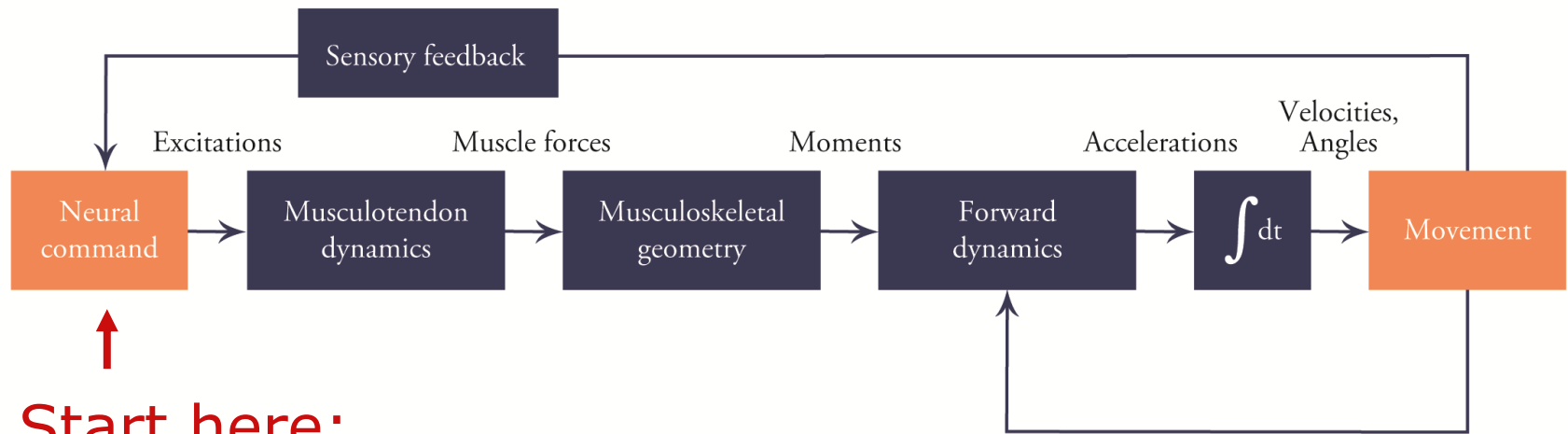


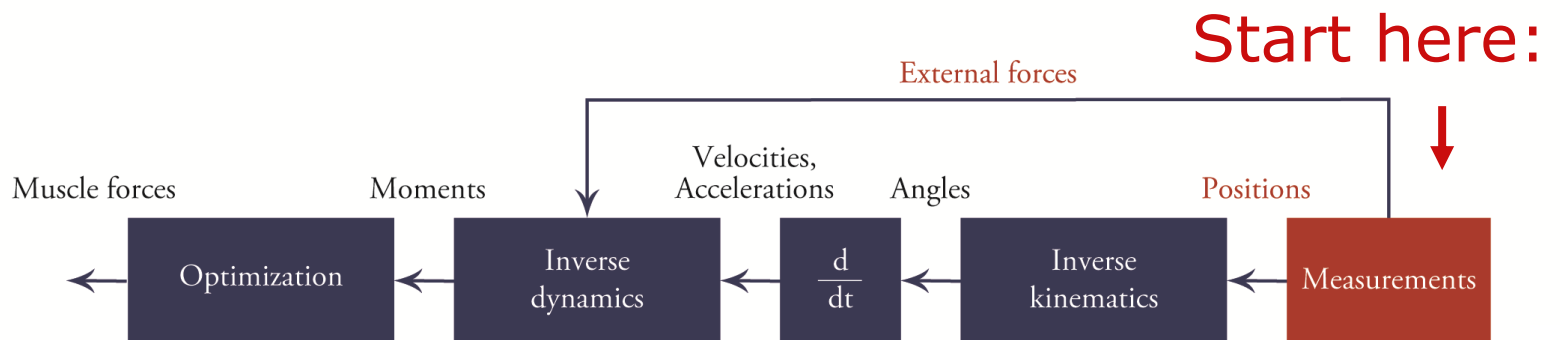
Simulation-Based Design to Prevent Ankle Injuries

