Workshop on Grand Challenge Competition to Predict In Vivo Knee Loads

B.J. Fregly[1], Darryl D. D'Lima[2], and Thor Besier[3]

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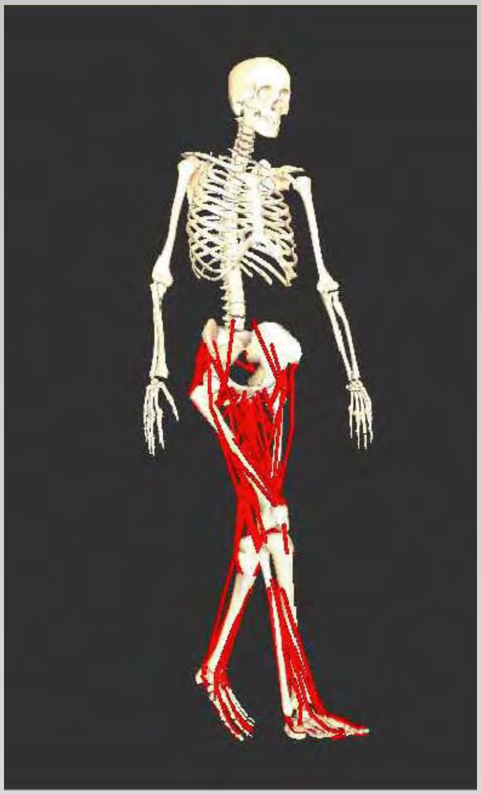
[2]Shiley Center at Scripps Clinic, La Jolla, CA
[3]Stanford University, Stanford, CA

The Ultimate Goal

- Why are we here this morning?
- What do we hope to achieve?

Our ultimate goal is clinical utility of musculoskeletal computer models.

The Ultimate Goal



Muscle loads
Cartilage loads
Ligament loads
Bone loads
Motion patterns

→ Osteoarthritis
→ Stroke
→ Cerebral palsy
→ Paraplegia

Standard Treatment Design

Currently, treatment design for neuromusculoskeletal disorders involves the following steps:

1. Observe what has worked well for previous patients.
2. Create implicit, mental model of patient.
3. Guess best treatment parameters for current patient.
4. Apply treatment and iterate if possible/necessary.

Treatment planning is highly subjective
and outcome is often variable for different patients.

Standard Treatment Design

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4. Apply treatment and iterate if possible/necessary.

"One size fits none"

Treatment planning is highly subjective
and outcome is often variable for different patients.

Personalized Treatment Design

In the future, treatment design for neuromusculoskeletal disorders could involve the following steps:

1. Observe what has worked well for previous patients.
2. Create explicit, computational model of patient.
3. Perform virtual treatments on patient-specific model.
4. Apply optimized treatment to patient.

Treatment planning becomes objective and outcome can be optimized for each patient.

Personalized Treatment Design

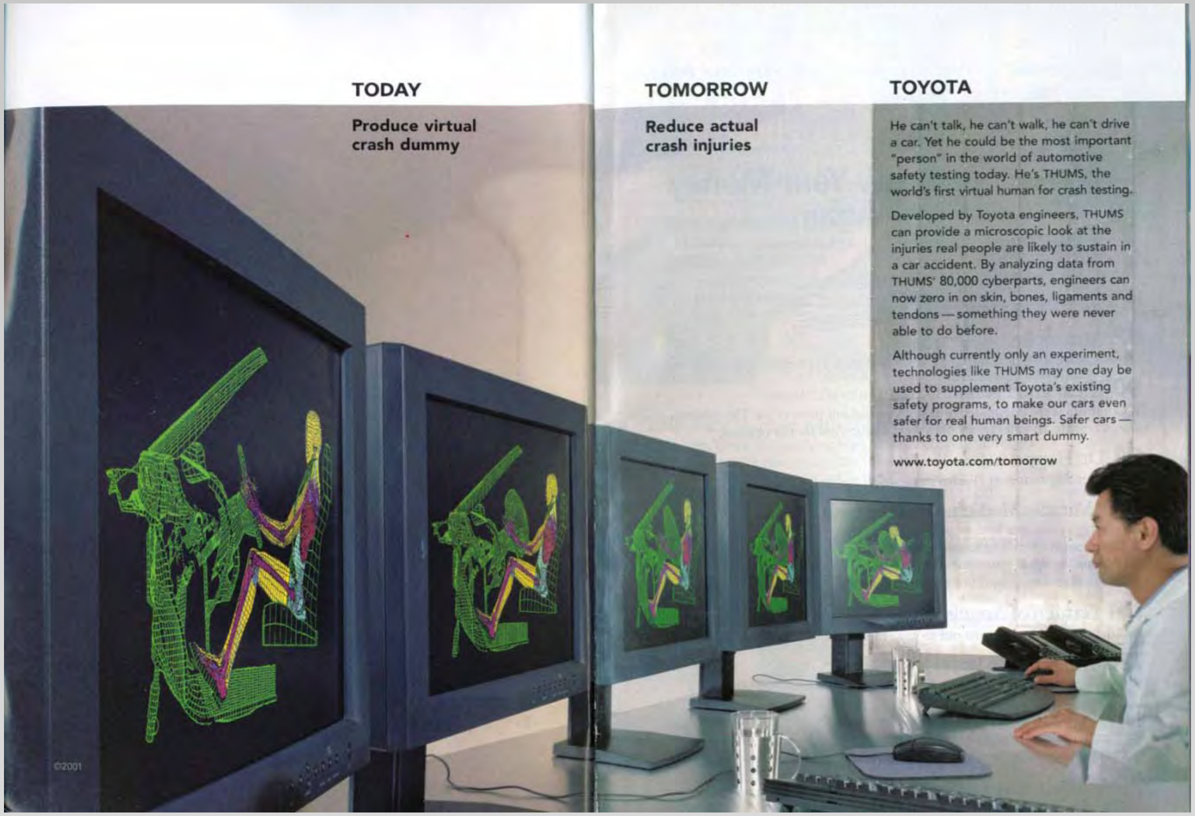
In the future, treatment design for neuromusculoskeletal disorders could involve the following steps:

1. Observe what has worked well for previous patients.
2.
3.
4. Apply optimized treatment to patient.

The National Academy of Engineering has identified “personalized medicine” as one of the 10 grand challenges of the 21st century.

Treatment planning becomes objective and outcome can be optimized for each patient.

Virtual Prototyping

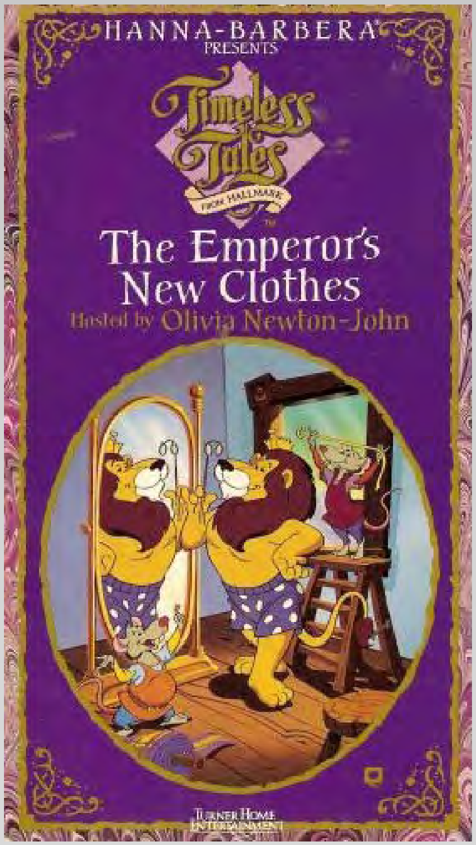


Barriers to Clinical Utility

1) Model Creation
   - Automated patient-specific calibration
   - No special engineering/programming skills
   - Computationally "fast"
2) Model Utilization
   - "Clinically useful locomotion measures"
   - Identification of such measures
   - Calculation of such measures
3) Model Validation
   - Accuracy of calculated measures
   - Challenge of unmeasurable quantities
   - Limitations in modeling capabilities

“The Emperor’s New Clothes”

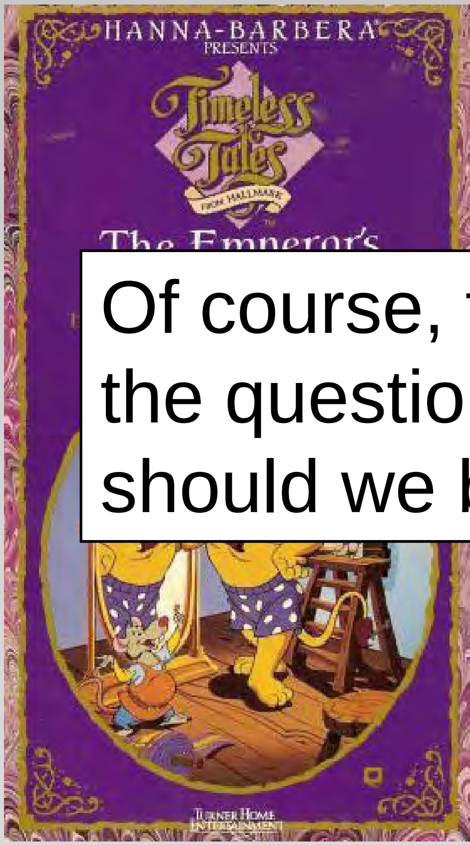
Computational Biomechanics Laboratory



Do we have a similar phenomenon in the musculoskeletal modeling community?

- Many publications that predict muscle and contact forces using unvalidated methods.
- Significant research funding going to projects that are making unvalidated predictions.
- Statements being made about clinical conditions and treatments based on unvalidated predictions.

"The Emperor's New Clothes"



Do we have a similar phenomenon in the musculoskeletal modeling community?

- ... and ... ods.
- ... predictions.
- Statements being made about clinical conditions and treatments based on unvalidated predictions.

Of course, the answer depends in part on the question we are trying to answer, but should we be more critical of our own work?

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Workshop Objective

To introduce you to a “grand challenge” competition, to be held next summer at the SBC, to critically evaluate *in vivo* muscle and contact force predictions at the knee during gait using data collected from a patient with a force-measuring knee replacement.

Big Picture

- We provide the *in vivo* data (minus the implant loads).
- You predict the muscle and contact forces.
- We evaluate the contact force predictions quantitatively.
- Best predictions are presented in a special session.
- Actual contact forces are revealed in the session.
- Winner is closest to the measured contact forces.

Rationale

In vivo measurement of muscle forces would be required for direct quantitative validation of muscle force predictions.

Though indirect, *in vivo* measurement of contact forces is the next best option for quantitative validation, since muscle forces are the primary determinants of joint contact forces (Herzog *et al*., 2003).

Workshop Outline

1. Motivation for Competition (B.J. Fregly)
2. Instrumented Implant Designs and Accuracy (Darryl D'Lima)
3. Experimental Data Collection (Thor Besier)
4. Modeling Results To Date (B.J. Fregly)
5. Logistics of Competition (Darryl D'Lima)
6. Questions and Answers (All)

Reminder

Please sign the attendance sheet if you want to receive e-mail updates about organization of the competition.

Workshop Outline

1. Motivation for Competition (B.J. Fregly)
2. Instrumented Implant Designs and Accuracy (Darryl D’Lima)

2. Instrumented Implant Design and Accuracy

Darryl D. D'Lima, M.D., Ph.D.
Director, Orthopaedic Research Laboratories
Shiley Center for Orthopaedic Research & Education
Scripps Clinic, La Jolla, CA

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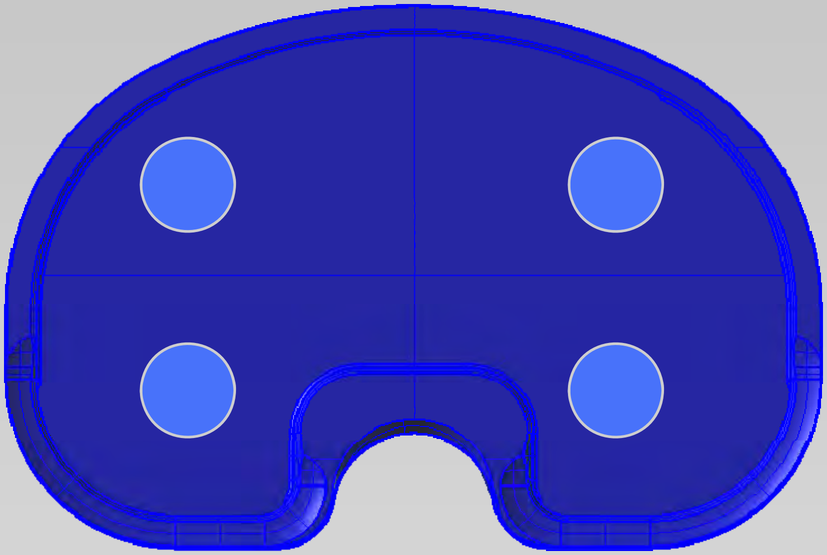
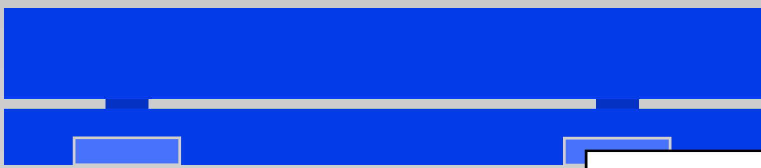
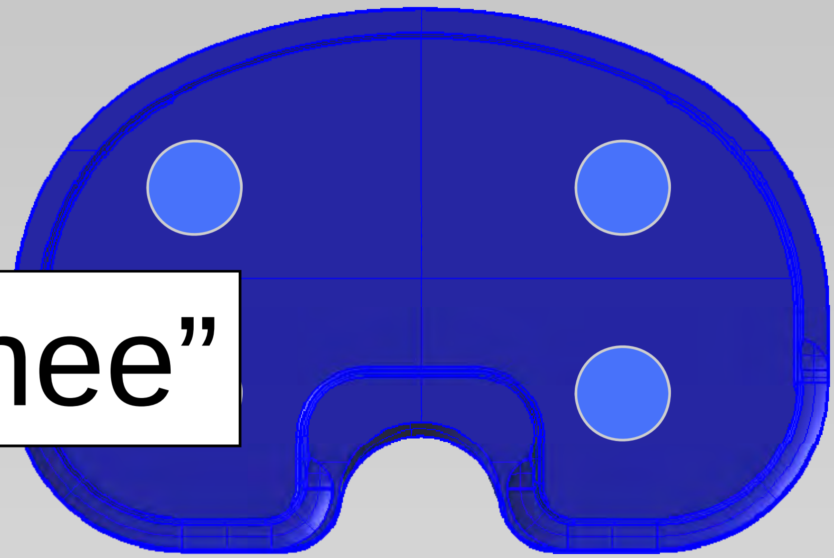
Generation I Tray Design



- **Axial Load Cells** (4)
  - Total Load
  - Mediolateral Distribution
  - Center of Pressure
  - AP/ML Moments
  - Shear
  - Axial Moment

Generation I Tray Design





“eKnee”

- **Axial Load Cells** (4)
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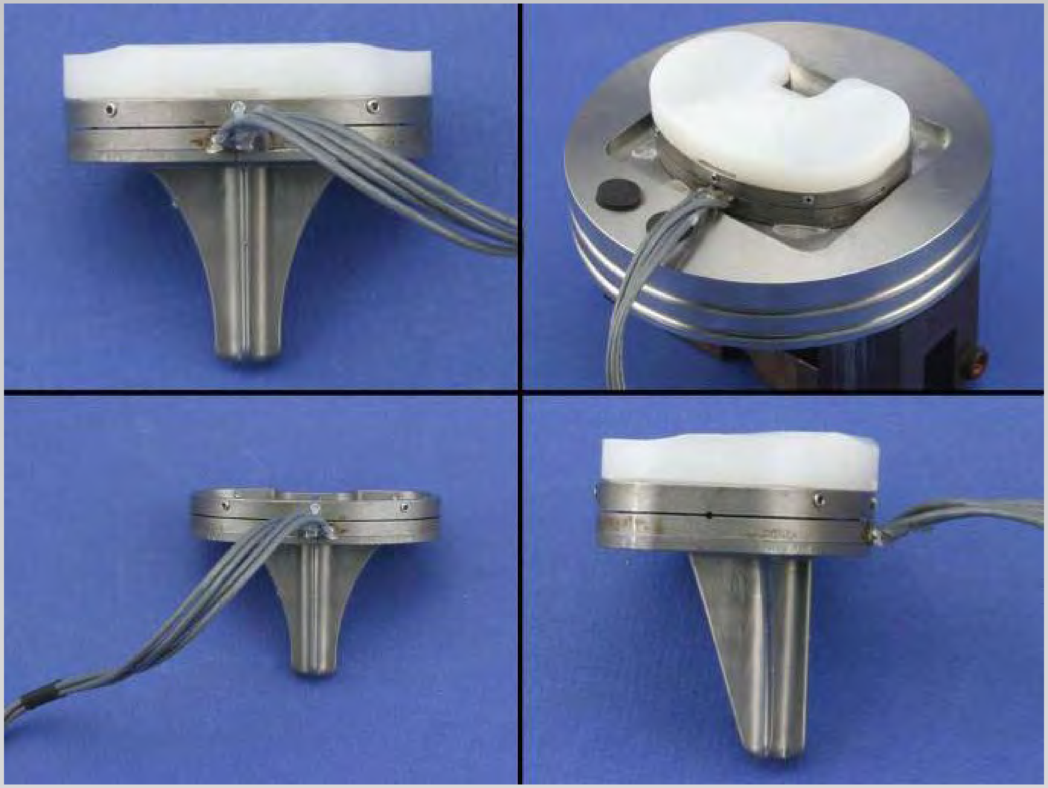
Generation I Tray Design



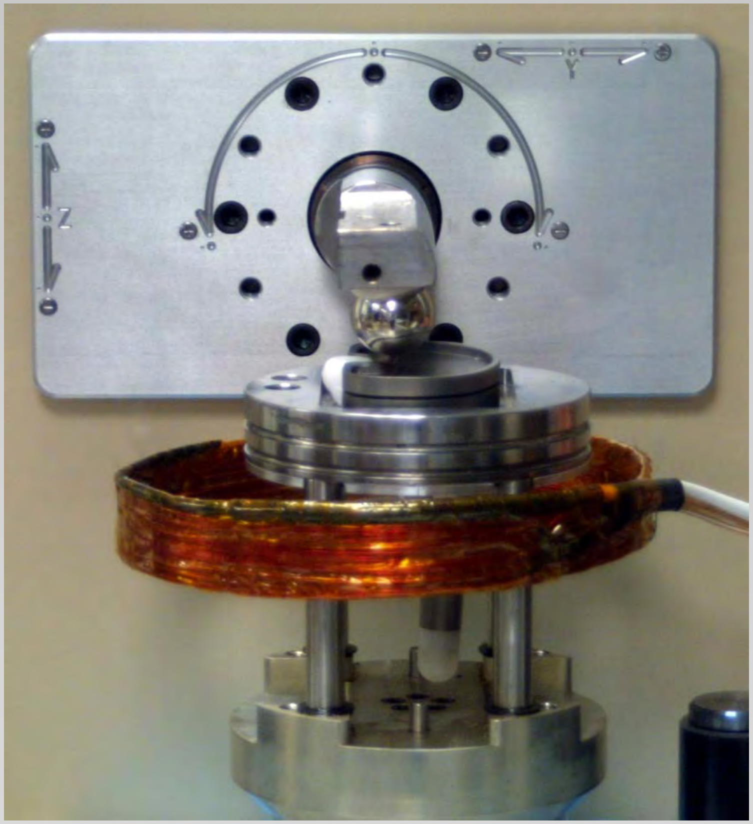
2. Implant Design and Accuracy

Generation I
Calibration Accuracy

- NIST Load cell
- $R^2 > 0.99$
- AAE Axial Force < 1.1% FS
- Shear cross-talk <0.3%
- AAE Center of Pressure <0.25 mm

Kaufman +, J Biomech 1996

Generation I
Calibration Accuracy

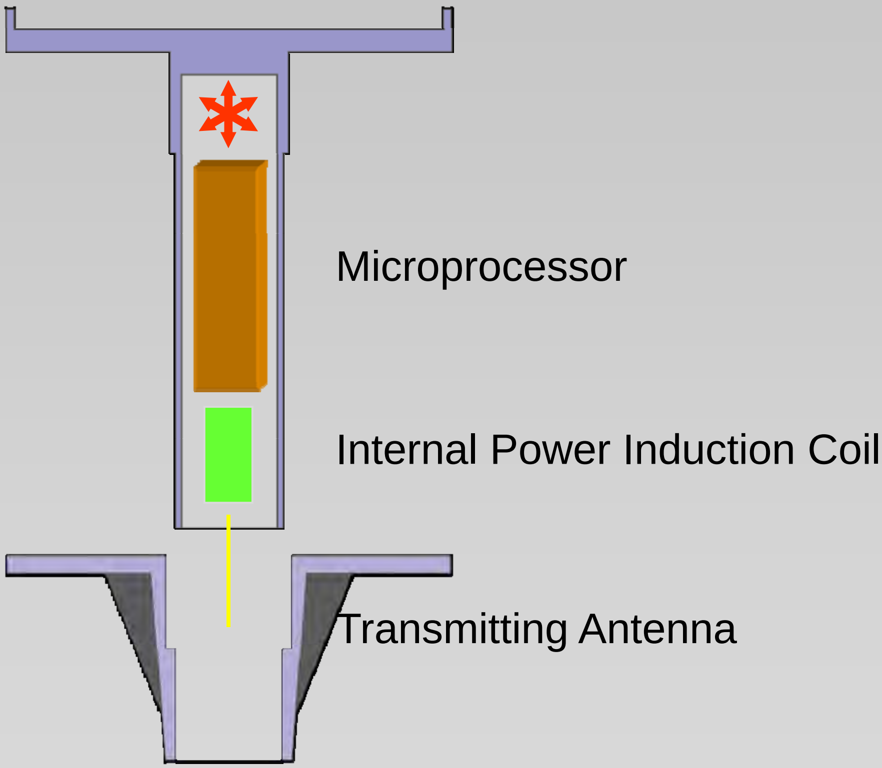


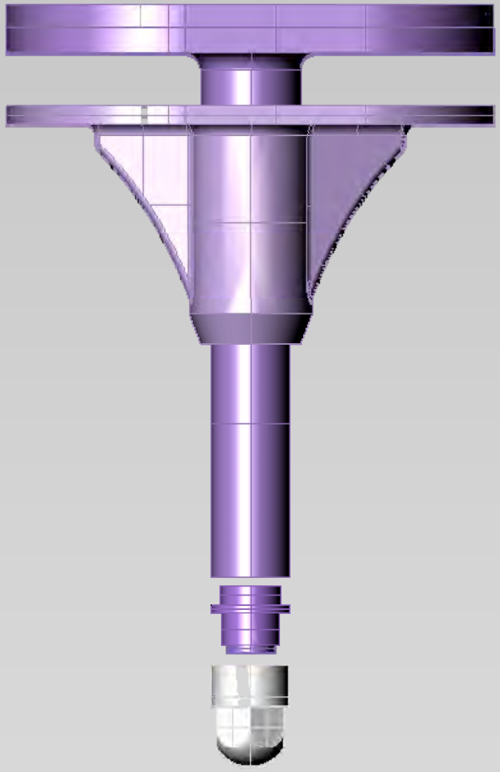
Generation I
Calibration Accuracy

- NIST Load cell
- $R^2 > 0.99$
- AAE Axial Force < 1.5% FS
- AAE Center of Pressure < 1.9 mm

