Simulating the healthy gait patterns in children with bone deformities

The tutorial was created by Basilio Goncalves and Hans Kainz. Results from [1].

I. Objectives

Background

Femoral and tibial torsional deformities are a common cause of pain even in individuals torsion deformities, otherwise healthy [2]. Individuals with idiopathic torsion deformities often present with abnormal gait patters and increased joint contact forces compared to controls [3]. In this project, femur and tibia of one child with idiopathic torsion deformities (femur and tibia) were personalised using a MATLAB based tool [4]. Later, marker trajectories and ground reaction forces during a static and walking trials, from two different children were used to run the simulations.

Purpose

The purpose of this tutorial is use OpenSim to simulate the effects of torsion deformities on muscle and joint contact forces during walking.

II. Explore the folders

- Click the **File** menu and select **Open Model**. Open the mode ".\Bone_deformities\Lernagopal_generic.osim". (alternatively drag and drop the model to OpenSim GUI).
- Explore the different **bodies** of the Model.
- Load the generic model from participant P01 ".\Bone_deformities\P01\session1\Torsion_model_generic.osim"
- **Hide** the markers, and forces from both models.
- Adjust the **offset** of the models and colour the left femur and tibia of Torsion_model_generic.osim with a different colour.

Questions

1. How many bodies does Lernagopal_generic.osim model contain?

2. How many DOF does Lernagopal_generic.osim have at the hip, knee, and ankle?
3. Describe the differences between the left femurs and tibias of both models.

Note: To help look up the terms "neck-shaft angle", "femoral anteversion angle", "tibial torsion".

III. Simulate external biomechanics

- **Close** the model name "Lernagopal_41_OUF_UniVie" in the OpenSim GUI.
- Select the ***Torsion_model_generic.osim***, and use the **Scale Tool** in ".\P01\session1\Static01" to scale the model.
- Use the **Scale Tool** to scale the model.
- Run **Inverse Kinematics** and **Inverse dynamics** for the dynamic trial.
- **Plot** the following moment arms of the **left hip muscles**:
    - hip_flexion_l moment arms -> "**hip_ext_l**" ->over hip_flexion_l
    - hip_add_l moment arms -> "**hip_abd_l**" ->over hip_add_l
    - hip_rotation_l moment arms -> "**hip_abd_l**" ->over hip_rotation_l
- Run all the previous steps for participant TD01

Note: check the set-up files including paths and time ranges for each of the trials.

Questions

4. What are the main differences in the static pose between the two participants?
5. How did you solve the scaling issue in participant TD1?
6. What are the average maximum IK errors for both trials?
7. How were the residual moments in the two participants?
8. Were joint moments similar between participants?
9. Are there any moment arm discontinuities in the two models that are relevant during the walking trials? Which muscle segments?

IV. Adjust the model and simulate muscle and joint contact forces

- Find the muscle segments with **non-physiological moment arms** and follow the steps:
    - Click the **body** that the muscle in attached to.
    - Click the **wrapping** surfaces in that body that are relative
    - **Reduce their radius** and plot moment arms again
    - Reiterate until no discontinuities
    - Save the model.

Note: do the same for all muscles with discontinuities.

- Run **Static Optimization** and plot residual moments.
- Run **Joint reaction analysis** (present the results in the **child** frame)
- Run **BodyKinematics** (use the analyse tool to run the setup file).

- **Plot** results:
    - Muscle activations, and muscle forces for the following muscles:
        - **vastus medialis**
        - **rectus femoris**
        - **gastrocnemius medialis**
        - **gluteus maximus**
        - Resultant hip and knee **joint contact loads:** $Resultant = \sqrt{x^2 \ \times y^2 + z^2}$

Note: Make sure the stating and end time of all the plots are similar.

Questions

1. Do the reserve moments differ between P01 and TD01?
2. How do the muscle activations compare with the measured electromyography signals?
3. What muscle produced the largest peak muscle forces at baseline? And after fatigue?
4. Did the healthy gait pattern reduce hip and knee loads in this participant?

VI. References

[1] B. Goncalves *et al.*, *Gait Posture*, 106, S68, (2023)

[2] C. Radler *et al.*, *Gait Posture*, 32, 3, 405–410, (2010)

[3] E. Passmore *et al.*, *Gait Posture*, 63, October 2017, 228–235, (2018)

[4] K. Veerkamp *et al.*, *J. Biomech.*, 125, 110589, (2021)