BIOE/ME 485: Modeling and Simulation of Human Movement

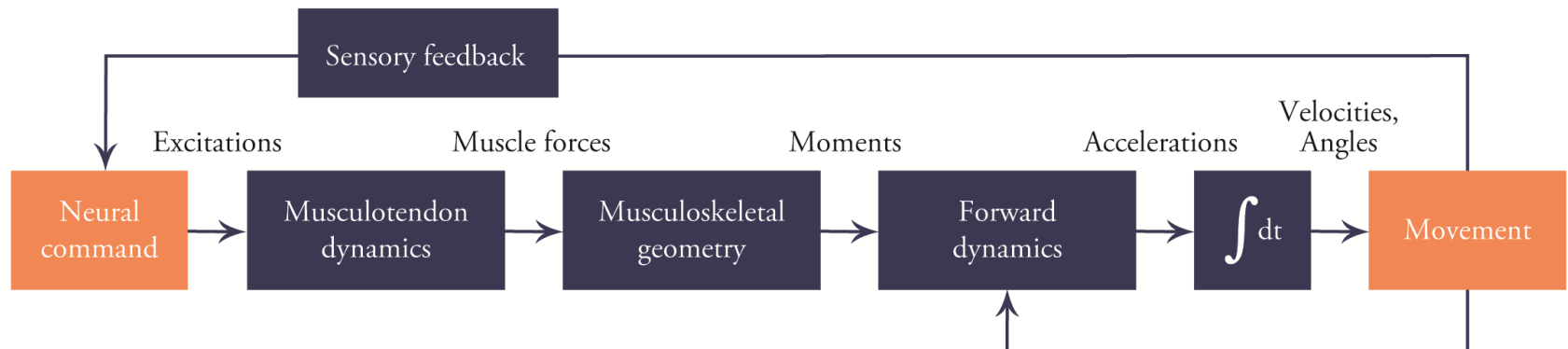
Forward vs Inverse Dynamics



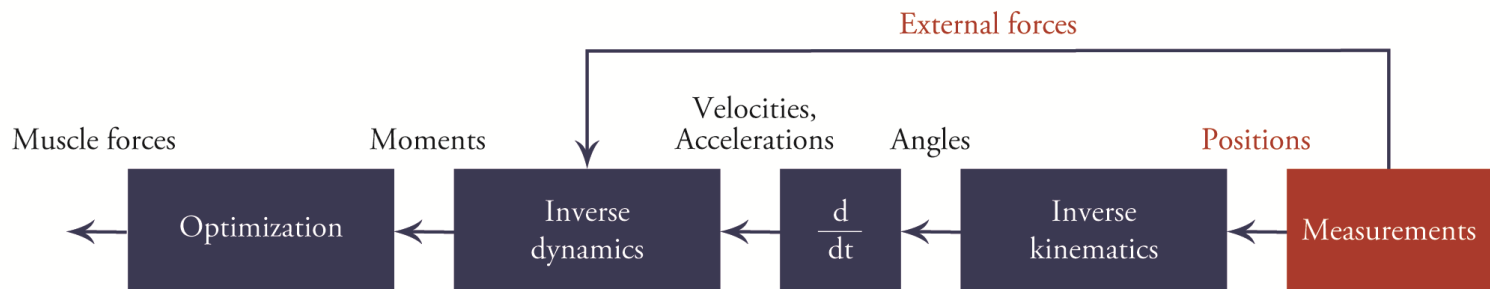
Start here:
Measure or Estimate



Forward vs Inverse Dynamics