D'Lima +, J Biomech 2005

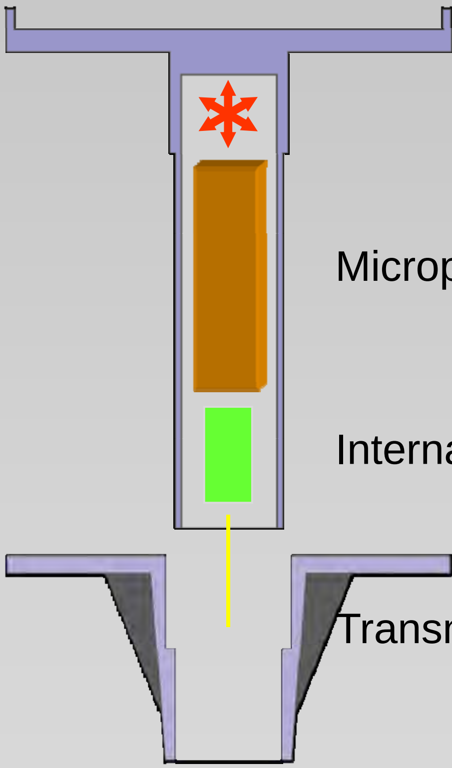
Generation II Tray Design



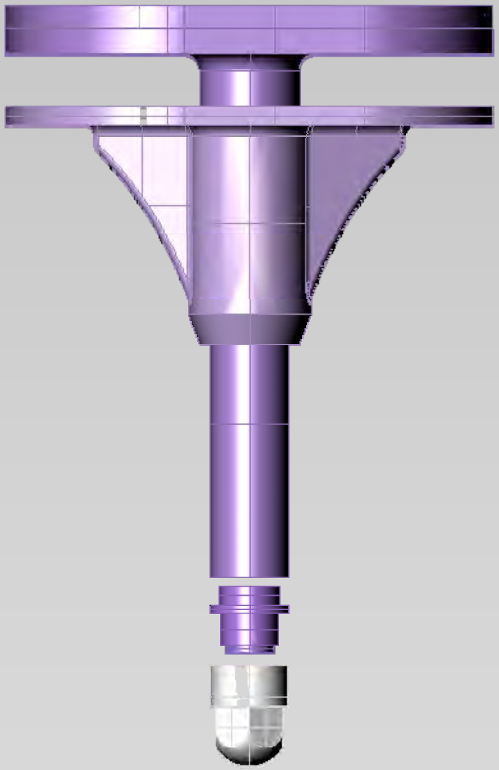


Kirking +, J Biomech, 2005

Generation II Tray Design

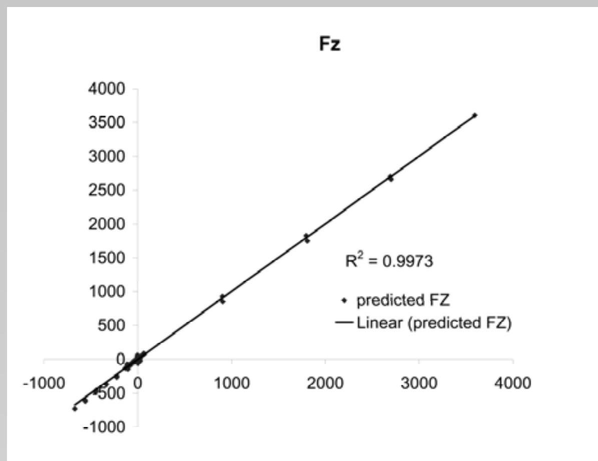


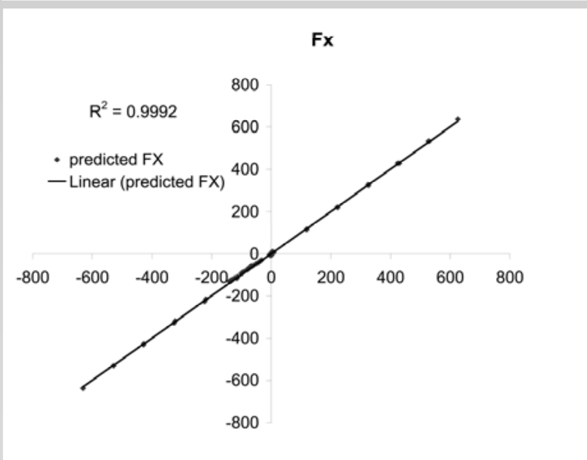
“eTibia”

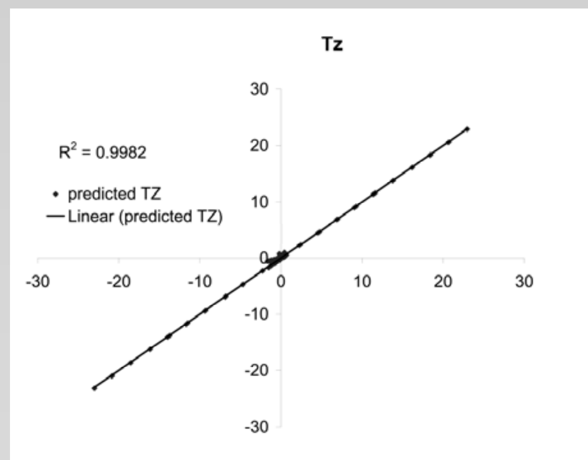


Kirking +, J Biomech, 2005

Generation II
Calibration Accuracy







Kirking +, J Biomech 2006

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2. Implant Design and Accuracy

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Generation II
Calibration Accuracy

Table 1
Calibration error analysis

	F_x	F_y	F_z	T_x	T_y	T_z
AAE	0.67	1.00	3.92	0.15	0.15	0.16
MAE	2.54	4.73	14.80	0.65	0.85	1.12
R^2	0.999	0.998	0.997	0.998	0.999	0.998

AAE = average absolute error (N for F_x, F_y, F_z; N m for T_x, T_y, T_z).
MAE = maximum absolute error (N for F_x, F_y, F_z; N m for T_x, T_y, T_z).

Kirking +, J Biomech 2006

Generation II
Calibration Accuracy

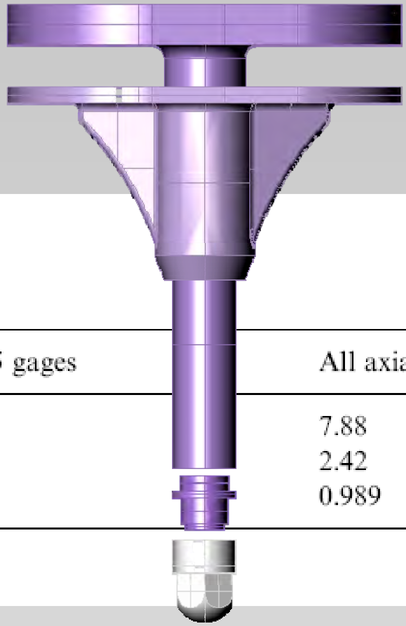

Table 2
Effect of loss of strain gages on accuracy

Loss of:	Any one gage	All −45 gages	All +45 gages	All axial gages
AAE	4.18	3.33	3.36	7.88
MAE	18.05	4.14	3.11	2.42
R^2	0.997	0.997	0.996	0.989

Kirking +, J Biomech 2006

Temperature Tests

- Water Bath 42°C
- High Temperature Burn-In 80°C

Durability Tests

- Shaker Tests
- Prototypes & Implantable Grade Units
  - +12 years

Data Transmission

- Power Channel
- Temperature Channel
- 12 Data Channels
- Start byte
- Checksum byte
- 2 ms delay

Conclusions

1. High sensor accuracy
2. Robust measurements
3. Consistent *in vivo* measurements

Acknowledgments

SCORE
Clifford Colwell, MD
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NIH R21 EB004581
NIH R21 AR057561
SCORE

Microstrain
Steve Arms
Christopher Townsend

Zimmer, Inc
Janet Krevolin
Todd Johnson

Workshop Outline

1. Motivation for Competition (B.J. Fregly)
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3. Experimental Data Collection (Thor Besier)

3. Experimental Data Collection

Thor Besier, Ph.D.
Research Director, Human Performance Lab
Department of Orthopaedics
Stanford University, Stanford, CA

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Organizers

Main Organizers

- Darryl D'Lima, Shiley Center at Scripps Clinic
- B.J. Fregly, University of Florida

EMG Data

- Thor Besier, Stanford University
- David Lloyd, University of Western Australia

Strength Data

- Marcus Pandy, University of Melbourne

Subject Description

- Subject: JW
- Gender: Male
- Age: 83 yrs
- Height: 166 cm
- Mass: 64.6 kg
- Right knee, generation I implant design
- Anthropometric data available from calibrated subject-specific skeletal model (Reinbolt *et al*., 2008)

Session Description

- Gait and other motion data collected in the morning.
- Strength data collected in the afternoon.
- Fluoroscopic motion data reported previously (Zhao *et al*., 2007).

Task Summary

Session 1: Gait Laboratory

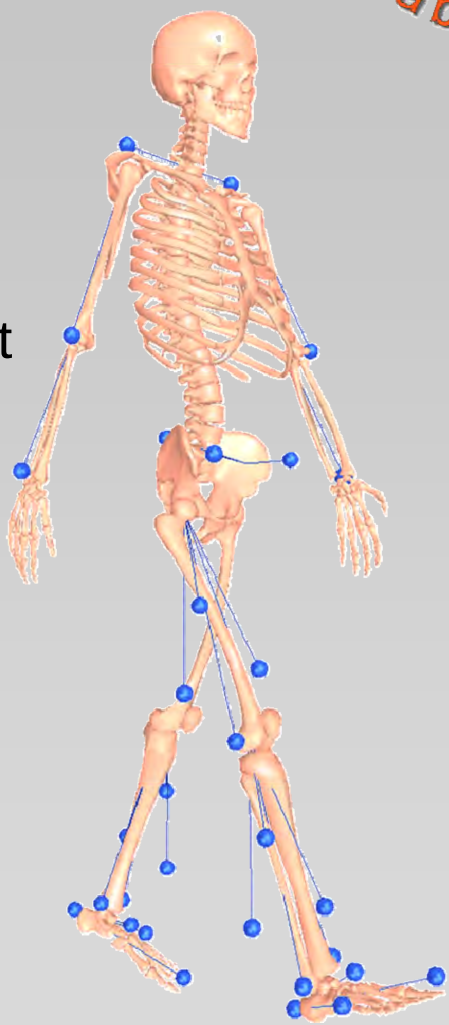
- Static trials
- Inverse dynamic model calibration
  – Hip, knee, and ankle isolated motion
- Musculoskeletal model calibration
- Medial-lateral load manipulation
- Gait trials (4 types)

Session 2: Dynamometer Laboratory

- Isometric, isokinetic, and passive dynamometry

Gait Lab Data

- Marker trajectories
  - 8-camera Motion Analysis system
  - Modified Cleveland Clinic marker set
- Ground reaction forces
  - 3 Bertec force plates
- Surface EMG
  - 14 muscles
  - Delsys Bagnoli EMG system
- Joint contact forces
  - eKnee: as described previously



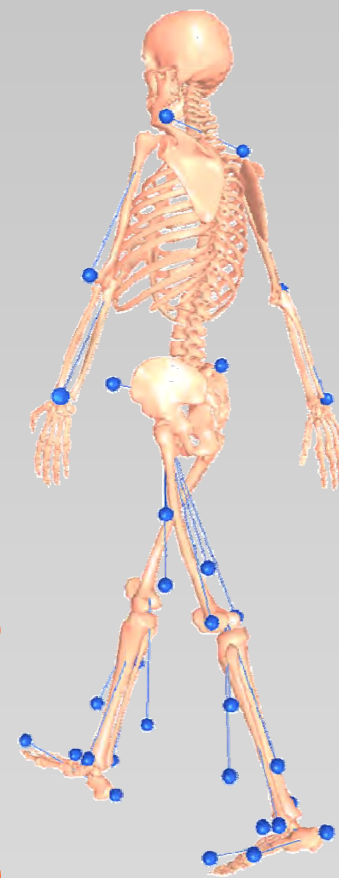
Dynamometer Lab Data

- Knee flexion angle
  - Goniometer & Biodex angle
- Joint torque (gravity corrected)
  - Biodex
- Surface EMG
  - 14 muscles
  - Delsys Bagnoli EMG system
- Joint contact forces
  - as described previously

Biodex dynamometer

Surface Marker Data

1-2 : Shoulder
3-4 : Elbow
5-6 : Wrist
7-8 : ASIS
9 : Sacrum
10-15 : Thigh superior, inferior, lateral
16-19: Knee medial and lateral (static only)
20-21 : Patella
22-27 : Shank superior, inferior, lateral
28-31: Ankle medial and lateral (static only)
32-33 : Heel
34-37 : Midfoot lateral and superior
38-39 : Toe tip
40-43 : Toes medial and lateral (static only)



Surface EMG Data

1. Semimembranosus
2. Biceps femoris
3. Vastus medialis
4. Vastus lateralis
5. Rectus femoris*
6. Medial gastrocnemius
7. Lateral gastrocnemius
8. Tensor fascia latae*
9. Tibialis anterior
10. Peroneus longus
11. Soleus
12. Adductor magnus
13. Gluteus maximus
14. Gluteus medius*

Electrode placement consistent with Perotto & Delagi (1980)

* Indicates double-differential electrode

EMG Preparation Trials

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- Skin shaved and abrased with gauze and then rubbed with alcohol prior to electrode placement
- Manual restraint of subject during maximum isometric voluntary contractions (3 repetitions):
  - Hip flexion-extension (standing)
  - Knee flexion-extension (seated w knee @ 80°)
  - Ankle dorsiflexion (seated w knee @ 40°; ankle @ 0° dorsiflexion)
  - Ankle plantarflexion (seated w knee @ 40° and standing tip-toes)
  - Ankle inversion-eversion (seated w knee @ 40°)

- Resting signals obtained during quiet sitting

Static Trials

- Standing (toes forward, toes in, toes out)
- Sitting
- Maximum isometric contraction

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Model Calibration Trials

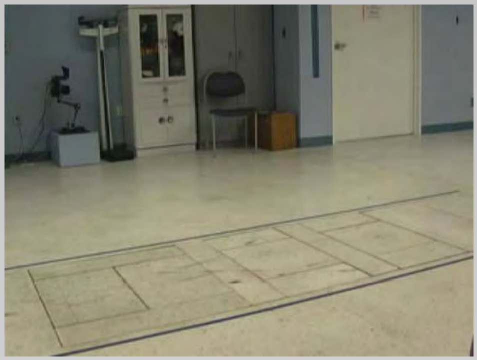
- Passive seated leg rest
- Unloaded seated leg extension
- Loaded seated leg extension
- One-legged standing
- Two-legged squat
- Chair rise
- Calf raise

Load Manipulation Trials

- Varus-valgus stress test
- Stance initiation tests

Gait Trials

- Normal gait
- Medial thrust gait
- Walking pole gait
- Trunk sway gait



Dynamometer Trials

- Isometric, passive, and isokinetic knee flexion/extension
- Isometric, passive, and isokinetic ankle plantarflexion/dorsiflexion

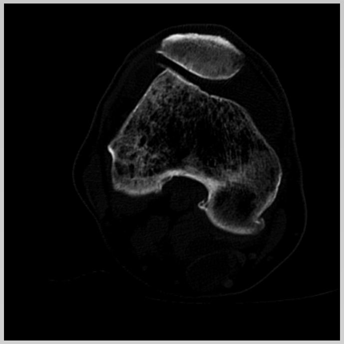
Data To Be Made Available

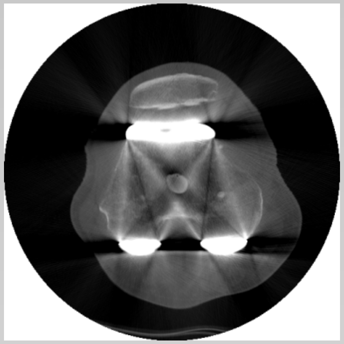
- EMG preparation trials
- Static trials
- Model calibration trials
- Gait trials
- Dynamometer trials

minus the eKnee contact forces for competition trials.

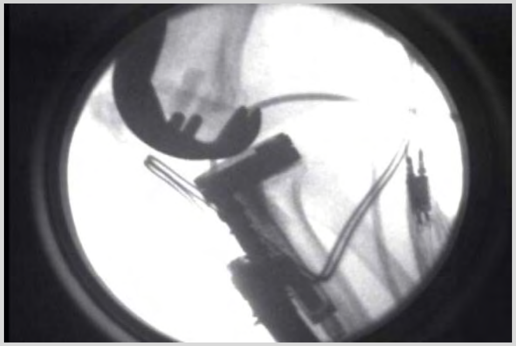
Additional Available Data

- Pre- and post-surgery CT scans of knee region

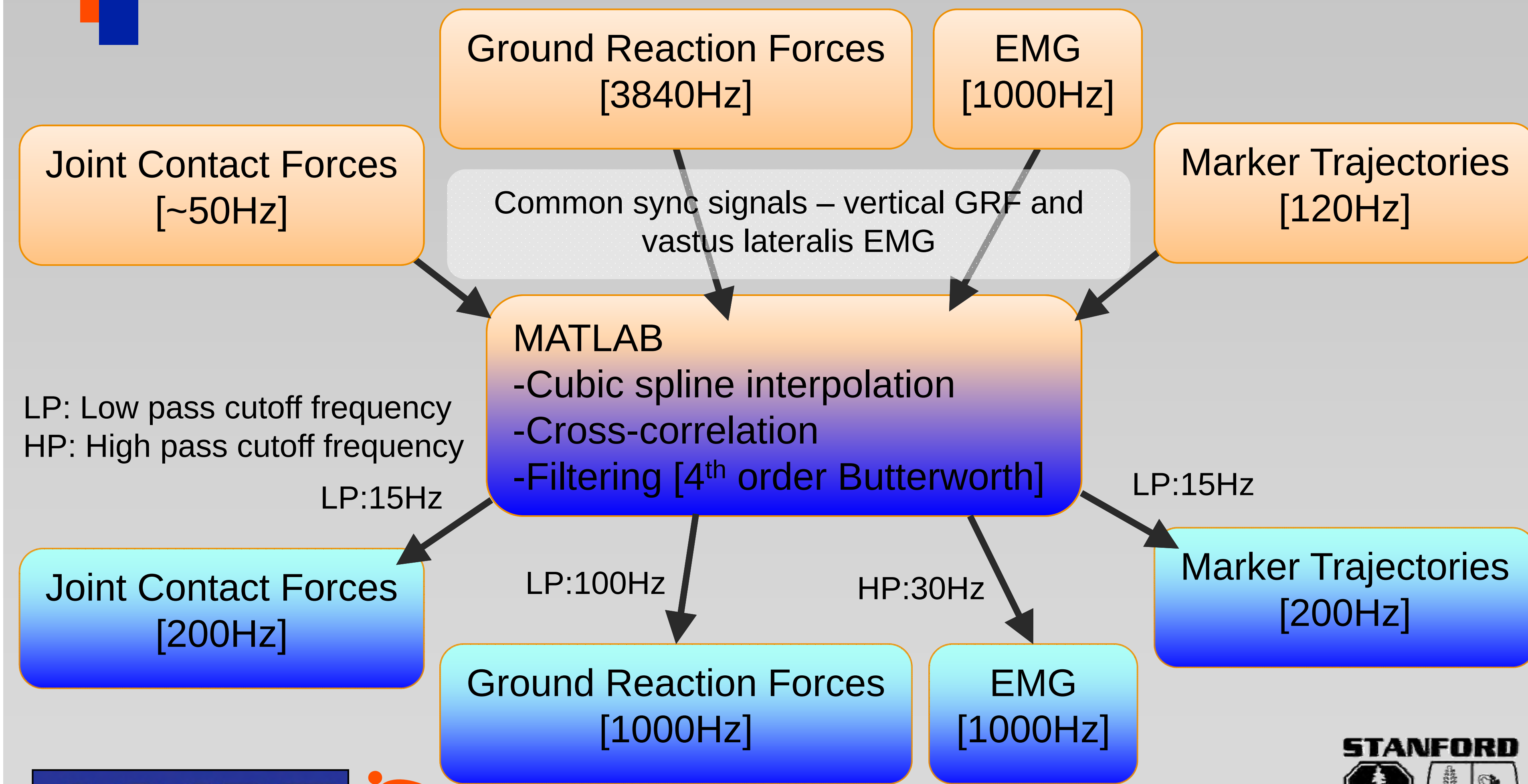




- Fluoroscopic motion measurements for treadmill gait (Zhao *et al*., 2007)



Data Synchronization



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3. Experimental Data Collection

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Acknowledgments

D'Lima

SCORE

Fregly

National Science Foundation

WHERE DISCOVERIES BEGIN

Besier

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4. Modeling Results To Date (B.J. Fregly)

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4. Modeling Results to Date

B.J. Fregly, Ph.D.

Department of Mechanical & Aerospace Engineering,
Department of Biomedical Engineering, and
Department of Orthopaedics & Rehabilitation
University of Florida, Gainesville, FL

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Previous Studies

1) First eKnee Data Set

Study 1 - Correlation between the knee adduction moment and medial contact force within the gait cycle

Study 2 - Estimation of muscle and contact forces in the knee during gait

2) Second eKnee Data Set

Study 3 - Do changes in peak knee adduction moment predict changes in peak medial contact force?

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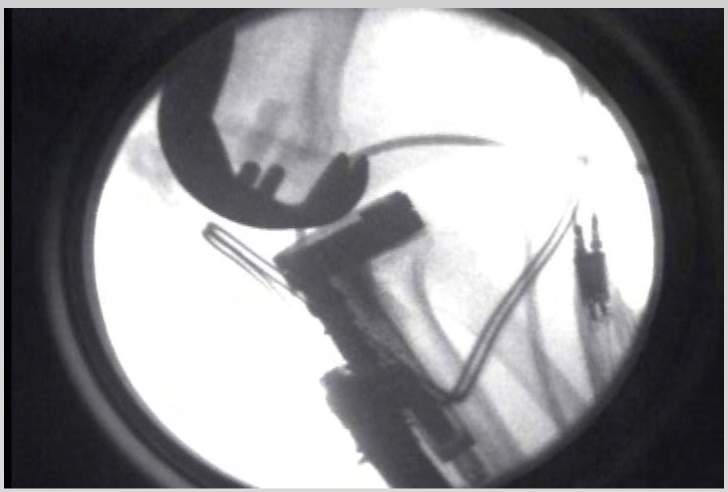
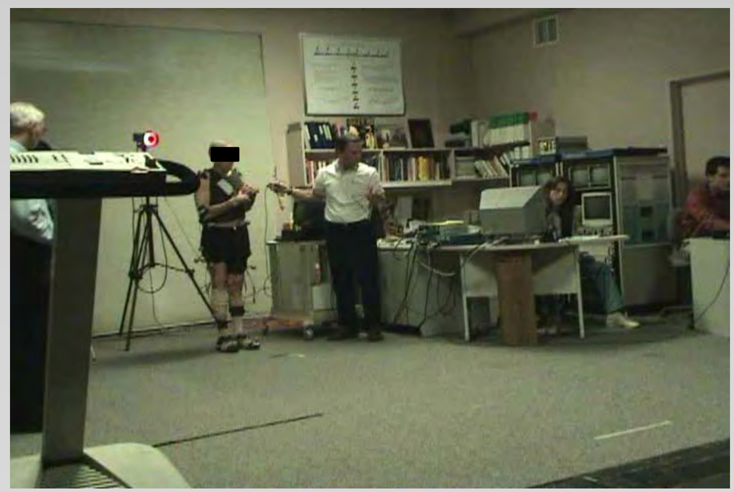
First eKnee Data Set

- Fluoroscopic motion data for treadmill gait, step up/down, kneel, and lunge
- Video motion and ground reaction data for step up/down and 5 gait patterns (normal, fast, slow, toe out, wide)





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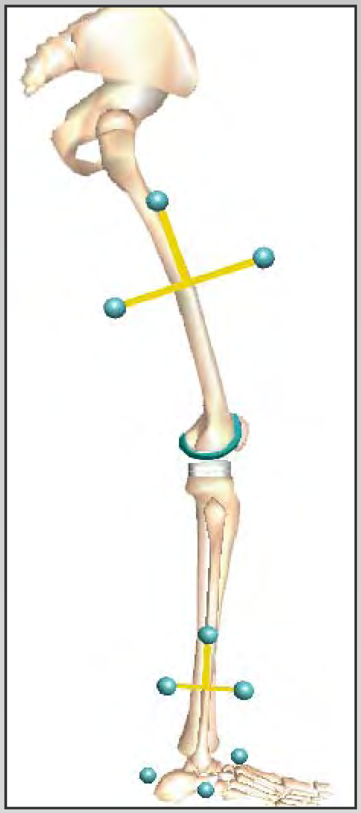
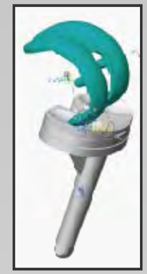
Study 1 Overview

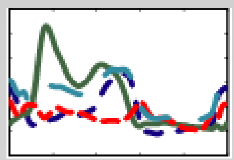
Gait Analysis



In vivo kinematic measurement

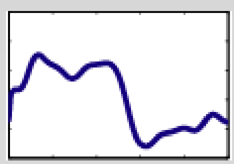
Dynamic Contact Model



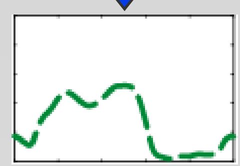


In vivo load measurement

Regression Model



Adduction moment

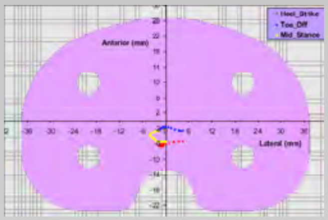


Medial contact force

at Scripps Clinic

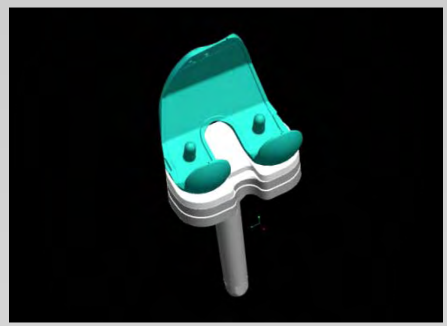
4. Modeling Results to Date

Dynamic Contact Simulation

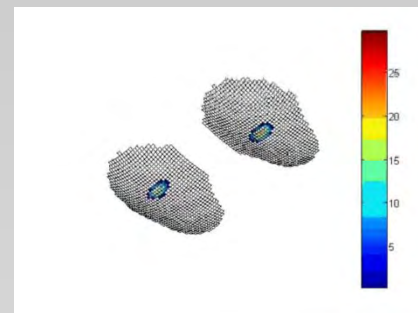


In vivo knee force data

In vivo knee motion data



Dynamic contact model



Contact conditions

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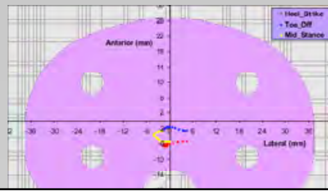
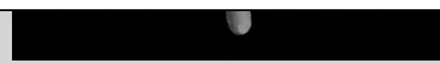
Dynamic Contact Simulation

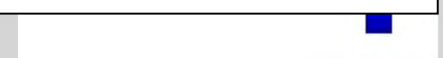


Simulation closely matches eKnee total contact force, eKnee A/P and M/L center of pressure, and fluoroscopic motion measurements.

