OpenSim

https://simtk.org/home/opensim

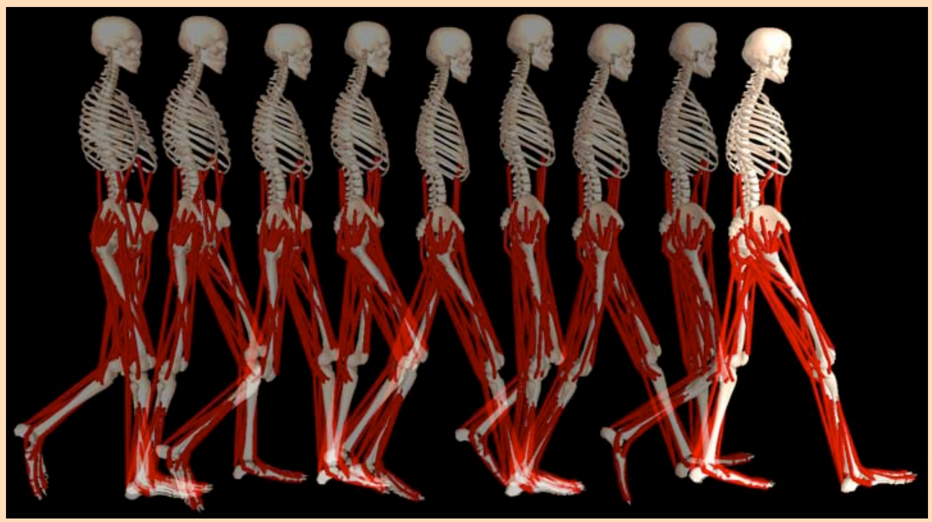
Supported by NIH R01HD046814 and Roadmap grant U54GM072970

Simbios

What can you do with musculoskeletal models?

Visualize complex movement patterns

Estimate forces that are difficult to measure



Perform “what if” studies

Identify cause-effect relationships

Problems with current paradigm

- Difficult to reproduce results of simulation papers
- Commercial codes valuable but not extensible
- Cost of commercial limits use in teaching
- Building your own is a challenge
- Difficult to bring your innovations to the world
- Continuity is lost when students graduate
- Isolation

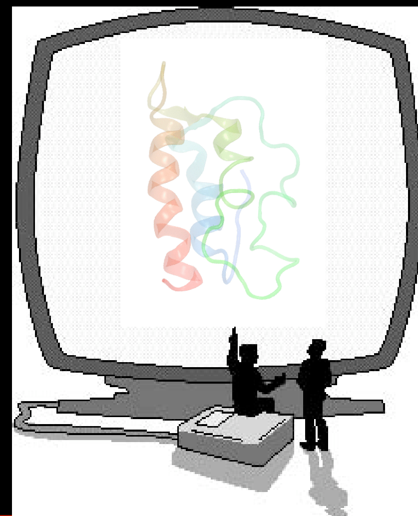
What does OpenSim provide?

- Open access - results can be reproduced
- Extensible - you can add your own features
- Widely available - bring your innovations to the world
- Free - teaching materials
- Access - a community of experts
- Continuity - for your lab

OpenSim features

- Standard format for exchanging models
- General purpose inverse dynamics
- Optimization to estimate muscle and joint forces
- Methods to create simulations from motion data
- Tools to analyze simulations
- Simbody: open source dynamics engine
- Software, models, and simulations you contribute

