Finite Element Models of the Knee & Hip Joints: Using OpenSim to Predict Muscle Forces

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Objectives

- To develop finite element computer models of the knee/hip joints to predict stresses and strains within cartilage.
- To find accurate muscle forces in the lower body during gait using OpenSim.

Why this Research?

- Among US adults, nearly 27 million have clinical osteoarthritis.
- Medical community has little quantitative data on stresses and strains within joint cartilage, which will help us better understand osteoarthritis.

OpenSim Description

- Open-source software program.
- Musculoskeletal model of the human body.
- Models human motion and can predict muscle forces during simple motions such as the walking/running cycle.
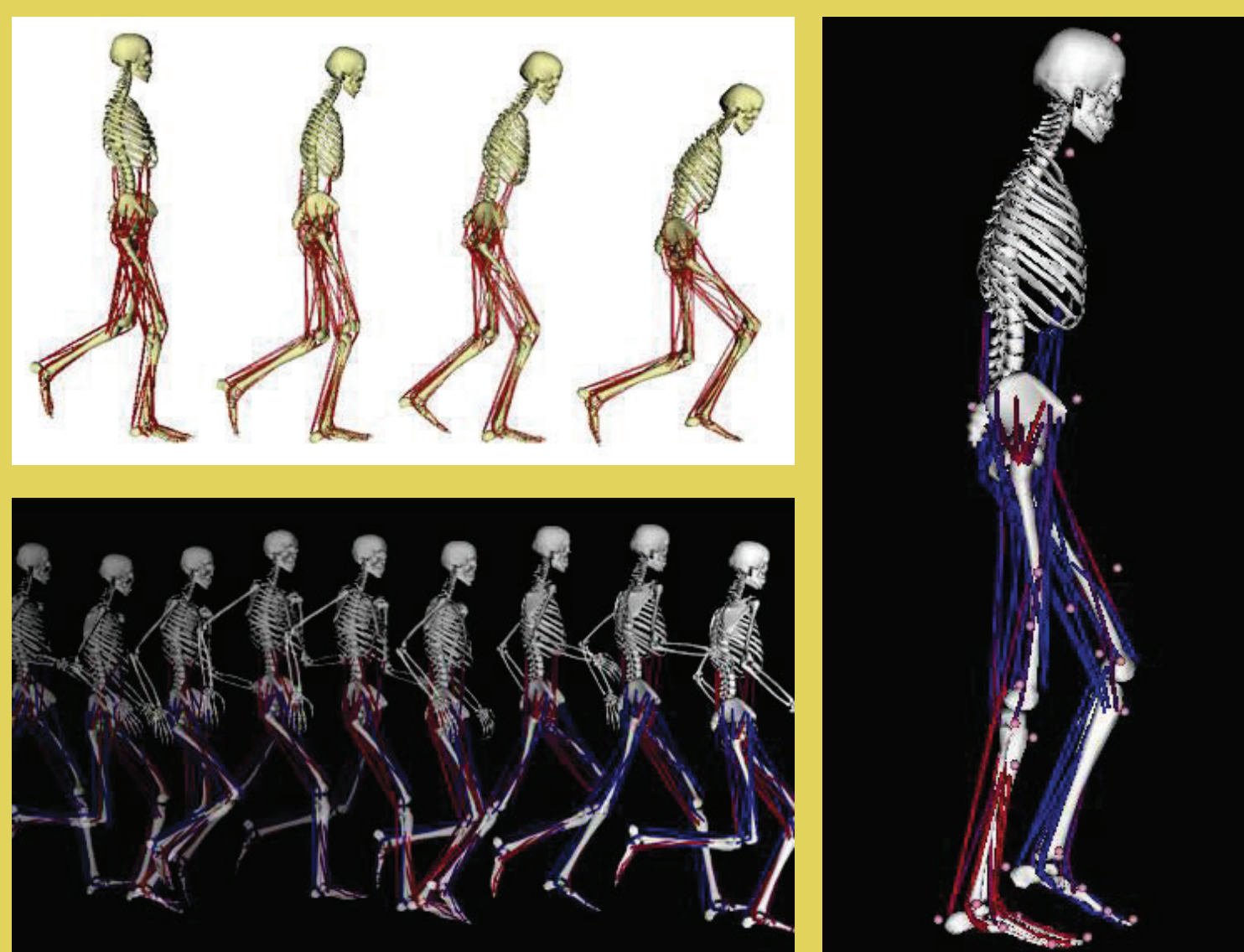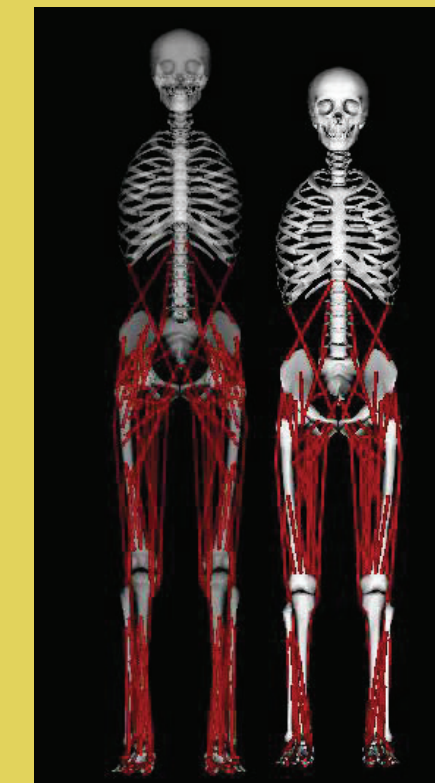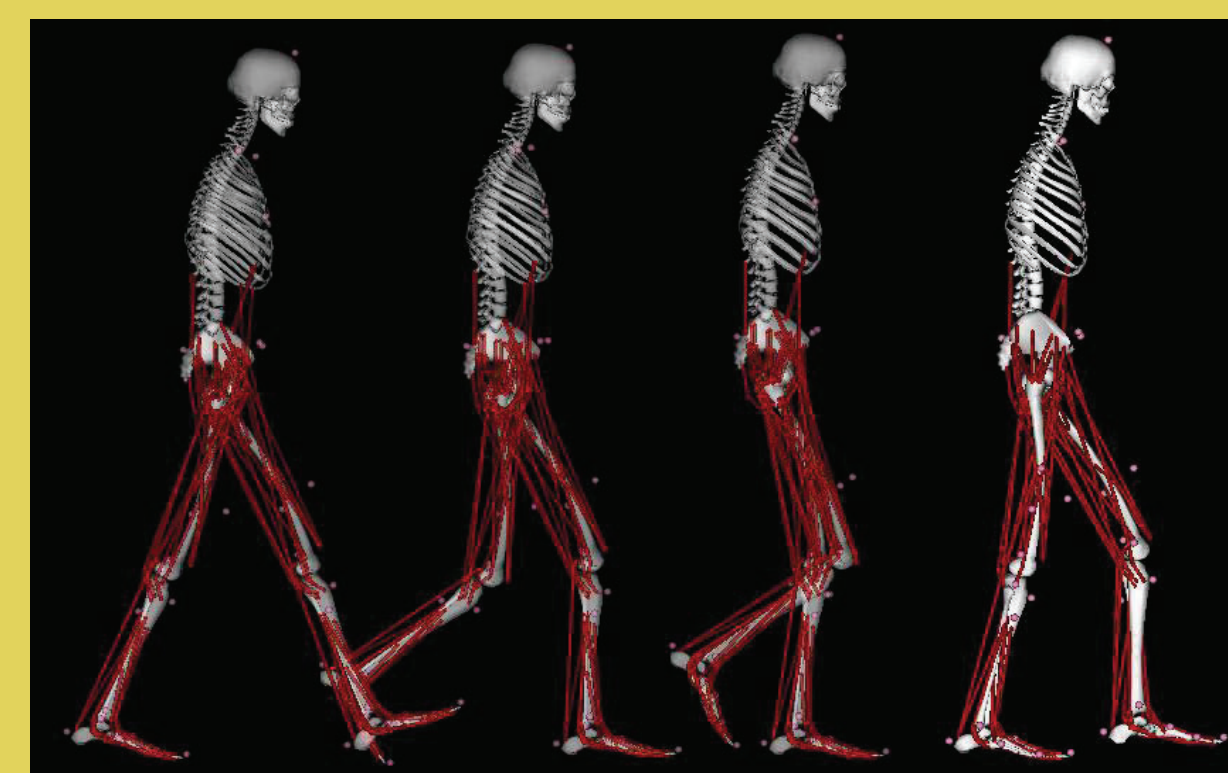