In vivo knee motion data



Dynamic contact model



Contact conditions

Zhao *et al*., 2007a, *Journal of Orthopaedic Research*

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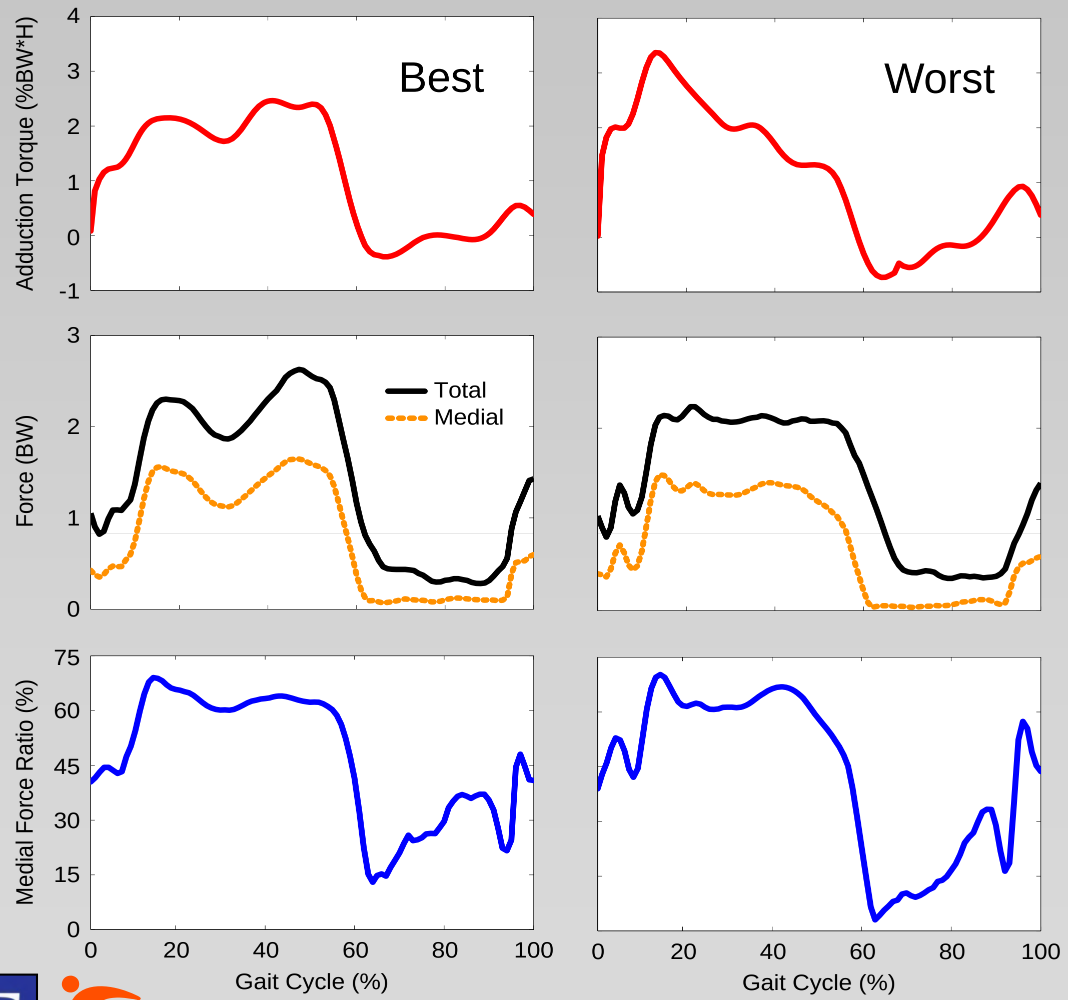
Knee Adduction Moment

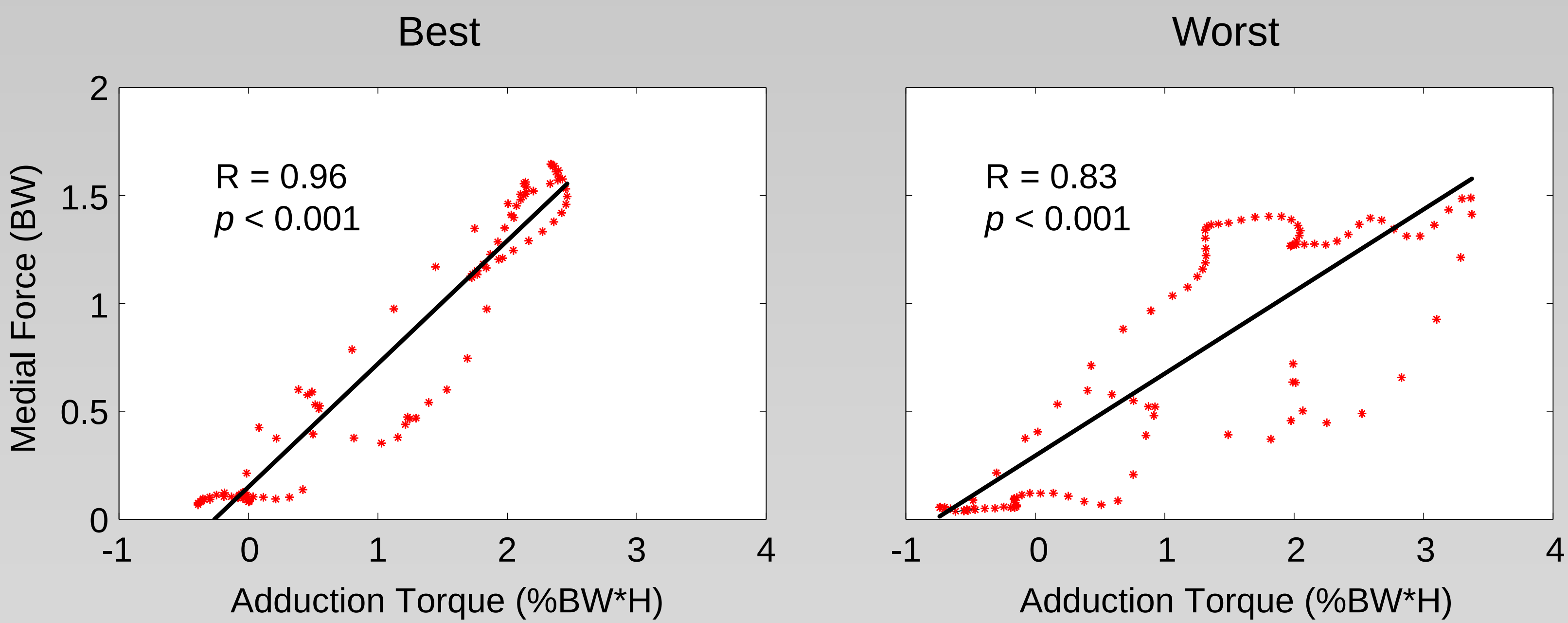
Are knee adduction moment changes within the gait cycle highly correlated with changes in medial contact force?

External-Internal Correlation

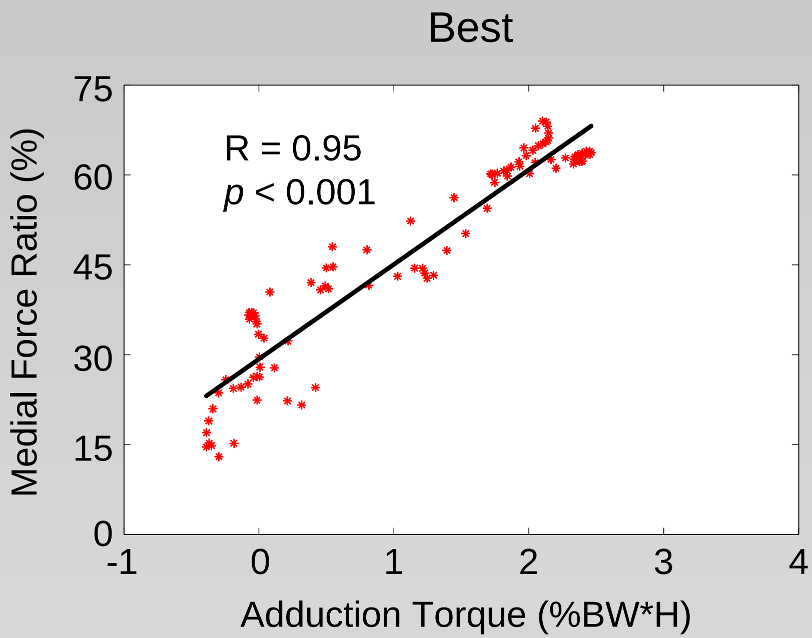


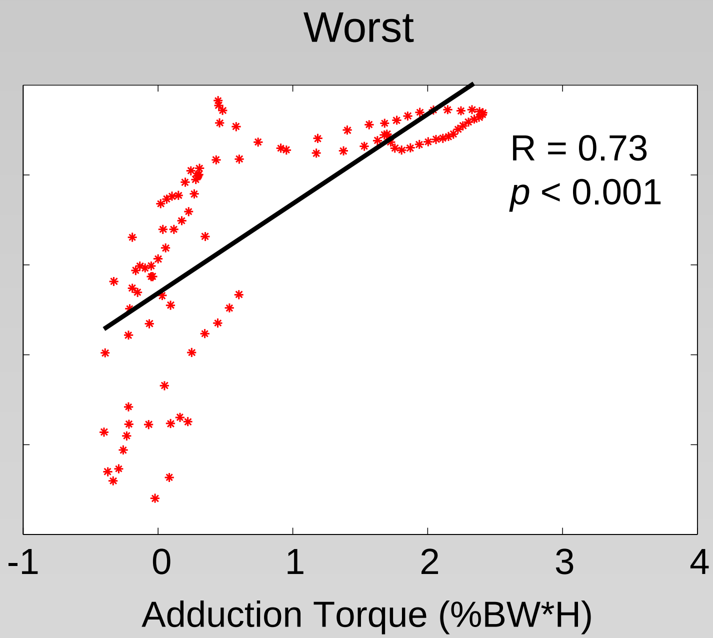
4. Modeling Results to Date

Correlation Coefficients



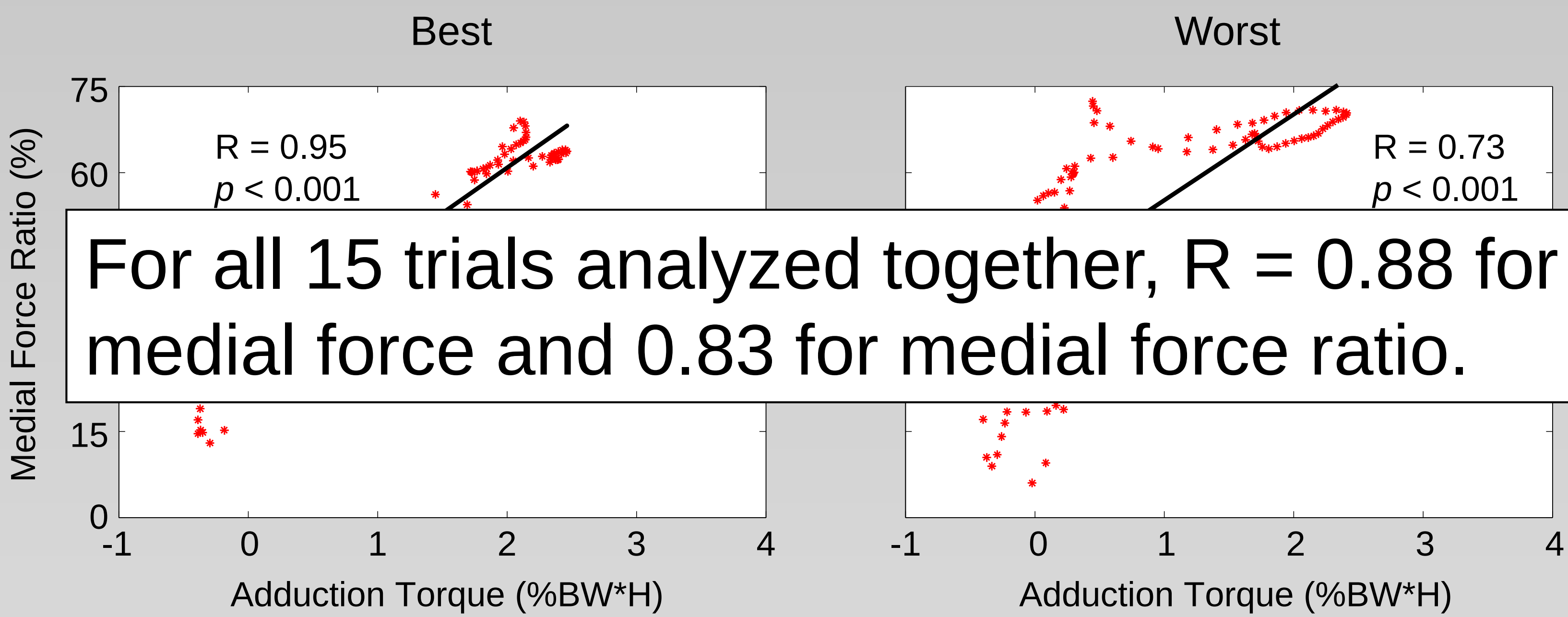
Correlation Coefficients





Zhao *et al*., 2007b, *Journal of Orthopaedic Research*

Correlation Coefficients



For all 15 trials analyzed together, R = 0.88 for medial force and 0.83 for medial force ratio.

Zhao *et al*., 2007b, *Journal of Orthopaedic Research*

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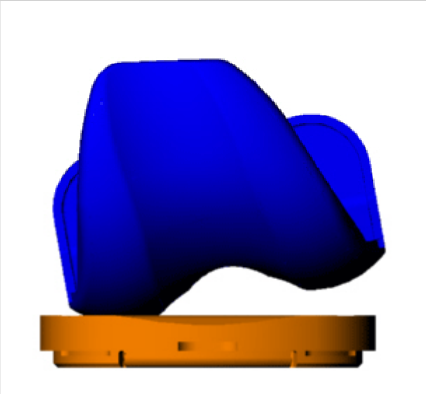
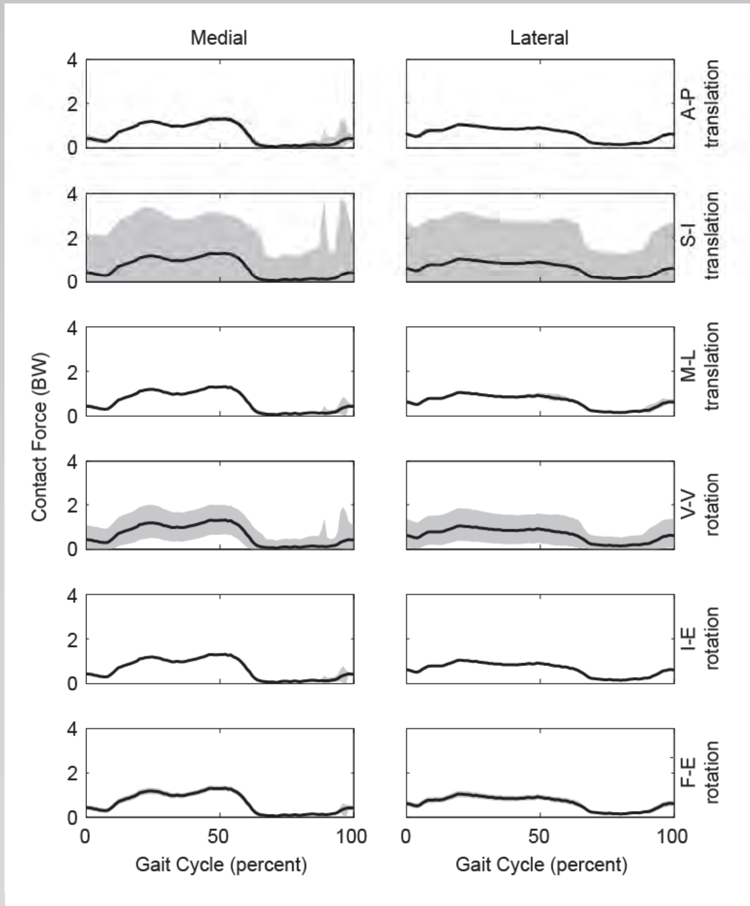
Contact Force Sensitivity

Should highly accurate fluoroscopic kinematic measurements be directly input into contact models to calculate *in vivo* contact forces?

Contact Force Sensitivity





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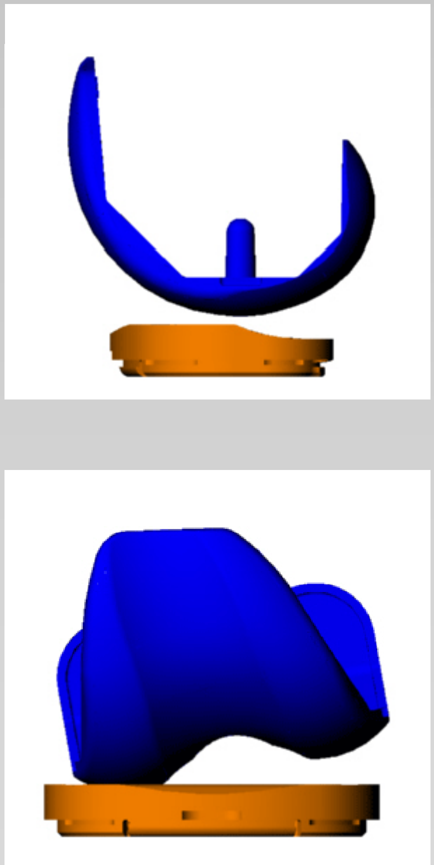
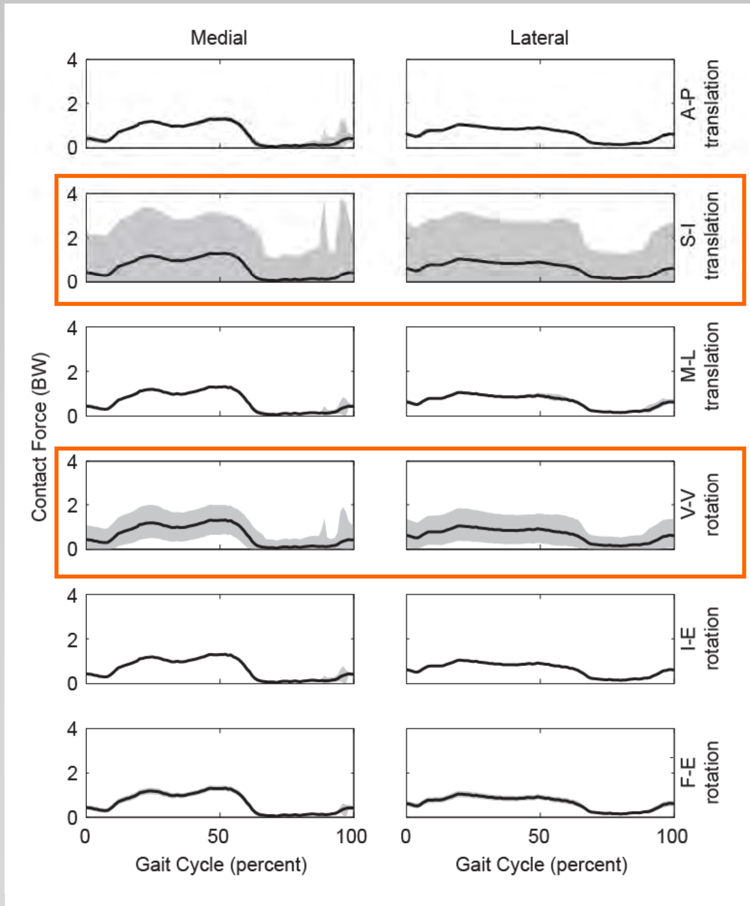
Contact Force Sensitivity





Fregly *et al.*, 2008, *Journal of Orthopaedic Research*

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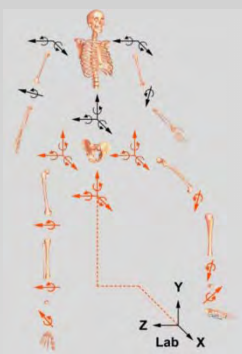
Computational Biomechanics Laboratory

Study 2 Overview

Geometric Model



Inverse Dynamic Model

Combined Model

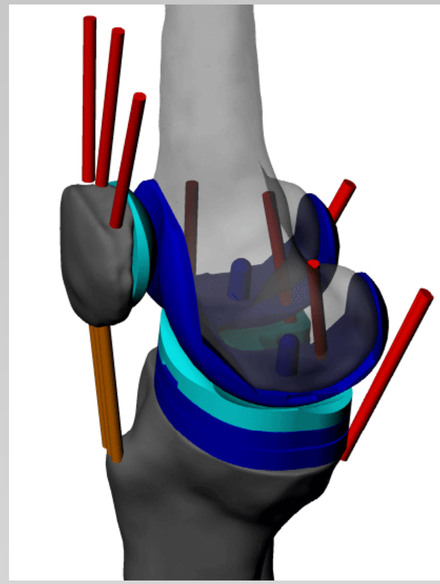
Muscle Forces

Contact Forces

Muscle & Contact Force Estimation

Muscle Force Optimization

Design variables related to *muscle activations*



No contact

Muscle & Contact Force Estimation

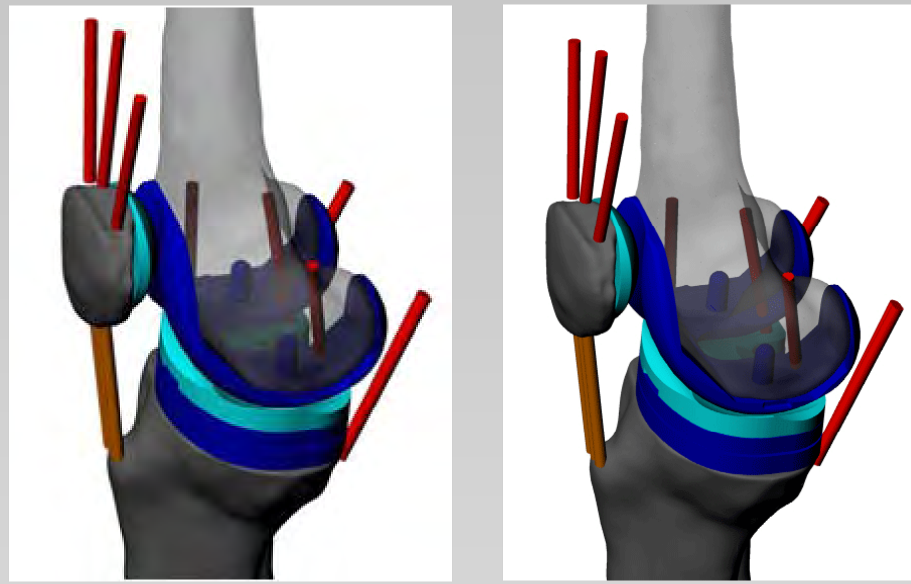
Muscle Force Optimization

Design variables related to *muscle activations*

↓ *muscle activations*

Pose Optimization

Design variables related to *bone poses* given current *muscle activations*



No contact | Contact

Assumptions required about contact contributions to inverse dynamic loads

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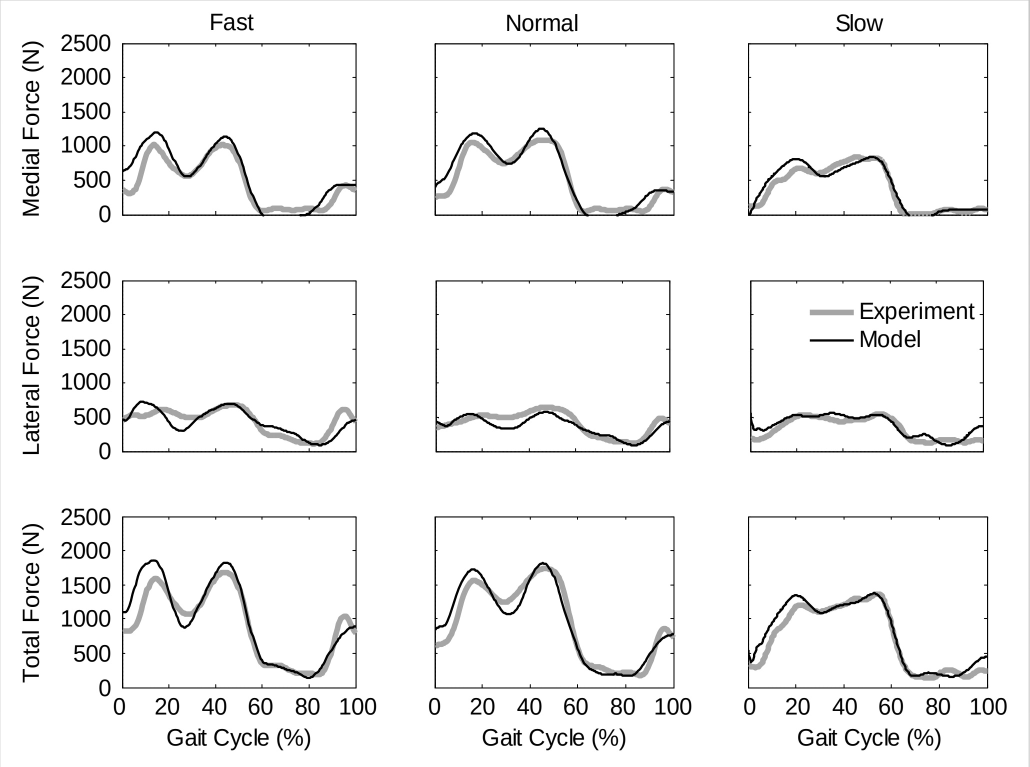
Sequential Contact Force