Simulation Toolkit



GUI Tools | Documentation Tools | Installation

Modeling

Linear Algebra

Multi Body Dynamics
Simbody
PRrobot
•

Integrator
ODE
DAE

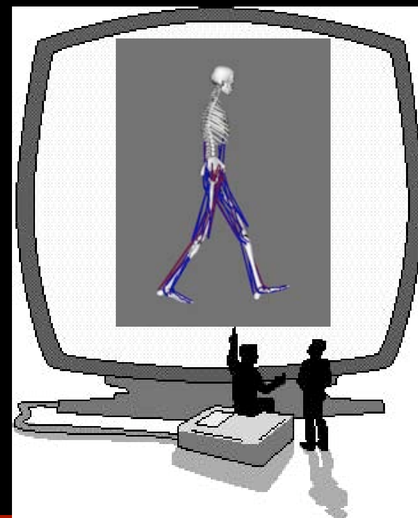
Contact
Rigid
Penalty
•

Optimize
Sim Anneal
Genetic
SQ Prog

Monte Carlo

Force Fields

Simulation Toolkit



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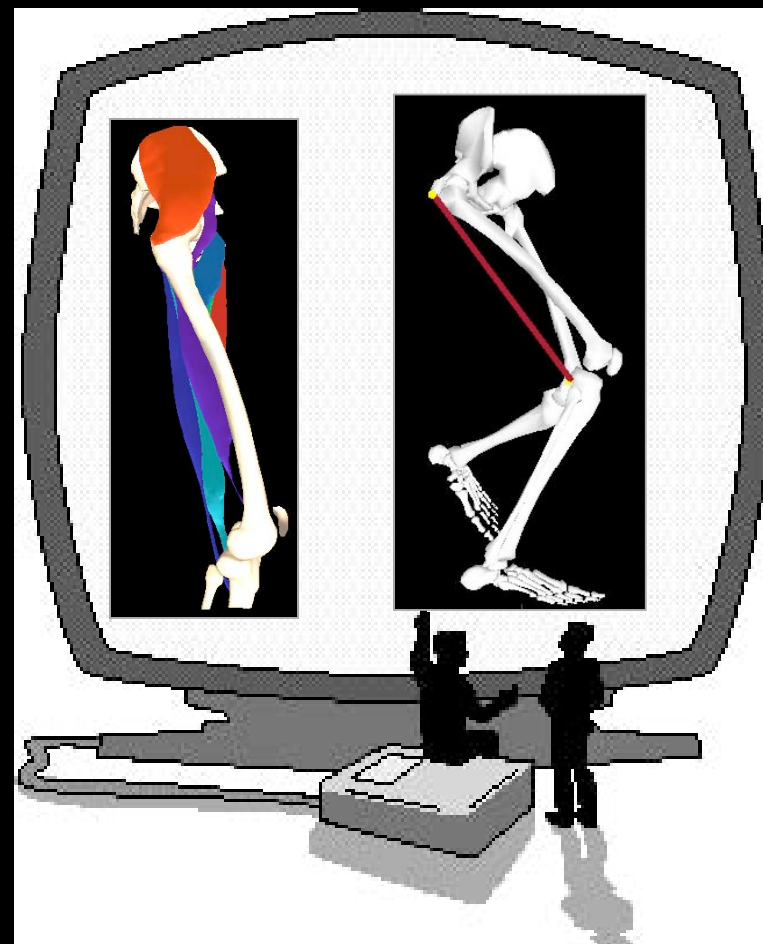
Simulation-Based Treatment Planning

Experimental Data

Biomechanical Models

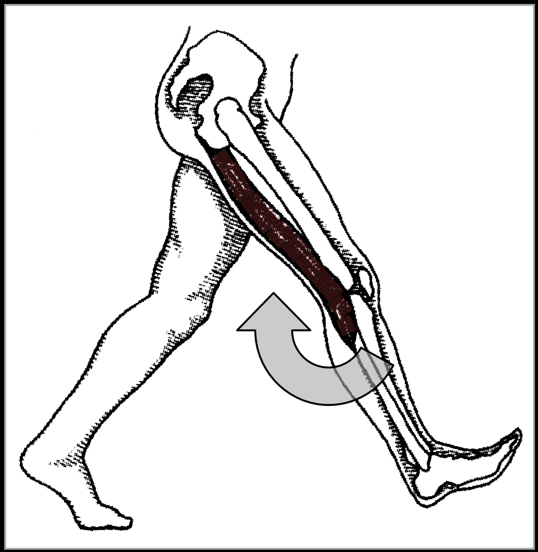


Treatment of Crouch Gait is Challenging

Courtesy of Gillette Children's Specialty Healthcare

Reputed Causes:

- hamstrings contracture
  i.e., *shortened muscle fibers*
- hamstrings spasticity
  i.e., *exaggerated reflexes*

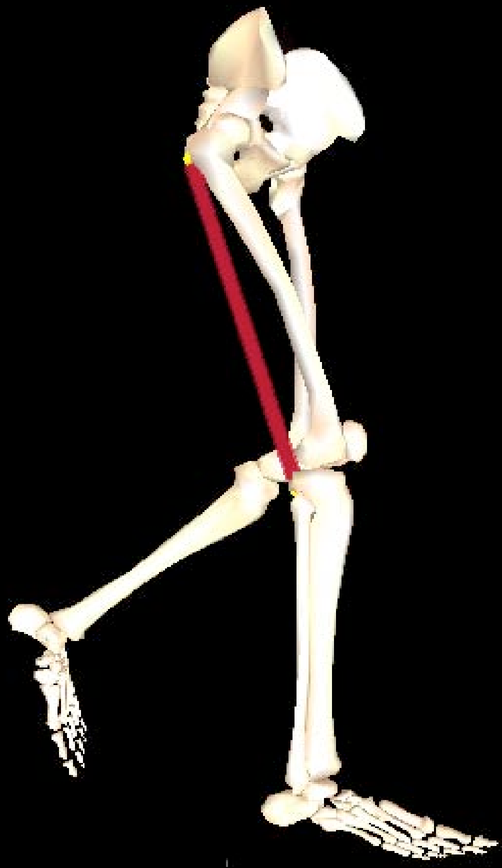


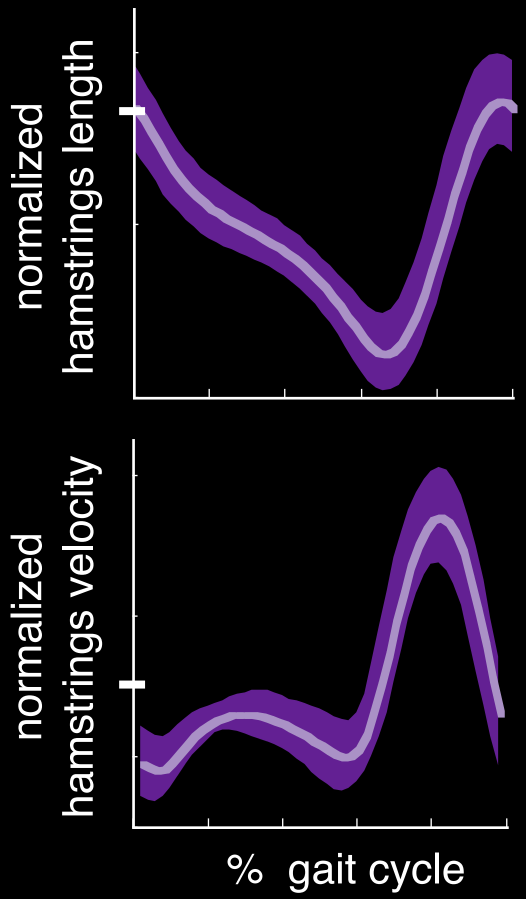
Adapted from Gage (2004)

Can Analyses of Muscle-Tendon Lengths & Velocities Provide Insight?