References:

[1] Kim, Hyung J, et al. "Evaluation of Predicted Knee-Joint Muscle Forces during Gait Using an Instrumented Knee Implant." *J Orthop Res* 27 (2009): 1326-1331.

Methods:

1. **Scale the Model:**
   The default model is scaled to match the subject of interest by using kinematic marker data.
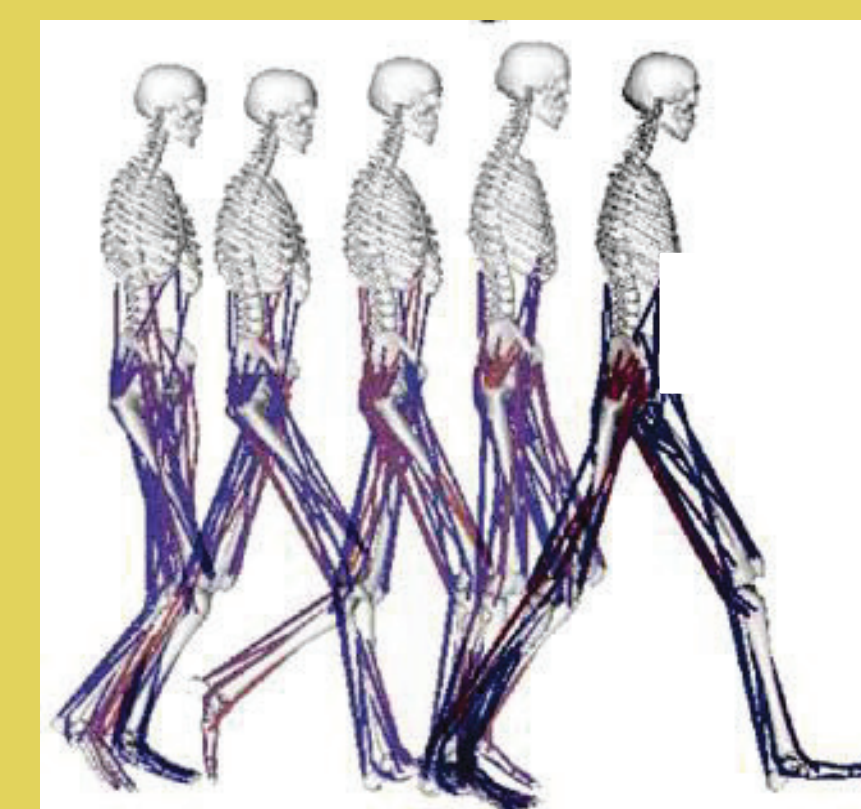

2. **Put the Model in Motion:**

   The subject-specific model is put in motion by tracking the kinematic marker data.

