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## EXPERIMENT: Electromyography (EMG)

## AIM:

To analyze surface electromyography (sEMG) signals recorded from the biceps during flexion and extension of the arm while carrying a 3kg load.

## OBJECTIVES:

To find the RMS amplitude and median frequency for the acquired sEMG signal from the right and left arm biceps

i. With two different electrodes (manufactured by different companies – Medtronic & ESVI)
ii. At three different electrode placement separations on the biceps (2cm, 2.5cm, 3cm)

## APPARATUS & SOFTWARE USED:

i. Electrodes (a. Medtronic, b. ESVI)
ii. BIOPAC MP 36 system for EMG acquisition
iii. 3kg load
iv. BIOPAC Student Lab MP 36 – Software for signal acquisition and filtering
v. MATLAB software for further analysis

Fig1: EMG electrodes

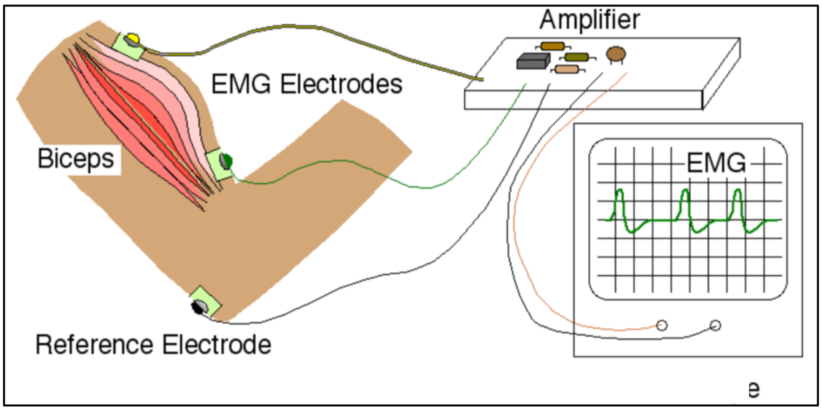


Fig2: EMG electrode placement instuctables.com

## THEORY:

### EMG:

EMG signal is the summation of all the Motor Unit Action Potentials (MUAP) in the region of the Electrodes that are spatially and temporally separated. Muscles are stimulated by signals from nerve cells called motor neurons. This stimulation causes electrical activity in the muscle, which in turn causes the muscle to contract, or tighten. Thus, muscle contraction producing electrical signals can be recorded. EMG signals are complex since the MUAP are inherently random, non-stationary, and non-linear. EMG is used for a number of applications including prosthesis control, biofeedback and diagnosis of muscle weakness, muscular dystrophy and nerve disorders.

Amplitude and spectral information of EMG have been used to estimate force of muscle contraction and torque and as indicators of localized muscular fatigue.

**Root-Mean Square (RMS-EMG):**

RMS of the signal is an indicator of the amplitude trend and density of the signal. It thus is a good indicator for the 'strength of EMG'. [1]

**Mean Frequency (MNF):**

MNF is an average frequency which is calculated as the sum of product of the EMG power spectrum and the frequency divided by the total sum of the power spectrum.

$$MNF = \sum_{j=1}^{M} f_j P_j \Big/ \sum_{j=1}^{M} P_j \, ,$$

where fj is the frequency value of EMG power spectrum at the frequency bin j, Pj is the EMG power spectrum at the frequency bin j, and M is the length of frequency bin. [2]

**Median Frequency (MDF):**

MDF is the frequency at which the EMG power spectrum is divided into two regions with equal amplitude. MDF is also defined as a half of the total power, or TTP (dividing the total power area into two equal parts). [2]

$$\sum_{j=1}^{MDF} P_j = \sum_{j=MDF}^{M} P_j = \frac{1}{2}\sum_{j=1}^{M} P_j \, .$$

## PROCEDURE:

i. The subject was asked to stand erect during the entire experiment.
ii. Three electrodes (1 channel) were used to acquire the EMG signal as shown in Fig2. The positive and negative electrode was placed on the biceps muscle. The distance between the electrodes for each trial was varied between a. 2cm, b. 2.5cm. c. 3cm. The reference electrode was placed on the elbow.
iii. The subject was given a load of 3kg (dumbbell) when the arm was completely extended in rest position. The subject then performed three curls (flexion and extension of the arm) while bringing the arm to rest after each curl.

iv. Step ii. and iii. were performed for both the right and left arm using two different electrodes manufactured by two companies (a. Medtronic, b. ESVI)

v. The signal was acquired using the BIOPAC MP 36 system. The EMG signal was filtered with a bandpass filter of range (5-500 Hz). The power line noise at 50Hz was eliminated using a notch filter. The sampling frequency was set to 10000Hz, the gain was set to 1000, and Q factor = 0.707.

vi. The EMG signals were then analyzed using MATLAB.