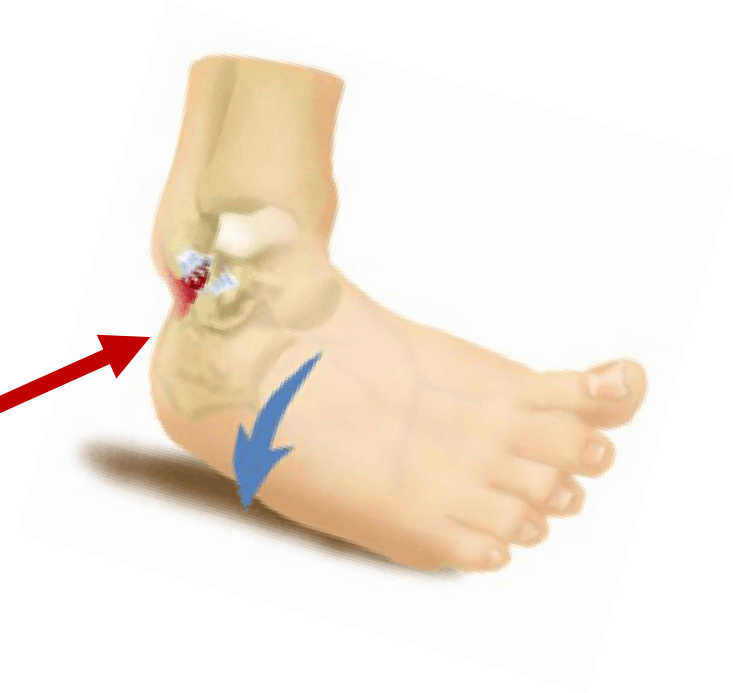
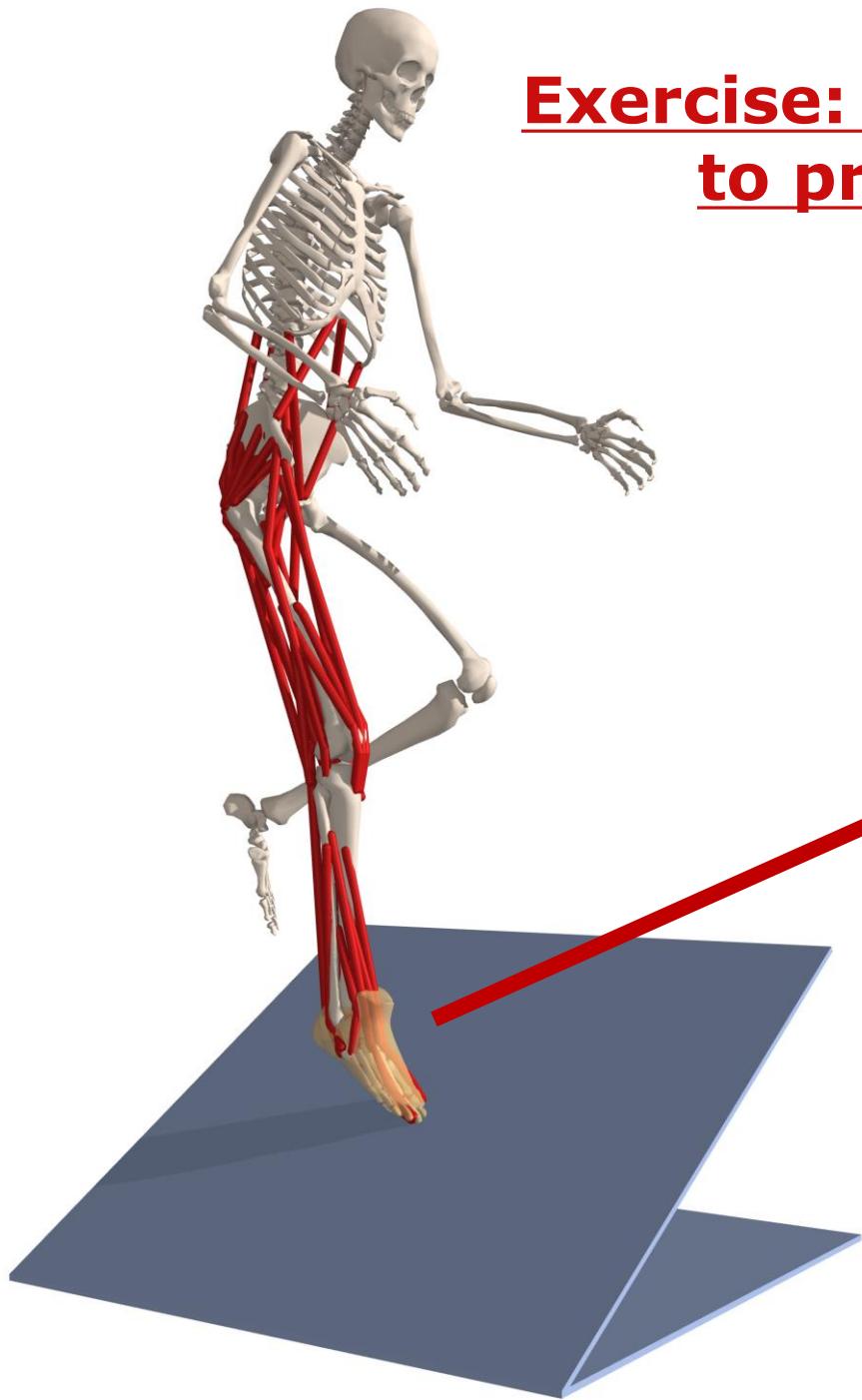
What are some examples where a Forward Dynamics approach might be a more appropriate tool than Inverse Dynamics for movement analysis?



