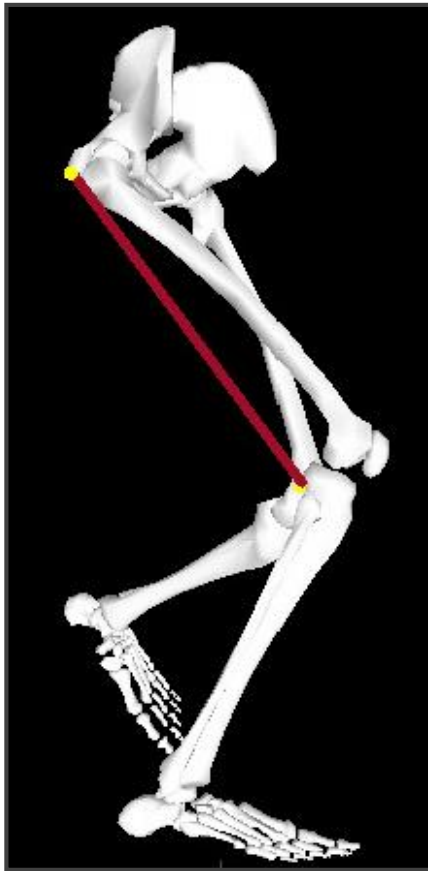


Introduction to muscle analysis

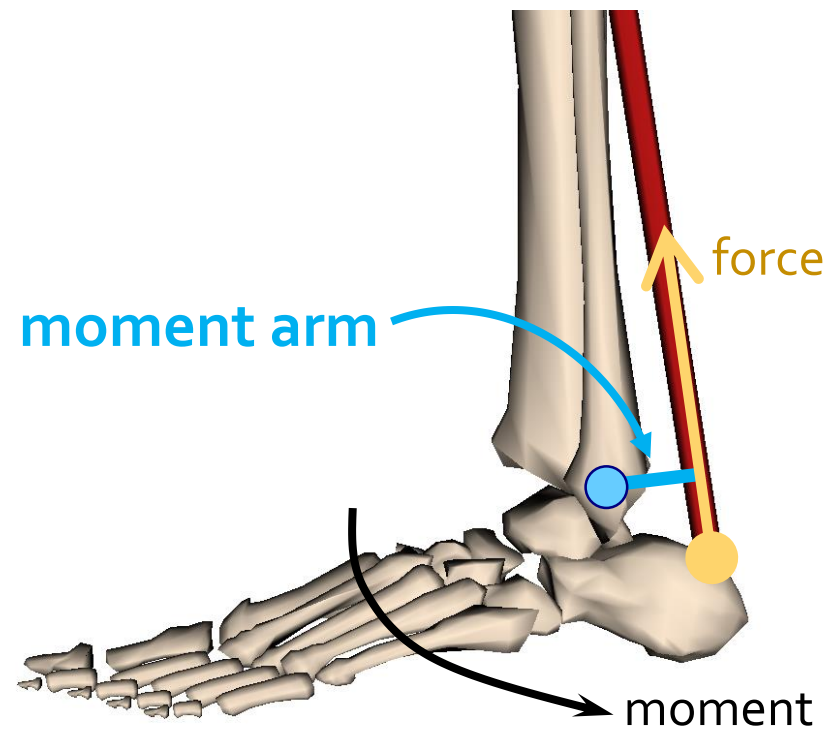
OpenSim Workshop

Musculotendon geometry

Muscle-Tendon Lengths

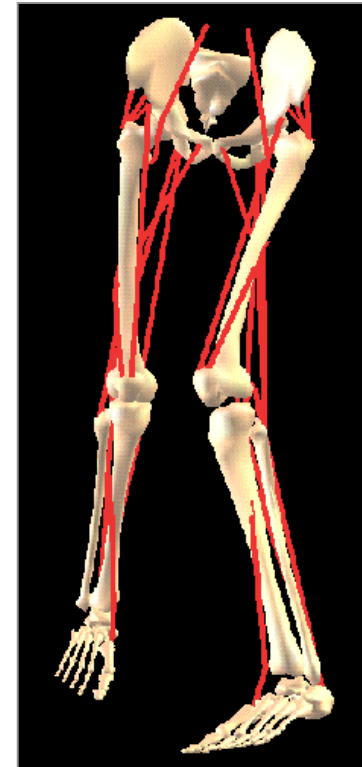
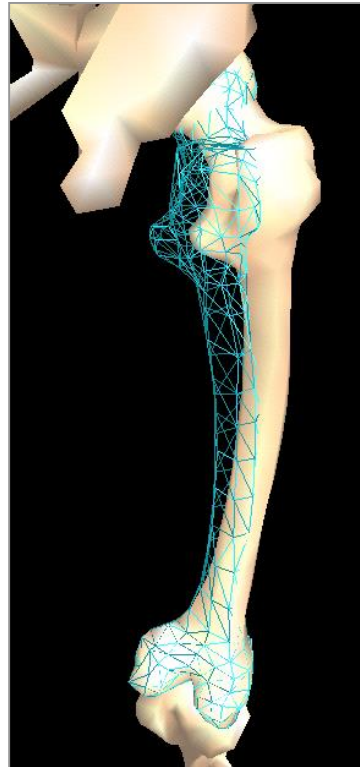


Muscle Moment Arms



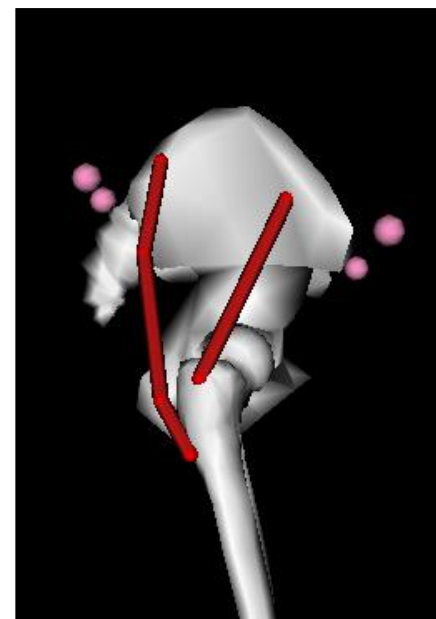
Muscle moment arms

Example: Which muscles have moment arms that internally rotate the hip?