## RESULTS & OBSERVATIONS:

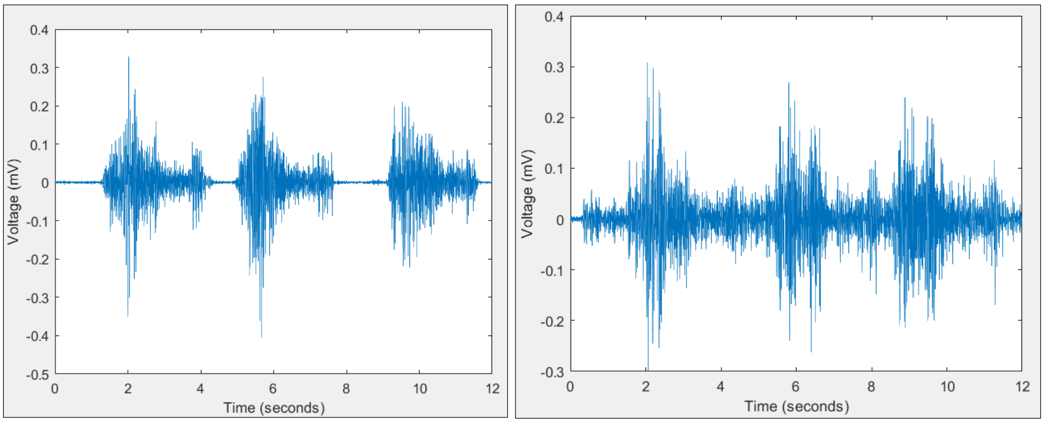


Fig 3a. Fig3b.

Fig3: EMG signal acquired from the right biceps for three curls; Distance between the electrodes = 2.5cm;
a. Medtronic electrode b. ESVI electrode

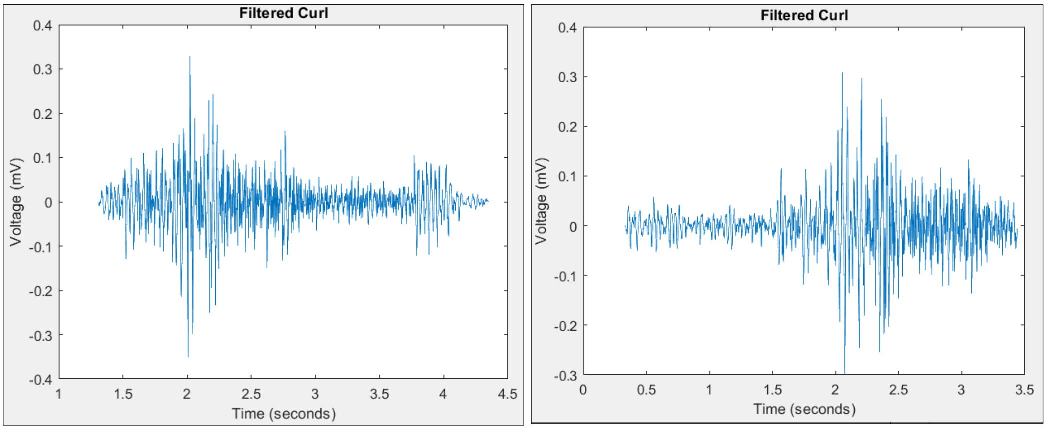


Fig 4a. Fig4b.

