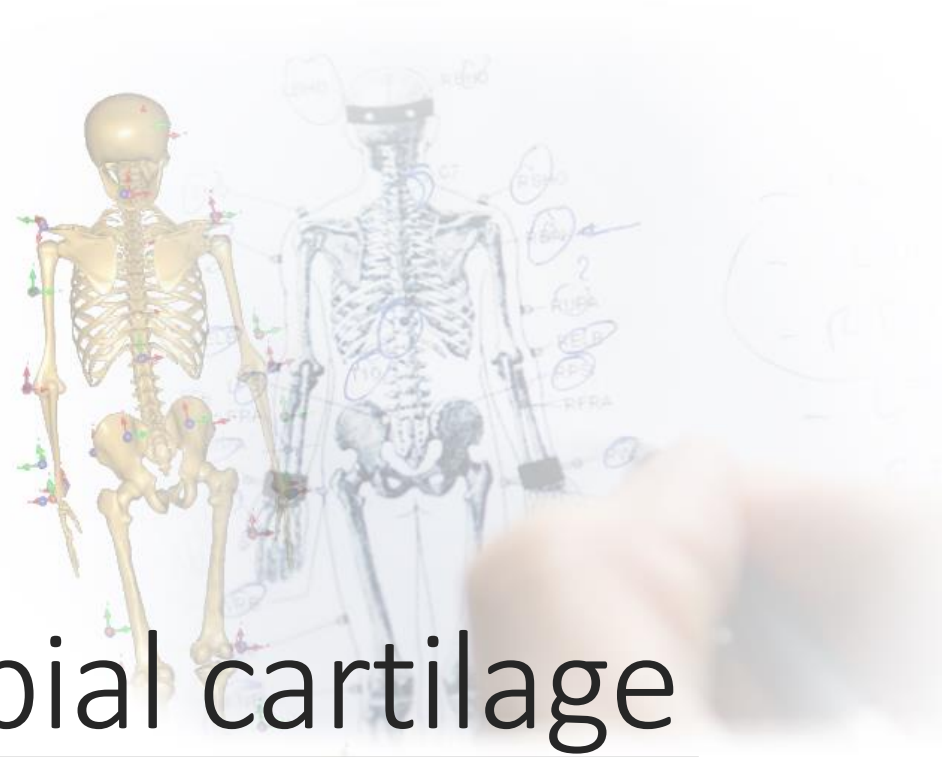
The webcast will start in a few minutes….



Stresses in the medial tibial cartilage

WORKFLOW ASSESSING THE EFFECT OF GAIT ALTERATIONS

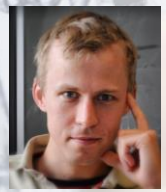
Outline

- Brief introduction
- Today's webcast:
  - Workflow assessing the effect of gait alterations on stresses in the medial tibial cartilage
- Questions and answers

Kimmo Halonen, PhD
Currently:
University Hospital of Turku,

Previously:
Post Doc
Aalborg University

Michael Skipper Andersen
Associate professor
Aalborg University



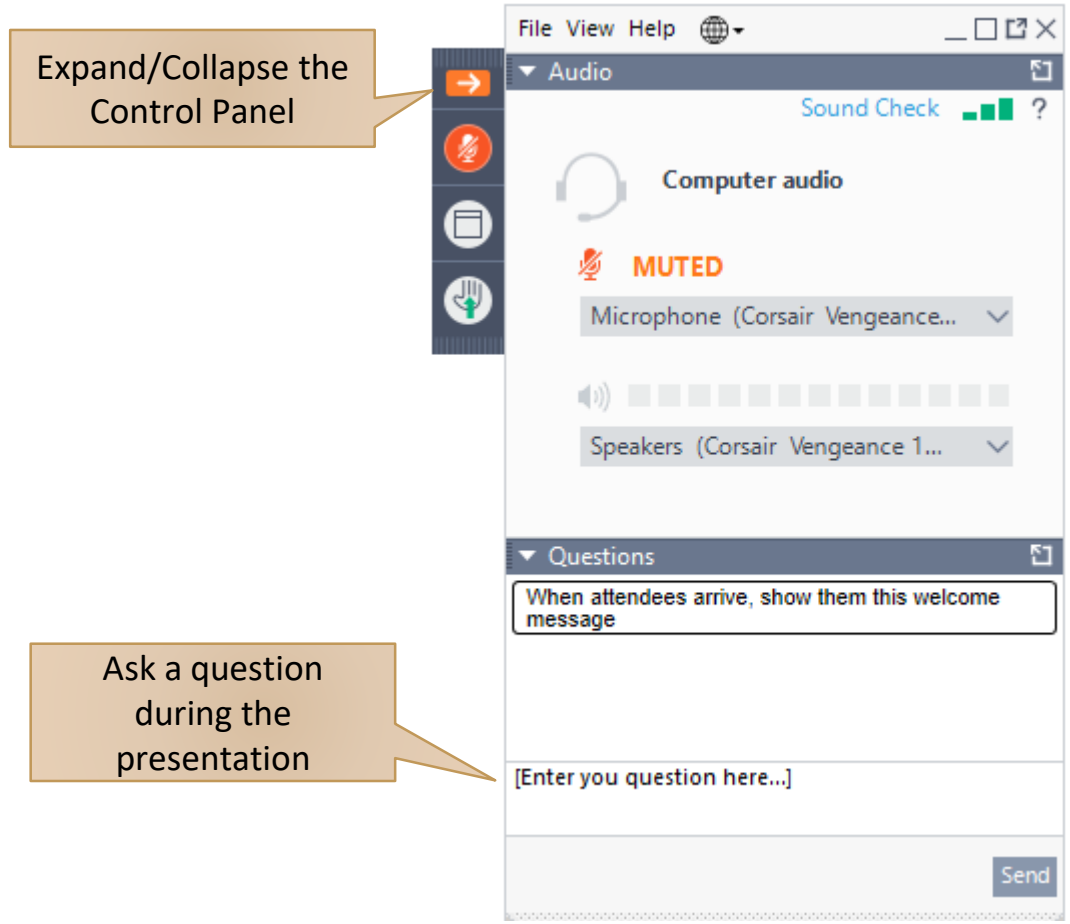
Host:
Morten Enemark Lund
R&D Engineer
AnyBody Technology

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 + Forces

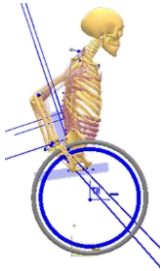
ANYBODY

Modeling System

Body Loads

- Joint moments
- Muscle forces
- Joint reaction forces

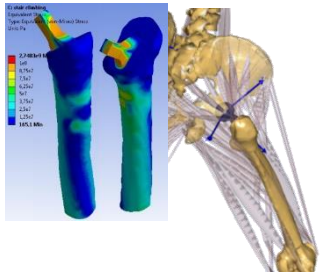
Movement Analysis



Product Design Optimization

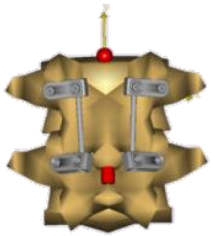
ANYBODY Modeling System

Ergonomic Analysis



Load Cases for Finite Element Analysis

Surgical Planning and Outcome Evaluation

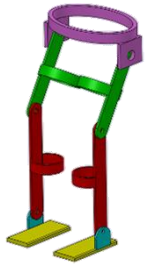


AnyBody Modeling System

Motion and Forces

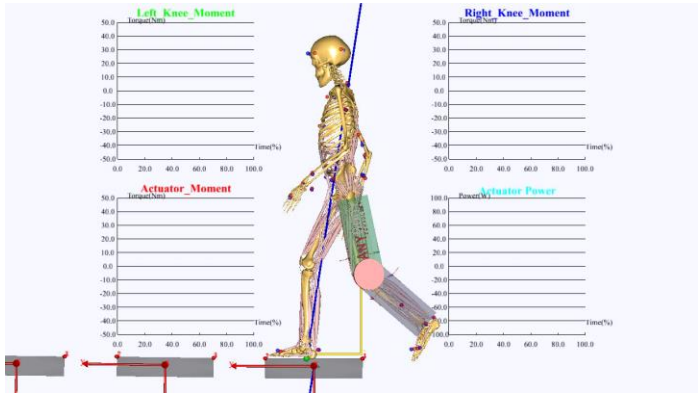
Body model

Environment model



Inverse dynamics
Muscle recruitment

Simulation



Internal body loads

- Muscle forces
- Joint forces

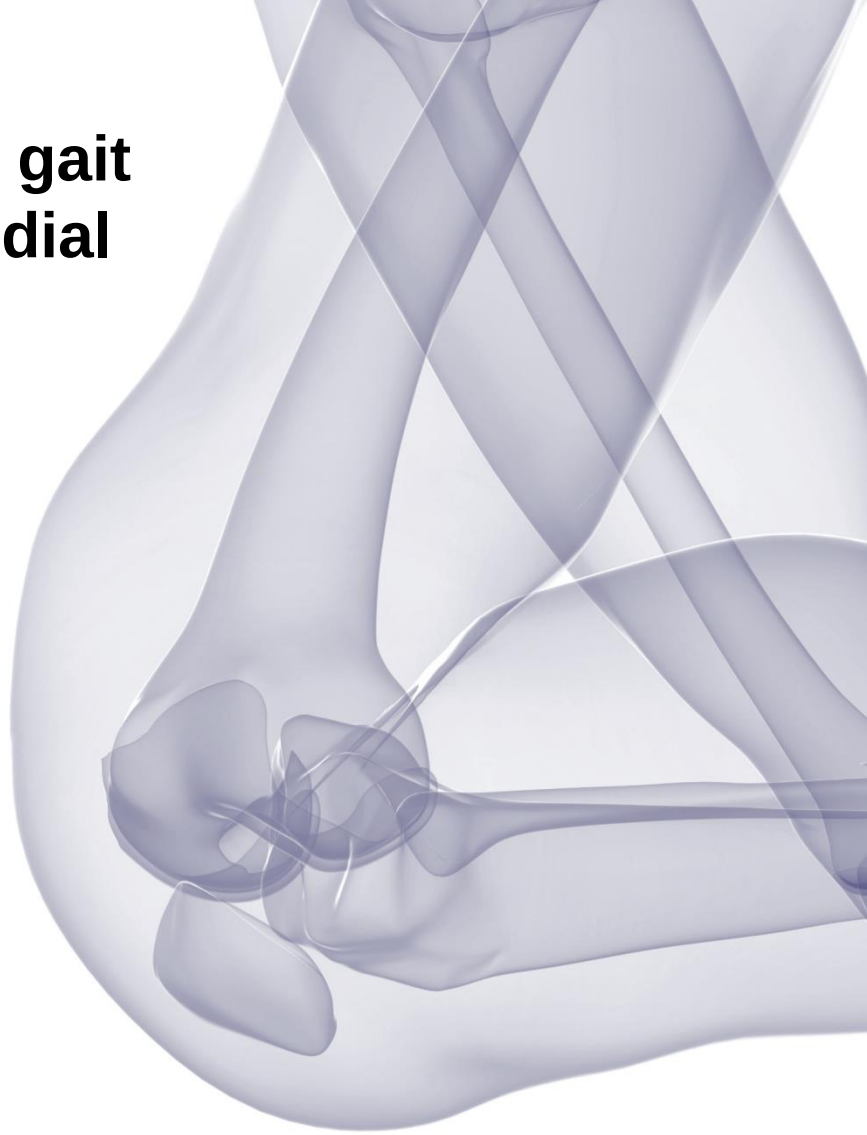
Design Optimization

Post Processing (e.g. FE tools)

Stresses in the medial tibial cartilage

WORKFLOW ASSESSING THE EFFECT OF GAIT ALTERATIONS

Workflow assessing the effect of gait alterations on stresses in the medial tibial cartilage



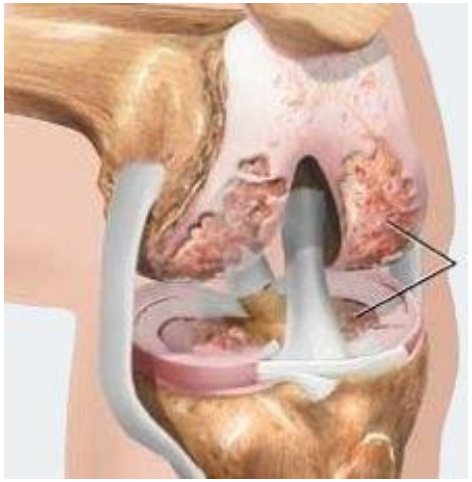
The Kneemo project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 607510.

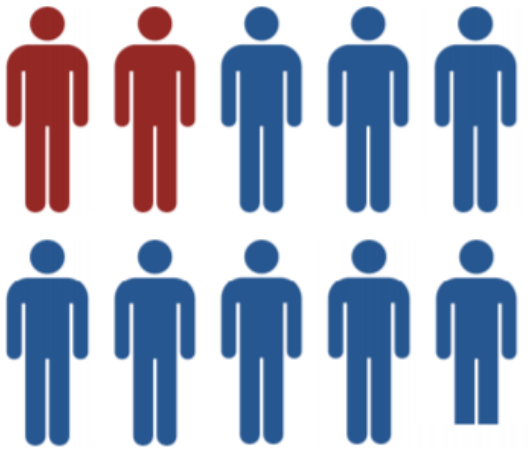
KNEEMO | Initial Training Network in Knee Osteoarthritis Research

BREAKING NEW GROUND
AALBORG UNIVERSITY

Osteoarthritis (OA)

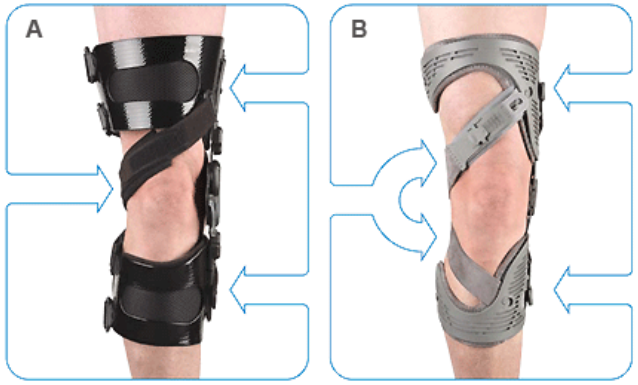
- Slow degeneration of cartilage, bone, meniscus, ligaments etc.
- The most common joint disease with the knee the most frequent site.
- Listed among the top 5 causes of disability worldwide (WHO, 2016)





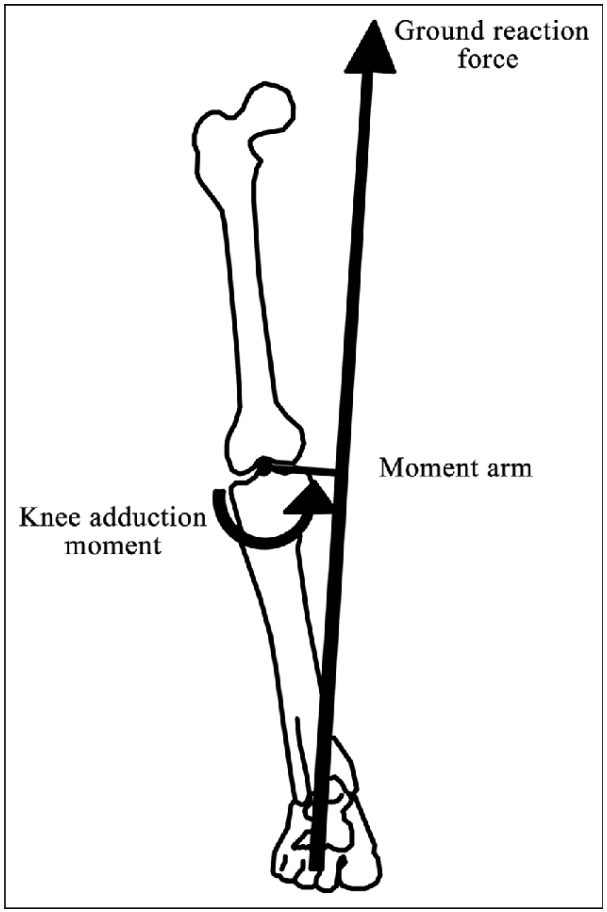
Non-surgical biomechanical interventions

