

ME/BIOE 481. LAB 2: Tendon Transfer

Updated: March 5, 2021

1 Critical info

- Due date: March 11, 2021 - 11:59 PM (US Central standard time)
- You may work in pairs. Include your names at the top of your lab report. You and your partner will receive the same grade. Only one person needs to turn in the assignment to compass. It can be neatly handwritten or typed (typed is preferred for text). Let the pride in your work show in the quality/legibility of the assignment you turn in. Illegible writing or poor scans/uploads will not be graded.
- Show all work!

2 Introduction

We have learned that torque generated at the joints is dependent on the muscle attachment. In this lab, you will learn how musculoskeletal models can be used to study orthopaedic surgical techniques and to illustrate how muscle moment arm influences the variation of muscle force with respect to changes in joint angle. Portions of this lab developed by Credits Wendy Murray and Scott Delp with help from many others.

3 Running wrist model in OpenSim

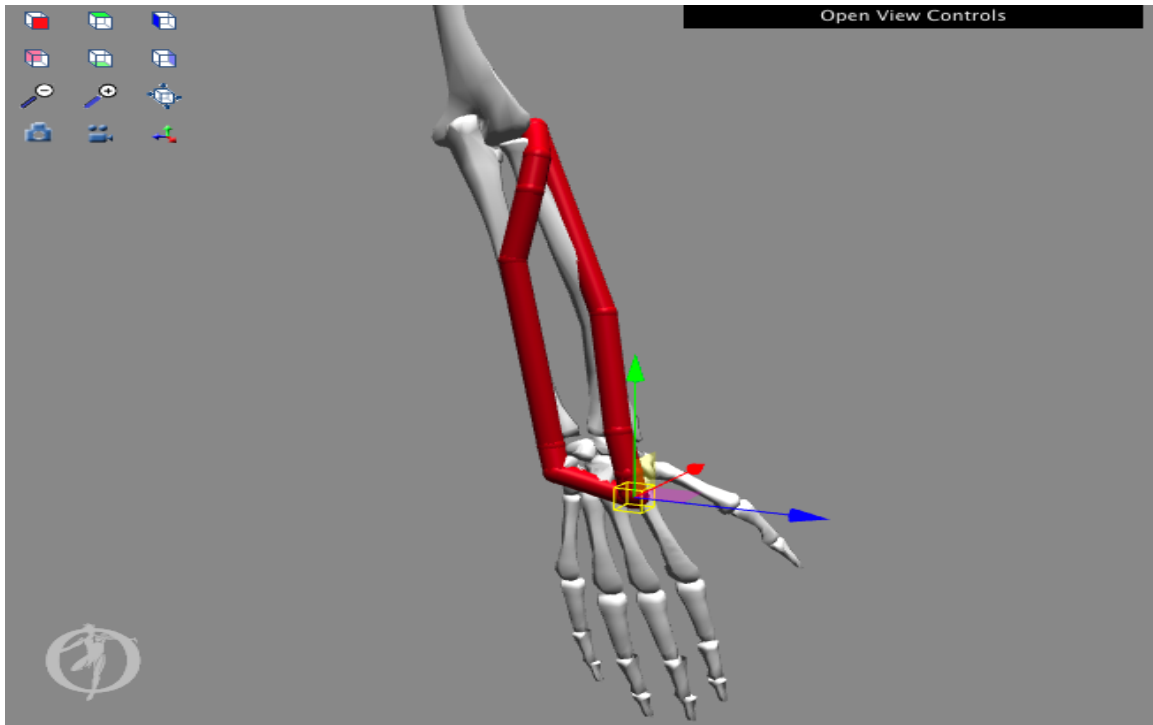
1. Click the **File** menu and select **Open Model**.
2. Find the Models folder, which is located under your Documents folder on PC e.g., Documents.0or your Documents folder on Mac, e.g., Documents/OpenSim/4.0/Models. Note: When you first launch OpenSim, the default to install models and scripts files is your Documents folders, you do have the choice to change the folder where you want to install these files.
3. Open the **WristModel** folder, select the file **wrist.osim**, and click **Open**.
To do: Use the Coordinate sliders to investigate the wrist model. In particular, become familiar with wrist **flexion** and extension and radial and ulnar **deviation**. It is important to understand the angle conventions to interpret the plots you will make later in the tutorial. Note: Radial deviation is defined as wrist motion toward the radius bone, or thumb side. Wrist flexion is defined as wrist motion that faces the palm towards the forearm, while wrist extension faces the palm away from the forearm.
4. In the Navigator, expand the **Forces** and **Muscles** headings. Use the buttons to the left of the Navigator (+ or -) to expand or collapse the heading.
5. To hide all of the muscles in the model, **right-click** on the **all** muscle group heading, then choose **Display > Hide**.
6. To show the flexors muscle group, **right-click** on the **flexors** heading, then choose **Display > Show**. Now the only muscles displayed should be the wrist flexors. To hide the wrist flexors, **right-click** on the **flexors** heading again and select **Display > Hide**. You can see which muscles are in the flexors group by **expanding** the list.
7. Repeat the same steps to display the **extensors**, **radial deviators**, and **ulnar deviators** muscle groups individually.

