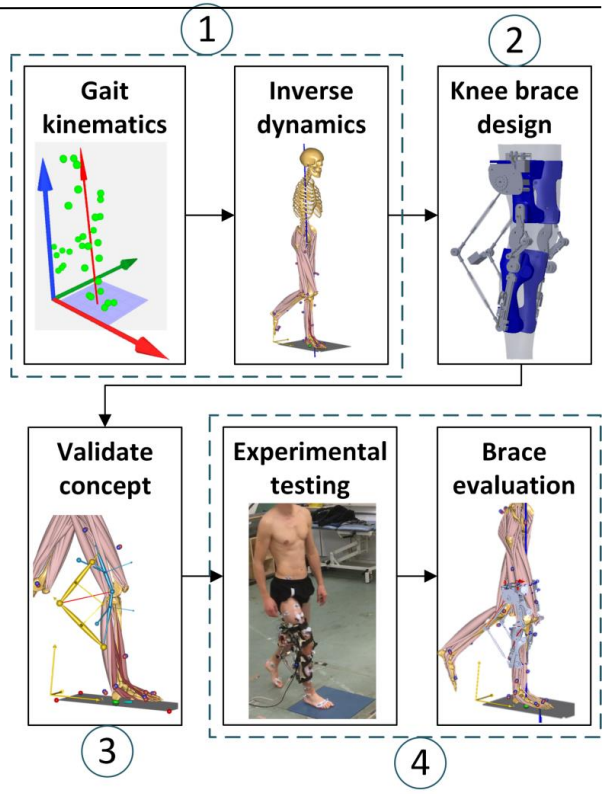
The webcast will begin shortly…

Investigation of bracing to unload muscle and knee contact forces for knee osteoarthritis patients

January 17th, 2022



Outline

- General introduction to the AnyBody Modeling System
- Presentation by PhD Candidate Jonas Stoltze
  - Investigation of bracing to unload muscle and knee contact forces for knee osteoarthritis patients
  - Upcoming events
- Question and answer session

Presenter:
Jonas Stoltze
PhD Candidate

Aalborg University

AALBORG UNIVERSITY

Host(s):
Bjørn Keller Engelund
R&D Engineer

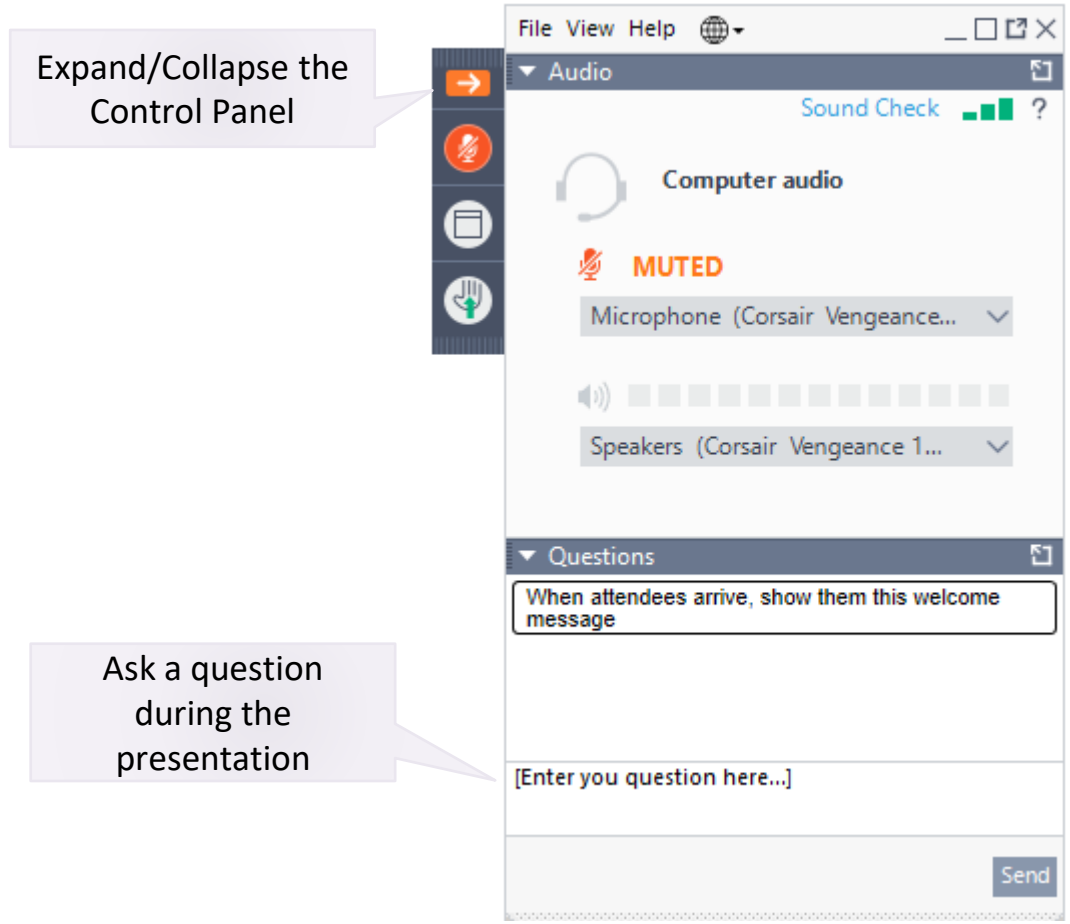
Kristoffer Iversen
Technical Sales Executive

Control Panel

The Control Panel appears on the right side of your screen.

Submit questions and comments via the Questions panel.

Questions will be addressed at the end of the presentation. If your question is not addressed, we will do so by email.



Musculoskeletal Simulation

Motion Data

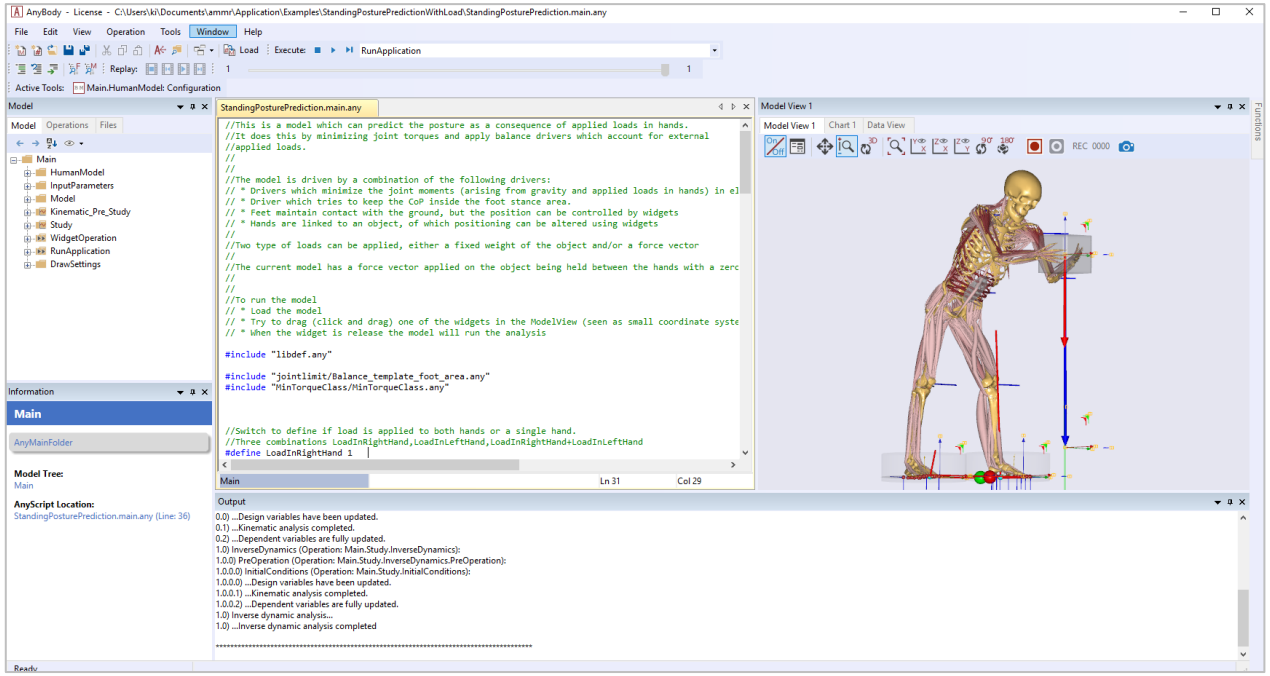
Kinematics and Forces

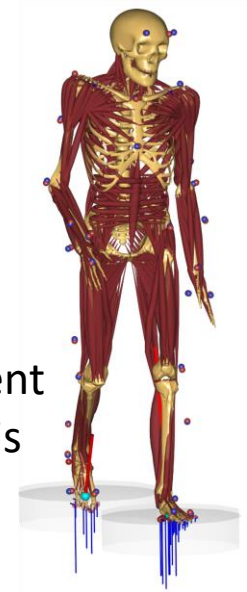
ANYBODY

Modeling System

Body Loads

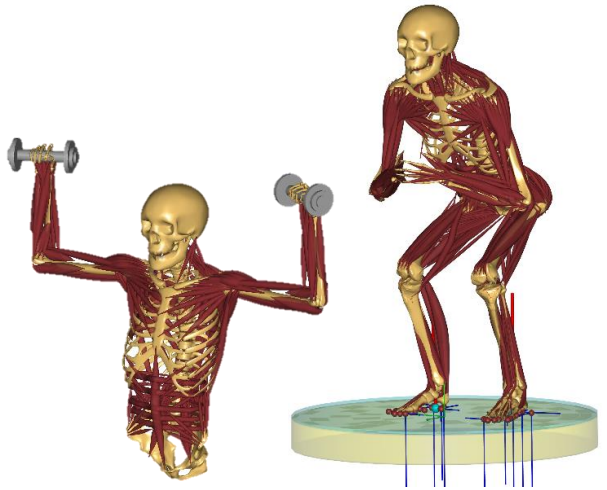
- Joint moments
- Muscle forces
- Joint reaction forces





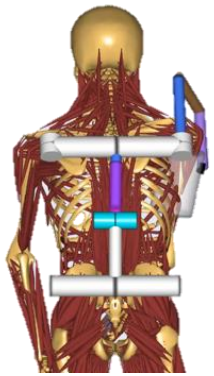
Movement Analysis

Product optimization design

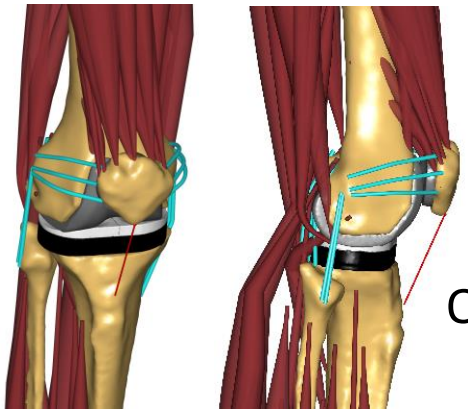


Sports

ANYBODY Modeling System



Assistive Devices



Orthopedics and rehab

AnyBody Modelling System

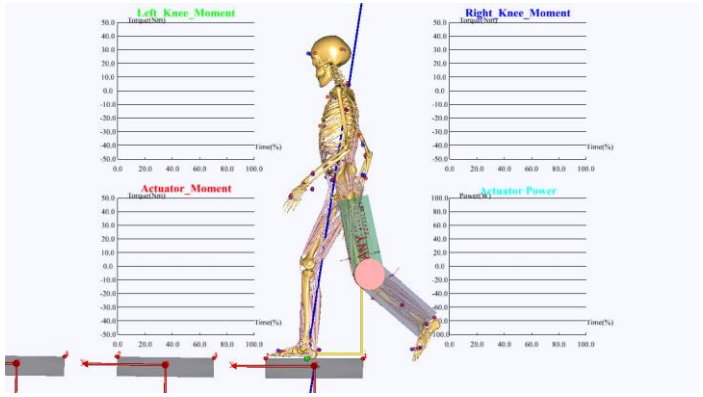
Motion and Forces

Body model

Environment model

Inverse dynamics
Muscle recruitment

Simulation



Internal body loads

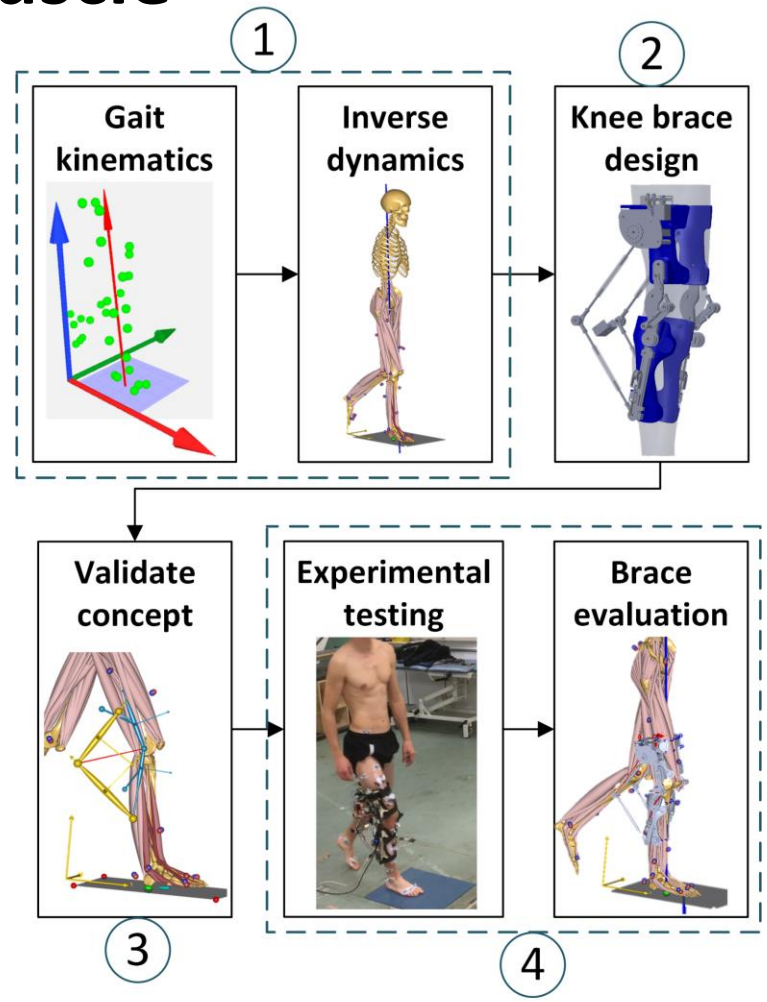
- Muscle forces
- Joint moments

Design Optimization

Post Processing (e.g. Finite element tools)

Investigation of bracing to unload muscle and knee contact forces for knee osteoarthritis patients

Presented by Jonas Stoltze



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DENMARK

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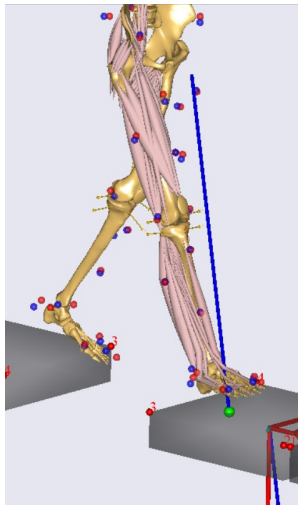
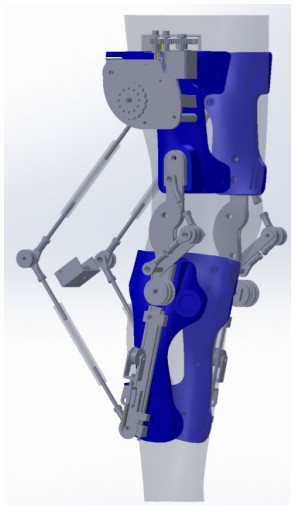
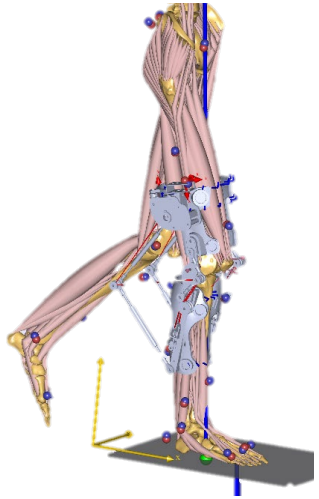
Individualized Osteoarthritis Interventions

Investigation of bracing to unload muscle and knee contact forces for knee oteoarthritis patients

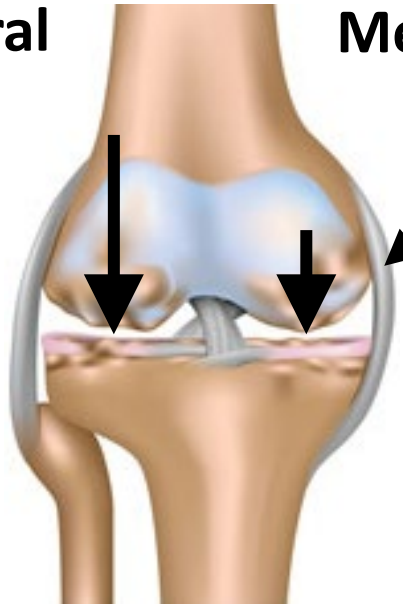
Jonas S. Stoltze, John Rasmussen and Michael S. Andersen

Department of Materials and Production, Aalborg University
E-mail: jss@mp.aau.dk

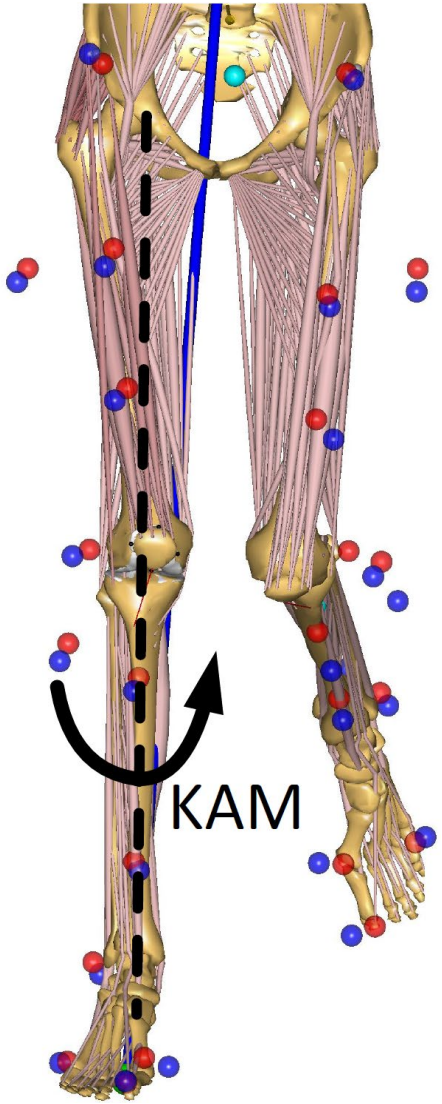
Motivation – Knee Osteoarthritis (KOA)

Innovation Fund Denmark
Individualized Osteoarthritis Interventions

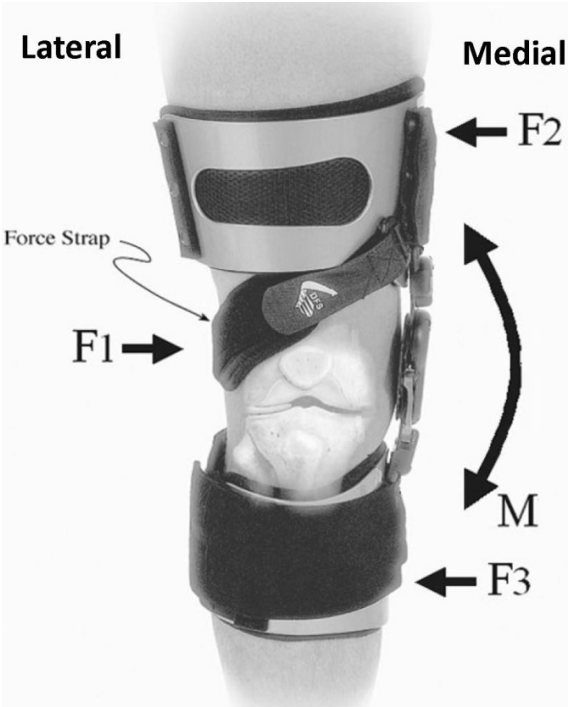


- Inflamation
- Stiffness
- Pain

- Multi-factoral disease
  - Genetic
  - Previous ligament ruptures
  - Underloading
  - Overloading



Non-invasive treatments of KOA



Modified picture from (Pollo et al. 2002)

- Skin surface displacement
- MCL may be too stiff
- Shifts load but not reducing

Aim

Innovation Fund Denmark

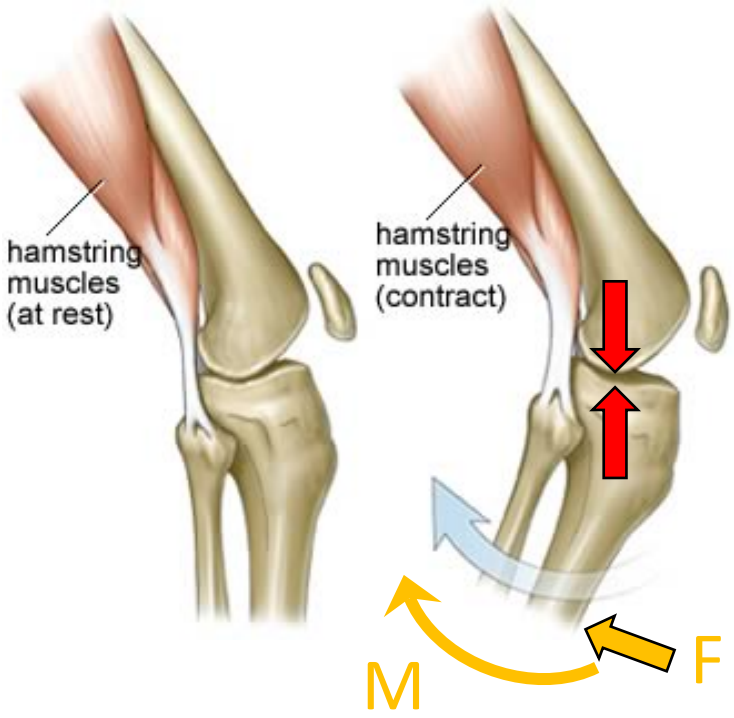
Individualized Osteoarthritis Interventions

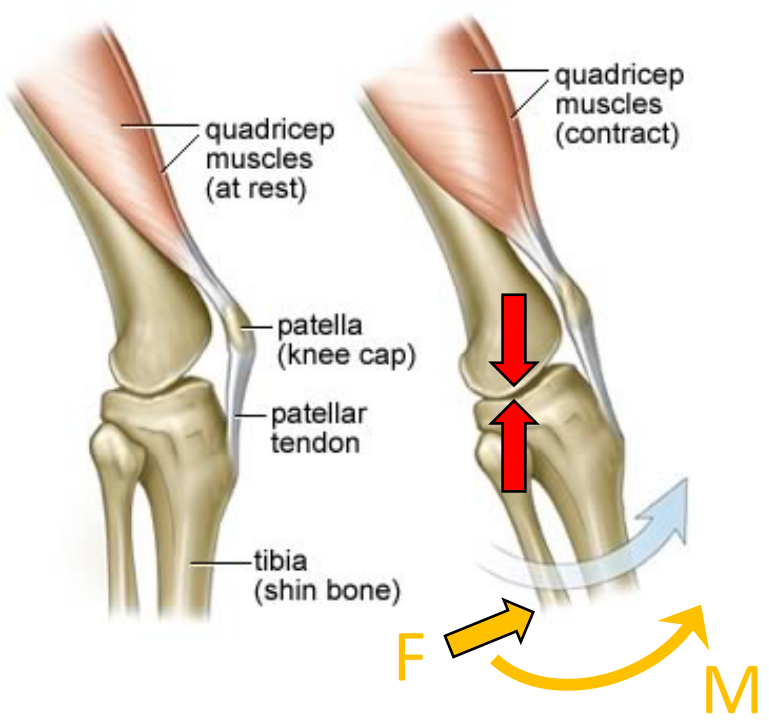
Develop a subject-specific knee brace to unload the knee joint for KOA patients

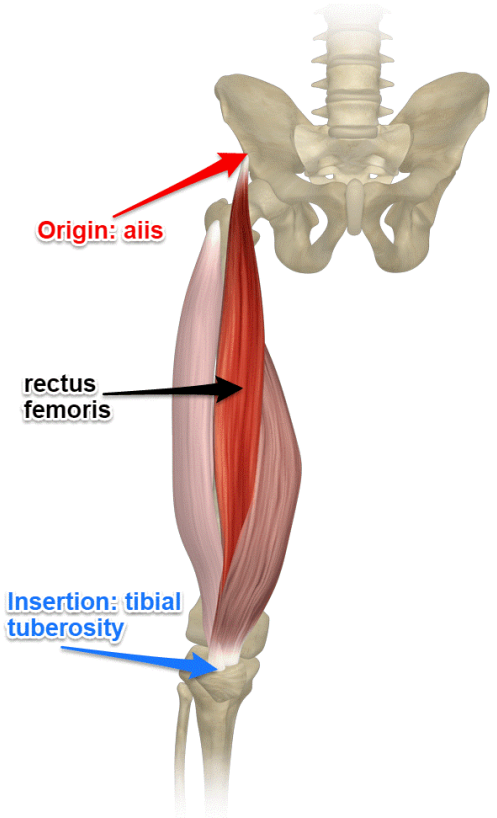
Study I: Moment study

How to unload the knee?