3mm Lateral Wedge



Literature gap

Knee Adduction Moment (KAM) may not be a good surrogate of the internal load[1,2]



(1) Saxby et al 2016 (2) Richards et al 2018

Aim

Develop a patient-specific workflow to estimate whole-body and tissue loads

(1) Saxby et al 2016 (2) Richards et al 2018

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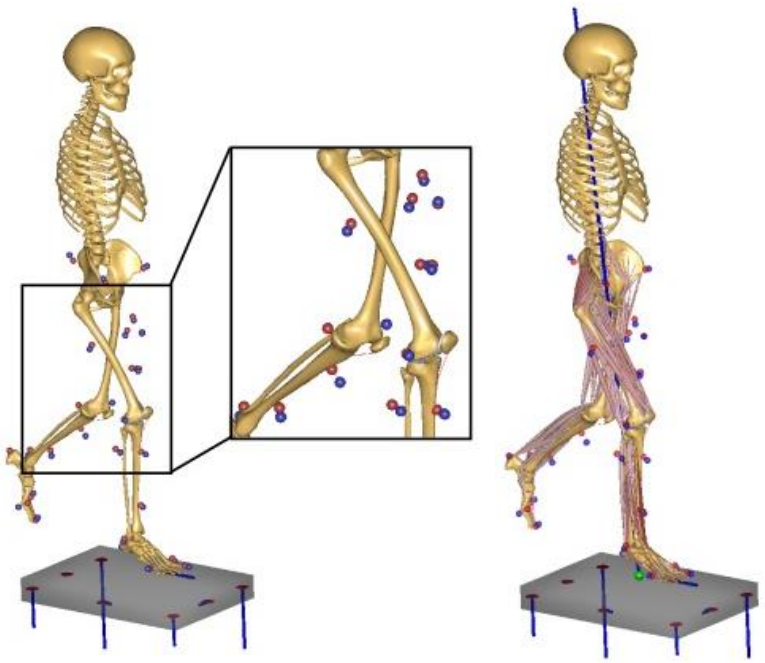
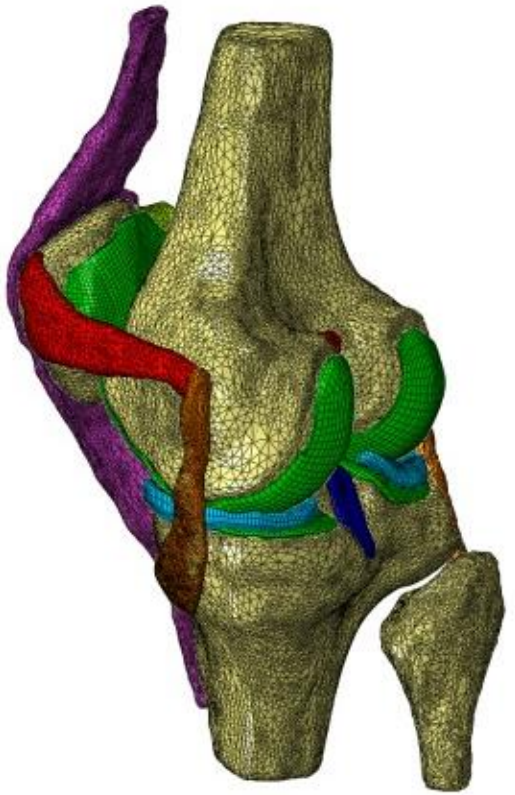
Musculoskeletal modelling and Finite Element modelling

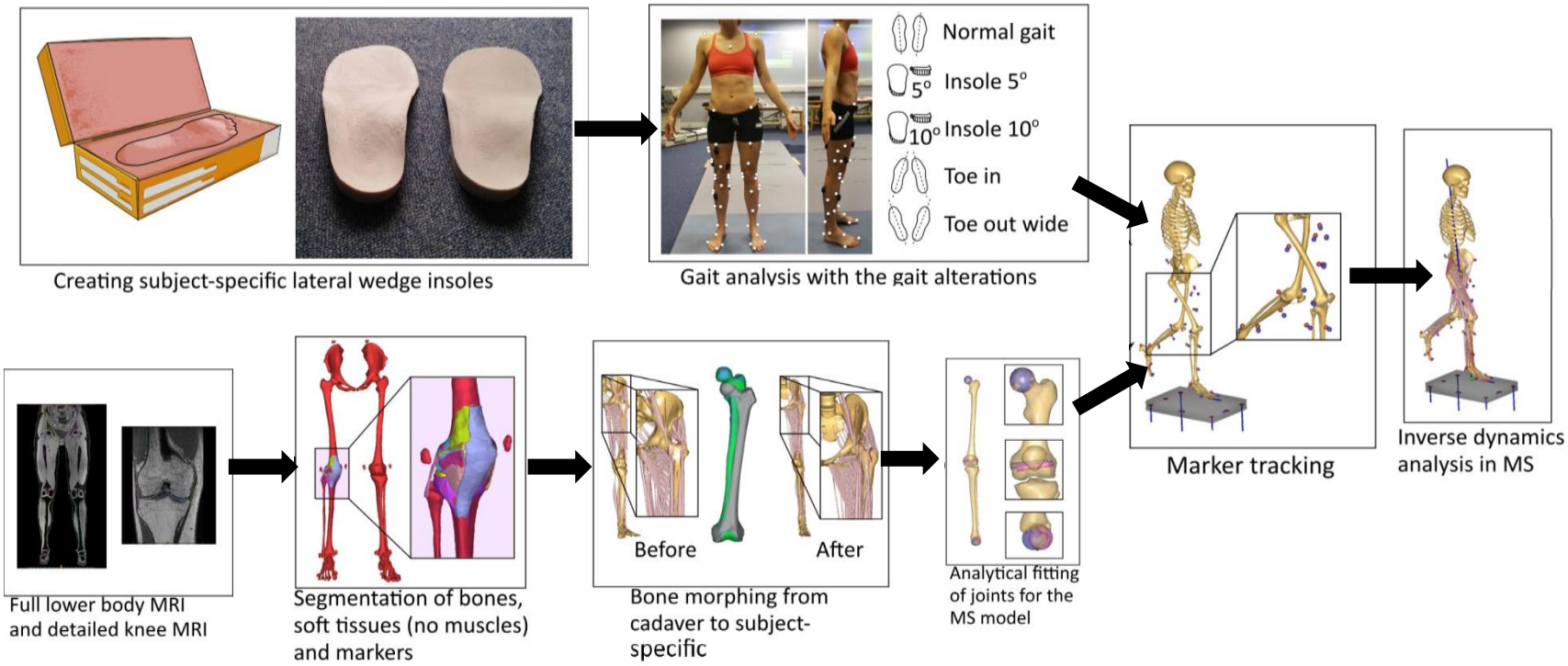


Musculoskeletal (MS)



Finite Element (FE)

Subject-Specific Multiscale Modelling: Study Design



Knee Joint Selection

-Hinge

-Force Dependent Kinematics (FDK)

-Moving-Axis

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FDK knee model

www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

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Workflow assessing the effect of gait alterations on stresses in the medial tibial cartilage - combined musculoskeletal modelling and finite element analysis

K. S. Halonen[1], C. M. Dzialo[2], M. Mannisi[3], M. S. Venäläinen[4], M. de Zee[1] & M. S. Andersen[2]

Introduction to Force-Dependent Kinematics: Theory and Application to Mandible Modeling

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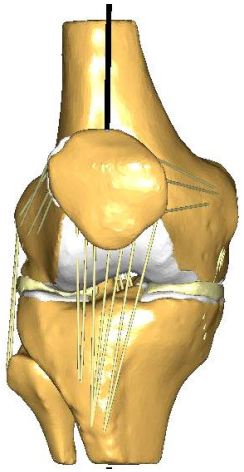
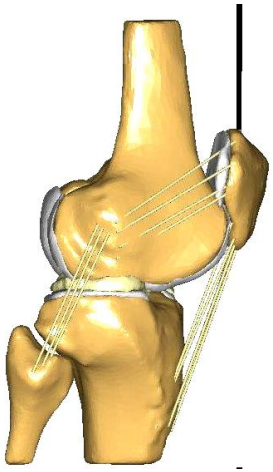
J. Biomech. Eng. 139. 091001-1. 2007





11 FDK DOF. (tibiofemoral and patellofemoral)

Elastic foundation contacts

Nonlinear elastic ligaments

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Contents lists available at ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech
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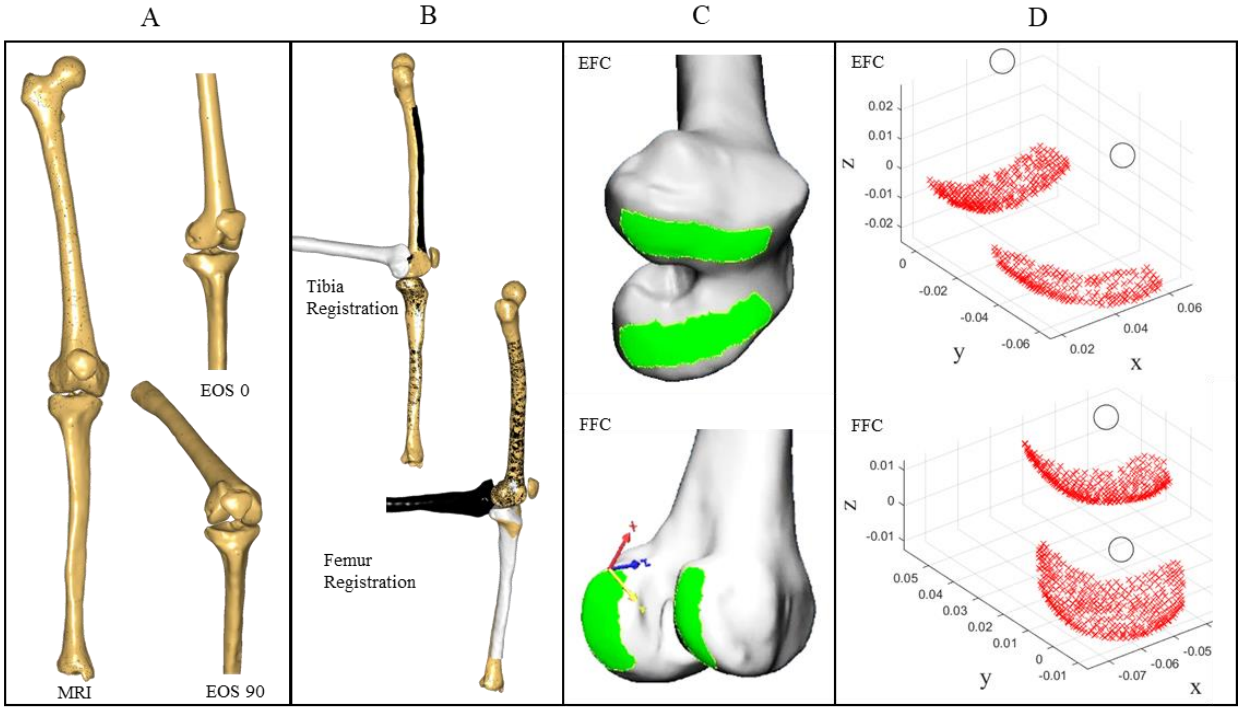
Development and validation of a subject-specific moving-axis tibiofemoral joint model using MRI and EOS imaging during a quasi-static lunge

C.M. Dzialo [a,*], P.H. Pedersen [b], C.W. Simonsen [c], K.K. Jensen [c], M. de Zee [d], M.S. Andersen [a]



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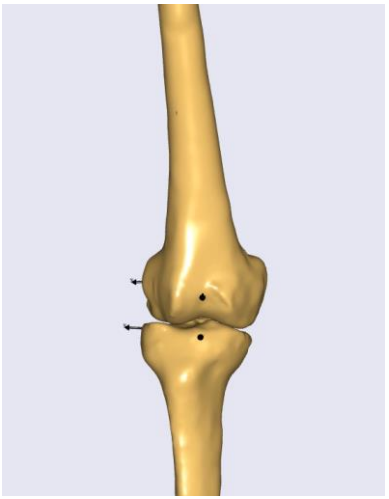
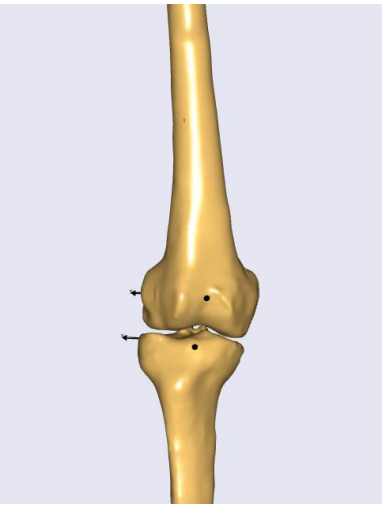
Moving-Axis

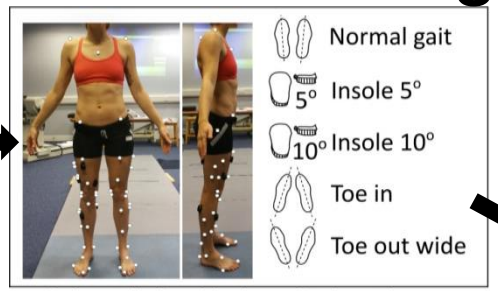


Hinge

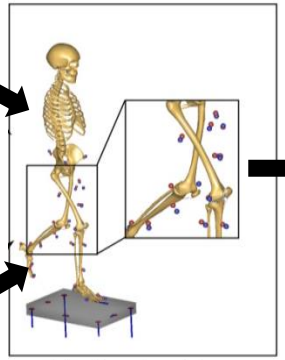


Subject-Specific Multiscale Modelling: Study Design

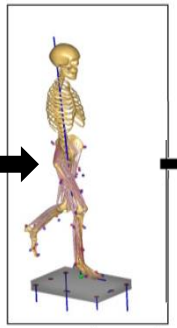
Creating subject-specific lateral wedge insoles



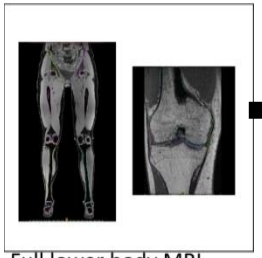
Gait analysis with the gait alterations



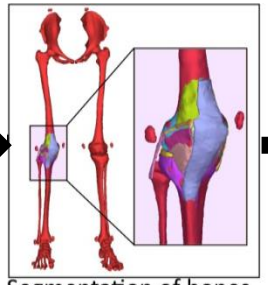
Marker tracking



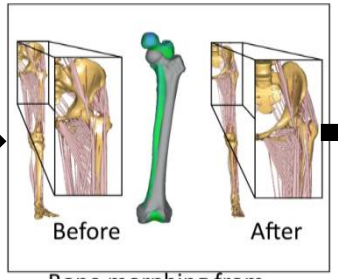
Inverse dynamics analysis in MS



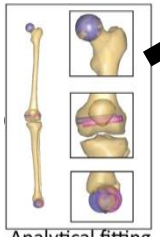
Full lower body MRI and detailed knee MRI



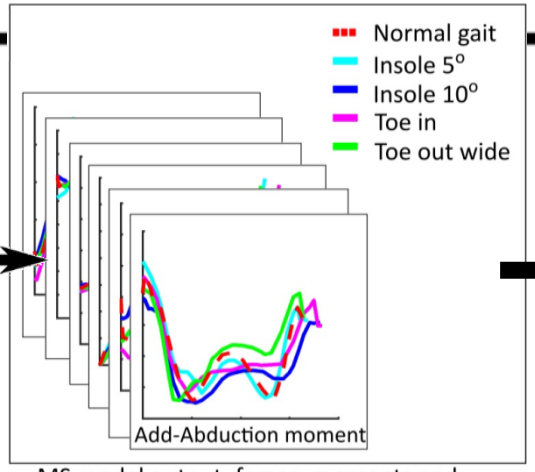
Segmentation of bones, soft tissues (no muscles) and markers



