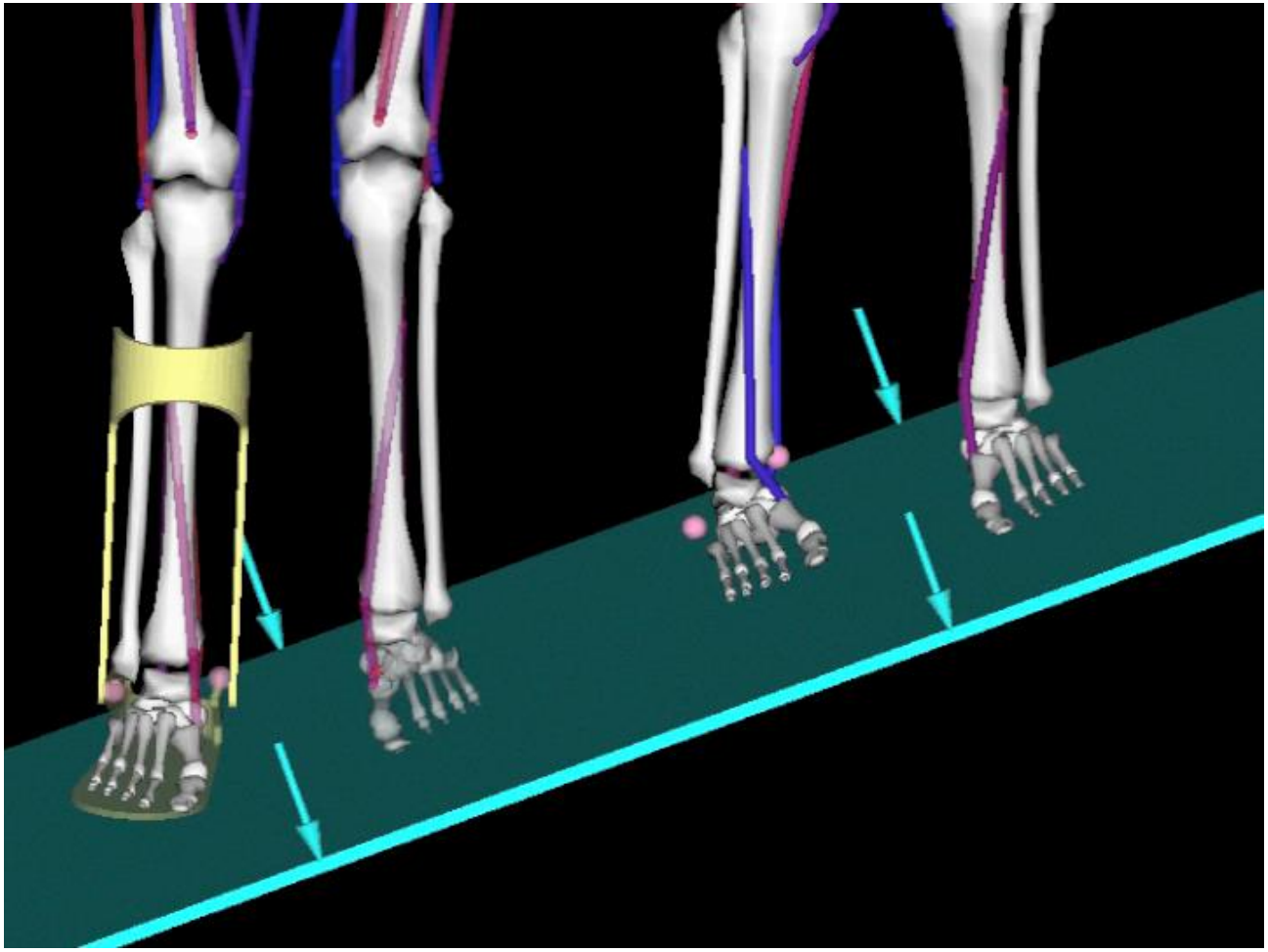
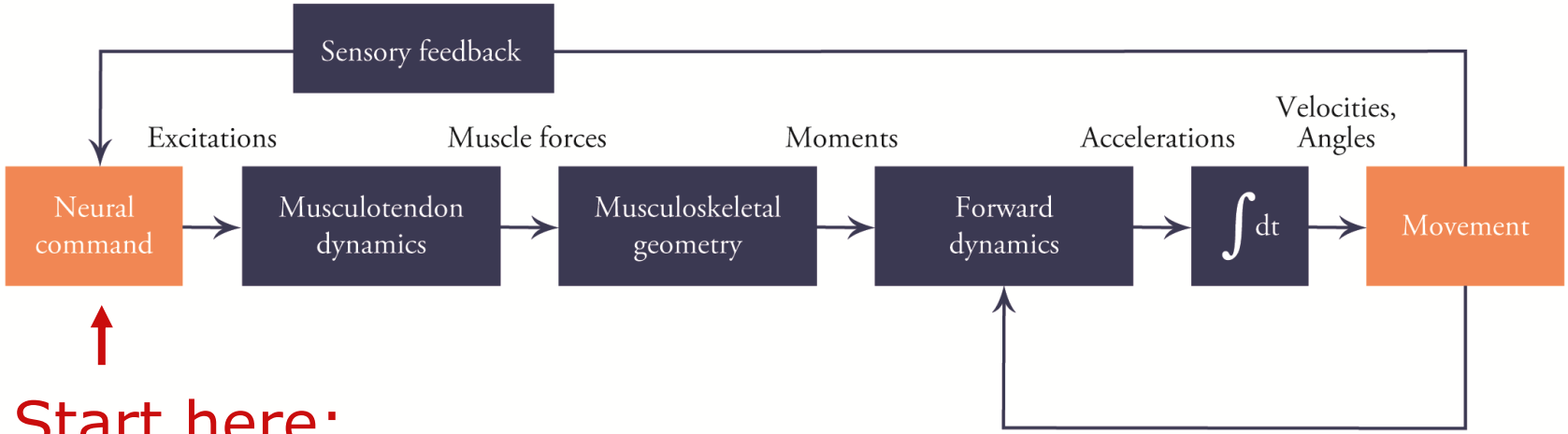


Simulation-Based Design to Prevent Ankle Injuries

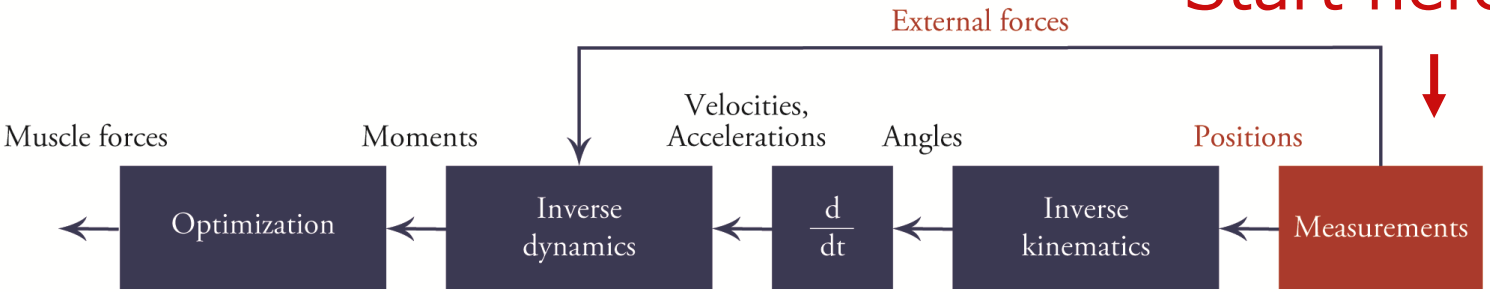
BIOE/ME 485: Modeling and Simulation of Human Movement

