Muscle Activation Visualization for Microgravity Environments

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Abstract

A system was developed to display a user’s muscle activation using sEMG sensors, a force transducer system, and LED lights. The user performs an isometric bicep contraction using a force transducer test system while sEMG sensors monitor their bicep muscle activity. They receive visual feedback through a color-coded LED system corresponding to their muscle activity. The feedback system is calibrated for each user based on their muscle activity when resting and applying maximum force to the test system.

Purpose

This muscle visualizing system will be a viable solution to monitor the muscle health of astronauts in microgravity environments. This device was designed to test the effectiveness of the prescribed workouts astronauts do aboard the International Space Station. Finding ways to keep muscles from weakening while in microgravity environments further advances the feasibility of commercial space travel and deep space exploration.

SEMG Data Acquisition & Filtering

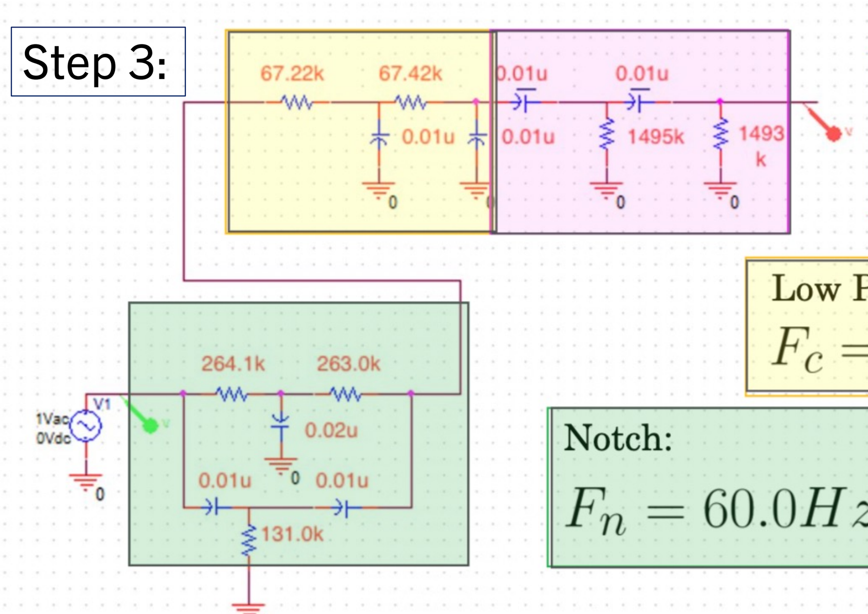
Step 1:

Three surface electrodes measured electrical activation from motor neurons in the user's bicep

Step 2:

Grove Surface Electromyography sensor measured and amplified potential difference between two ends of the bicep brachii

Step 3:



High Pass: $F_c = 10.65Hz$

Low Pass: $F_c = 236.4Hz$

Notch: $F_n = 60.0Hz$

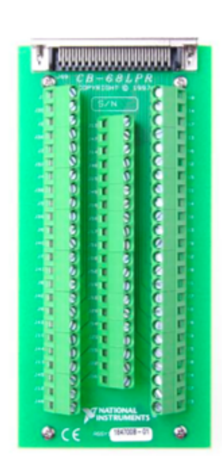
$$F_c = \frac{1}{2\pi\sqrt{R_1 R_2 C}}$$

Cutoff Frequency calculation to determine resistor and capacitor values.

