The Effect of Electrode Position on Human Biceps EMG Amplitude

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INTRODUCTION

Electromyography (EMG) is the acquisition of electrical signal emitted by the muscle. It provides us with an insight to muscle activity by relating the motion of the body to electrical signals. In Lab 4, to collect the EMG signal from human biceps muscle, the two main surface electrodes were set to be 1 cm apart at the center of the muscle belly, lining up with the longitudinal axis of the arm [1, 2]. Due to the nature of the signal, the RMS amplitude is quite small, and we would like to find out if other electrode configurations exist that can improve the strength of the collected signal. We hypothesized that the signal strength may depend on the position of the electrodes on the biceps and/or the distance between the electrodes, and that the conventional positioning would be the best. We used an amplifier circuit, which consists of a differential amplifier and a band-pass amplifier, and the computer software LabVIEW, to conduct the signal collection and recording. We mainly focused on the RMS amplitude of the EMG signal during our experiment.

METHODS

An amplifier circuit that consisted of an LM741 op-amp and an AD620 in-amp was built based on Lab 4's manual [2] (**Figure 1**). The circuit was then tested and validated using standard sine waves as the input to get the frequency responses. A LabVIEW program was configured to capture and record the raw EMG data from the amplifier, and to serve as a timer.

5 electrodes separated by 1 cm were placed on the biceps of subjects' left arm (**Figure 2**), with an additional one on the elbow as the reference. 6 pairs of electrodes, i.e. 1-2, 2-3, 3-4, 4-5, 1-4, and 2-5, were chosen to measure EMG readings both at rest and when lifting a 15 lb weight. Three sets of data were recorded in 5 s intervals for each state with 60 s breaks between to prevent muscle fatigue. Each group of 3 trials was combined, yielding a 15 s waveform, and 4 subjects were tested.

Mathematica was then used to calculate RMS values based on the data. The effective RMS values were obtained by subtracting the rest-level RMS values from the loaded ones. Here we assumed that the EMG signals were independent of time.