Forward *vs* Inverse Dynamics

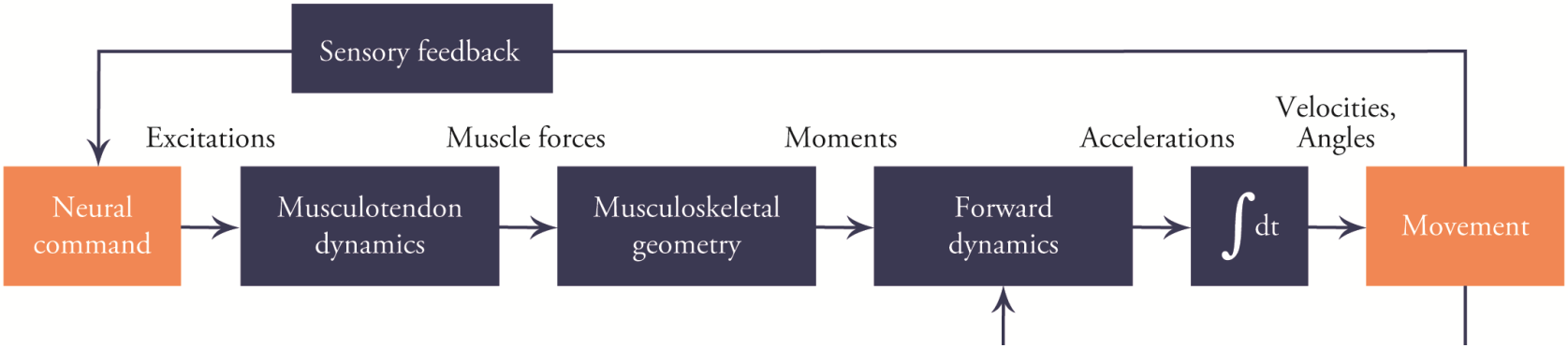


Start here:
Measure or Estimate

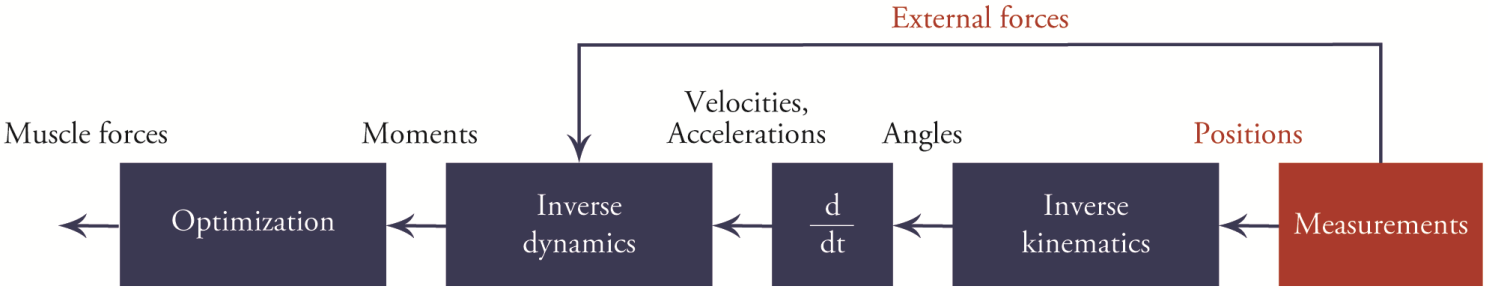
Start here:



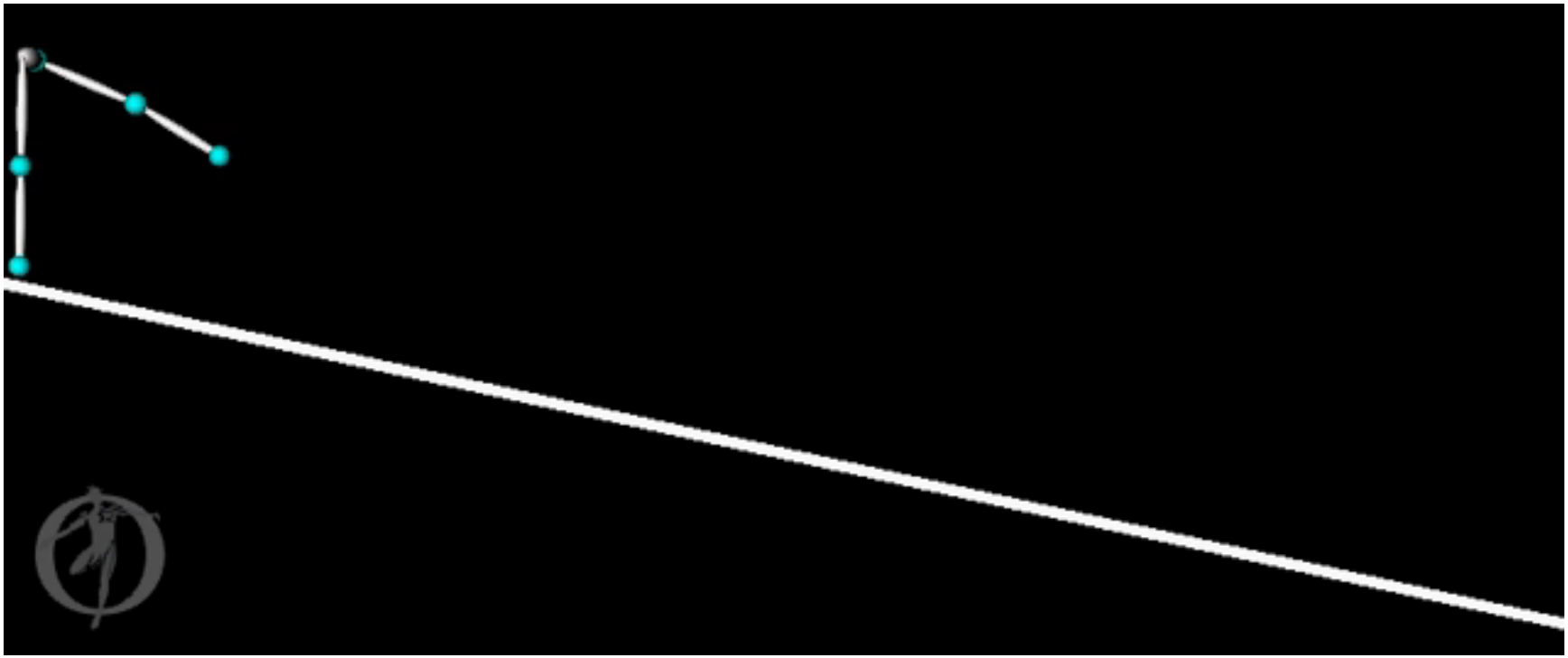
Forward *vs* Inverse Dynamics



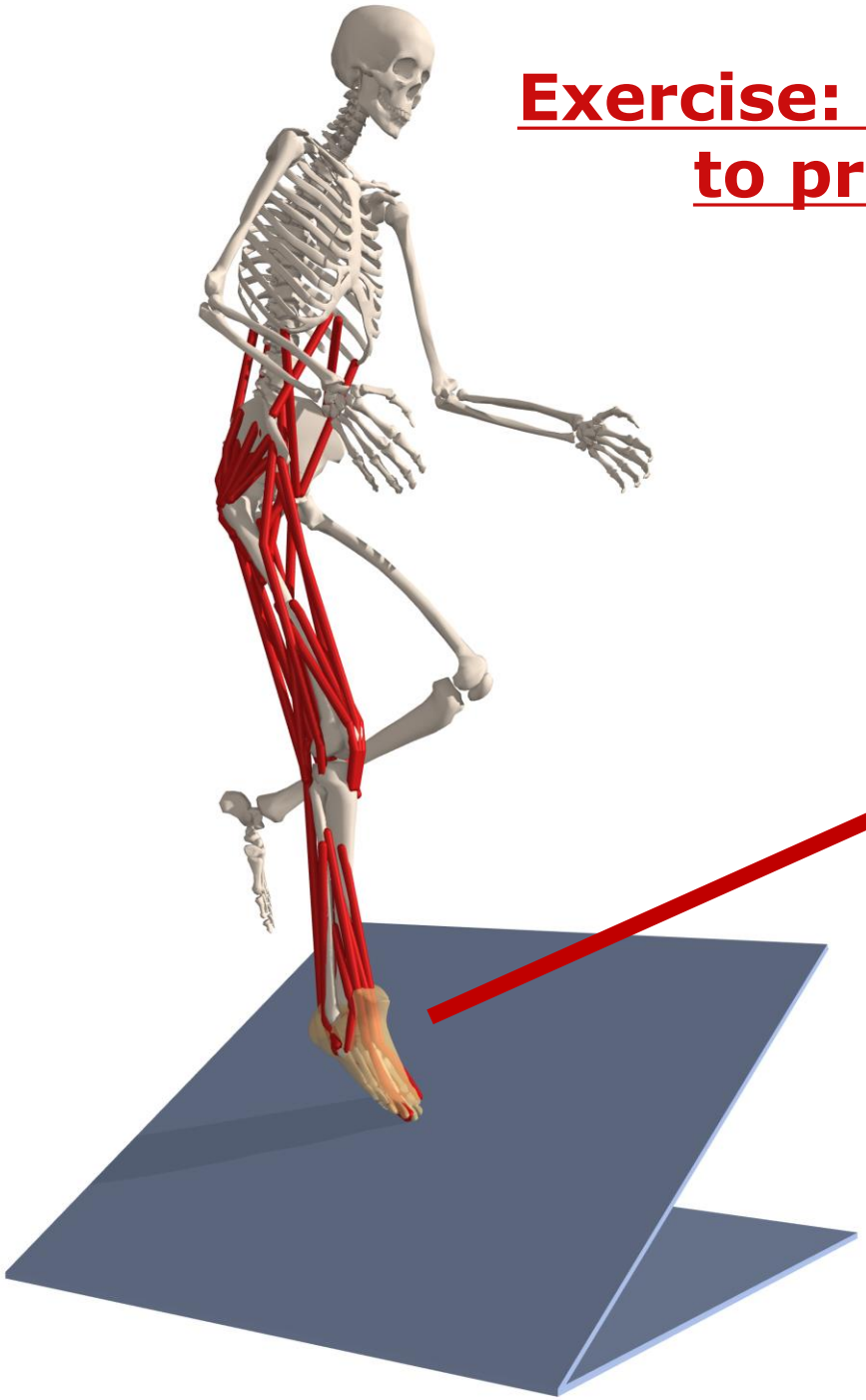
What are some examples where a Forward Dynamics approach might be a more appropriate tool than Inverse Dynamics for movement analysis?