Bone morphing from cadaver to subject-specific



Analytical fitting of joints for the MS model

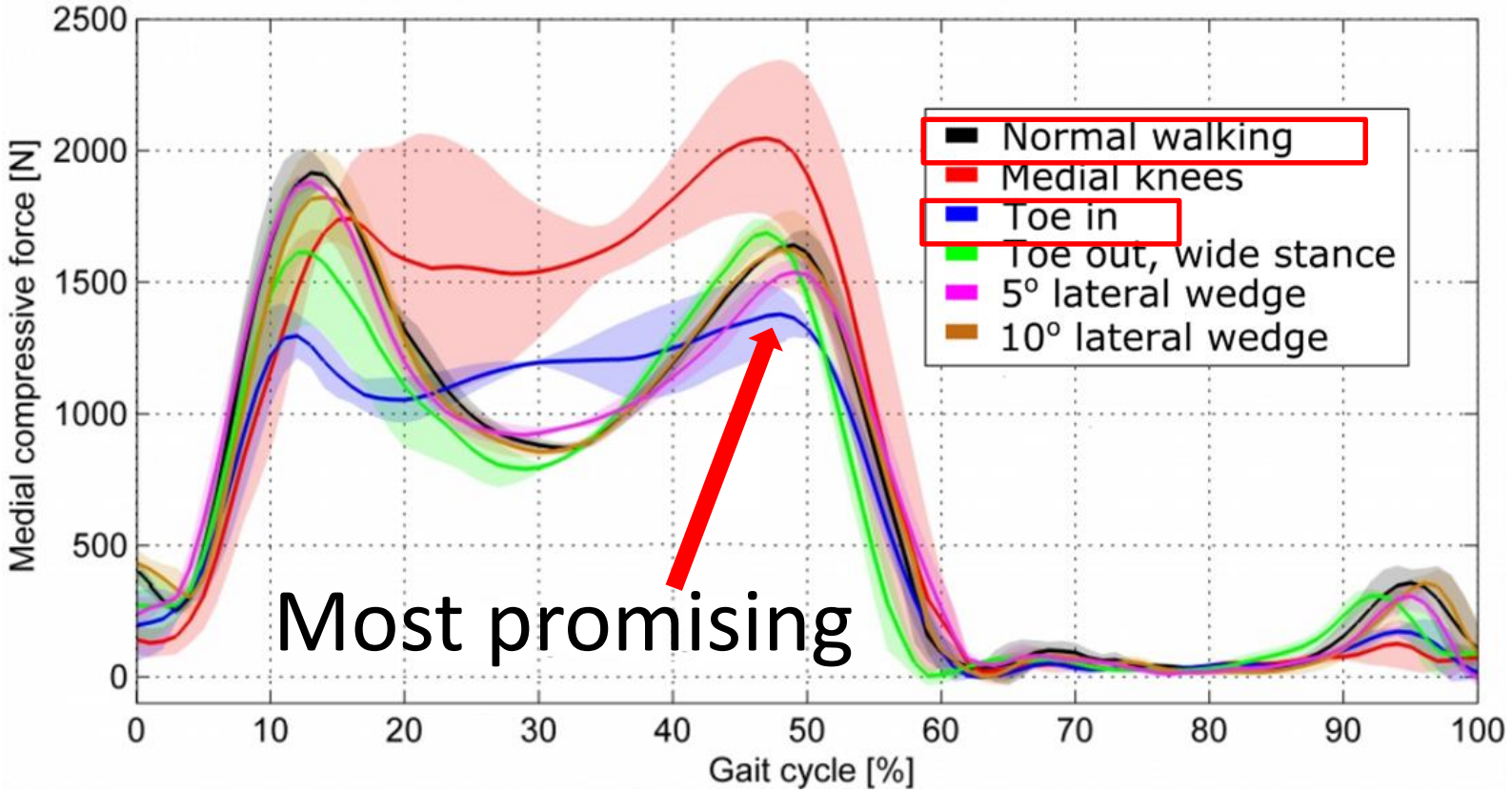


MS model output: forces, moments and extension-flexion rotation during walking

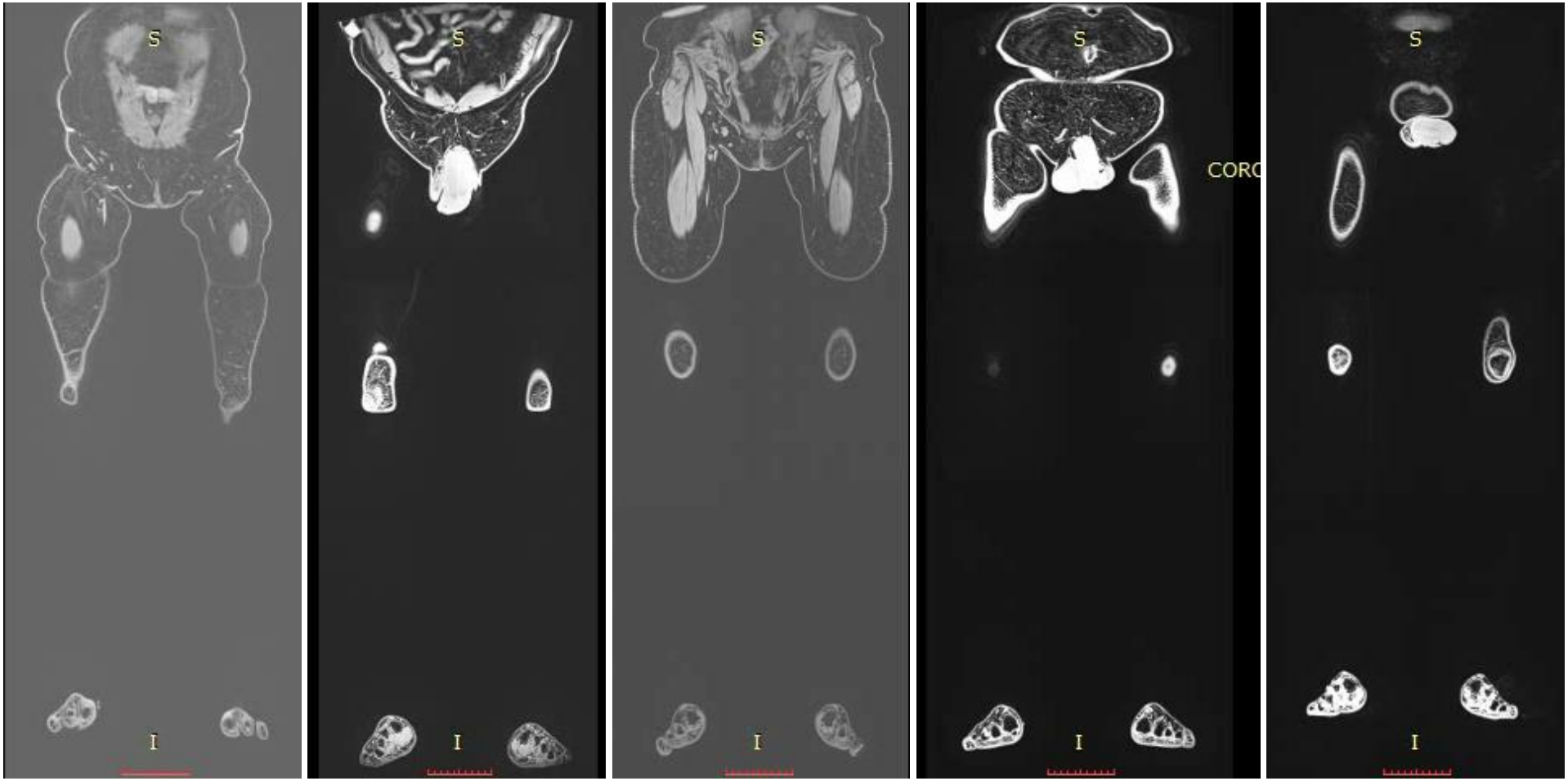
(a) End with musculoskeletal model results

(b) Continue onto FEA modelling, using MS outputs as boundary conditions

Healthy subject result from Scientific Reports paper



Patient-Specific Multiscale Modelling: MRI Imaging



Patient 1 Patient 2 Patient 3 Patient 4 Patient 5

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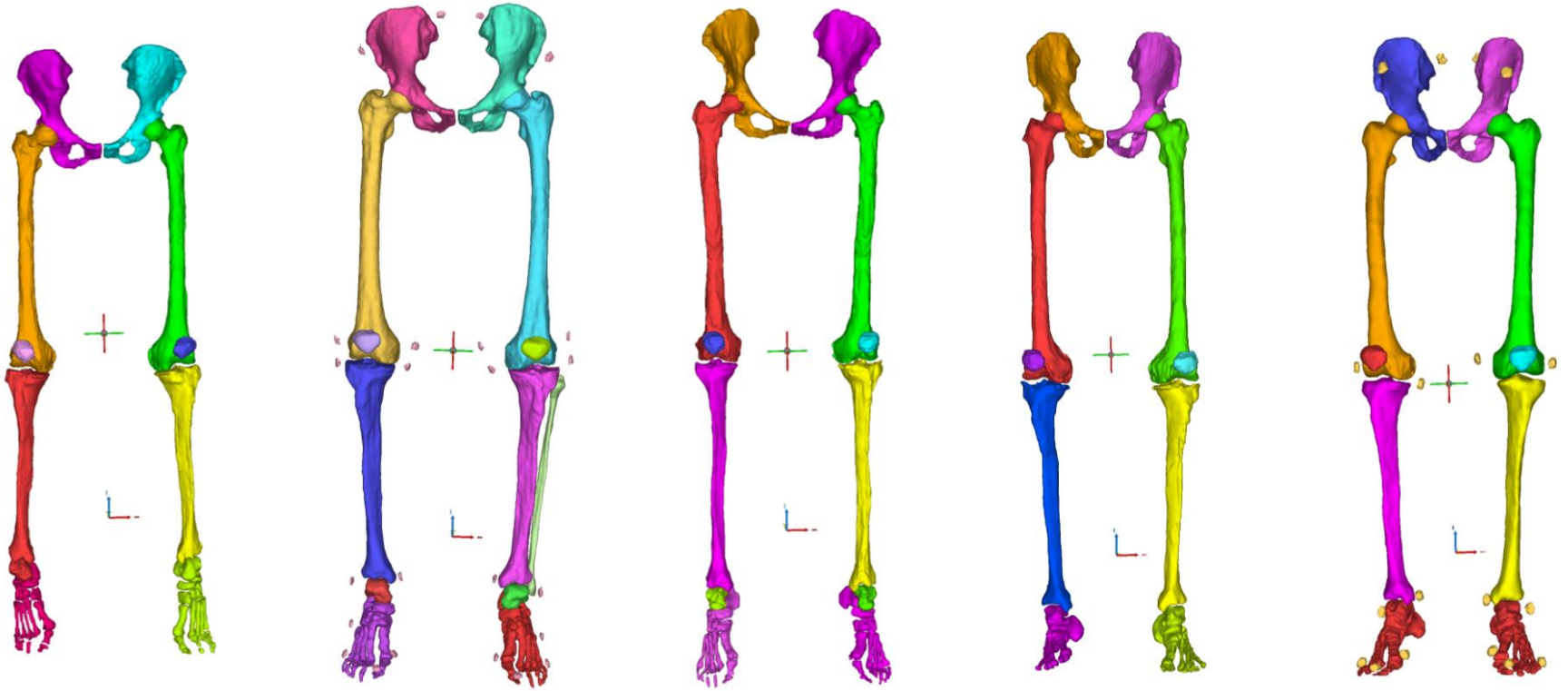
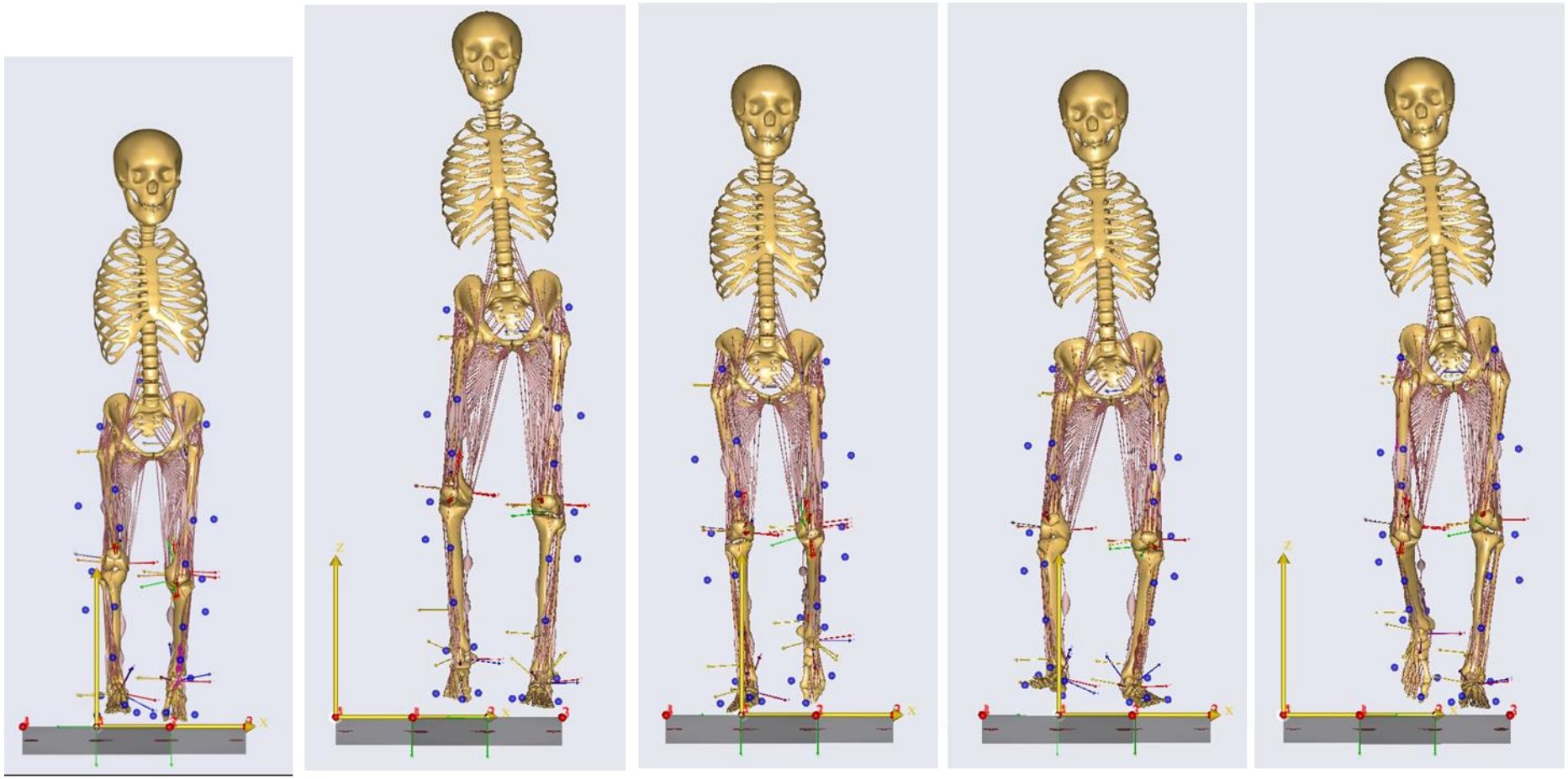
Patient-Specific Multiscale Modelling: Segmentation