- Investigate how internal knee compressive forces (KCF) depend on external moments



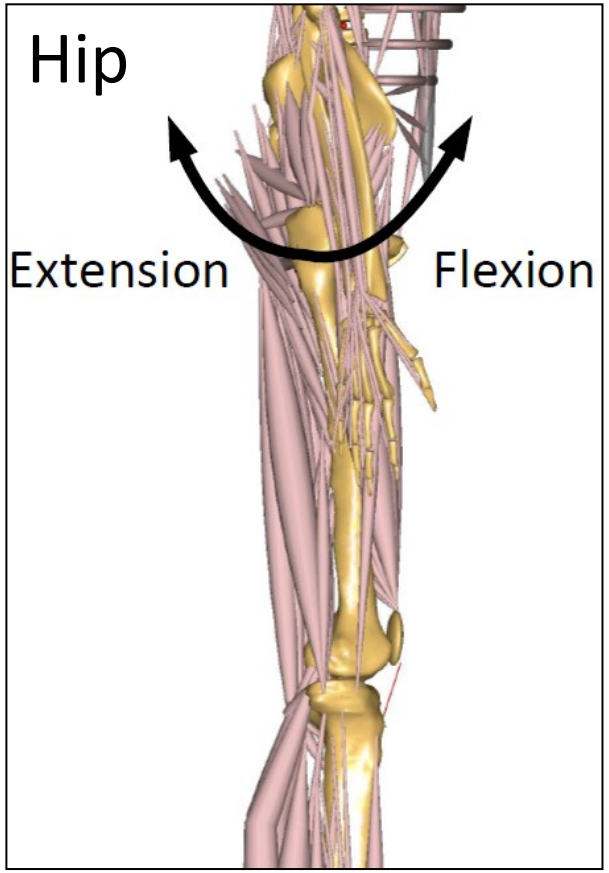


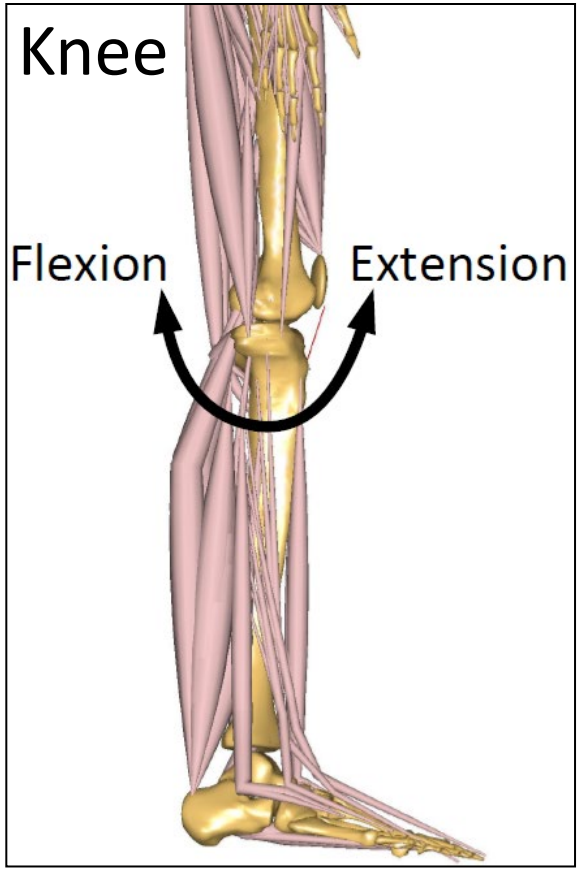


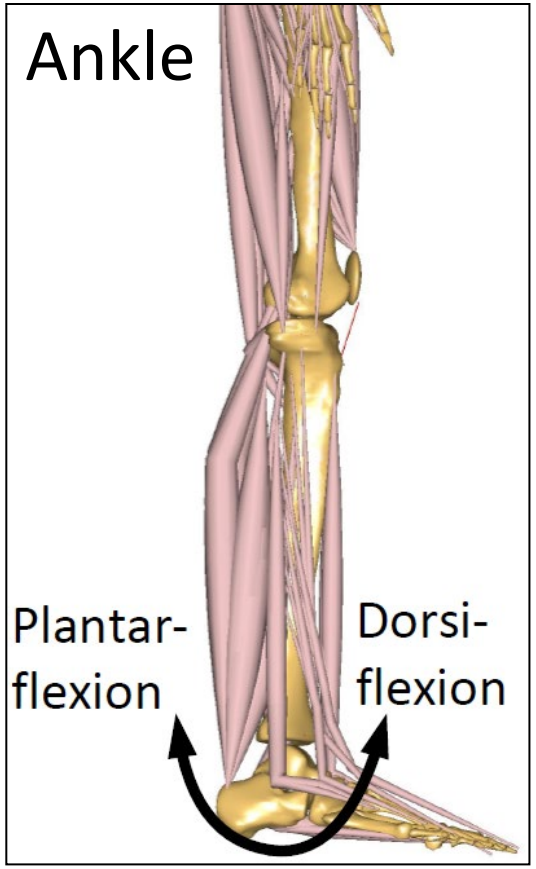
Study I: Moment study – Method

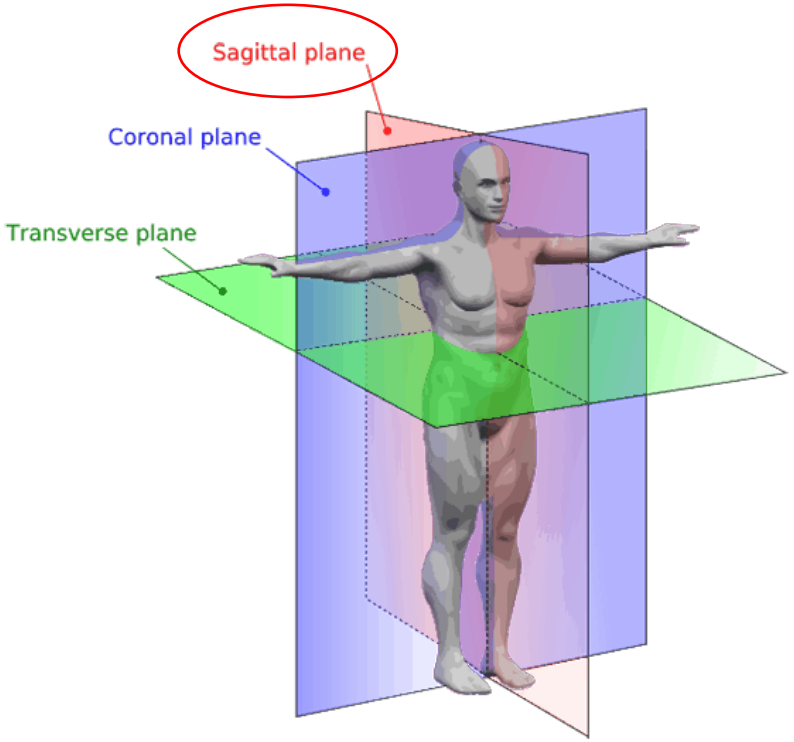
Apply external joint moments to simulate a brace *in-silico*

- **40**% compensation of muscle moment → Reducing joint load





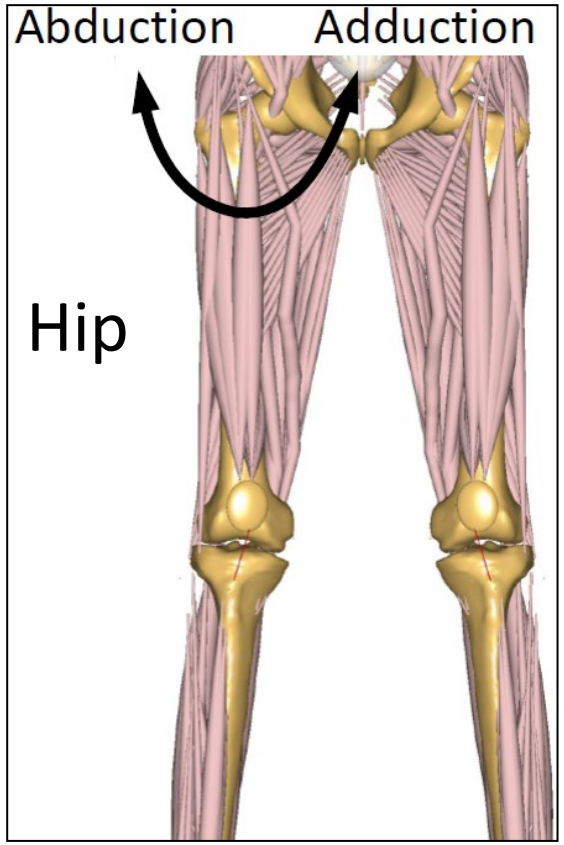


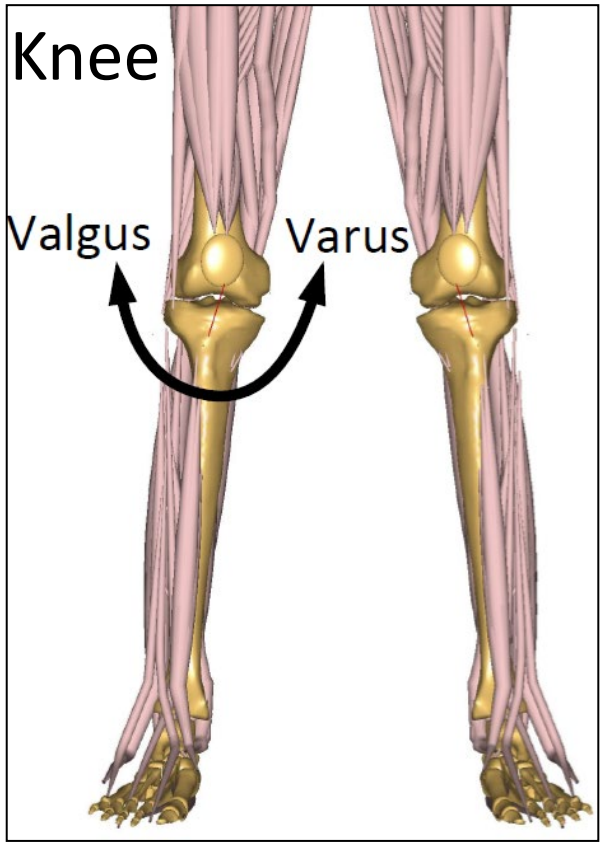


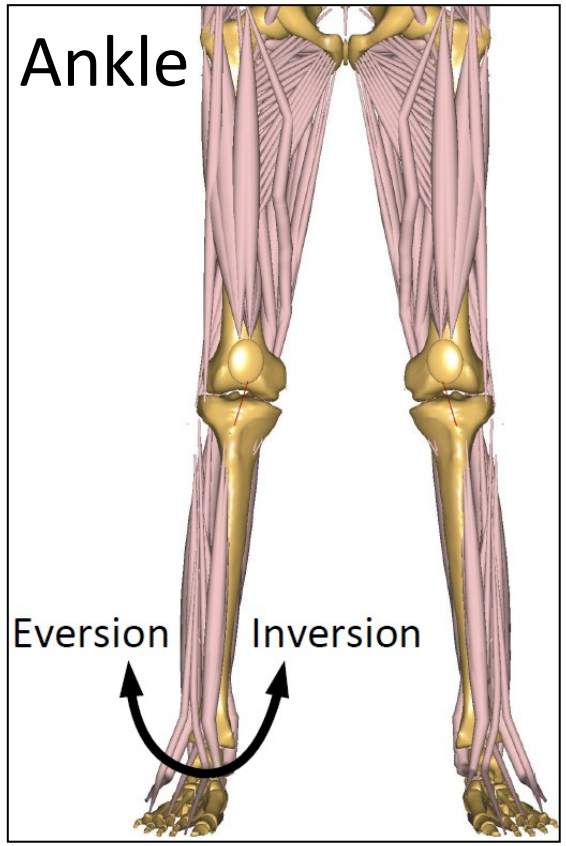
Study I: Moment study – Method

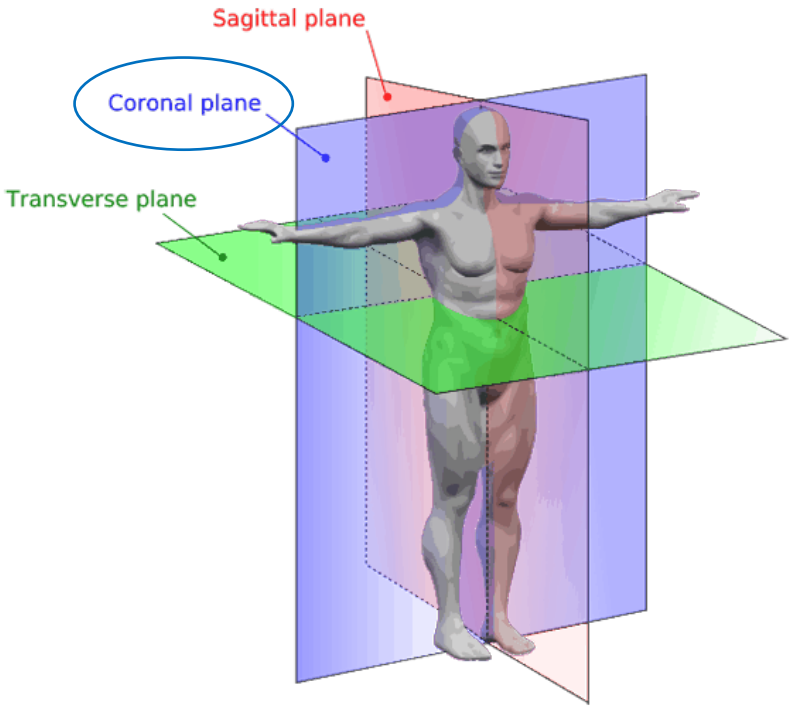
Apply external joint moments to simulate a brace *in-silico*

- Compensating muscle work → Reducing joint load



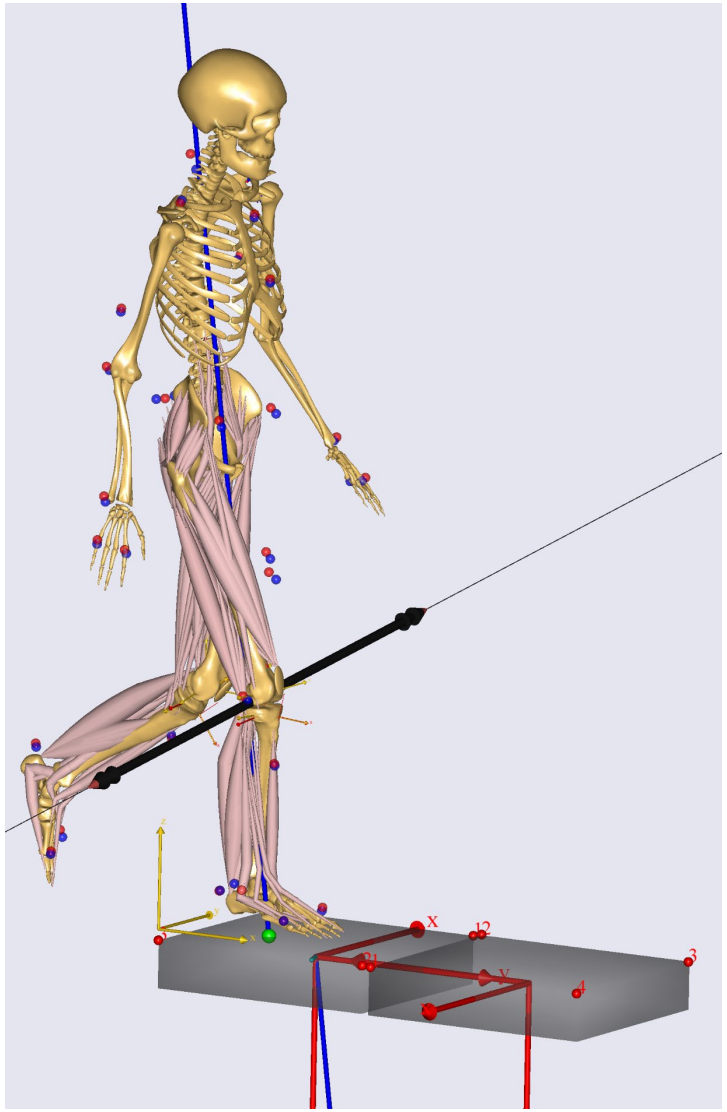




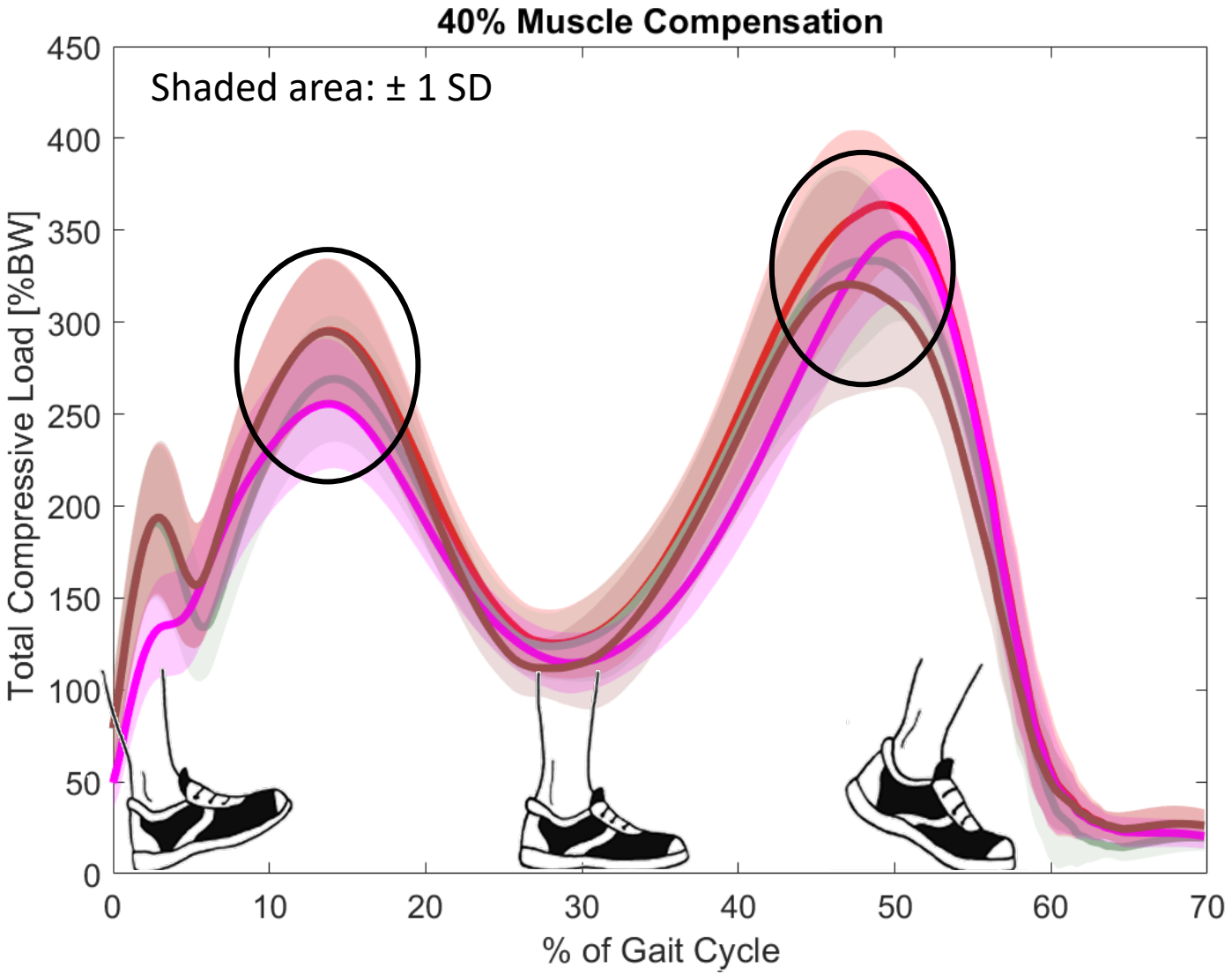


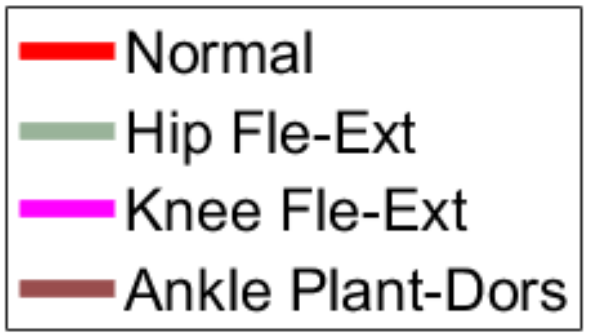
Study I: Moment study – Method

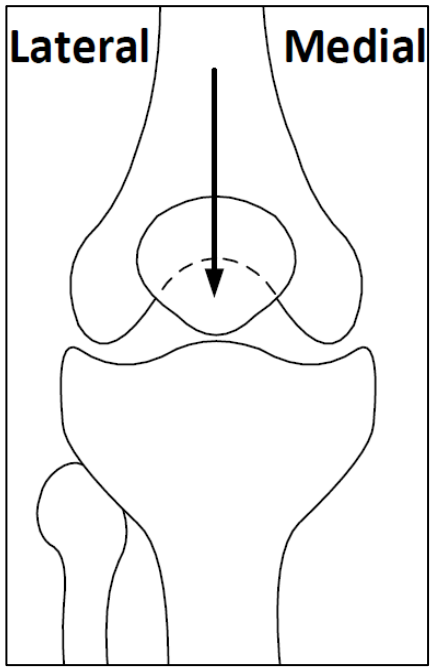
Example of knee flex-ext

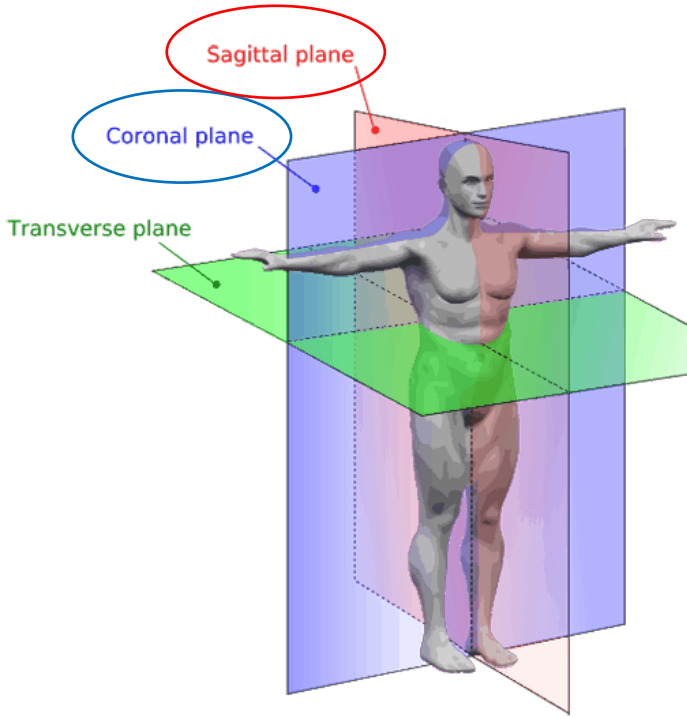


Study I: Moment study – Results









Study I: Moment study – Findings

- Muscle contraction → Joint compressive force
  - First peak: Knee and hip compensation
  - Second peak: Ankle compensation
- Published in Stoltze et al. 2018

  On the biomechanical relationship between applied hip, knee and ankle joint moments and the internal knee compressive forces, International Biomechanics, **5**(1) DOI: 10.1080/23335432.2018.1499442

- Take home message:

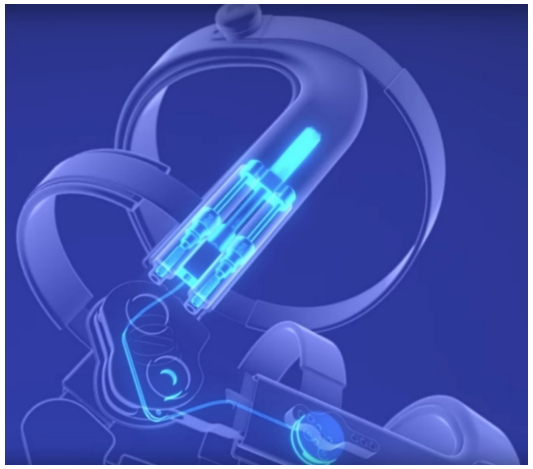
  Muscle compensation might be a more efficient approach for joint load reduction than external KAM compensation

Study II: Brace prototype – Design

AIM: Reduce first peak with applied knee extension moment

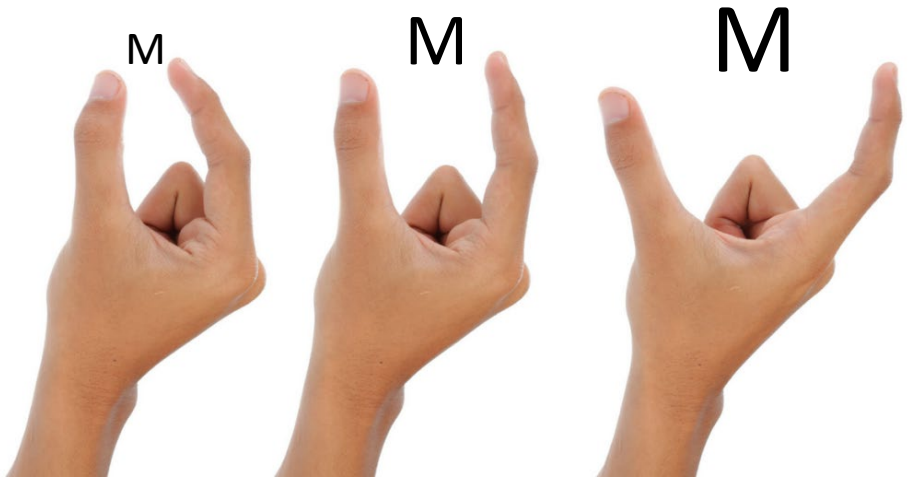
- Levitation brace (passive)
  Spring Loaded Technology
- Ascend Brace (active)
  Roam Robotics