Forward Simulations: Passive Dynamic Walker

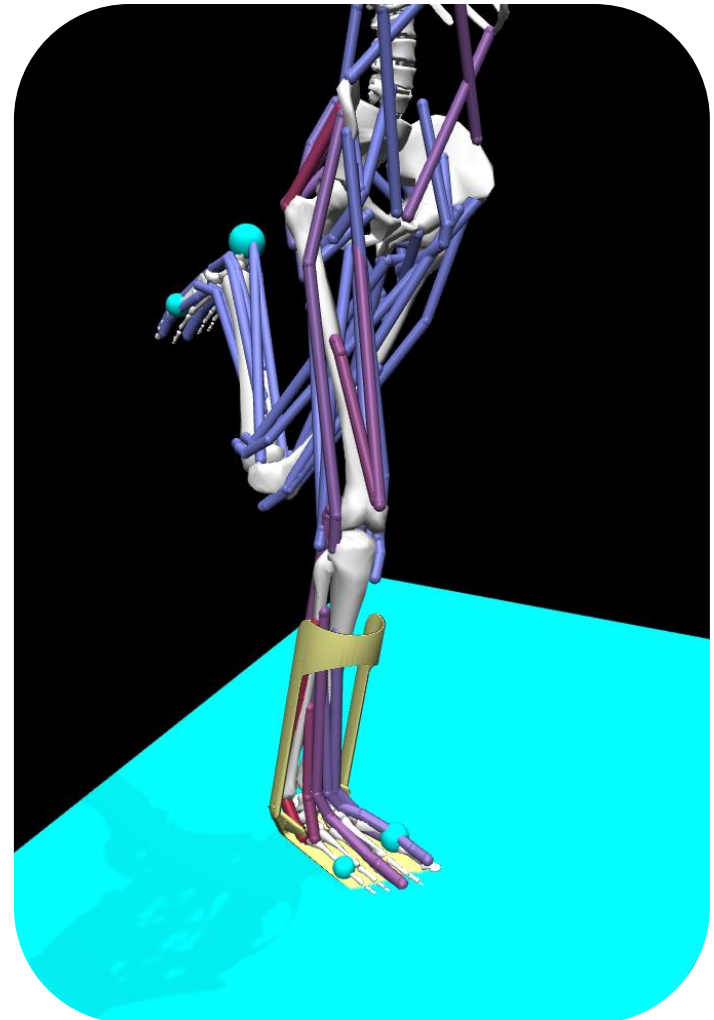


Exercise: Simulation-based design to prevent ankle injuries



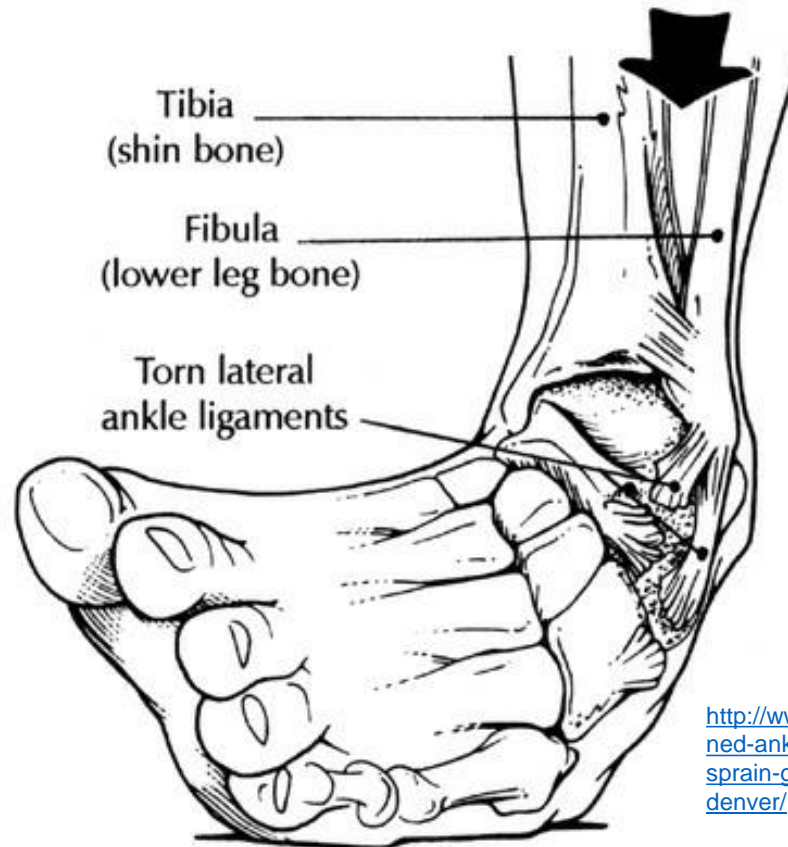
Exercise Overview

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

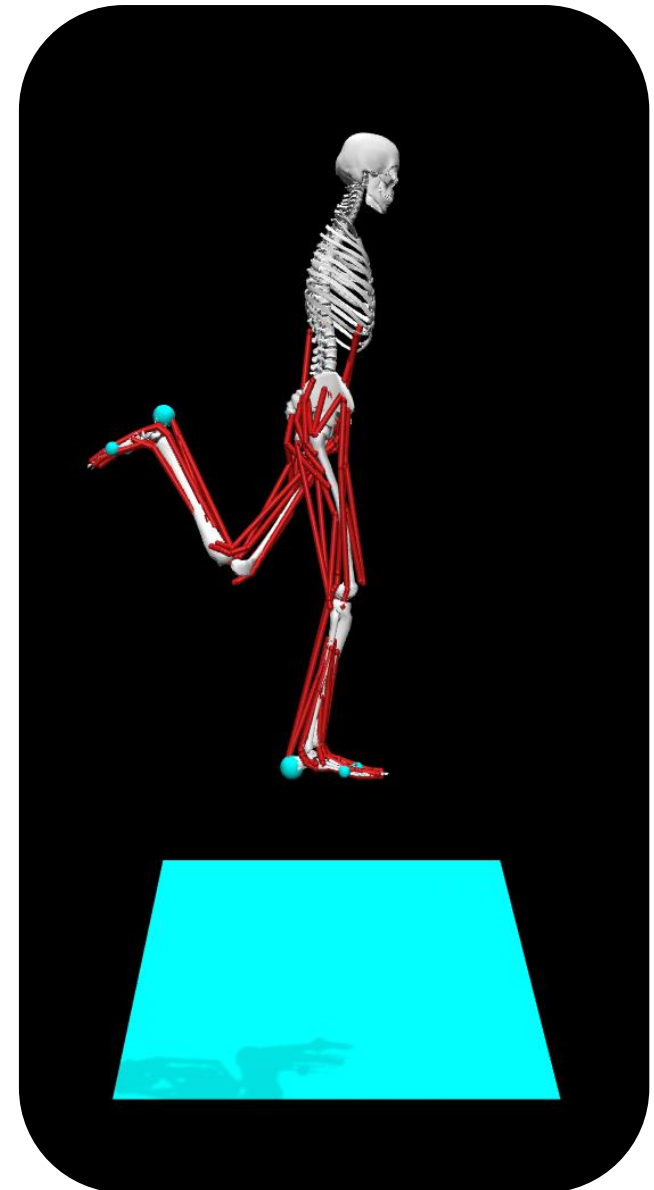


<http://www.midwestsportsfans.com/2009/04/sprained-ankle-treatment-rehab-recovery-time-ankle-sprain-grade-ligaments-chronic-ankle-sprains-denver/>