Second-order passive filters attenuated noise from motion artifacts and external radiation. A notch filter reduced the power line noise at 60Hz

Step 4:

Data Acquisition (DAQ) Board (model CB-68LPR) acquired the electrically filtered sEMG signals using a differential analog input with a grounded lead. The DAQ also provided 5V power and ground to the sEMG sensor and filtering circuit. DAQ input data was used for the MATLAB post-processing program



Power Spectrum Results

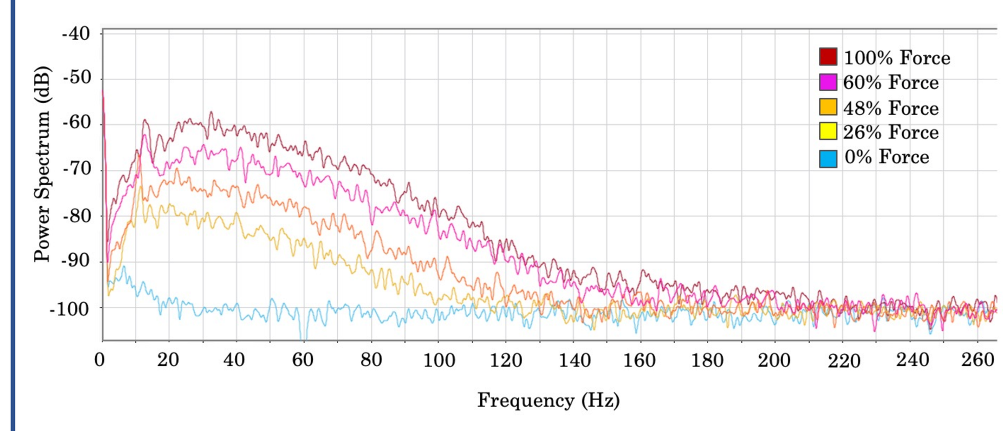


Figure 1: Four Levels of Activation for One Test Subject

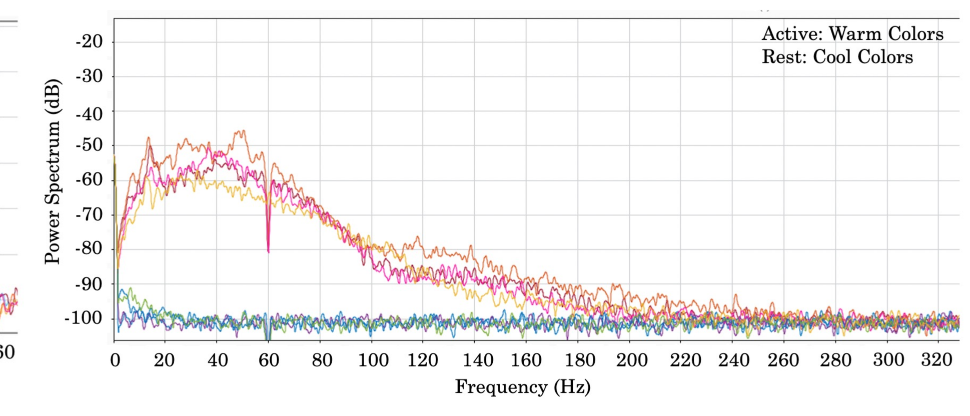


Figure 2: Active and Rest for Four Test Subjects

Power spectrum curves were plotted from voltage-time data for ten second intervals of muscle activation. Power Spectrum levels were found to correlate with the user's percentage of maximum force applied to the force transducer system.