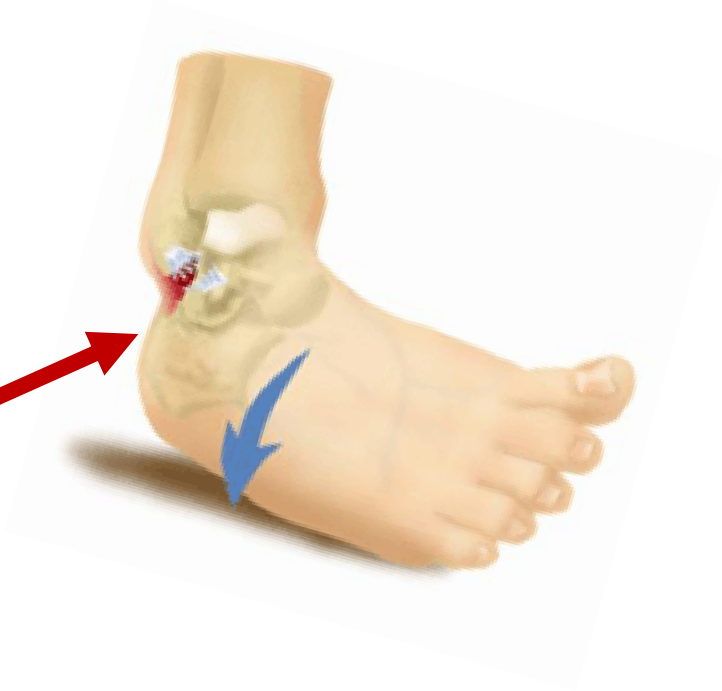


Forward Simulations: Passive Dynamic Walker



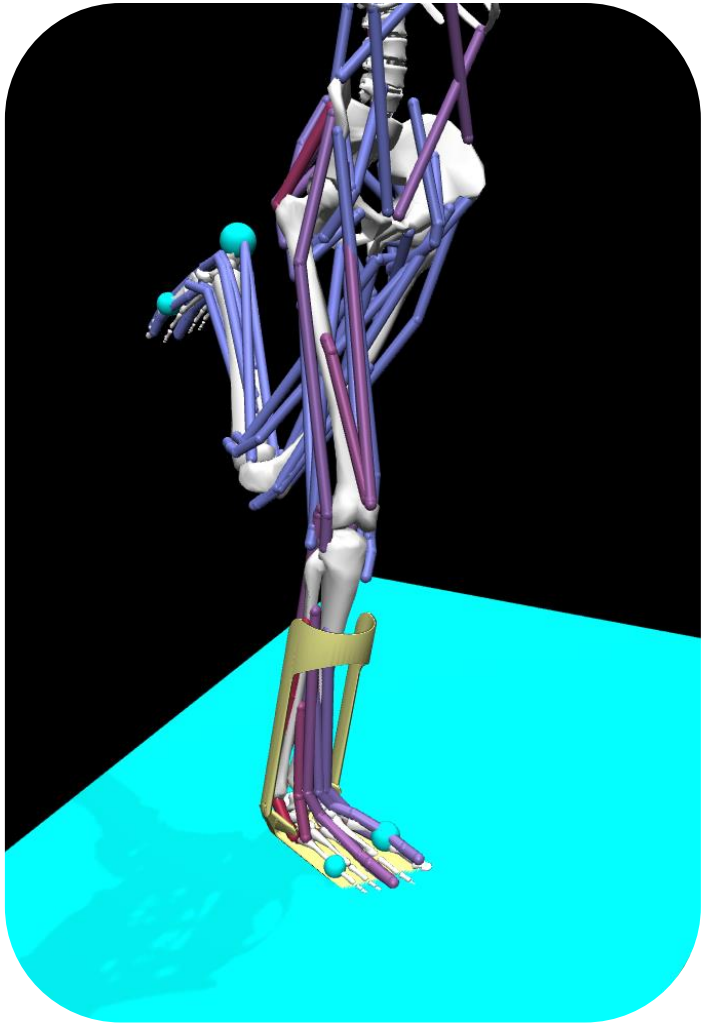
Exercise: Simulation-based design to prevent ankle injuries





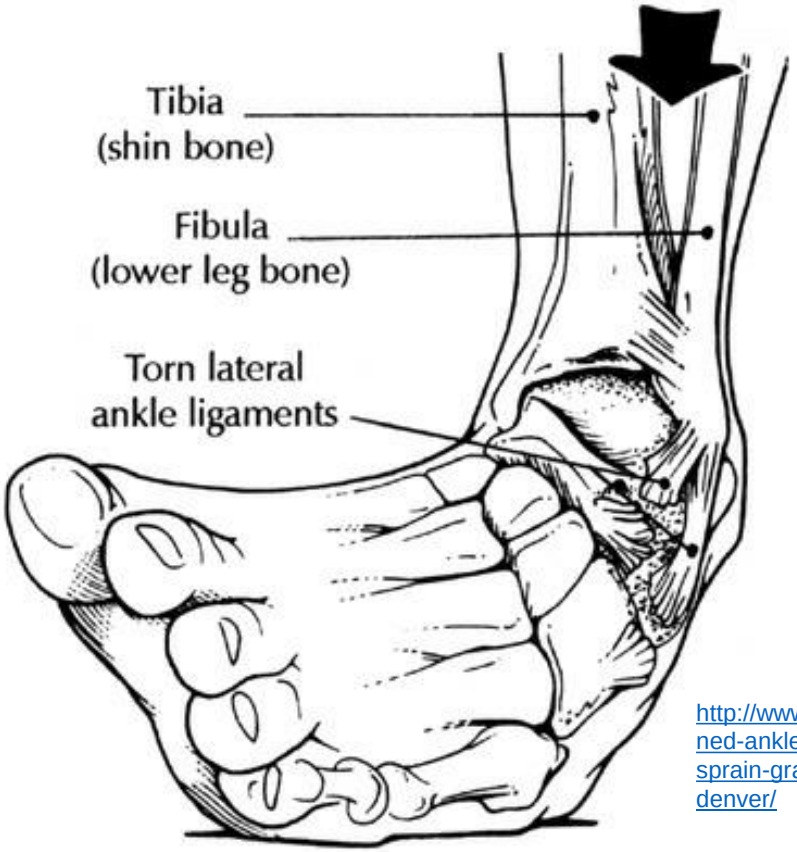
Exercise Overview

1. Explore the model
2. Evaluate ankle inversion injury risk in a simulated drop landing
3. Analyze effect of reflexes, co-contraction, and assistive devices on injury risk



What is an ankle inversion sprain?

Damage to the ligaments that restrain ankle inversion



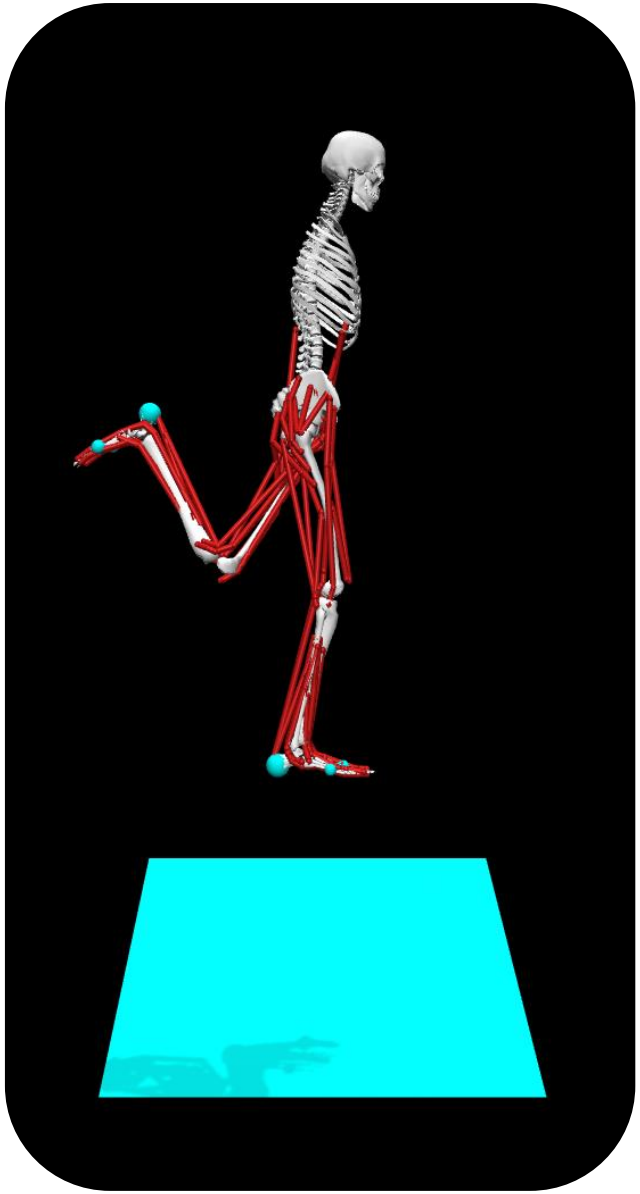
http://www.midwestsportsfans.com/2009/04/sprained-ankle-treatment-rehab-recovery-time-ankle-sprain-grade-ligaments-chronic-ankle-sprains-denver/