3D Gait Kinematics → **Musculoskeletal Model** → **Muscle-Tendon Lengths & Velocities**

Courtesy of S. Õunpuu





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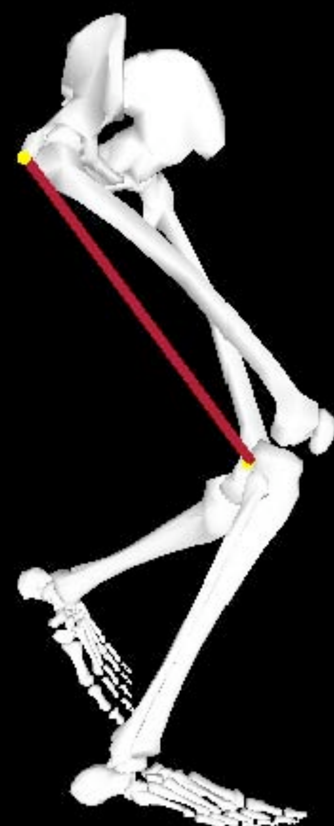

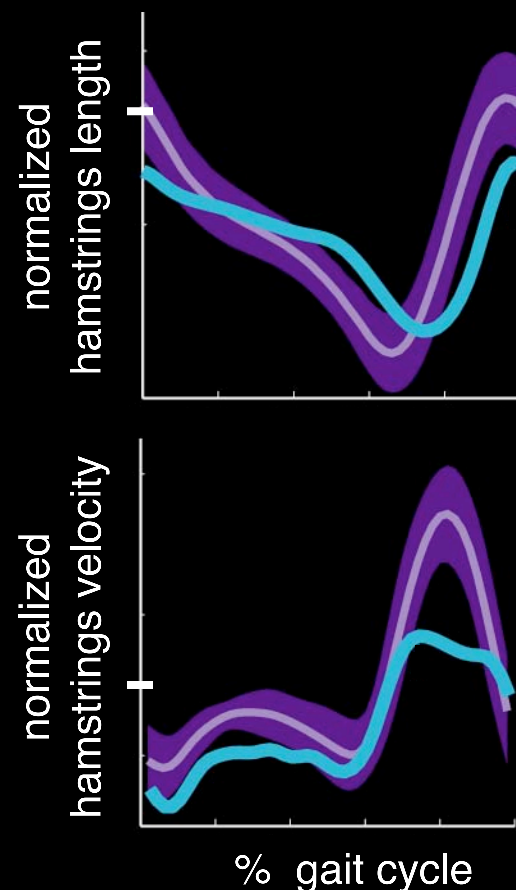

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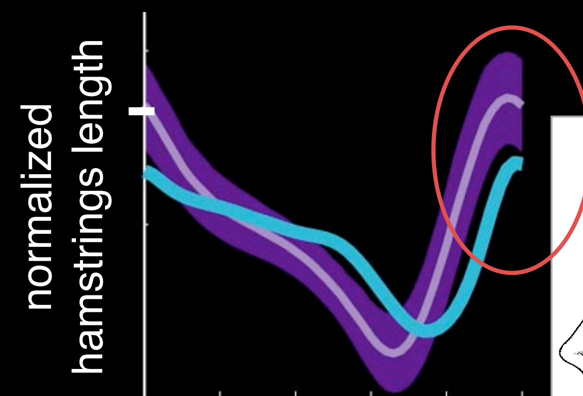
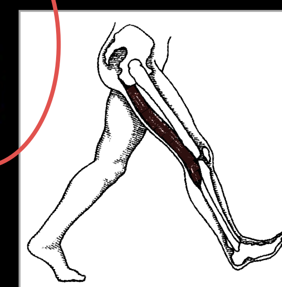
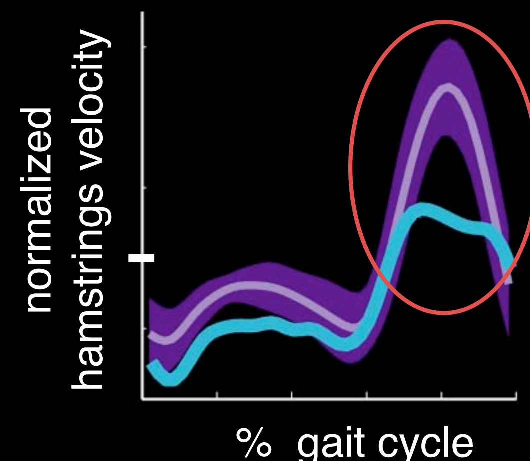
hamstrings contracture