Fig4: Filtered EMG signal acquired from the right biceps for a single curl;
Distance between the electrodes = 2.5cm;
a. Medtronic electrode b. ESVI electrode

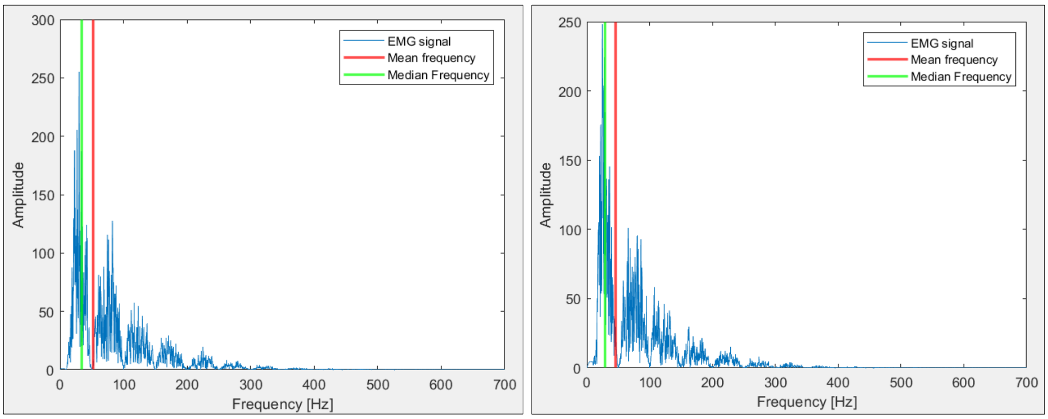


Fig 5a. Fig 5b.

Fig5: FFT Amplitude spectrum of the EMG signal acquired from the right biceps for a single curl;
Distance between the electrodes = 2.5cm;
a. Medtronic electrode b. ESVI electrode

From Fig 3 it can be observed that the signal obtained from the Medtronic electrode is less noisy than the signal acquired from the ESVI electrode.

From the amplitude spectrum it can be observed that the EMG signal lies within the range of 5-500 Hz.

| Arm | Electrode | Distance between +ve & -ve electrode (cm) | RMS Amplitude (mV) | | | | Mean Amplitude (mV) | | | | Max Amplitude (mV) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Curl1 | Curl2 | Curl3 | Average | Curl1 | Curl2 | Curl3 | Average | Curl1 | Curl2 | Curl3 | Average |
| Right | ESVI | 2.000 | 0.041 | 0.042 | 0.063 | 0.049 | 0.025 | 0.027 | 0.042 | 0.031 | 0.150 | 0.148 | 0.176 | 0.158 |
| | | 2.500 | 0.051 | 0.061 | 0.059 | 0.057 | 0.033 | 0.044 | 0.044 | 0.040 | 0.215 | 0.173 | 0.165 | 0.184 |
| | | 3.000 | 0.045 | 0.061 | 0.055 | 0.053 | 0.031 | 0.042 | 0.037 | 0.037 | 0.184 | 0.188 | 0.196 | 0.189 |
| | Medtronic | 2.000 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 | 0.001 | 0.001 | 0.001 | 0.002 | 0.002 | 0.003 | 0.002 |
| | | 2.500 | 0.050 | 0.060 | 0.053 | 0.055 | 0.033 | 0.040 | 0.039 | 0.037 | 0.188 | 0.217 | 0.163 | 0.189 |
| | | 3.000 | 0.077 | 0.066 | 0.067 | 0.070 | 0.050 | 0.044 | 0.046 | 0.047 | 0.219 | 0.238 | 0.278 | 0.245 |
| Left | ESVI | 2.000 | 0.045 | 0.035 | 0.040 | 0.040 | 0.032 | 0.025 | 0.027 | 0.028 | 0.144 | 0.098 | 0.116 | 0.119 |
| | | 2.500 | 0.041 | 0.044 | 0.038 | 0.041 | 0.030 | 0.031 | 0.025 | 0.029 | 0.116 | 0.131 | 0.155 | 0.134 |
| | | 3.000 | 0.045 | 0.050 | 0.055 | 0.050 | 0.031 | 0.035 | 0.038 | 0.034 | 0.145 | 0.171 | 0.231 | 0.182 |
| | Medtronic | 2.000 | 0.002 | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.005 | 0.004 | 0.005 | 0.005 |
| | | 2.500 | 0.058 | 0.047 | 0.053 | 0.053 | 0.040 | 0.033 | 0.039 | 0.037 | 0.191 | 0.143 | 0.146 | 0.160 |
| | | 3.000 | 0.078 | 0.063 | 0.067 | 0.069 | 0.054 | 0.044 | 0.044 | 0.047 | 0.303 | 0.206 | 0.289 | 0.266 |