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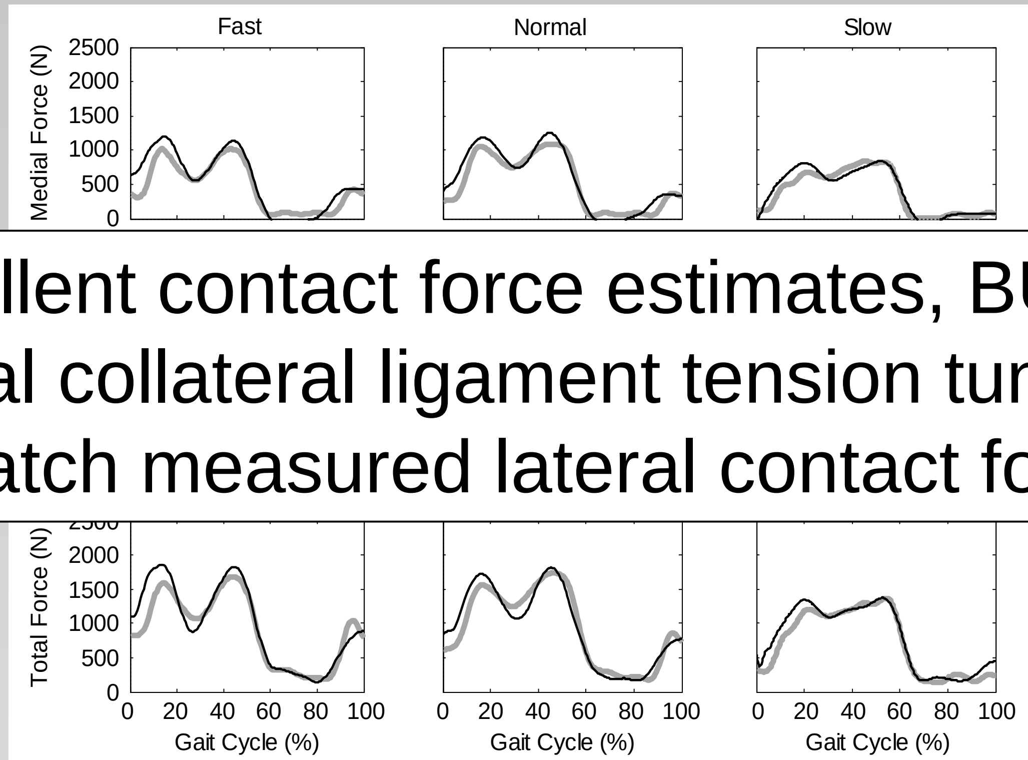
Sequential Contact Force



Excellent contact force estimates, BUT lateral collateral ligament tension tuned to match measured lateral contact forces.

Kim *et al*., 2009, *Journal of Orthopaedic Research*

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Muscle & Contact Force Estimation

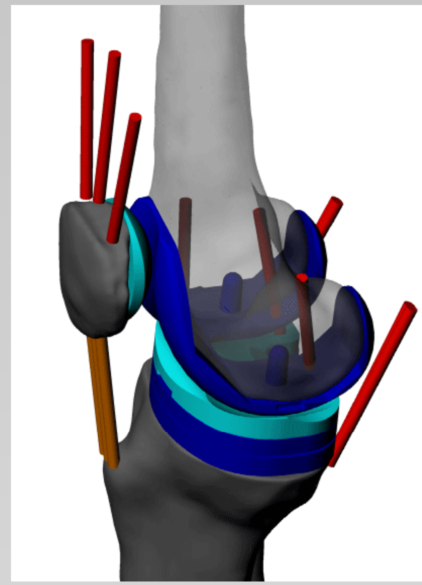
Muscle Force Optimization

Design variables related to *muscle activations*

cost function and constraints ↑ | ↓ *muscle activations*

Pose Optimization

Design variables related to *bone poses* given current *muscle activations*



Contact

No assumptions required about contact contributions to inverse dynamic loads

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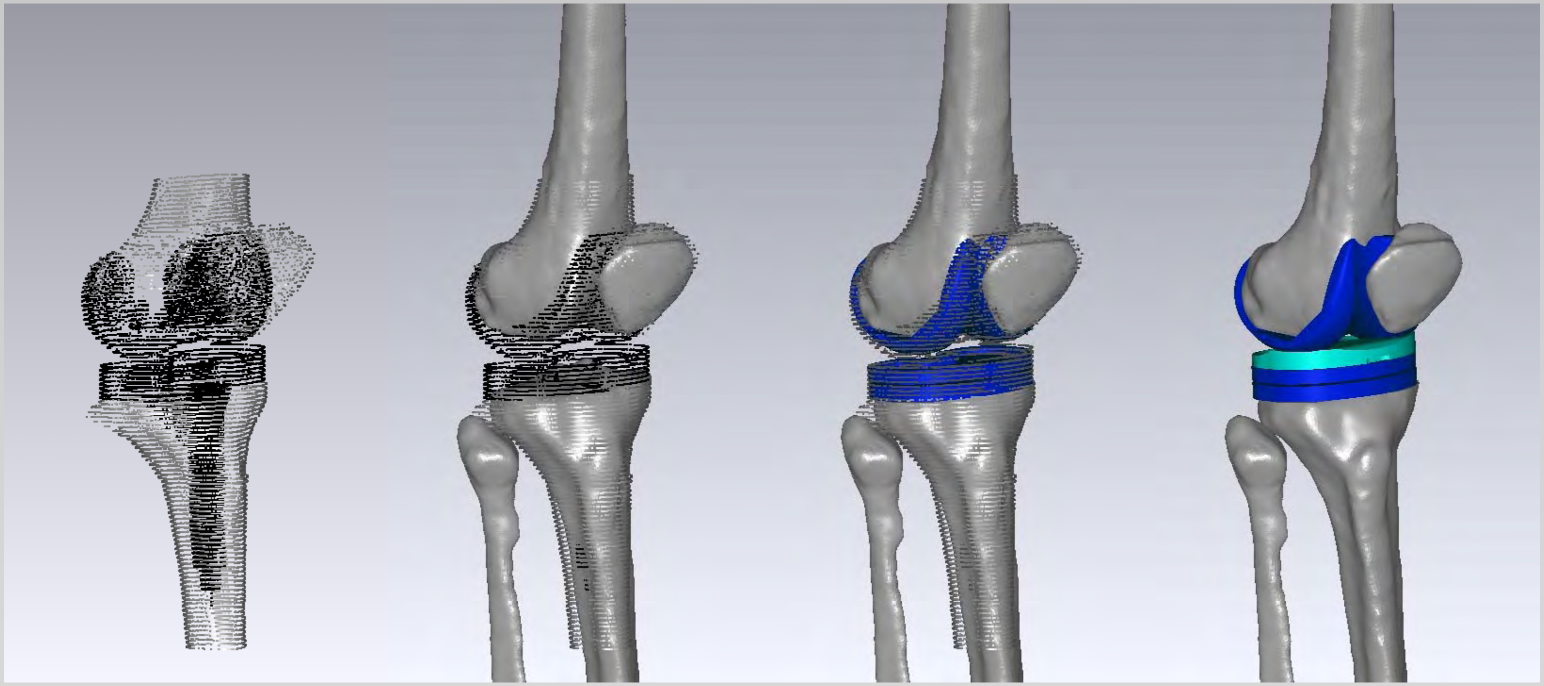
Knee Contact Model



+ surrogate contact models of TF and PF joints

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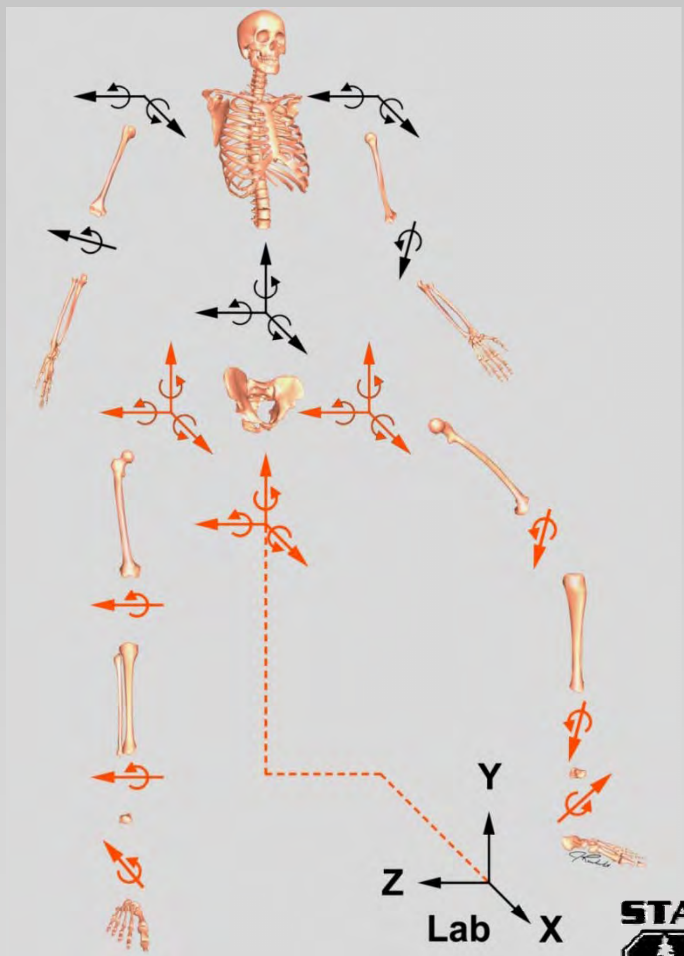
Inverse Dynamic Model

- Full-body model
- Three-dimensional
- Engineering joints
- Calibrated lower body joints
- Calibrated full body masses

Reinbolt *et al*., 2005, *Journal of Biomechanics*; Reinbolt *et al*., 2008, *Medical Engineering & Physics*



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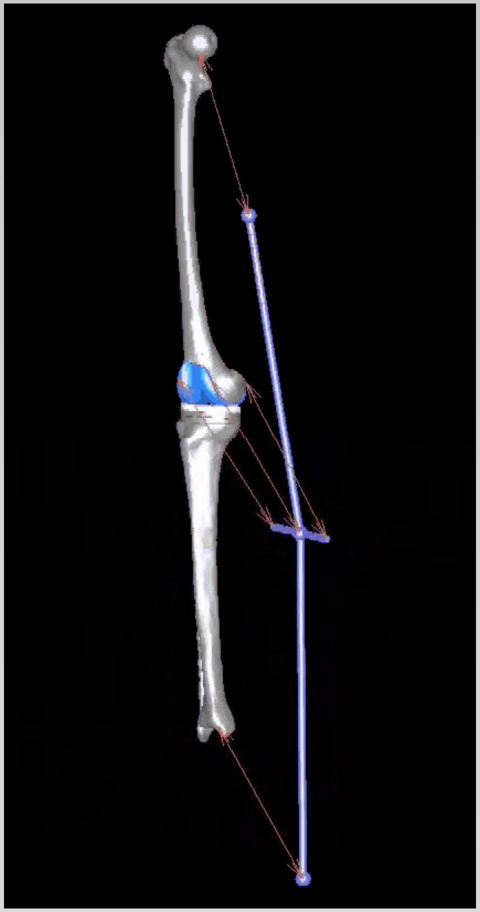
Model Registration



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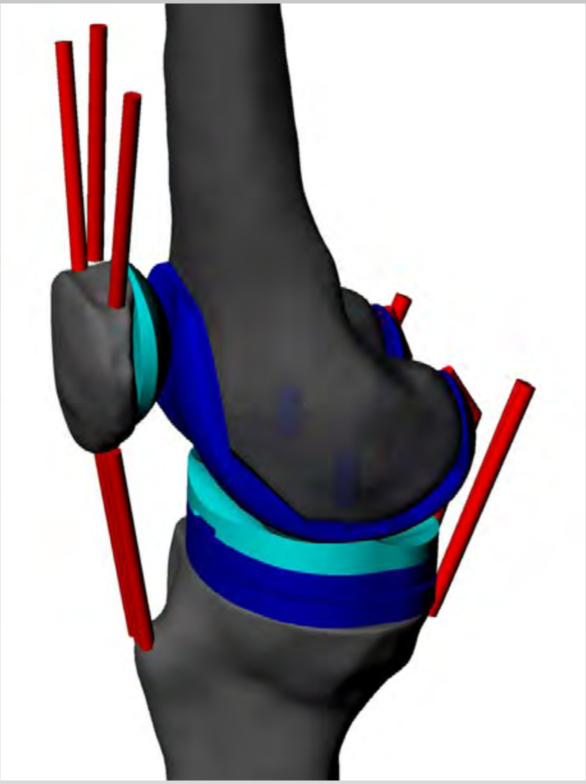
Complete Knee Model



- 11 muscles controlled by 8 activation signals
- Muscle force = peak isometric force x activation
- Patellar ligament modeled as 3 parallel springs
- Grounded femur
- 6 DOF patellofemoral joint (6 free DOFs)
- 6 DOF tibiofemoral joint (3 free and 3 prescribed DOFs)

Optimization Problems

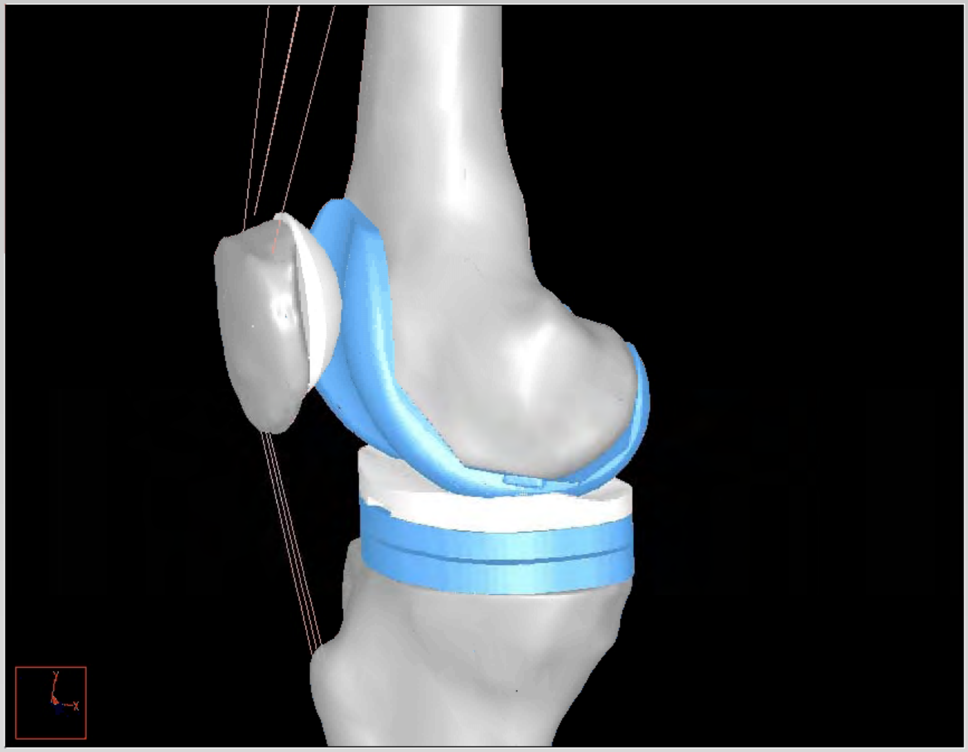
Cost Function	Equation
1	$\min \sum_{i=1}^{8} a_i^2$
2	$\min \sum_{i=1}^{3} F_i$

Constraint Set	Flexion-Extension Torque	Anterior-Posterior Force	Internal-External Torque
1	x		
2	x	x	
3	x		x
4	x	x	x

"Constrained" formulations – *in vivo* contact forces used as additional constraints.

"Unconstrained" formulations – *in vivo* contact forces not used as additional constraints.

Predicted Motion



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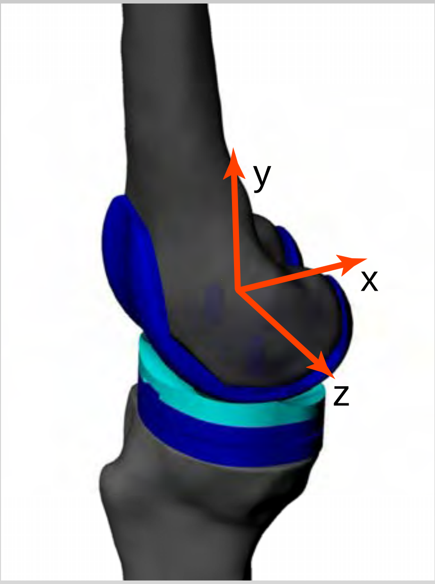
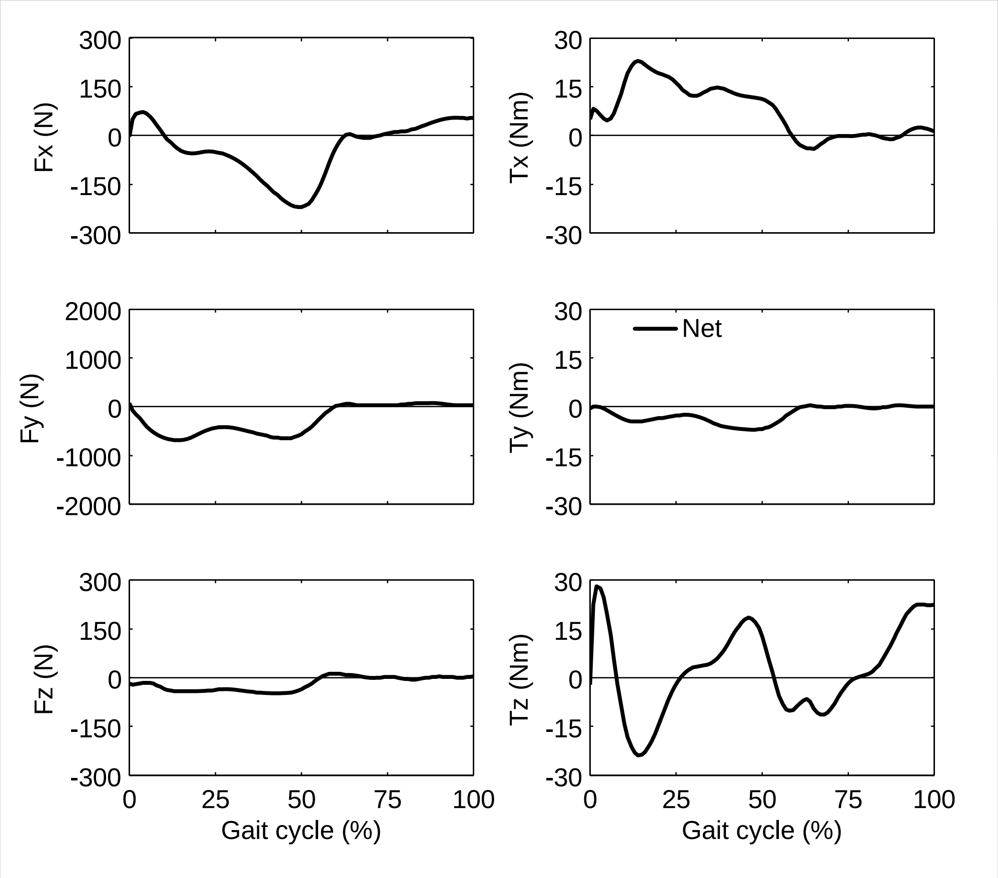
Load Decomposition

How do muscle and contact forces contribute to the six inverse dynamic loads at the knee during gait?