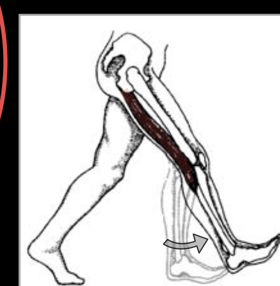




Gage (2004)

hamstrings spasticity





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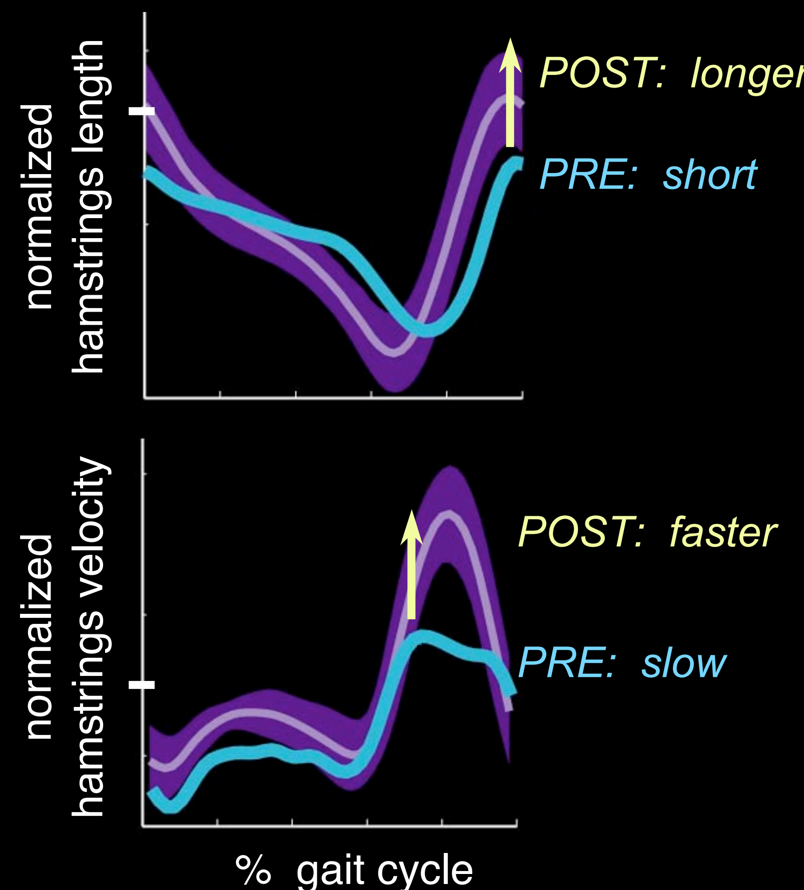
hamstrings contracture ⇨

hamstrings spasticity ⇨



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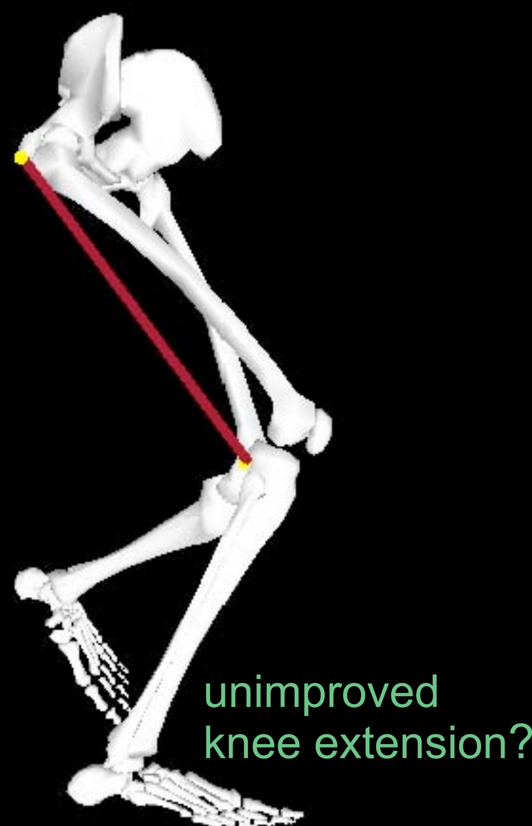
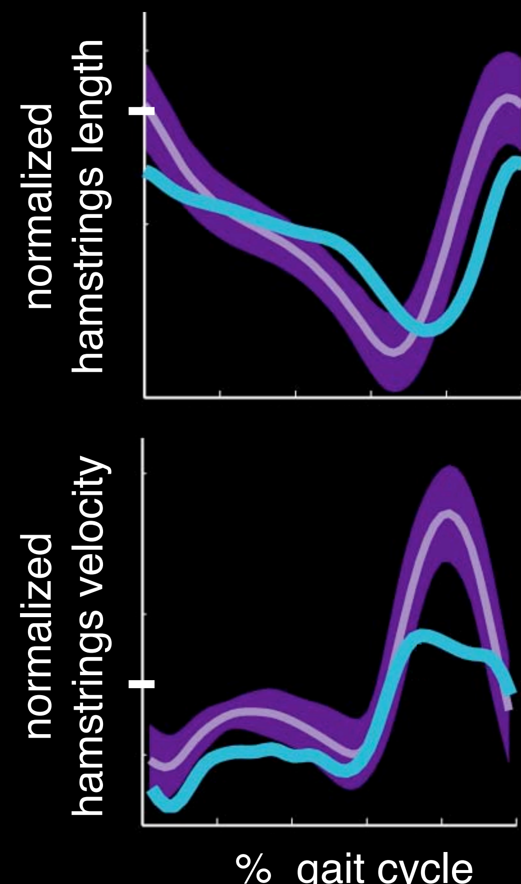




Questions

1. What percentage of patients walk with *short* or *slow* hamstrings?

2. After surgical lengthening:

   Do *short* hamstrings operate at *longer* muscle-tendon lengths?