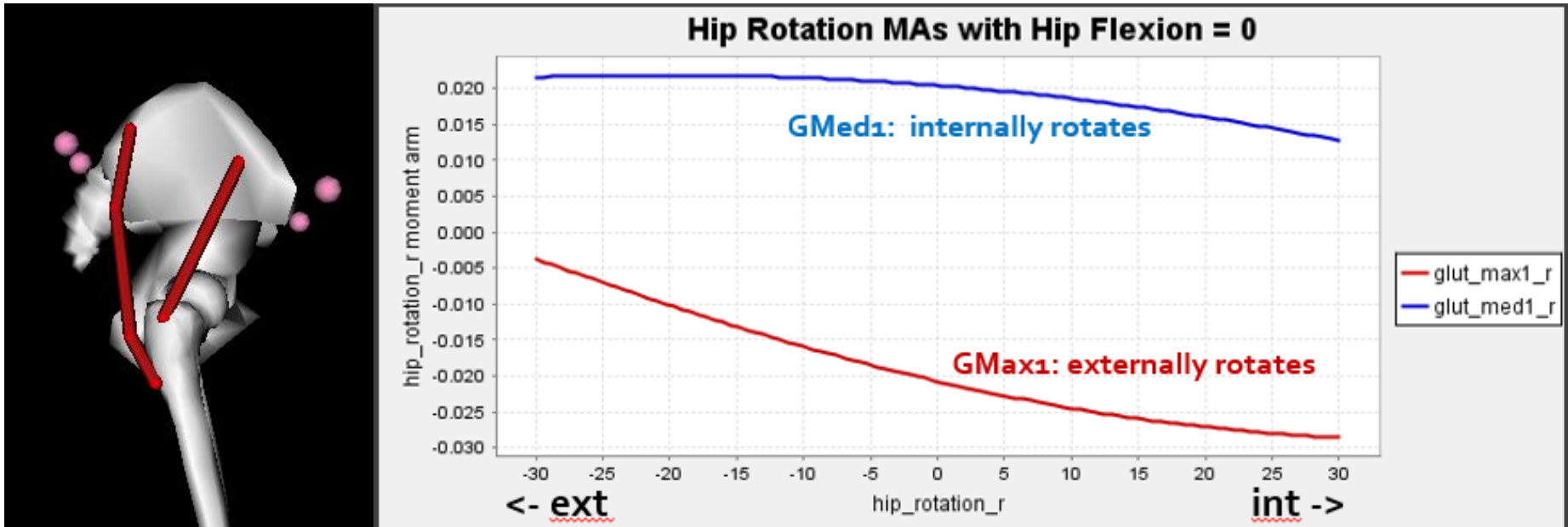


Using the plotting tool

- Plotting hip internal rotation moment arm versus hip rotation in the range -30° to 30°
- Tools>plot:
 - **Y quantity**: moment arm>hip_rotation_r
 - **X quantity**: hip_rotation_r
 - **Muscles**: select "glut_max1_r" and "glut_med1_r"
 - **Advanced**: xmin = -30, xmax = 30

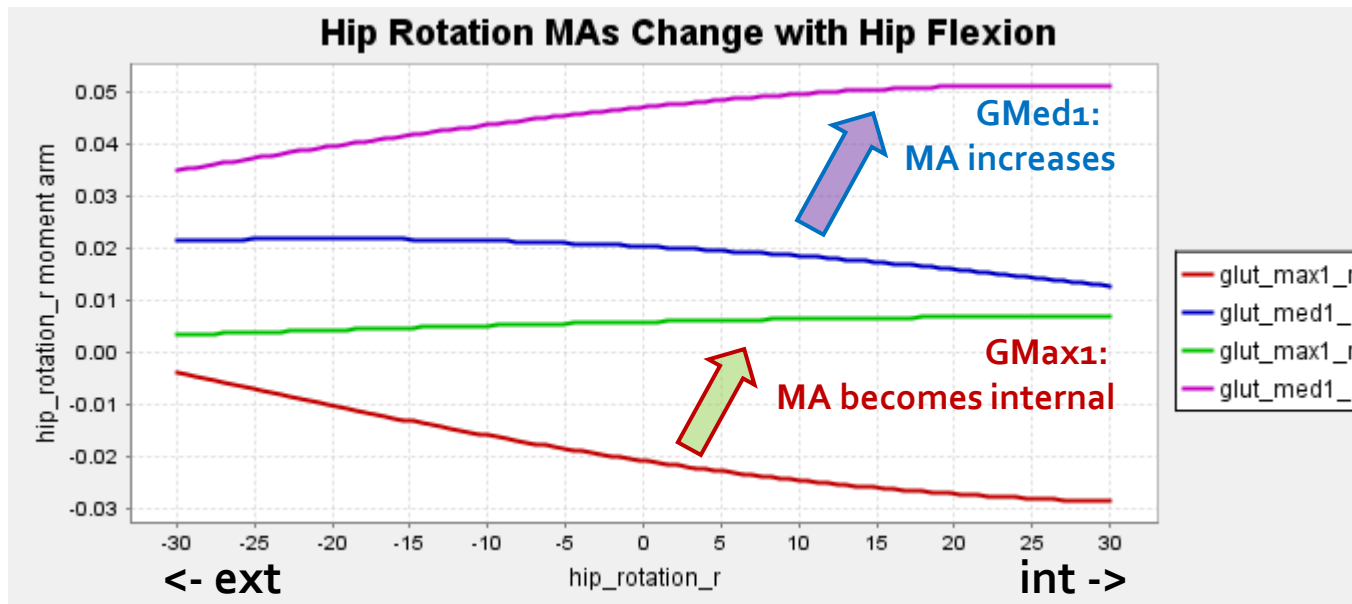


Using the plotting tool



Using the plotting tool

- How do hip rotation moment arms change with hip flexion?
- Set hip_flexion_r = 50 in Coordinates panel