Load Decomposition





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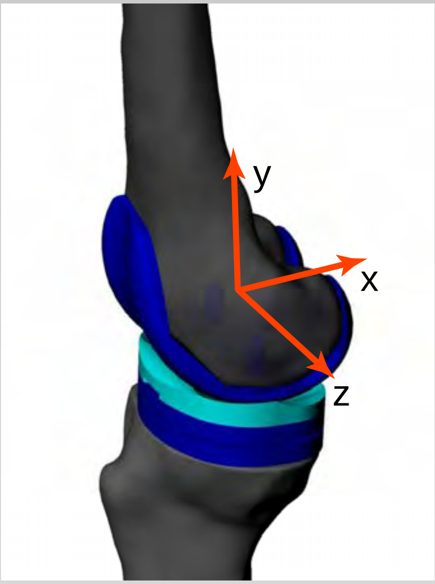
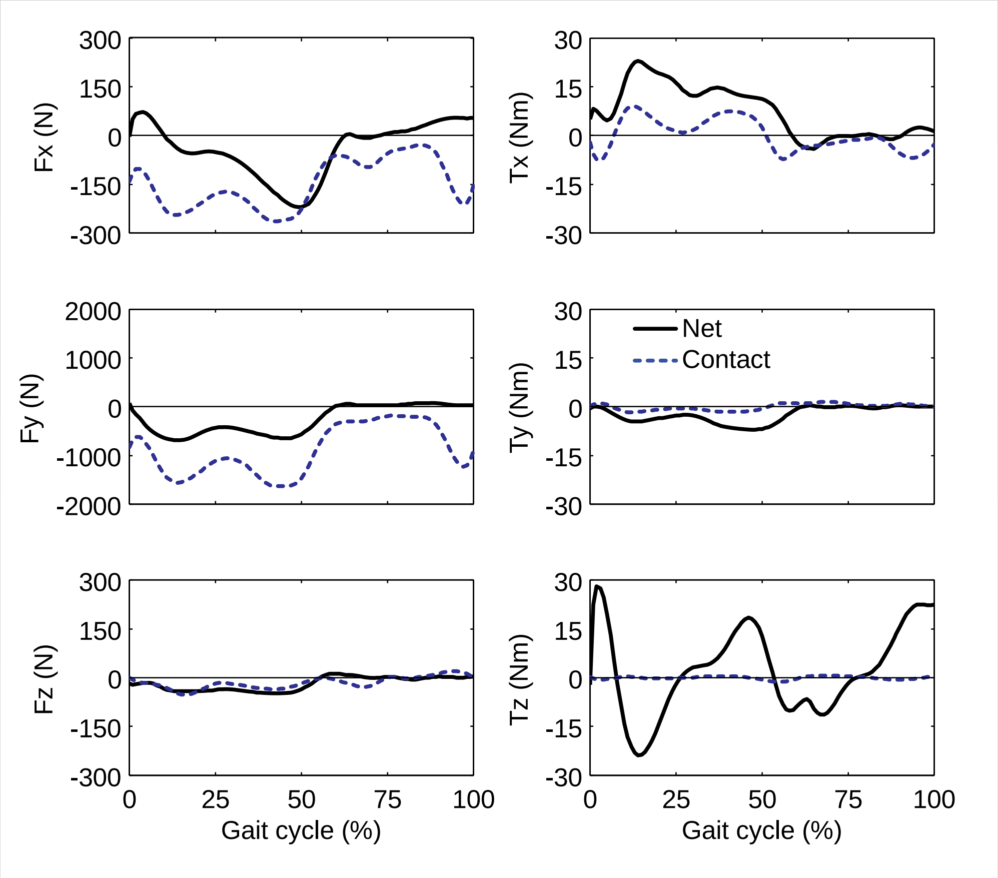
Load Decomposition





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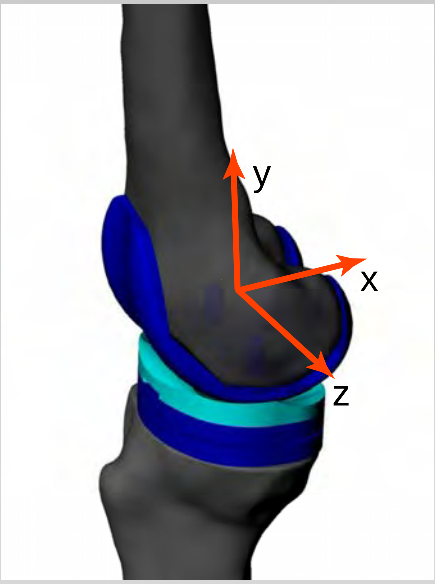
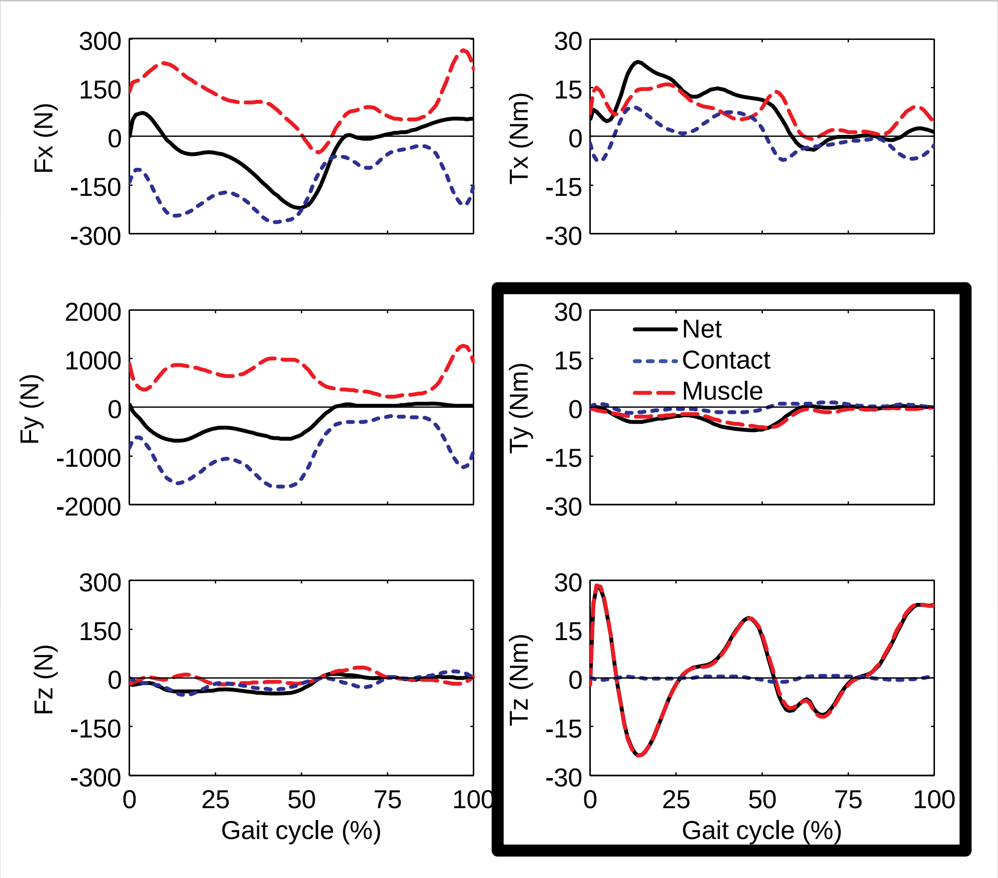
Load Decomposition





Fregly *et al*., 2009, *SBC*

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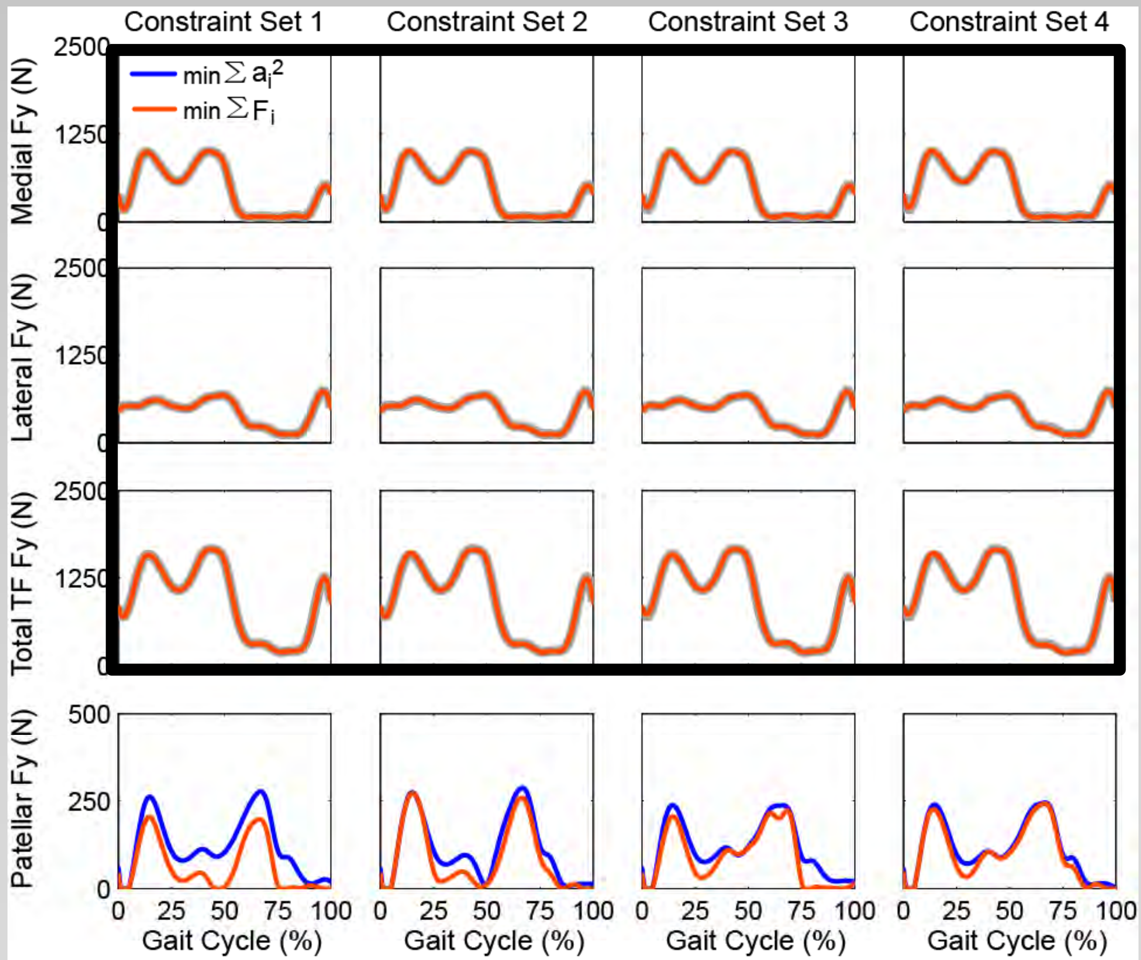
Muscle & Contact Force Estimates

Does inclusion of explicit contact models in a musculoskeletal knee model improve the estimation of muscle and contact forces during gait?

“Constrained” Contact Forces



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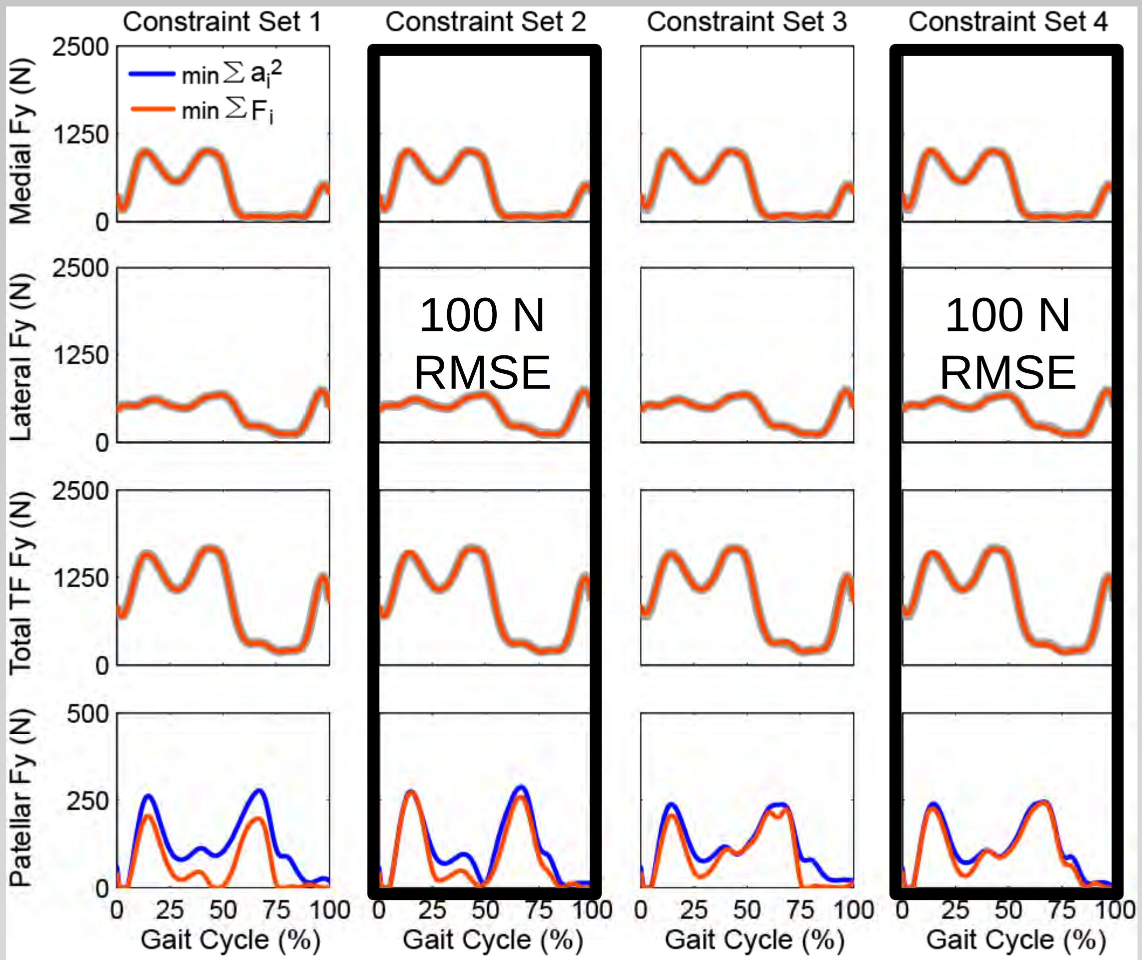
"Constrained" Contact Forces



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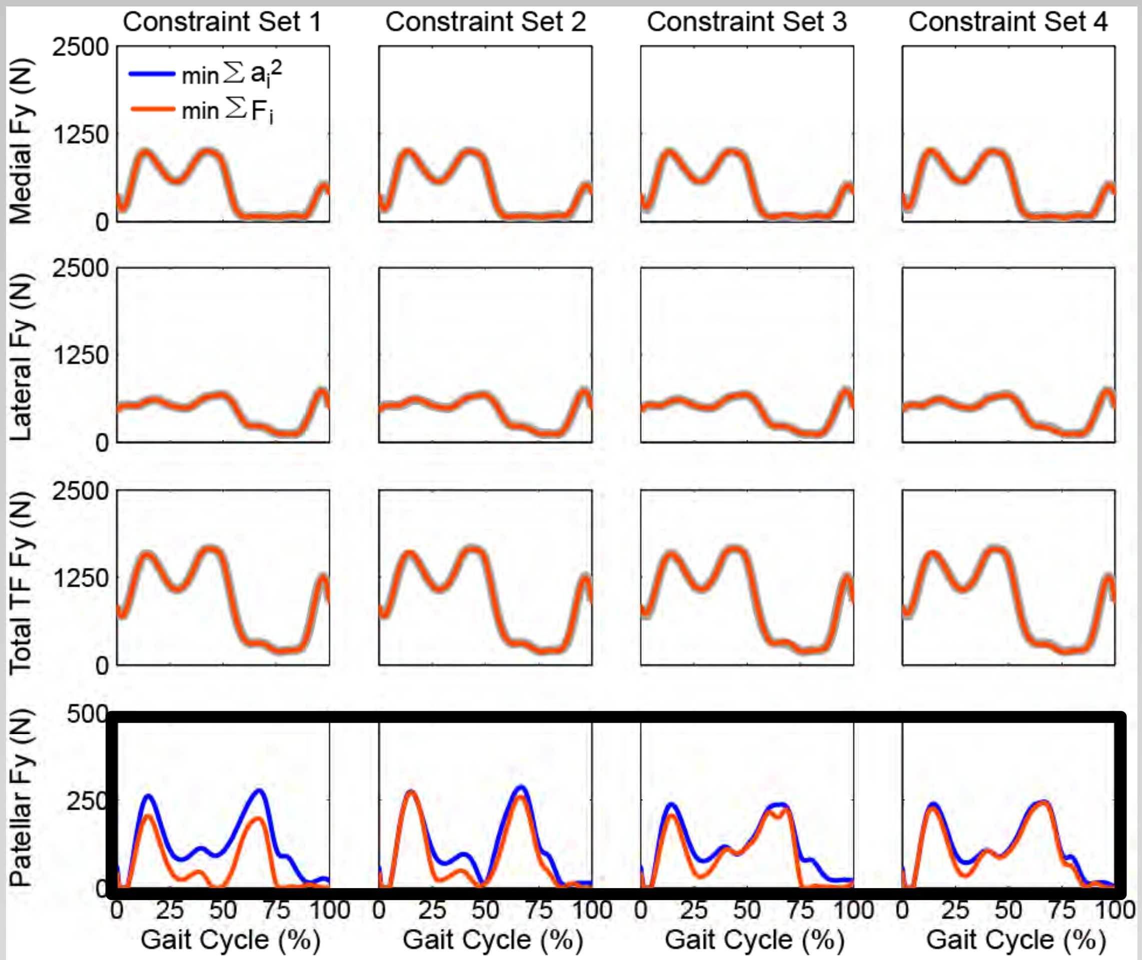
“Constrained” Contact Forces



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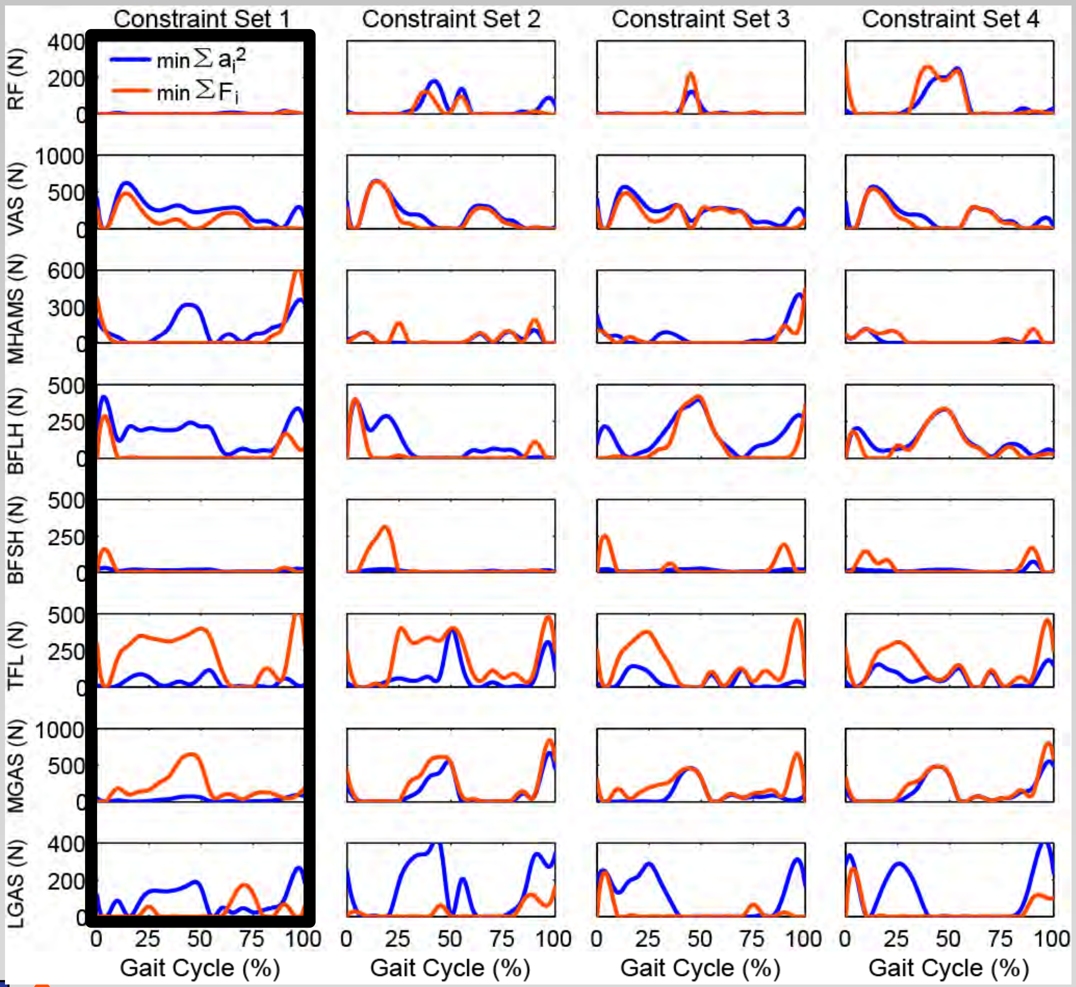
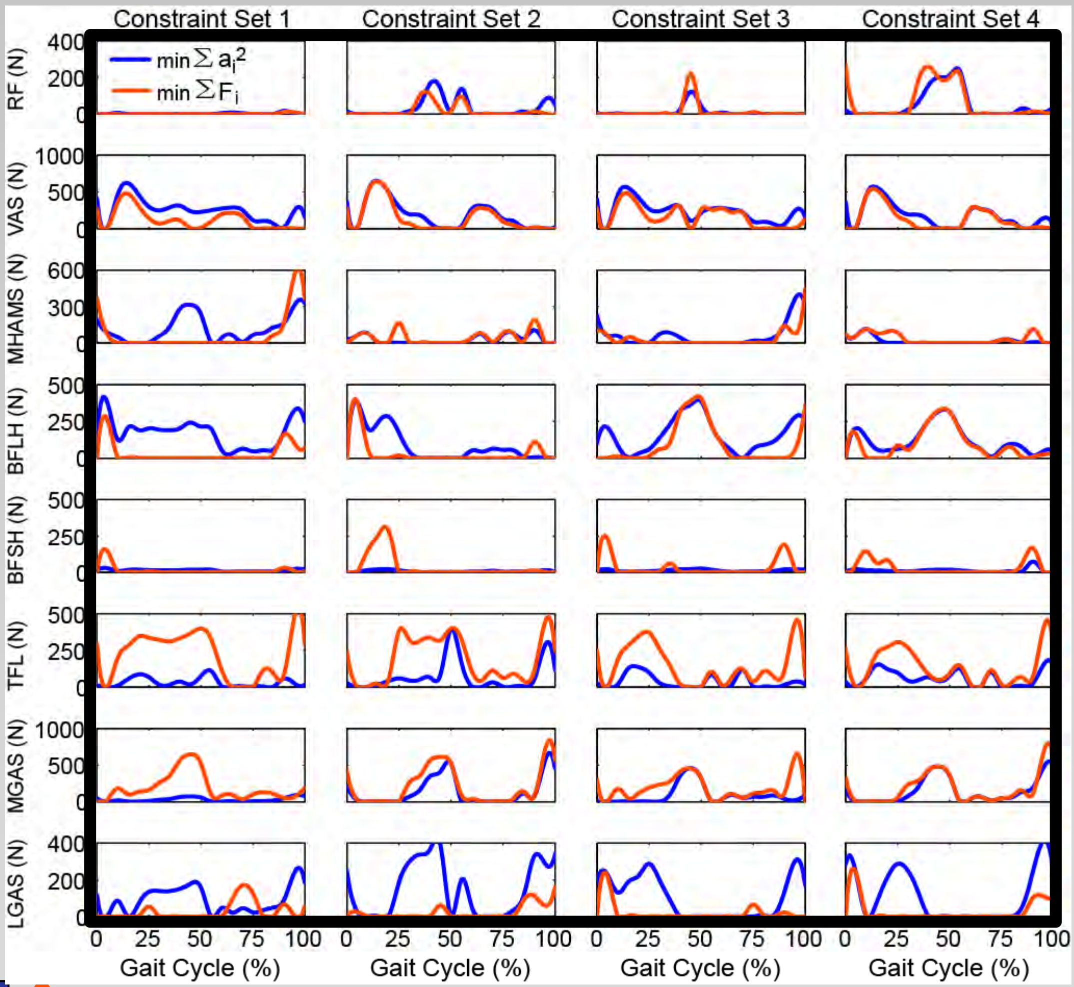
“Constrained” Muscle Forces



4. Modeling Results to Date

“Constrained” Muscle Forces



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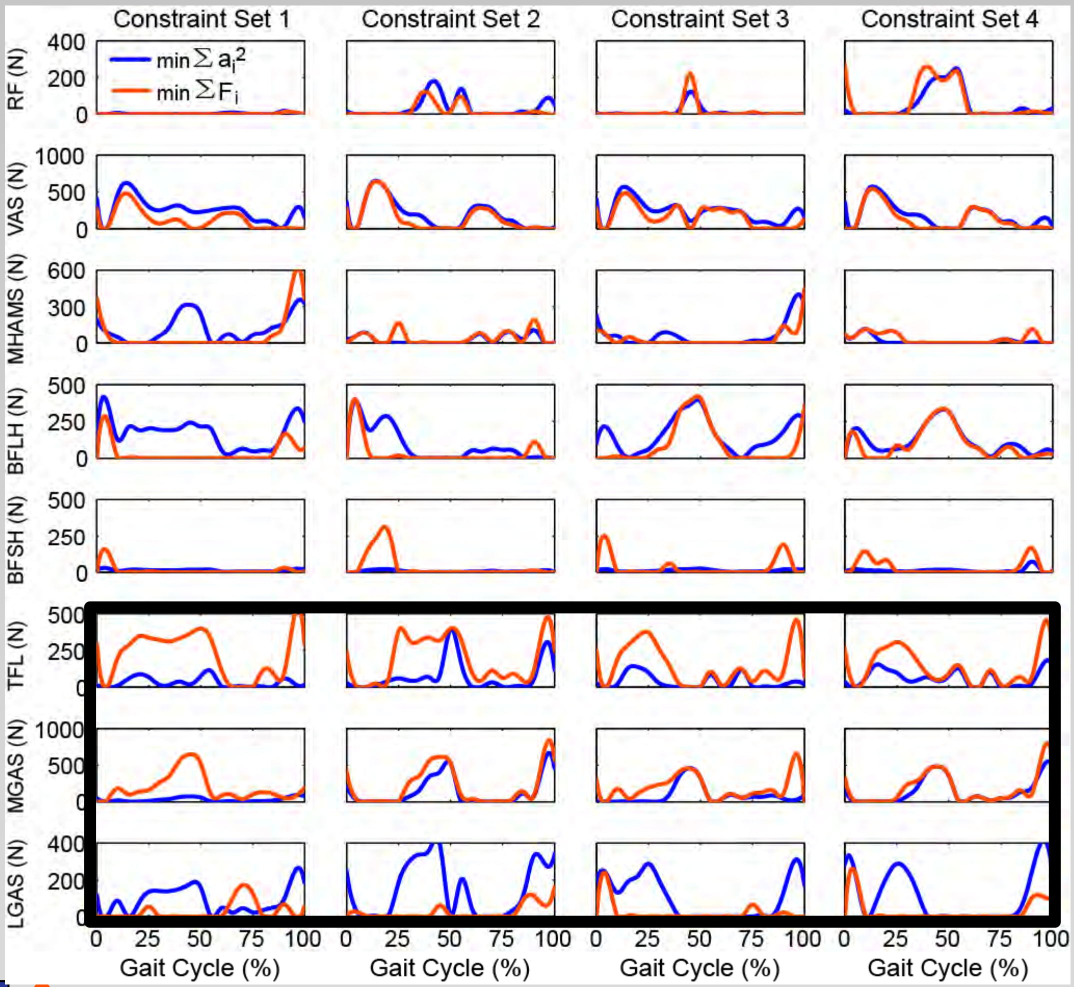
“Constrained” Muscle Forces



