABSTRACT: In this lab, muscular physiology was studied using the method of electromyography (EMG). The impulses of the motor neurons were studied as more force was required of a muscle, as two antagonistic groups were activated and as an electrical impulse was employed on the muscle. It was found that there is a strong increase in EMG amplitude as more weight was added, 2.5 pounds was 0.0583 ± 0.002886751346 mV*s, 5 pounds was 0.0833 ± 0.01527525232 mV*s, 8 pounds was 0.1133 ± 0.005773502692 mV*s. The idea of coactivation was tested, with the results being: biceps during biceps contraction was 0.42333 ± 0.0680 mV*s, biceps during triceps contraction was 0.07333 ± 0.025166 mV*s, triceps during triceps contraction was 0.14333 ± 0.020816 mV*s, triceps during biceps contraction was 0.2966 ± 0.06429 mV*s. Showing that coactivation is happening in the experiment. Additionally, the nerve conduction velocity was measured to be 688 m/s, when compared to an expected range of 40-60 m/s it is very large and likely not accurate. These results give credit to the efficacy of EMG as a way to study the muscle and nervous system interactions in times of health and disease.

INTRODUCTION: Skeletal muscles are responsible for the body's abilities of movement, fine and course. The larger side of the control system are the motor units, made up of multiple muscle fibers connected to one motor neuron. The neuron receives a signal from the brain and fires, this causes the fibers to contract, causing the muscle to exert force.

In this lab, the underlying physiology of this contraction is studied through the use of an electromyogram (EMG). This is a way to read the firing, or impulses, of those motor neurons as they tell the muscle to contract. This will be used to study the impulses of the neurons as the muscles are required to exert more force. It is expected that the amplitude of the signal will increase as more motor neurons will be enlisted to carry the burden

Additionally studied, will be the impulses in antagonistic muscle groups as one side is worked. Antagonistic muscles are ones that work together, this is usually to provide balance and finer control to the movement. It is expected that the muscles in antagonistic groups will provide less of an amplitude as the protagonist muscles but will still provide some impulse as they are expected to be coactivated.

And finally, an electric stimulus will be applied to the muscle to see the response time of the motor neurons. The distance between the stimuli and the EMG receiver will be measured and the response time will be recorded. These datapoints will be used to solve for the speed of an impulse in the neuron.

These will experiments will help to bolster what is known of the physiology of movement.

METHODS: In exercise 1, three electrodes were placed along one arm (Fig 1). These were connected to snap on leads which were plugged into shielded Bio Amp cable and connected to the Bio Amp input on a PowerLab 26T module.

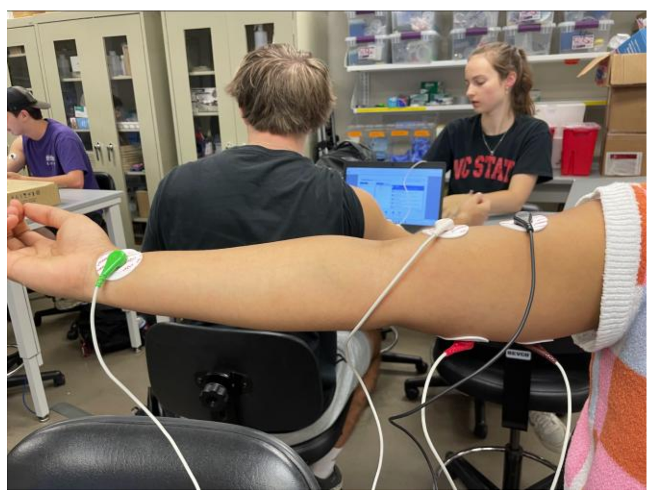

Fig. 1. Electrode placement for Exercise 1

Weights of 2.5 lb, 5 lb and 8 lb were held one at a time and then removed. Three trials were taken for each weight. That data was recorded using LabChart software and the RMS EMG channel, which smooths the otherwise noisy EMG signal. And used for mean and standard deviation calculations. This data was also taken among all of the lab sections and used for ANOVA analysis.

In exercise 2, the electrodes were replaced, one on the biceps and one on the triceps, same arm. Three trials were then taken, each with one period of activating the biceps and then the triceps for 30 seconds. This data was recorded same as in exercise 1 and used for mean and standard deviation of the amplitude of both muscles during both phases of contraction.

In exercises 3, one student researcher had an electric stimulus applied to the muscle, using a stimulating bar electrode, to see the response of the muscle to being stimulated. These points where the muscle twitched the most were recorded to for use in exercise 4 (Fig 2). The pulses were controlled through the LabChart software.