Subject-specific



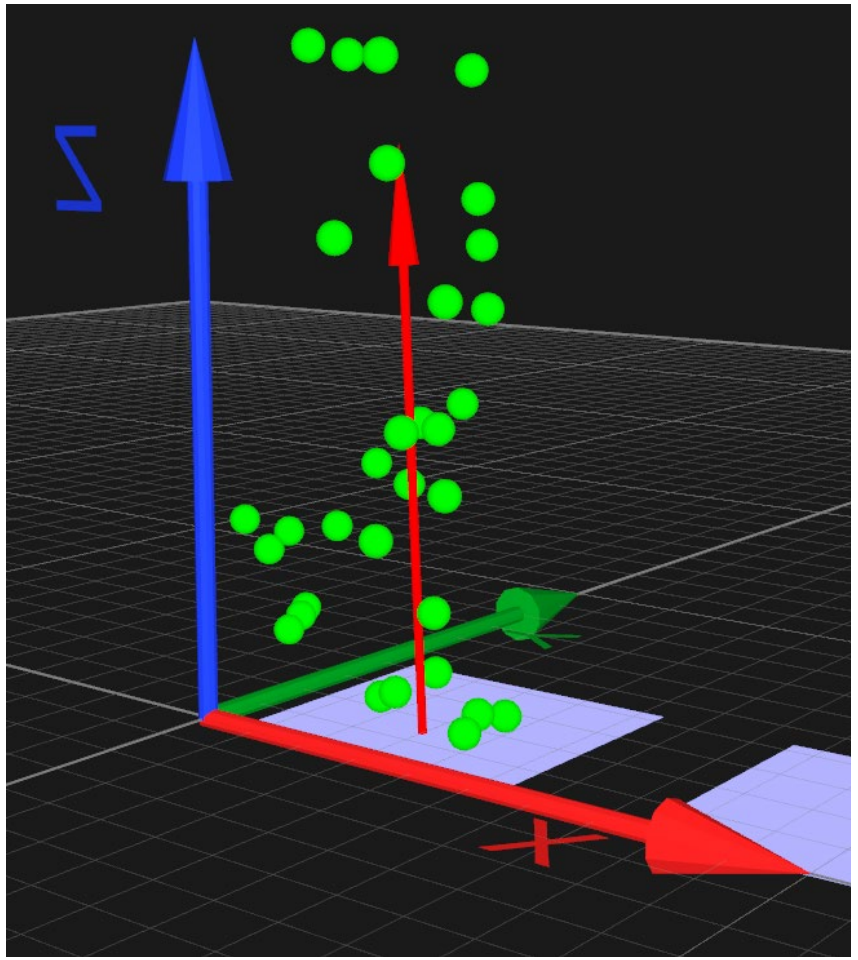
Study II: Brace prototype – Design

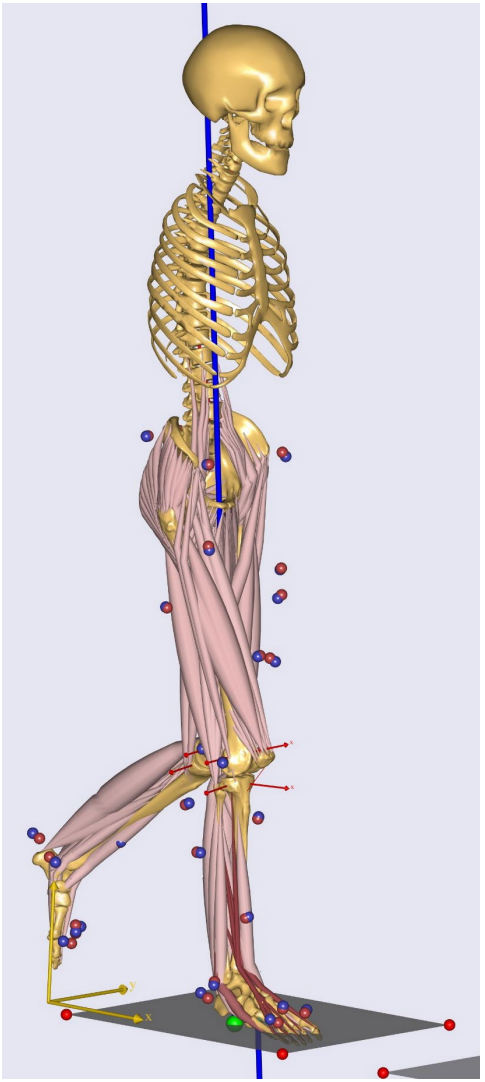
- Individually adjustable (subject-specific)
- Only applied during first peak
- No actuators for applying the moment
  - Store potential energy in springs
- What type of springs?
- Depends on the size (and shape) of the moment



Study II: Brace prototype – Design

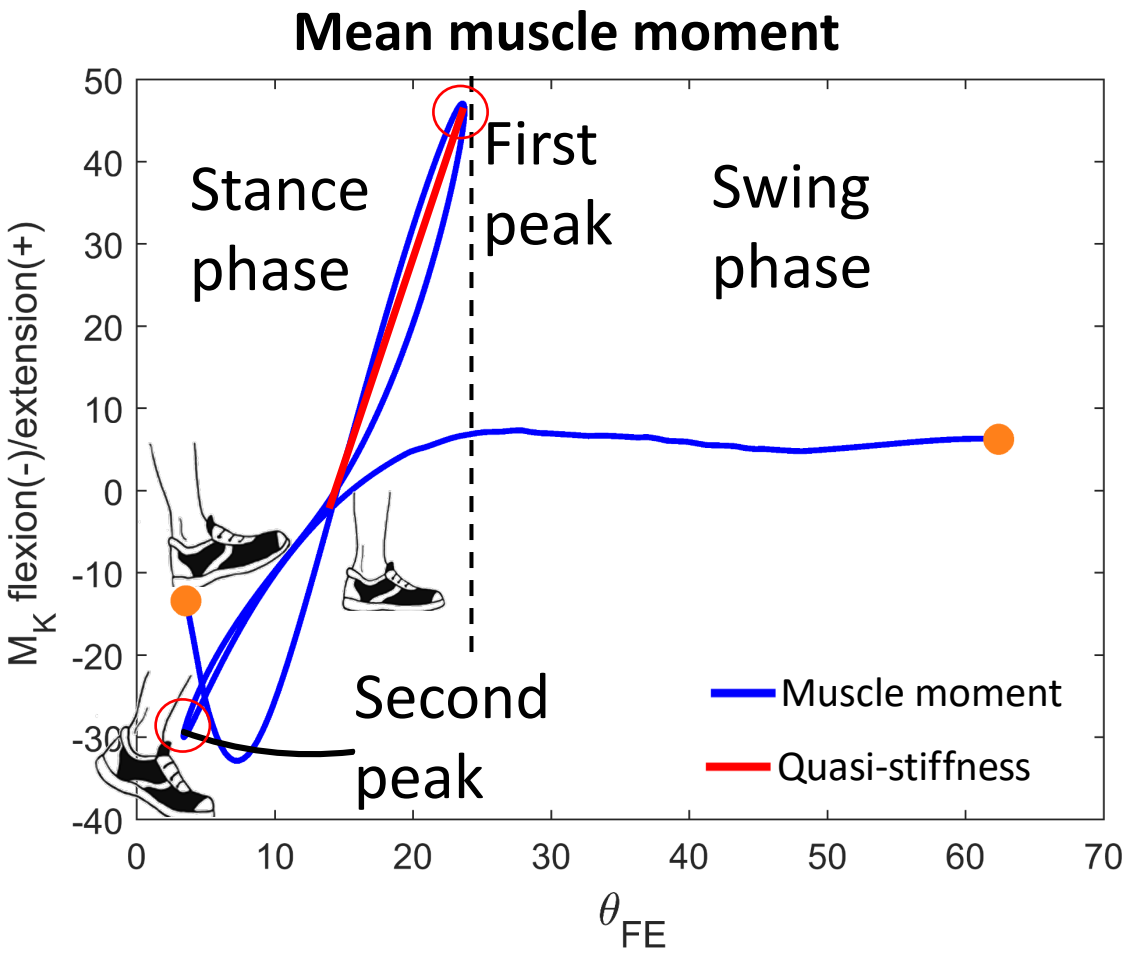
MoCap of 5 gait trials (healthy subject)



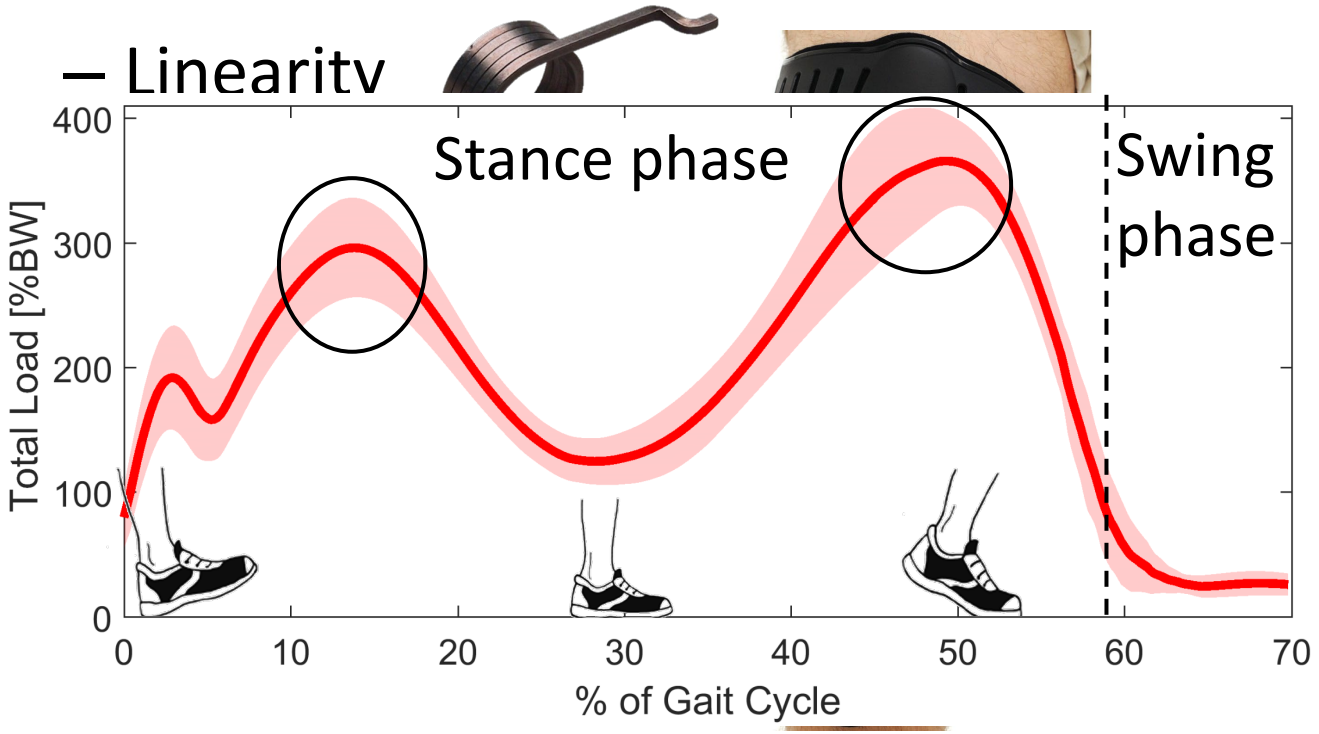


Study II: Brace prototype – Design

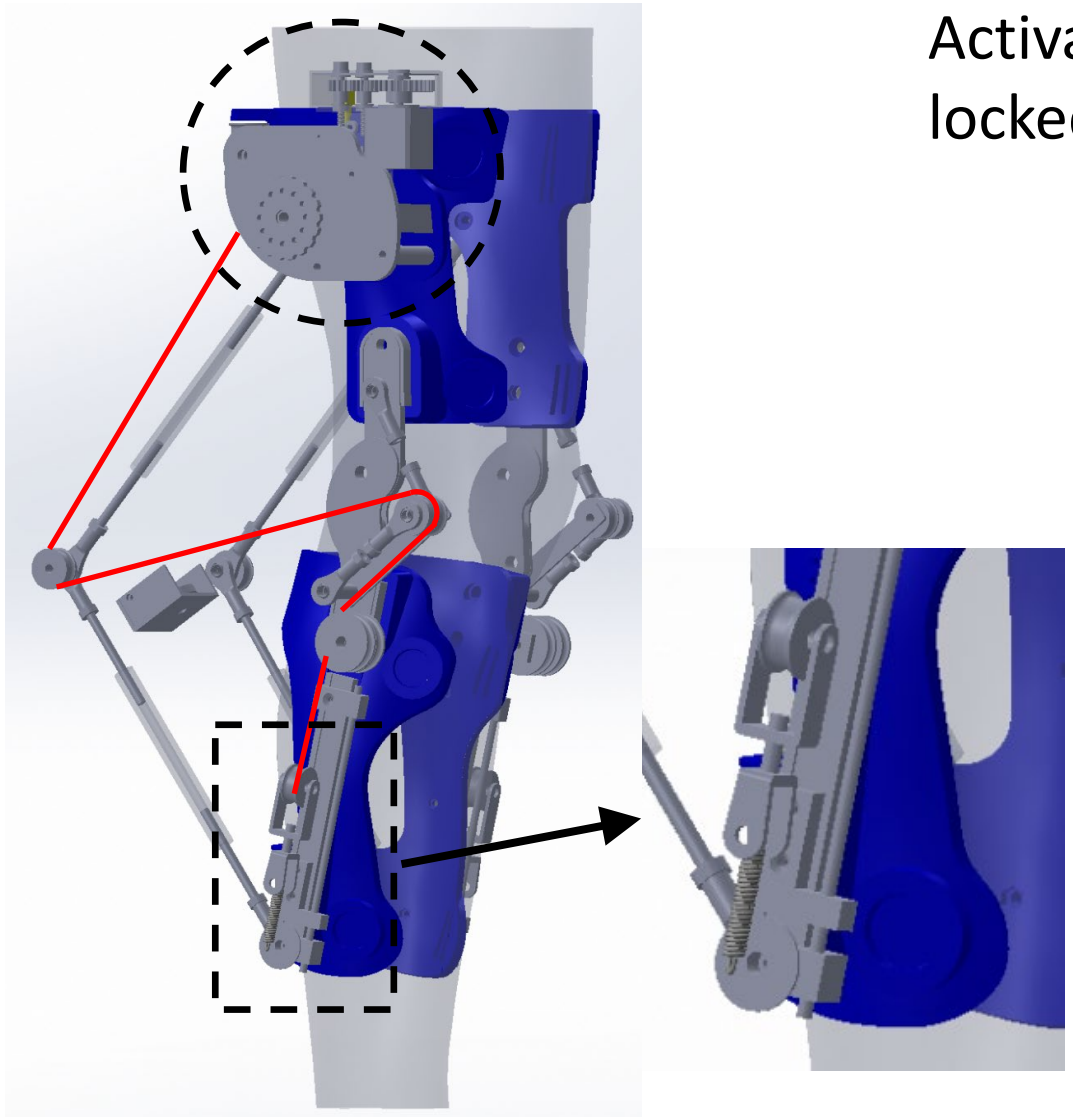
Muscle moment during gait (healthy subjects)



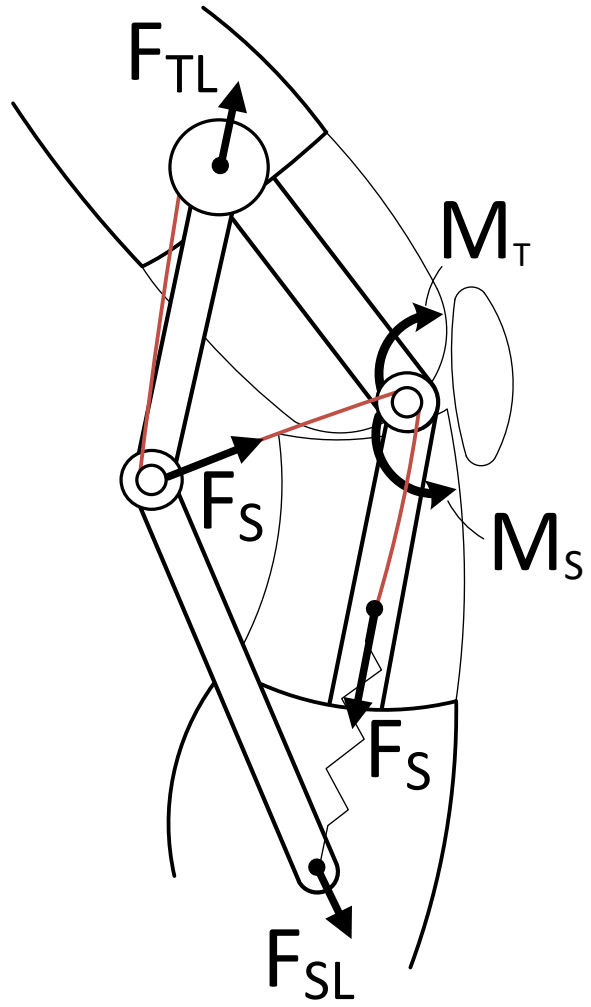
- Obvious choice is torsional springs
  - Linearity



