Introduction

Articular cartilage mechanics are determined by complex interactions across multiple scales involving movement dynamics, neuromuscular coordination, ligament mechanics, and cartilage morphology and internal microstructure.

Simulating the contributions of these factors to knee behavior can enhance our understanding of knee pathologies, e.g., osteoarthritis, and enable improvements in clinical treatments.

We developed a multiscale knee model and simulation framework that leverage recent advancements in musculoskeletal simulation, statistical shape modeling, and high throughput computing (HTC) [1]. The framework is used to stochastically simulate muscle, ligament and cartilage mechanics during complex movements such as gait.

Monte Carlo Type Analyses
IMAG/OpenSim Webinar, 2016 [5]

Stochastic Simulation Framework
High Throughput Computing (HTC)
Worker Nodes

- Desktop PC
- Submit Server

- 0.5 hours: 1 simulation on desktop PC
- 2 hours: 2000 simulations on HTC grid

Statistical Shape Modeling
Clouthier, ORS, 2017

Morphology Effects on Knee Mechanics

- Segmented MRI
- Statistical Shape Model
- A Shallow lateral facet of the trochlear groove increases lateral patellar translation
- Increased frontal plane tibial slope and femoral joint line reduces internal tibial rotation

Simulation Results

- Contact force
- Gait cycle [%]
- Soleus Activation

Clinical Applications
Knee Ligament Injury and Repair
Smith, J Knee Surg, 2016

- Intact
- ACL Deficient
- Menisci Deficient
- ACL + Menisci Deficient

Total Knee Arthroplasty
Smith, J Biomech Eng, 2016

- In Vivo Measurement
- Model Prediction

Pediatric Orthopedics
Lenhart, J Biomech, 2017

- Pre-Operative
- Post-Operative

Future Directions
Adouni, J Biomech, 2016

- Molecular Dynamics
- Continuum Mechanics

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References