   Do *slow* hamstrings operate at *faster* muscle-tendon velocities?

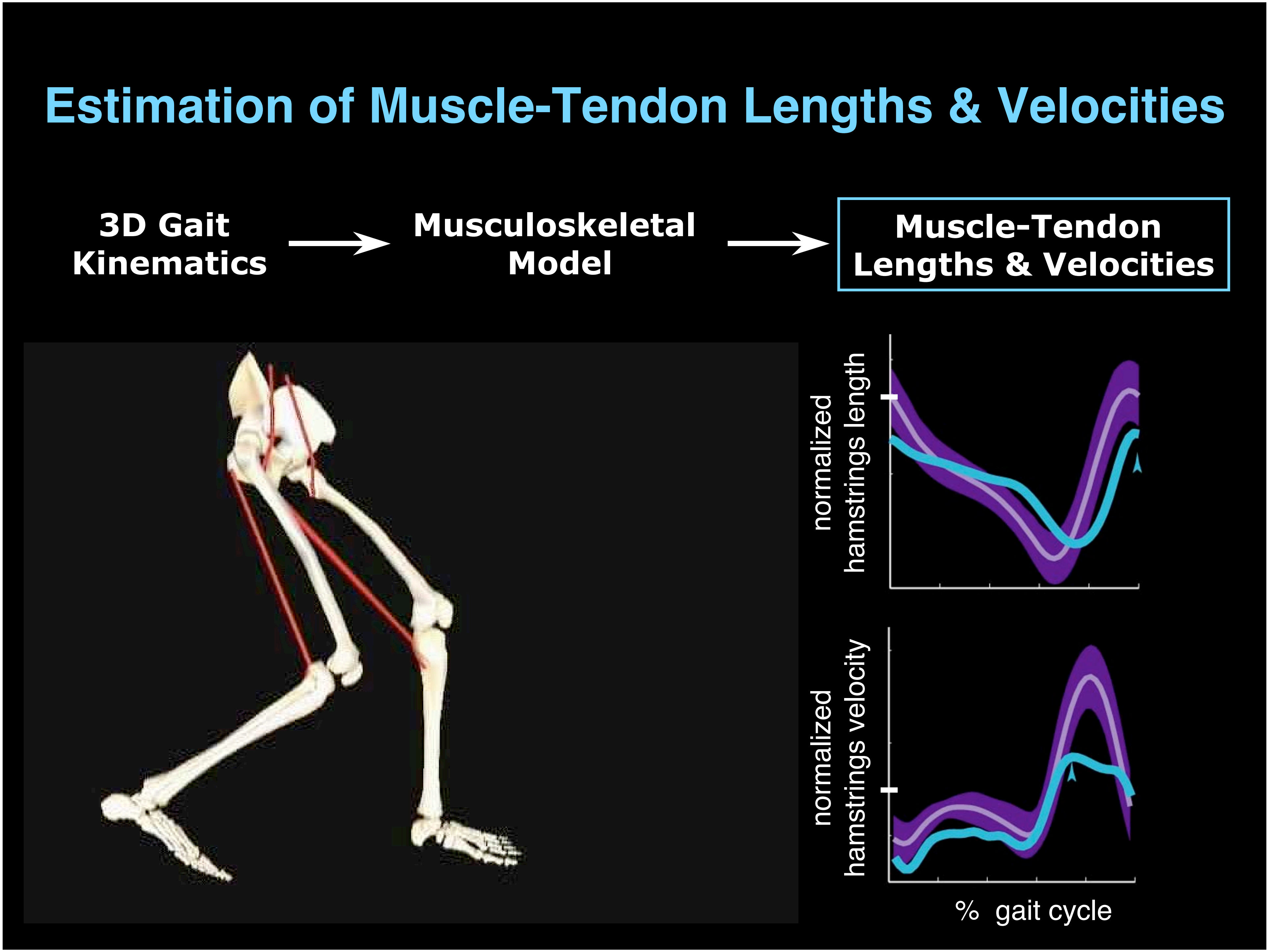
3. Are clinical outcomes for treatment of crouch gait related to hamstrings lengths?

