Big Picture

The purpose of today's lab is to learn to collect electromyography (EMG) and use musculoskeletal models for the application of controlling myoelectric prosthetic devices. We will learn how to collect EMG of the biceps/triceps, process the signals through a linear envelope and normalizing, and use the signals through Forward Dynamics to predict elbow movement. In the process, we will also explore potential issues with the use of EMG and modelling and how they may affect results.

Pre-Lab Preparation

1. Watch the pre-recorded video (Week 8A – EMG) on refresher of electromyography.
2. Bring this document. Please read the lab document fully prior to coming to the lab.
3. Wear a t-shirt for easy access to the arm. To record muscle electrical activity, we will be placing electrodes on some of the muscles of the elbow.
4. Let your TA know if you have any injuries and/or concerns that prohibit you from performing any of the lab activities.
5. Most importantly, have fun while completing the lab! Be curious and don't be afraid to explore any opportunities you may find interesting in the lab. 😊

(A) EMG Preparation & Setup:

1. Use alcohol wipes to clean off the following sites:
    - Middle of biceps
    - Middle of triceps
    - Lateral epicondyle of the elbow
2. Place 2 electrodes on the **biceps brachii** (BIC) parallel to the muscle fibres. Ensure that the electrodes are placed on the bulk of muscle belly. As the biceps can be quite mobile and move considerably, have the participant go through their flexion-extension range of motion and contract the muscle to locate the centre of the belly for most of the range of motion.
3. Similarly, place 2 electrodes on the **triceps brachii** (TRI) parallel to the muscle fibres on the bulk of the muscle belly.
4. Place 1 electrode on the **lateral epicondyle of the elbow** (termed the "ground" or "reference" or "common" electrode – sets the electrical baseline for your signals). Alternatively, you can use any other bony landmark near the arm.
5. Attach the BioAmp cable to the electrodes (Note: make sure electrodes are attached to proper channels!):
    - Channel 1 electrodes (x2) attach to the BIC
    - Channel 2 electrodes (x2) attach to the TRI
    - Ground electrode to the lateral epicondyle of the elbow
6. Open the LabChart Data File: "Biceps and Triceps" under the following directory:
    - Desktop > KIN 4GG3 – Fall 2021 > EMG Lab
7. Change the recording to 10.0 seconds:
    - Setup > Sampling > Stop Sampling > Check off "Fixed Duration" for 10.0 s
8. Click Start on the software to begin collecting. The first two graphs are associated with the EMG signals of your muscles:
    - First Chart: Raw Biceps muscle activity [mV]
    - Second Chart: Raw Triceps muscle activity [mV]
9. To ensure electrodes are recording activity of the appropriate muscles, have the participant flex their elbow against manual resistance. You should see increased amplitude of the biceps muscle activity and relatively quiet triceps muscle activity. Repeat with the participant extending their elbow against manual resistance. Check your raw EMG signals with Dan/Ryan.

CHECKPOINT*: What are some concerns regarding the electrode location that could affect the EMG signal? What is the purpose of the "ground" or "reference" electrode?*

(B) <u>EMG Processing:</u>

1. Create filtered versions of your raw EMG data using the following steps:
   a) Setup > Channel Settings.
   b) Increase the number of channels from 2 to 4 in the bottom left corner.
   c) For Channel 3:
      - Change the Channel title to "Processed Biceps Signal".
      - Select Arithmetic under the Calculation column.
      - Apply a linear envelope to the raw BIC EMG signal by performing a full wave rectification (i.e., absolute value) and a lowpass filter of 4 Hz using the available functions. Remember, you will want to rectify before filtering!
   d) Repeat step 1c but for Channel 4 and using the Triceps signal.
   e) You should now have a total of four channels. Channels 1 & 3 are for the biceps (raw and filtered, respectively) and 2 & 4 for the triceps (raw and filtered, respectively). Again, ensure electrodes are recording activity of the appropriate muscles, by having the participant flex their elbow against manual resistance. Check your signals with Dan/Ryan.

***CHECKPOINT**: If you change the cut-off frequency of the low pass filter, what happens to the processed EMG signal? For example, try increasing the cut-off frequency from 4 Hz to 20 Hz. Or alternatively, decreasing the cut-off from 4 Hz to 1 Hz.*

(C) Data Collection #1 – Maximal Voluntary Exertions (MVE)

