ES 656 Human-Robot Interaction
Activity 6

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Problem 1: Measuring Agonist and Antagonist Muscle Activation Levels During Single-Joint Movement(Elbow -Extension-Flexion)

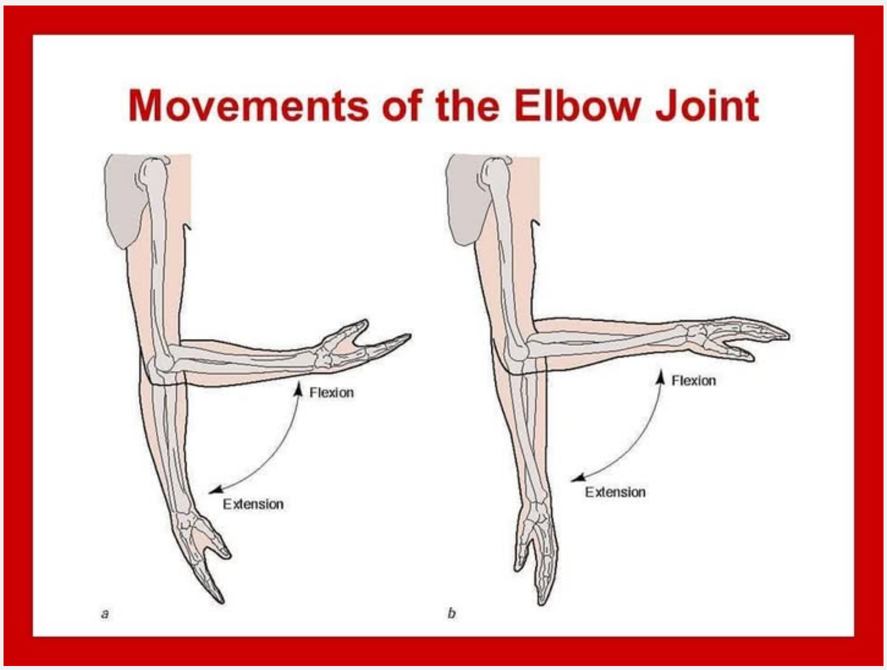

Figure 1: Elbow Flexion Extension routine

Solution 1.

This study explores how agonist and antagonist muscles contribute to joint torque during single-joint movement under different movement and loading conditions. Building on neuromechanics modeling, this experiment aims to enhance the understanding of muscle activation patterns in response to external and internal changes. This work is based on research by Milner (1993) and Milner Cloutier (1993), which analyze the influence of speed, load, and instability on muscle behavior during voluntary joint motion.

1 Methods

1.1 Motion Selection

The single-joint movement selected for this experiment was [”elbow flexion/extension”]. The primary agonist and antagonist muscles involved in this movement are:

- Agonist Muscle: ["Biceps Brachii"]
- Antagonist Muscle: ["Triceps Brachii"]

1.2 EMG Data Collection

Two EMG electrodes were used to measure the activation levels of the agonist and antagonist muscles during the selected motion. The EMG probes were attached to Biceps and Triceps muscles evenly.

1.3 Experimental Conditions

Trials were conducted under the following four conditions:

1. Varying Movement Speed: Slow vs. Fast
2. Stable Limb Loading: [Describe the stable loading condition, e.g., "Holding some weight"]

1.4 Data Analysis

The EMG recordings were analyzed to observe changes in muscle activation patterns across the different experimental conditions.