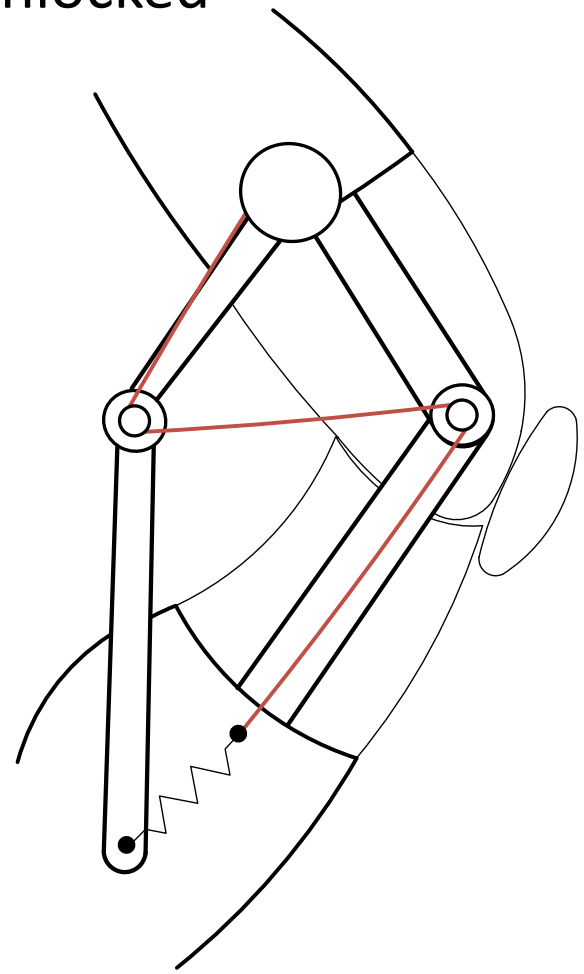
Study II: Brace prototype – Design



Activation mechanism locked

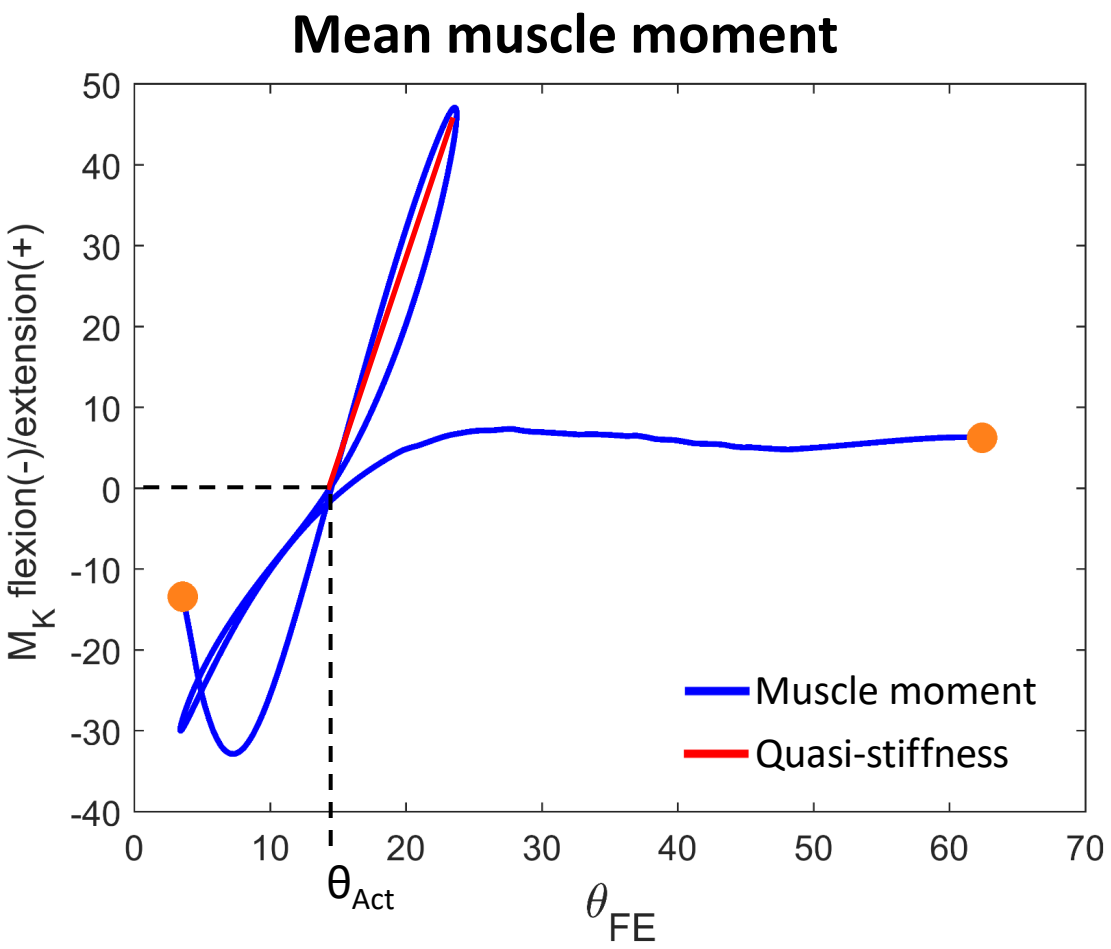


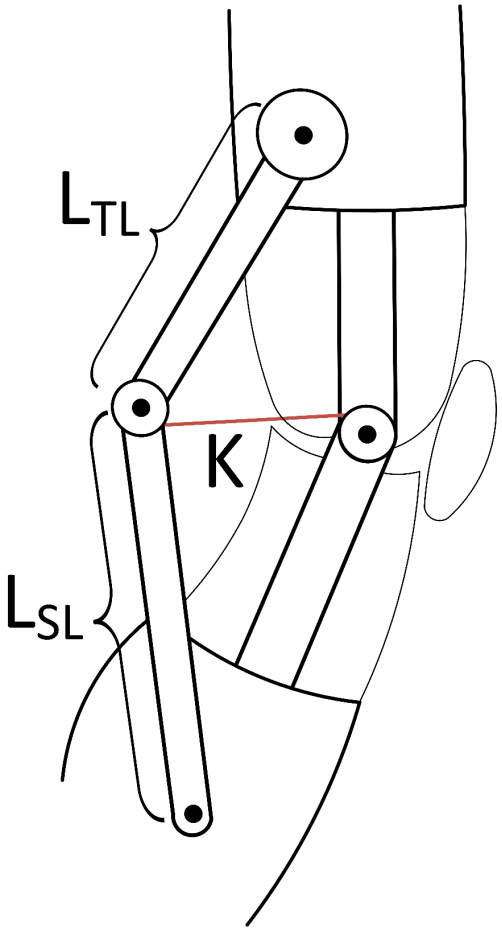
Activation mechanism unlocked

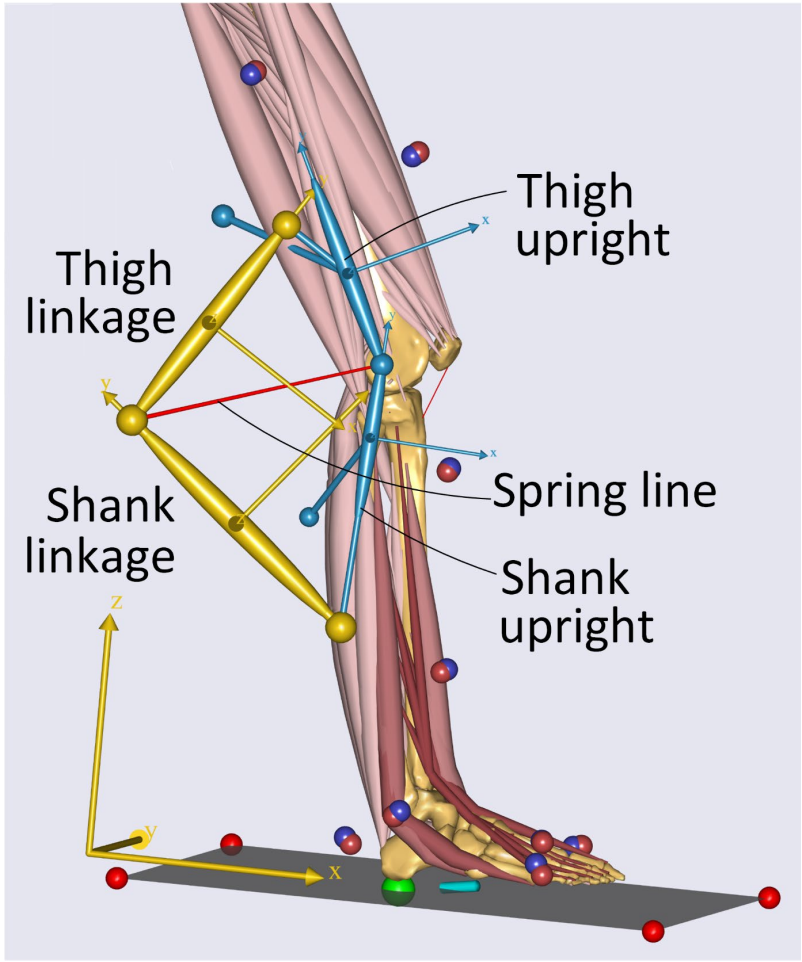


Study II: Brace prototype – Simulation

Individual adjustment



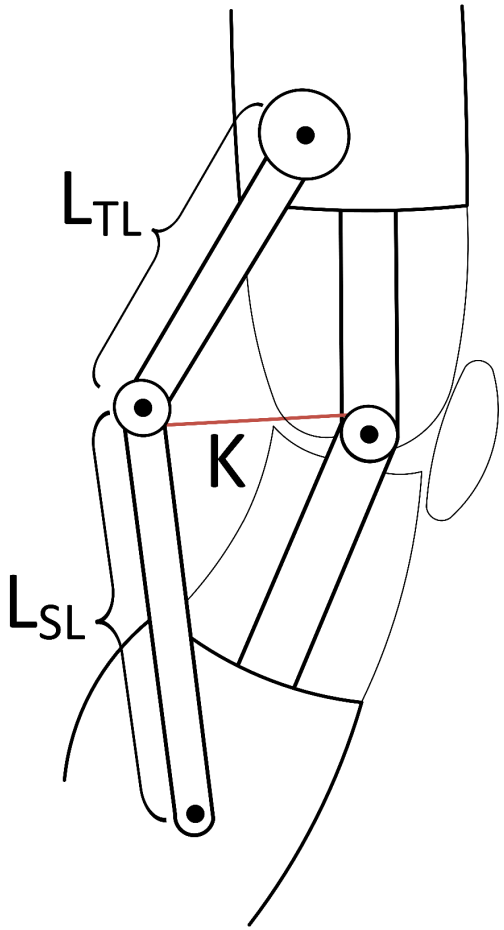


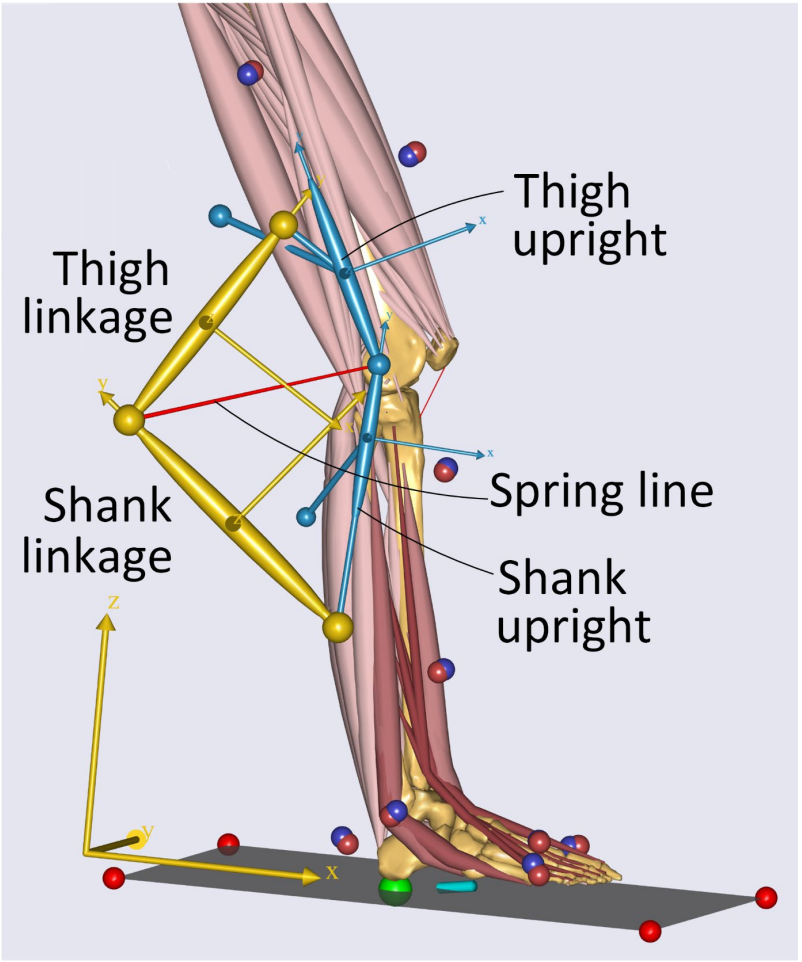


Study II: Brace prototype – Simulation

Individual adjustment

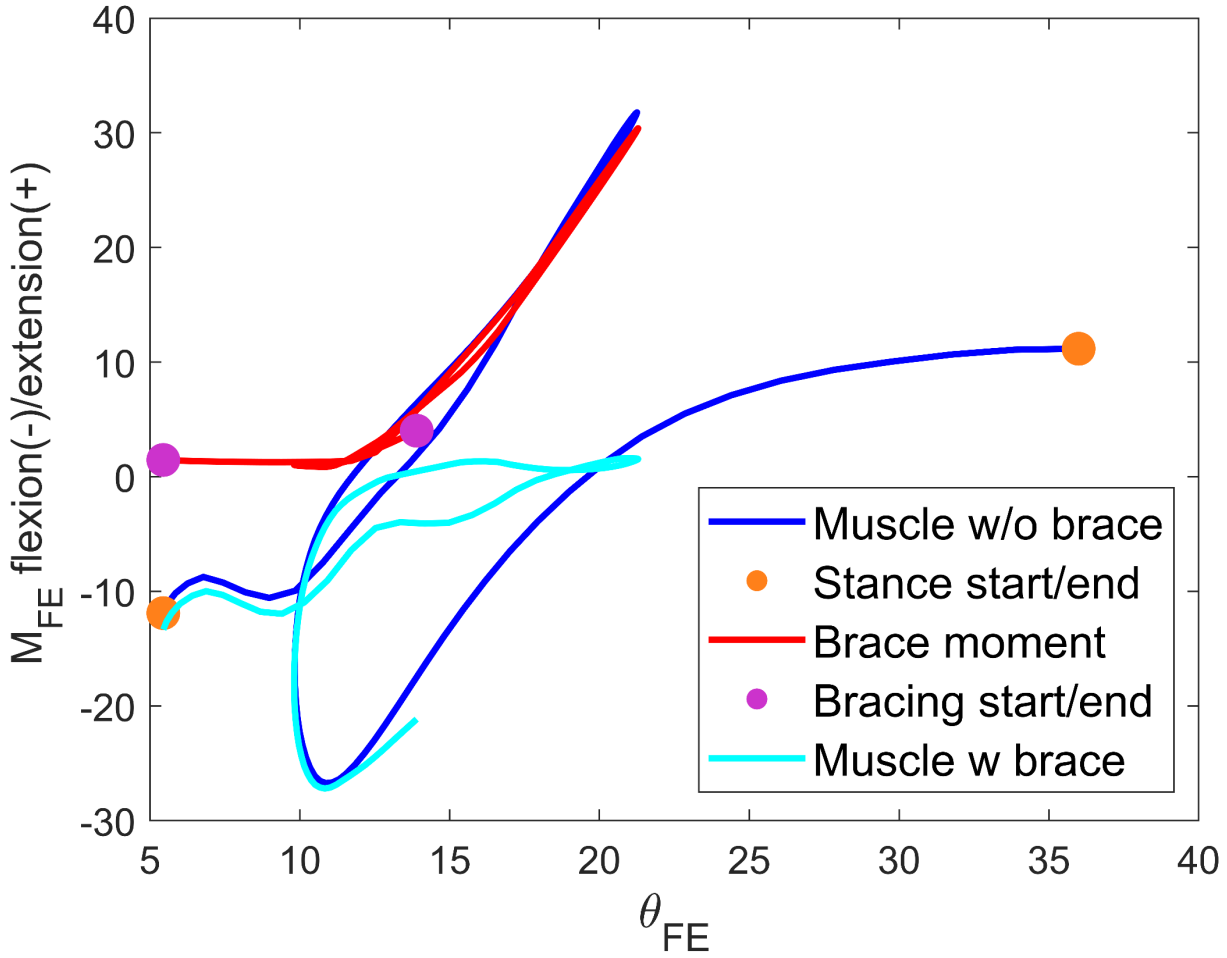
1. Parameter study:
   Vary L_{TL}, L_{SL} and K
   L_{TL} = 22-26 cm
   L_{SL} = 22-26 cm
   K = [7.1, 7.92, 8.91
   9.91, 11.09] N/mm
2. Choose optimal brace parameters (peak KCF, impulse, …)

