UMC St Radboud

TLEM*safe*: An integrated system to improve predictability of functional recovery of patients requiring

The webcast will start in a few minutes….

Check your audio while waiting….

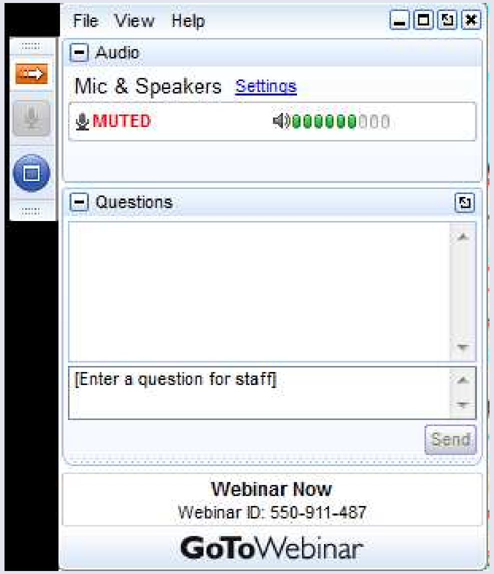
TLEMsafe

SEVENTH FRAMEWORK PROGRAMME

TLEMsafe

Agenda & Presenter

- Who and what is AnyBody? (Arne)
- What is TLEM*safe*?
- Global status of TLEM*safe*
- Q & A (submit questions any time)



Submit to Presenter, Panelist, & Host

Nico Verdonschot
(presenter)

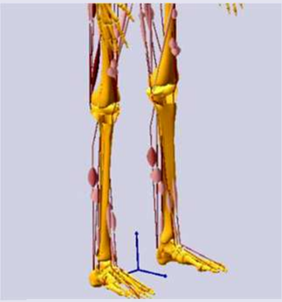
Arne Kiis
(Host/Panelist)

Michael Damsgaard,
Head of R&D, AnyBody
Technology
(Panelist)