4 Simulation of Tendon Transfer

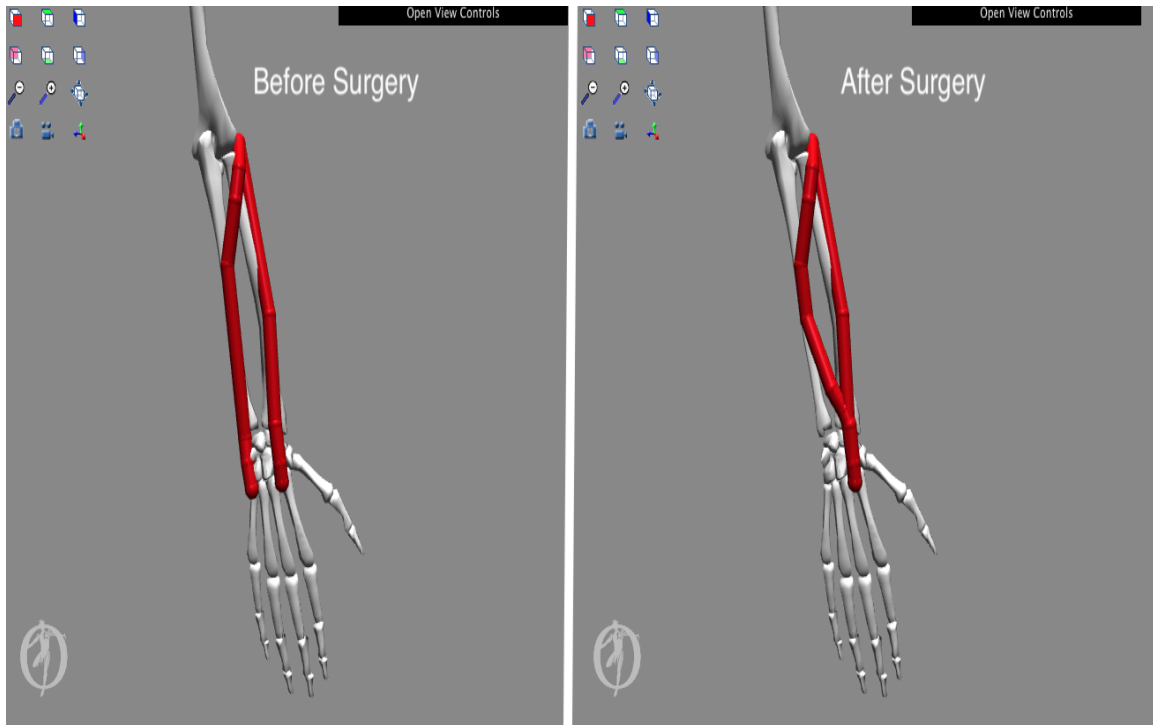
Spinal cord injury at the level of the cervical spine causes a loss of hand function. In some patients, the ability to grasp and release objects may be restored through electrical stimulation of paralyzed muscles, called functional electrical stimulation (FES). However, FES is only feasible in those muscles where the connection between the nervous system and the muscle remains intact within the muscle. In many cases, the muscles that perform the desired functions (e.g., finger flexion, thumb abduction) have been damaged too greatly to respond to FES. In addition, there is often a loss of balance at the wrist joint, causing the wrist to remain in a flexed and ulnarly deviated position [2]. In these situations, tendon transfers are performed to i) alter the paths of muscles that do respond to FES to locations where they can enhance hand function, and ii) restore a more functional configuration of the wrist joint so that grasp and release tasks can be accomplished.

In this lab, you will transfer the ECU tendon to the ECRB tendon and evaluate the mechanism by which this tendon transfer restores balance to the wrist.

1. Display the **transfer** muscle group only by **right-clicking** its heading and selecting **Display > Show Only**. The ECU_pre-surgery and the ECRB muscle paths should now be visible on the model. Note: ECU_pre-surgery represents the ECU muscle before the simulated tendon transfer surgery.
2. Expand the transfer muscle group and identify each muscle by using Display > Show Only on each.
To simulate the surgery, you will edit the paths of the muscles in the visualizer window. Each end of a muscle-tendon complex connects to bone. In this model, the most proximal connection is the origin, and the most distal connection is the insertion point. You will first select the insertion point of the ECU_pre-surgery muscle and move its location. Then you will perform a similar operation for the two via points proximal to it. All muscle via points are graphically represented as small red spheres on the muscle path, and coincide with the "kinks" in the muscle path.
3. Before editing the model, go to the **File** menu select **Save Model As...** Save the current model as **wrist_TendonSurgery.osim**.
4. Once you have done this, right-click on the **Wrist_Model** name in the OpenSim Navigator window and select "**Rename...**" Rename the model to "Wrist_Model_Tendon_Surgery."
5. To return the model to its default pose, click **Poses > Default** in the Coordinates window.
6. To view muscle properties, **click** on the **ECU_pre-surgery** muscle name in the Navigator. The muscle parameters will appear in the window below the Navigator. Note: If the Properties Window is not open, you can open it by going to Window > Properties in the main menu bar on top of the OpenSim window.
7. Before starting the simulated surgery, make sure you can see both muscles from the **transfer** muscle group. Then, zoom in on the wrist joint. **Click** on the insertion muscle point of ECU_pre-surgery. Note: Once selected, a yellow box will appear around the muscle point. Its name (ECU_pre-surgery-P7) should be displayed at the bottom-left of the GUI
8. To move the selected muscle point, use the red, blue, and green arrows that appear on muscle selection to adjust the muscle point's location along a single axis.