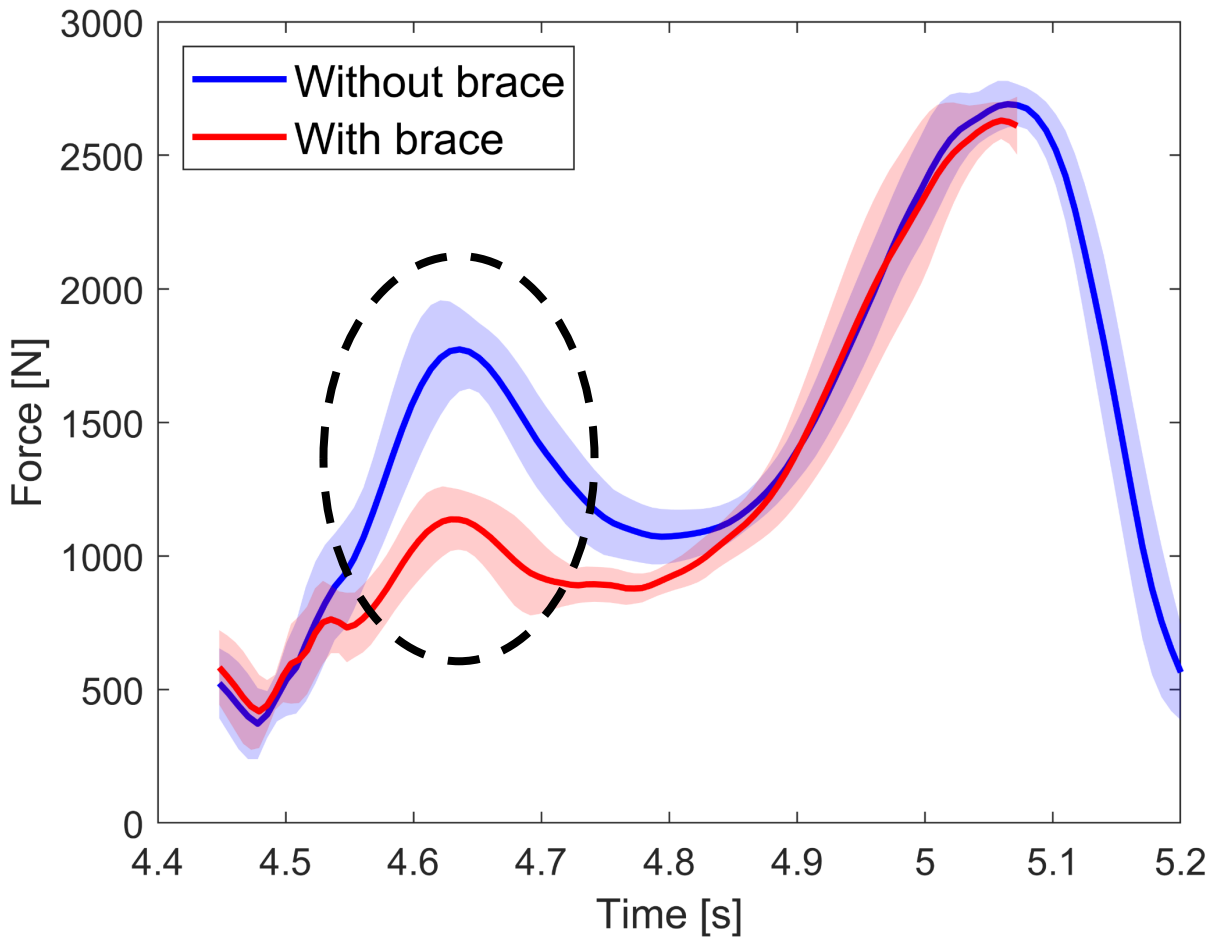




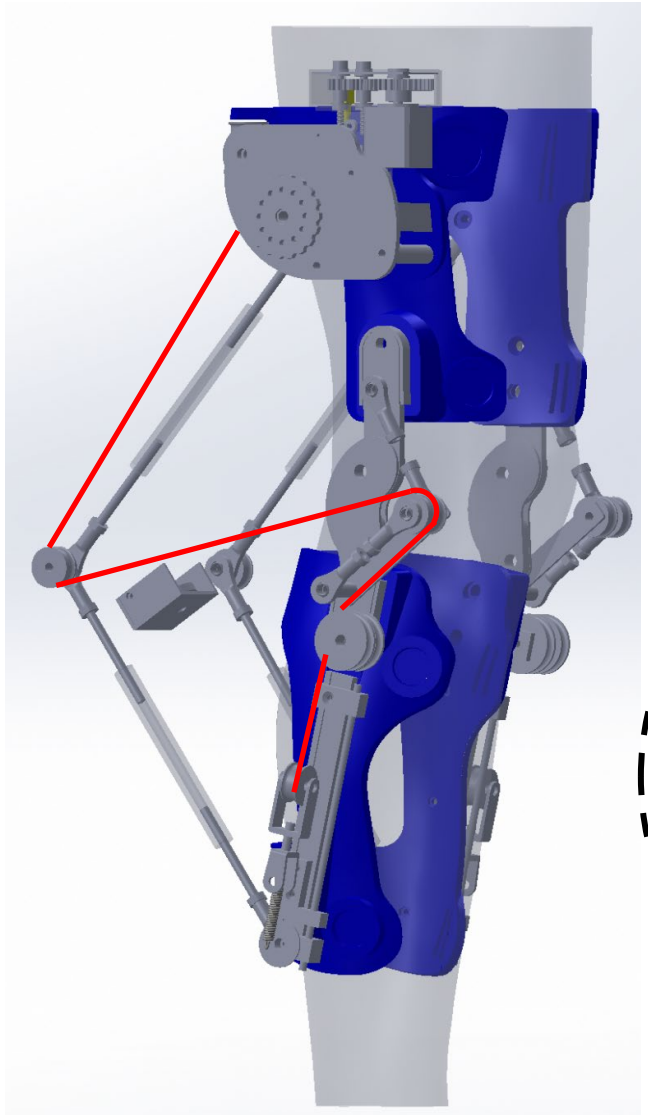
Study II: Brace prototype – Simulation

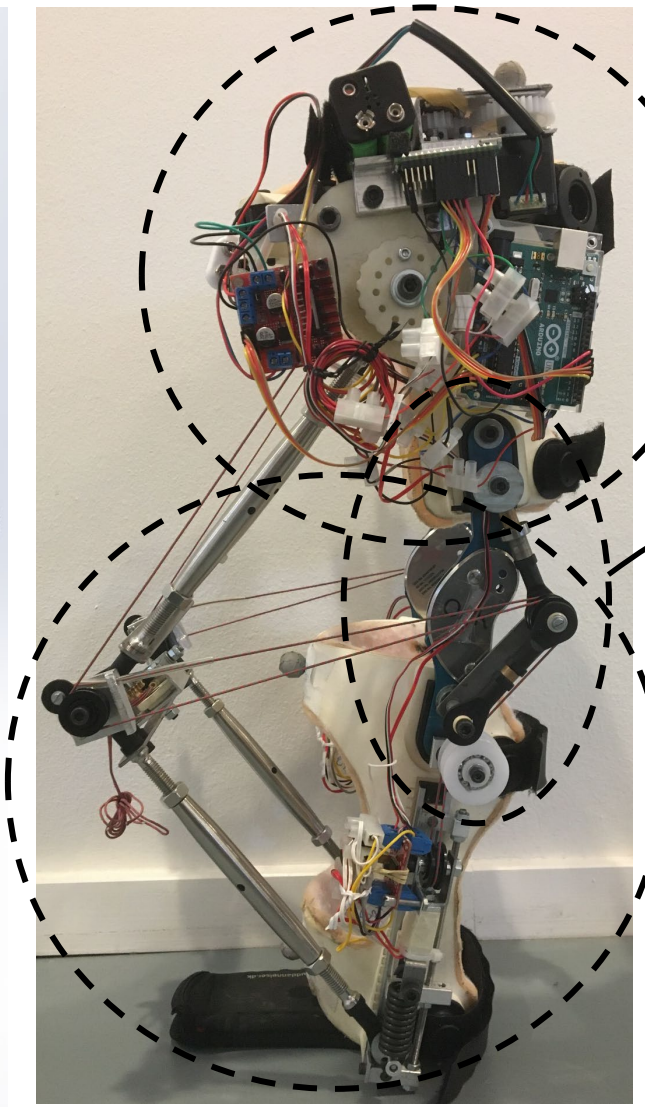
Brace simulation

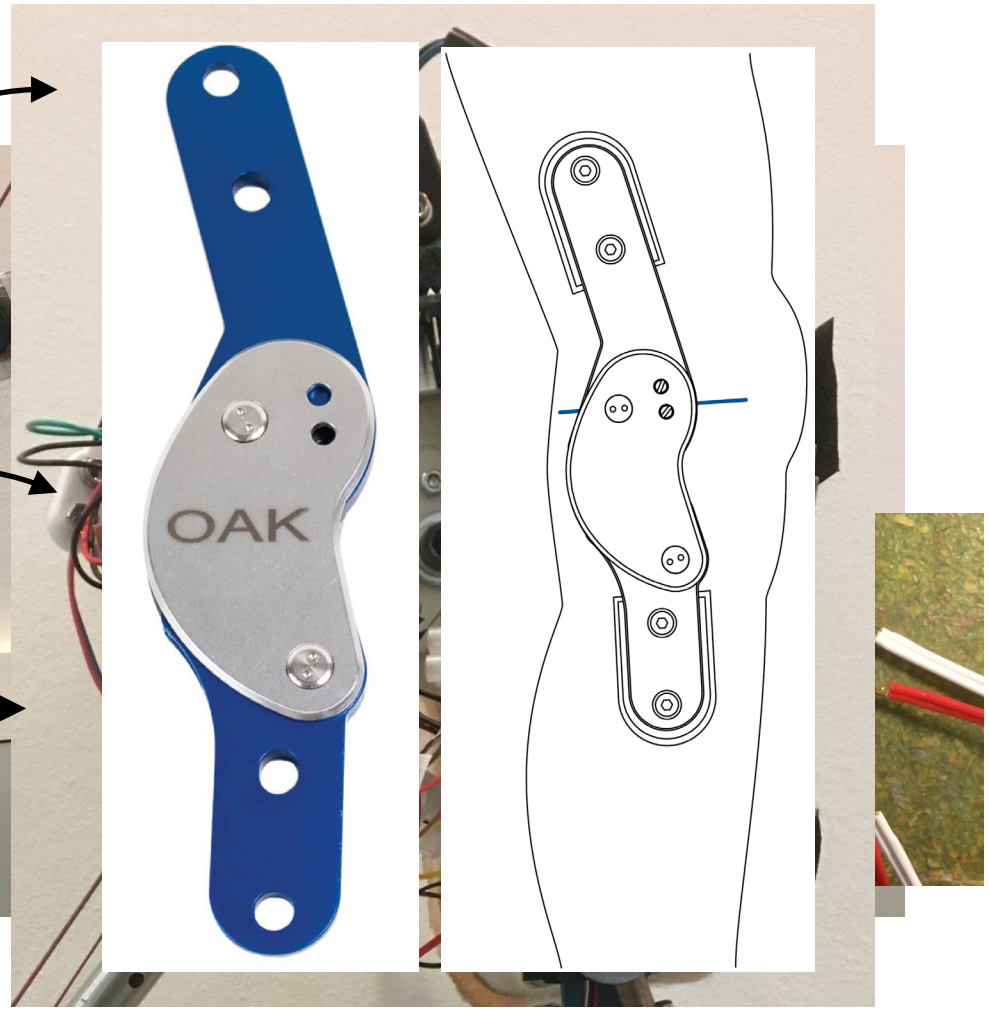




Study II: Brace prototype – Test

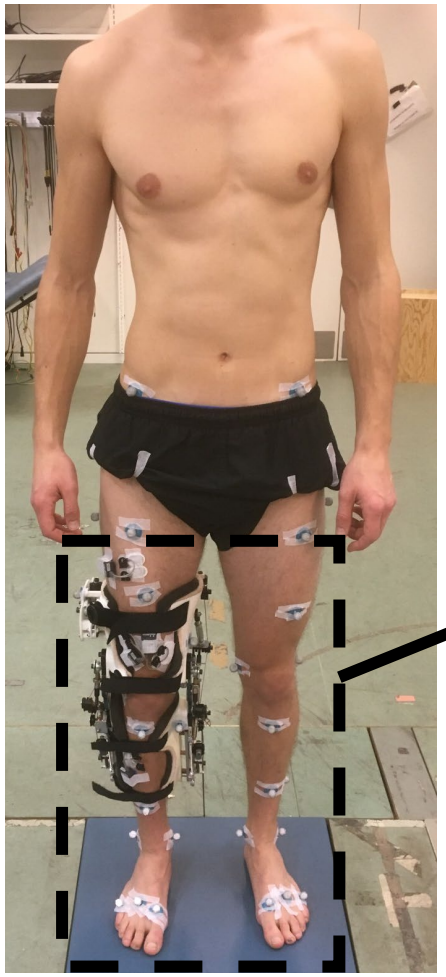


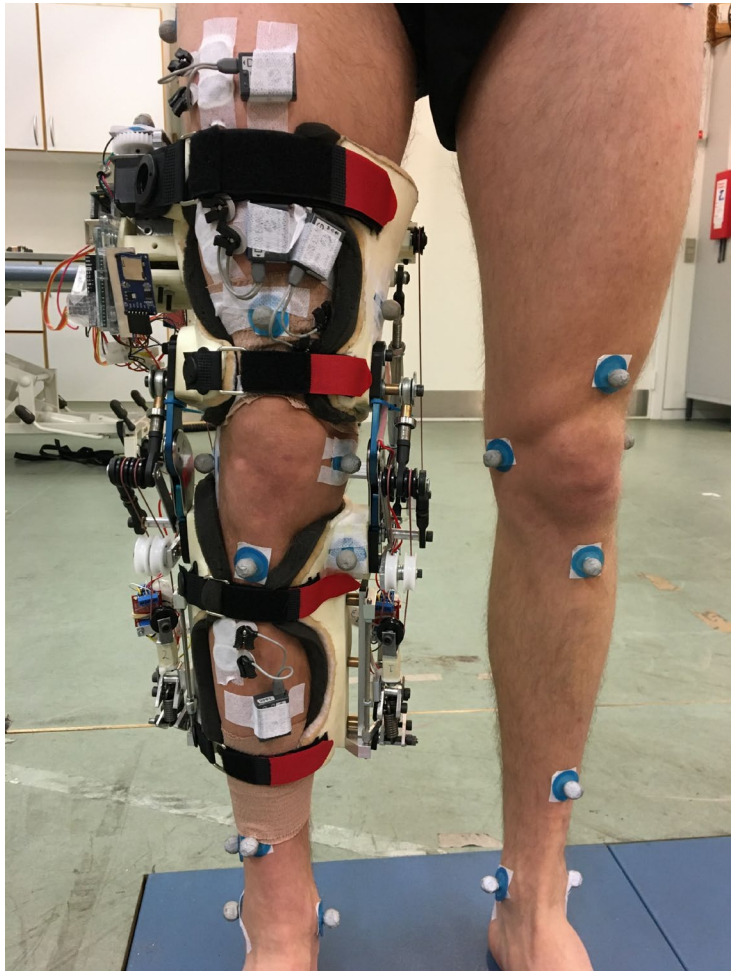


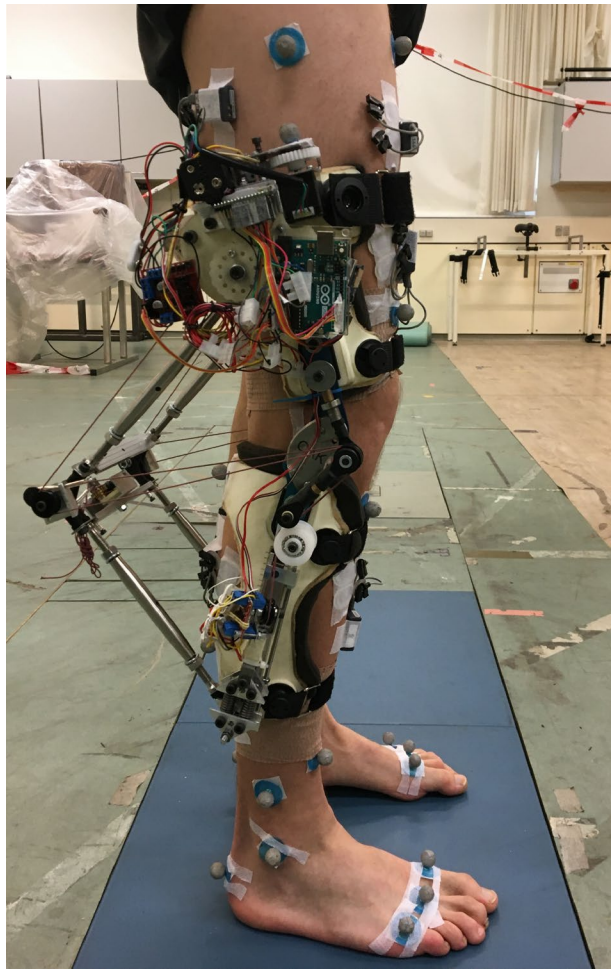


Study II: Brace prototype – Test

Test on one healthy subject

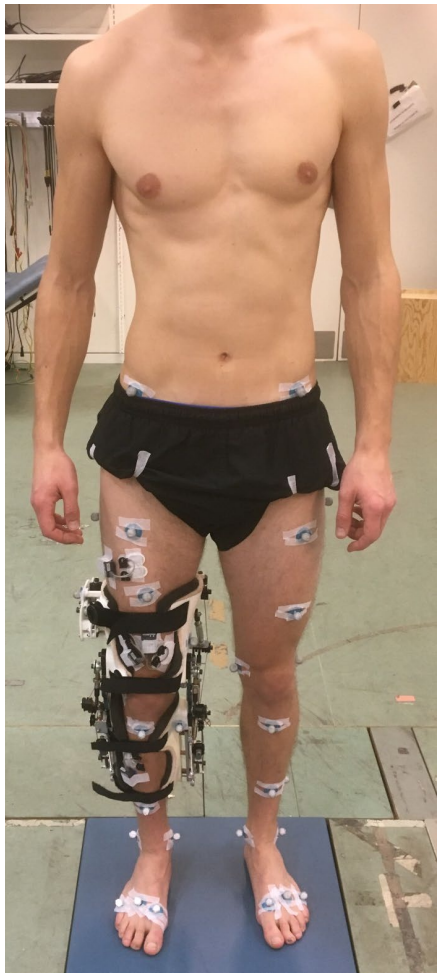




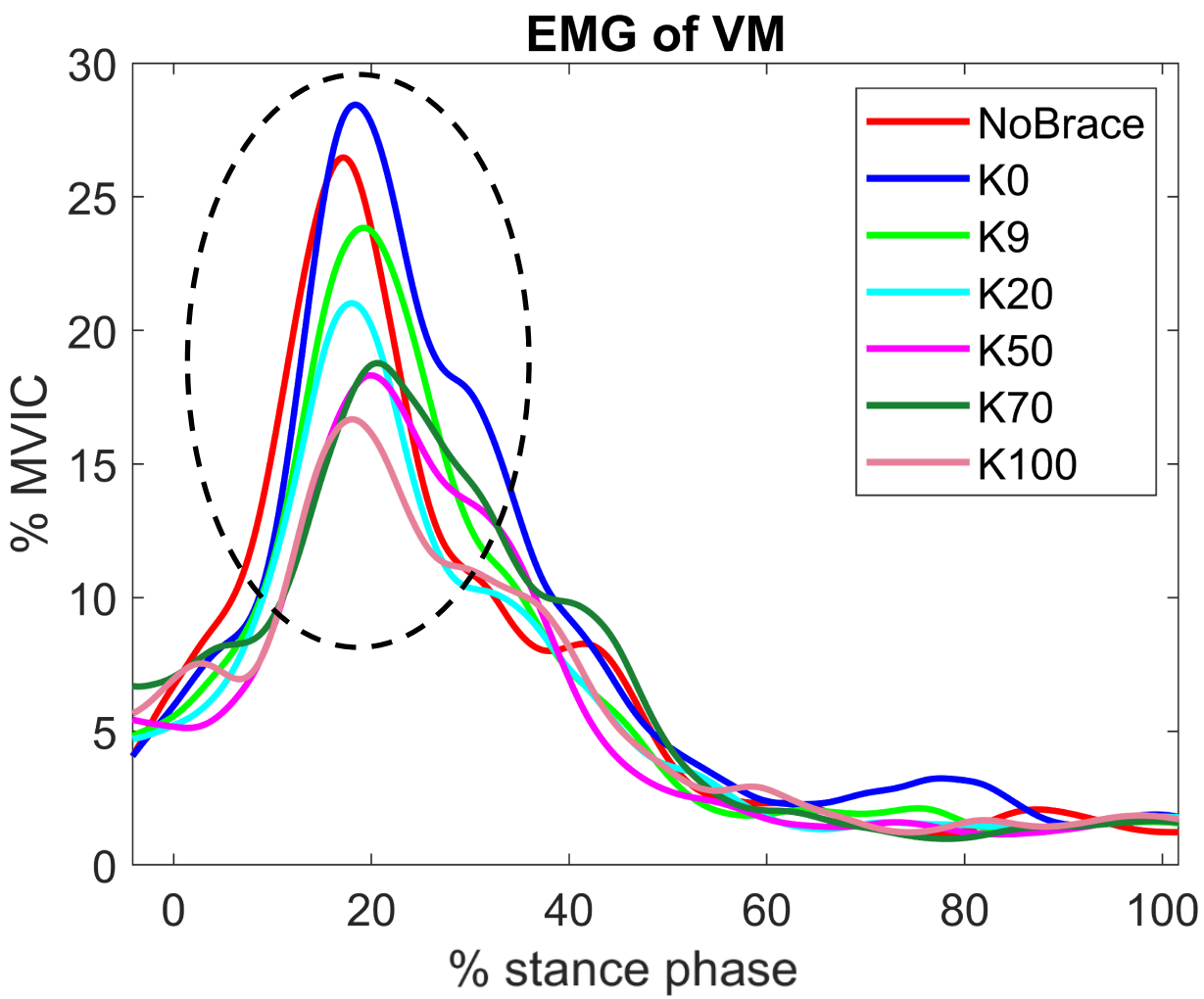


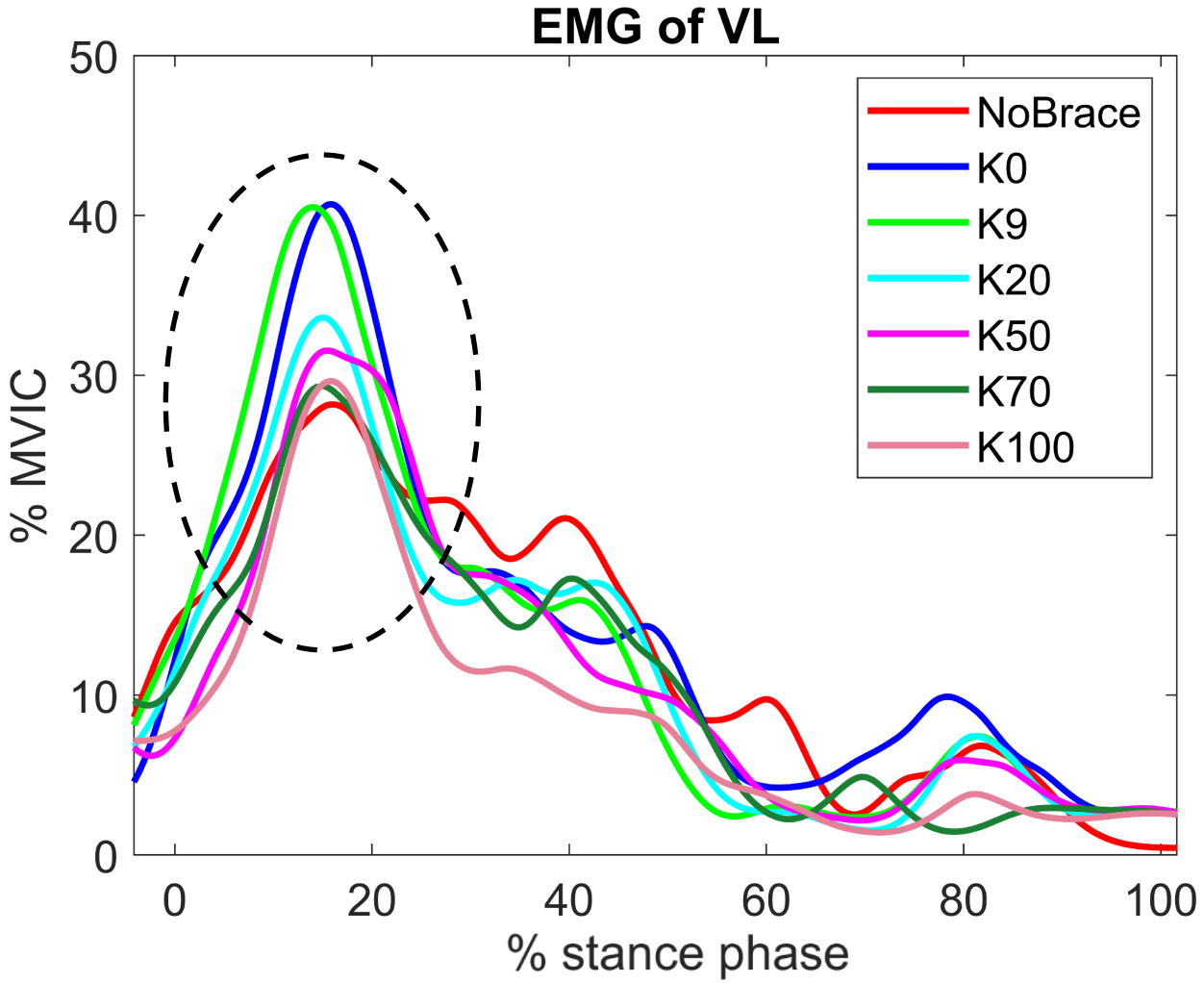
Study II: Brace prototype – Test

Test on one healthy subject

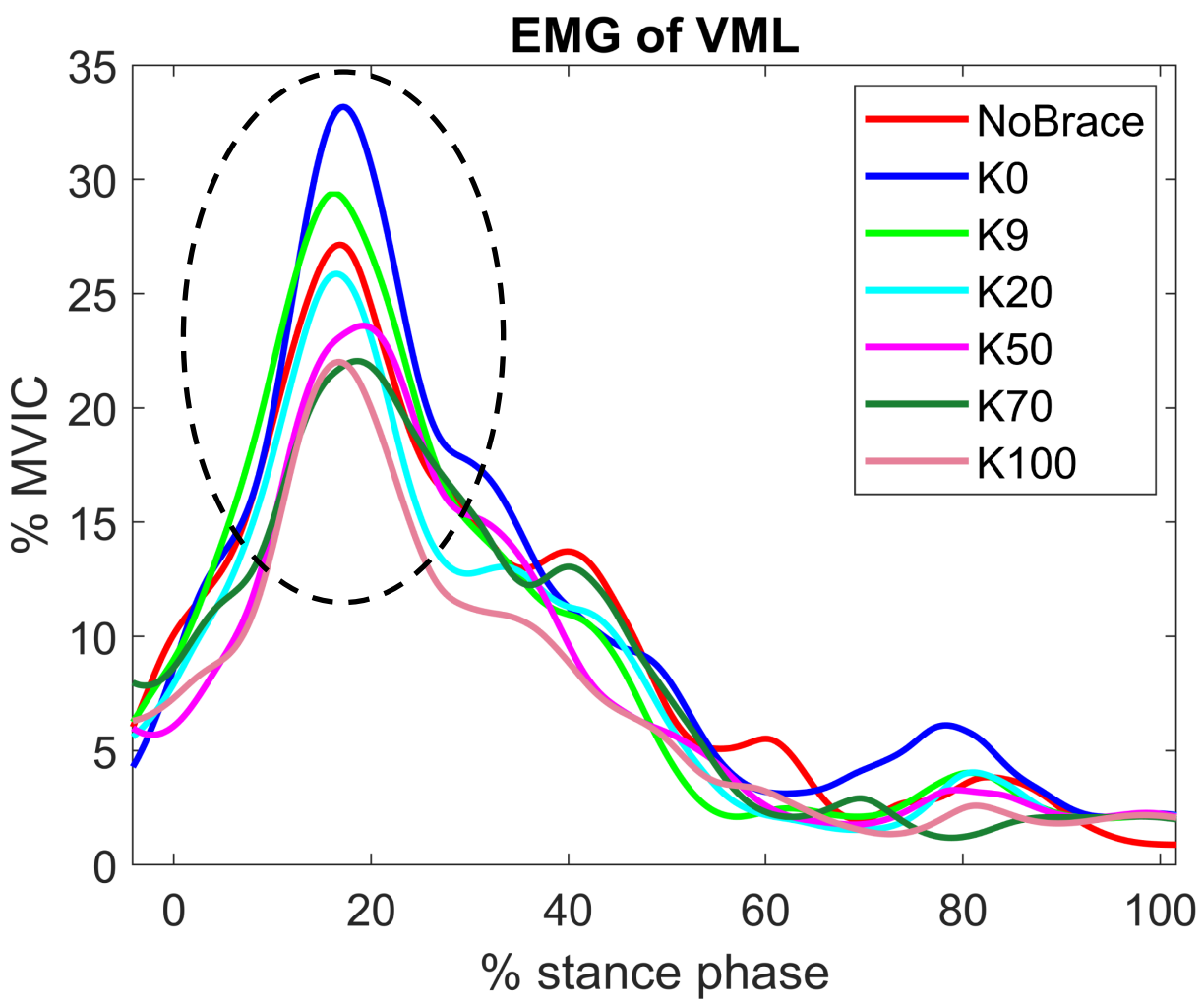


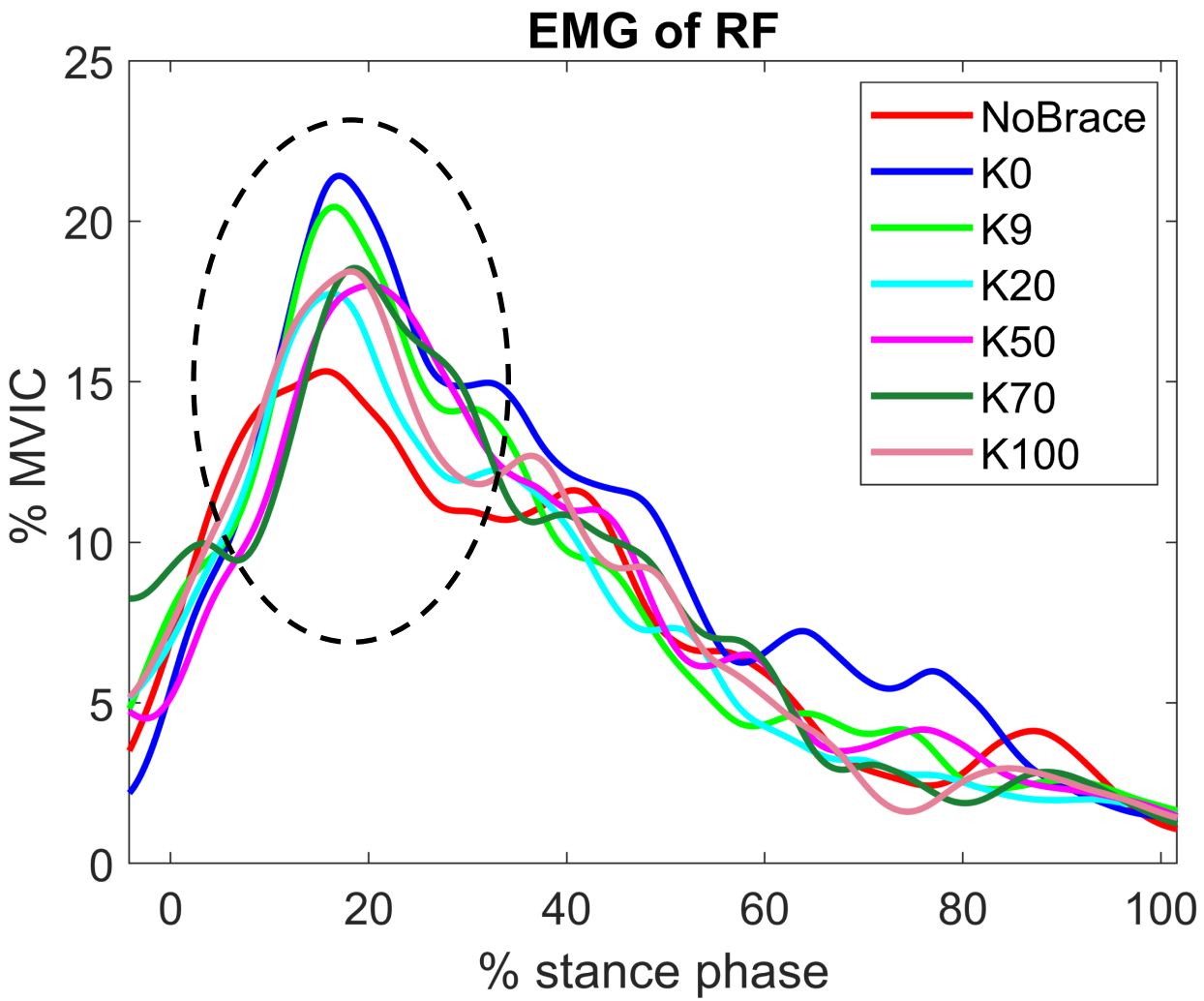
Study II: Brace prototype – Test





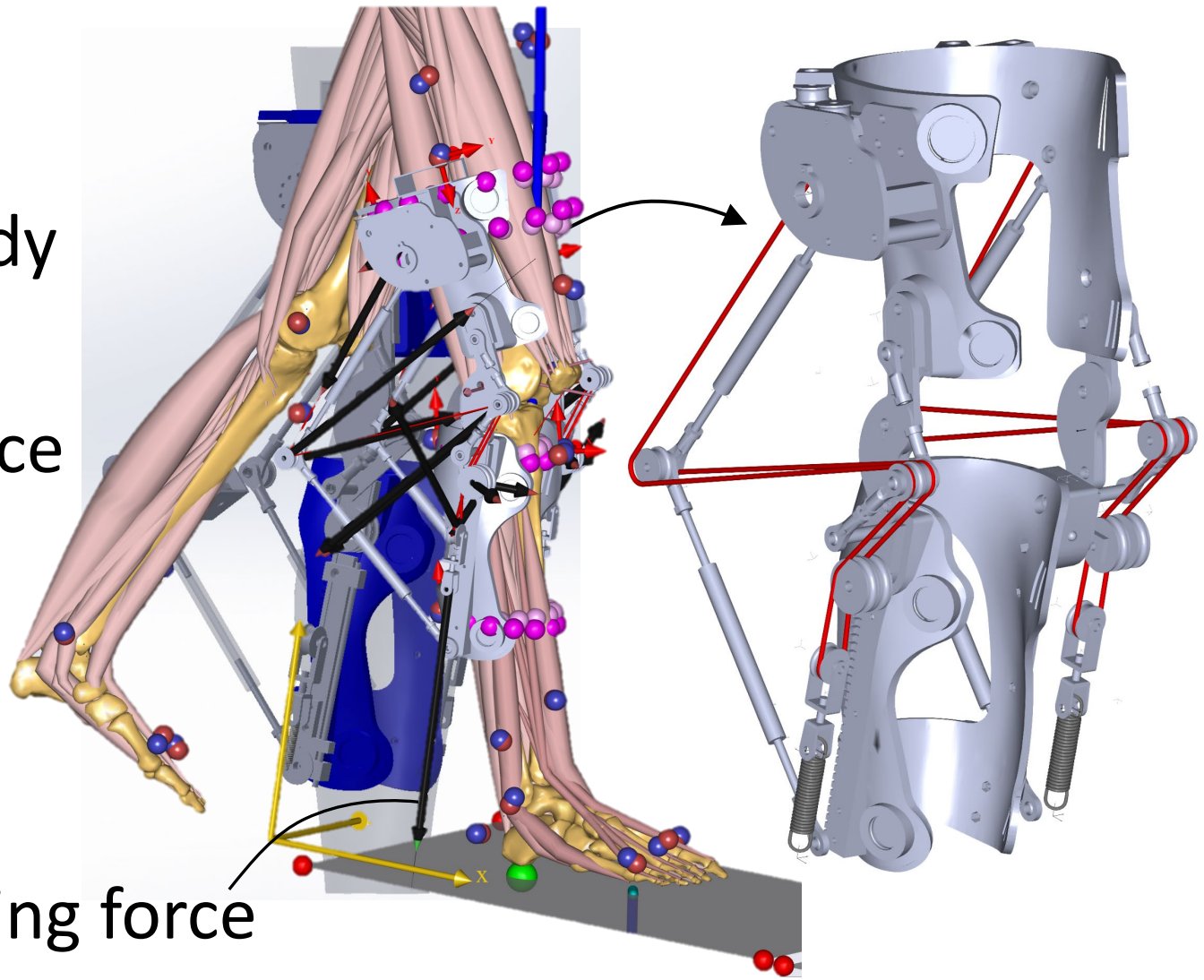
Study II: Brace prototype – Test





Study II: Brace prototype – Test

- Reduced EMG → Reduction of compression forces?
- Evaluating the effect in AnyBody
  - AnyExp4SOLIDWORKS
- Apply the measured spring force