AnyBody Technology

- Software
- Consulting
- Training
- Support
- US Office

2002

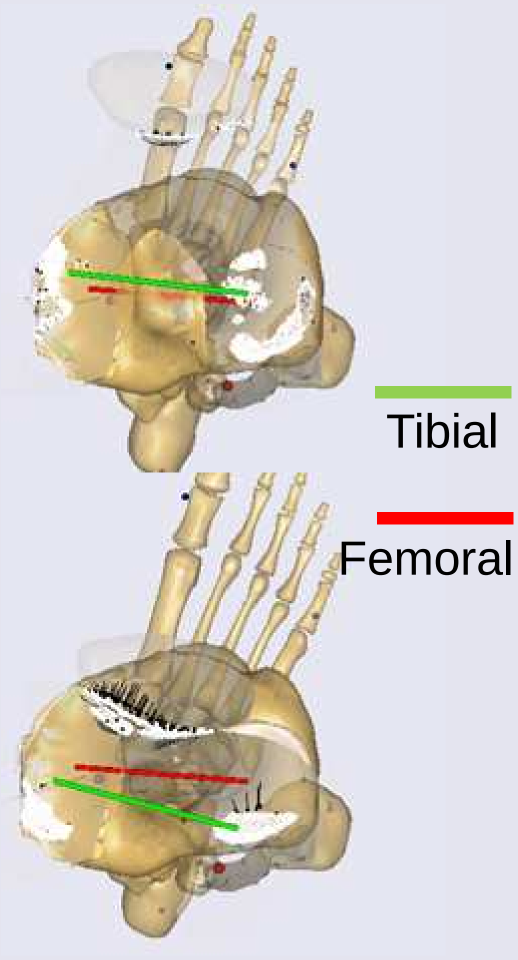


2006

2010

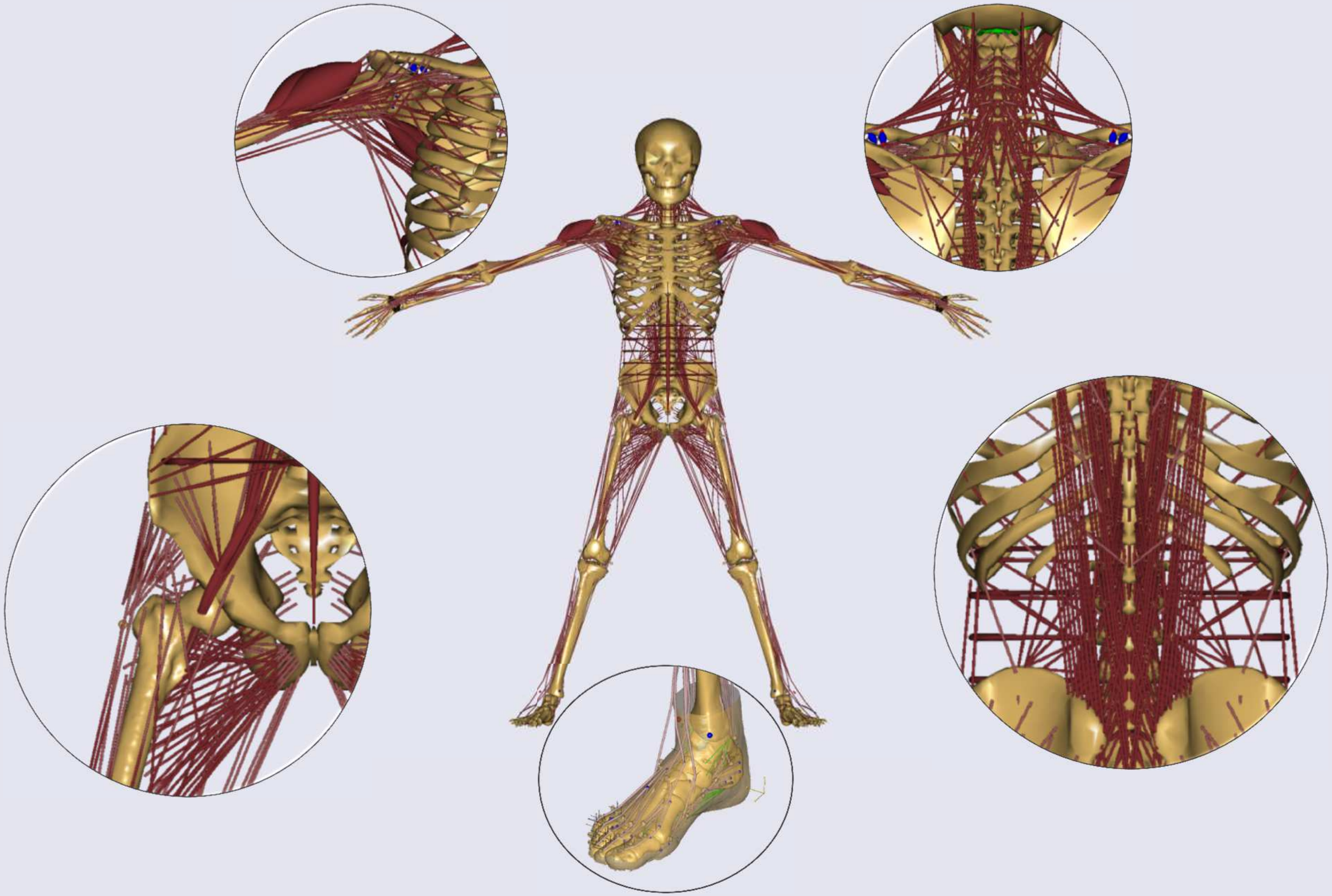
AnyBody Modeling System

- Developed in-house for musculoskeletal analysis
- Self-contained system
- Interfacing to…
  - motion capture
  - image-based bone and muscle data
  - finite-element software
  - CAD systems
  - office systems
- Open body model
- Broad and deep model validation
- GUI + batch mode for skilled users
- API for imbedded use