1. Change the recording to 10.0 seconds:
   a. Setup > Sampling > Stop Sampling > Check off "Fixed Duration" for 10.0 s
2. **Maximal Biceps Muscle Activity – Elbow Flexion**
   a. Participant instructions: Place your elbow in a 90° flexion posture with your forearm supinated (i.e., palm facing up). Perform a couple of practice submaximal isometric elbow flexion trials against resistance until you feel comfortable. The resistance can be performed using your other hand or from your partner. You will soon be asked to perform a maximal isometric elbow flexion exertion in this position by flexing your elbow as hard as possible for 5 seconds using a ramped contraction (ramp up to your maximal and ramp down back to rest) – don't start yet!
   - Researcher instructions: Give appropriate encouragement to the participant to elicit maximal exertion. It is very important for the participant to give a proper maximal as all the EMG values will be normalized to maxes.
   - You have a 10 second recording window. When everyone is ready, the researcher will click Start and the participant will perform the maximal isometric elbow flexion trial.
   - Once recorded, look at the graphs and identify the point of highest biceps electrical activity on the third chart. Have Dan/Ryan double-check your data before proceeding.
   - Highlight the 3 seconds of area around the highest point using the cursor. Record the peak values for the following variables in Table 1:
     i. Peak BIC EMG amplitude (mV) – value available in Cell B1
   - Repeat the maximum trial two more times.
3. **Maximum Triceps Muscle Activity – Elbow Extension**
   a. Repeat steps 2a-2f in the same posture, but this time performing maximal isometric elbow extension against resistance. Record your maximal triceps EMG amplitude (mV) – value available in Cell D1.
4. **Normalization**
   a. Normalize your filtered data (Channel 3 & 4) by dividing the values using the peak EMG signal of that specific muscle from Table 1. Verify with Dan/Ryan.

Table 1: Biceps and Triceps EMG peak amplitude values

Muscle	Trial 1	Trial 2	Trial 3	Peak
Biceps				
Triceps				

***CHECKPOINT**: What is normalization? What is the purpose of it? What are some errors that may be associated with the normalization step?*

(D) Data Collection #2 – Dynamic Trials

1. **Dynamic Trials**
    a. Change the recording to 6.0 seconds:
        - Setup > Sampling > Stop Sampling > Check off "Fixed Duration" for 6.0 s
    b. Participant instructions: You will be moving your elbow through its full range of motion, starting in an extended position, flexing to your end range of motion, and returning to the original extended position. Practice a few times to make sure you can get the full motion in the allotted time.
    c. Researcher instructions: Ensure that the participant is able to achieve the full range of motion.
    d. When ready, click Start to begin recording and have the participant flex and extend their elbow.
    e. Once recorded, look at the graph and have Dan/Ryan double-check your data before proceeding
    f. Open a blank worksheet in Microsoft Excel.
    g. Highlight the entire trial and copy the data into the blank excel sheet (right click and copy from LabChart and paste it into Excel). You want to paste the time and Channels 3 and 4. Verify with Dan/Ryan.
    h. Repeat steps 1a-1g, but this time starting with the elbow flexed, extending into your end range of motion and returning back to your original flexed position.
    i. Save your Excel file into the following directory:
        - Desktop > KIN 4GG3 – Fall 2021 > EMG Lab

(E) OpenSim Forward Dynamics

1. Open OpenSim.
2. Load the **arm26.osim** model into OpenSim. Model file is located in the following directory:
   - Desktop > K4GG3 – Fall 2021 > 4.2 > Models > Arm26
3. Open the following file in Excel: **arm26_controls – blank.sto**. This file has a sample dataset of activations for all the muscles in the model.
4. Copy and paste the EMG data from Excel into the .sto file for Dynamic Trial #1. Hint: You can use Control + Shift + Up/Down to select all the data. The biceps EMG will be pasted into all of the biceps and brachialis columns. The triceps EMG will be pasted into all the triceps. Make sure to copy over the time columns. Save the .sto file as a new file in the same directory.
5. In OpenSim, lock the shoulder degree of freedom so it cannot be moved. Set the elbow to a fully extended posture.
6. Let's now use the EMG data as control inputs and see what the predicted motion is using Forward Dynamics.
   - Tools > Forward Dynamics
   - Select the appropriate .sto file under Controls
   - Ensure the directory is set to Desktop > K4GG3 – Fall 2021 > EMG Lab
   - Click Run
7. Did the model successfully predict the motion that the participant performed?
   - If successful, hooray! Try the opposite direction (started flexed, extend, and flex again)
   - If no, booo! What is the predicted motion?
     i. If the model is overextending, it means that we need to increase the biceps activity (triceps are overpowering the biceps).
     ii. If the model is over-flexing, it means we need to increase the triceps activity (biceps are overpowering the triceps).
     iii. How can we scale the muscle activity without collecting more trials?

CHECKPOINT: *What do you think are limitations to our approach of using EMG signals as inputs into a musculoskeletal model for predicting movements?*

Bonus (Re-assessment with fatigue):

If you still have time left in the lab, complete a fatiguing trial. Have the participant hold an isometric flexion contraction by holding a heavy object for 2 minutes. Re-collect your dynamic trials from Part D and repeat your Forward Dynamics from Part E.

CHECKPOINT: *Was the model still successful? How do you think muscle fatigue affects EMG signals? In turn, how would this affect our ability to use EMG signals for predicting movement to control myoelectric prosthetics in real-life settings?*