Patient 1 Patient 2 Patient 3 Patient 4 Patient 5

Patient-Specific Multiscale Modelling: MS Models



Patient 1 Patient 2 Patient 3 Patient 4 Patient 5

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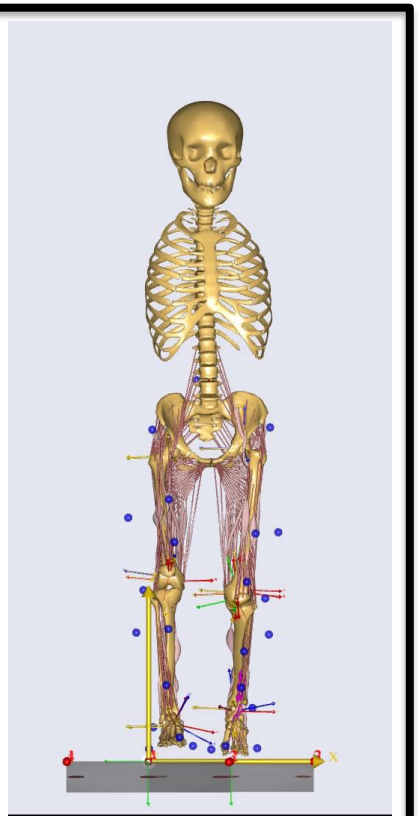
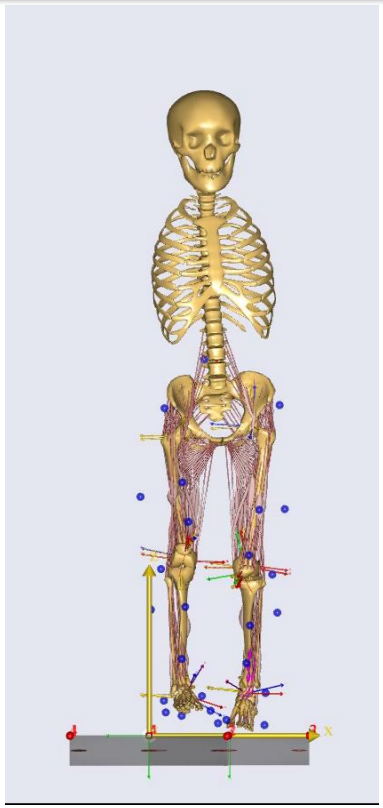
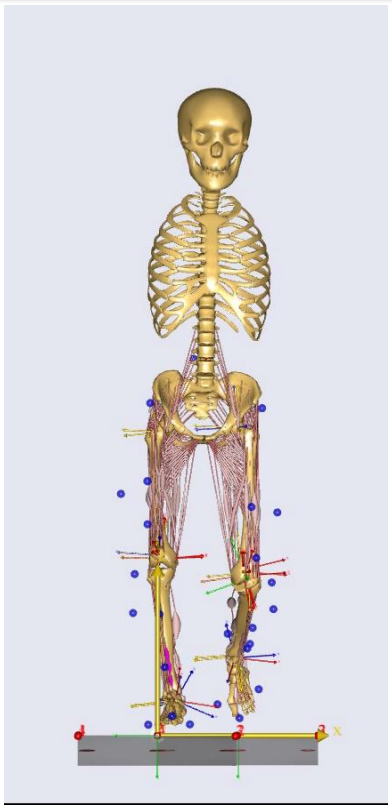
Patient-Specific Multiscale Modelling: Gait Modifications



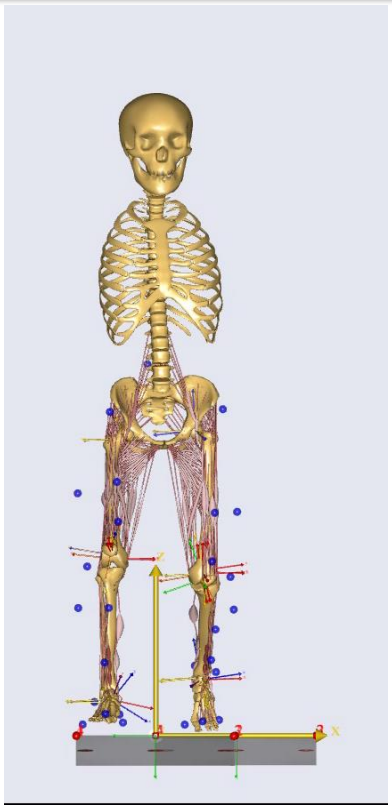
Shod



Toe-In

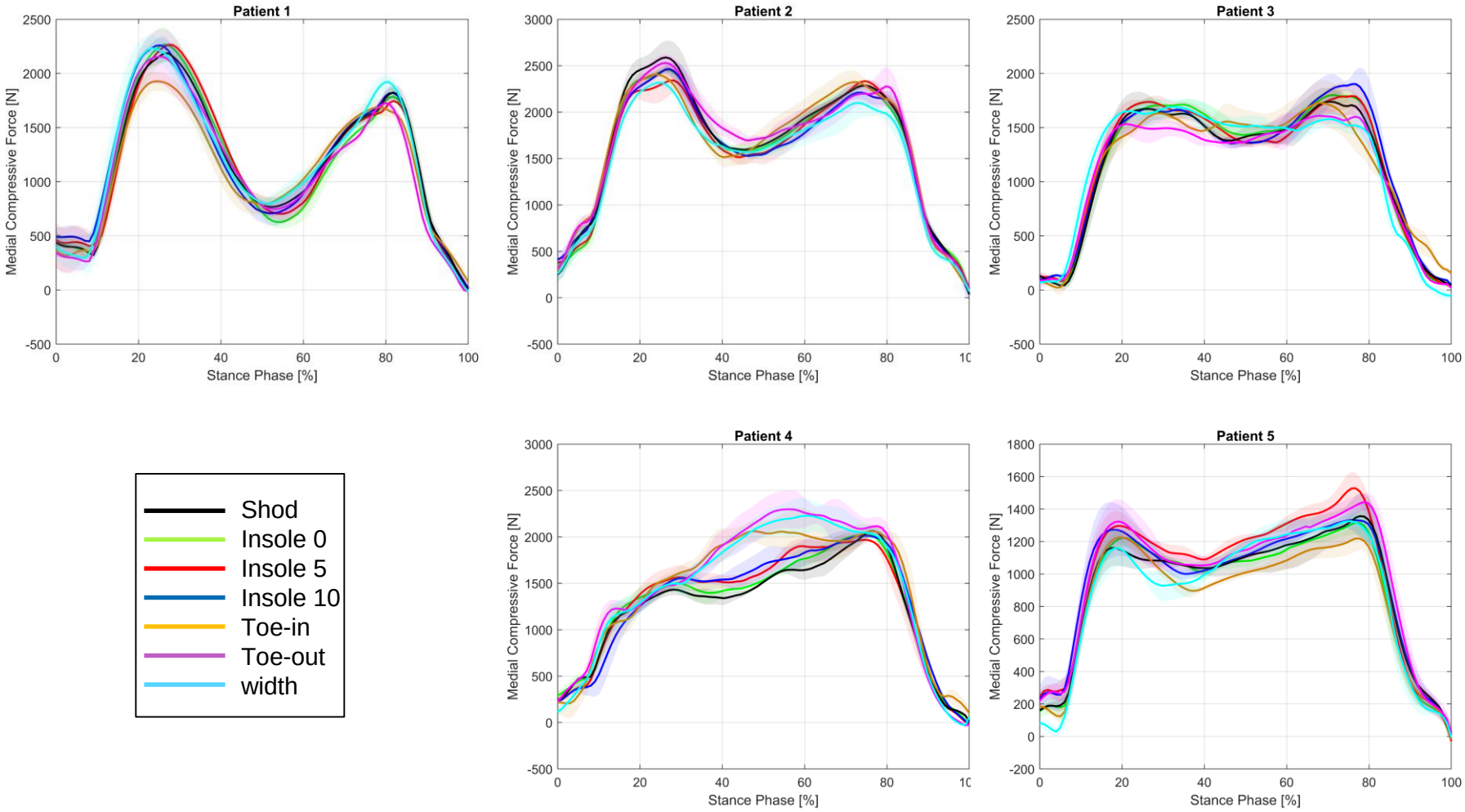


Toe-Out

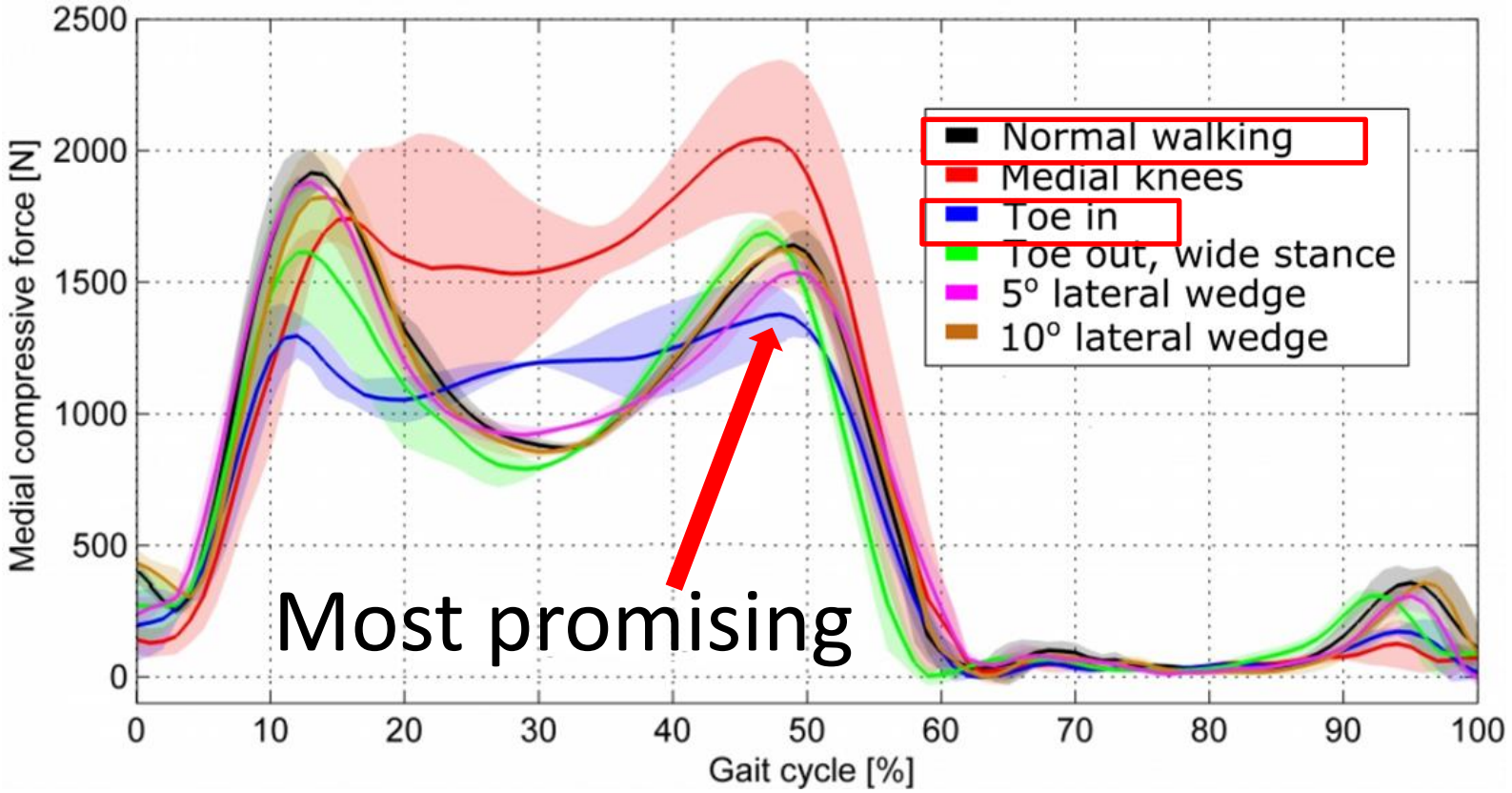


Width

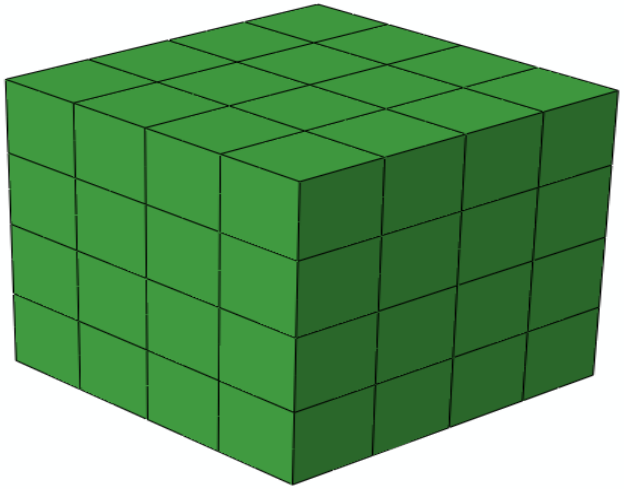
Patient-Specific Multiscale Modelling: MS Outputs
(Ex. Medial Compartment Compressive Force)



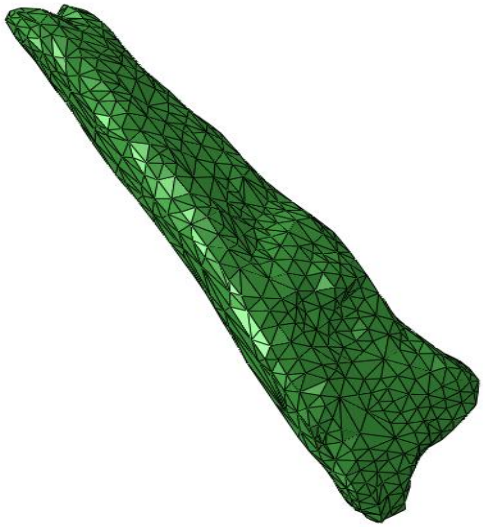
Healthy subject result from Scientific Reports paper



Finite element modelling

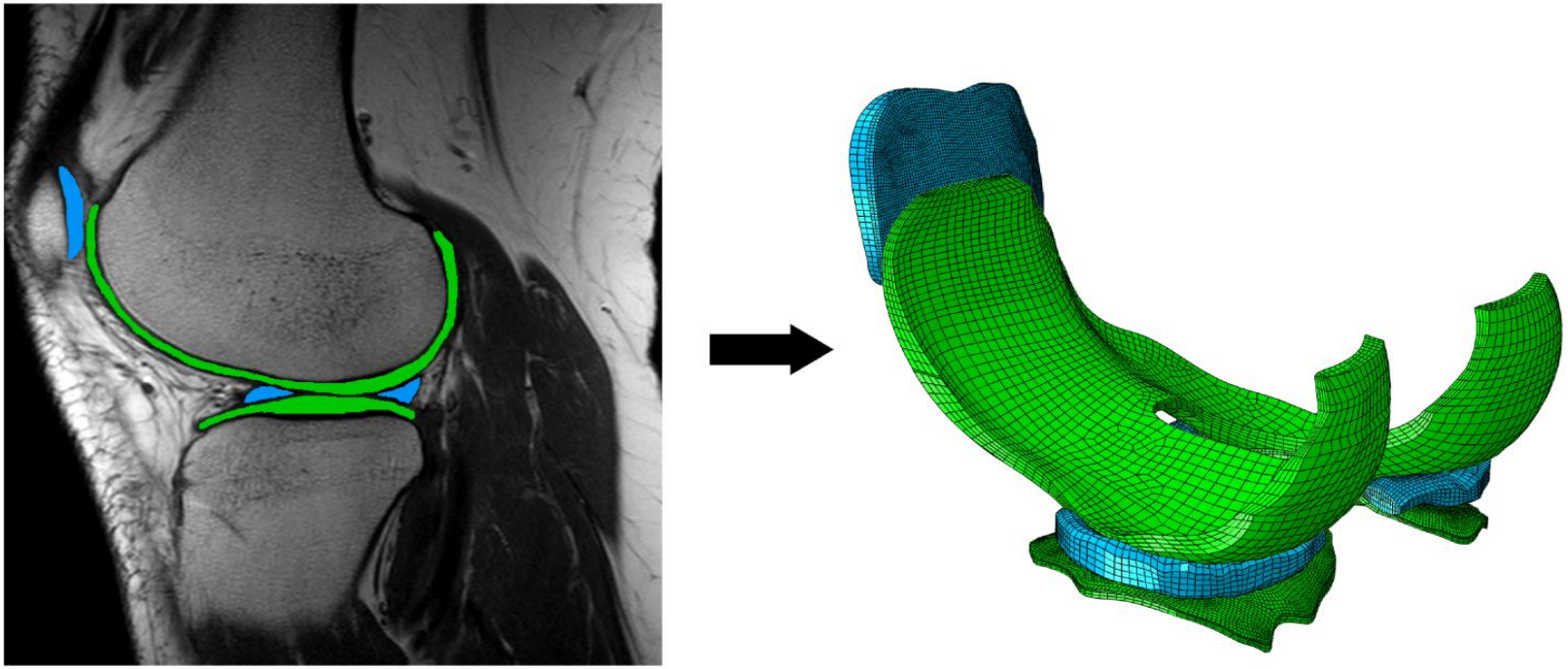


A box.