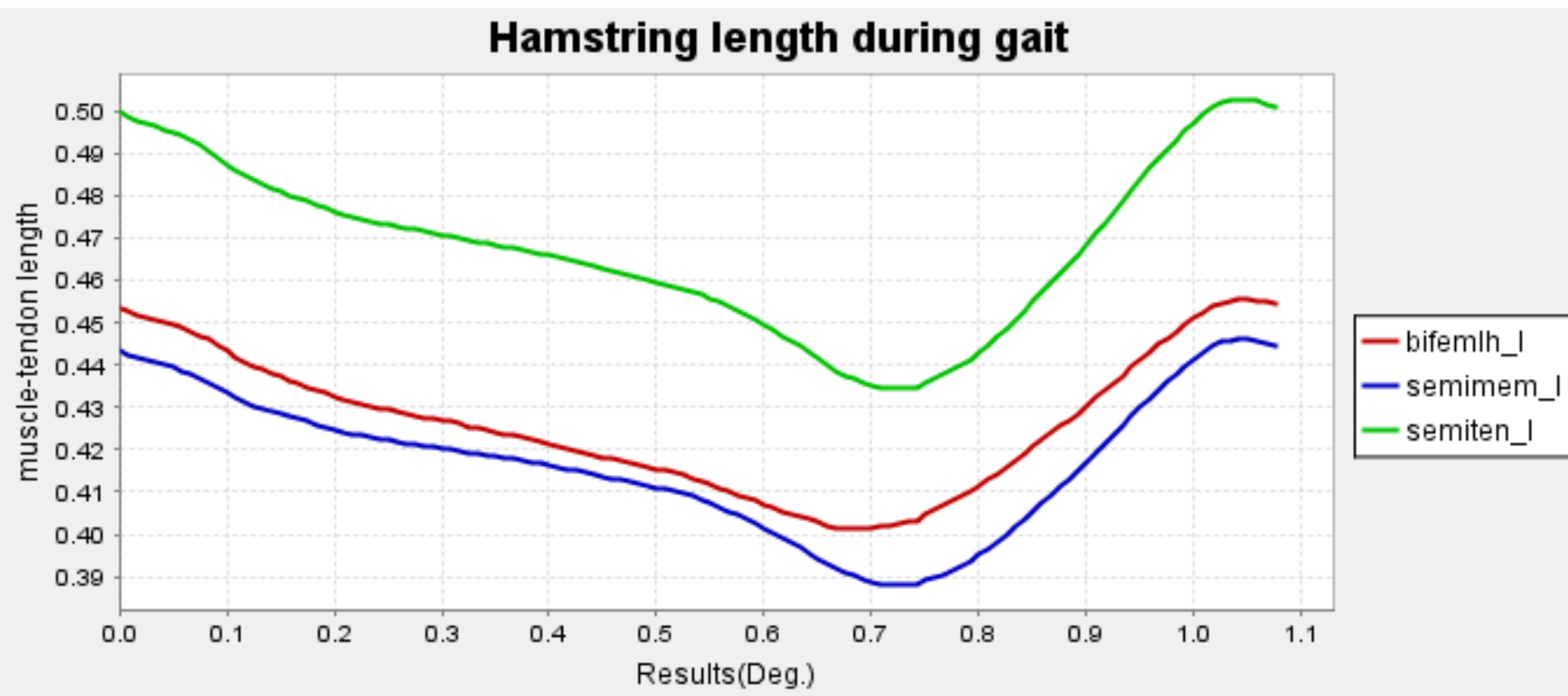


Musculotendon length

- Example: What is the length of the hamstrings during a walking trial?
- Motion (.mot file) can be loaded from HandsOnMaterial>5_Muscle_Analysis folder
- Tools>plot
 - Y-Quantity: muscle-tendon length
 - Muscles: "semimem_l", "semiten_l", "bifemlh_l"
 - X-Quantities: Select "Coordinates(Deg.)"