Estimation of Muscle-Tendon Lengths & Velocities

3D Gait Kinematics → **Musculoskeletal Model** → **Muscle-Tendon Lengths & Velocities**

Courtesy of S. Õunpuu

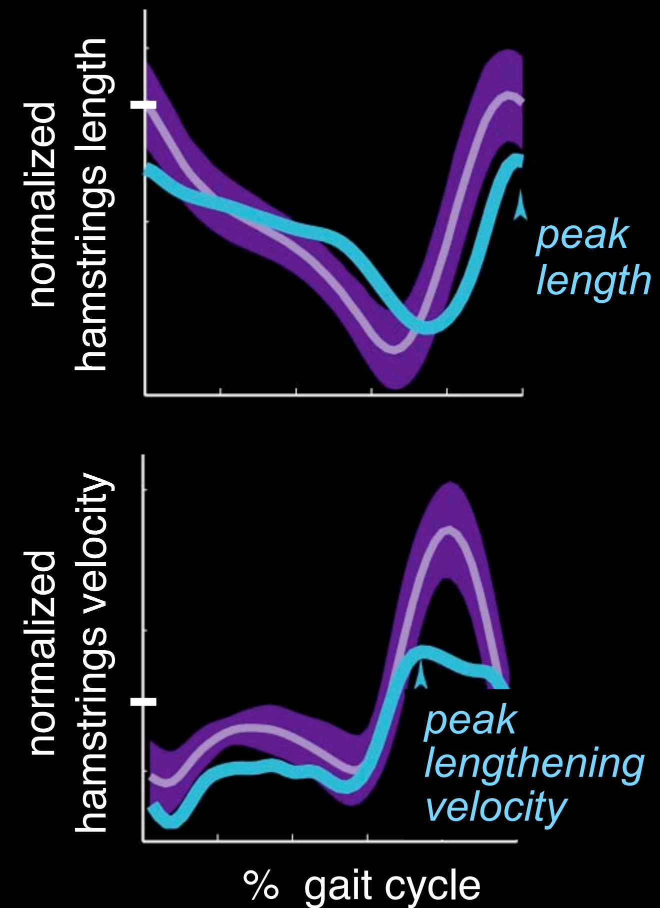
- 152 subjects with spastic cerebral palsy
- 2 children’s medical centers
- at least 20° of knee flexion in early stance or terminal swing
- **no** rhizotomy
  no prior orthopaedic surgery at hip or knee
  no botulinum toxin within 6 months of exam


Estimation of Muscle-Tendon Lengths & Velocities
3D Gait Kinematics
Musculoskeletal Model
Muscle-Tendon Lengths & Velocities
normalized hamstrings length
normalized hamstrings velocity
% gait cycle

Estimation of Muscle-Tendon Lengths & Velocities

3D Gait Kinematics → **Musculoskeletal Model** → **Muscle-Tendon Lengths & Velocities**

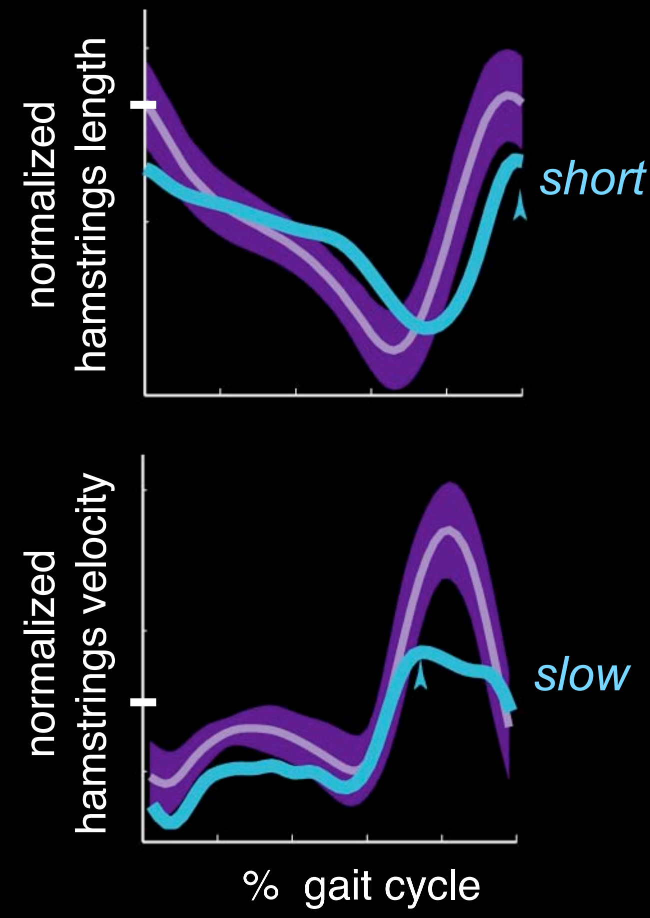
- identified "peak" lengths & velocities of semimembranosus during walking
- normalized data by peak values averaged for 45 unimpaired subjects



Classification of Peak Lengths & Velocities

3D Gait Kinematics → **Musculoskeletal Model** → **Muscle-Tendon Lengths & Velocities**