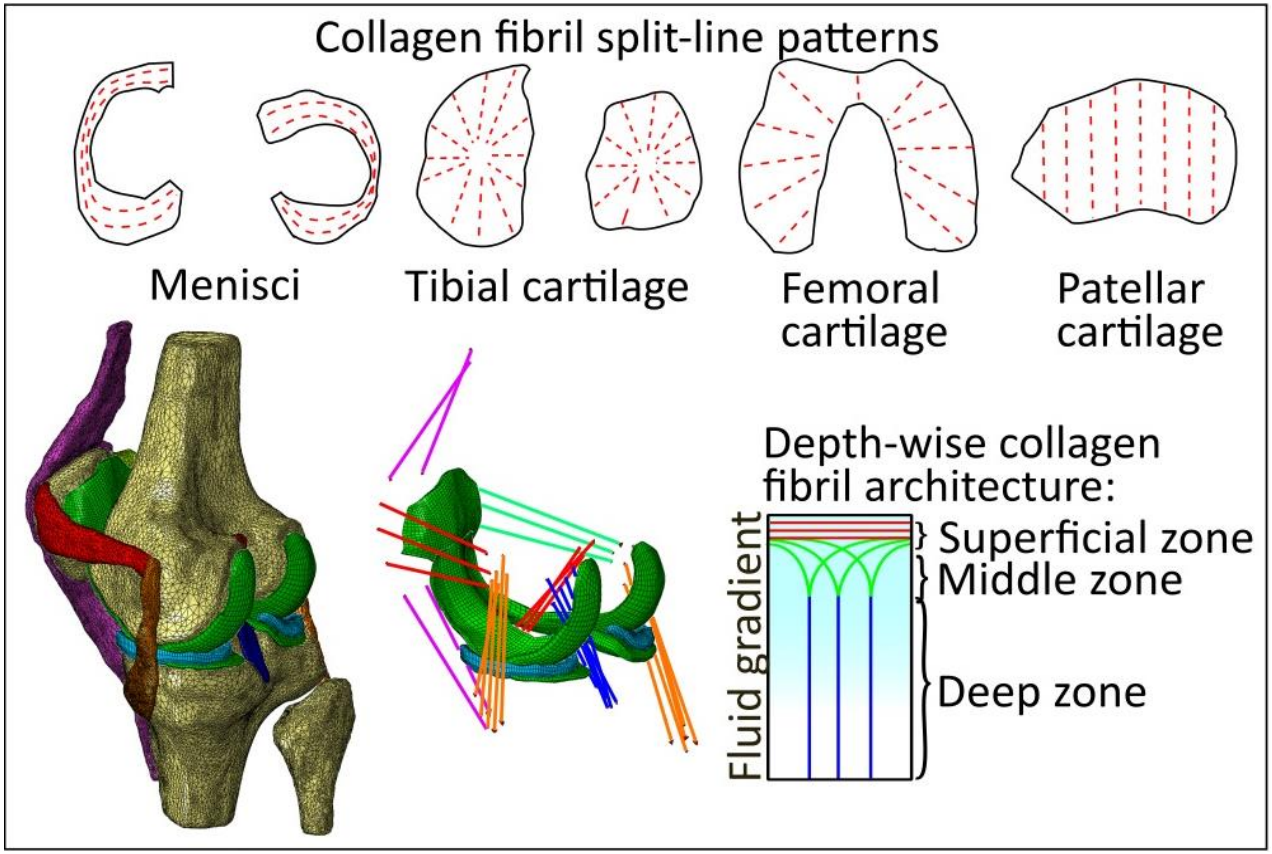
Meshed ACL.

Finite element modelling



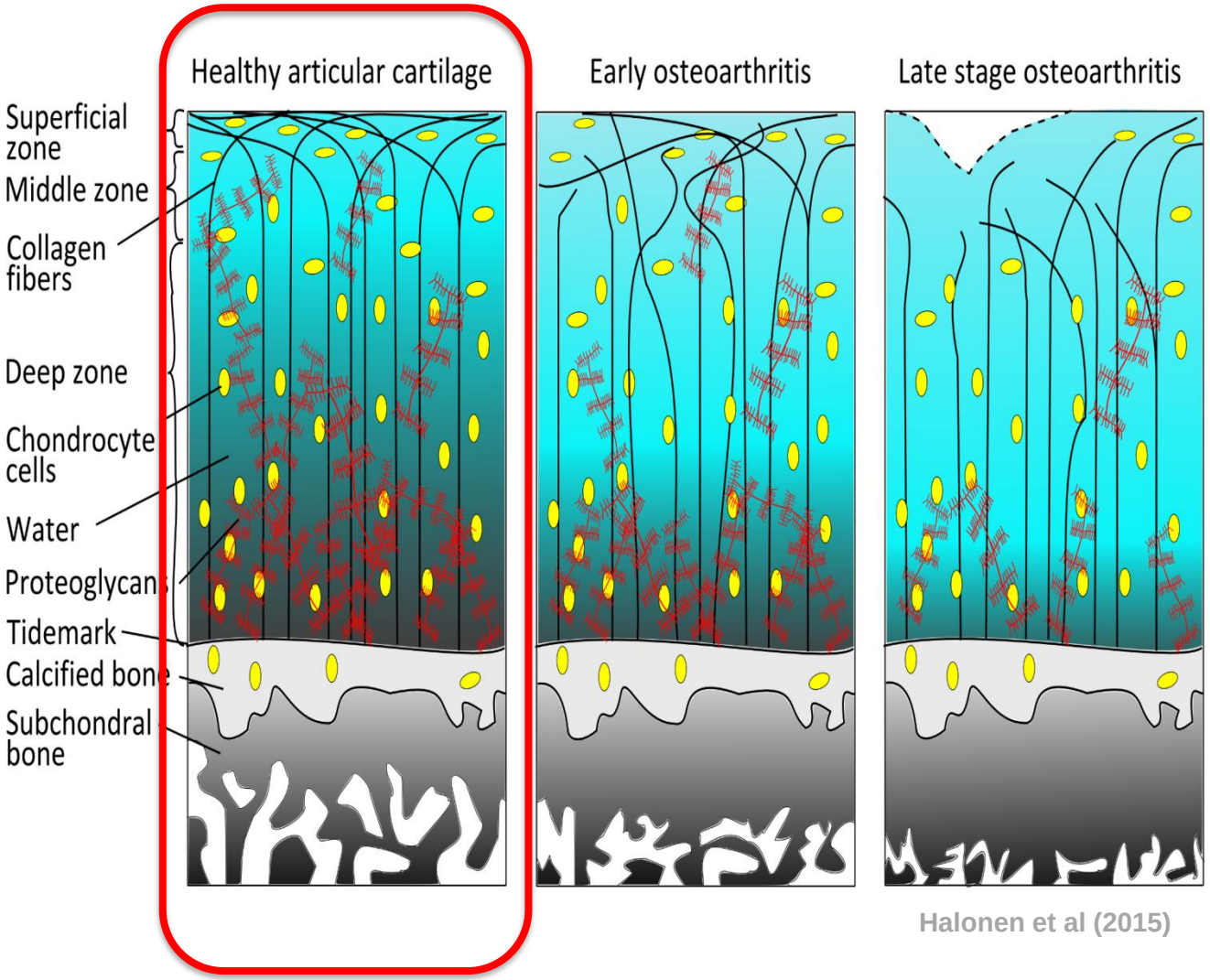
Segmentation **(left)** and an FE model **(right)**.

Finite element modelling



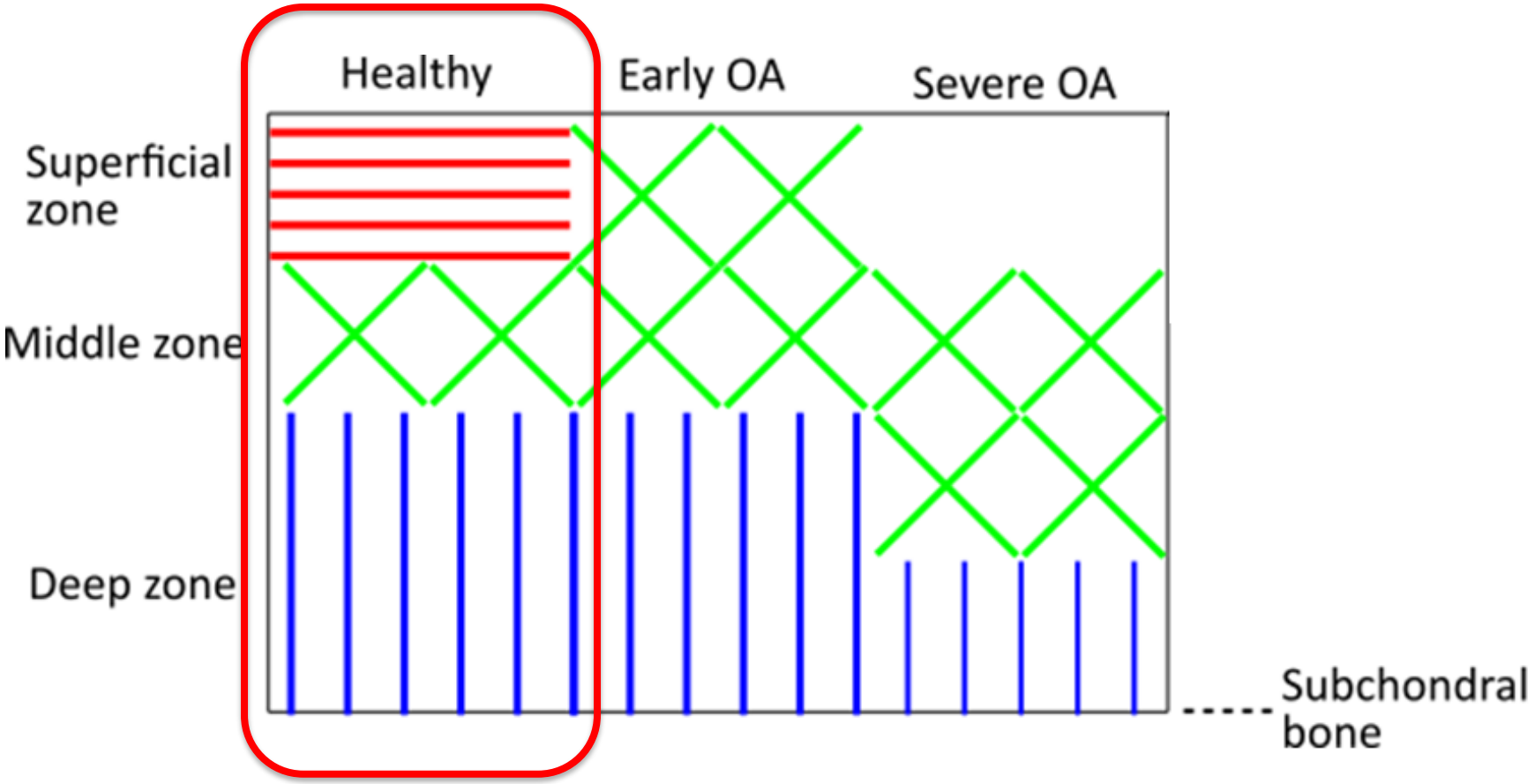
Subject-specific MS output is used as input to move FE model of patient's knee joint

Finite element modelling



Halonen et al (2015)

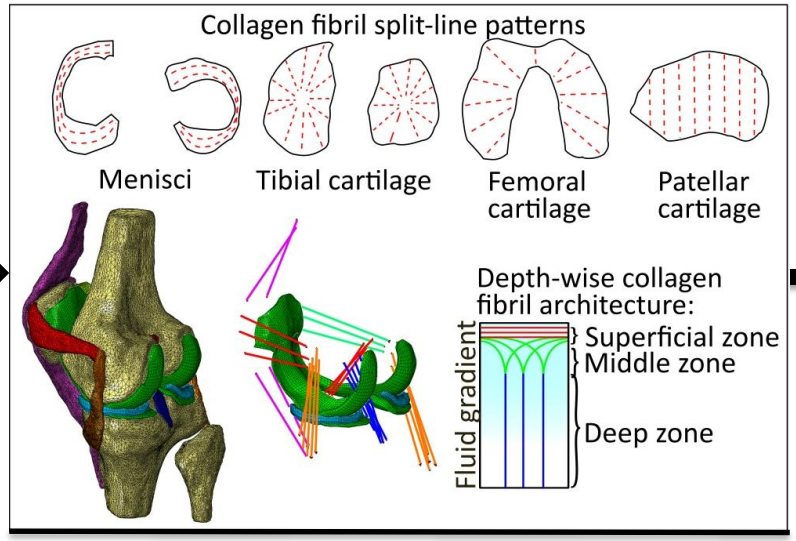
Finite element modelling



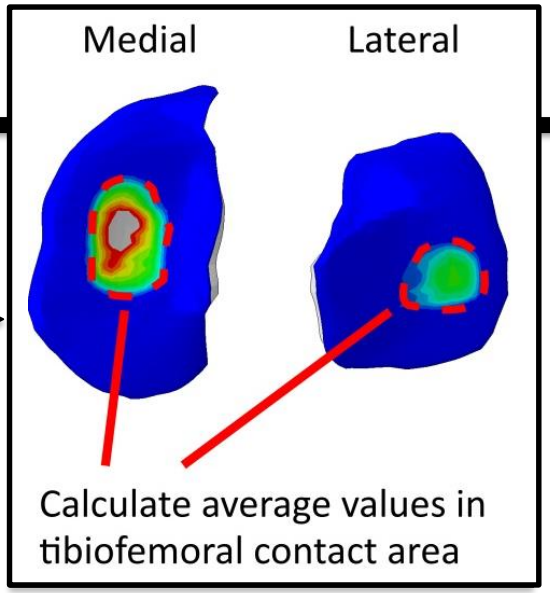
Finite element modelling

MS Input

Subject-specific MS output is used as input to move FE model of patient's knee joint



FE model output: stresses and strains in tibial cartilage



Initial results

- Insoles seemed promising, especially Insole 10
- Toe in helped during the 2nd peak, Toe out wide during the 1st

HOWEVER:

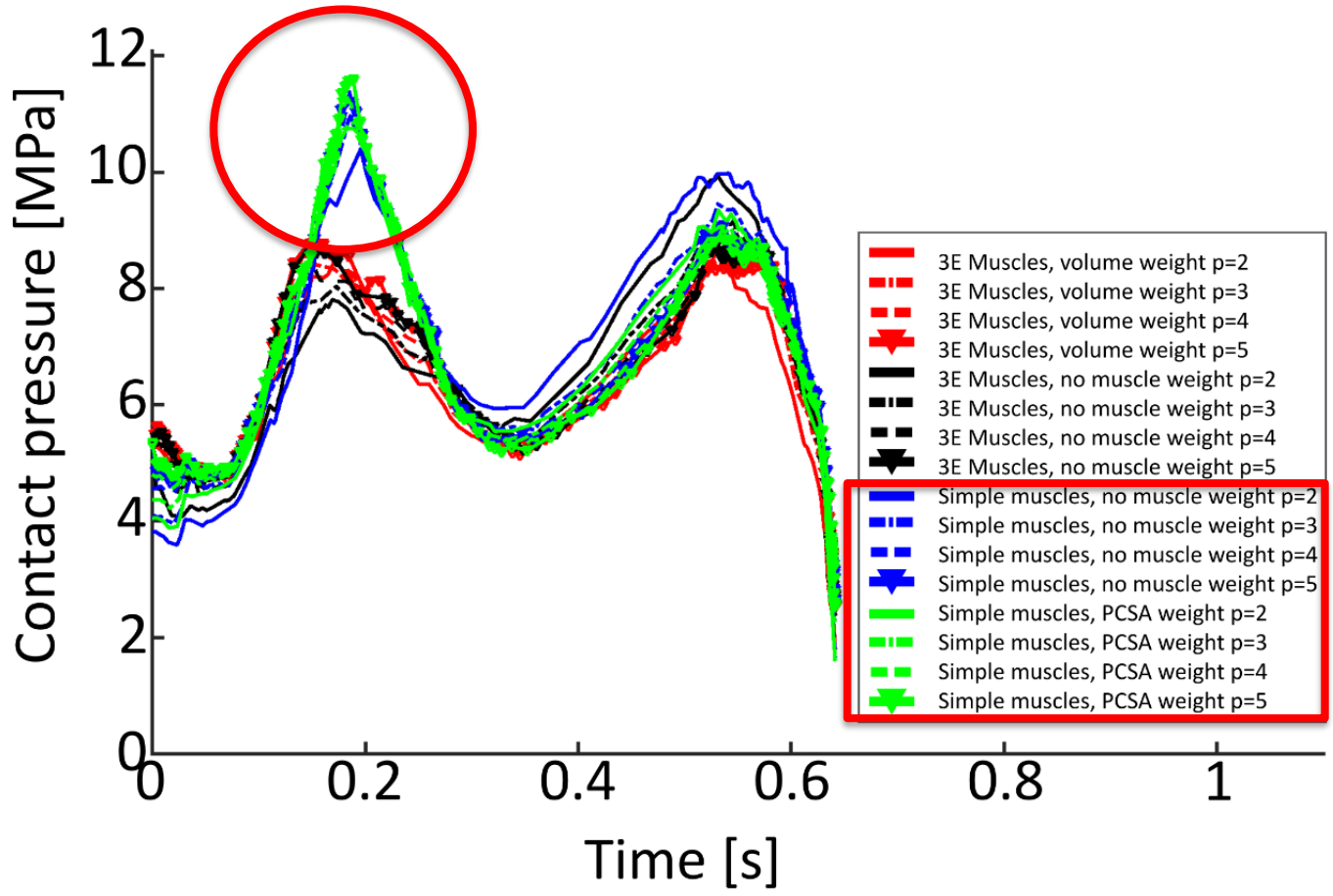
- High tibial contact pressures (up to 25 MPa)

What's going on?