Musculotendon length

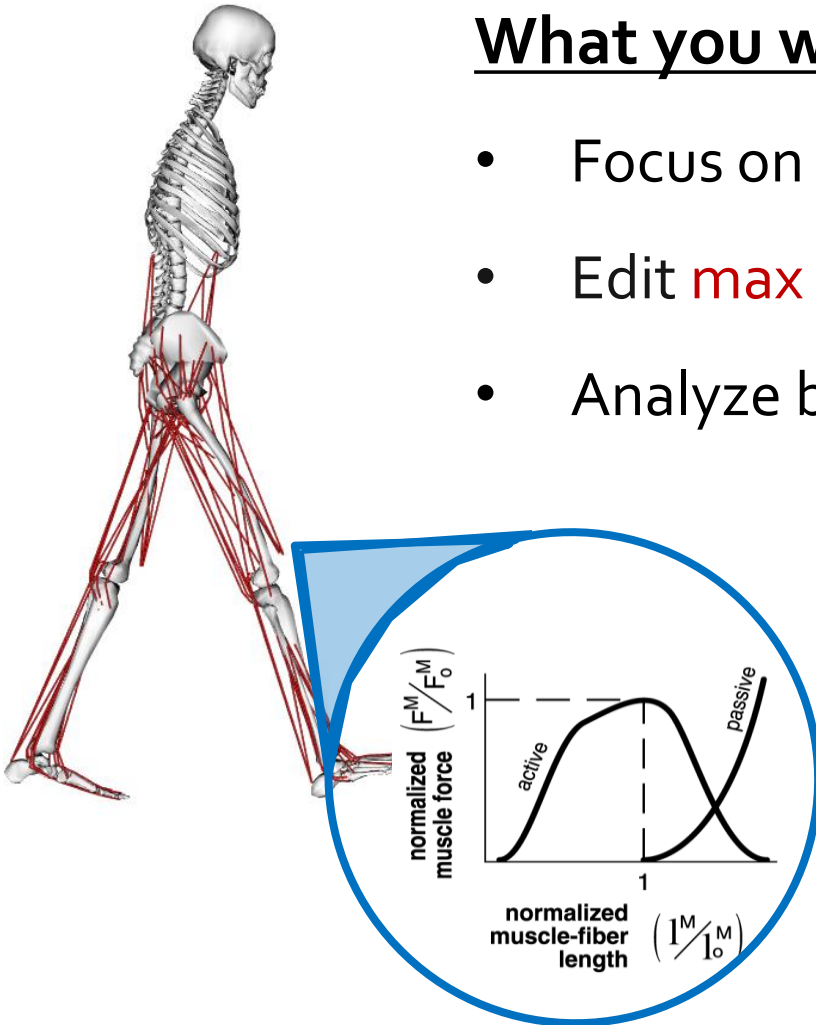
- Example: What is the length of the hamstrings during a walking trial?



Simulating quadriceps weakness after TKR

What you will do:

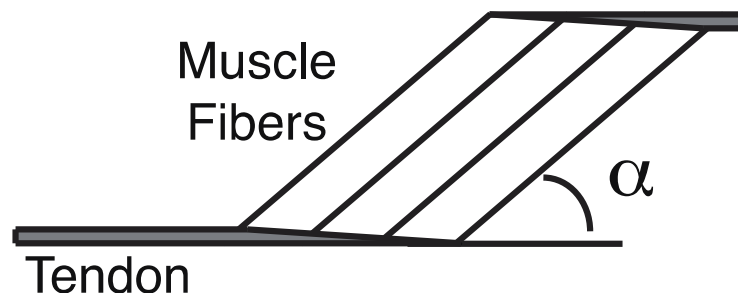
- Focus on **vastii and rectus femoris** of the left leg
- Edit **max isometric force** to simulate weakness
- Analyze biomechanical consequences



How much active moment is lost by the quadriceps after total knee replacement (TKR)?

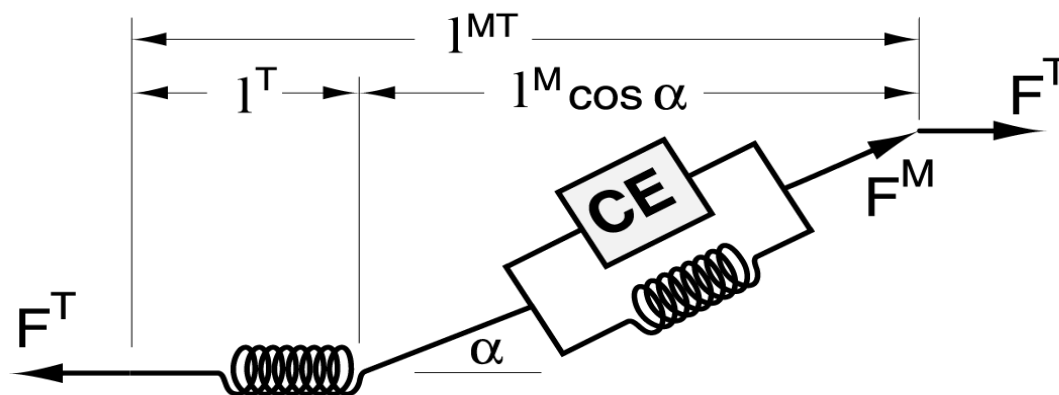
Modeling muscle force in OpenSim

Muscles are modeled as a set of **fibers** attached to **tendon** at **pennation angle α**

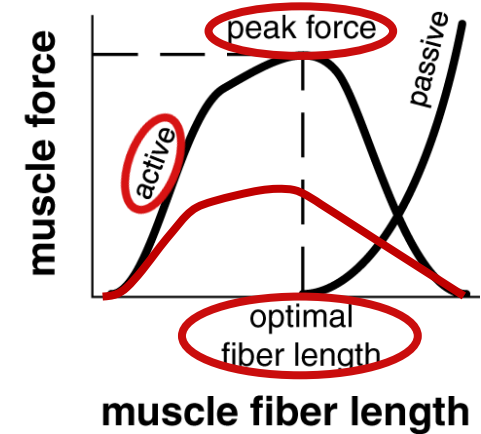
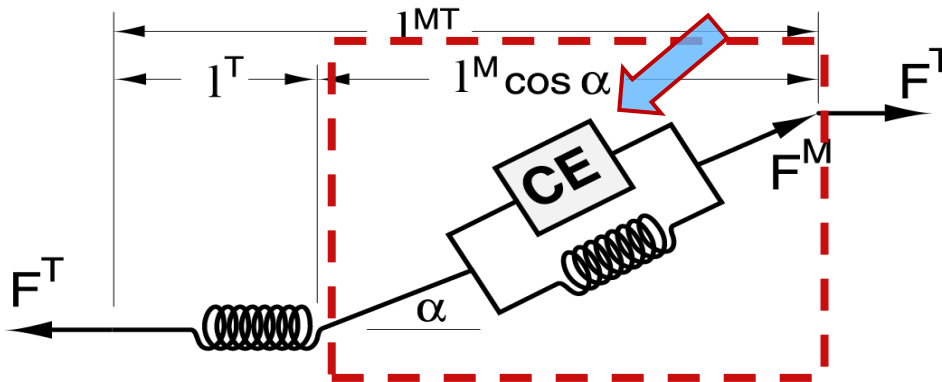