2 Results

2.1 Varying Movement Speed

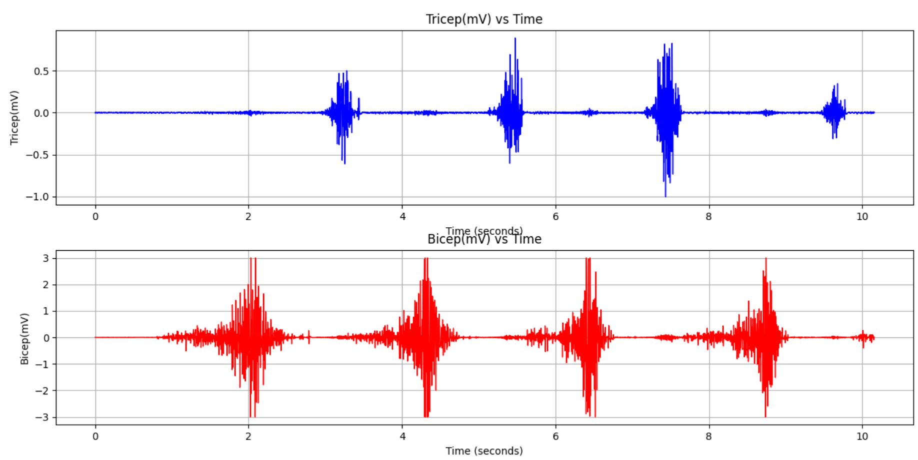

Figure 2: Slower routine

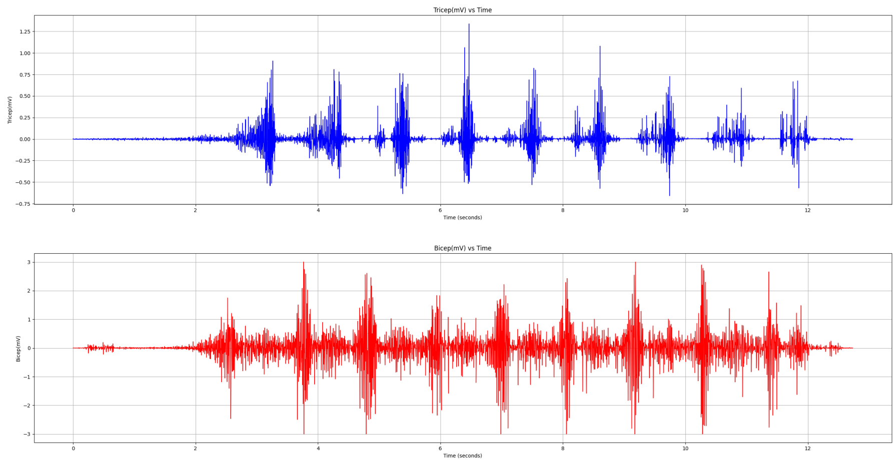

Figure 3: Faster routine

2.2 Unstable Limb Loading

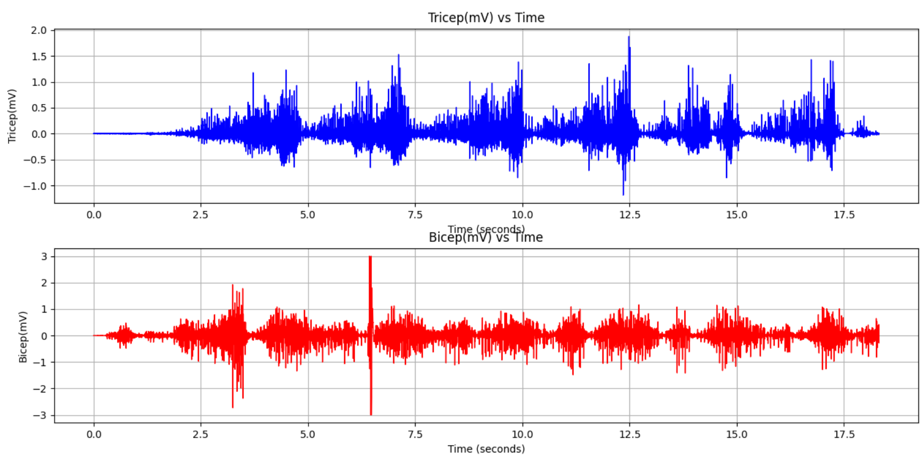

Figure 4: Unstable Loading - weight attached

3 Discussion

1. **Repetitive Motion:** Both plots display distinct, repeated bursts of electrical activity interspersed with periods of lower activity. Approximately 5-6 such cycles occur within the $\approx$ 15-second duration shown. This pattern confirms the agonist-antagonist role of bicep tricep pair.(Figure 2,3)