Ankle inversion angle indicates ligament strains

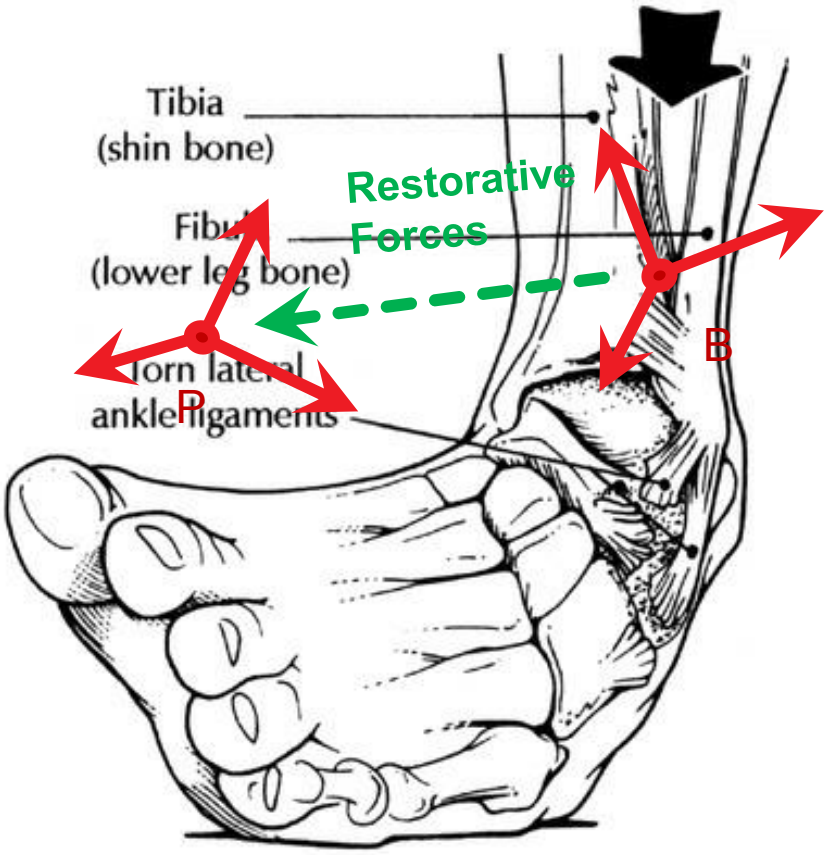
> **25°** correlates with injury

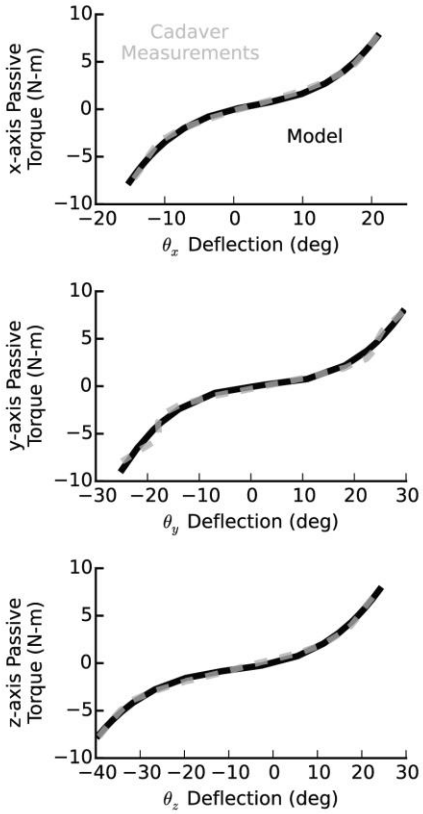
Model details

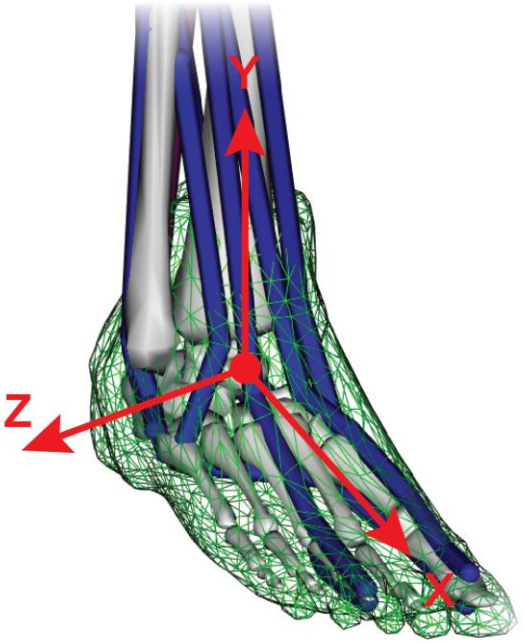
1. Degrees of Freedom = 23
    - Subtalar joint enables inversion/eversion
2. Muscles = 70
3. Passive joint stiffness at the back and ankle
4. Compliant contact (Hertz) with friction (Hunt-Crossley)
5. Stretch reflex muscle controller
6. Ankle muscle controllers to simulate co-activation
7. Ankle Foot Orthosis



Modeling ligaments as bushings







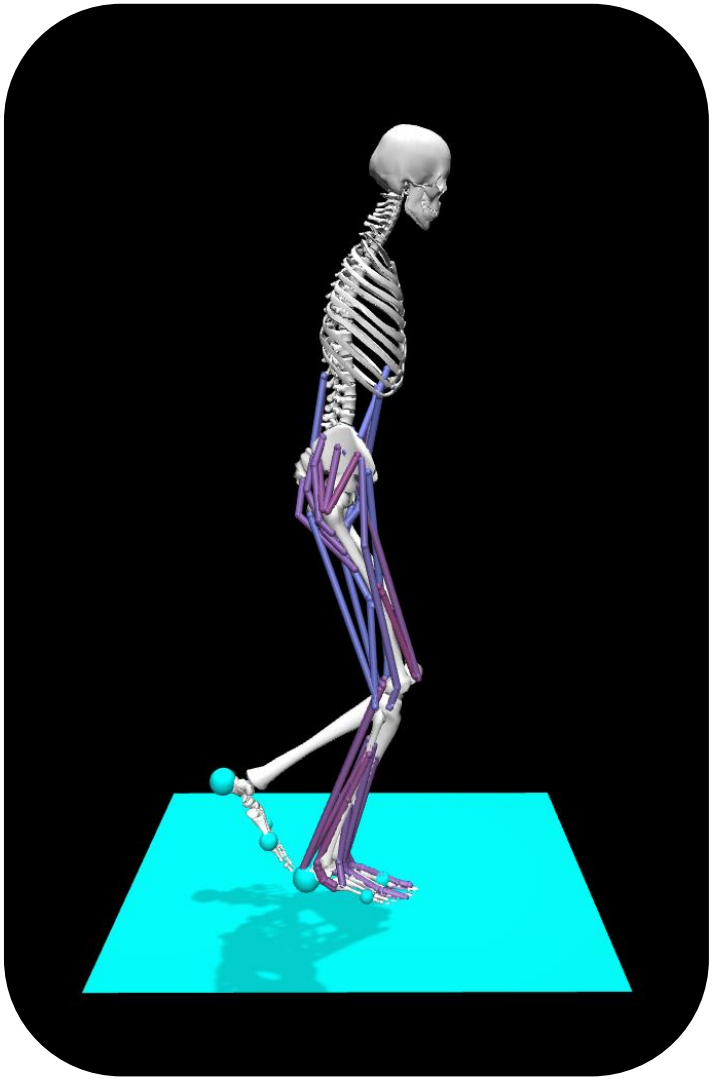
http://www.midwestsportsfans.com/2009/04/sprained-ankle-treatment-rehab-recovery-time-ankle-sprain-grade-ligaments-chronic-ankle-sprains-denver/