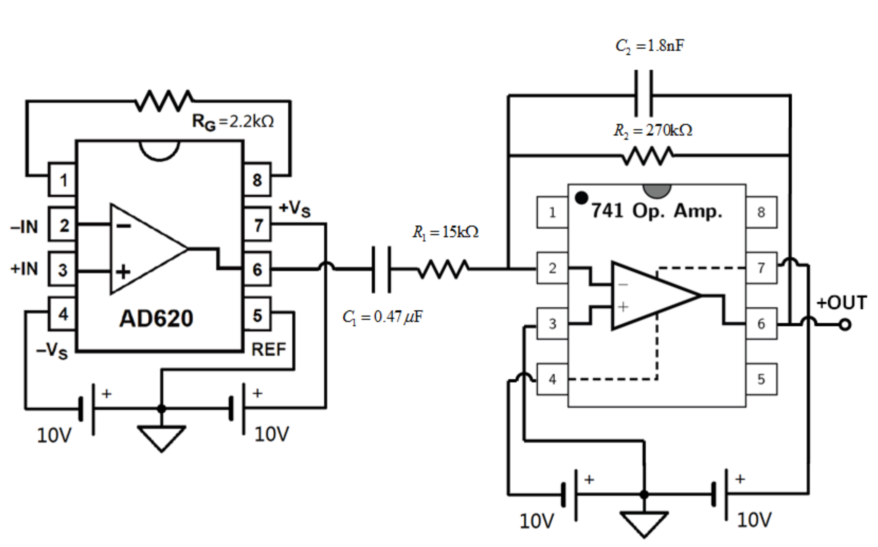

Figure 1. Amplifier Circuit Diagram

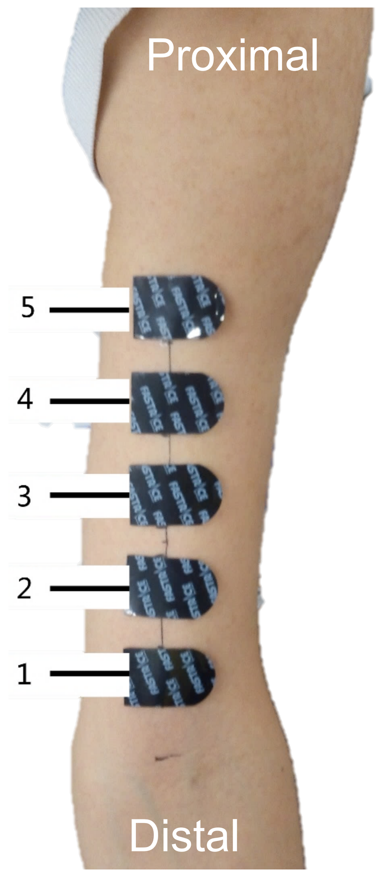

Figure 2. Electrode position and numbering

RESULTS

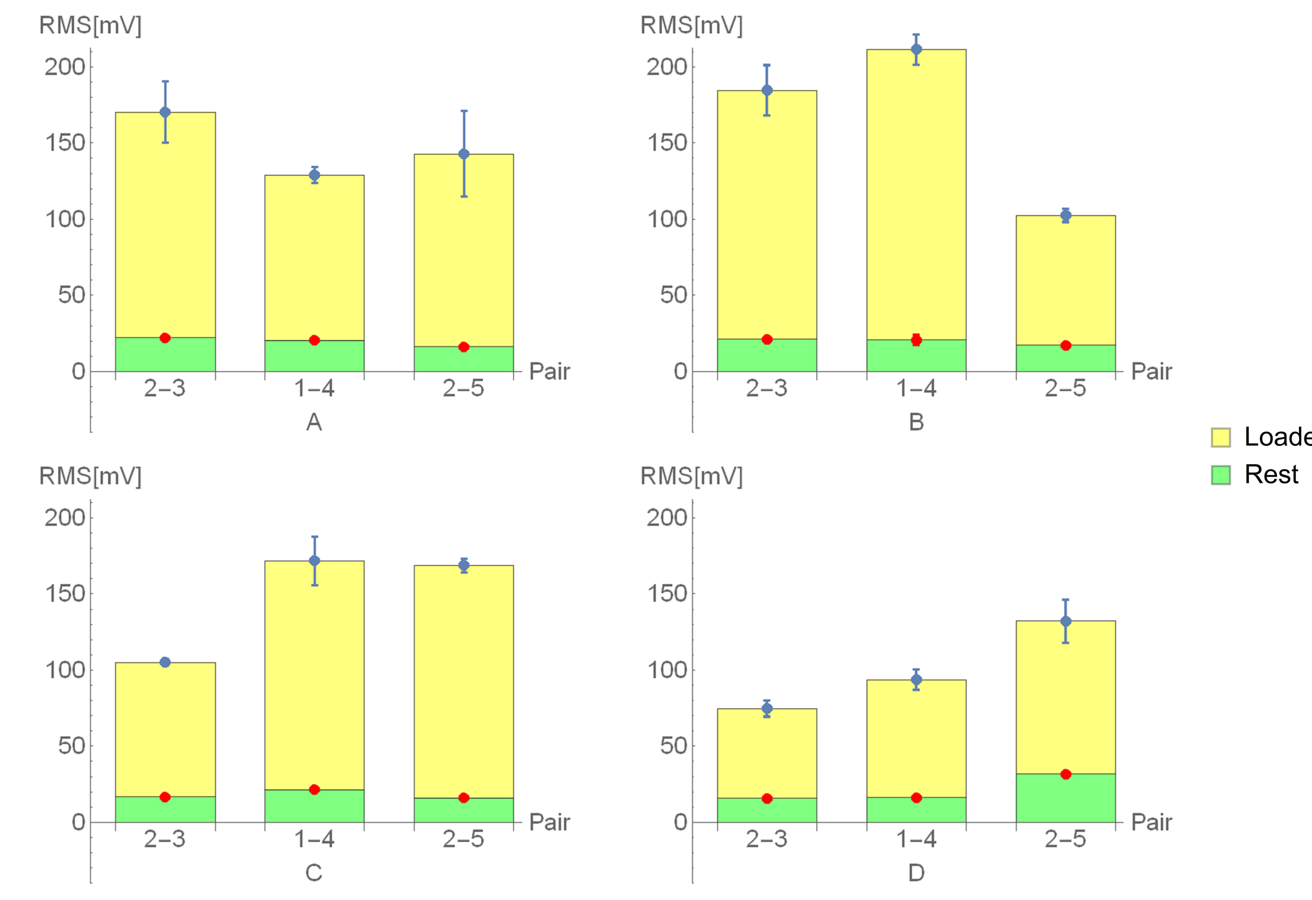

Figure 3. Individual measurements of 2-3, 1-4, and 2-5 pairs showing no clear pattern (Std. dev.s based on three 5-s segments)