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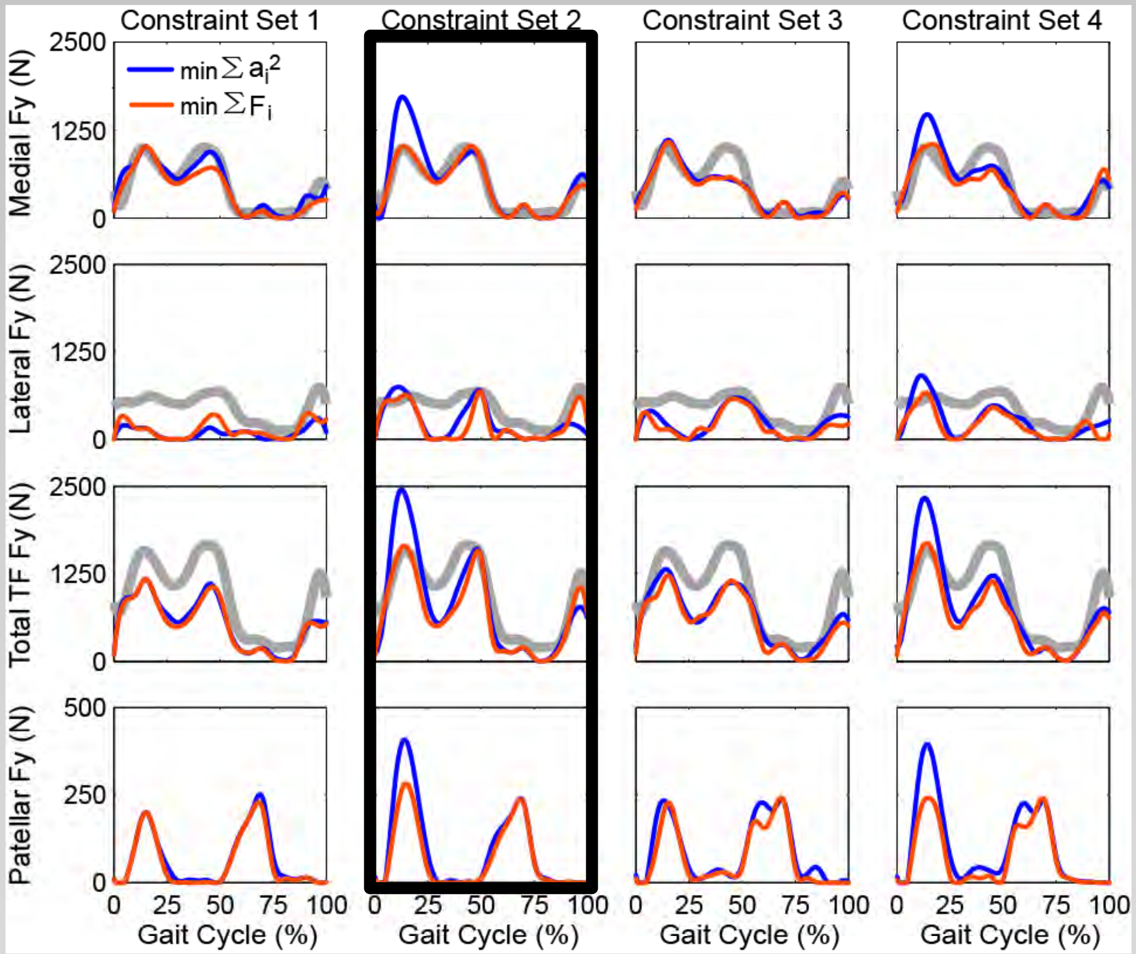
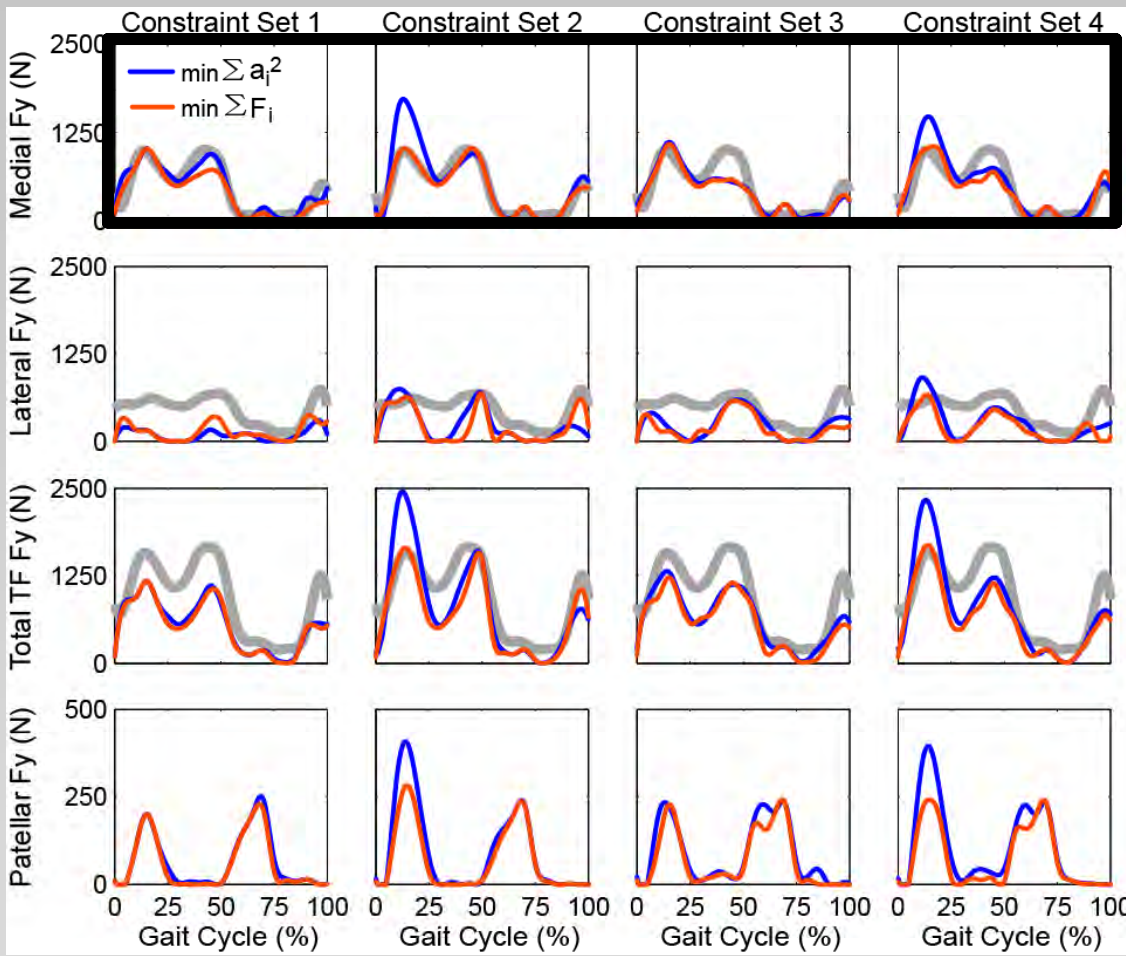
"Unconstrained" Contact Forces



4. Modeling Results to Date

“Unconstrained” Contact Forces



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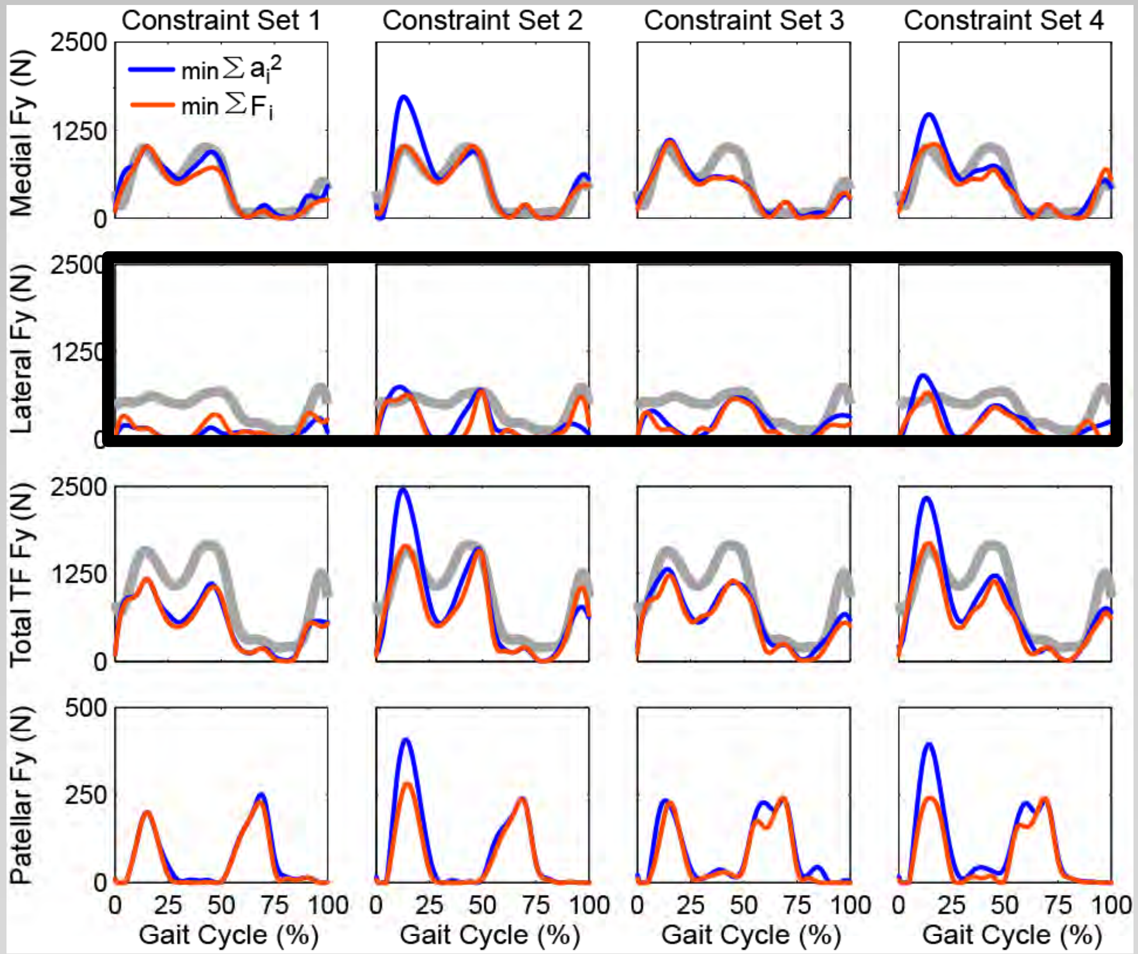
“Unconstrained” Contact Forces



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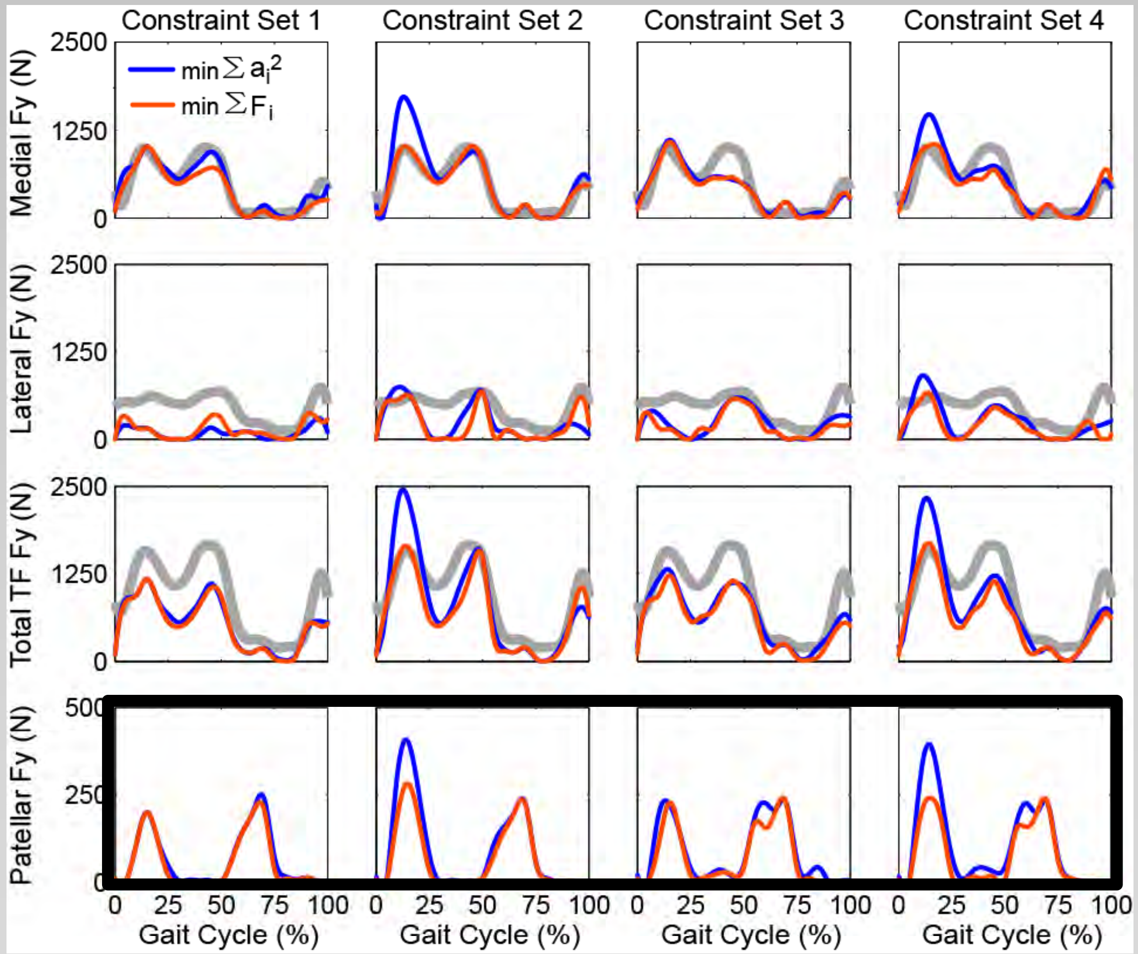
"Unconstrained" Contact Forces



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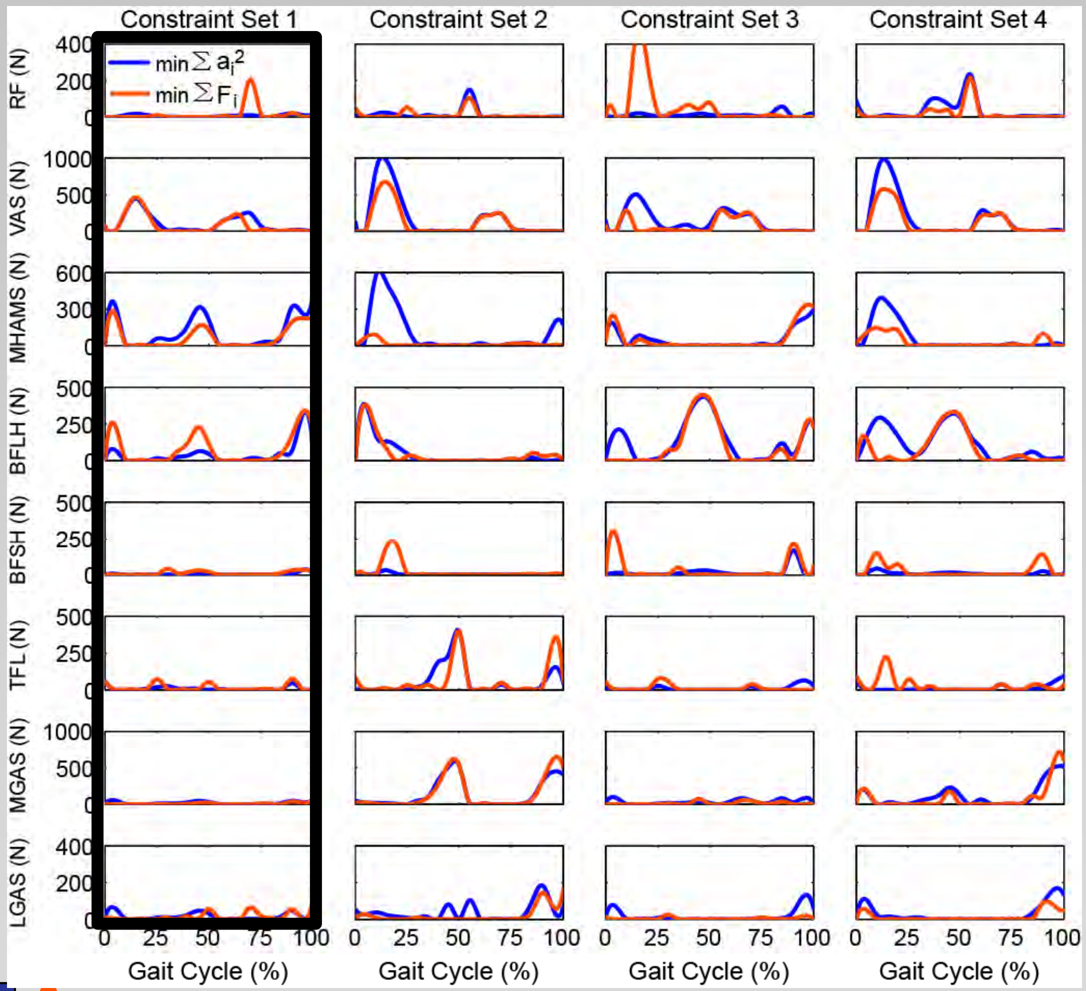
“Unconstrained” Muscle Forces



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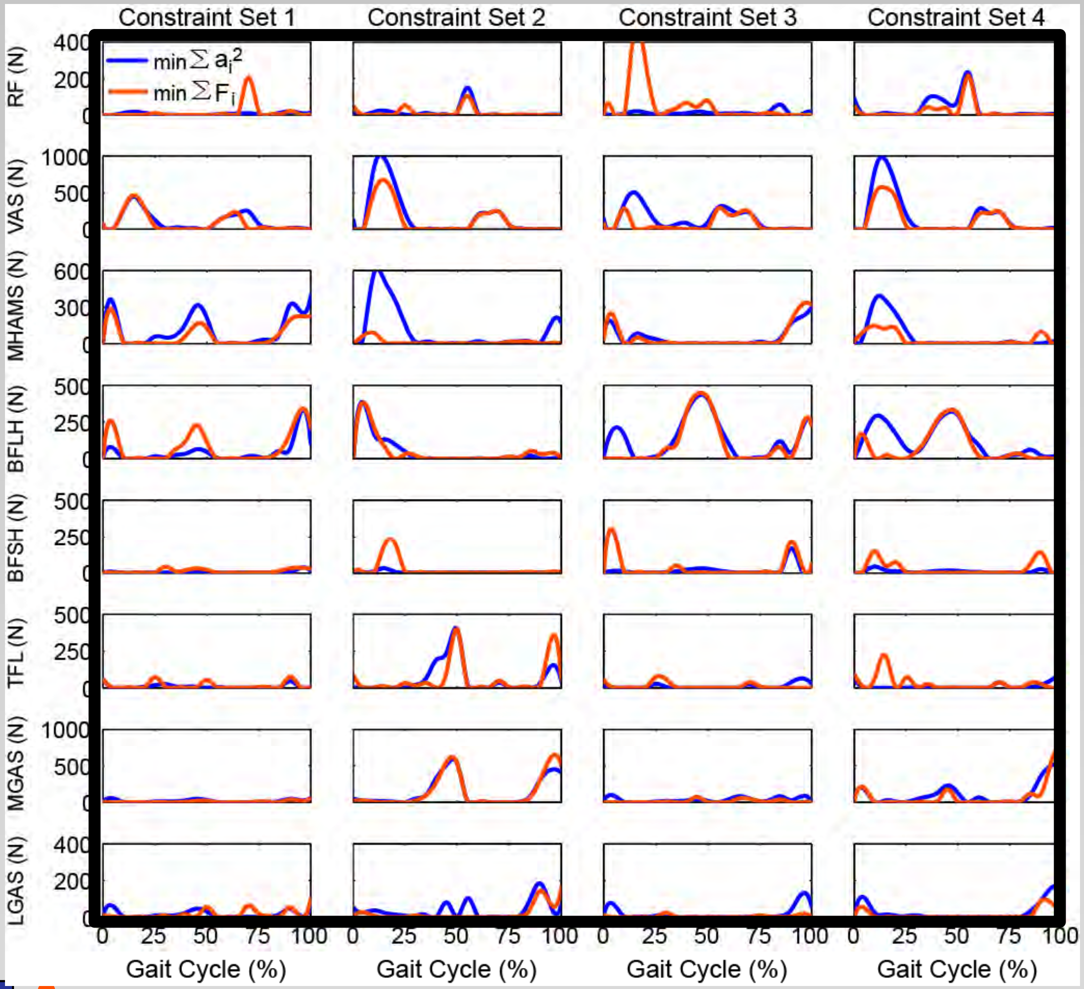
Computational Biomechanics Laboratory

“Unconstrained” Muscle Forces



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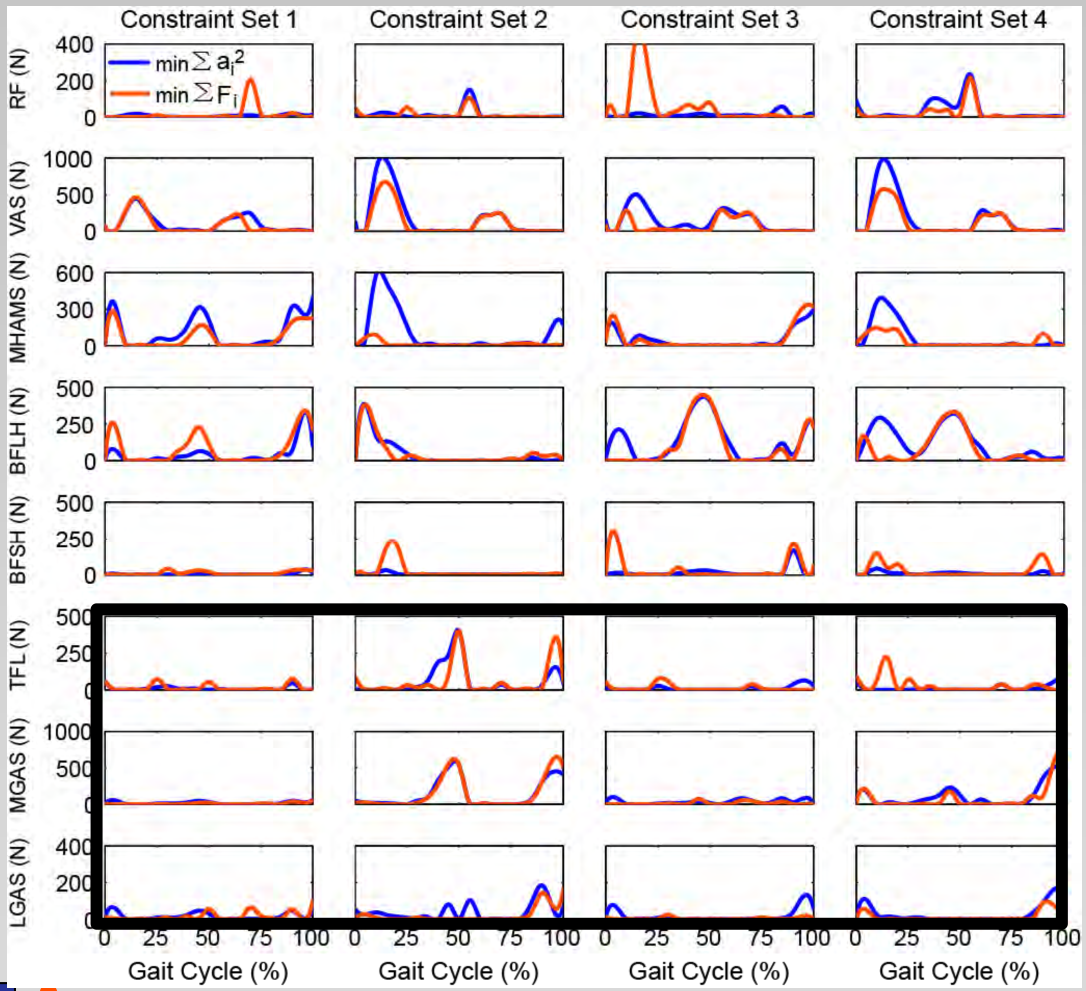
"Unconstrained" Muscle Forces