$$\vec{F}(\vec{\delta}),\ \ \vec{M}(\vec{\delta})$$

$$M_x = 0 + c_1\theta_x + c_2\theta_x^2 + c_3\theta_x^3$$

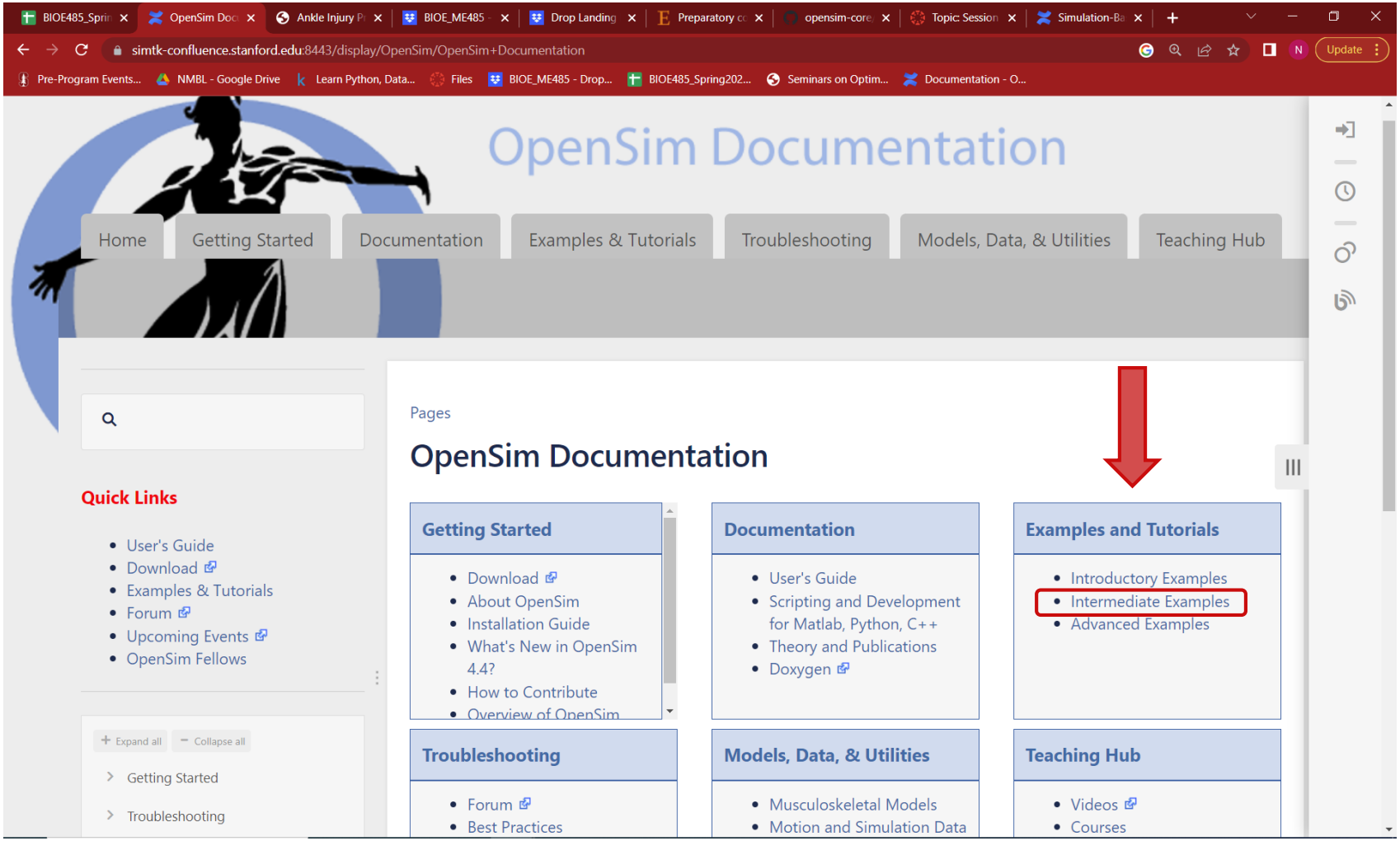
Muscle Stretch Reflex Control

$$u_m(t) = k_p\left(l(t) - l^d\right)_+ + k_v\left(\dot{l}\right)_+$$

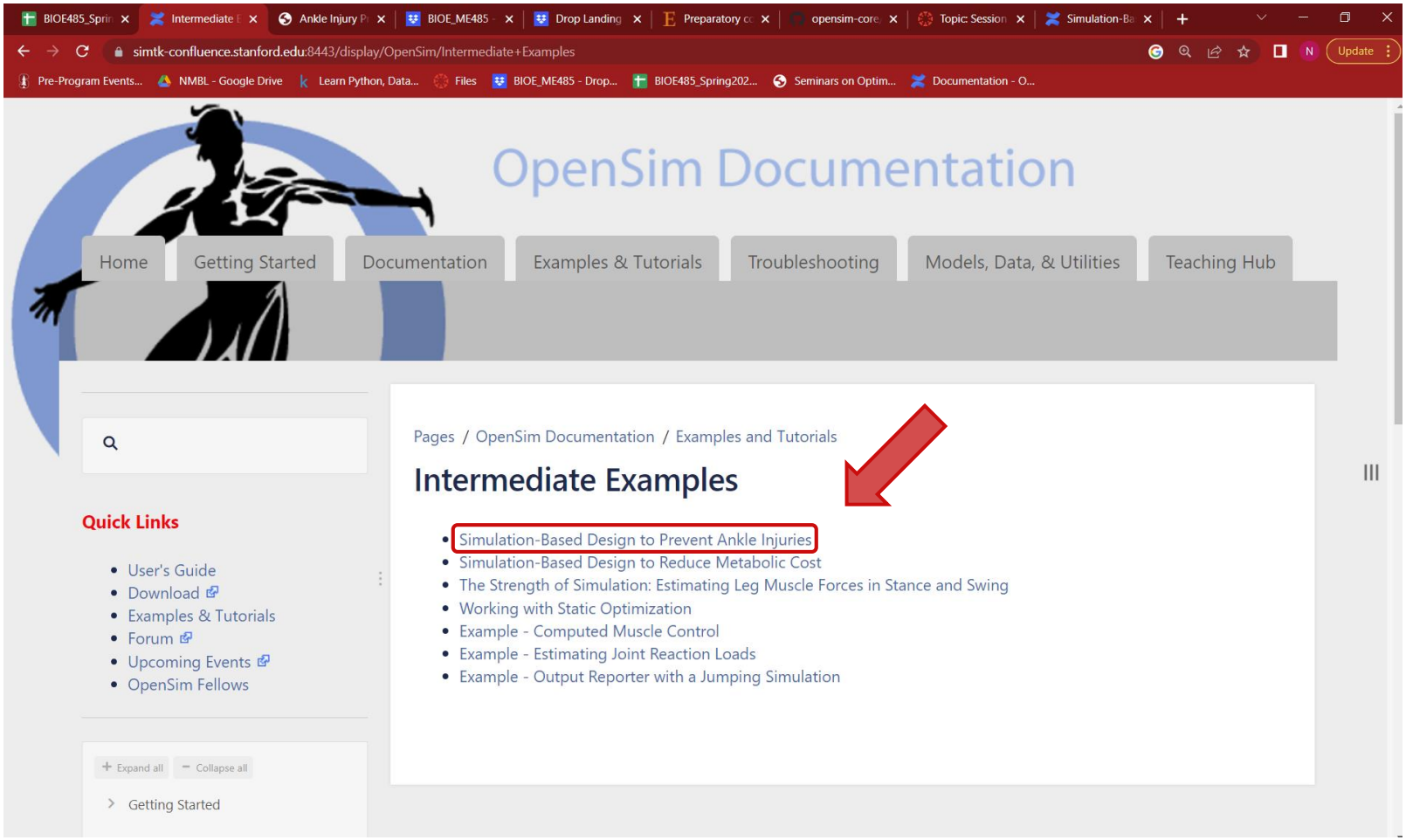


- Muscles organized into functional groups
- 3 parameters per group:
  - $\tilde{l}_m^d$ desired length
  - k_p stretch gain
  - k_v velocity gain
- Each muscle activates to return to its desired length and zero velocity
- Muscles stretch as the leg compresses, like a spring