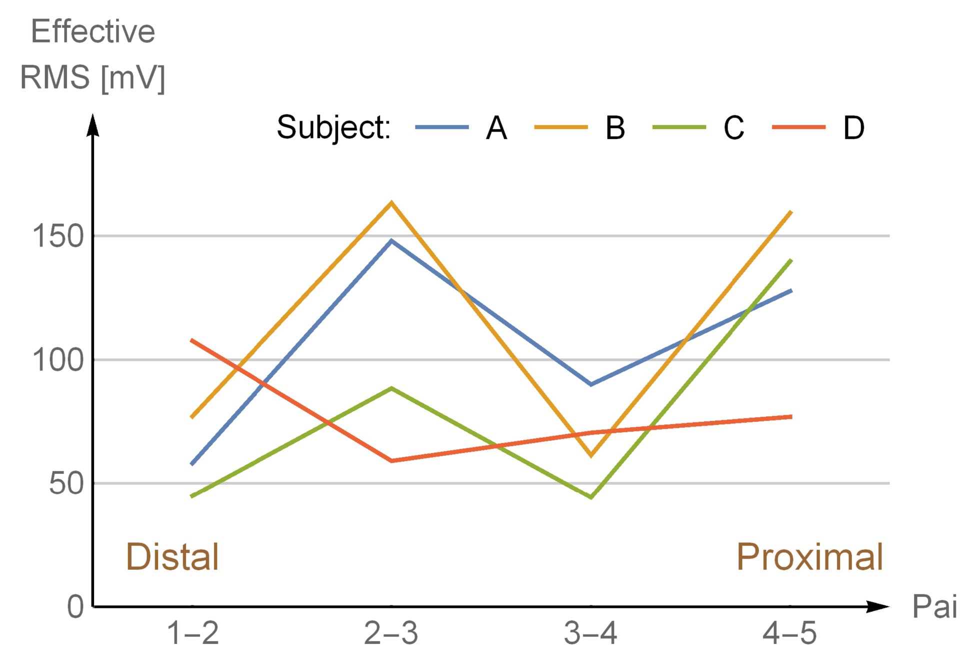

Figure 4. Individual measurements of effective EMG RMS values (Effective = Loaded - Rest) *

