BIP OpenSim

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Required Software

- OpenSim (version 4.4 preferable)
- Mokka
- Windows OS (tutorial works for Mac with minor adjustments)

Useful tutorials:

- https://simtk-confluence.stanford.edu:8443/display/OpenSim/Tutorial+1+-+Intro+to+Musculoskeletal+Modeling
- https://simtk-confluence.stanford.edu:8443/display/OpenSim/Workshops+and+Events
- https://simtk-confluence.stanford.edu:8443/display/OpenSim/ESMAC+Workshop+September+2022
- https://simtk-confluence.stanford.edu:8443/display/OpenSim/Overview+of+OpenSim+Workflows#OverviewofOpenSimWorkflows-SimulationPipelines(Workflows)

Useful tools:

- VSCode or other IDE
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Check the cheat_sheet.pdf for detailed information on terminology used throughout

- Bodies
- Actuators
- Probes
- Markers

Day 1

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1. Intro - 3h

1.1Quick examples based on presentations (20 min)

For years, we've been fascinated with measuring muscle and joint loads. But not easy to measure in-vivo.

Paper 1 - Komi 1982

Let's start by simulating running quickly and examining tendon forces. Later, we'll compare our findings with those presented in Komi's paper.

Paper 2 - Loads on the Body

Ever wondered how many loads are placed on the shoulder while lifting a cup? Check out this research paper. Let's simulate a shoulder movement as a quick demonstration.

Paper 3 - Bone Deformities

Explore bone deformities in this research paper. Now, let's proceed with a quick demonstration.

1.2 What is an MSK Skeletal Model? Open your first model (30 min)

- Open the folder "Hello_world_of_simulations"
- Open OpenSim
- Load model
- Let's go through the different components step by step
- Show the different commands and tools
- Preview experimetnal data (markers and grf)

Questions:

- What are the components of a model?
- How can a model be edited? (GUI, text editor, scripting)
- How many bodies does this model have?
- How many muscles does this model have in each leg?
- Max force rec fem?
- How many dof hip and knee joint have?
- How heavy is the tibia segment?
- Load experimetal trc. Why are the markers doing a moon walk?

1.3 Getting to know the files and plotting tool (30 min)

- Open the folder
- Ensure everyone can open .trc, .mot, .xml files (test everyone's software)
- For those who cannot, we will provide assistance during a break

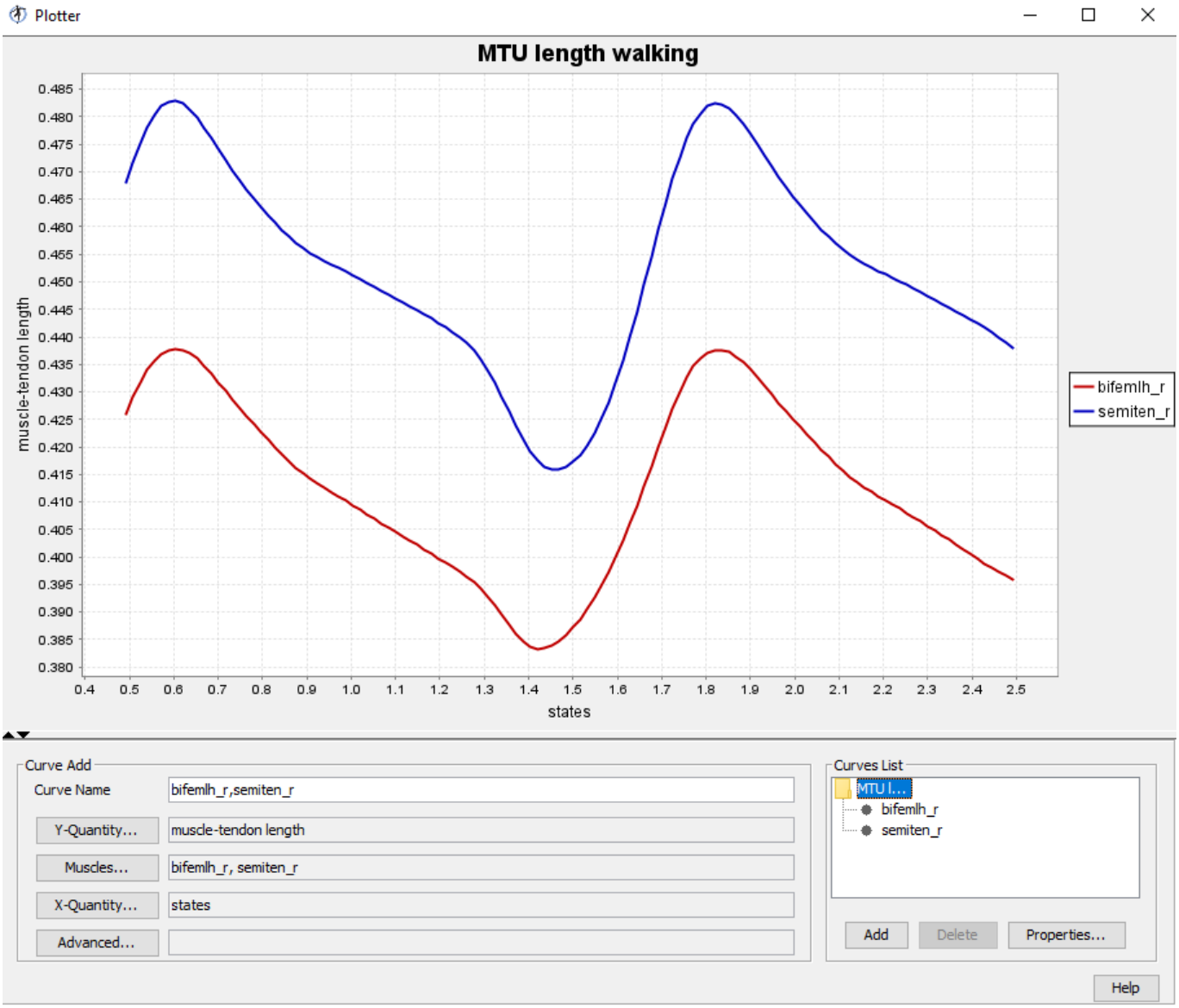
Questions:

- What is the max moment arm of psoas during hip flexion?
- Why are moment arms negative?
- Plot the mtu lenght of the Psoas during hip flexion. Explain the figure.

---------- 10 min Break ----------

1.4 Run all the steps of the simulation Gait2392 (60 min)

- Run scale tool
- Inverse kinematics tool
- Inverse dynamics tool
- Static optimization
- Analyze tool
- Plot simulation results for each step



Questions

- What are the peak hip, knee, and ankle angles?
- what are the peak joint moments?
- What are the RF forces and activation?
- How many body weights does the model output during the JRA for the vertical compontent of hip contact loads?

Summary and questions

Day 2

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2. The importance of scalling and marker registration (3h)

2.0 Add markers to the model

2.1 Scaling, Inverse kinematics (1h)

- Theory https://simtk-confluence.stanford.edu:8443/display/OpenSim/How+Scaling+Works https://simtk-confluence.stanford.edu:8443/display/OpenSim/How+Inverse+Kinematics+Works
- Load the model
- Open the setup file
- Attempt scaling with incorrect settings
- Show how to adjust and apply proper scaling settings
- Scale the same model with two different sets of weights (1000 vs 500 vs 1 for anatomical landmarks)

    1. Load C:\Git\BIP_OpenSim_Hungarian_USports\ExampleData\Sprinting\009\ (make sure model is called Rajagopal_with_deep_hip_muscles)
    2. Change the weights and save new setup file
    3. Run Scale tool
    4. Overlay experimental markers (right click "subject01 -> Motions -> static pose")
    5. Load subject01_Setup_IK.xml and run IK tool
    6. Assess marker errors
    7. Repeat with different weights

  Note: Right click the models to show/hide, change offset,...

2.1.1 Questions

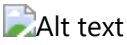
- How do marker weights change scale factors?
- What are, approximately, total, RMS, and maximum marker errors?
- Plot hip, knee, and ankle angles
- What is the peak hip flexion angle during sprinting?
- What is the peak knee flexion angle during sprinting?
- What is the peak ankle plantarflexion angle during sprinting?
- How can you increase the trust on your results?

