Evaluating a Musculoskeletal Model

Getting Started: Defining your Research Goals for the Model

- What results do I need to answer my research question?
- What elements of a model might these results be sensitive to?
- In what ranges will my study be conducted and in what ranges has the model been validated? If a model is not valid in the ranges of your study, how can you extend those ranges and re-validate the model?

Sample Responses - Defining your Research Goals for the Model

General Questions

- What structures or systems are modeled?
- Is it a kinematic model or full dynamic model? Is it 3D?
- Is it a model of a new structure or structures? Does it build on an existing model? What models can it be compared to?
- What experimental data was used to build and test the model? If human or animal subjects were used, how many and what type of subjects (age, size, etc.)?
- What platform(s) is the model implemented in?
- Can the model be scaled or otherwise customized?
- Has the model been published or otherwise peer reviewed?
- Do other studies use/cite the model?
- Has the author of the model changed or updated the model since the original publication? Do I have and understand the most recent version?

Kinematic Models

Musculoskeletal Geometry

- Bone Geometry
    - What bony segments are included in the model?
    - What experimental or literature data was used to define bone geometry?
- Joint Geometry
    - How many joints and how many degrees of freedom?
    - How are the joints modeled? Types? Joint axis definitions? Coordinates? Neutral positions?
    - Is there coupling of joint motions?
    - What is the joint range of motion? Are there other limits or other constraints?
    - What experimental or literature data was used to define the joint geometry?
- Muscle Geometry
    - How many muscles are included in the model?
    - How are muscle attachment points defined?
    - Are broad muscles represented by multiple segments?
    - Does the model have wrapping surfaces or via points? What features do they represent?
    - What experimental or literature data was used to define the muscle geometry?
- Other Structures
    - Does the model include ligaments?
    - Does the model include prosthetics, orthotics, or other devices?

Dynamic Models

Inertial Properties

- Does the model include segment inertial parameters?
- What experimental or literature data was used to define the intertial parameters?
- Are there segments without intertial parameters? (This is a challenge for creating forward simulations with the model.)

Actuators and Other Force-Generating Elements

- Does the model include muscle actuators?
    - What type of model is used for muscle-tendon force generation?
    - How is muscle architecture modeled? What parameters define muscle architecture?
    - How is activation-contraction dynamics of muscles modeled? What parameters define?
    - Was there any fine-tuning/adjustment of muscle model parameters?
- Does the model have any other actuators (e.g. powered prosthetics, reserve actuators at the joints)?
- Does the model have any other passive force-generating elements (e.g. damping at joint extremes)?

Controllers and Sensors

- Does the model have any custom controllers?
- Does the model have any custom sensors?

Contact

- Is a model of foot/floor contact included?
- Does the model include any other representations of of contact with external objects?

Model Testing

- Were model moment arms compared to experimental data?
- Were maximum active joint moments compared to experimental data?
- Were passive joint moments compared to experimental data?
- Was a sensitivity analysis performed for any of the parameters of the model?
- Has the model been used to generate simulations?
    - How much time is required to generate simulations of standard motions (e.g. walking, reaching)?
    - How do the results compare to previously published data?
    - For example, if a lower extremity model, does the model accurately predict knee forces from the grand challenge data set (https://simtk.org/home/kneeloads)?

More Help

- The webinar “Musculoskeletal Models Deconstructed” provides some specific examples of how to evaluate and develop a model (watch | view slides).