3. **Estimate Muscle Forces:**

   Muscle forces are estimated by calculating the combination of muscle activations that produce the walking motion from step 2 with minimal effort.
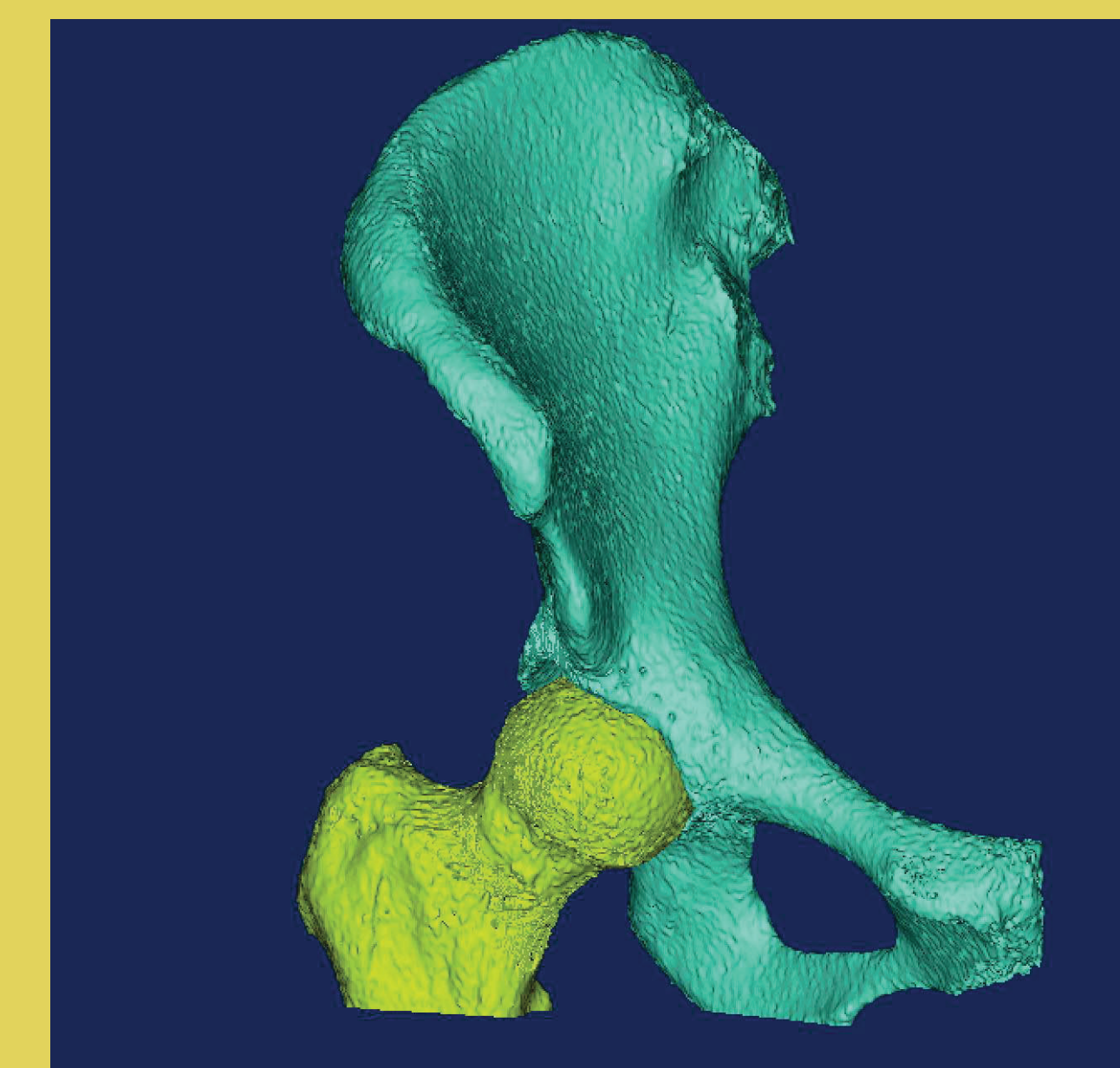