- classified PRE lengths & velocities:
  short, not short
  slow, not slow



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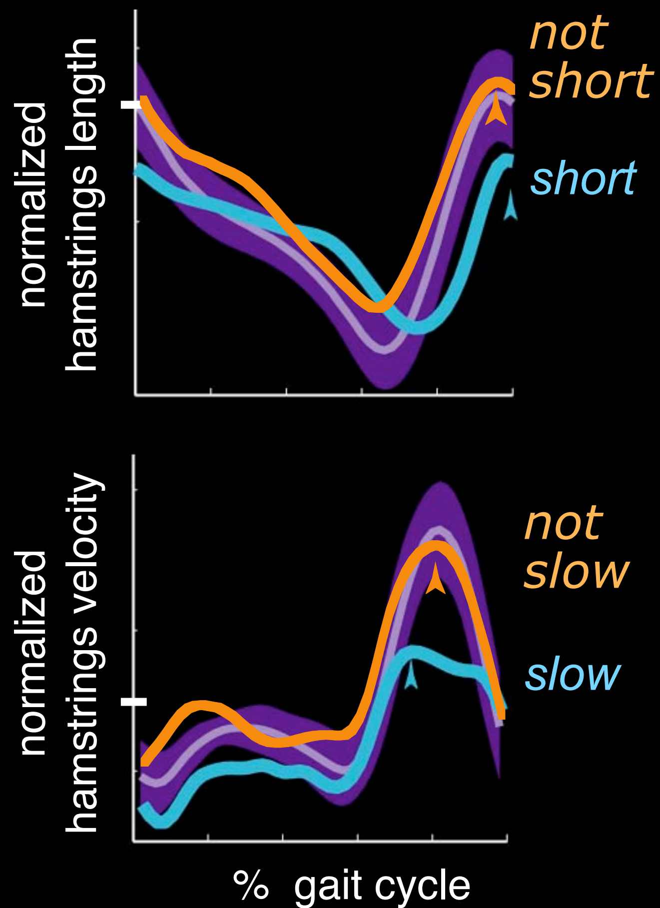
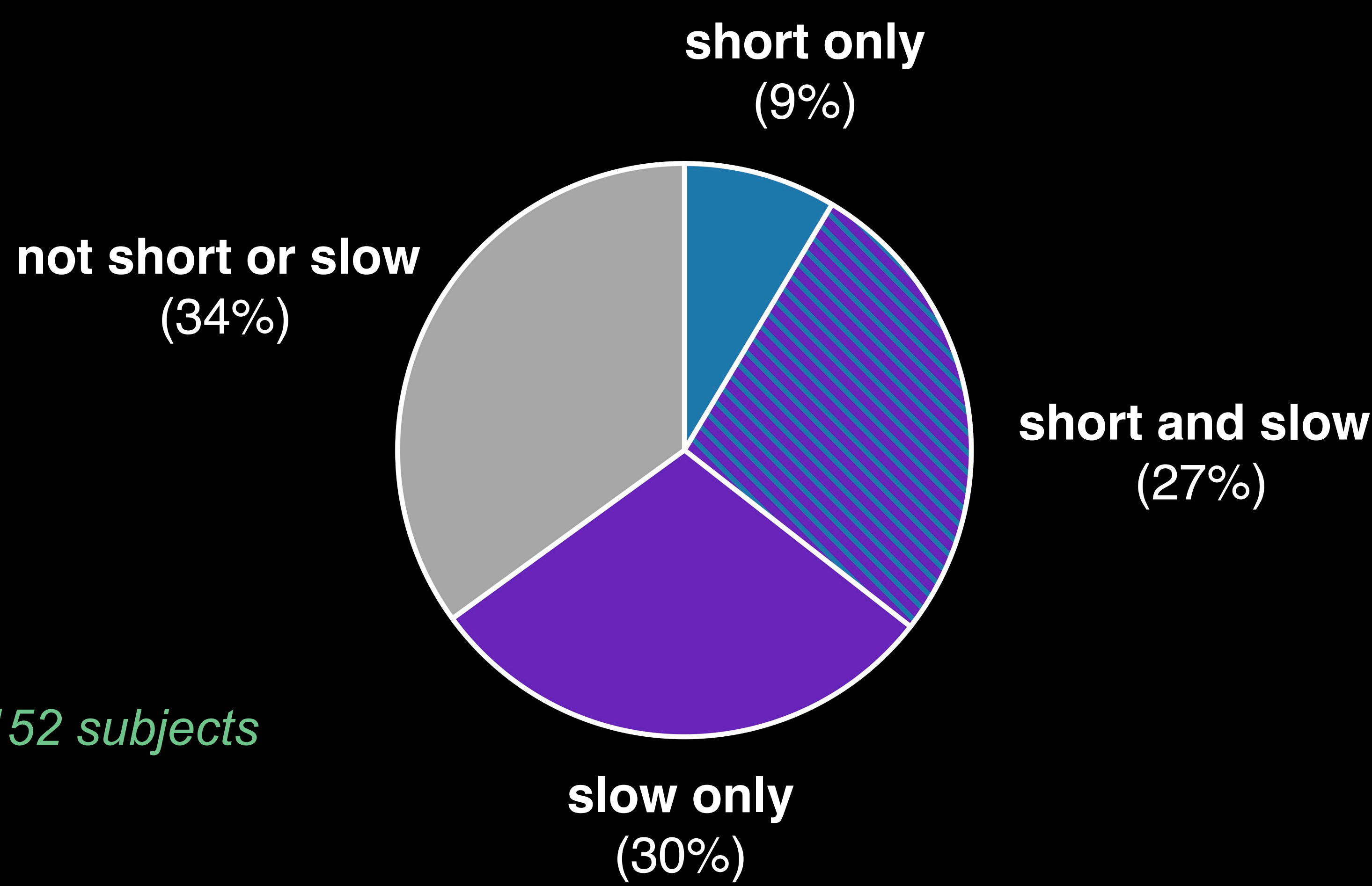


How Many Subjects Walked With Short or Slow Hamstrings?



n = 152 subjects

Did the Hamstrings Operate at Longer Lengths or Faster Velocities after Surgery?