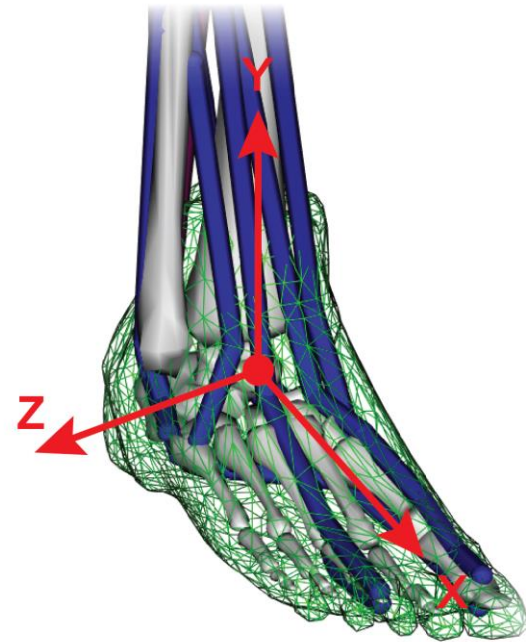
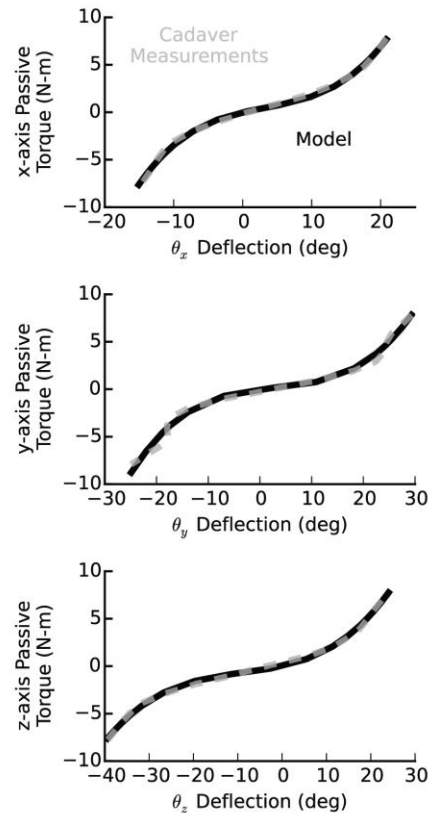
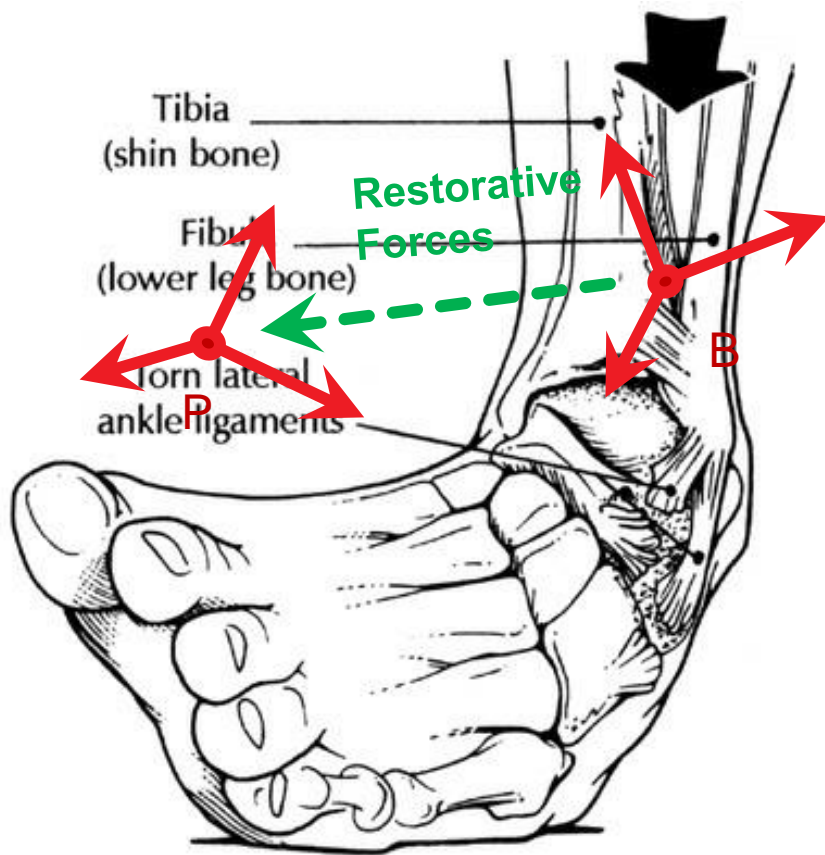
Ankle inversion angle indicates ligament strains
> **25°** correlates with injury

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



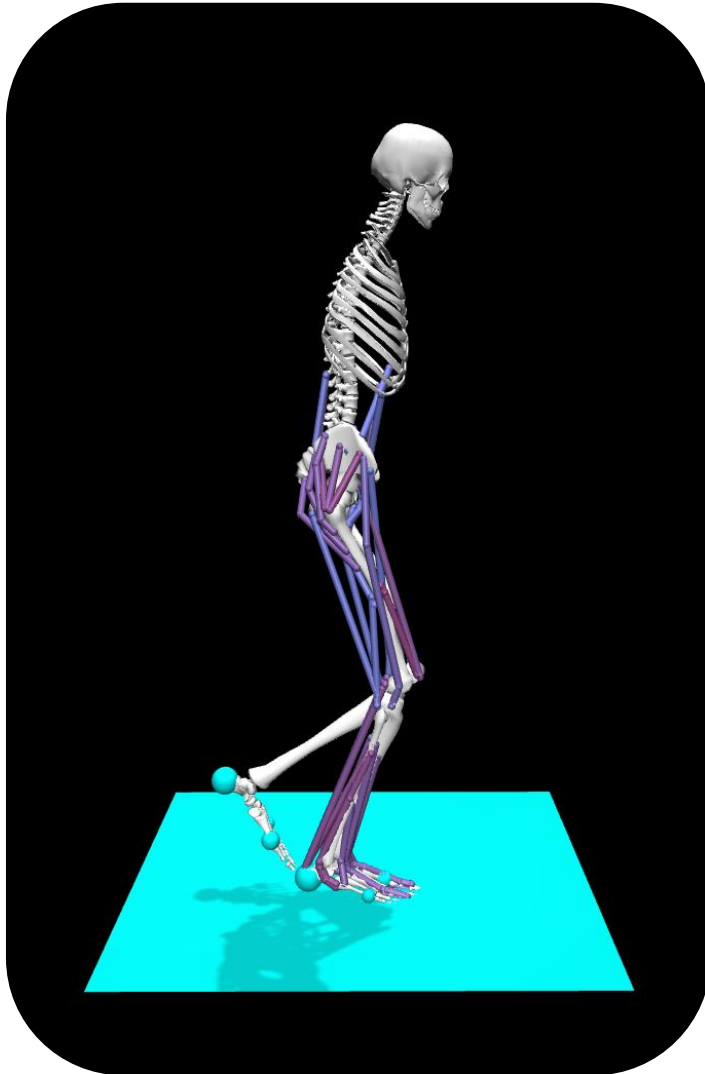
<http://www.midwestsportsfans.com/2009/04/sprained-ankle-treatment-rehab-recovery-time-ankle-sprain-grade-ligaments-chronic-ankle-sprains-denver/>