4. **Calculate Joint Contact Forces & Moments:**
   3D statics problem is solved to find resultant forces and moments at each joint using muscle forces as inputs.
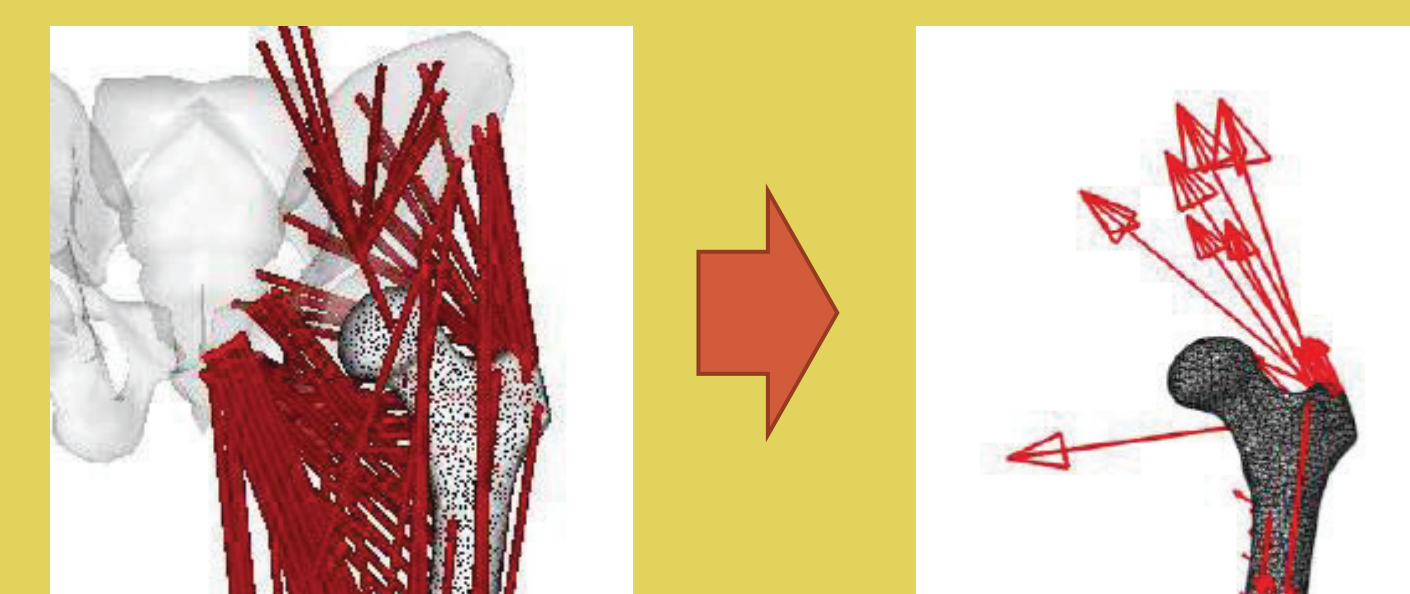
Computer Models