9. Repeat this process for the two remaining, proximal muscle points of the ECU: ECU_pre-surgery-P6 and ECU_pre-surgery-P5.
10. Your goal is to align the ECU_pre-surgery path with the ECRB path, as shown to the right. Note: in the image below, we have increased the size of the muscle path points to improve their visibility.



5 Biomechanical Effects of Tendon Transfer

To analyze the effects of the surgery, you need a model of the ECU muscle both before and after surgery.

1. In this **wrist_TendonSurgery.osim** model ensure no muscle points are selected and the model is in the neutral (**default**) configuration. Note: You can return the model to its default configuration by selecting **Poses > Default** in the **Coordinates** tab.

Now you will investigate the effect of the transfer on wrist extensor strength by creating plots of the maximum isometric wrist moments before and after the simulated surgery. To see how the surgery will affect wrist extension strength, you will examine maximum isometric wrist extension moments (i.e., the moments generated when all the extensor muscles are maximally excited). Note: Isometric moments assume zero muscle velocity.

2. Open a new plot from the Tools menu. Click the **Properties** button and type **Wrist Flexion Moment vs. Flexion Angle** into the Textbox under the **Title** tab. Click **OK**. Click the **Y-Quantity** button, and select **moment > flexion**. Note: Do not select **elbow_flexion**!
3. Filter the muscle list by model and extensors group. Select all of the muscles in the extensors group by checking the **select all shown** checkbox. De-select the ECU_post-surgery muscle by "**un-checking**" the **ECU_post-surgery** checkbox. To plot the sum of all the moments, check the **sum only** checkbox.
4. Click the **X-Quantity** button and select **flexion**.
5. Edit the **Curve Name** text to read **After Surgery**.
6. Then click **Add**.
7. Please note that you have to **de-select ECU_post-surgery** in any cases, because even in the model you performed the surgery, the muscle is still called **ECU_pre-surgery**.

A curve labeled "After Transfer" should appear on the plot, which is the sum of the isometric moments generated by all of the wrist extensors after the surgery you just did. Now you will need to **open the original wrist model** that is before the surgery. Repeat the same process to open a new plot.

8. Repeat the same procedure, but in the muscle selection window, de-select ECU_post-surgery and select ECU_pre-surgery. Note: Ensure the sum only checkbox is still selected and keep the muscle selection window open.
9. **Add a Curve** named **Before Surgery**. Note: To print or save a plot, **right-click** on the plot and select **Print** or **Export Image**.

Now let's examine the effects of the transfer on the deviation strength of the wrist muscles.

10. Start a new plot, edit the plot title to read **Wrist Deviation Moment vs. Deviation Angle**. Click **Y-Quantity** and select **moment > deviation**.
11. Filter the **ulnar deviators** group and click the **select all shown** check box.
12. Use the wrist model that you have operated surgery, and de-select ECU_post-surgery muscle Note: Ensure the **sum only** checkbox is still selected and keep the muscle selection window open.
13. Click **X-Quantity** and select **deviation**, edit the **Curve Name** to be "After Surgery", and click **Add**. Export the image and save as a PNG file.
14. Now reopen and select the **original wrist model**, Repeat the above steps, **de-select** the ECU_post-surgery muscle and **select** the ECU_pre-surgery muscle. **Add** the **Curve** named **Before Surgery**. Export the plot.

References 1. Gonzalez, R.V., Buchanan, T.S., Delp, S.L. How muscle architecture and moment arms affect wrist flexion-extension moments. *Journal of Biomechanics*, vol. 30, pp. 705-712, 1997. 2. Herrmann, A., Delp, S.L. Moment arms and force-generating capacity of the extensor carpi ulnaris after transfer to the extensor carpi radialis brevis. *Journal of Hand Surgery*, vol. 24A, pp. 1083-1090, 1999. 3. Zajac, F.E. Muscle and tendon:

properties, models, scaling, and application to biomechanics and motor control. *Critical Reviews Biomedical Engineering*, vol. 17, pp. 359-411, 1989. 4. Delp, S.L. and Zajac, F.E. Force- and moment-generating capacity of lower-limb muscles before and after tendon lengthening. *Clinical Orthopaedics and Related Research*, vol. 284, pp. 247-259, 1992.