Simulation Analysis: Estimating Joint Loads

OpenSim Workshop
Investigating a Simulation:

- Controls
- EMGs
- Forces
- Moments
- Accelerations
- Velocities, Angles
- Simulated Movement

OpenSim Model

Analysis

- Fiber/Tendon Lengths
- Moment Arms
- Body Kinematics
- Joint Reactions

OpenSim Workshop
The Analyze Tool:

- Controls
- Simulation States
- Model
- Analysis
- Results
Example: Quantifying Joint Loads

- Design Biomedical Devices
  - Argenson et al, J. Biomech 2005

- Predict Tissue Stress
  - Besier et al, MED. SCI. SP & EXERCISE, 2006

- Study degradation
  - USC2000, 2009,
    http://www.flickr.com/photos/usc2000/3189533413/
Joint Reaction Analysis

Joint reaction forces and moments
- satisfy joint constraints
- represent internal loads carried by the joint structure
- result from all loads acting on the model

Prevent movements that cannot be produced

Available from the Analyze Tool
$F_{\text{external}}$

$F_{\text{muscle}}$

$M_{\text{ig}}$

$M_{\text{i} a \text{i}}$

$R_{\text{i} i}$

$R_{\text{i} i+1}$
Cut apart the joint

What loads are transferred across the joint interface?

Joint loads constrain the tibia to move on the ellipse.
Estimating Joint Loads

Know

- Model
- Joint Kinematics
- External Loads
- Muscle Forces

Fit to measurements

Estimate

Calculate

- Joint Reaction Forces and Moments
Static Optimization

Input
- Model
- Joint Kinematics
- External Loads

Output
- Muscle Forces
- Muscle Activations

Complete dynamic description
Joint Reaction analysis calculates joint loads in a post processing step.

This step traverses all joints in the musculoskeletal model.
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Calculation of the joint reaction forces on $S_i$
\[
\sum F_{\text{external}} + \sum F_{\text{muscles}} + R_{i+1} + R_i = M_i \ddot{a}_i
\]
\[ R_i = M_i a_i - \left( \sum F_{\text{external}} + \sum F_{\text{muscles}} + R_{i+1} \right) \]
Joint Reaction Analysis: Setting It Up

Inputs from Static Optimization

Model
Kinematics
External Loads data
Residual Actuators

Inputs specific to JointReaction

Muscle force data
Joints of interest
Bodies of interest
Coordinate reference frames

Output

*_JointReaction_ReactionLoads.sto*