- *Short* hamstrings tended to operate at *longer* lengths ($p < 0.01$)
- *Slow* hamstrings tended to lengthen at *faster* velocities ($p < 0.01$)
- Hamstrings that were ***not*** short or slow did ***not*** tend to operate at longer lengths or faster velocities

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SimTK - the Simulation Toolkit, part of the Simbios project - Windows Internet Explorer

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PROJECT

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Project Administrator

Chand John
Contact

Eran Guendelman
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Michael Sherman
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Scott Delp
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Frank Clay Anderson
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Ayman Habib
Contact

Paul Mitiguy
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Peter Eastman
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OpenSim

Overview

OpenSim is an open-source software system that lets users develop models of musculoskeletal structures and create dynamic simulations of movement. The software provides a platform on which the biomechanics community can build a library of simulations that can be exchanged, tested, analyzed, and improved through multi-institutional collaboration. The underlying software is written in ANSI C++, and the graphical user interface (GUI) is written in Java. OpenSim technology makes it possible to develop customized controllers, analyses, contact models, and muscle models among other things. These plugins can be shared without the need to alter or compile source code. Users can analyze existing models and simulations and develop new models and simulations from within the GUI.

Purpose Provide easy-to-use, extensible software for modeling, simulating, controlling, and analyzing the neuromusculoskeletal system.

Audience Biomechanics scientists, clinicians, and developers who need software tools (or code) for modeling and simulating motion and forces for neuromusculoskeletal systems.

Project Lead

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Eran Guendelman
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Scott Delp
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Frank Clay Anderson
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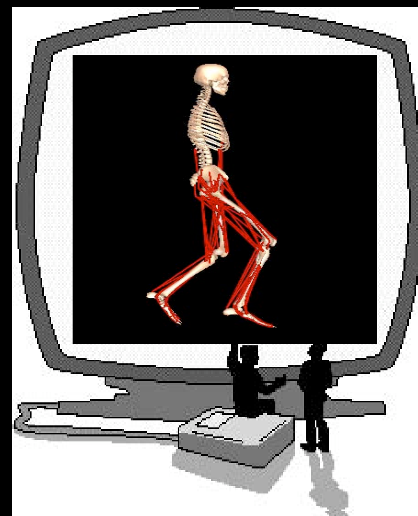
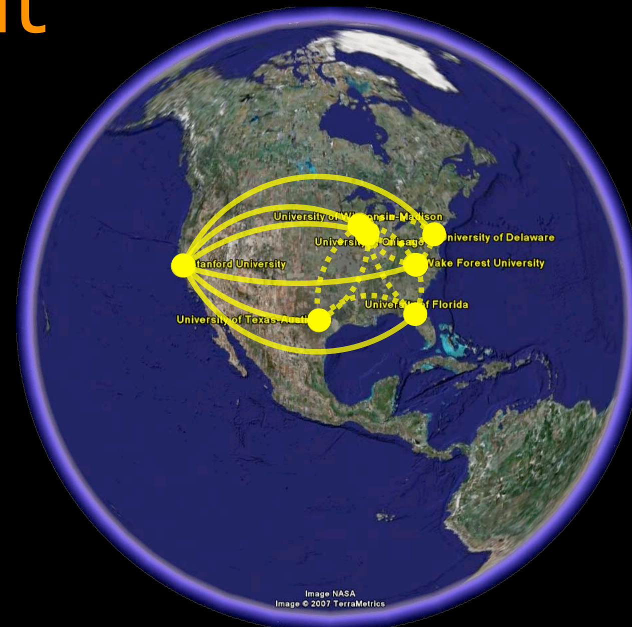
Internet | 100%


EXIT

Simulation Toolkit





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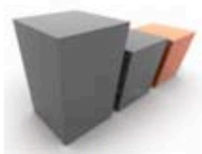
Enabling groundbreaking biomedical research by providing open access to high-quality simulation tools, accurate models and the people behind them.

About SimTK

SimTK, the Simulation Tookit, is part of the **Simbios** project funded by the National Institutes of Health. Learn more.

Simbios Sites

NIH Center for Physics-based Simulation



Simbiome

Biomedical Computation Review

Biological Application Areas

Biomolecular Simulation - Current Emphasis

RNA Folding
RNA, even more than DNA, implements its functions using complex structural strategies.

Myosin Dynamics
Myosin is the fundamental source of motive force in many living systems.

Cardiovascular Dynamics
The dynamics of fluid flow through the human cardiovascular system has many clinical applications, including surgical bypass planning.

Neuromuscular Biomechanics
The modeling of human motion has applications in the planning of interventions to assist patients with abnormal movement dynamics, resulting for example from cerebral palsy.

Simulation Applications

Free downloadable stand-alone simulation software

Simulation Technology

The underlying algorithms and computational tools applicable to a variety of biological application areas.

How to Contribute

Featured Project

SimTK ToRNADo RNA 3D Structure Morphing and Visualization Application

SimTK ToRNADo is a dynamic visualization tool for coarse grain (lumped) representations of RNA and/or protein structure.

Feedback | Simbios | BCR | Our Pledge Your Responsibility

SimTK, the Simulation Toolkit, is a part of the Simbios project funded by the National Institutes of Health through the NIH Roadmap for Medical Research, Grant U54 GM072970. Information on the National Centers for Biomedical Computing can be obtained here.

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