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

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

Muscle Stretch Reflex Control

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



- 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

The screenshot shows the OpenSim Documentation page on a Confluence instance. The browser's address bar indicates the URL is `simtk-confluence.stanford.edu:8443/display/OpenSim/OpenSim+Documentation`. The page features a navigation menu with tabs for Home, Getting Started, Documentation, Examples & Tutorials, Troubleshooting, Models, Data, & Utilities, and Teaching Hub. A search bar is located on the left side. Below the navigation, there are several sections: Quick Links, a search bar, and a grid of content boxes. A red arrow points to the 'Intermediate Examples' link in the 'Examples and Tutorials' box.

OpenSim Documentation

Home Getting Started Documentation Examples & Tutorials Troubleshooting Models, Data, & Utilities Teaching Hub

Quick Links

- User's Guide
- Download
- Examples & Tutorials
- Forum
- Upcoming Events
- OpenSim Fellows

Pages

OpenSim Documentation

Getting Started

- Download
- About OpenSim
- Installation Guide
- What's New in OpenSim 4.4?
- How to Contribute
- Overview of OpenSim

Documentation

- User's Guide
- Scripting and Development for Matlab, Python, C++
- Theory and Publications
- Doxygen

Examples and Tutorials

- Introductory Examples
- Intermediate Examples**
- Advanced Examples

Troubleshooting

- Forum
- Best Practices