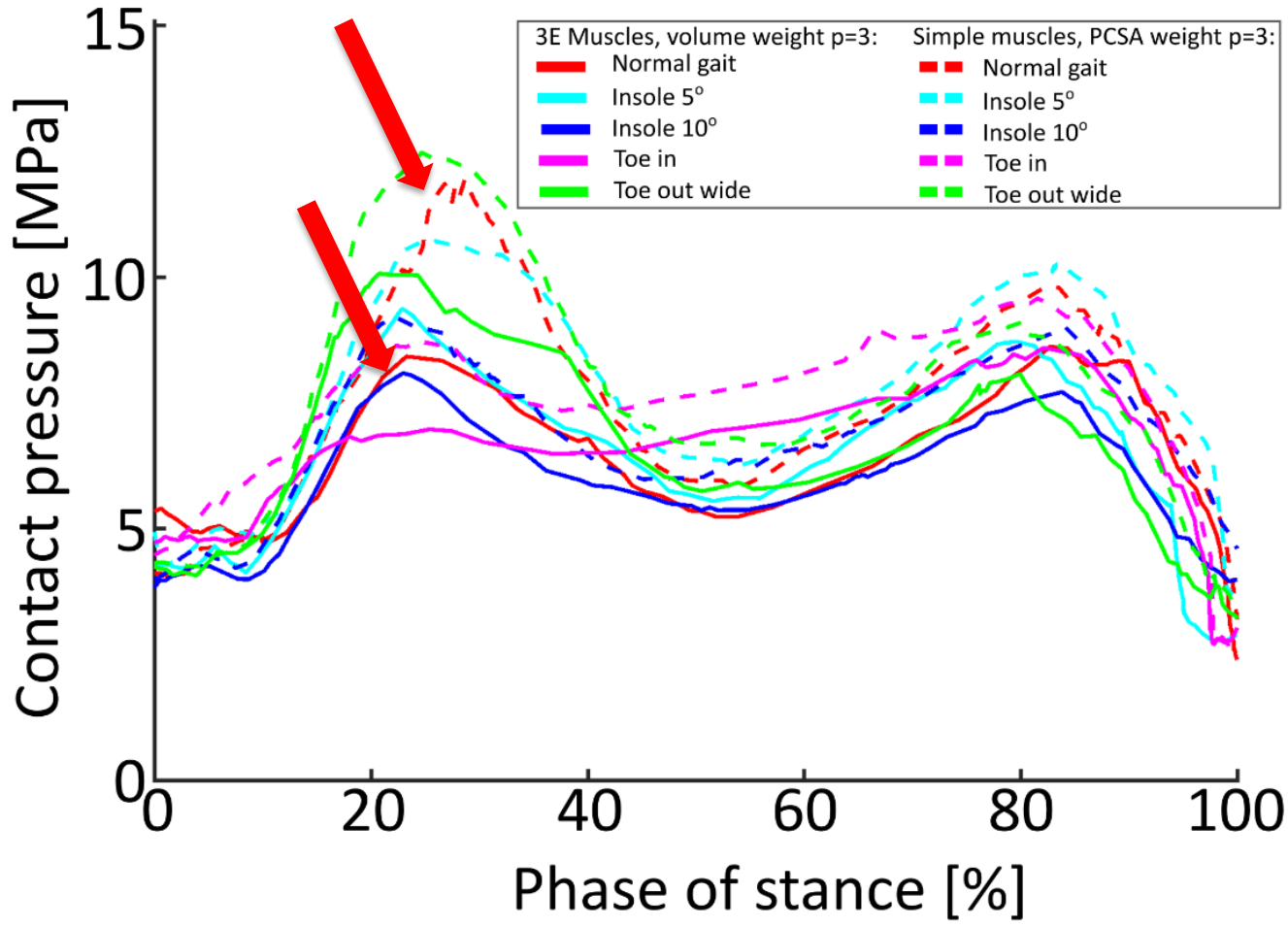
Actions taken

- Parametric studies with different muscle models
- Knee extensor strength testing
- Changing a simple hinge joint knee into a complex Force-dependent kinematics (FDK) model

Actions taken



Actions taken



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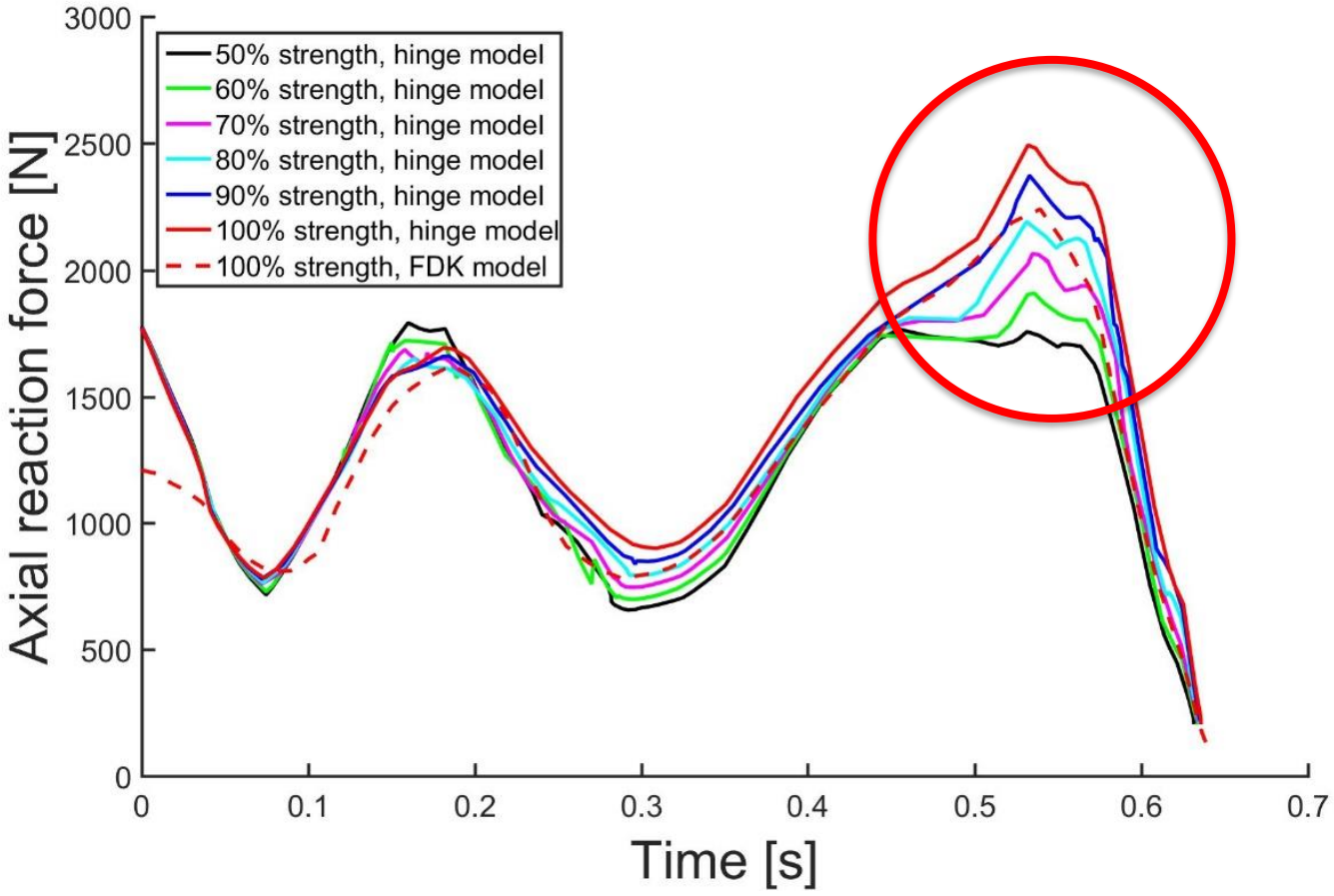

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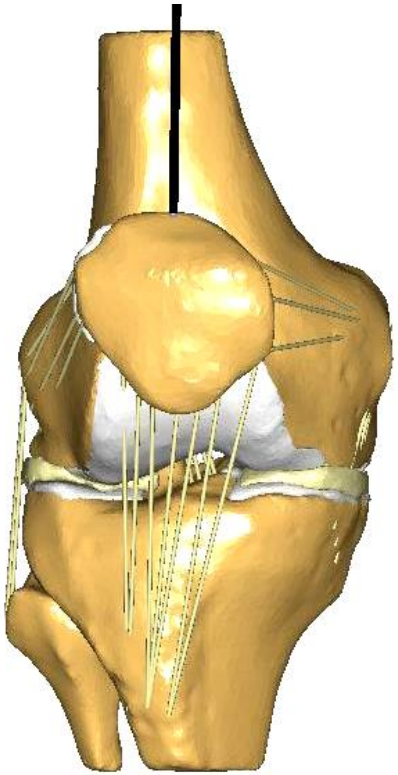