Hill-type muscle model:

Muscle is comprised of a **contractile element** and a **parallel elastic element** in series with an **elastic tendon**



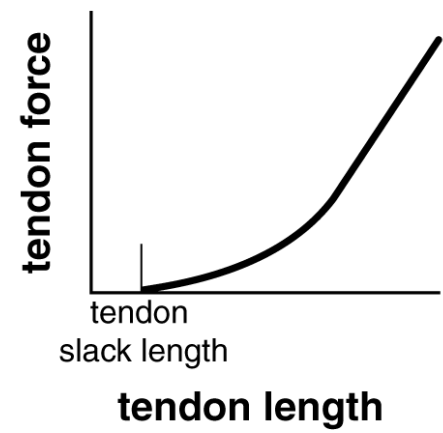
Modeling muscle force in OpenSim



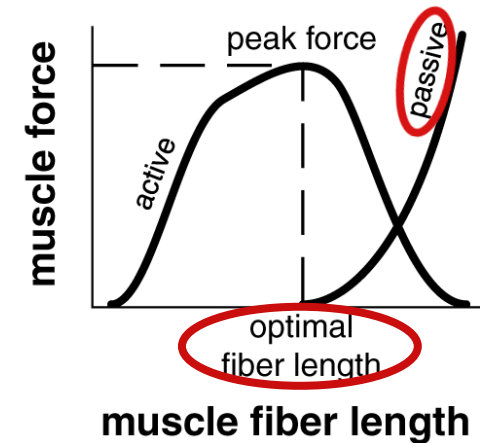
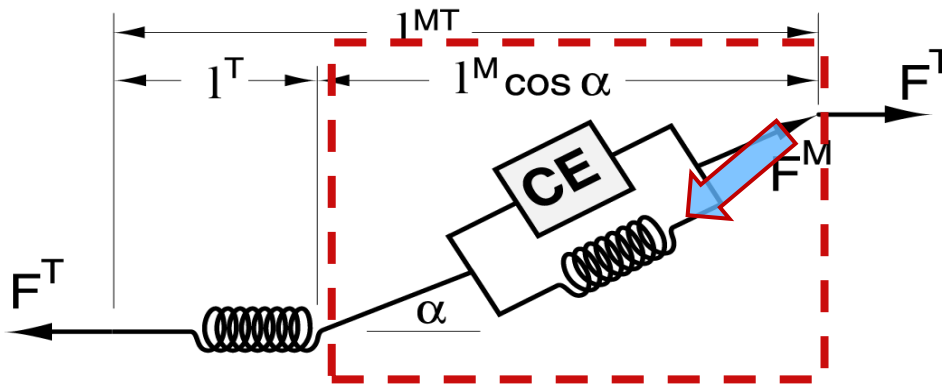
Muscle is a complex actuator:

Produces **active force** up to some **peak** value depending on:

- **fiber length**
- **activation**



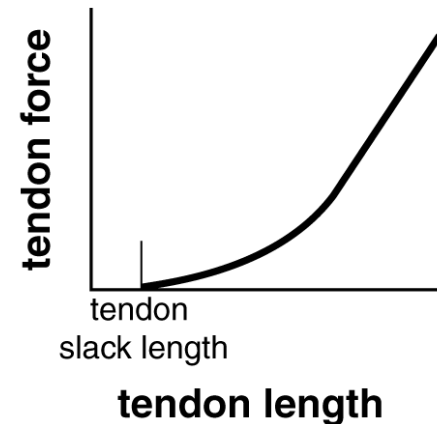
Modeling muscle force in OpenSim



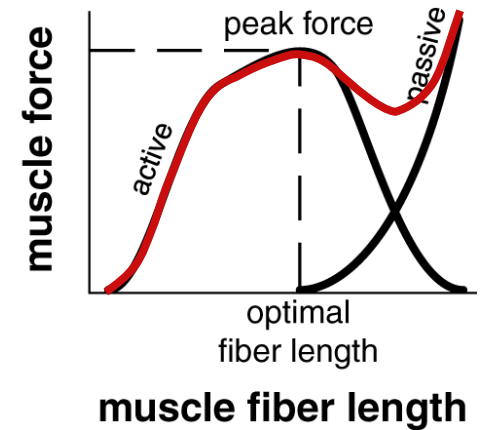
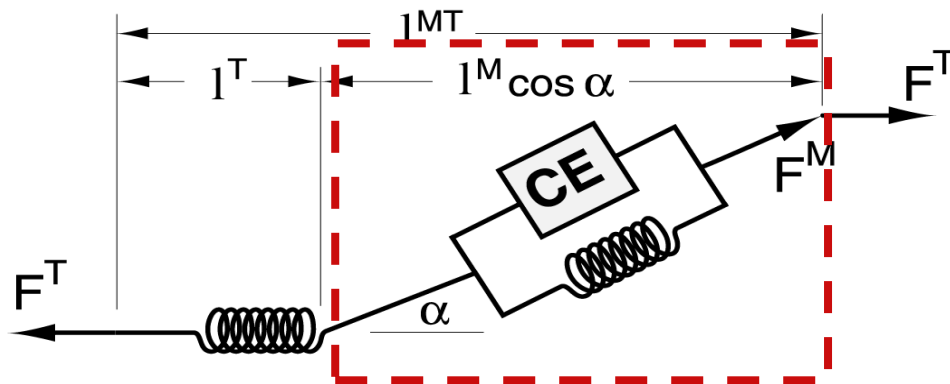
Muscle is a complex actuator:

Produces **passive force** independent of activation depending on

- **fiber length**

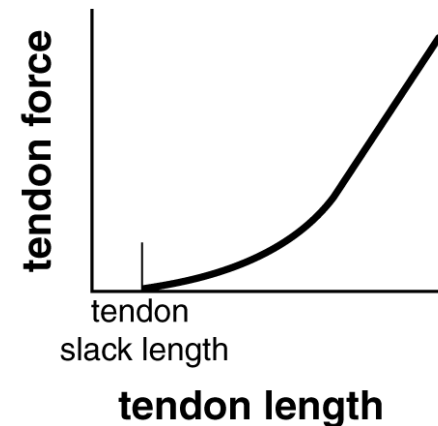


Modeling muscle force in OpenSim

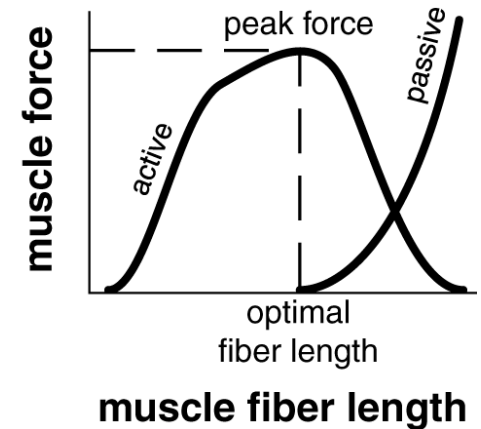
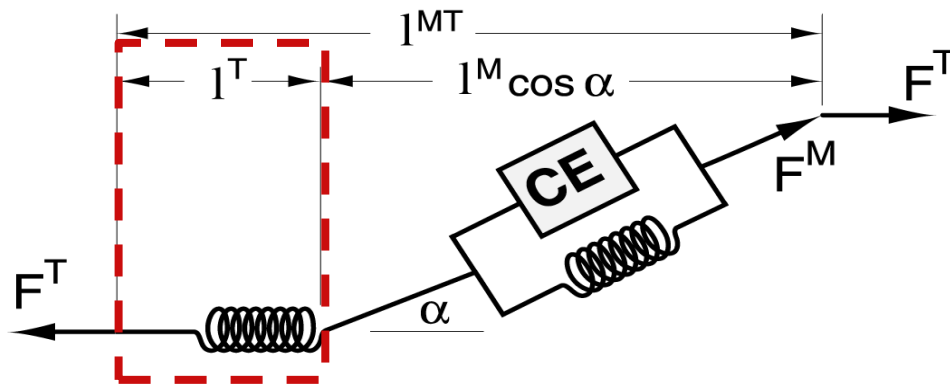


Muscle is a complex actuator:

total force = **active** + **passive** force

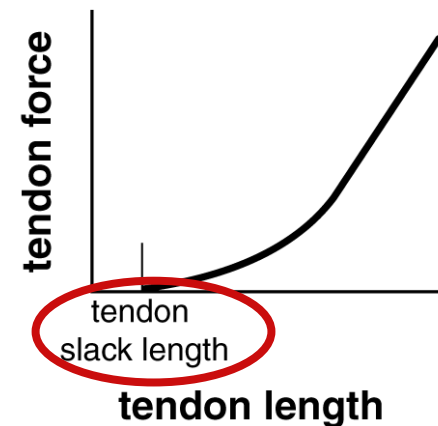


Modeling muscle force in OpenSim



Tendon is a passive element:

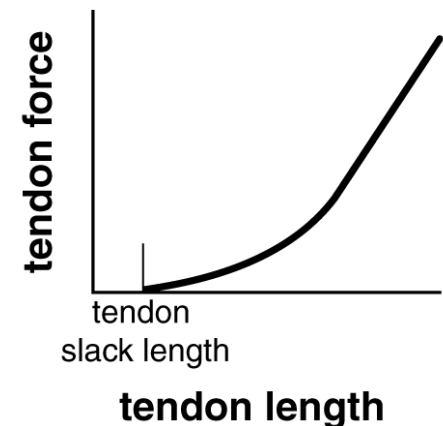
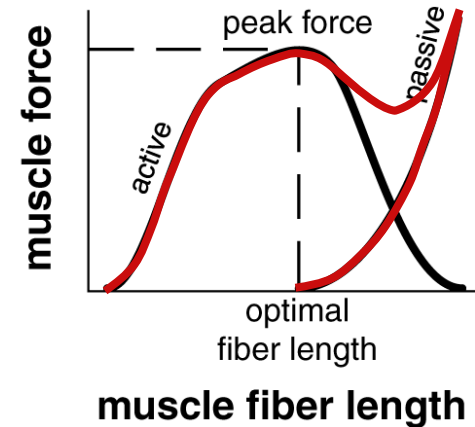
Transmits force when stretched beyond **slack length**



Calculating muscle-generated moments

moment = moment arm * muscle force

- When passive (activation = 0%), a muscle's moment represents **passive resistance** to joint motion
- When maximally activated (activation = 100%), a muscle's moment results from a **maximal effort** isometric contraction



Plotting passive and active moments

With the scaled model loaded:

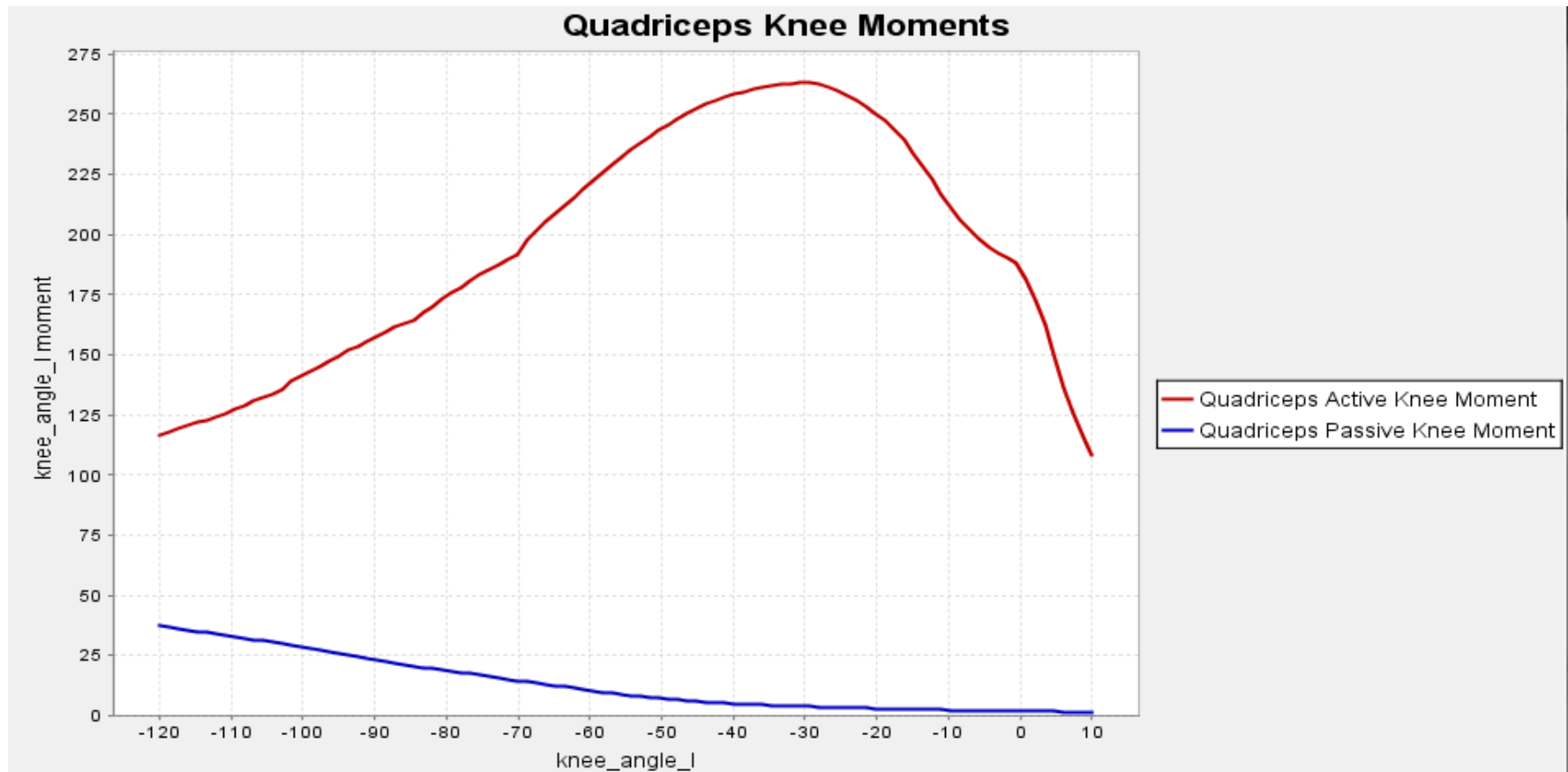
- Plot **quadriceps passive joint moment**
- Plot **quadriceps maximum active joint moment**

Questions:

- *At what knee angle does passive moment begin to rise?*
- *How do magnitudes of the peak passive and active moments compare?*

Plotting passive and active moments

- Using the plotting tool:

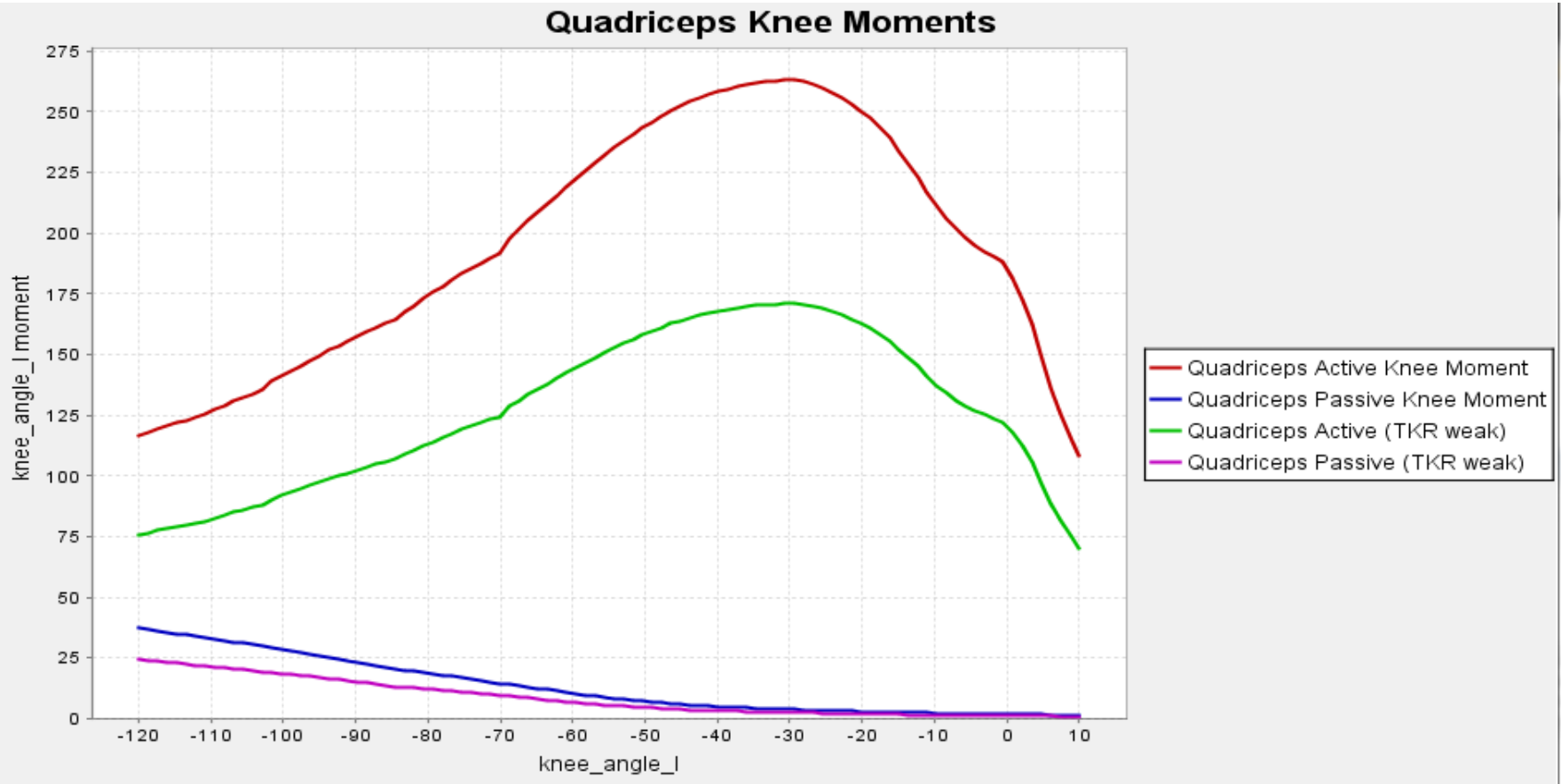


Implementing quadriceps weakness

- Reduce by 35% (Marra et al. J Biomech Eng, 2015) the maximum isometric force of quadriceps muscles on the TKR side (left):
 - rectus femoris: from 1169 N to 760 N
 - vastus intermedius: from 1365 N to 887 N
 - vastus lateralis: from 1871 N to 1216 N
 - vastus medialis: from 1294 N to 841 N
- Example script that reduces muscle strength using the OpenSim API provided
- What is the effect of total knee replacement on the active and passive knee extensor moments?

Plotting passive and active moments

- Plotting on top of previous plot

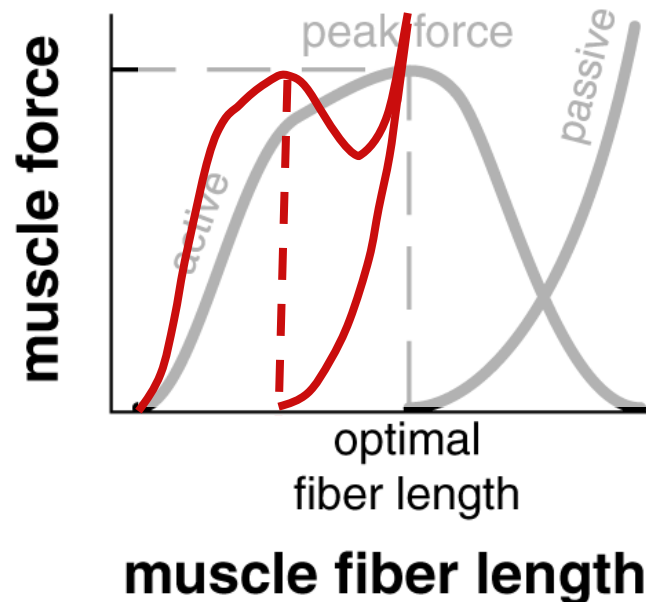


Exploring muscle analysis on your own

- What happens to the passive joint moments if you shorten the optimal fiber length?
- What happens to the passive joint moments if you lengthen the tendon slack length?

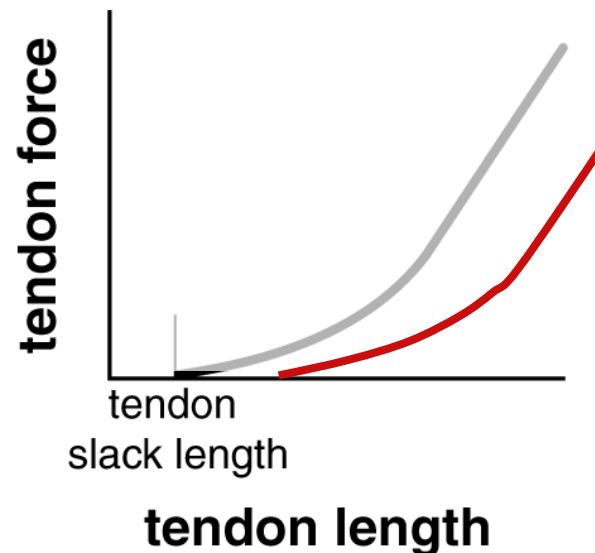
Effects of shortening optimal fiber length

- Joint passive moments will increase due to stretching abnormally short fibers.
- Could be used to simulate muscle contractures, e.g. of medial and lateral gastrocnemius.



Effects of lengthening tendon slack length

- Longer tendon slack length will reduce the passive joint moments by allowing the tendon to stretch more at the same musculotendon length.
- Could be used to simulate tendon lengthening procedures, e.g. at the Achilles tendon.



Additional resources and tutorials

- GCMAS 2015 materials and detailed tutorial using CP data available at <https://simtk-confluence.stanford.edu/display/OpenSim/GCMAS+Tutorial+2015>
- Additional material, including advanced tutorials, are available at <https://simtk-confluence.stanford.edu/display/OpenSim/Examples+and+Tutorials>