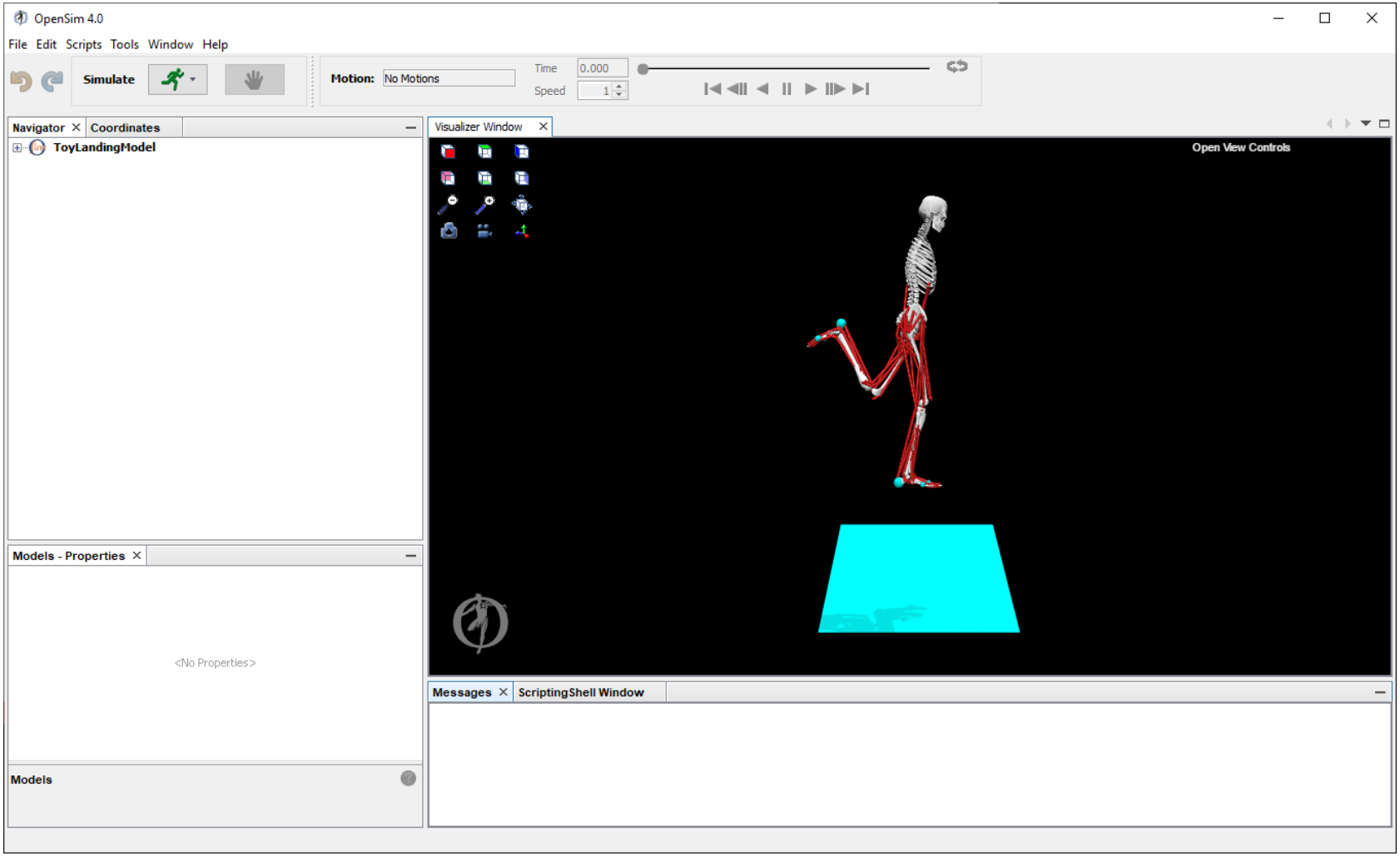
OpenSim Confluence



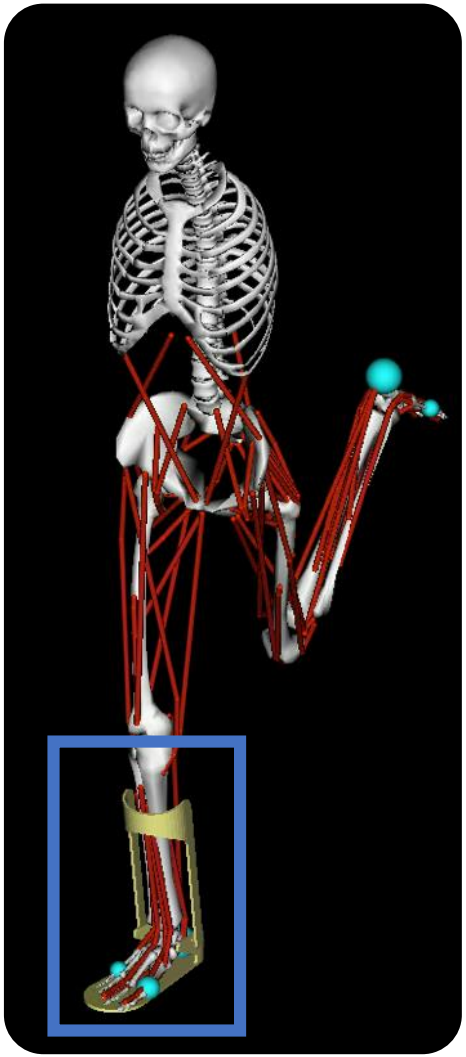
OpenSim Confluence

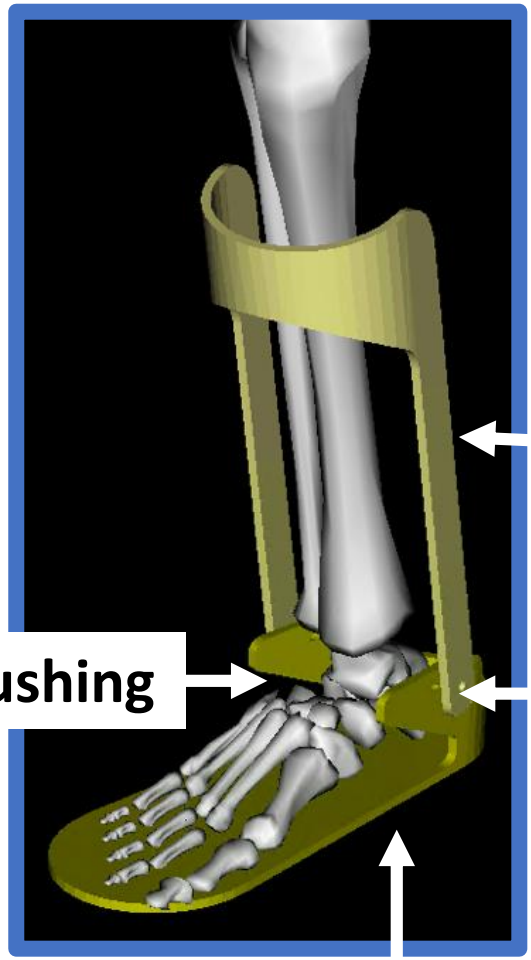


Part I: Simulate a drop landing and analyze ankle inversion injury risk

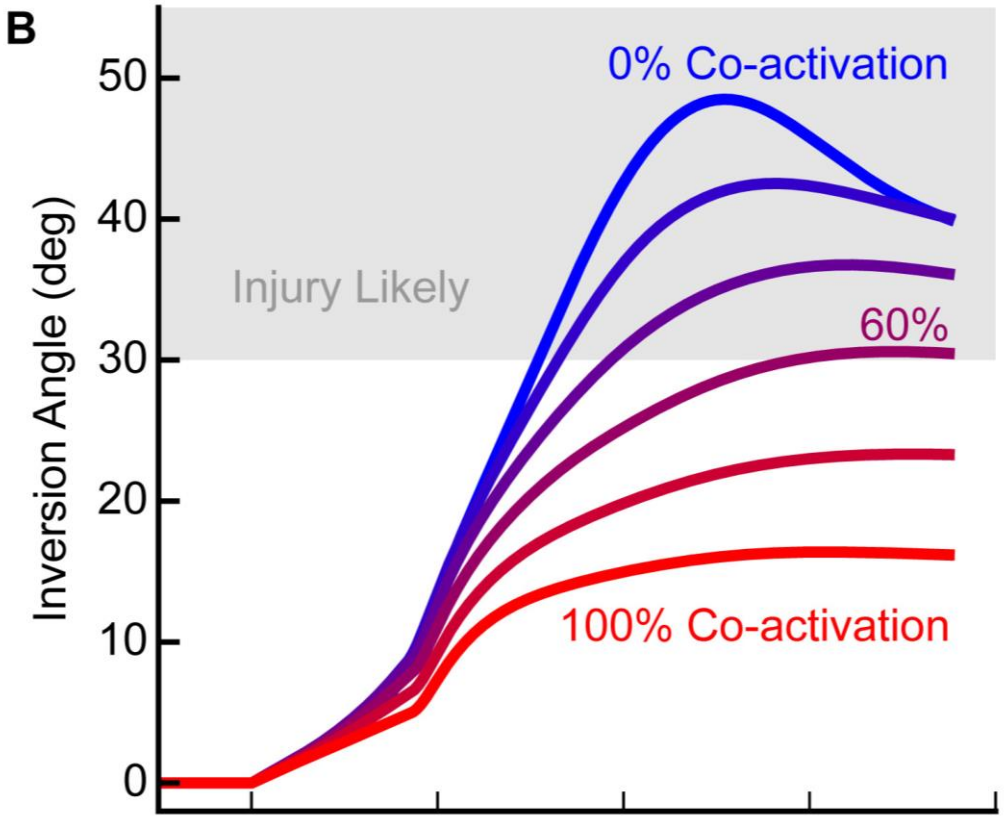


Part II & III: Analyze the effects of an ankle-foot orthosis