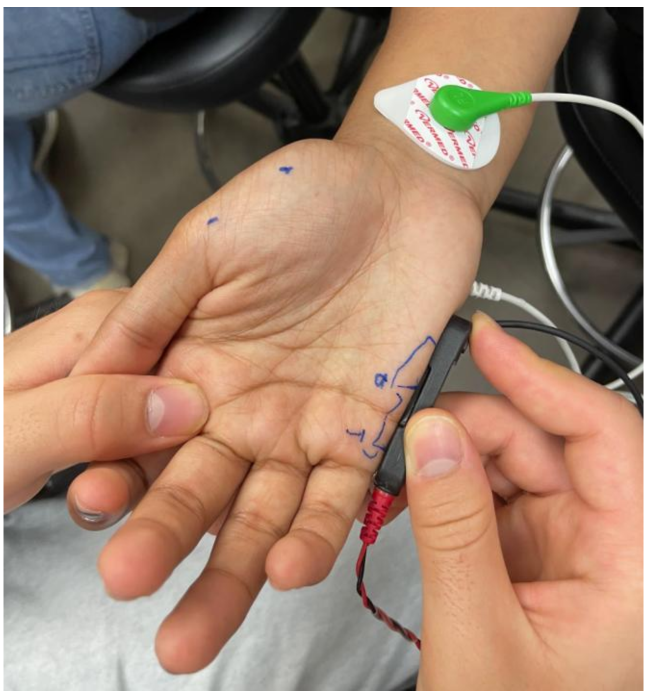

Fig. 2. Setup for exercises 3 and 4, stimulating bar electrode placement.

In exercise 4, one student researcher had an electric stimulus applied to the muscle to see the response time of the motor neurons. The distance between the stimuli and the EMG receiver was measured and the response time was recorded. These data points were divided respectively to solve for the speed of an impulse in the neuron.

Graphics and figures were produced in MATLAB, with code generated by ChatGPT and manually manipulated for legibility and consistency.

RESULTS: In exercise 1, the average amplitude of the bicep holding a weight of 2.5 pounds was 0.0583 ± 0.002886751346 mV*s, for 5 pounds was 0.0833 ± 0.01527525232 mV*s, 8 pounds was 0.1133 ± 0.005773502692 mV*s (Fig. 3). The full class data shows lots of uncertainty but an overall positive trend between bicep amplitude and mass (Fig 4). In exercise 2, the average amplitude of the biceps during biceps contraction was 0.42333 ± 0.0680 mV*s, and the average amplitude of the biceps during triceps contraction was 0.07333 ± 0.025166 mV*s (Fig 5). The average amplitude of the triceps during triceps contraction was 0.14333 ± 0.020816 mV*s, and the average amplitude of the triceps during biceps contraction was 0.2966 ± 0.06429 mV*s (Fig 5). In exercise 4, the nerve conduction velocity was 688 m/s, it is compared to an expected range of 40-60 m/s (Fig 6).

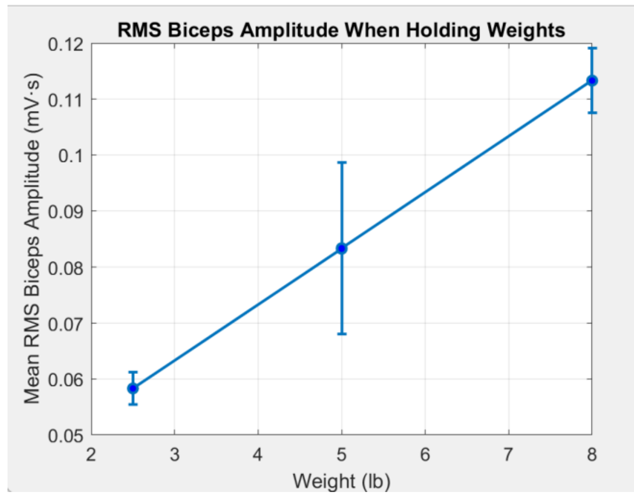

Fig. 3. Average amplitude of EMG when holding weights, within one lab group.