| Arm | Electrode | Distance between +ve & -ve electrode (cm) | Mean Frequency (Hz) | | | | Median Frequency (Hz) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Curl1 | Curl2 | Curl3 | Average | Curl1 | Curl2 | Curl3 | Average |
| Right | ESVI | 2 | 54.255 | 54.26 | 57.88 | 55.465 | 37.55 | 37.28 | 40.44 | 38.424 |
| | | 2.5 | 45.705 | 52.86 | 60.43 | 52.999 | 29.59 | 35.86 | 41.31 | 35.585 |
| | | 3 | 50.226 | 54.18 | 53.71 | 52.705 | 34.13 | 35.87 | 37.64 | 35.88 |
| | Medtronic | 2 | 113.88 | 97.24 | 103.2 | 104.78 | 105.4 | 83.99 | 90.58 | 93.327 |
| | | 2.5 | 52.298 | 54.73 | 50.2 | 52.41 | 33.69 | 36.48 | 33.42 | 34.529 |
| | | 3 | 44.827 | 50.99 | 52.09 | 49.303 | 28.38 | 33.16 | 36.87 | 32.807 |
| Left | ESVI | 2 | 54.677 | 55.28 | 61.66 | 57.205 | 37.49 | 34.91 | 45.1 | 39.168 |
| | | 2.5 | 48.8 | 49.41 | 45.77 | 47.992 | 34.67 | 32.73 | 30.46 | 32.618 |
| | | 3 | 48.49 | 50.87 | 52.95 | 50.768 | 34.19 | 32.93 | 34.47 | 33.862 |
| | Medtronic | 2 | 101.1 | 100.3 | 97.28 | 99.543 | 85.6 | 84.18 | 83.87 | 84.553 |
| | | 2.5 | 46.655 | 56.34 | 56.1 | 53.032 | 31.96 | 34.07 | 35.64 | 33.888 |
| | | 3 | 48.05 | 57.01 | 50.81 | 51.955 | 32.5 | 36.42 | 33.82 | 34.249 |