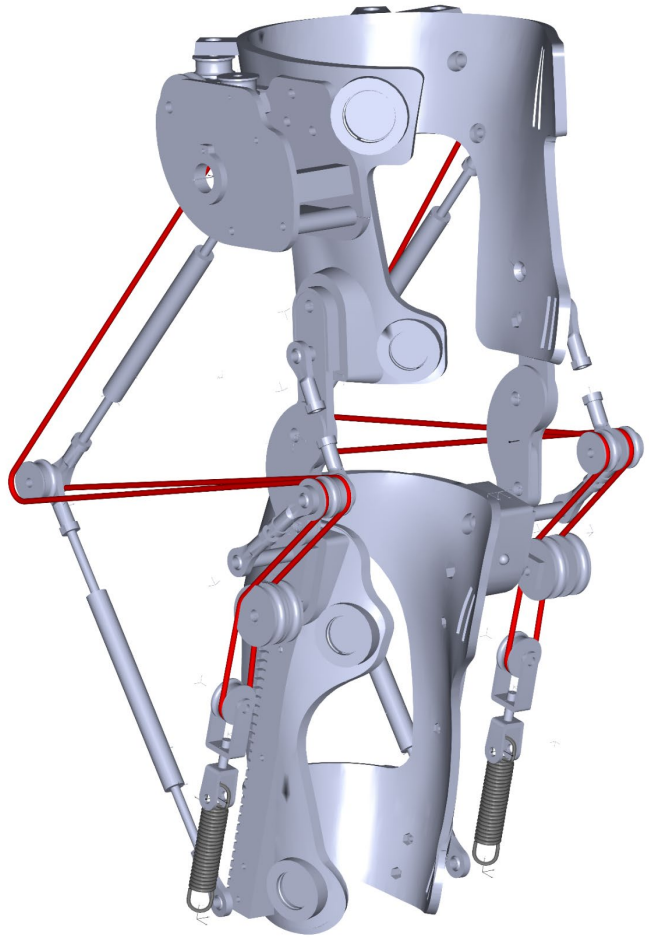


Study II: Brace prototype – Test

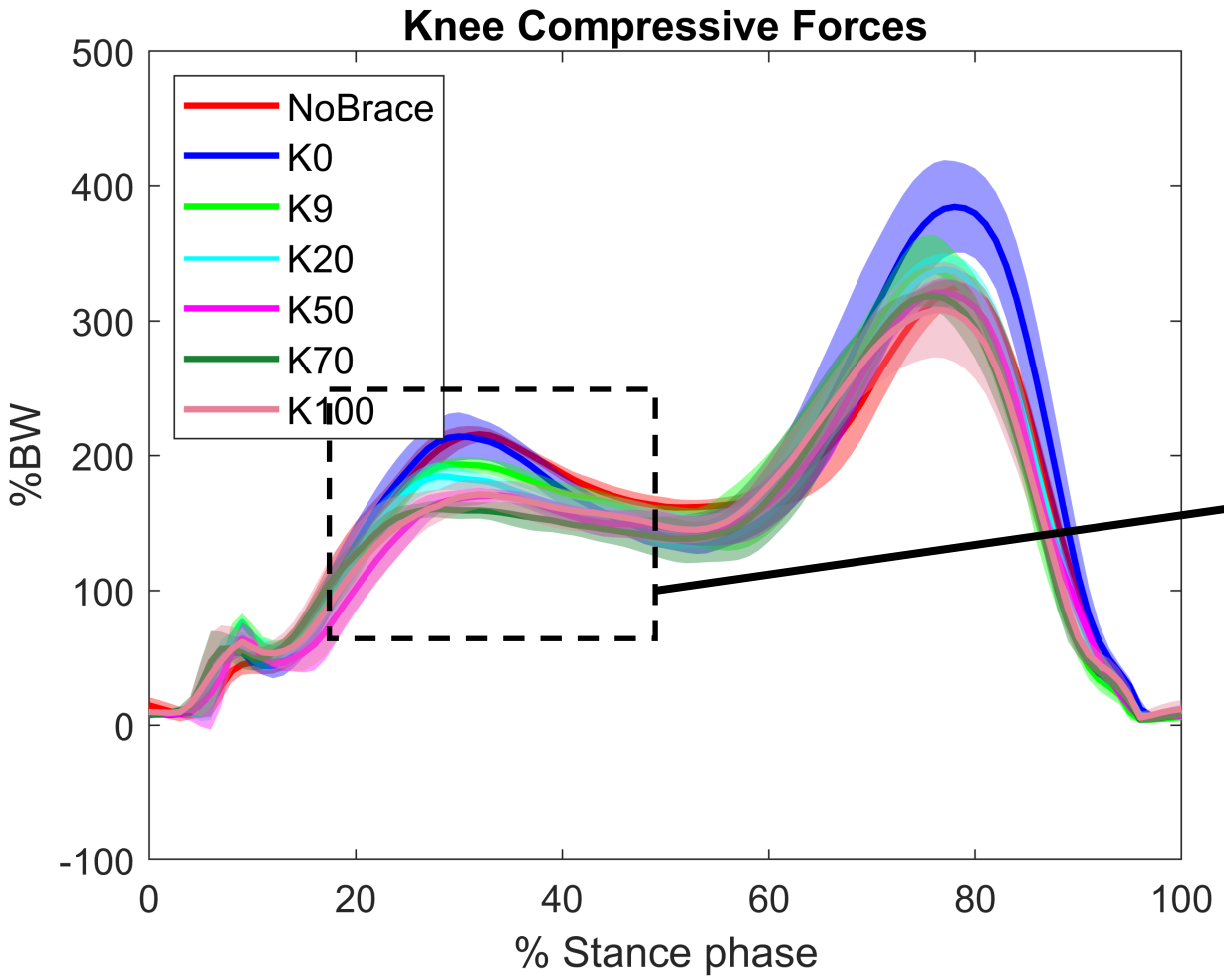
Innovation Fund Denmark

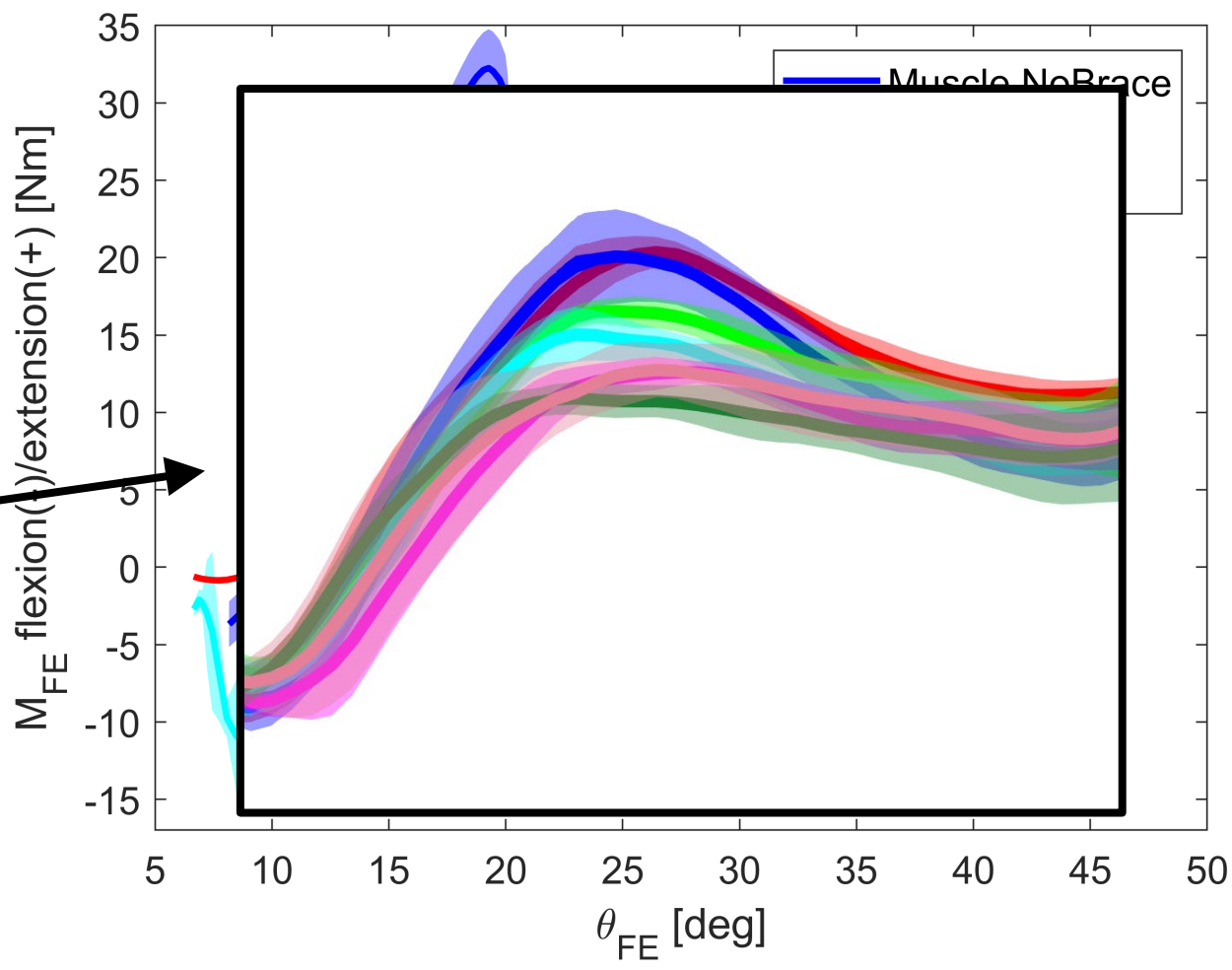
Individualized Osteoarthritis Interventions

AnyBody simulation of experimental tests



Study II: Brace prototype – Test





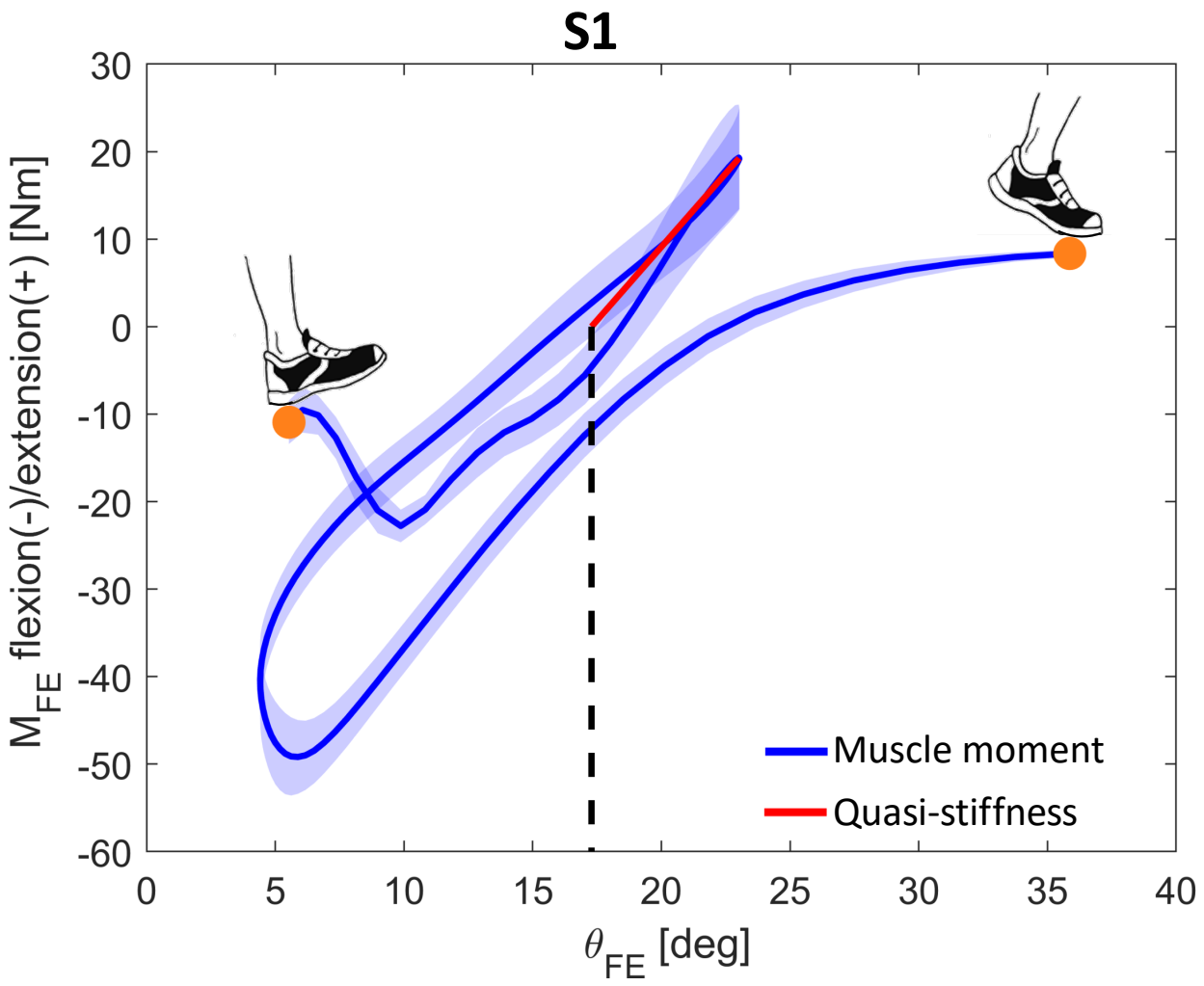
Study II: Brace prototype – Findings

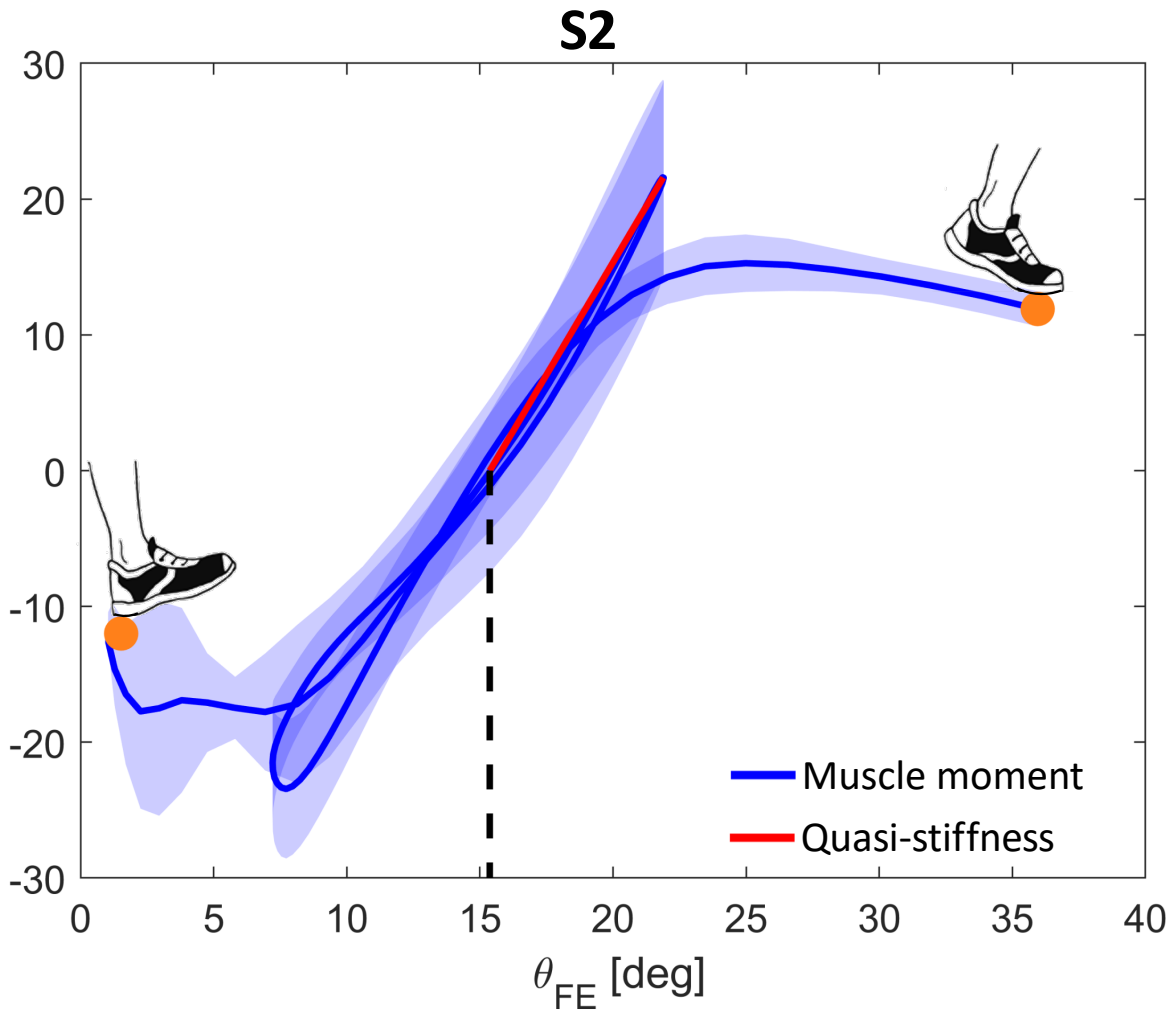
- Reduces EMG and knee compressive forces
- Published in Stoltze et al. 2021

  Development and Functional Testing of An Unloading Concept for Knee Osteoarthritis Patients: A Pilot Study, Journal of Biomechanical Engineering, **144**(1)
  DOI: 10.1115/1.4051847

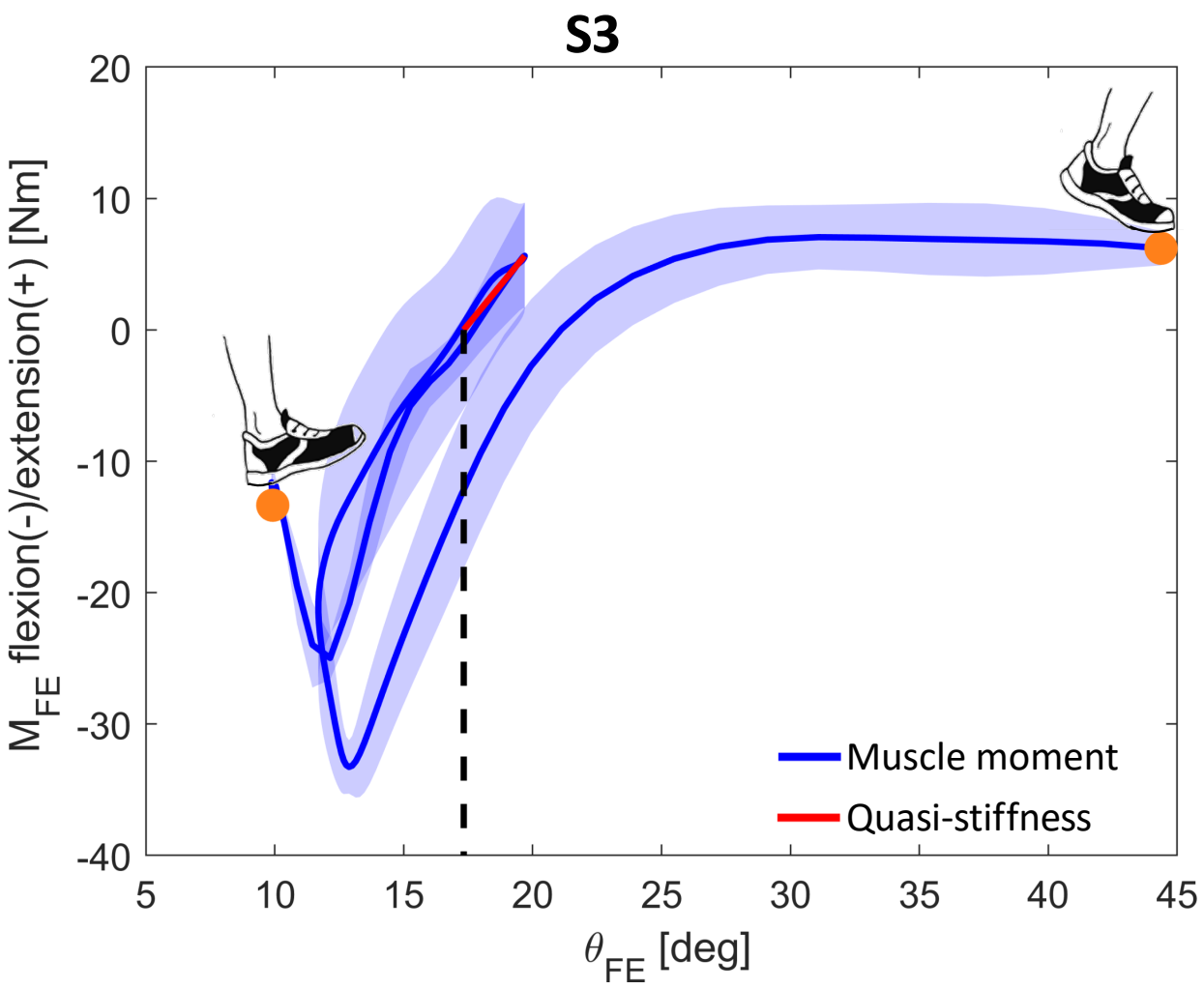
- Influence on pain?
  – Requires KOA patient analyses
- Who is suited for this intervention?