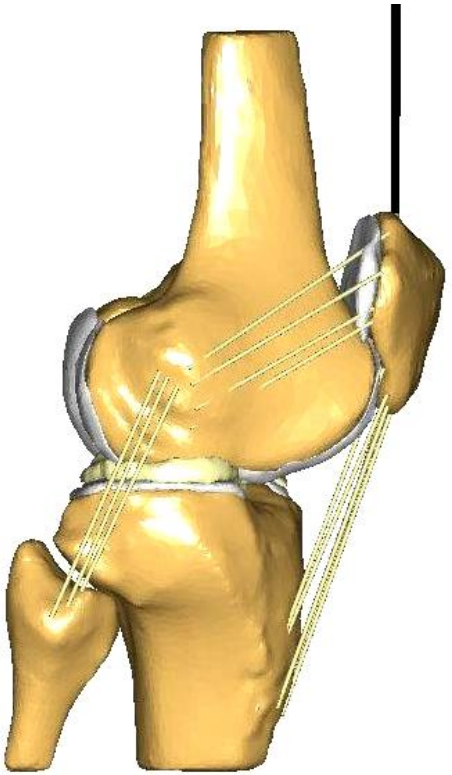

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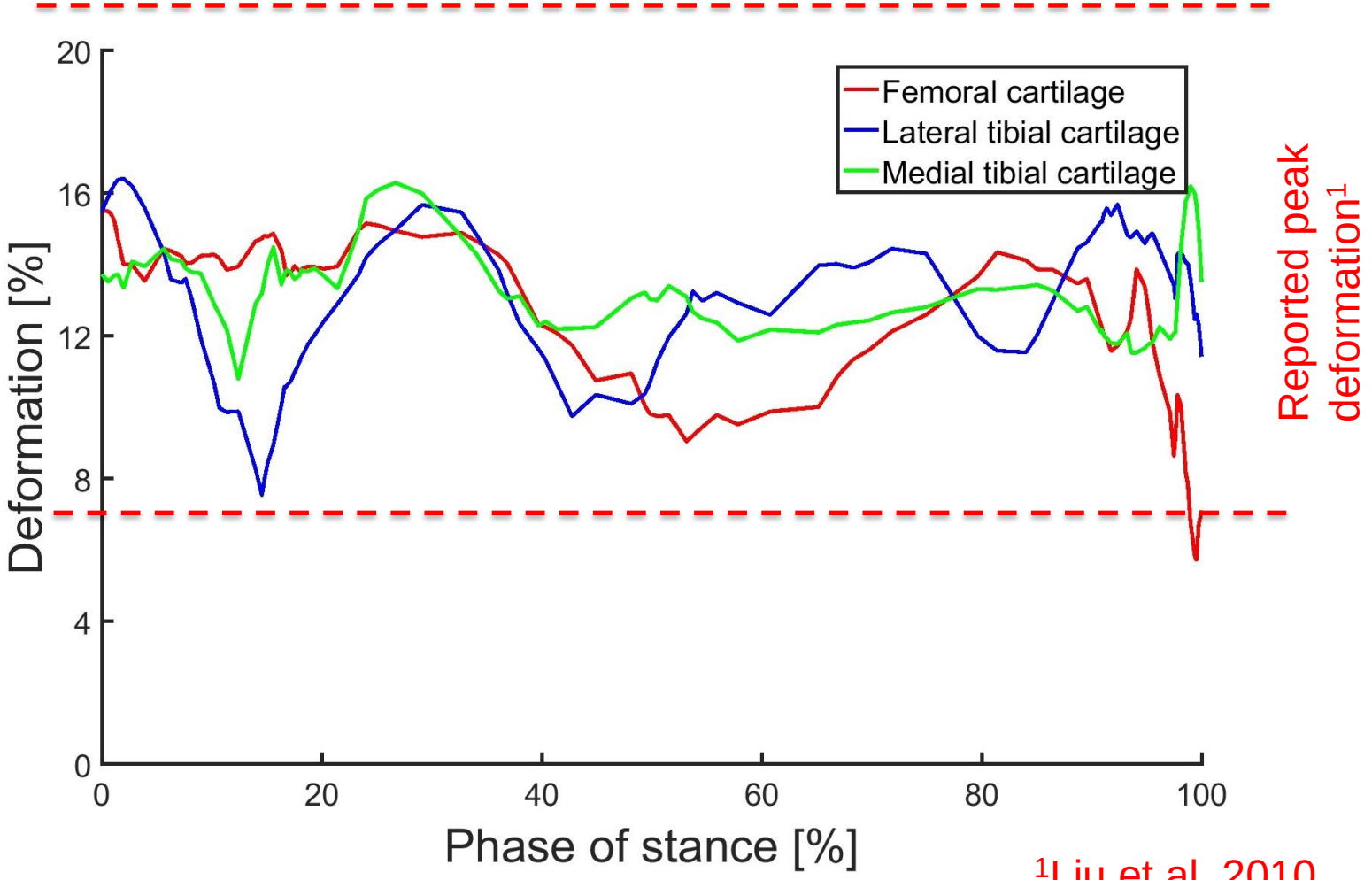
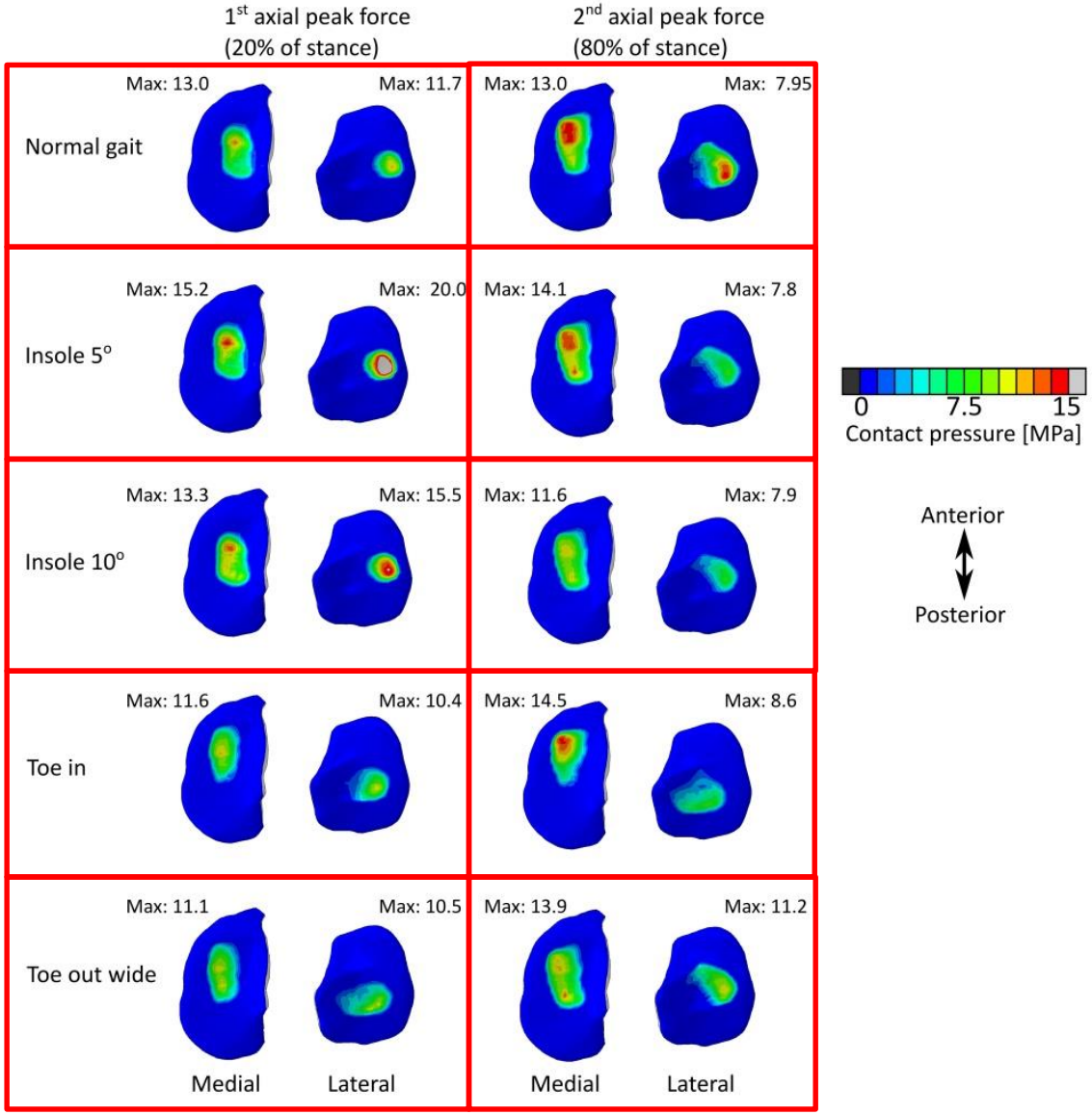
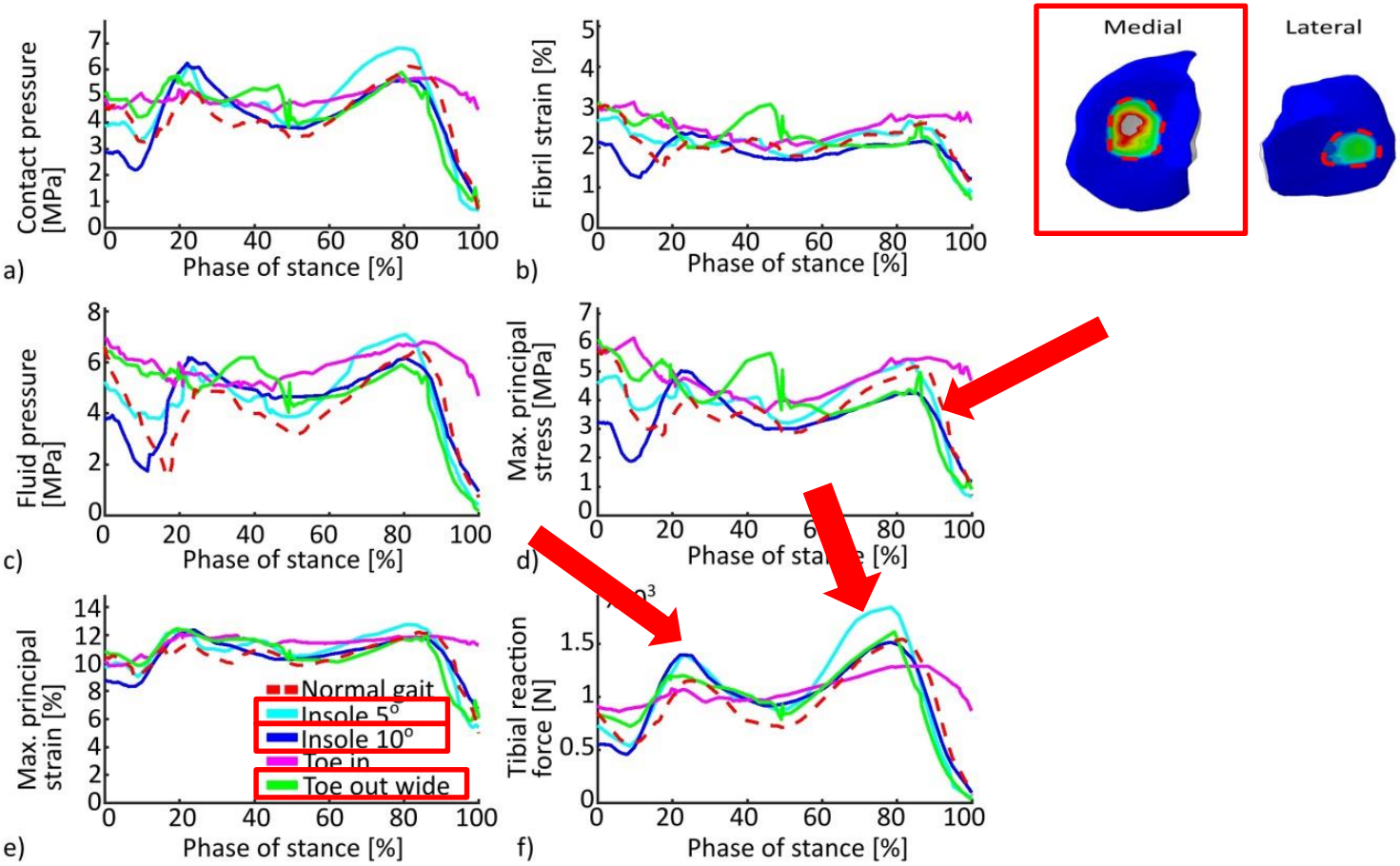


[1]Liu et al. 2010

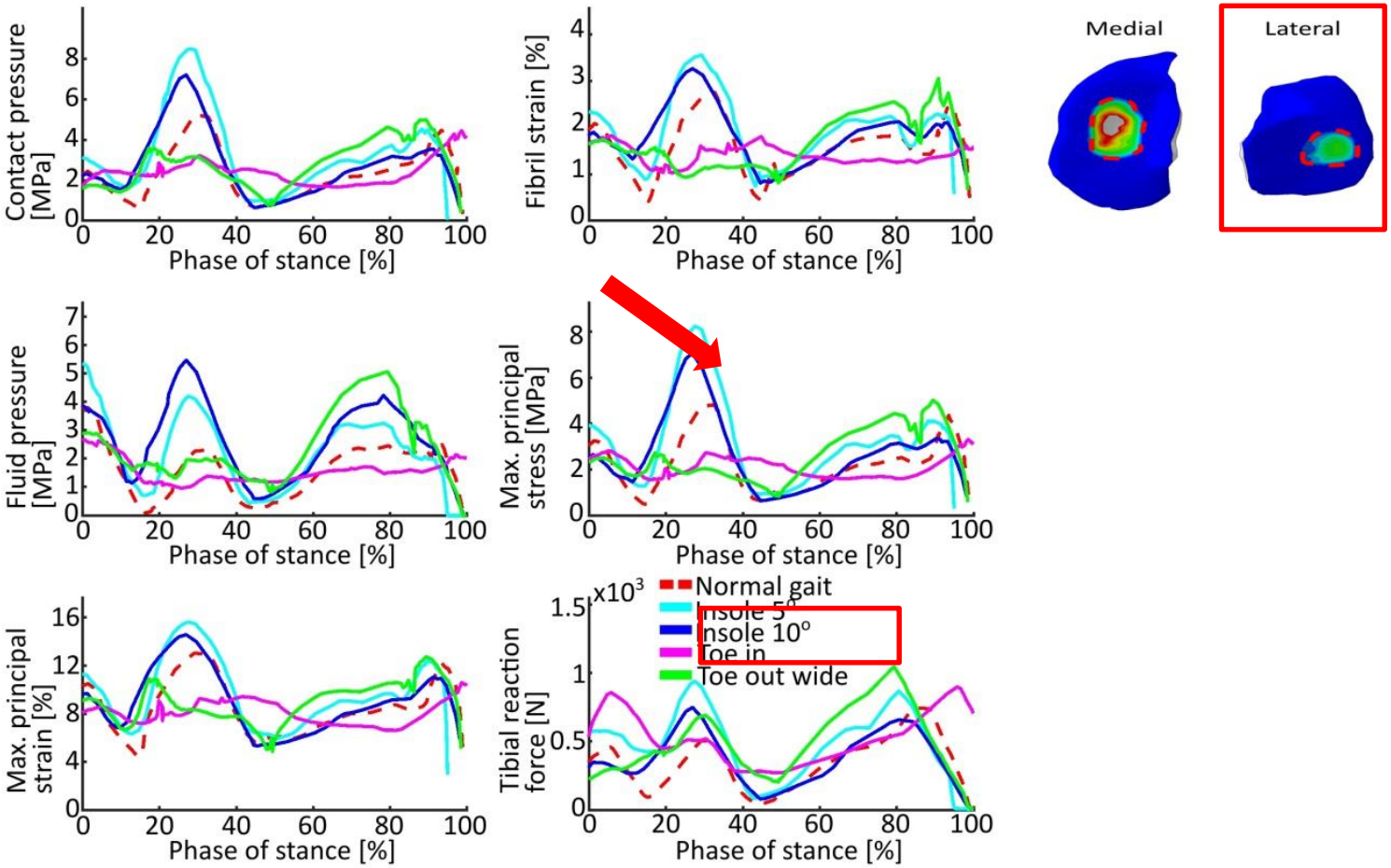
Results



Tibiofemoral contact pressures during the axial peak forces.



Average contact pressures, fibril strains, fluid pressures, maximum principal stresses and strains in the **medial** tibiofemoral contact area during the stance.



Average contact pressures, fibril strains, fluid pressures, maximum principal stresses and strains in the **lateral** tibiofemoral contact area during the stance.

Conclusions

- This method provides a very subject-specific analysis and may help evaluate stresses in the cartilage non-invasively
- Both 5 ° and 10° insoles failed to reduce peak pressures apart from 10° at 2nd peak
- Both Toe in and Toe out wide failed to reduce peak pressures at 2nd peak

Limitations:

- Only one healthy subject. Currently, we have created models for 5 OA patients for the next step