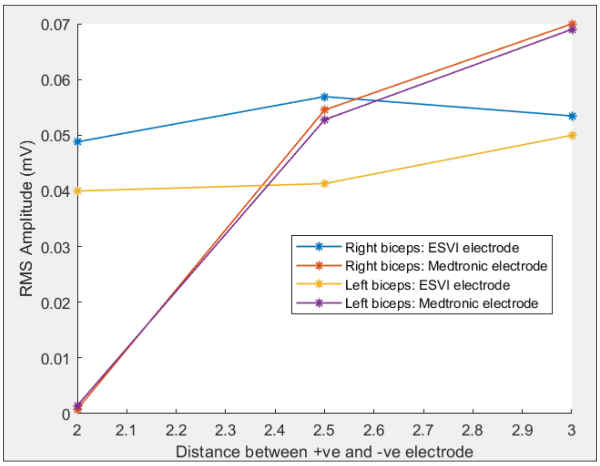


Fig6a. RMS Amplitude

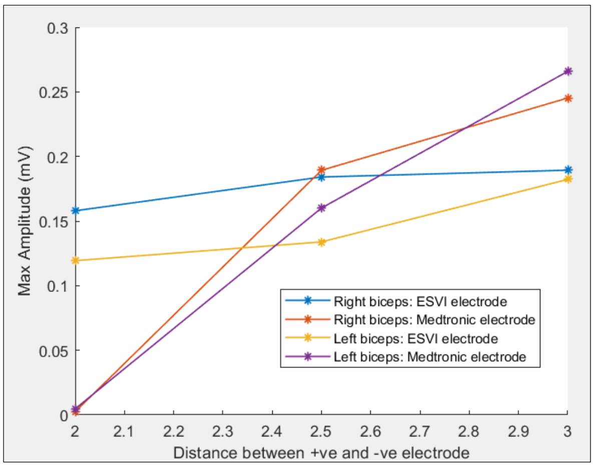


Fig6b: Max Amplitude

From Fig6, considering the Medtronic electrode, it can be observed that as the distance between the electrodes increases the RMS amplitude and Mean amplitude increases. This can be justified since as the distance between the electrodes increases a larger muscle area, and hence more electrical activity is captured. In addition, there is no comparable difference between the left and right biceps.
Considering the ESVI electrode, no clear correlation can be made. This could be due to the noise and motion artifacts while acquiring the signal.
In addition, at 2cm inter electrode distance, the large electrode (Medtronic) had lower RMS amplitude and Maximum amplitude than the smaller electrode (ESVI).

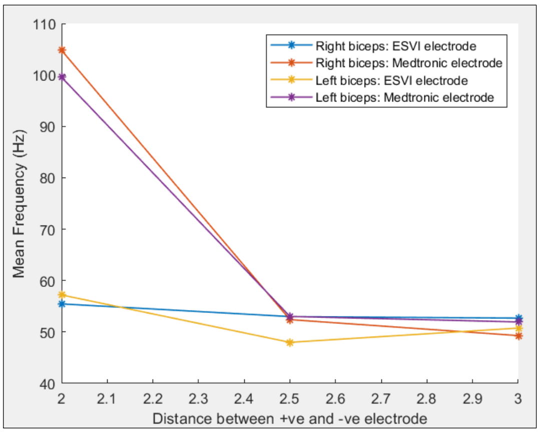


Fig7a. Mean Frequency

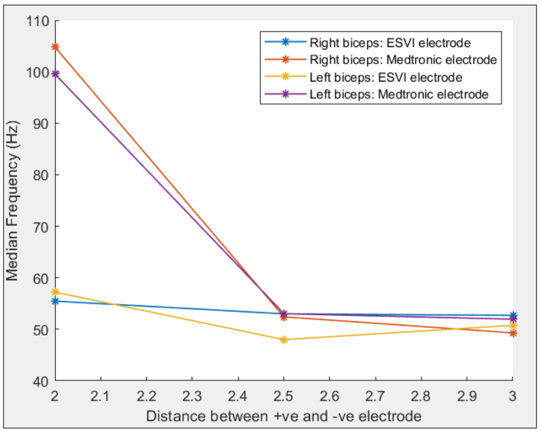


Fig7b: Median Frequency

From Fig7, considering the Medtronic electrode, it can be observed that as the distance between the electrodes increases the Mean frequency and Median frequency decreases. In addition, there is no comparable difference between the left and right biceps.
Considering the ESVI electrode, no clear correlation can be made. This could be due to the noise and motion artifacts while acquiring the signal.
In addition, at 2cm inter electrode distance, the large electrode (Medtronic) had higher mean and median frequency than the smaller electrode (ESVI).

## CONCLUSIONS:

i. The surface electromyography (sEMG) signals recorded from the biceps during flexion and extension of the arm while carrying a 3kg load have been analyzed for different inter electrode distances using electrodes from two different manufacturers.
ii. The experiment demonstrates that there is significant effect of inter-electrode distance and electrode size on the RMS amplitude, Max amplitude, Mean and median frequency.
iii. As the inter electrode distance increases the RMS amplitude and Mean amplitude increases.
iv. As the inter electrode distance increases the Mean and median frequency decreases.
v. Therefore, it is important to consider the inter-electrode distance while recording the EMG signal.

## CRITICAL REMARKS:

i. The electrode should be tightly secured to the muscle. Electrode movement while performing the curls can result in noisy signals.
ii. The subject should try to maintain the same pace while performing the curls across all trials to make comparisons between electrode size and distance.

## REFERENCES:


1. A. Melaku, D. K. Kumar and A. Bradley, "Influence of inter-electrode distance on EMG," 2001 Conference Proceedings of the 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2001, pp. 1082-1085 vol.2, doi: 10.1109/IEMBS.2001.1020377.

2. Phinyomark, Angkoon & Thongpanja, S. & Hu, Huosheng & Phukpattaranont, P. & Limsakul, Chusak. (2012). The Usefulness of Mean and Median Frequencies in Electromyography Analysis. 10.5772/50639.