Visual Output Calculations

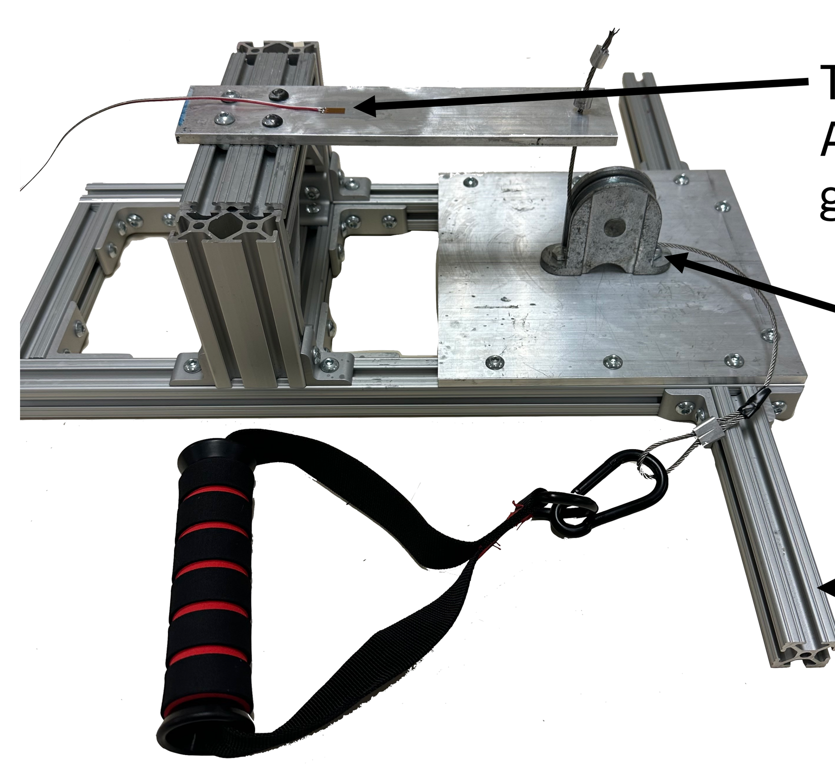
sEMG scaled muscle activation values are calculated from the integral of the power spectrum curve. Since the reciprocal of the sEMG scaled value is proportional to the voltage from the force transducer system, the following calculation was performed in MATLAB code:

$$num = \frac{1}{10^{-4}(integral_1 + integral_2)}$$

The integral values are calculated before and after 60Hz to omit power line noise.

The system was calibrated for the individual by calculating the num variable for maximum force output and finding the slope of the plot in Figure 5. The sEMG post-calibration measurements were used to extrapolate estimated percent force ranges. The LED visual output corresponds to the percent force.

Force Transducer Design



The force transducer test system utilizes an Aluminum 6061 cantilever beam and a single strain gauge to detect the upward force a user applies.

The pulley and cable ensure that users apply a force to the cantilever in the same location as a point load for repeatable testing.

Footrests allow the user to stabilize the force transducer and prevent the system from lifting during the upward force

Figure 3: Finalized Force Transducer Test Fixture

The test procedure involved subjects performing periods of isometric muscle contraction and rest for 10 seconds. Figure 4 shows a subject during muscle contraction. Subjects laid their arm on their leg during periods of rest. The subjects were seated and kept their arm at a 90˚ bend to ensure their arm was isolated and the bicep was the working muscle.

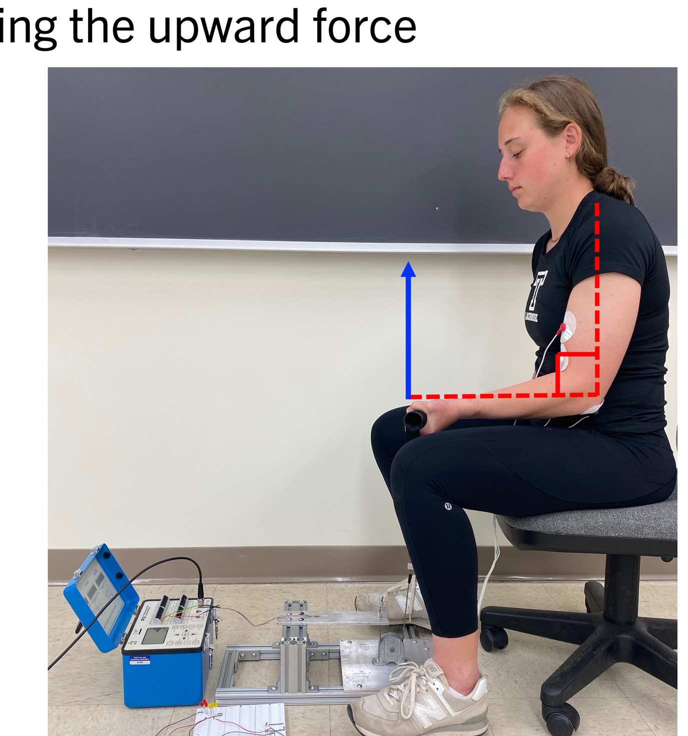


Figure 4: Subject Preforming Isometric Bicep Contraction While Wearing sEMG Sensors