The below solid models must be meshed to create finite element models:

(above) Solid computer model of the knee joint. **(below)** Solid model of the hip joint from a CT (or CAT) scan.

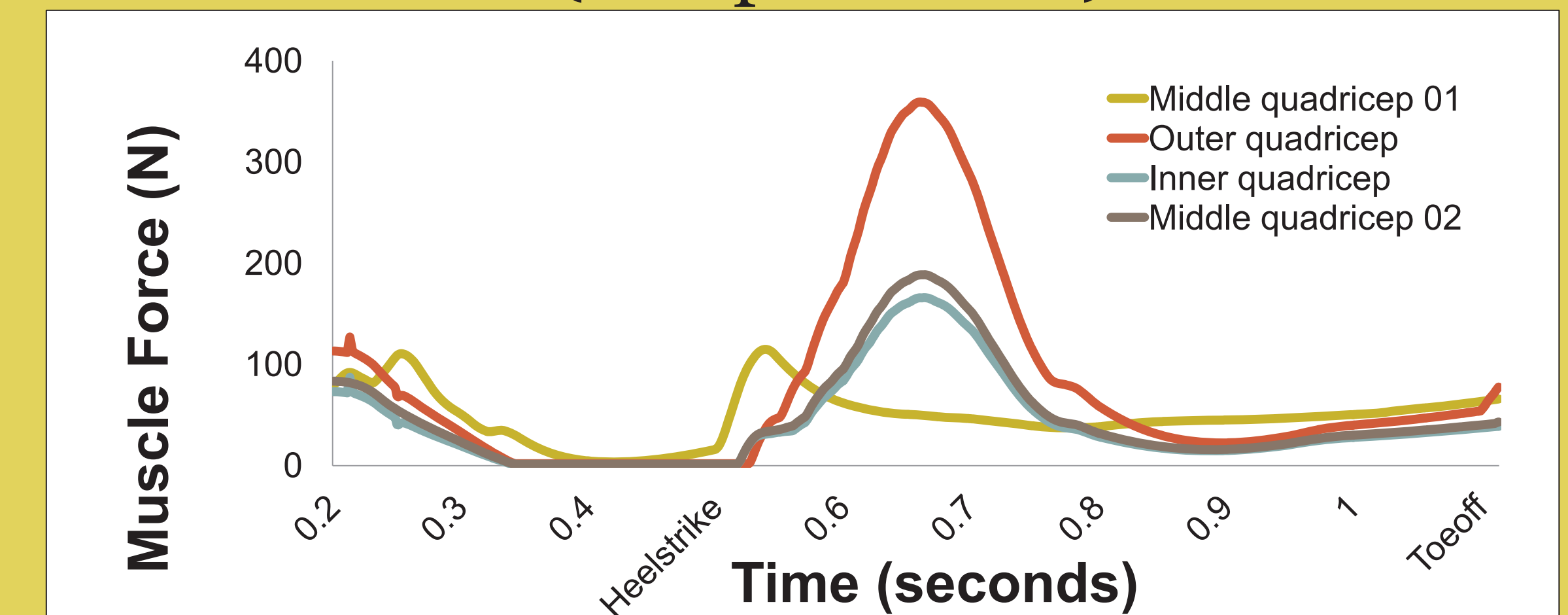### Muscle Forces as Inputs to Finite Element Models
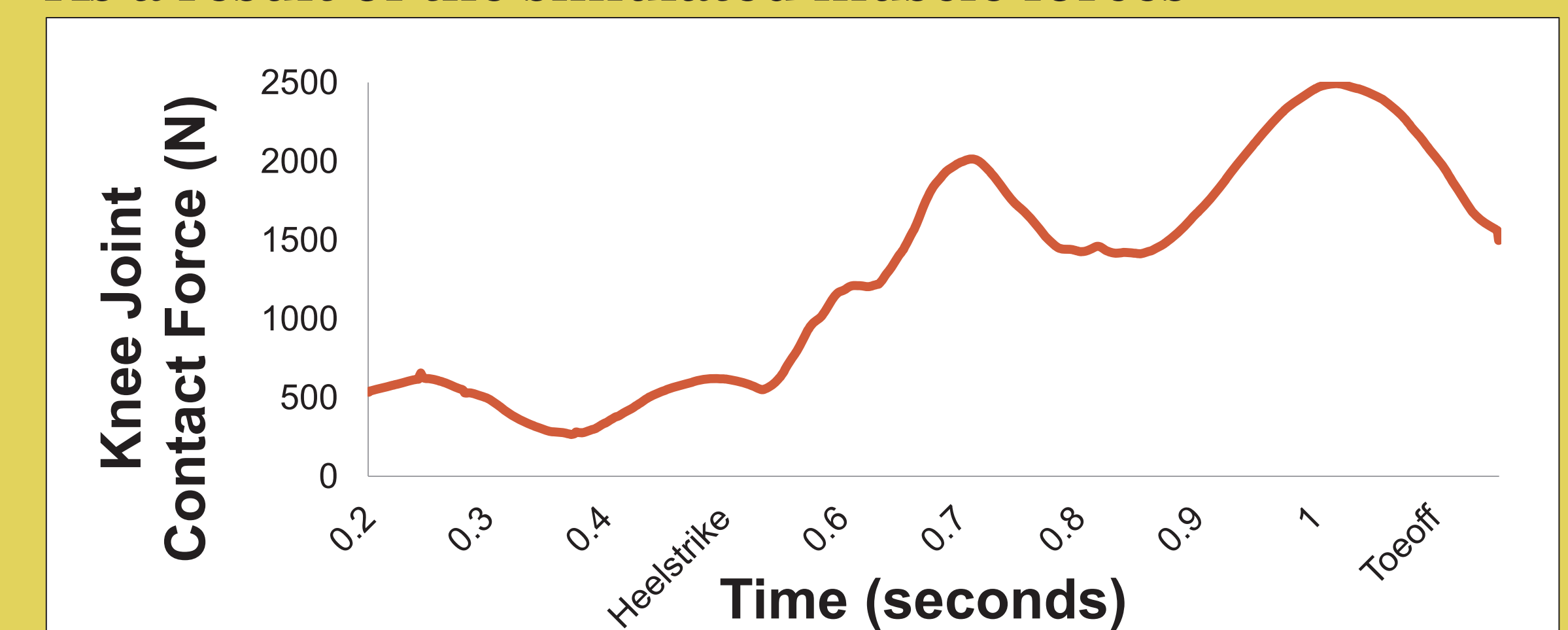