Conclusions

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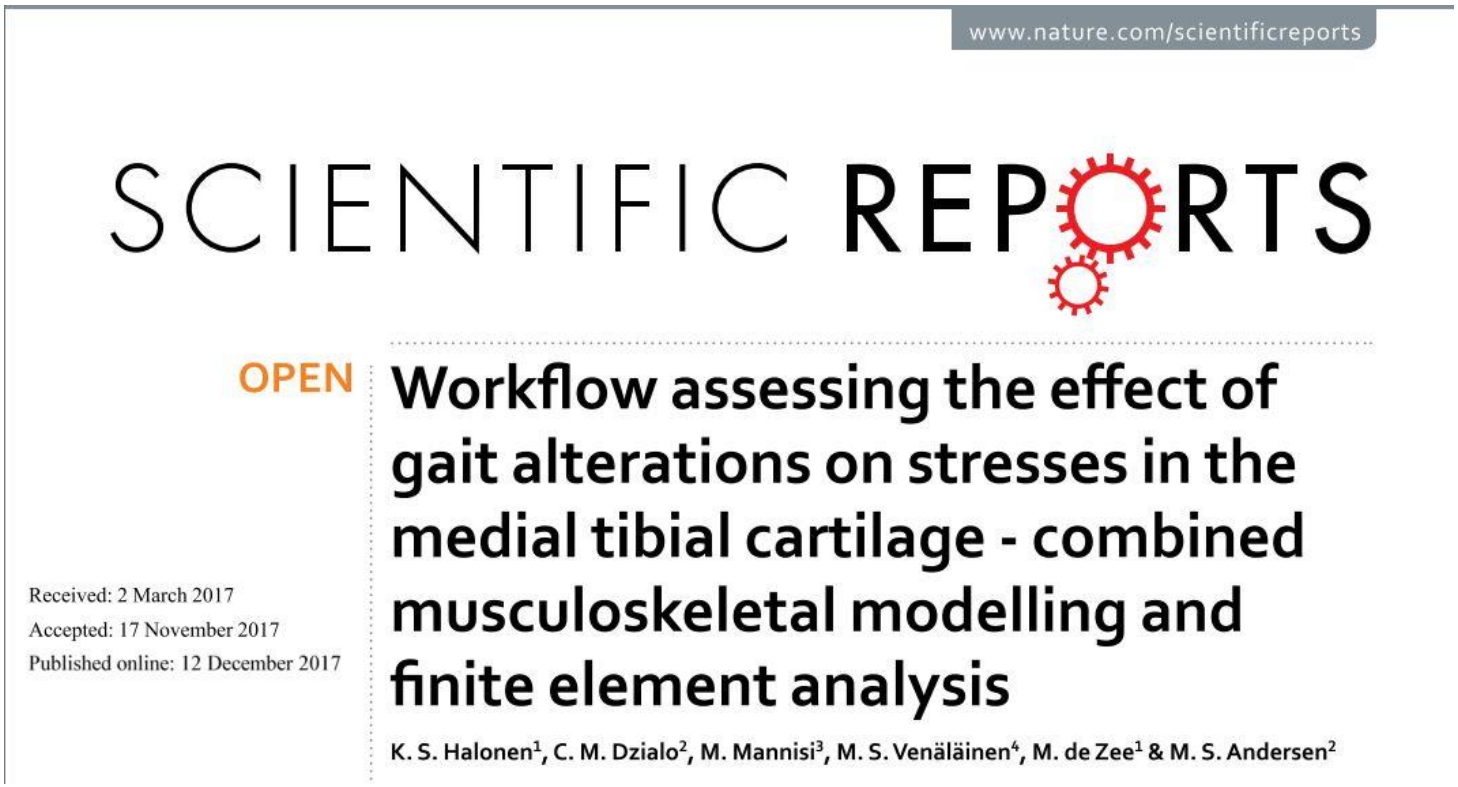
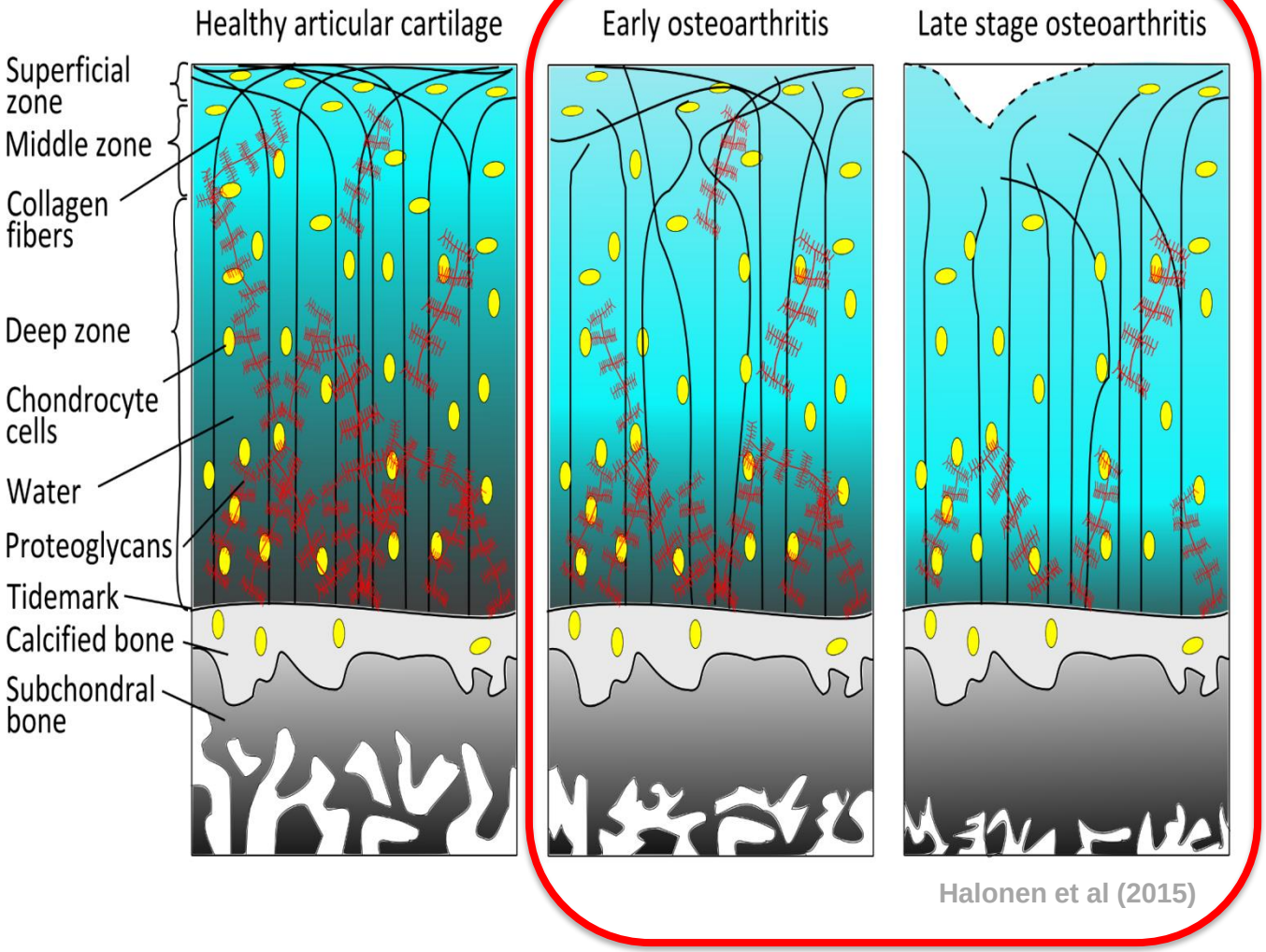
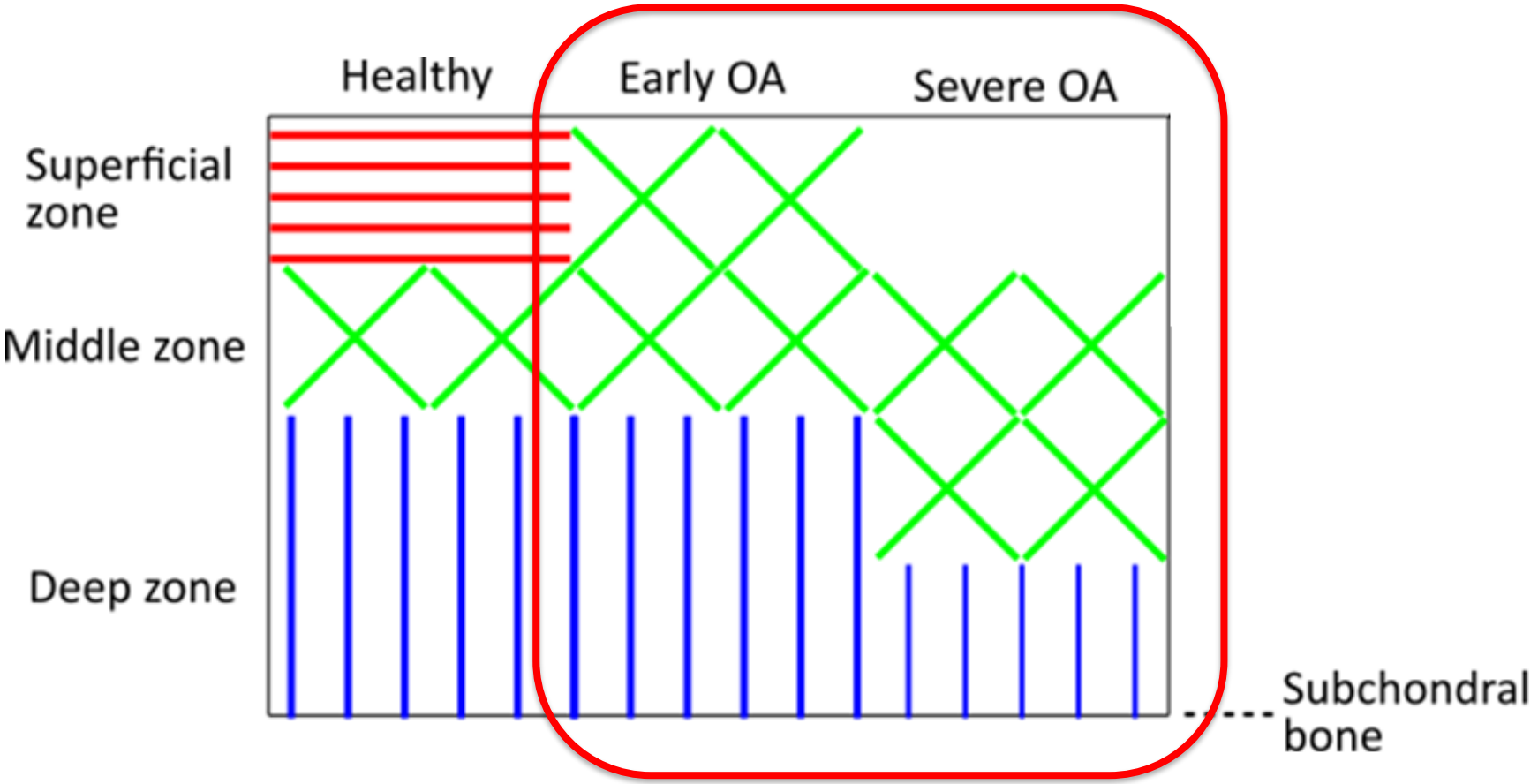


Finite element modelling – OA patients



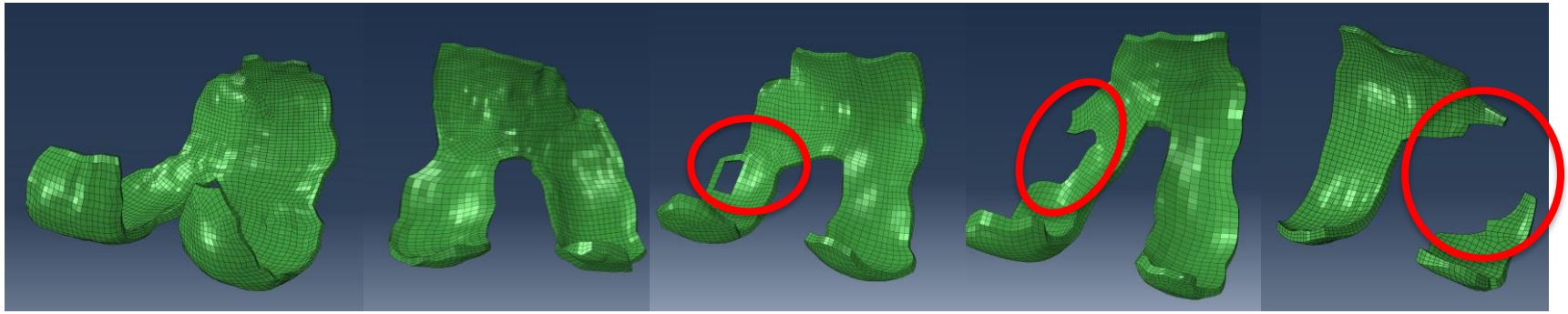
Halonen et al (2015)

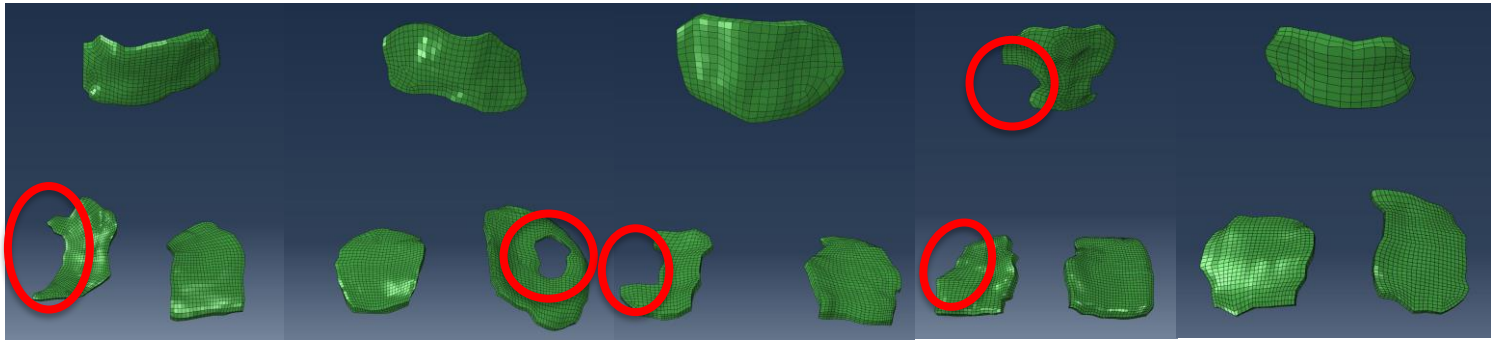
Finite element modelling – OA patients



Finite element modelling – OA patients

Patient 1 Patient 2 Patient 3 Patient 4 Patient 5

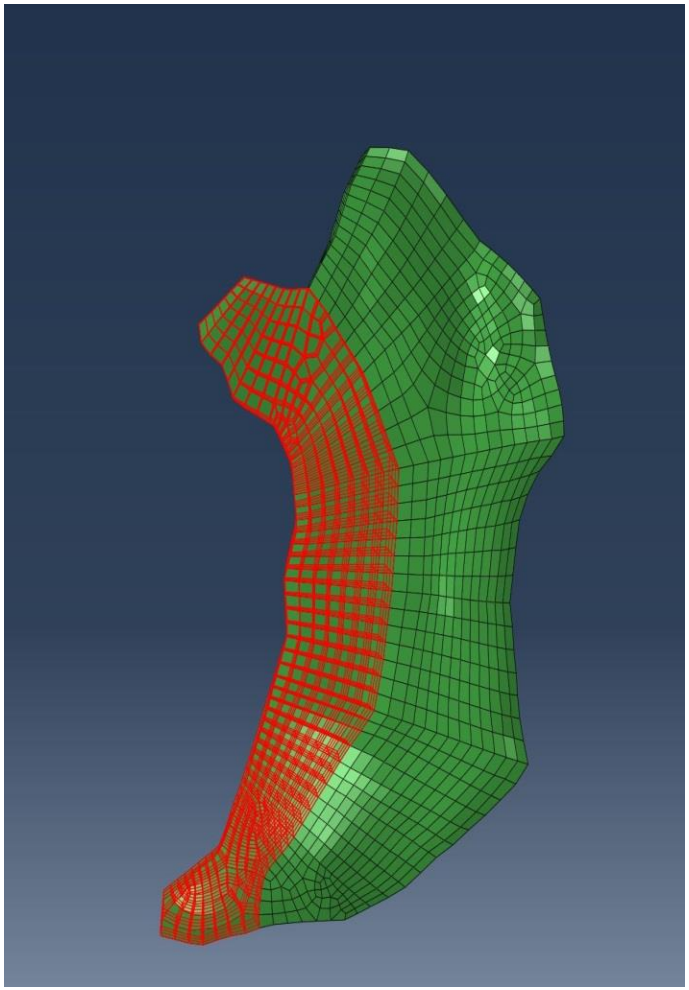




(Left knee) (Left knee)

Finite element modelling – OA patients

- Altered material properties from MRI?



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KNEEMO | Initial Training Network in Knee Osteoarthritis Research

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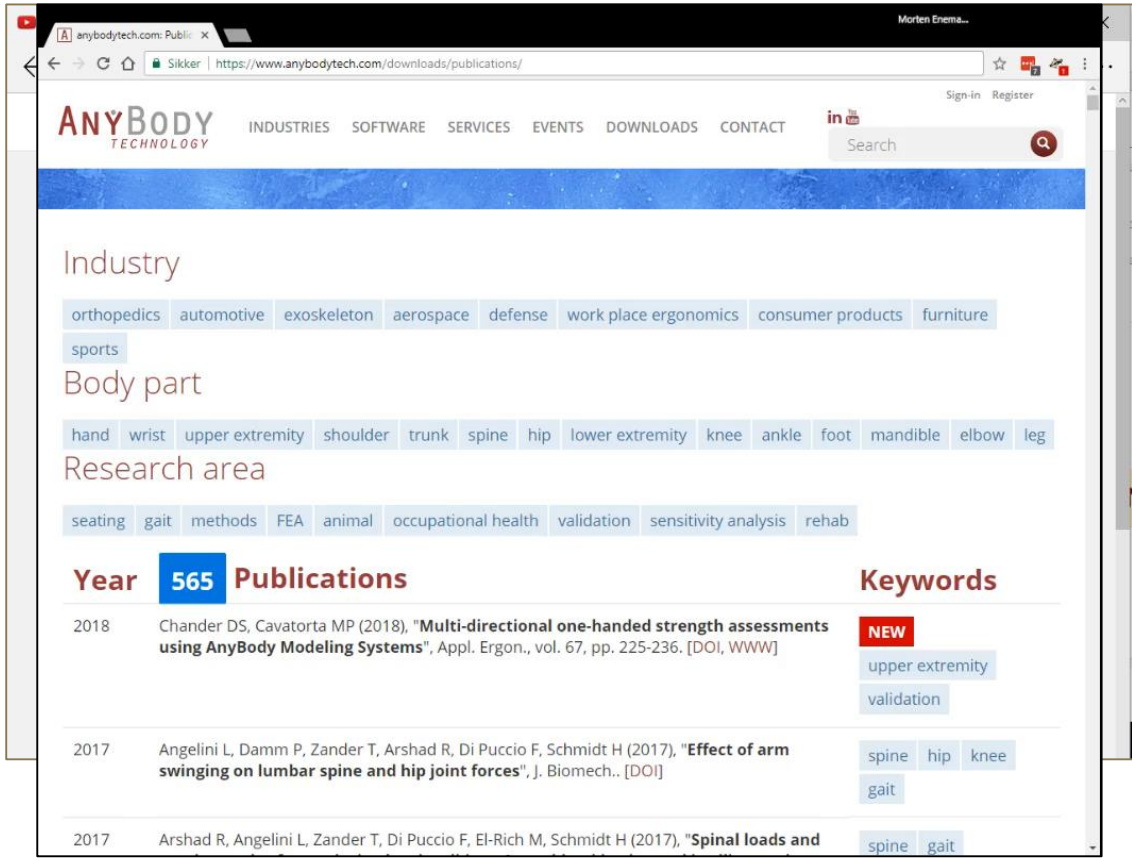
- Events, dates, publication list, ...

Events:

8-12 Jul: WCB in Dublin, Ireland. See you on booth #42 at and for our session with Xsens

We are hiring:

- Biomechanics Specialist and Simulation Core Developer



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Time for questions: