Tutorial 3 – Muscle-tendon Personalization

The Muscle–tendon Model Personalization tool finds an optimal set of subject-specific muscle–tendon properties and muscle activations from EMG, joint kinematic, and joint moment data by balancing optimization cost function terms related to muscle properties, similarity of properties among grouped muscles, and matching of EMG-driven and experimental inverse dynamics joint moments. Muscle activation and force predictions are sensitive to optimal muscle fiber length and tendon slack length. Therefore, reliable personalization of these parameters is essential for generating reliable predictions of muscle activations and forces during predictive simulations of movement.

The inputs to the MTP tool are a post-JMP OpenSim model as well as IK motion, ID load, muscle–tendon length and velocity, and muscle moment arm data from one or more motion trials of interest.

The previous step in this tutorial was preprocessing and is required before running MTP. Preprocessing will process EMG data and provide critical muscle kinematic data needed by the Hill-type muscle model used in MTP. If preprocessing was done correctly, its output should be able to be used as the MTP input with no extra modifications.

Before running MTP:

1. Open the OpenSim model **UF_Subject_3_reduced_muscles.osim** in the OpenSim GUI.
2. Under the *Forces* tab on the model, explore the muscles available.
3. Take note of the extra groups added.
    a. These are added for organization so that MTP/NCP knows which OpenSim model muscles to group together in the optimization.
    b. The four important groups are:
        i. Activation Muscle Groups – Muscles that we would expect to have similar activation profiles (ie lateral hamstrings; BFSH and BFLH will have similar activations to each other)
        ii. Normalized Fiber Length Muscle Groups – Muscles that we would expect to have similar normalized fiber lengths.

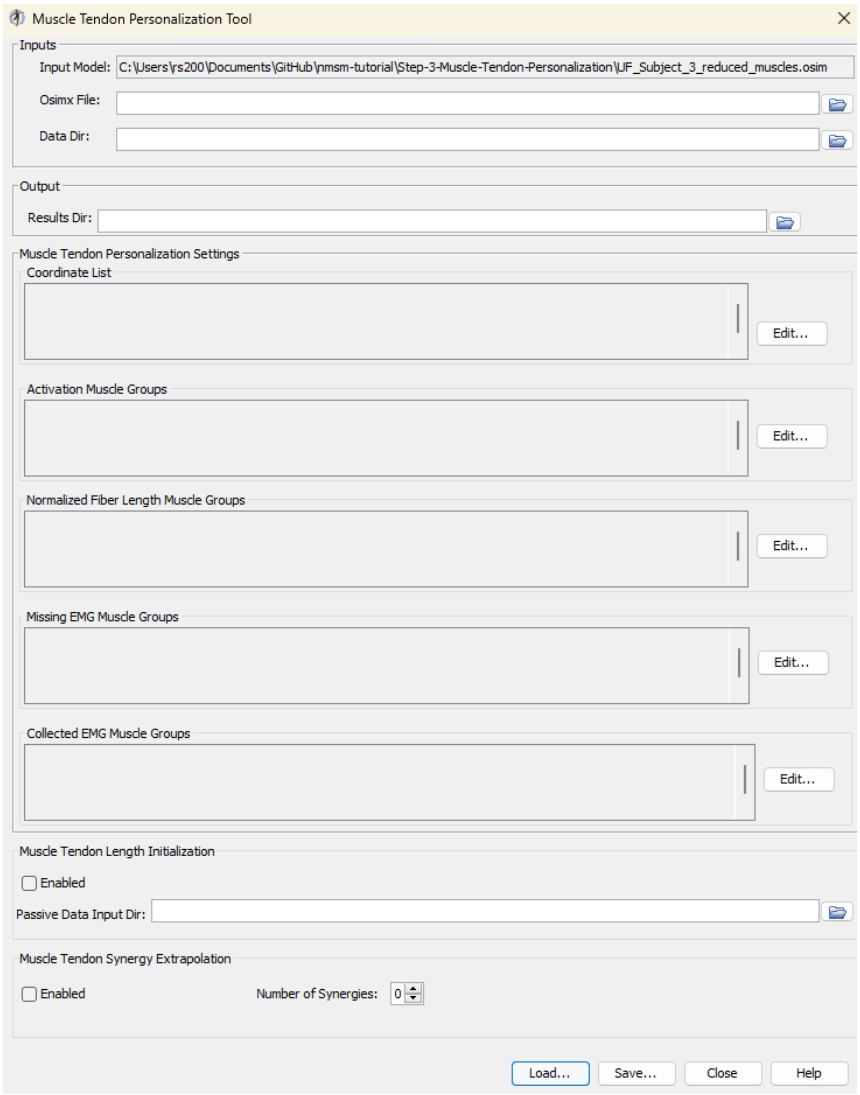
iii. Collected EMG Muscle Groups – Muscle groups that we **do have** experimental EMG data for. These must have the same name as the respective EMG channel name your EMG data file (**preprocessed\EMGData\gait_1.sto**)

iv. Missing EMG Muscle Groups – Muscle groups that we **do not have** experimental EMG data for.

c. These groups need to be created manually in a text editor such as Notepad++, but we have example groups for lower limb models in the *NMSM Article* download on SimTK: https://simtk.org/frs/?group_id=2397

Setting up an MTP settings file:

1. Activate the NMSM GUI in OpenSim by navigating to *Tools>User Plugins* and click **rcnlPlugin.dll.**
2. With **UF_Subject_3_reduced_muscles.osim** selected in the OpenSim GUI, navigate to *Tools>Model Personalization>Muscle-tendon Personalization.*
    a. The following window should be opened:



3. Leave the *Osimx File* field empty. This tool outputs an Osimx file, but we do not have one to work with yet. If this field is filled out, the MTP tool will concatenate new elements to the existing Osimx file.
4. Set the *data directory* to be **preprocessed.**

5. Set the *results directory* to be **MTPResults.**
6. For the *coordinate list*, select: (**hip_flexion_r, knee_angle_r, ankle_angle_r**).
7. For *activation muscle groups*, select (**HipFlexorsActivationGroupR, GlutmaxActivationGroupR, HamslatActivationGroupR, VasActivationGroupR, GasActivationGroupR**).
    a. Use filter term "activation" and click *select all shown*
8. For *normalized fiber length groups*, select (**GlutmaxNormalizedFiberLengthGroupR, HamsNormalizedFiberLengthGroupR, VasNormalizedFiberLengthGroupR, GasNormalizedFiberLengthGroupR**).
    a. Use filter term "fiber" and click *select all shown*
9. For *missing EMG muscle groups*, select (**HipFlexorsMissingEMGChannelGroup**)
    a. Use filter term "missing" and click *select all shown*
10. For *collected EMG muscle groups*, select (**GlutMaxLat, RecFem, BicFemLong, BicFemShort, VastMed, GasMed, Sol, TibAnt**).
11. **Enable** *Muscle Tendon Length Initialization* (MTLI).
    Set the *passive data input directory* to **passive_moment_data.**
12. **Enable** *Muscle tendon Synergy Extrapolation* (SynX) with **3 synergies**.
13. Save this settings file as **MTPSettings.xml.**
14. Open **MTPSettings.xml** in a text editor and explore the settings file.

Running MTP:

1. Open MATLAB and open **runMTP.m** in your tutorial directory.
2. Open the project file (**Project.prj** inside your installation of nmsm-core).
3. Run the MATLAB file **RunMTP.m.**

Alternate MTP Formulations:

Synergy Extrapolation (SynX) is a crucial part of a successful MTP run. Without SynX, MTP will need to over-use muscles spanning joints with missing EMG data, thus yielding a less accurate solution. To explore this further, disable SynX in your settings file, and compare the results between runs with and without SynX. How does the moment matching for the hip joint

(where the iliacus is) compare to the moment matching for the knee and ankle joints when you don't use SynX? What about the muscle model parameters for the other muscles that span the hip?