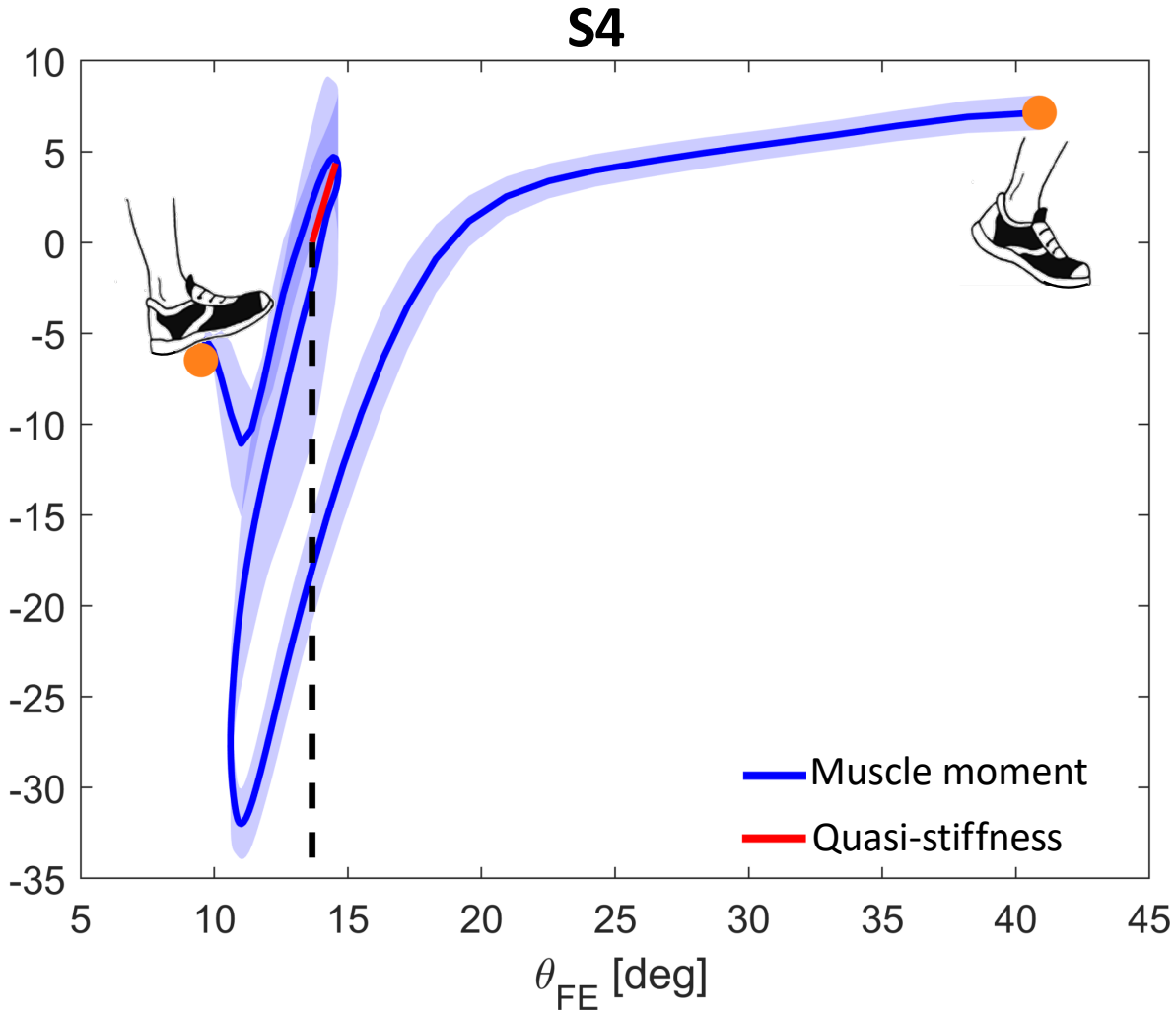
Study III: KOA patients – Gait trials



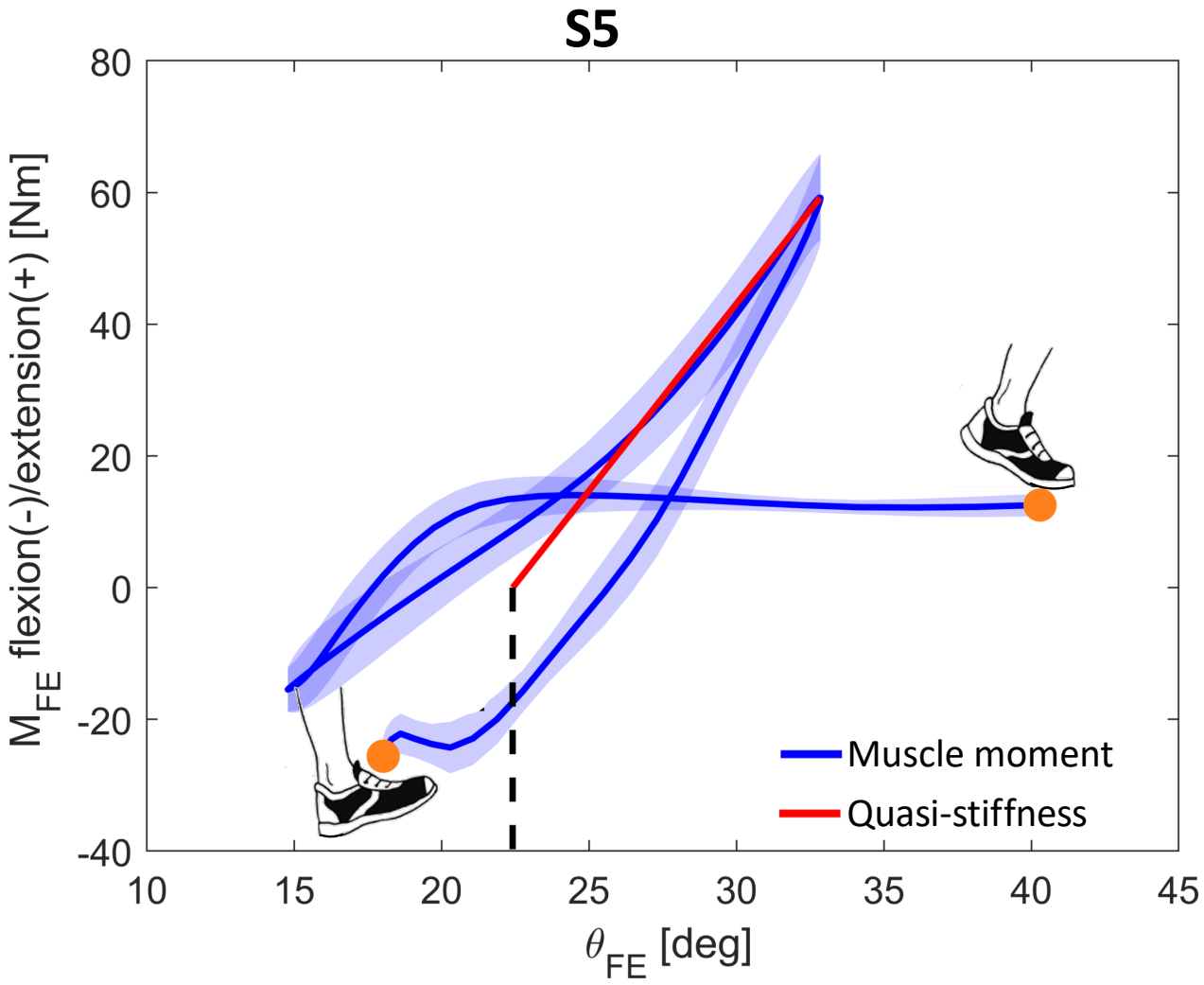


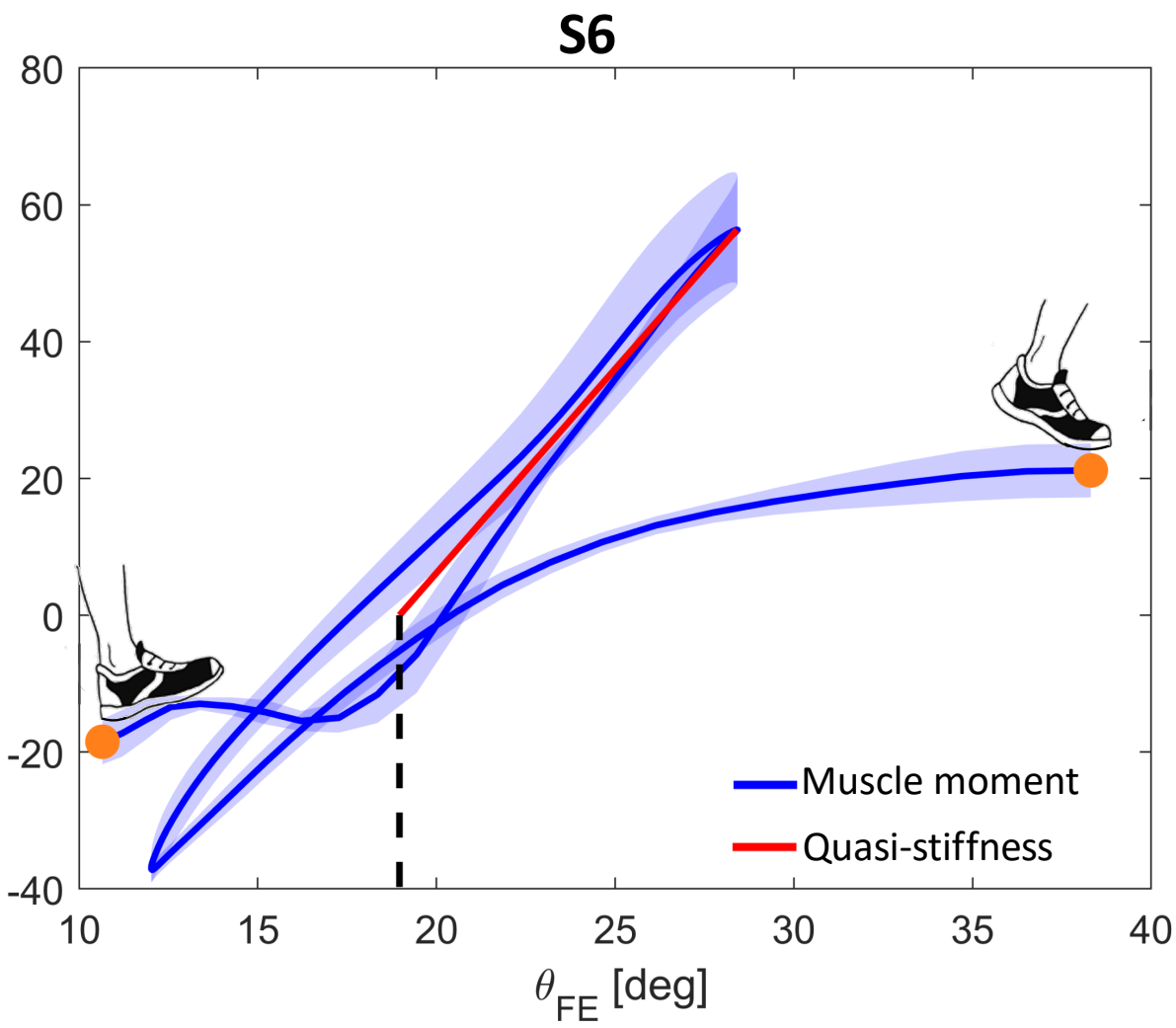
Study III: KOA patients – Gait trials



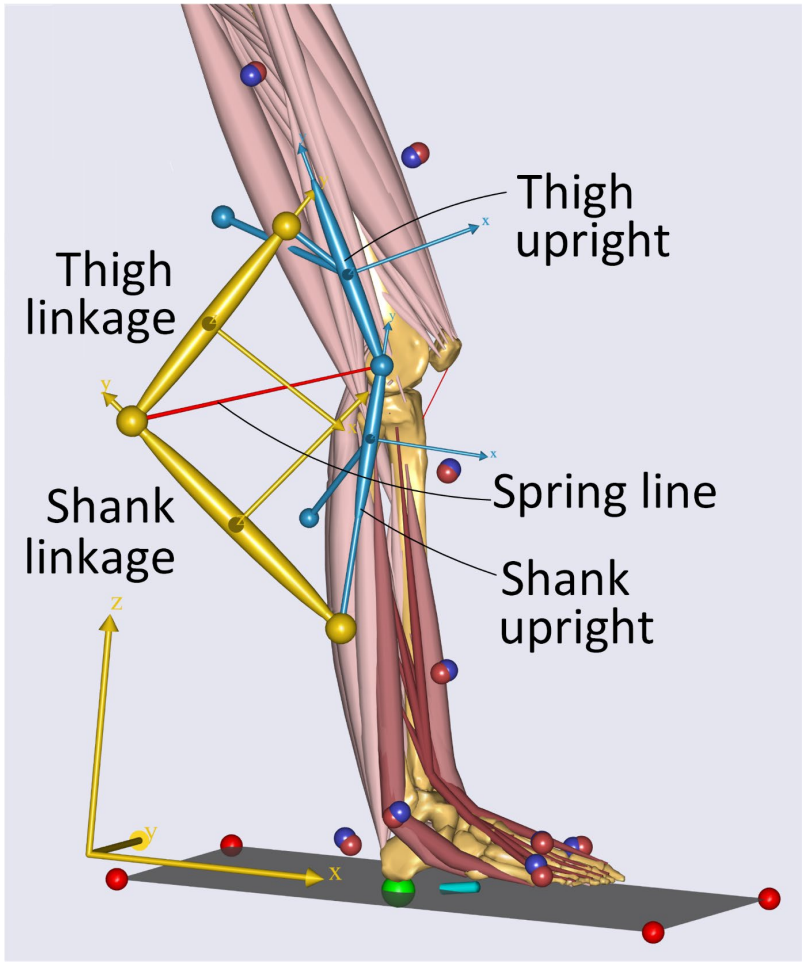


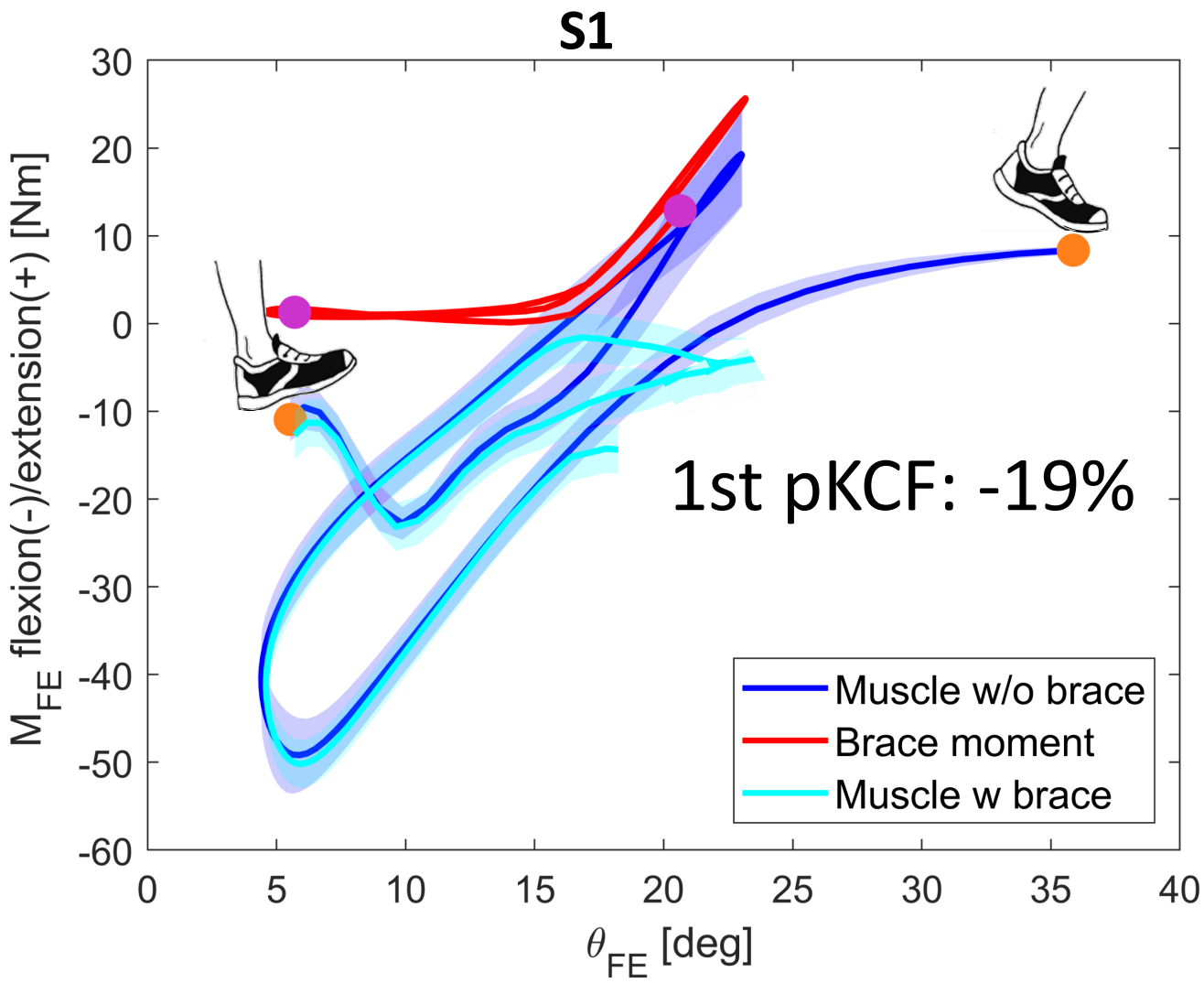
Study III: KOA patients – Gait trials



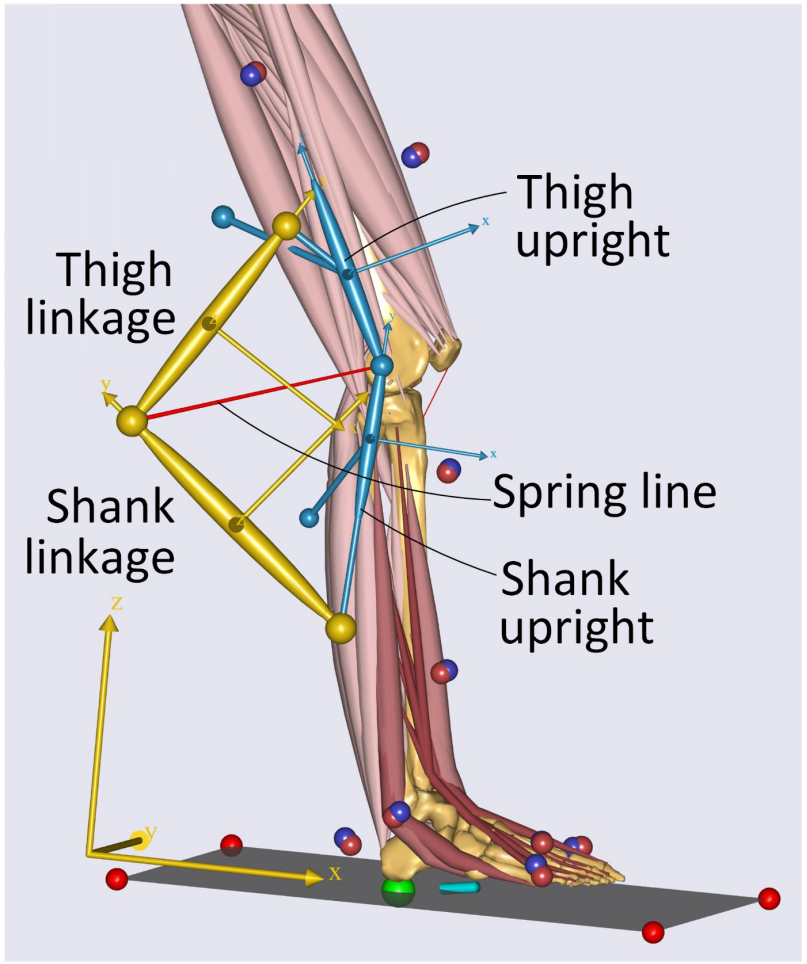


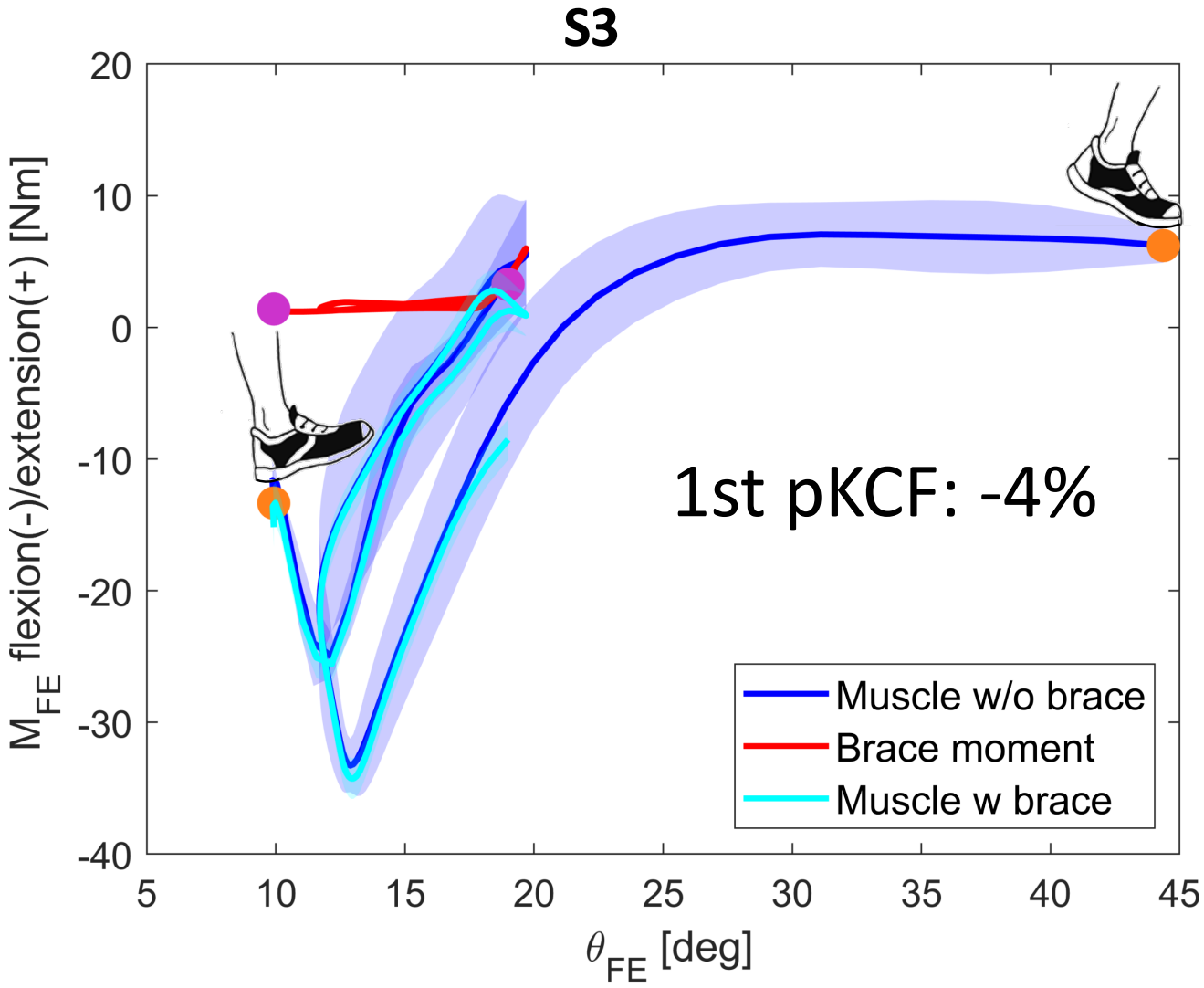
Study III: KOA patients – Simulation





Study III: KOA patients – Simulation

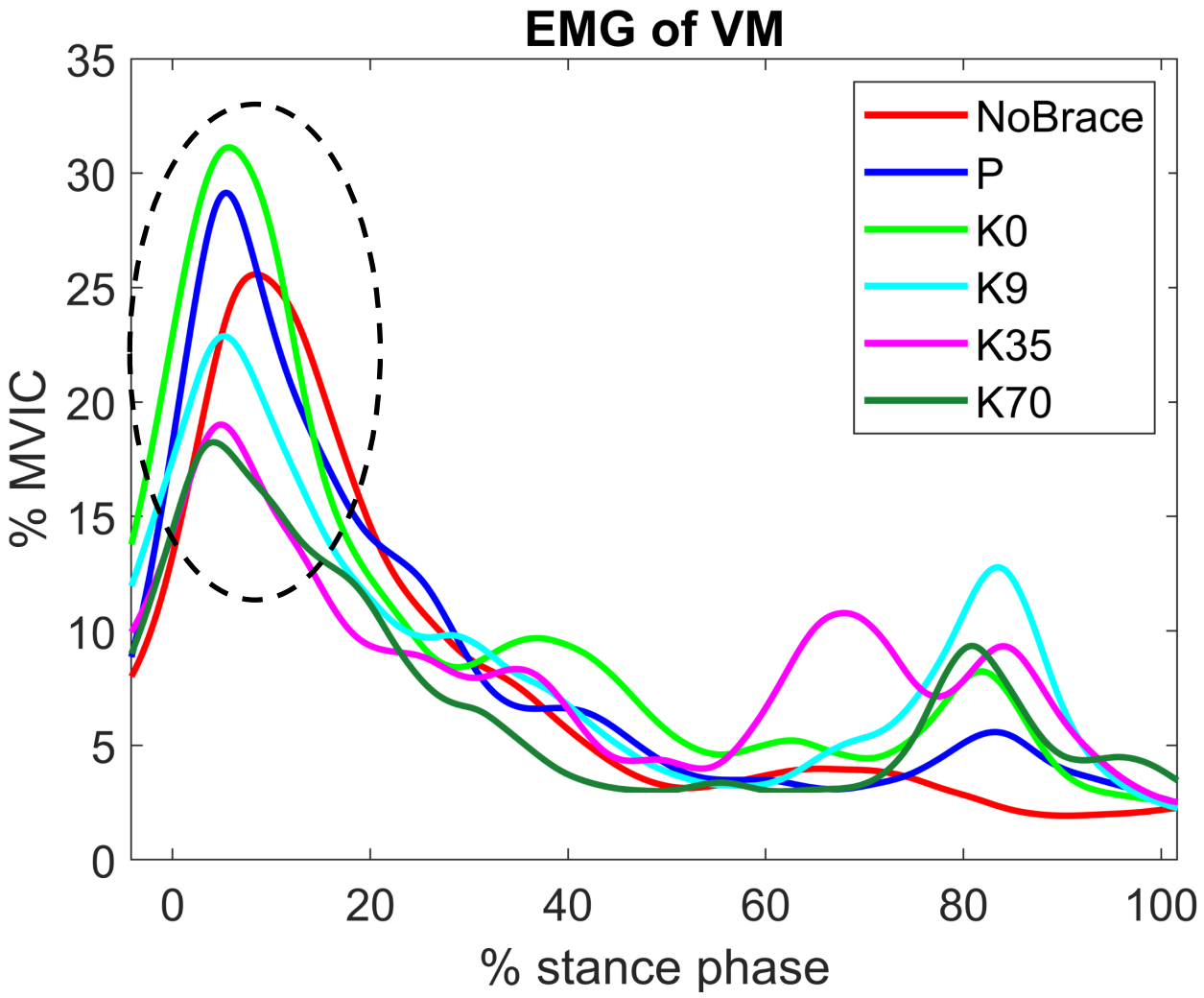


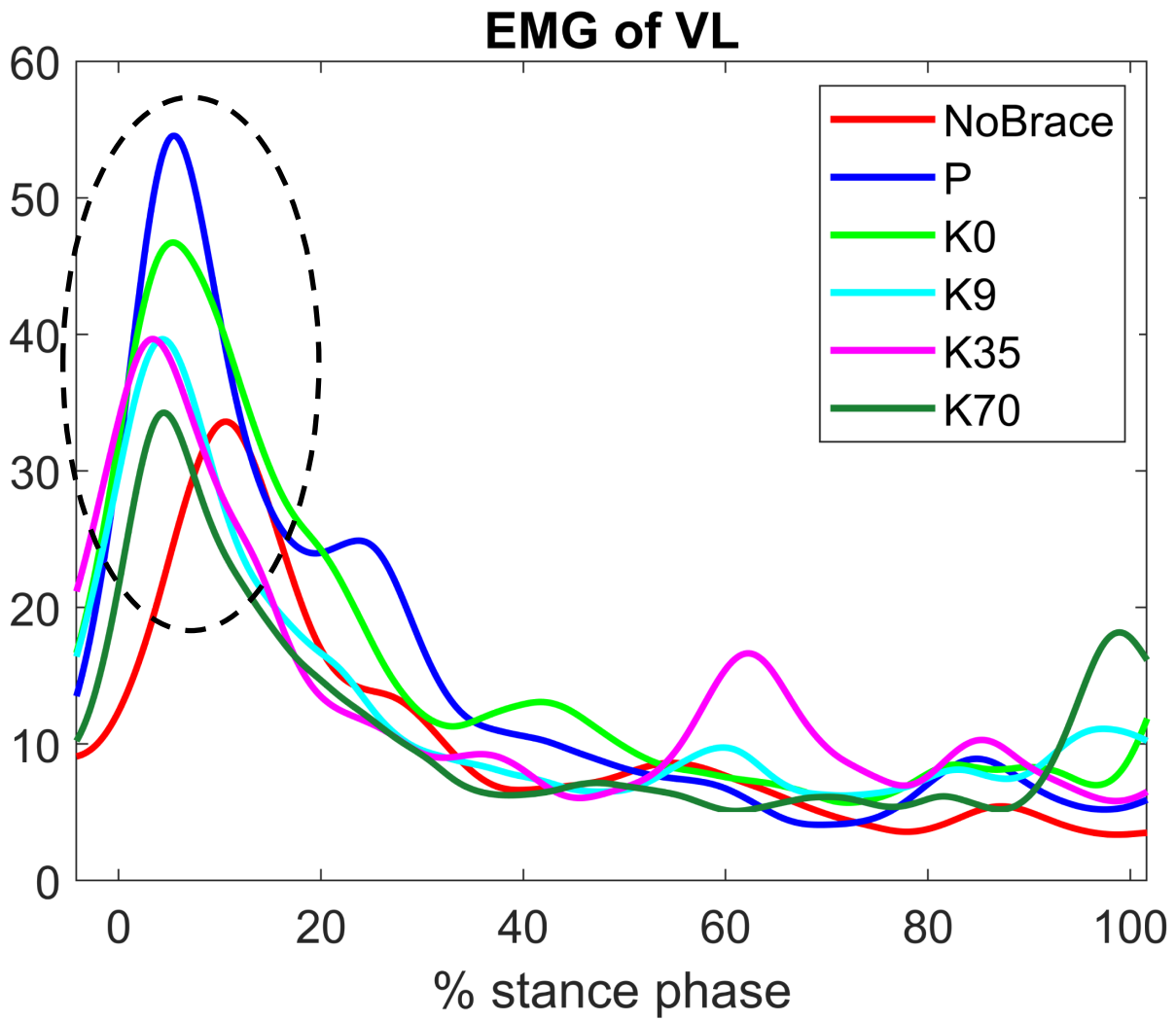


Study III: KOA patients – Test

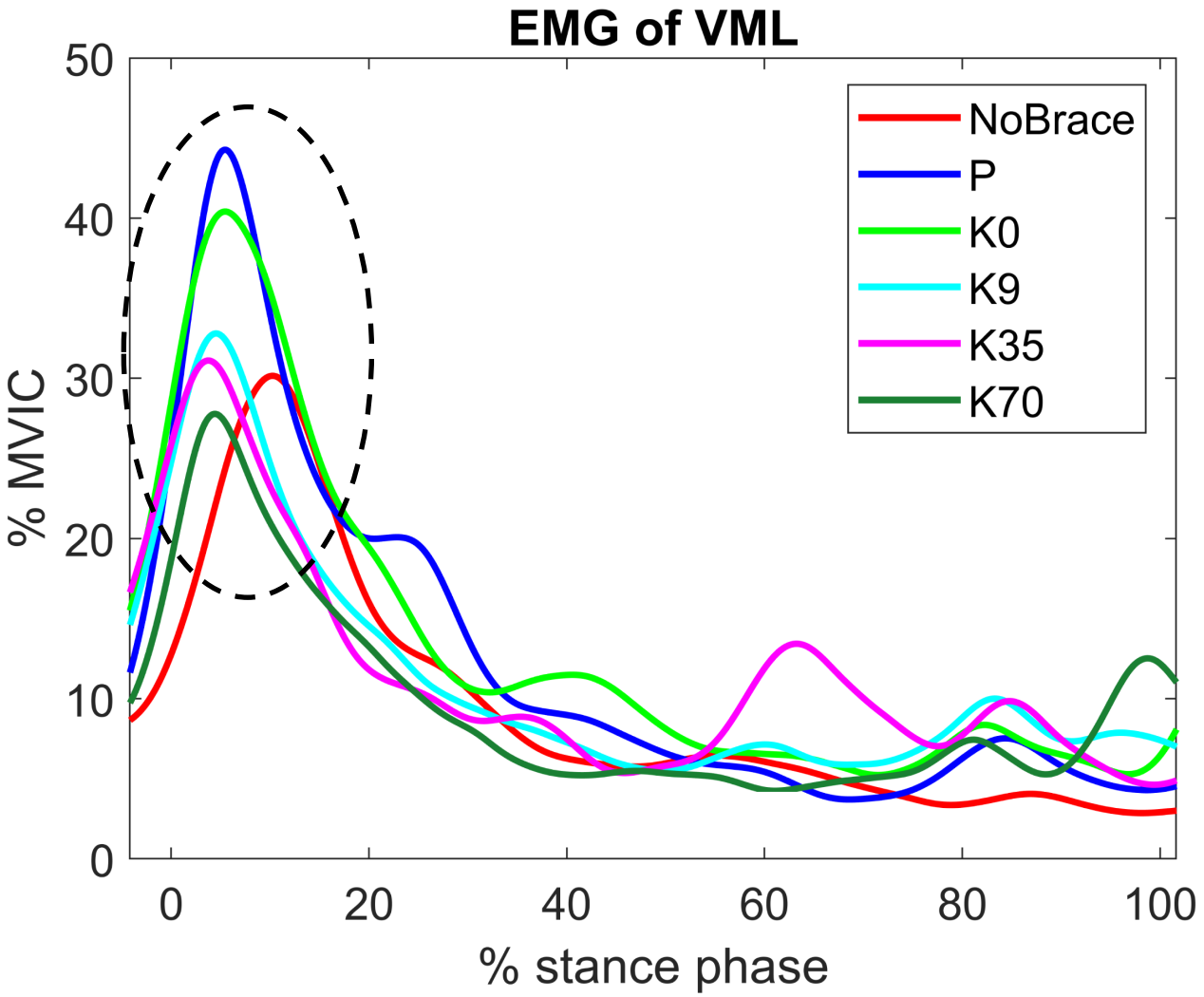
- KOA patient tests (N=1)