Muscle forces applied as external forces

Results

Results represent one step of the walking cycle.
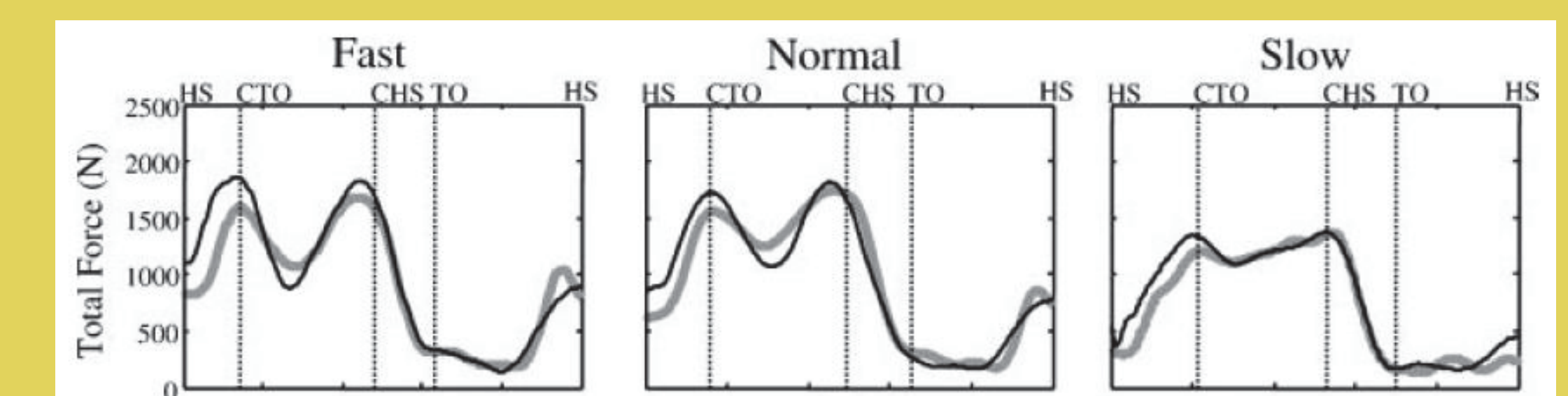
- **Muscle Forces (Sample results)**

- **Knee Joint Contact Force (JCF)**
  As a result of the simulated muscle forces

- Our modeled JCFs are consistent with the JCFs seen in other studies[1]:

  Grey line = Instrumented knee at 3 different speeds.
  Black line = Results from Kim, et al. study

Conclusion

Calculated knee JCFs are only slightly above JCFs from instrumented knees, thus allowing us to use the muscle force results as inputs to our finite element model.