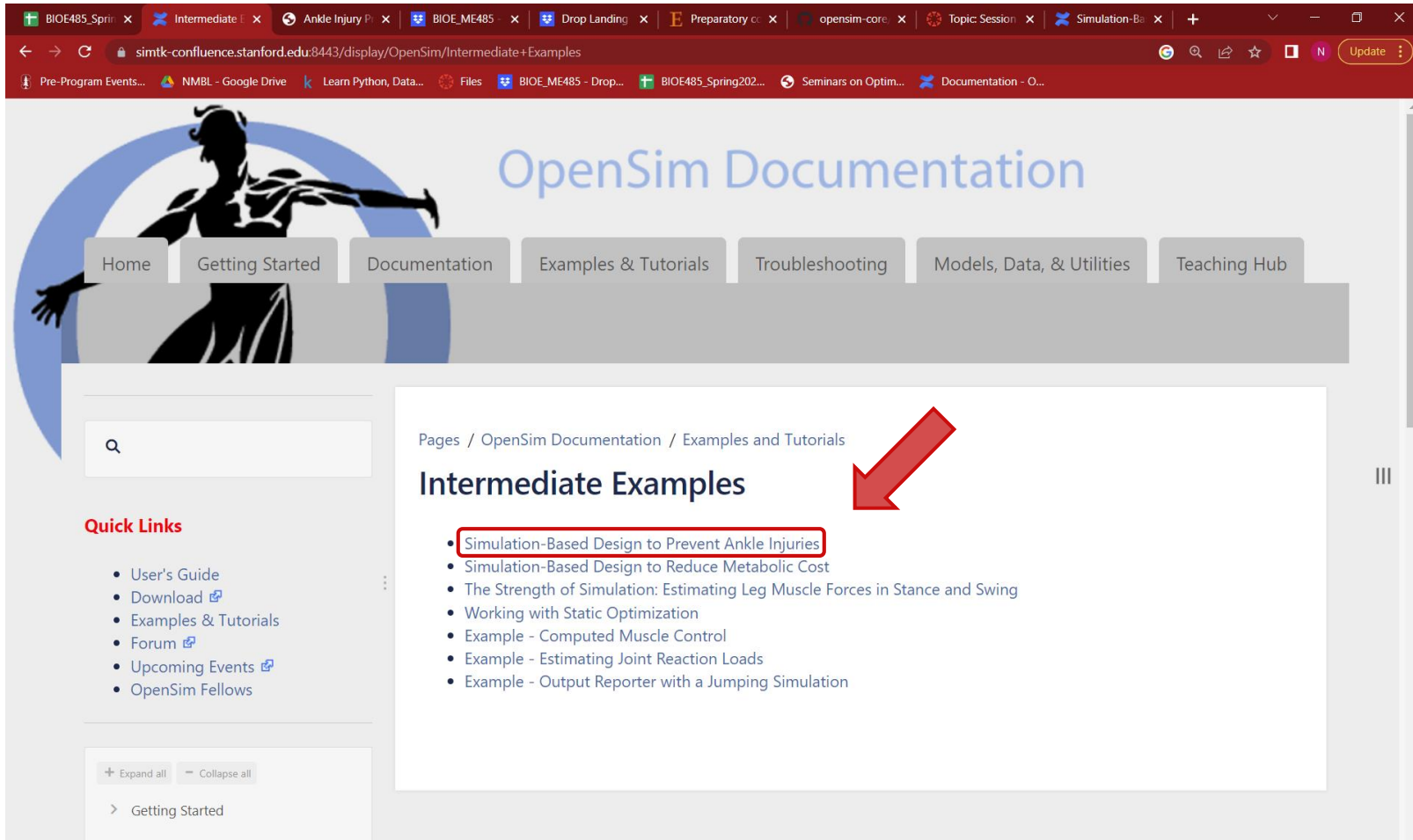
Models, Data, & Utilities

- Musculoskeletal Models
- Motion and Simulation Data

Teaching Hub

- Videos
- Courses

OpenSim Confluence



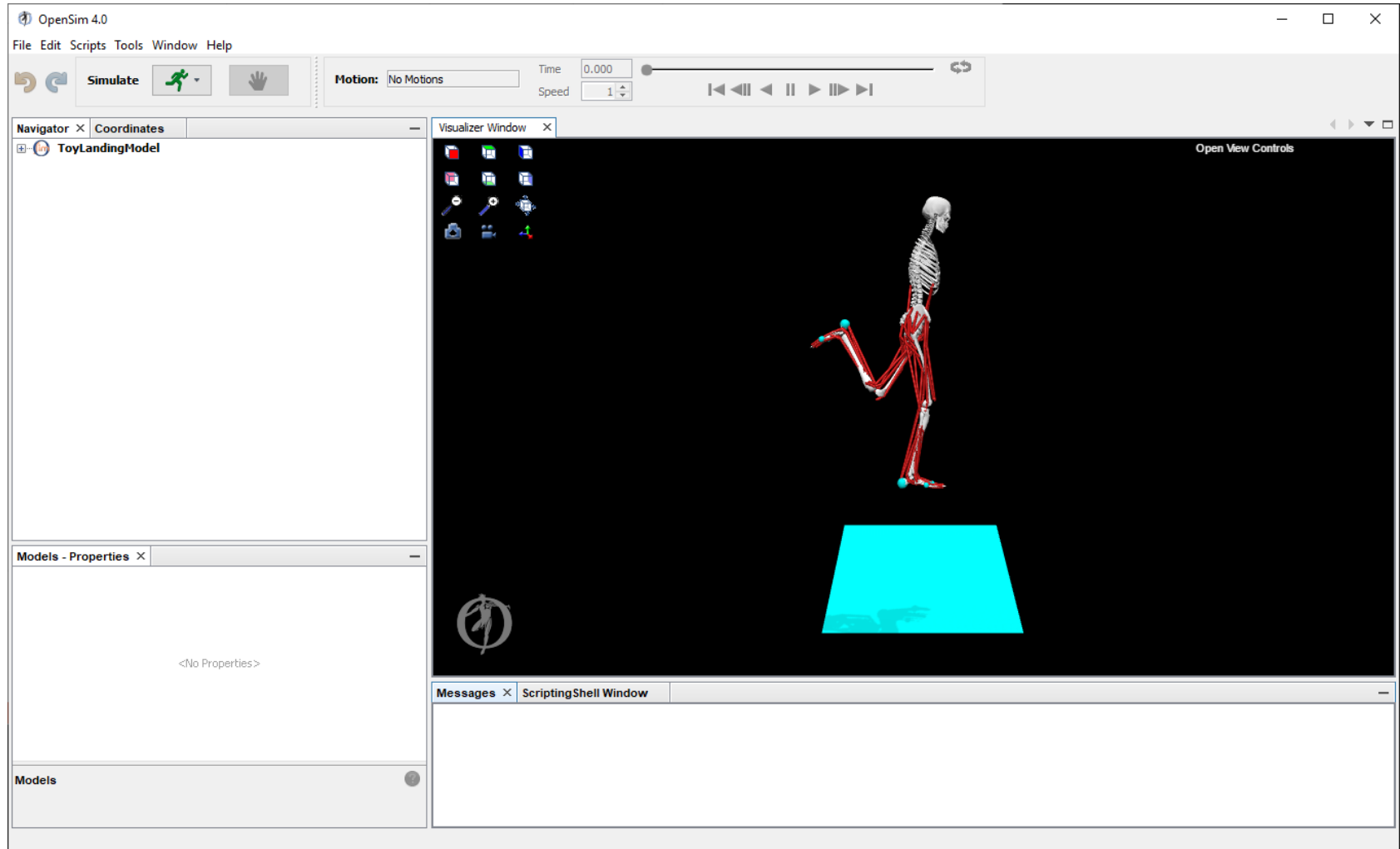
The screenshot shows a web browser window displaying the OpenSim Documentation website. The browser's address bar shows the URL: `simtk-confluence.stanford.edu:8443/display/OpenSim/Intermediate+Examples`. The website features a header with a silhouette of a muscular figure and the text "OpenSim Documentation". Below the header is a navigation menu with the following items: Home, Getting Started, Documentation, Examples & Tutorials, Troubleshooting, Models, Data, & Utilities, and Teaching Hub. On the left side, there is a search bar and a "Quick Links" section with the following links: User's Guide, Download, Examples & Tutorials, Forum, Upcoming Events, and OpenSim Fellows. The main content area displays the breadcrumb "Pages / OpenSim Documentation / Examples and Tutorials" and the section title "Intermediate Examples". A red arrow points to the first item in the list, "Simulation-Based Design to Prevent Ankle Injuries", which is highlighted with a red box. The other items in the list are: Simulation-Based Design to Reduce Metabolic Cost, The Strength of Simulation: Estimating Leg Muscle Forces in Stance and Swing, Working with Static Optimization, Example - Computed Muscle Control, Example - Estimating Joint Reaction Loads, and Example - Output Reporter with a Jumping Simulation.