Force Transducer Data Acquisition

The relationships between output voltage, strain, and force are shown below [1][4]. The output voltage is from the quarter Wheatstone bridge used to detect the change in electrical resistance across the strain gauge. Output voltage is proportional to strain and force.

$$\varepsilon = \frac{MY}{IE} = \frac{FL\left(\frac{t}{2}\right)}{IE} \qquad V_{out} = \frac{1}{4} * G_f * \varepsilon * V_{in}$$

SEMG and Force Relationship

7 test subjects performed isometric bicep curls on the force transducer system, while wearing the sEMG sensors, at many different exertion levels. The data collected was used to find the relationships shown in Figures 5 and 6.

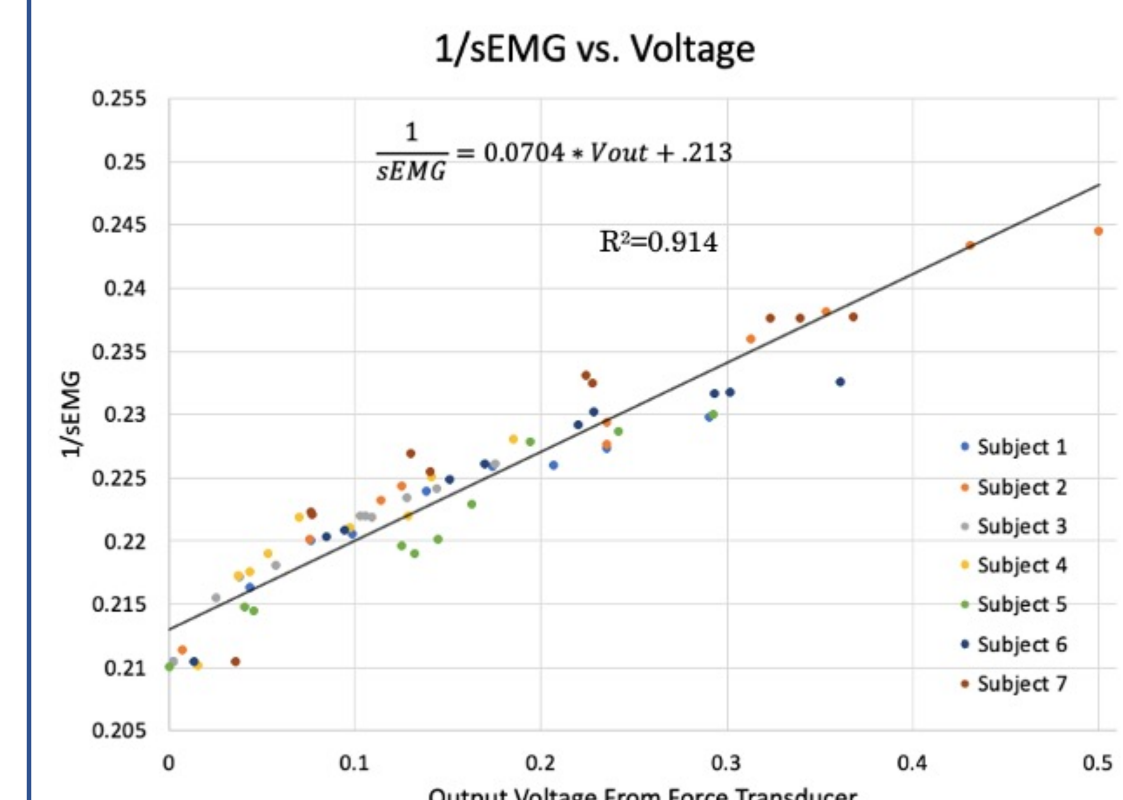


Figure 5: A linear relationship between the reciprocal of the sEMG data and the output voltage from the force transducer.