2.2 Register markers (30 min)

- Create a new model with all the markers set to not "fixed" (Tip: use the replace function in the tex editor)
- Save model
- Load the new model and run scale
- Run inverse kinematics

2.2.1 Questions

- What happened to the marker errors during scalling?
- Compare hip, knee, and ankle angles between the two models.
- Describe what happened to each joint angle.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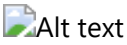
---------- 10 min Break ----------

2.3 Visualize GRF and set up .xml file (10 min)

- Associate motion data "subject01_walk1_grf.mot"
- Check if the force vecotrs are syncronized with motion (if there is a delay or offset, restart opensim)
- run inverse dynamics tool
- plot right and left ankle moments

2.3.1 Questions

- What are the peak plantar flexion moment?
- Why is the left ankle moment so much smaller compared with right?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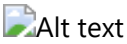
2.4 Apply GRF to correct bodies (30 min)

- Load the setup_ID.xml
- Change the point of application of the forces
- run inverse dynamics tool

2.4.1 Questions

- Compare hip, knee, and ankle moments
- How did moments change during stance?
- How did moments change during swing?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2.5 Residual reduction analysis (45 min)

- Theory about RRA https://simtk-confluence.stanford.edu:8443/display/OpenSim/How+RRA+Works
- Load .\Run_baseline\setup_RRA.xml and run RRATool
- Plot results for pelvis moments from .\Run_baseline\inverse_dynamics.sto

- Plot results for pelvis moments from .\Run_baseline\RRA_Actuation_force.sto

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Note: the presnet residuals are recomendations for walking, during running residuals are expected to be higher.

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2.4.1 Questions

- What changes in the trunk segment properties?
- What changed more hip flexion or trunk extension angles?
- How did the residual moments change after RRA?
- Are the residual moments acceptable?

Day 3

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3. Muscle and joint contact forces (3h)

Theory (15 min)

https://simtk-confluence.stanford.edu:8443/display/OpenSim/How+Static+Optimization+Works

3.1 Calculate muscle forces during sprinting (60 min)

- Load rra adjusted model
- Run SO tool
- Plot muscle forces and muscle activations (bflh_r and gaslat_r)

Questions

- What is the main difference between the actuator.xml files from RRA and SO?
- What are peak force of biceps femoris and soleus muscles?
- How do the muscle activations look?
- What are the errors that show up on the messages window?
- Double the maximum isometric force of all muscles and re-run the simulations. What changed?

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---------- 10 min Break ----------

3.3 Calculate joint reaction loads (30 min)

- Load rra ajudsted model
- Open Analyze tool and run setup_Analyze.xml
- Plot the three components of hip contact force

3.3.1 Questions

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3.4 Explore muscle analysis (45 min)

- plot moment arms (all the hip muscles)
- plot muscle-tendon lengths (all the hip muscles)
- Increase the radius of wrapping surface of Gmax1_r to 0.055 and plot results again
- Do the same for one knee muscle

3.4.1 Questions

- Are there any muscle moment arm dicontinuities?
- What is the hip muscle with longest length during sprinting?
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3.5 Summary

Day 4

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4. Practical examples (3h)

4.1 Bone deformities (45 min)

Protocol described here: https://www.sciencedirect.com/science/article/abs/pii/S0966636223010044

- For each participant follow these steps
- Load torsion model (Bone_deformities\P01\pre\Torsion_model_generic.osim)

- Load scaled model for each participant (Bone_deformities\P01\pre\Static03\Setup_Scale.xml)
- Plot moment arms Glutes and change wrapping surfaces
- Run IK, ID, SO, and JRA for both participants (one trial)
- Plot kinematics, moments, muscle forces (recfem, gmax1, psoas)
- Plot hip contact forces

Questions

- How do subjects differ in kinematics
- How were moments arms affected by the torsion

4.2 Compare muscle forces before and after maximal repeated sprints (45 min)

Protocol described here: https://www.sciencedirect.com/science/article/abs/pii/S1440244021000608

- Load scaled model
- Run IK, ID, RRA, and SO for trial Run_post_fatigue (use the RRA adjusted model)
- Plot muscle forces and muscle activations (bflh_r and gaslat_r)

Questions

- What are peak force of biceps femoris and soleus muscles?

4.3 Simulation and Analysis of a Tendon Transfer Surgery (45 min)

Protocol described here: https://simtk-confluence.stanford.edu:8443/pages/viewpage.action?pageId=92110947

Questions

Day 5

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5. Future directions and questions (3h)

Scripting commands

run a simple setup file from cmd

```
opensim-cmd run-tool \path\to\xmlFile\arm26_Setup_InverseKinematics.xml
```