Pages / OpenSim Documentation / Examples and Tutorials

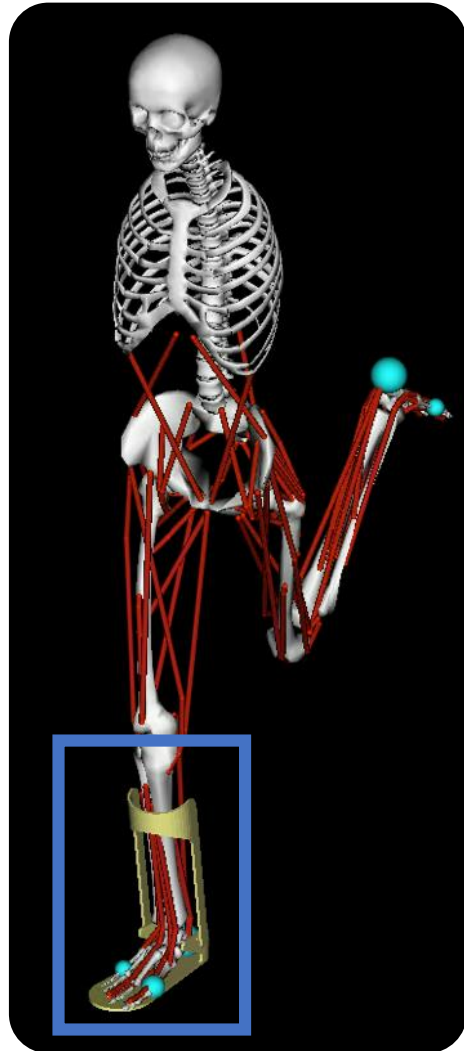
Intermediate Examples

- [Simulation-Based Design to Prevent Ankle Injuries](#)
- [Simulation-Based Design to Reduce Metabolic Cost](#)
- [The Strength of Simulation: Estimating Leg Muscle Forces in Stance and Swing](#)
- [Working with Static Optimization](#)
- [Example - Computed Muscle Control](#)
- [Example - Estimating Joint Reaction Loads](#)
- [Example - Output Reporter with a Jumping Simulation](#)

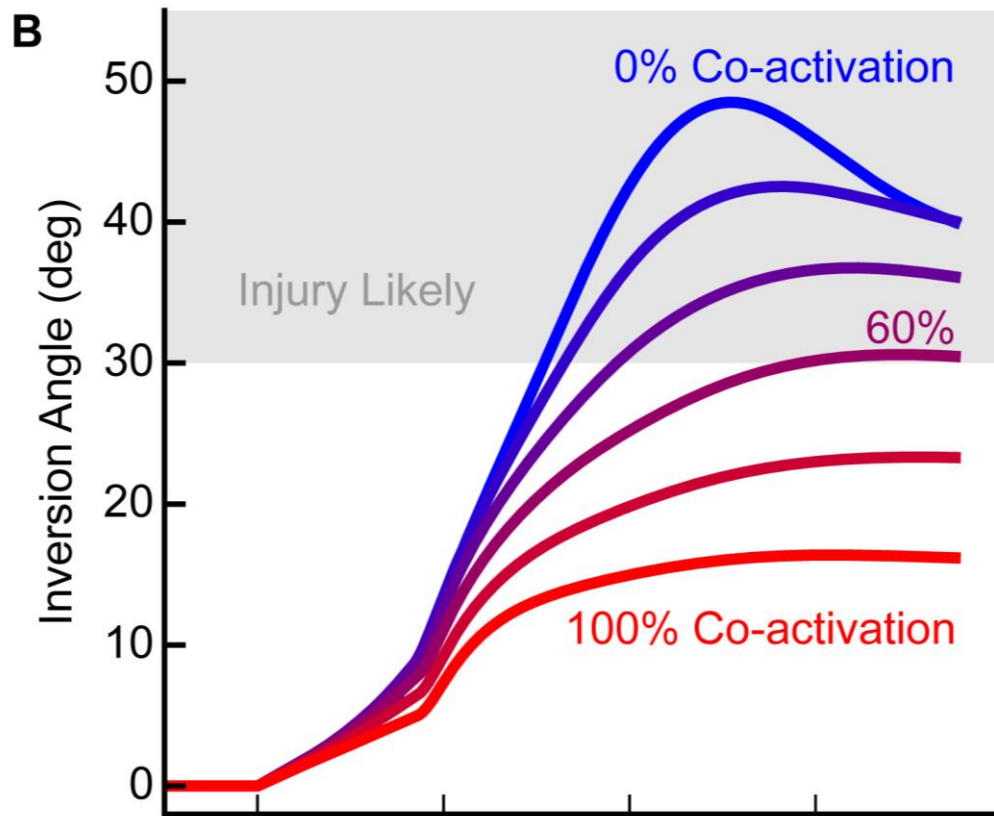
Part I: Simulate a drop landing and analyze ankle inversion injury risk



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



Part IV: Analyze the effects of muscle co-activation



*You will be doing
a simplified
version*

DeMers 2017

Part V: Prevent injury with a device and training program

Muscle strength

Reflex gains

Initial landing conditions

Optimal force of AFO