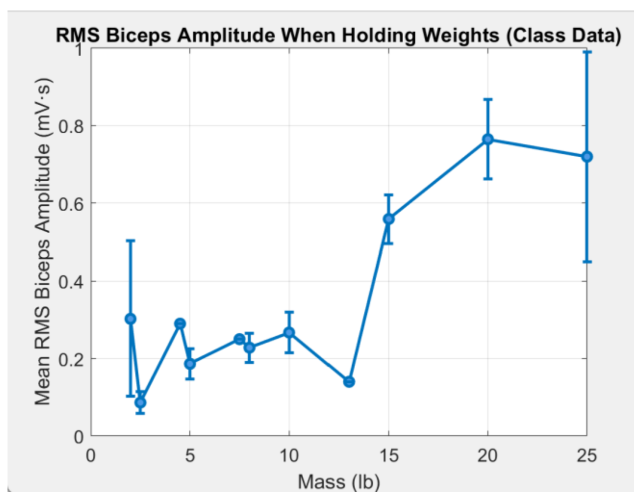

Fig. 4. Average amplitude of EMG when holding weights, across all lab sections.

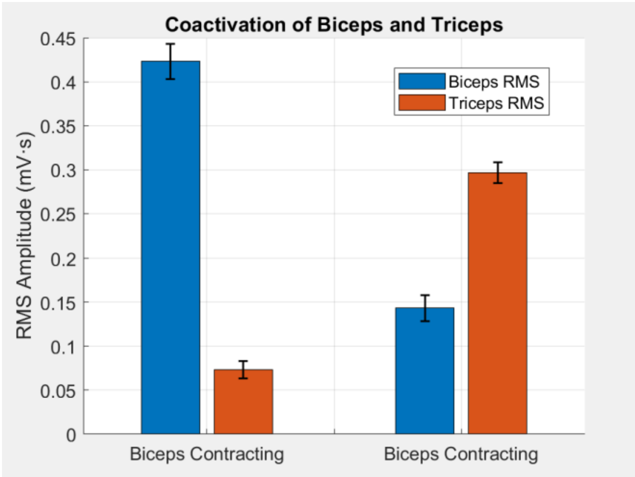

Fig. 5. Levels of activation in antagonistic muscles.

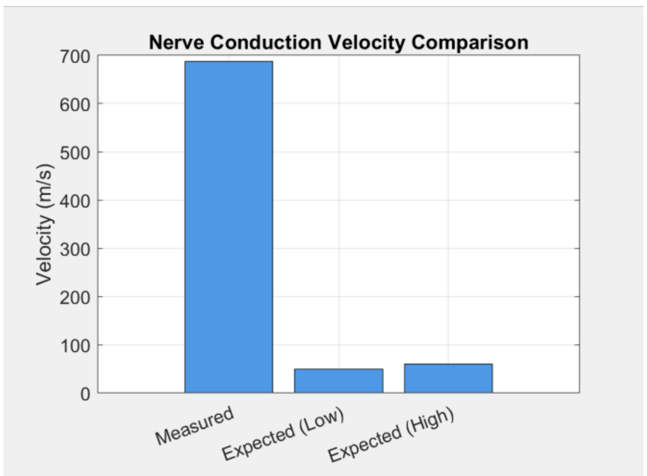

Fig. 6. Nerve velocity measured in lab vs. expected results.

DISCUSSION: In this experiment previous knowledge on the physiology of the muscles were examined using EMG methods. This experiment worked well to prove the hypothesis. In exercise 1, as more motor units are recruited to bear the increased weight, the amplitude of the EMG signal increases. This is because the motor neurons are not able to produce an impulse of varying magnitudes, they are either firing or not. So then, more neurons are having to fire to hold up the weight on the hand. In exercise 2, the amplitude of the EMG of both groups of muscles fire when their antagonistic counterpart is activated. This is a great display of coactivation as although the muscles are working against each other, they both have a purpose in that movement. We can also see that the triceps usually have lower EMG amplitudes than the biceps. This can mean that the triceps are a smaller or weaker muscle group, that the electrodes are placed at a less ideal spot on the triceps or all of the above. In exercise 3, it was found that certain places on the limb were more susceptible to the stimulus than others. Perhaps this can inform the location of areas with a high localization of motor neurons. And in exercise 4, the measured nerve conduction velocity was way higher than any expected value. This may be explained by an error in understanding the LabChart software or picking the impulse up instead of the response. This work can be used in the future to study more pressing issues in muscular or nervous health, such as degenerative diseases and their effects on muscle strength and neuron signaling.

CONCLUSION: This project demonstrated the usefulness of EMG in muscular and nervous physiology. This technique allowed for the testing of concepts such as motor units, motor neurons and coactivation. It allowed for the generation of data that shows that more contraction force is gained from more motor units being recruited. And that coactivation happens in an antagonistic muscle whenever a protagonist is contracted. Both of these outcomes point to methods of smooth and controlled movement of the body, at the fiber and skeletal muscle levels.

ASSOCIATED CONTENT

Raw data and code can be located in the supplemental Information section in Moodle.

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