2. **Biceps as Primary Mover (*Agonist*):** The EMG signal amplitude for the biceps (bottom plot, red trace) is significantly larger during the active phases, with peaks reaching approximately ± 2.5 to 3 mV. This high level of electrical activity is consistent with the role of the biceps brachii as the primary *agonist* muscle generating the force required for elbow flexion.(Figure 2,3)

3. **Triceps as Antagonist with Co-contraction:** The triceps brachii is the *antagonist* muscle

to elbow flexion (its primary role is extension). However, the triceps plot (top plot, blue trace) shows clear bursts of activity that occur partially concurrently with the biceps activation bursts.

- *Lower Amplitude:* The peak amplitude of the triceps EMG signal during these bursts (around $\pm 1\ mV$) is considerably lower than that of the biceps.(Figure 2,3)
- *Co-contraction:* The simultaneous activation of the antagonist muscle (triceps) during the action of the agonist muscle (biceps) is known as *agonist-antagonist co-contraction.*(Figure 2,3)

4. **Functional Role of Co-contraction:** The observed triceps co-contraction during flexion is likely functional and serves purposes such as:
   - Enhancing elbow joint stability by increasing joint stiffness.
   - Assisting in decelerating the limb towards the end range of motion or preparing for a subsequent movement (like extension).
5. **Timing Relationship:** Within each movement cycle, the onset of major biceps activity appears to slightly precede or occur simultaneously with the onset of the triceps co-contraction burst. This timing supports the idea of the biceps initiating the flexion, followed by the triceps activating for control and stability.
6. **Resting State and Inter-Movement Periods:** Both muscle signals show minimal electrical activity (close to $0\ mV$) between time $t = 0$ and approximately $t = 2$ seconds, representing a baseline resting state before the movements began.
7. **Increased Muscle Activation (Amplitude)**: Lifting or holding a weight requires muscles to generate more force compared to moving the limb without external load. This increased force requirement translates directly to higher electrical activity in the contracting muscles, which would be reflected as higher amplitude EMG signals.
8. While holding a weight, particularly an unbalanced one, explains for the high level of biceps (antagonist) co-contraction observed during the likely extension movements in the second plot. This is because such a load would demand greater joint stabilization.

Summary: The EMG data clearly illustrates the physiological principles of muscle activation during voluntary movement. It highlights the strong activation of the agonist (biceps) required for elbow flexion, coupled with functionally significant co-contraction of the antagonist (triceps) to ensure joint stability and controlled motion throughout the repetitive task.

4 Conclusion

In conclusion, our experimental investigation into the neuro-mechanics of single-joint motion, specifically elbow flexion and extension, provides valuable insights into the dynamic interplay between the nervous system and musculoskeletal system. The EMG data clearly illustrates the physiological principles of muscle activation during voluntary movement. We observed distinct changes in muscle activation patterns in response to variations in movement speed, limb loading stability and instability, highlighting the intricate coordination required for precise motor control. The study highlights the strong activation of the agonist (biceps) required for elbow flexion, coupled with functionally significant co-contraction of the antagonist (triceps) to ensure joint stability and controlled motion throughout the repetitive task. This co-contraction is particularly evident under unstable loading conditions, where increased joint stabilization is required. The timing of muscle activation, with the biceps activity slightly preceding or occurring simultaneously with the triceps co-contraction, further supports the role of the biceps in initiating flexion and the triceps in providing control and stability. Through careful manipulation of experimental variables such as movement speed, limb loading stability, instability, and limb configuration, we have elucidated the complex patterns of muscle activation in the agonist and antagonist muscles, namely the biceps brachii and triceps brachii, respectively.