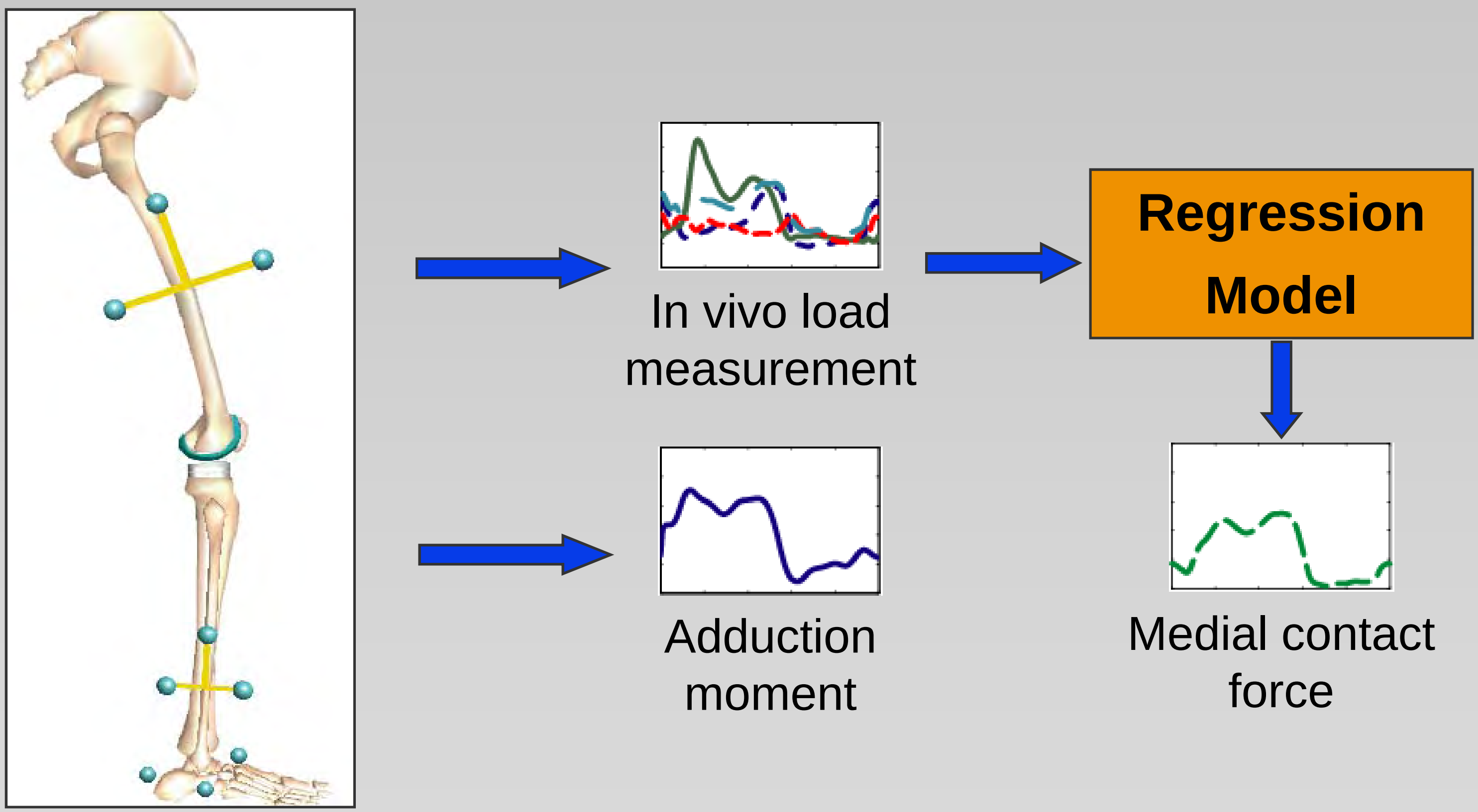


Fregly *et al*., 2009, *SBC*

Study 3 Overview

Computational Biomechanics Laboratory

Gait Analysis



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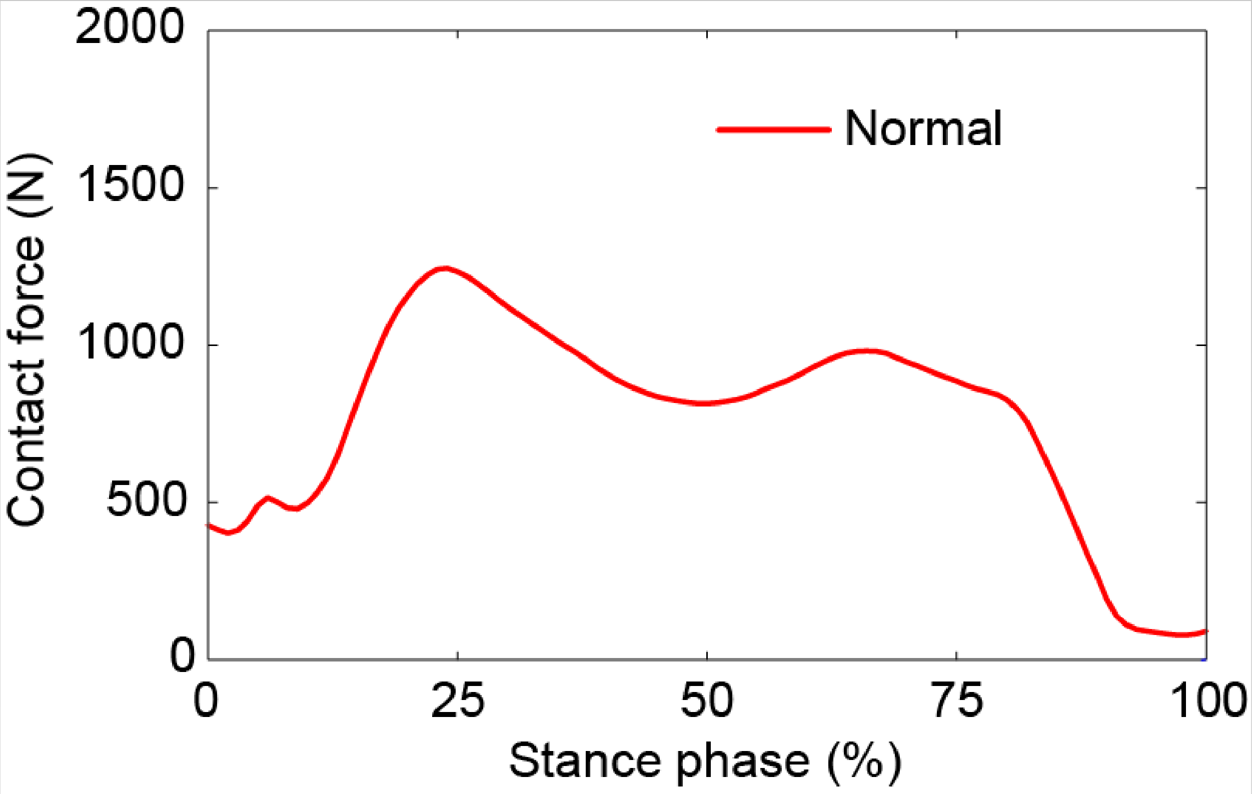
Joint Contact Forces

How do medial thrust and walking pole gait affect medial and lateral contact force?

Medial Contact Force



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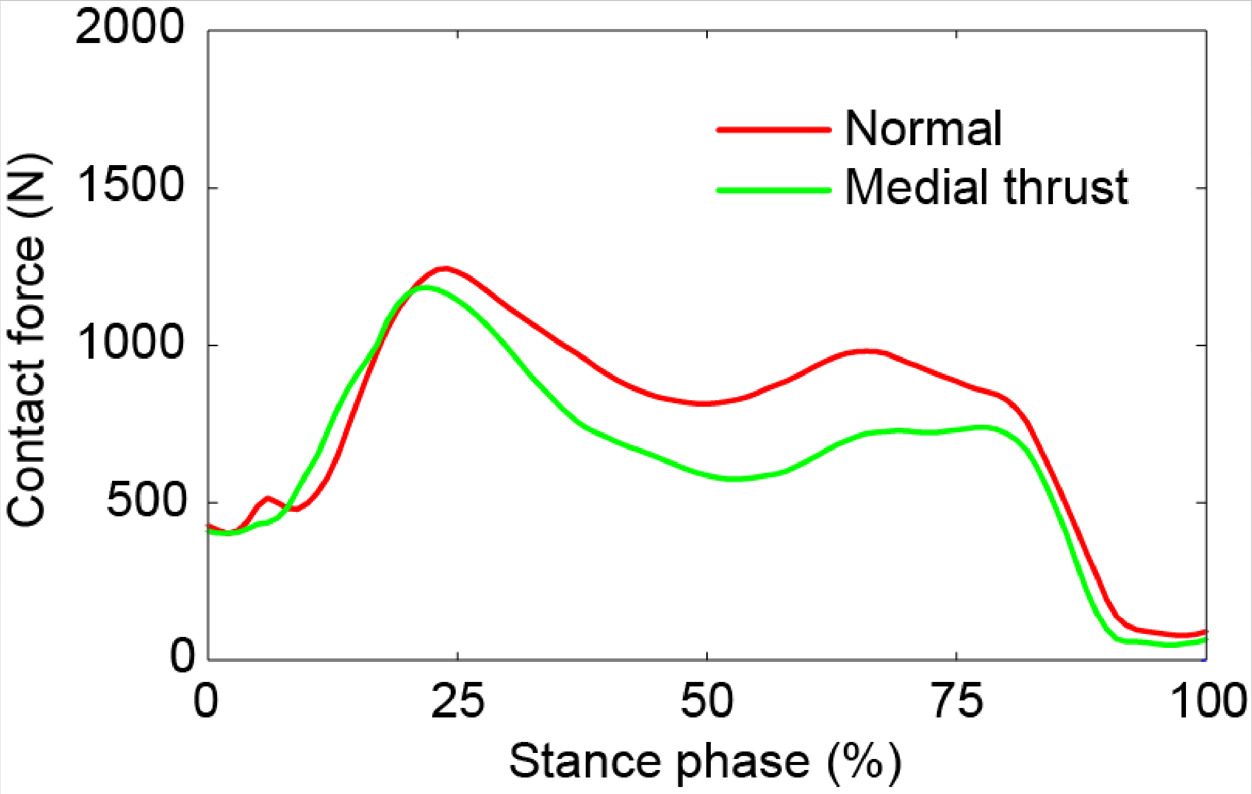
Medial Contact Force



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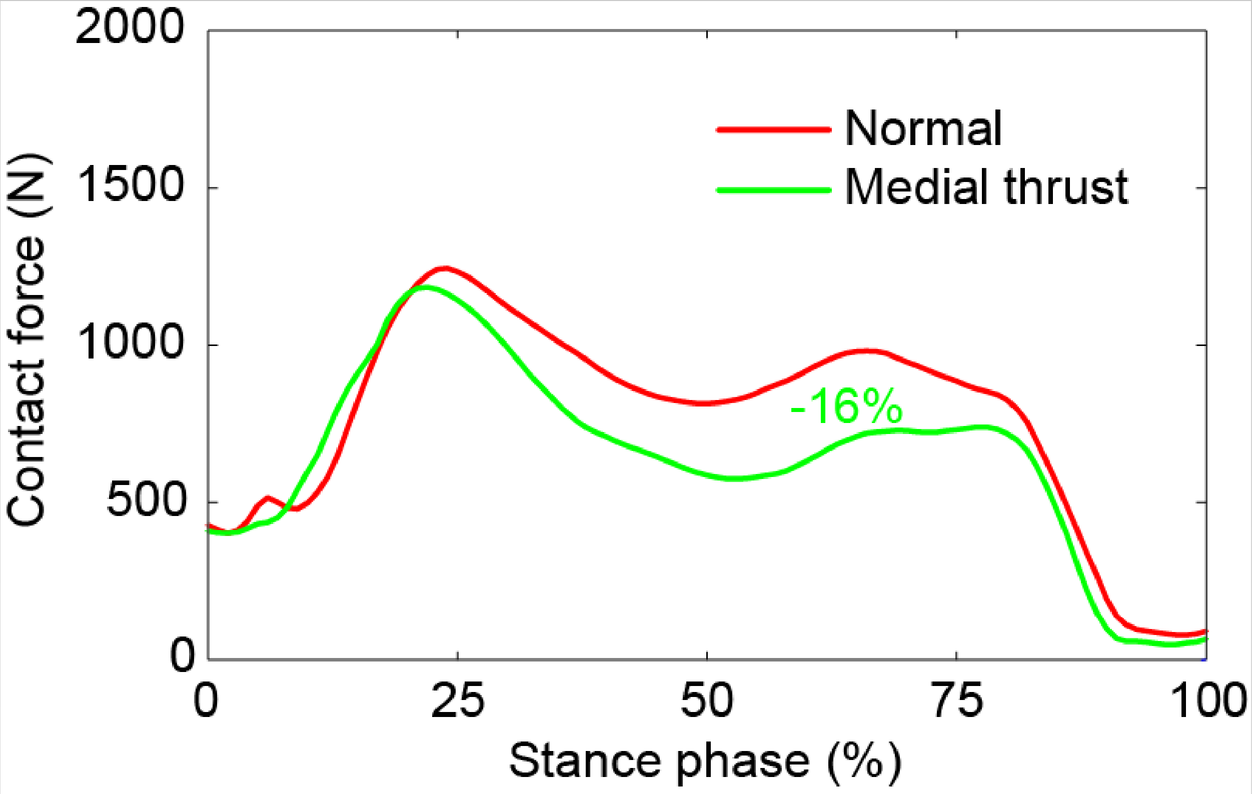
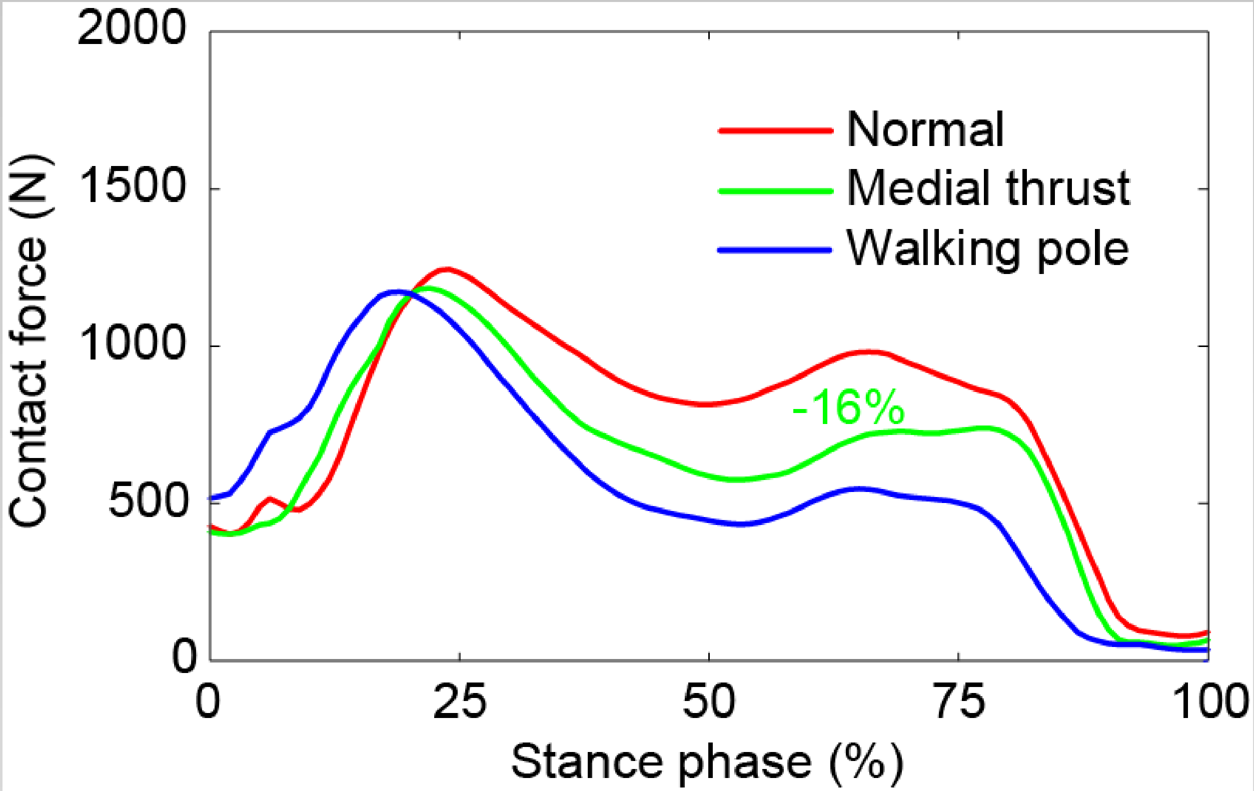
Medial Contact Force



Medial Contact Force



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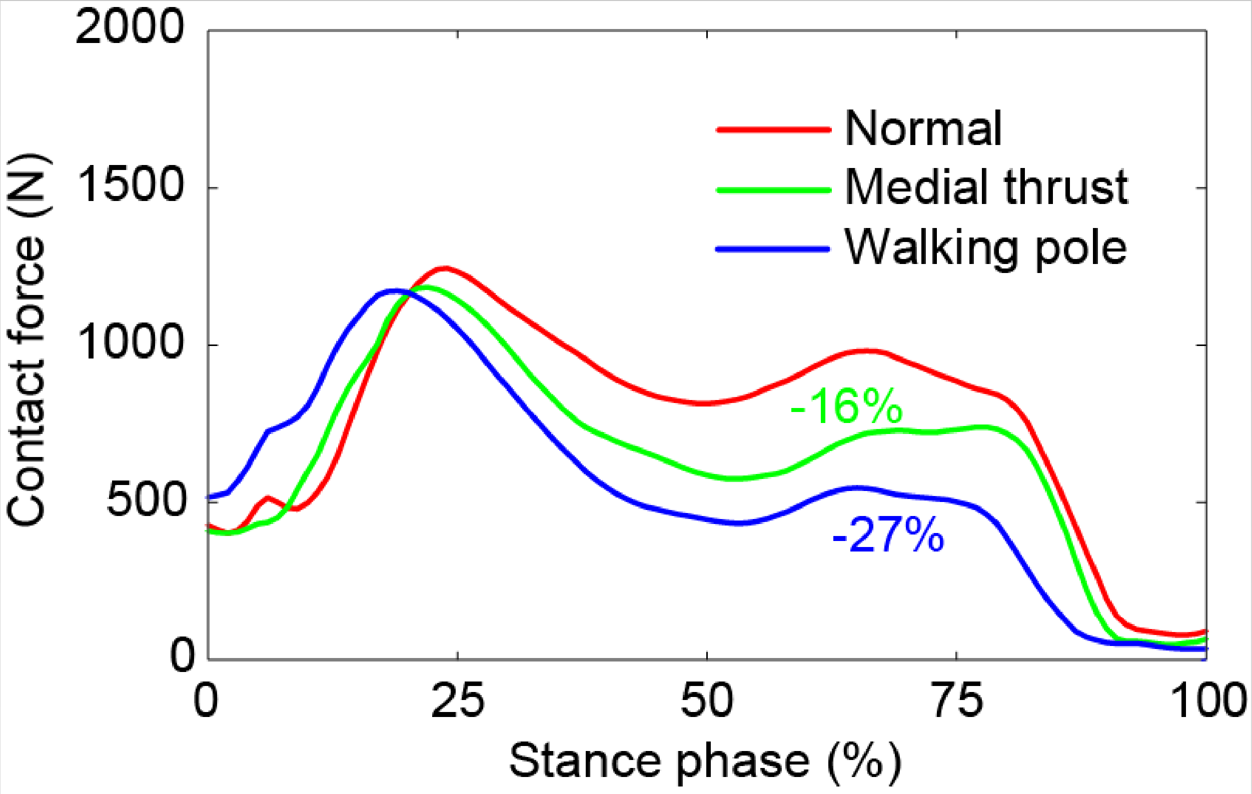
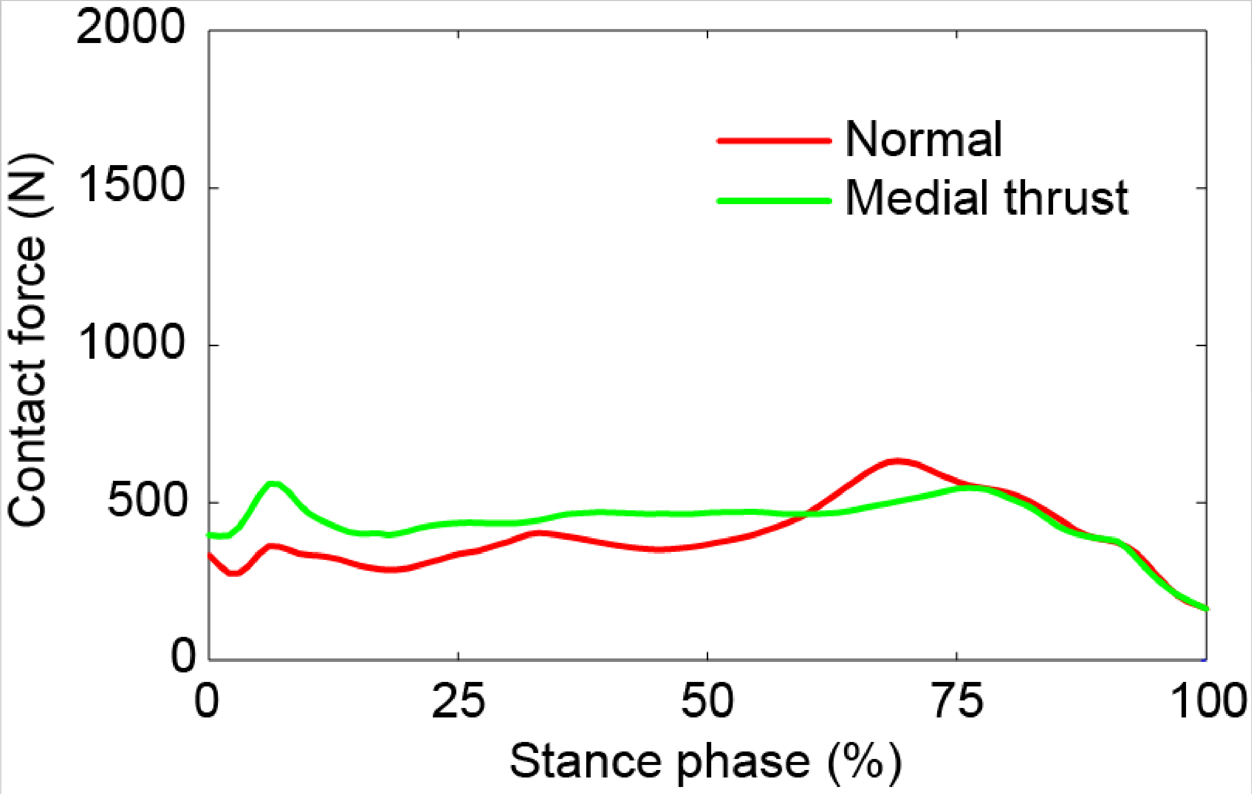
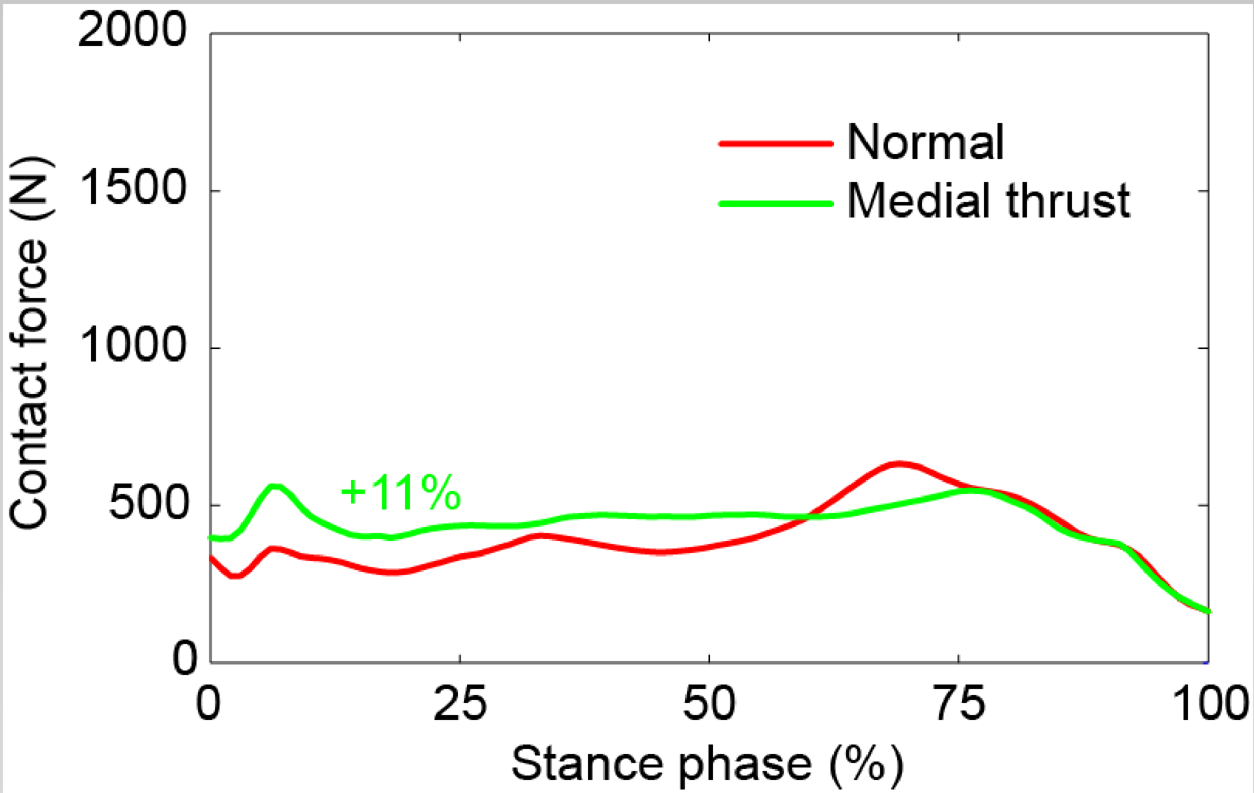
Medial Contact Force