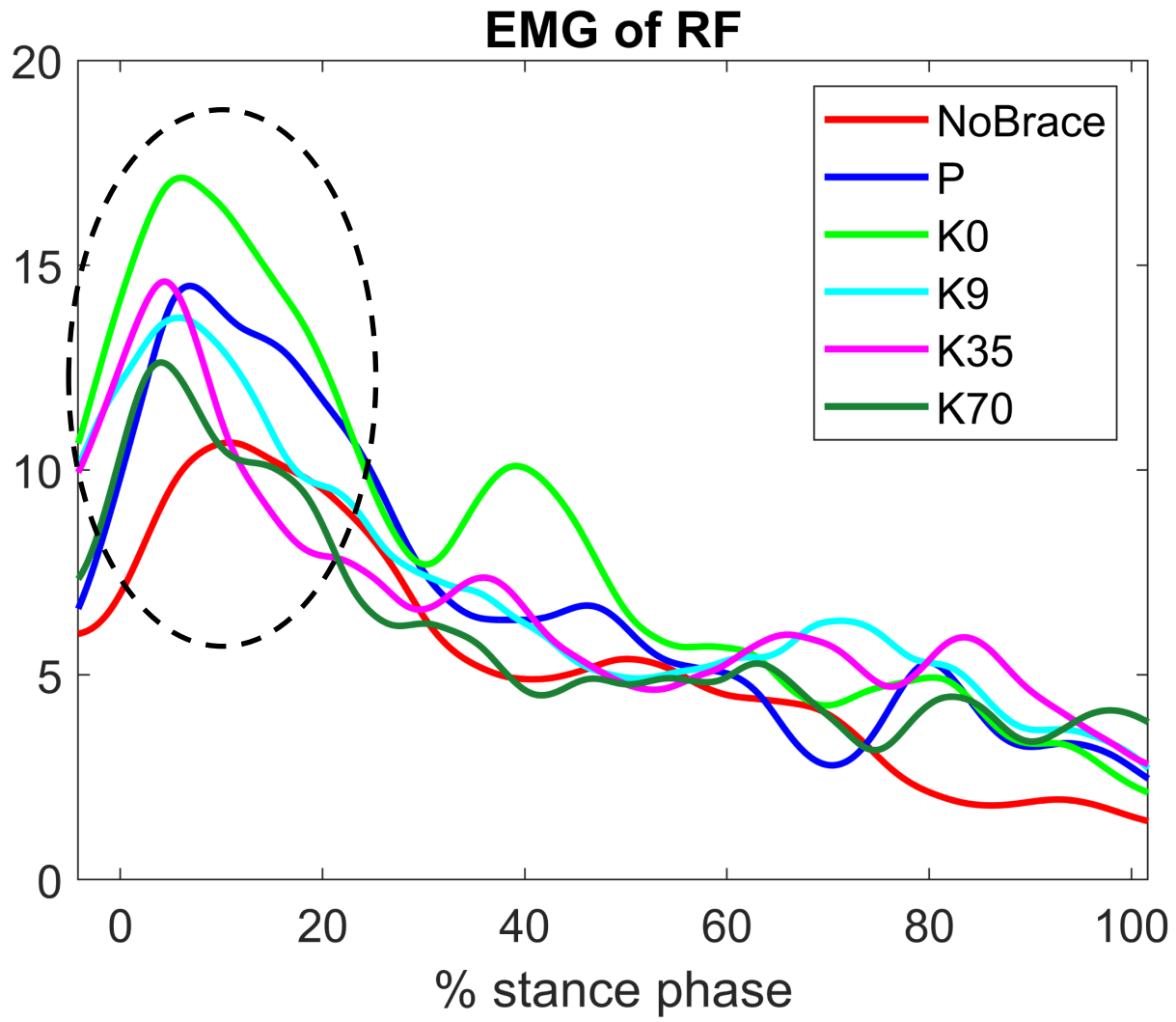
Study III: KOA patients – Test



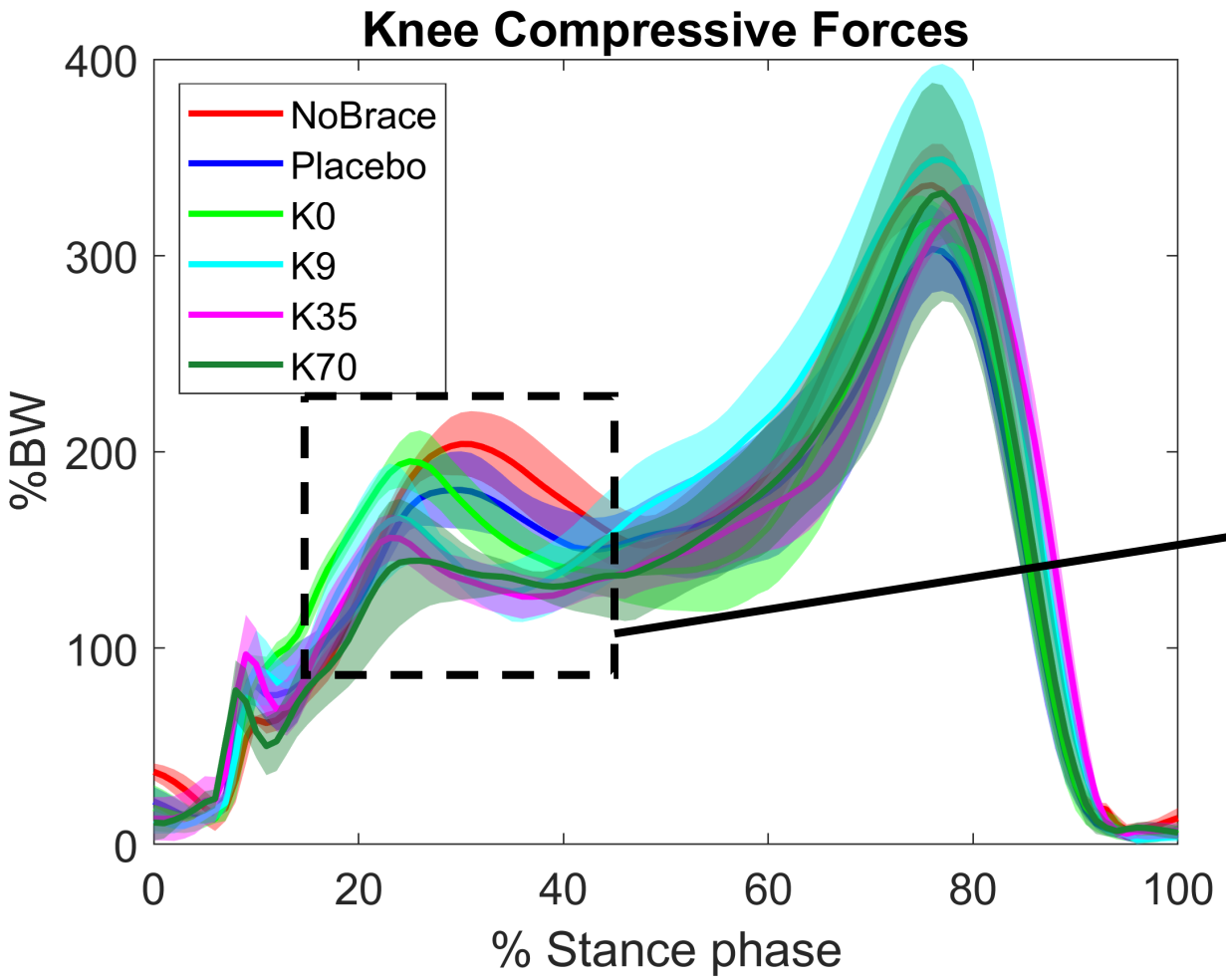


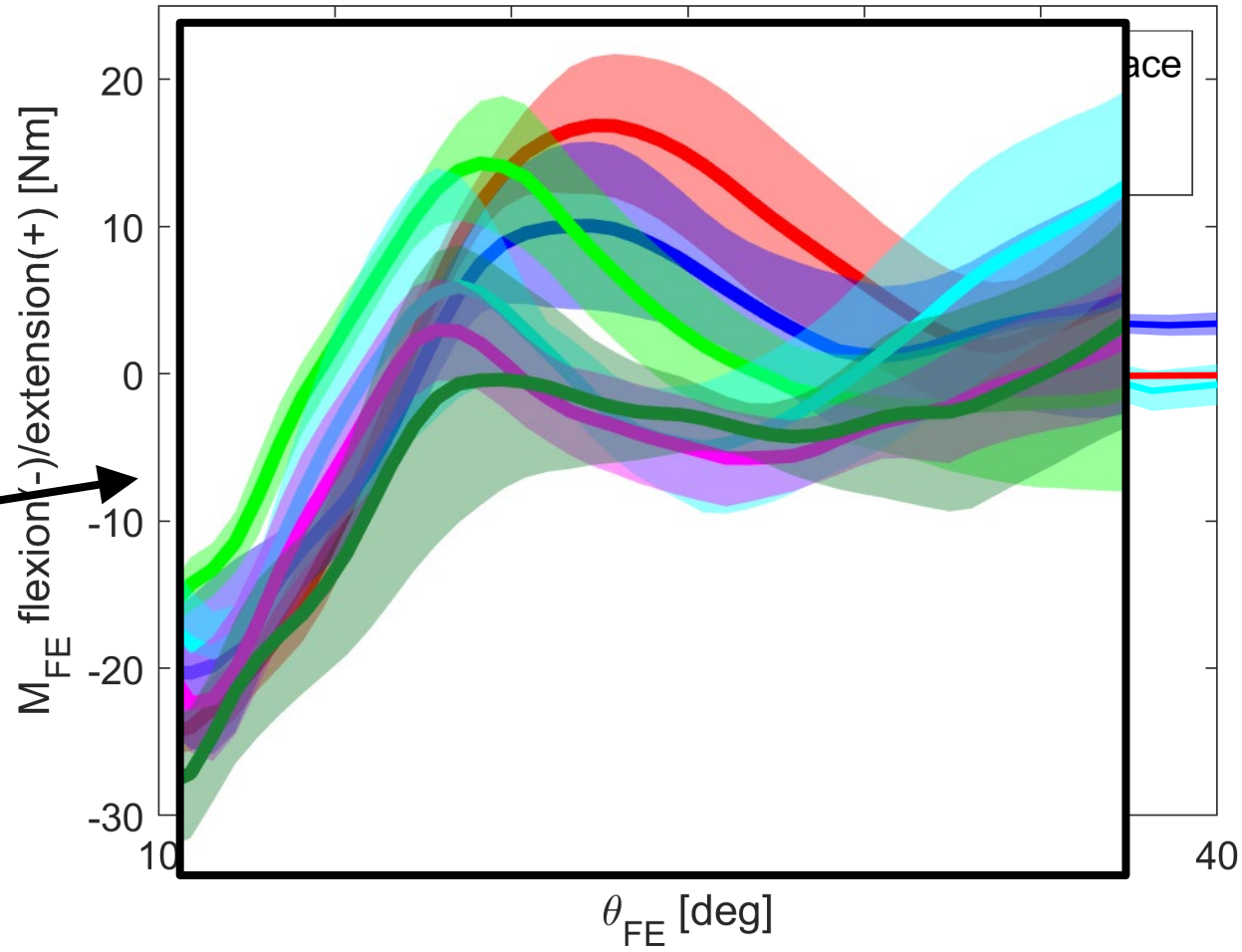
Study III: KOA patients – Test



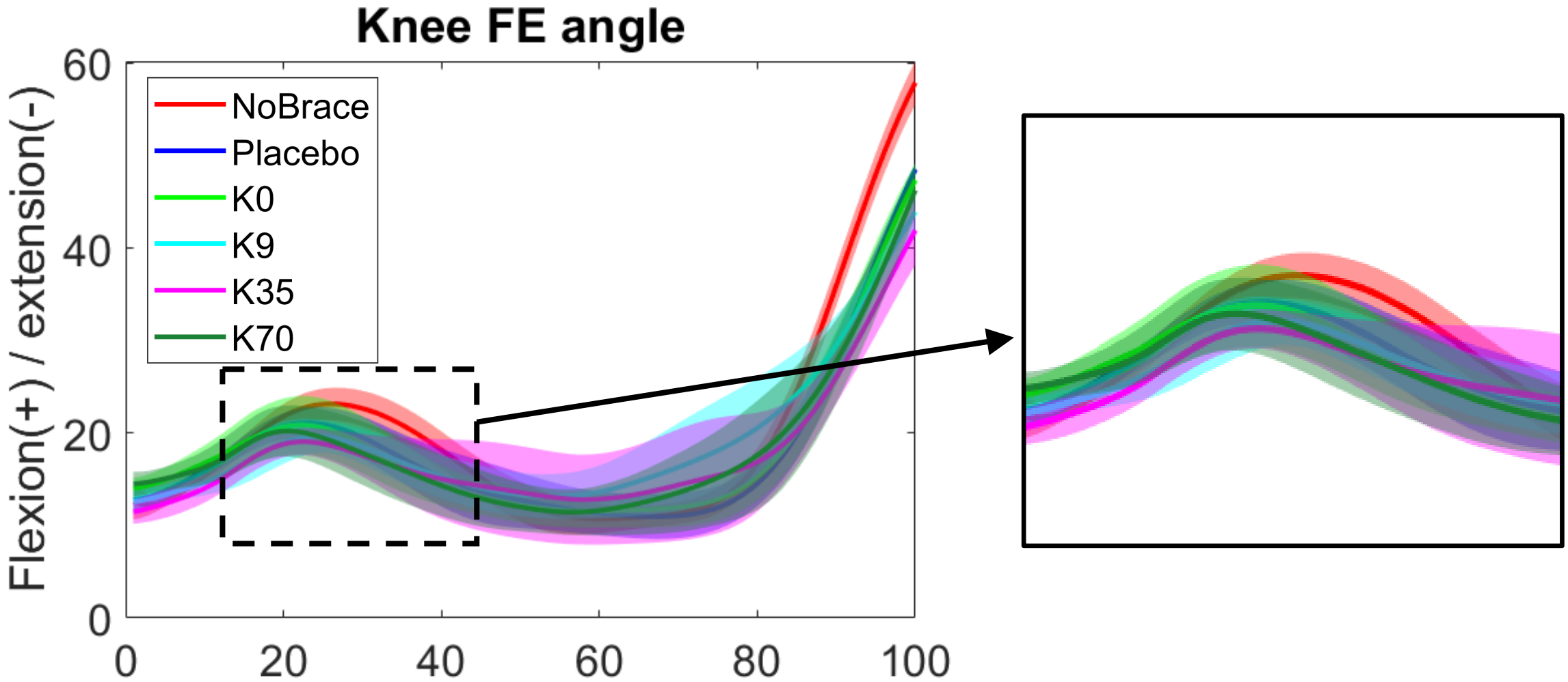


Study III: KOA patients – Test





Study III: KOA patients – Test

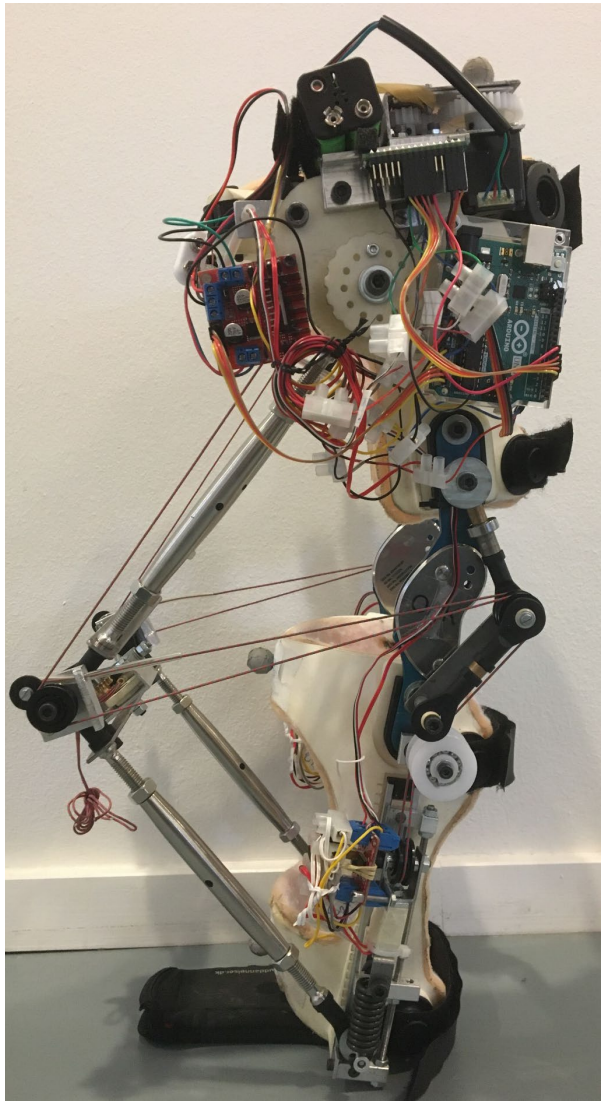


Study III: KOA patients – Findings

- Potential to reduce peak EMG and peak KCF
  - For some patients
- No influence in pain was detected
- Placebo trials are important for brace tests

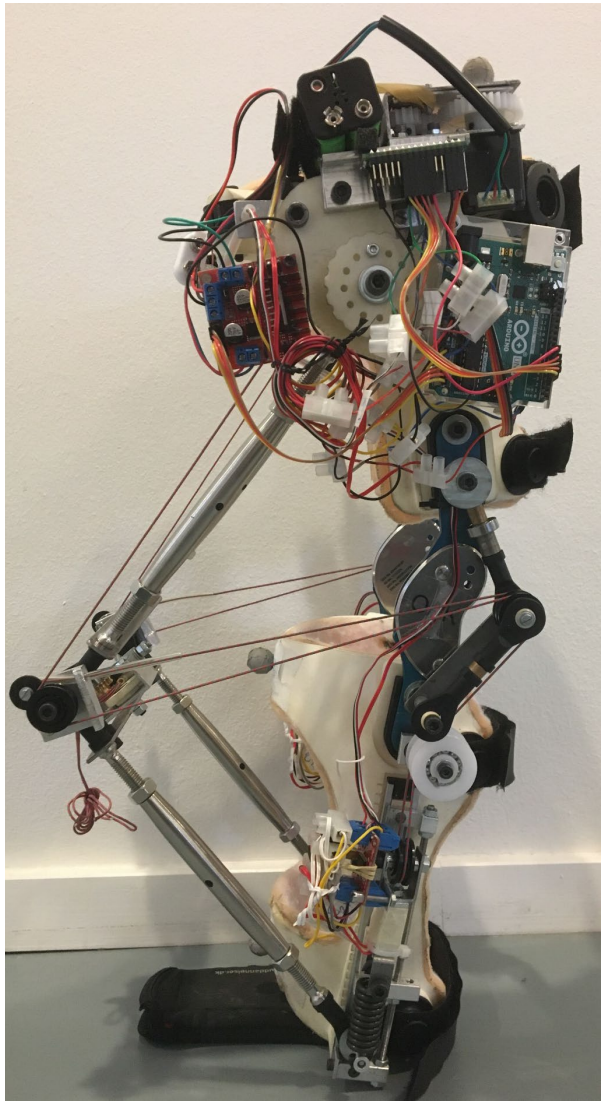
- Take home message:

An applied knee extension moment in early stance has the potential to reduce KCF in KOA patients, but not all patients are suited for this treatment



Discussion

- Only tested one KOA patient
  - More patient tests are required
- Applicaple for more activities than gait
  - Advanced control is needed
- Very bulky and heavy
  - Still needs to apply a large moment
- Vertical migration over time



Thank you - Questions

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Acknowledgements:
- Sebastian Leigaard Skals for sharing models
- Innovation Fund Denmark for fundings
- Peacocks for assistance in prototype development
- Anderson Oliveira and Cristina-Ioana Pirscoveanu for laboratory assistance

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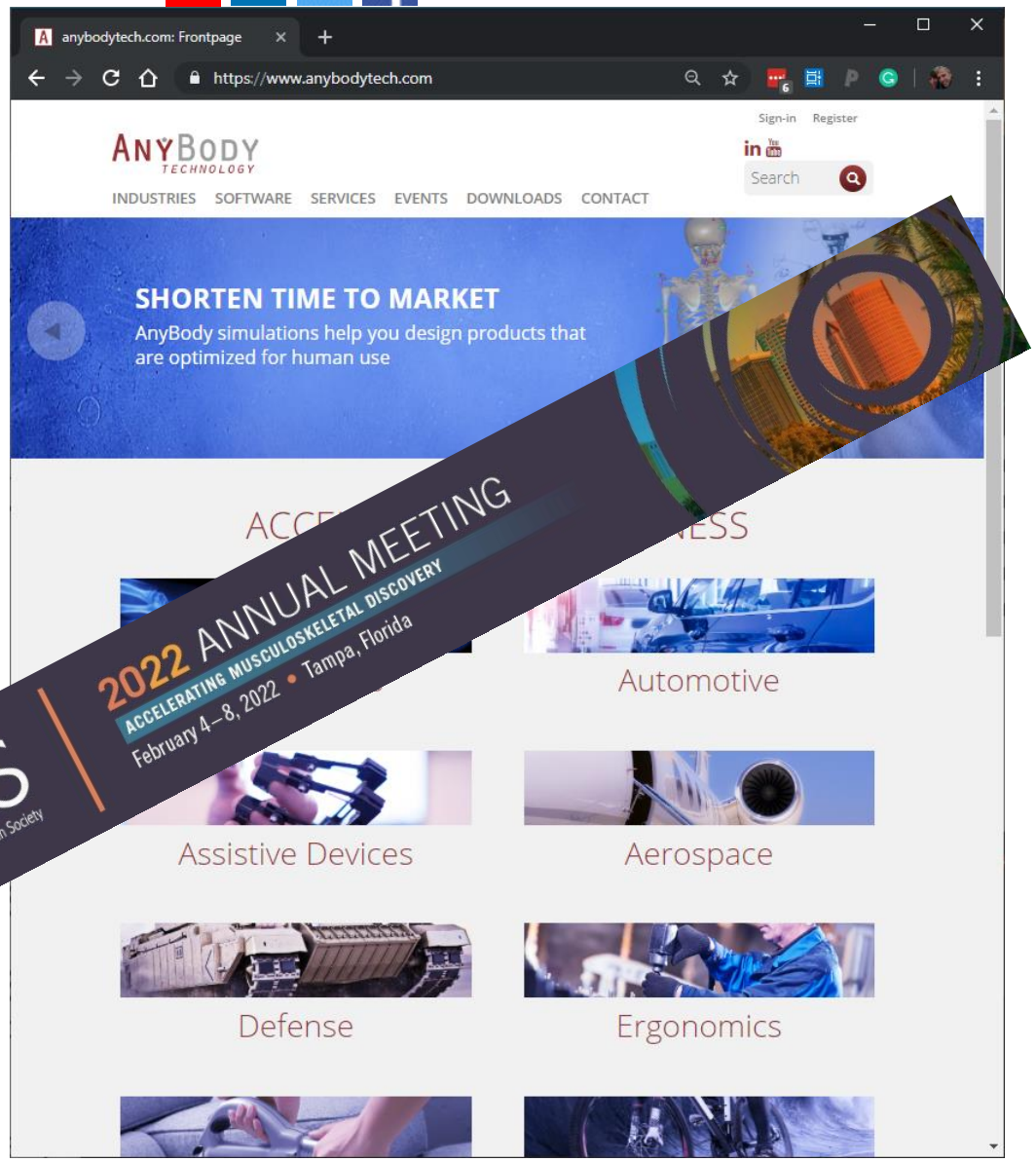
Events

- Orthopedic Research Society Annual meeting – Booth #146
  - Feb 4 – 8, 2022 in Tampa, FL
- Webcast: Automatic ergonomics whole-body motion analysis and physical human-robot interaction
  - Feb 28, 2022



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Thank you for your attention - Time for questions