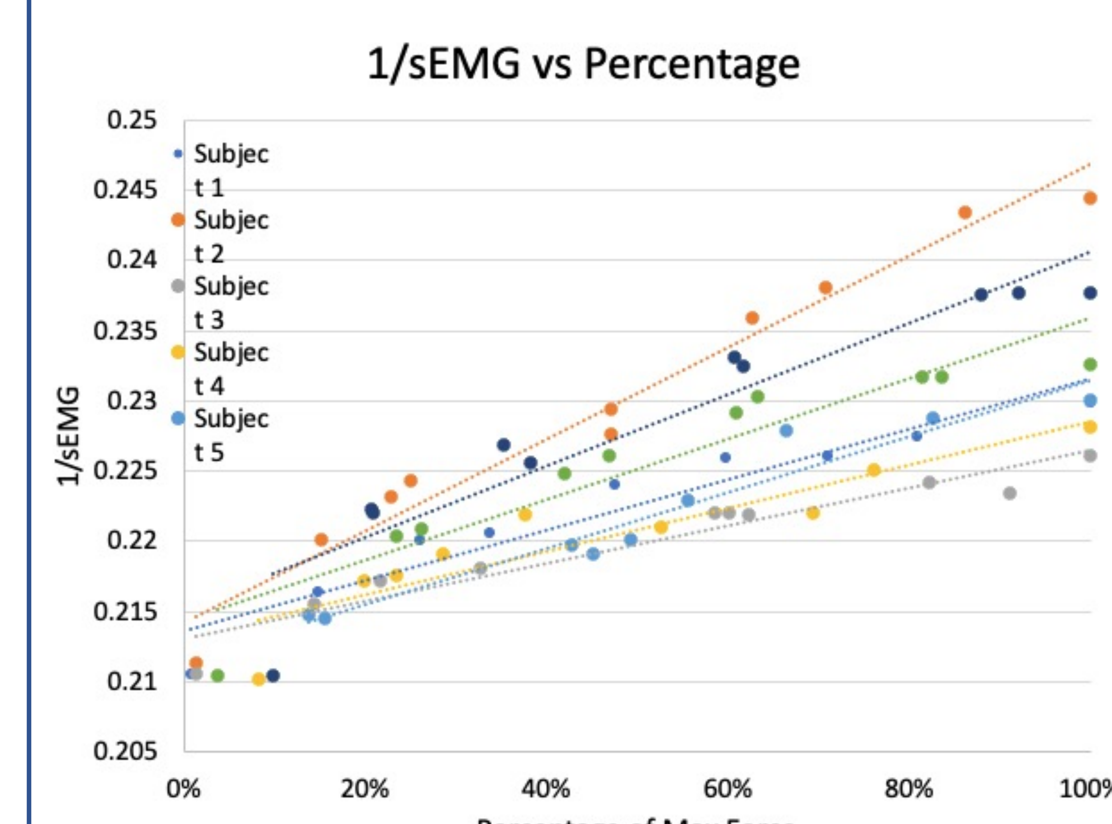


Figure 6: A linear relationship between 1/sEMG and the exertion level from the user. The slope of the curve changes based on the strength of the user.

Acknowledgments

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References

[1]Beer, Ferdinand P., et al. *Mechanics of Materials*. McGraw-Hill Education, 2020.
[2]Johnson, Michael. “Bone and Muscle Loss in Microgravity.” NASA, NASA, 7 Jan. 2020.
[3]“Model P3 Strain Indicator And Recorder Instruction Manual.” Bjo.
[4]“Relations between Transducer Output Signals in Strain and Voltage.” *KYOWA*.