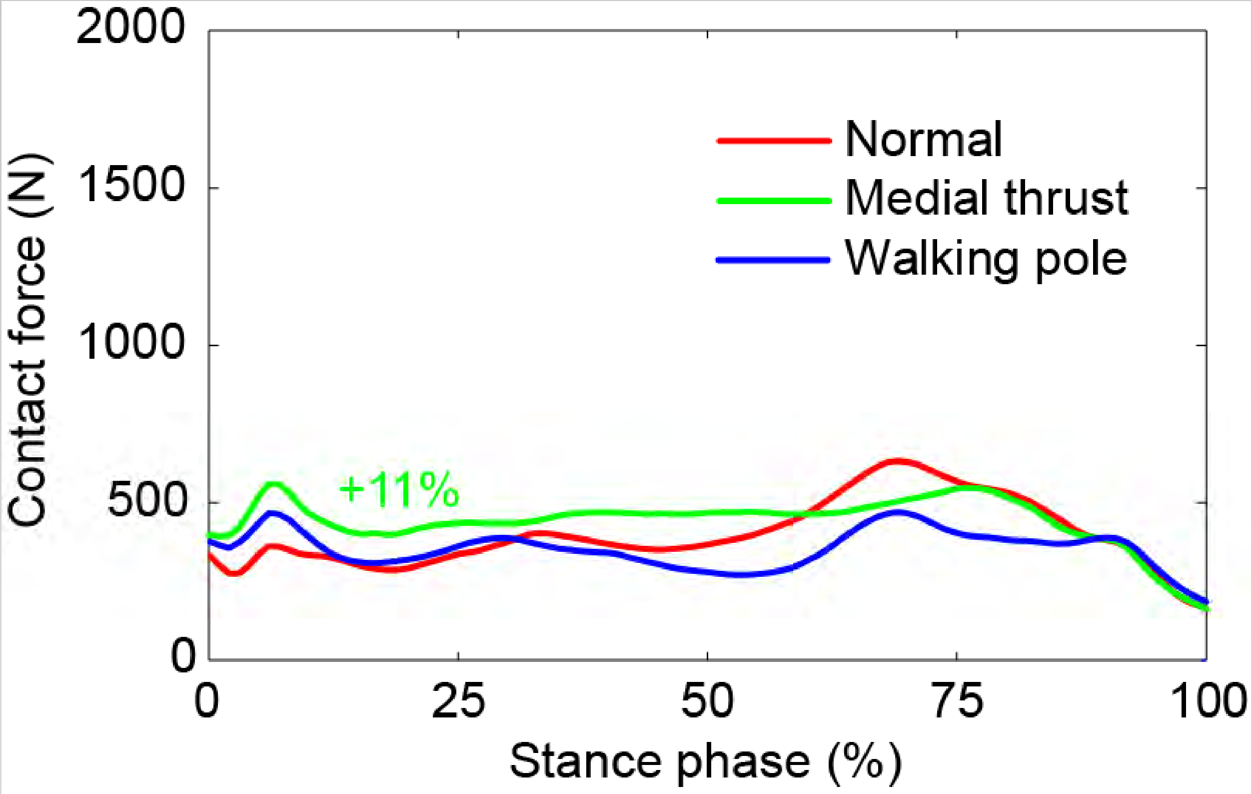
Lateral Contact Force



Lateral Contact Force



Lateral Contact Force



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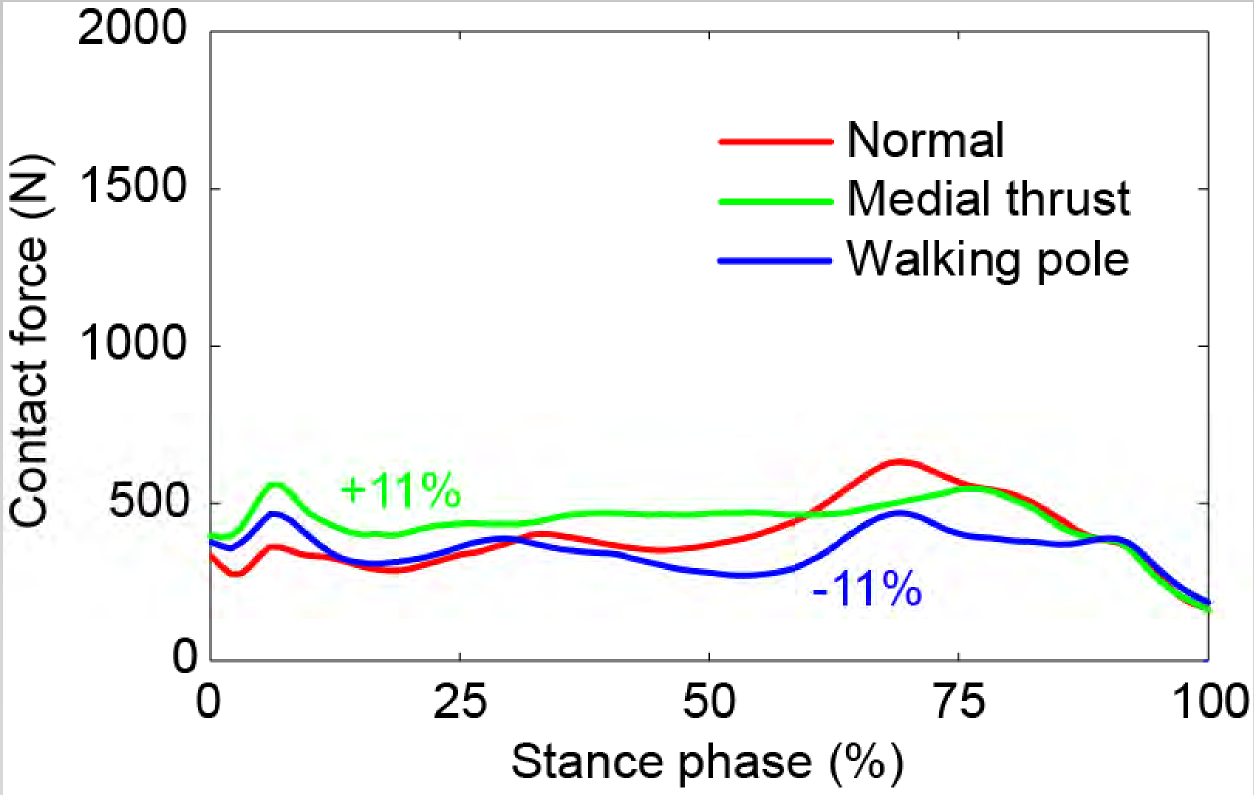
Lateral Contact Force

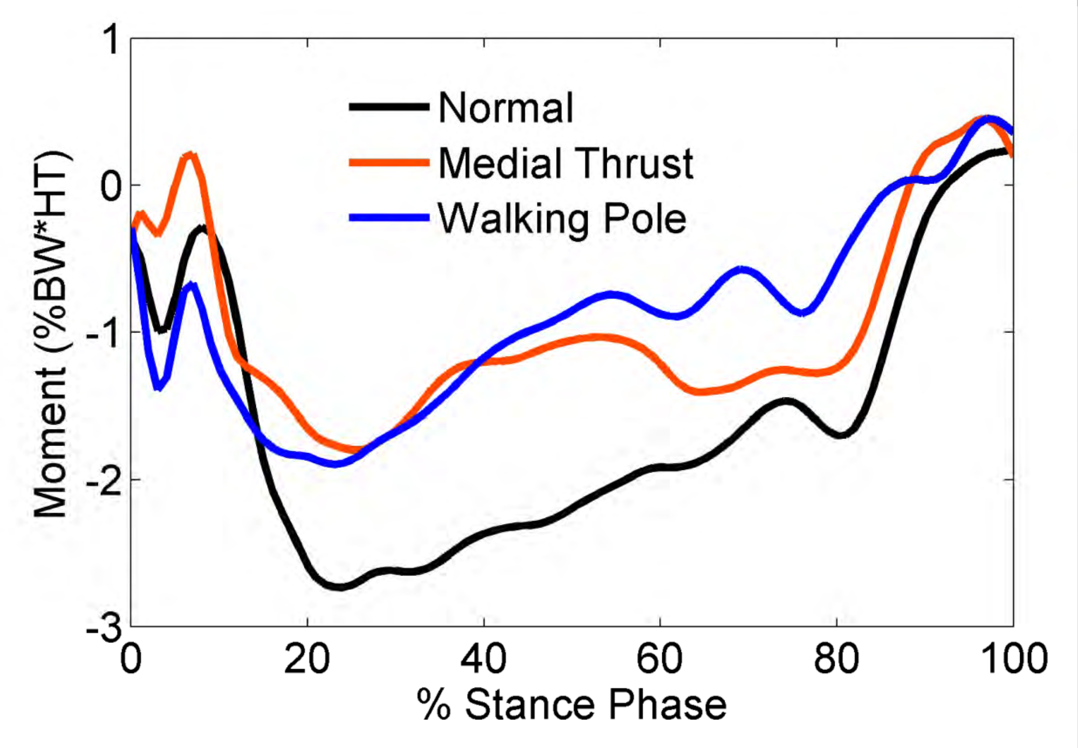


Fregly *et al*., 2009, *Journal of Orthopaedic Research*

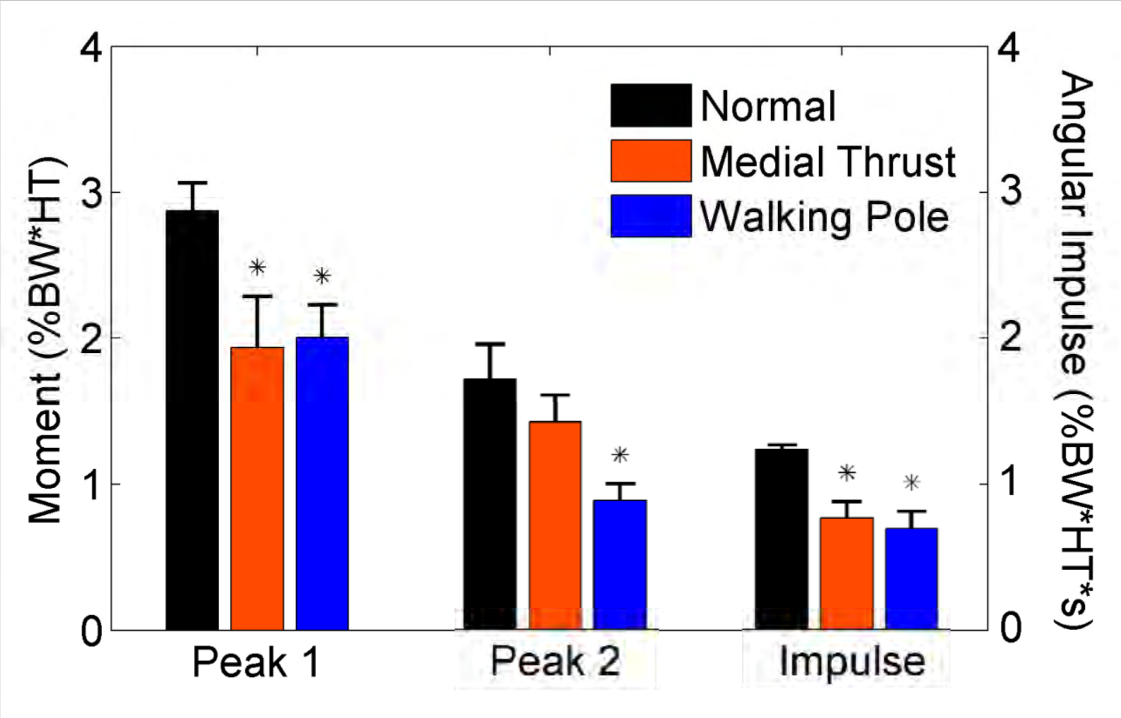
Knee Adduction Moment

Does the knee adduction moment predict no change in the first peak and a significant reduction in the second peak of medial contact force?

Knee Adduction Moment



Knee Adduction Moment



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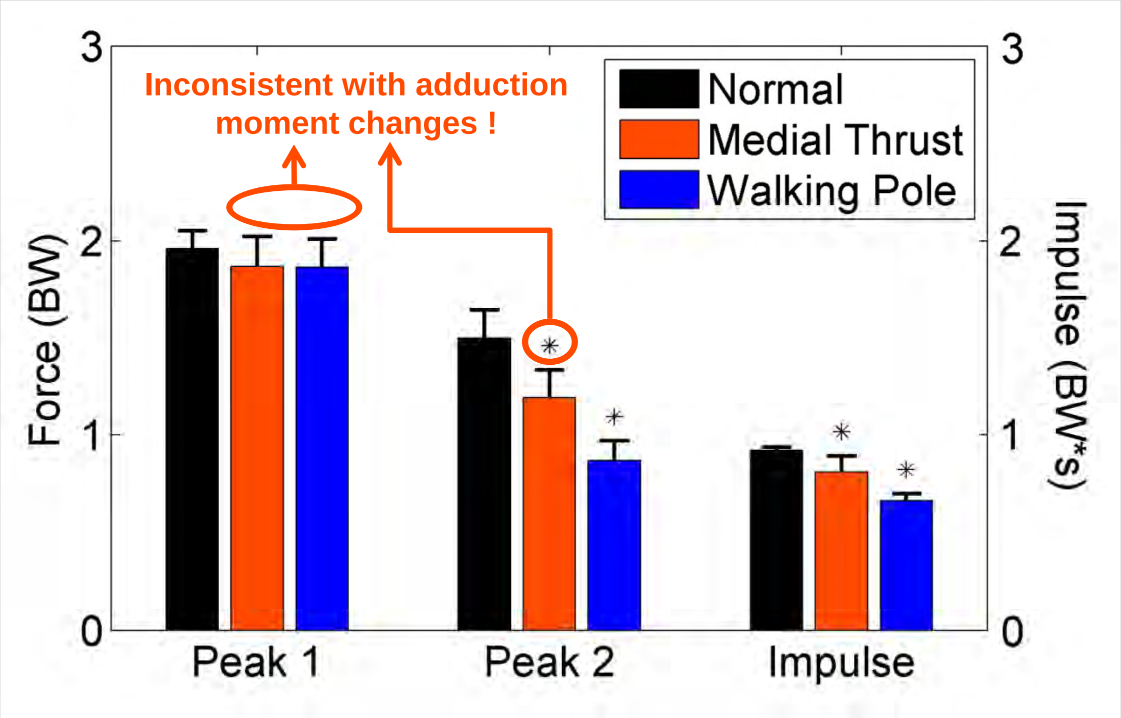
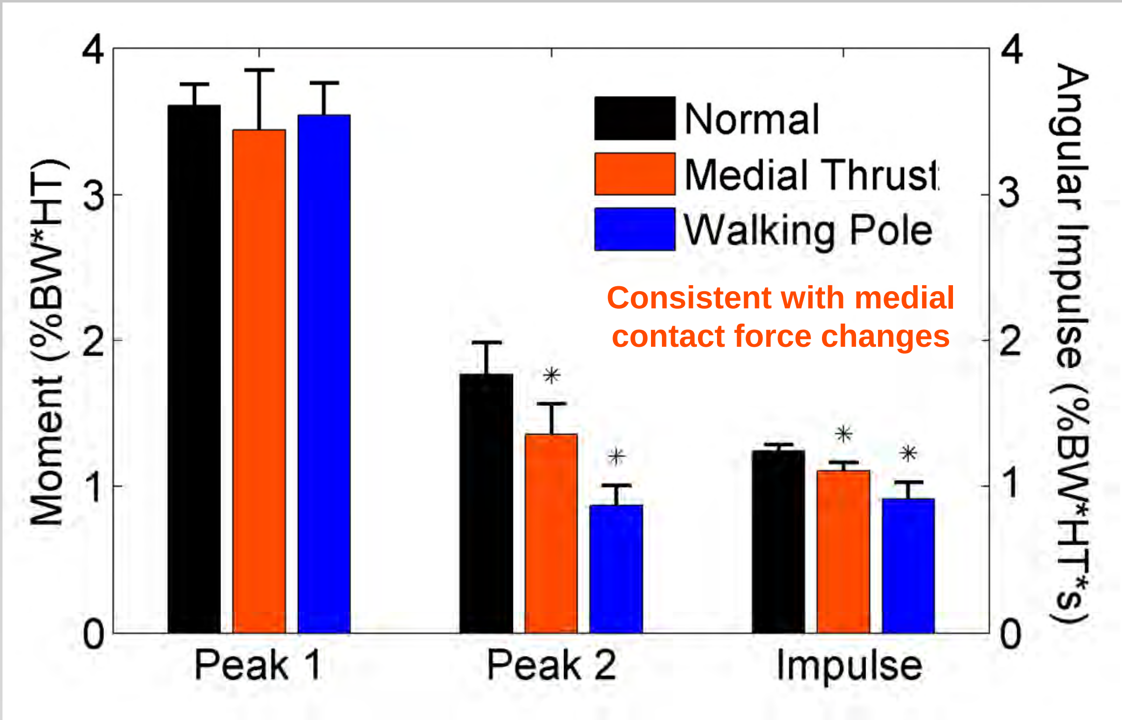
Medial Contact Force



Optimal Axial Rotation



Optimal rotation:	20 deg	-5 deg	15 deg
Optimal R^2 value:	0.57	0.70	0.74

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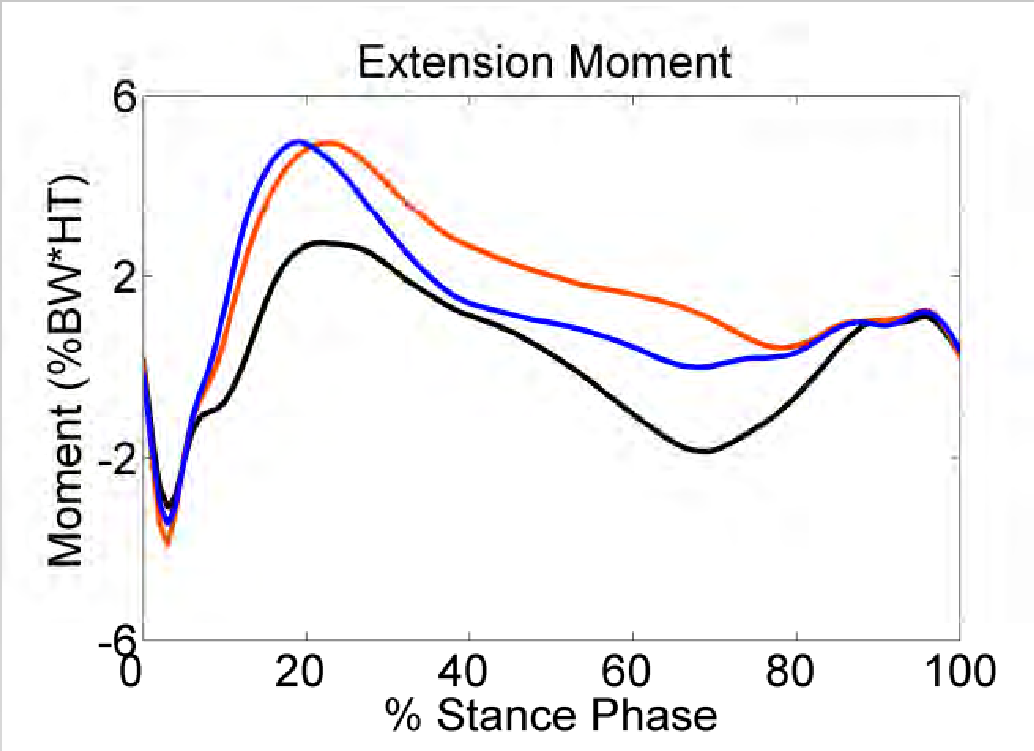
Knee Extension Moment



Walter *et al*., 2009, *SBC*

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Conclusions

1. Inclusion of explicit contact models in a musculo-skeletal knee model allows additional inverse dynamic loads to be used as constraints and alters the muscle and contact force estimates.
2. The second eKnee data set provides the unique opportunity to evaluate muscle and contact force predictions for gait patterns that modulate medial contact force.

Acknowledgments

NSF CAREER award CBET 0239042 and
NSF award CBET 0602996

Workshop Outline

1. Motivation for Competition (B.J. Fregly)
2. Instrumented Implant Designs and Accuracy (Darryl D'Lima)
3. Experimental Data Collection (Thor Besier)
4. Modeling Results To Date (B.J. Fregly)
5. Logistics of Competition (Darryl D'Lima)

5. Logistics of Competition

Darryl D. D'Lima, M.D., Ph.D.
Director, Orthopaedic Research Laboratories
Shiley Center for Orthopaedic Research & Education
Scripps Clinic, La Jolla, CA

Announcement of Competition

Focus on the musculoskeletal modeling community:

- BIOMCH-L Newsgroup
- ISB Technical Group on Computer Simulation Newsgroup
- **ASME Summer Bioengineering Conference**
- American Society of Biomechanics Newsletter
- International Society of Biomechanics Newsletter
- SimTK.org e-mail list
- Personal invitation

Journal of Orthopaedic Research

- Publication
  - Make data available
  - Announce competition
  - Peer reviewed
  - Tim Wright, PhD (Editor)
- Data
  - Anthropometric measurements
  - Marker positions
  - Ground reaction forces
  - EMG signals
  - Limited tibial contact forces
  - OpenSim model of subject and implant geometry

www.SimTK.org

- Registration
- Data published in *J Orthop Research*
- Contact models of implant components
- Videos of data collection
- Post-competition implant contact forces
- Special requests

Predicted Quantities

Time histories of

- Medial contact force
- Lateral contact force

for selected gait trials

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Abstract Submission

- Introduction
- Methods
- Results
- Discussion
- Predictions – upload to SimTK.org

Review Criteria

- Reviewers
- Significance (0-3 points)
- Technical content (0-5 points)
- Completeness (0-2 points)
- Accuracy (0-5 points - new)
- Novelty (0-5 points - new)
- Max 20 points

Special Session

- Top scoring papers given podium presentations in a special session at next year's conference.
- More than one special session may be possible.
- Participants present models and predictions.
- Actual contact force measurements revealed at end of special session.
- Post-mortem mini-workshop after special session to evaluate competition and lessons learned.

Award Presentation

- Certificate
- Cash prize (hopefully)
- Manuscript submitted to *J Orthop Research* (investigating)
- Runners ups

Workshop Outline

1. Motivation for Competition (B.J. Fregly)
2. Instrumented Implant Designs and Accuracy (Darryl D'Lima)
3. Experimental Data Collection (Thor Besier)
4. Modeling Results To Date (B.J. Fregly)
5. Logistics of Competition (Darryl D'Lima)
6. Questions and Answers (All)

6. Questions and Answers

B.J. Fregly, Ph.D., University of Florida and
Darryl D’Lima, M.D., Ph.D., Shiley Center at Scripps Clinic

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Data Related Questions

1. For which tasks should *in vivo* contact force data be released BEFORE the competition?
   - EMG preparation trials?
   - Static trials?
   - Model calibration trials?
   - Gait trials (4 patterns)?
   - Dynamometer trials?

Data Related Questions

2. Are the current filter cutoff and output frequencies acceptable for the data?

Experimental Quantity	Input Frequency (Hz)	Filter Frequency (Hz)	Output Frequency (Hz)
Marker positions	120	Low pass 15	200
eKnee forces	~50	Low pass 15	200
Ground reactions	3840	Low pass 100	1000
EMG signals	1000	High pass 30	1000

Model Related Questions

1. Should we provide our surrogate contact model in Matlab so that every participant can calculate tibiofemoral and patellofemoral contact forces easily?
2. If so, how should muscle forces be applied to it?
3. Should we provide an OpenSim version of the geometric/inverse dynamic knee model?
4. What other modeling information is needed?

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Organization Related Questions

1. Should accuracy be the primary scoring criterion, or should the proposed 5 scoring criteria (significance, technical content, completeness, accuracy, and novelty) be used?
2. Should selection of the winning paper be subjective or objective? If subjective, who should do it?

Other Relevant Questions

What questions and suggestions do you have for us?