Part IV: Analyze the effects of muscle co-activation



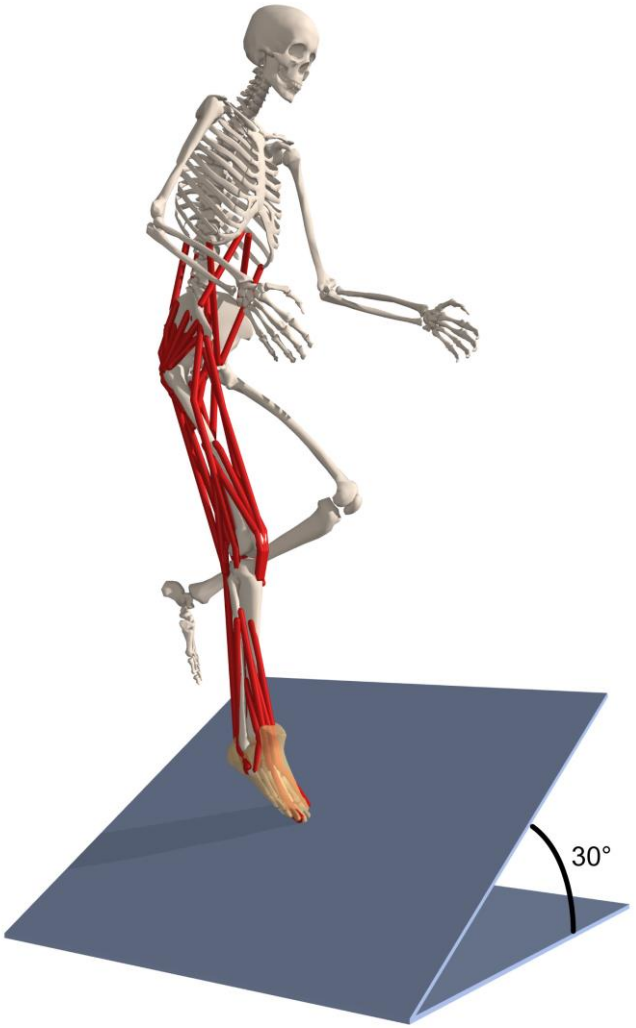
DeMers 2017

You will be doing a simplified version

Part V: Prevent injury with a device and training program

Muscle strength

Reflex gains



Initial landing conditions

Optimal force of AFO

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