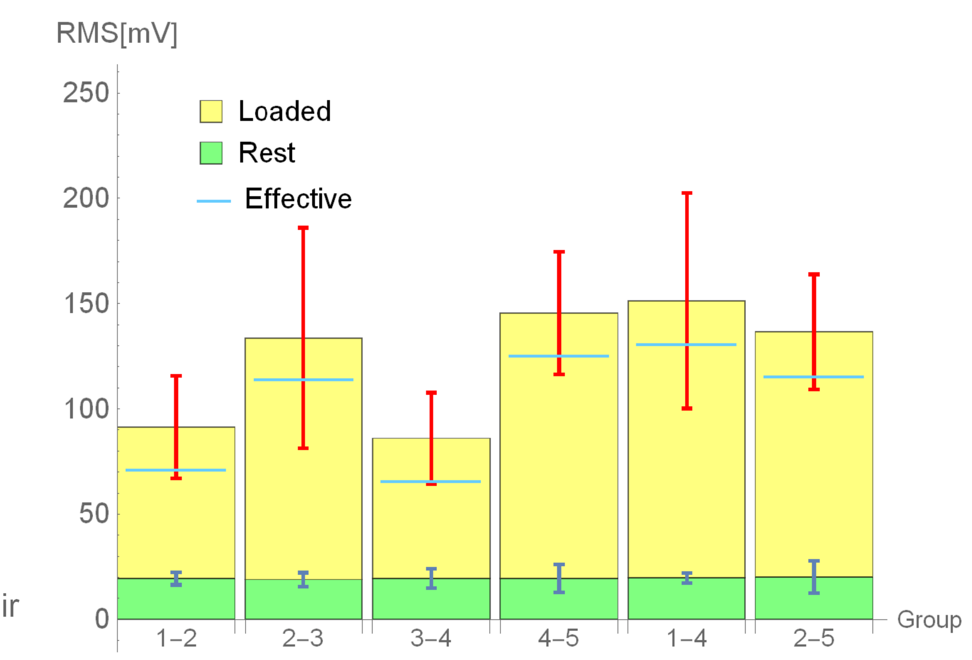

Figure 5. RMS data across 4 subjects. The middle pair (2-3) has no significant advantage in amplitude.*

* Here we were not able to get the std. dev. of the effective RMS values from the difference of the std. dev.s of loaded and rest values, since we cannot guarantee their independence, i.e. they may be correlated.

After performing a one-way ANOVA test, examining whether the means of RMS values of pairs 1-2, 2-3, 3-4, and 4-5 are the same using the pooled data, we get p-values between 0.025 and 0.072, thus we cannot guarantee any difference between them at a confidence level of 95%. However, when using individual data (each divided into 6 segments of equal length) from a single subject to do four separate ANOVA tests, all tests showed that at least the means of two electrode pairs have a significant difference. The p-values are 6.81×10^{-8}, 4.18×10^{-13}, 2.65×10^{-10} and 5.90×10^{-7} for subject A, B, C and D respectively.

For the relationship between electrode distances and EMG RMS values, two two-sided two-sample t-tests were conducted using the pooled data between pairs 2-3 / 1-4 and pairs 2-3 / 2-5. The results showed that the differences between RMS values are not significant enough to guarantee that they were caused by different electrode distances rather than random errors under a confidence level of 95%. Thus the distance of the electrodes may not be a significant factor in the strength of EMG signals.

The result was not consistent with the hypothesis that middle pair 2-3 would generate the EMG signal of the largest RMS amplitude. Two ideas illustrated in two papers could serve as explanations for the observed results:

- Innervation Zone
  Kenji's paper pointed out that the innervation zone, which located near the middle point of the biceps, yields a reduced EMG magnitude. Therefore, placing the electrodes between the innervation zones and tendons is recommended [3]. This idea is consistent with our results. As shown in **Figure 4**, for subjects A, B, and C, two peaks occurred at electrodes 2-3 and 4-5, which were good positions for EMG signal acquisition. A possible explanation for the low EMG at 1-2 was being too close to the tendon, and for 3-4, based on Kenji's paper, the relatively small amplitude was due to the innervation zone.
- Subcutaneous Fat
  In Kuiken's paper, it is shown that the EMG amplitude drops significantly as the subcutaneous fat layer gets thicker [4], which possibly explains why subject D exhibited a different EMG pattern in Figure 4. Different fat distributions amongst subjects could account for some of the major differences in EMG signals acquired.

SUMMARY

- The four subjects' individual EMG signals showed statistically significant dependence on electrode positions with small ANOVA p-values of around 10^{-8} and 10^{-10}.
- When data from all four subjects were combined and analyzed, the p-value of the ANOVA test increased to 0.072, and the dependence was not statistically significant.
- The two two-sample t-tests showed that the dependence of EMG signal on electrode distance was not statistically significant for any subject.
- The influence of subcutaneous fat on EMG signal was observed in this project, which could be a potential project topic for future BME 241 students.

CONCLUSIONS

- Individual EMG signals showed statistically significant dependence on electrode positions, while the combined analysis opposed it.
- No statistically significant dependence of EMG amplitude on electrode separation distance was found.
- The region of EMG signal acquisition suggested in lab 4 is good, but it might not be the only way. There is another region closer to the proximal end that yielded equally good signals. Both regions can be chosen as potential signal acquisition sites.

REFERENCES

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4. Kuliken TA, Lowery MM, Stoykov NS. "The Effect of Subcutaneous Fat on Myoelectric Signal Amplitude and Cross-talk". *Prosthetics and Orthotics International.* **27**(1): 48-54. (2003).

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