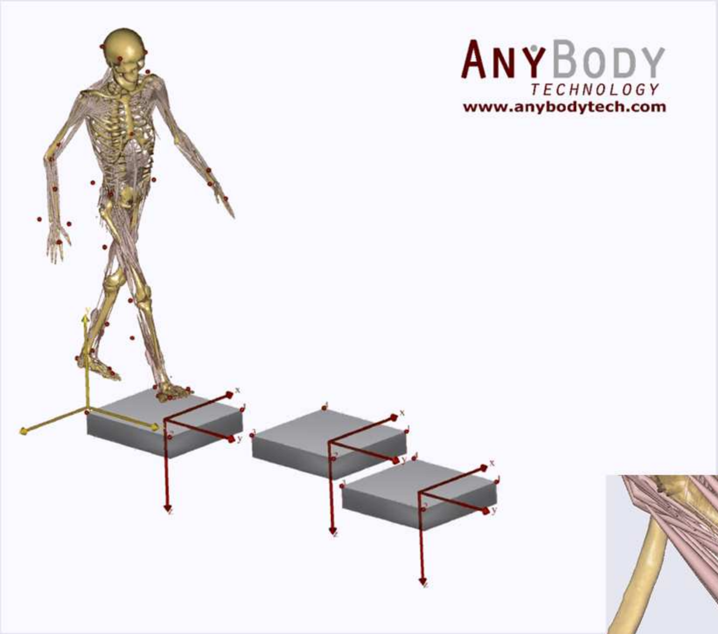


ANYBODY TECHNOLOGY

Model Repository



AnyBody Modeling System



TLEM*safe*: An integrated system to improve predictability of functional recovery of patients requiring musculoskeletal surgery

N Verdonschot (1,2), HFJM. Koopman (1), V Weerdesteyn (2), R Wirix-Speetjens (3), S Tørholm (4) R Sitnik (5), T Feilkas (6), MM. van der Krogt (1)

(1) University of Twente, The Netherlands;
(2) Radboud University Nijmegen Medical Centre, The Netherlands;
(3) Materialise NV, Belgium;
(4) AnyBody Technology A/S, Denmark
(5) Warsaw University of Technology, Poland;
(6) Brainlab, Germany

www.TLEMsafe.eu

Optimizing complex musculo-skeletal surgery using patient-specific models coupled to a navigation system

[TLEM*safe*]; Twente Lower Extremity Model

Part.no. *	Participant organisation name	Part. short name	Country
1	University of Twente	UT	NL
2	Radboud Nijmegen Medical Centre	RUNMC	NL
3	BrainLab A.G.	BRA	DE
4	Anybody Technology A/S	ABT	DK
5	Materialise	MAT	BE
6	University of Warchau	WUT	PL

The TLEMsafe team

Casus – MRI scan

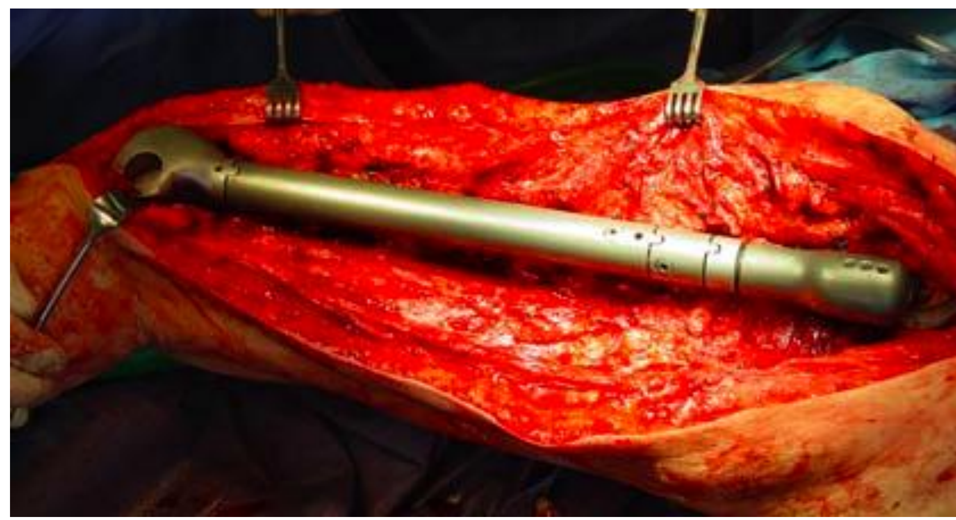
16 year female
Painful right knee

AP-view

lateral view

Surgical options: resection of the tumor

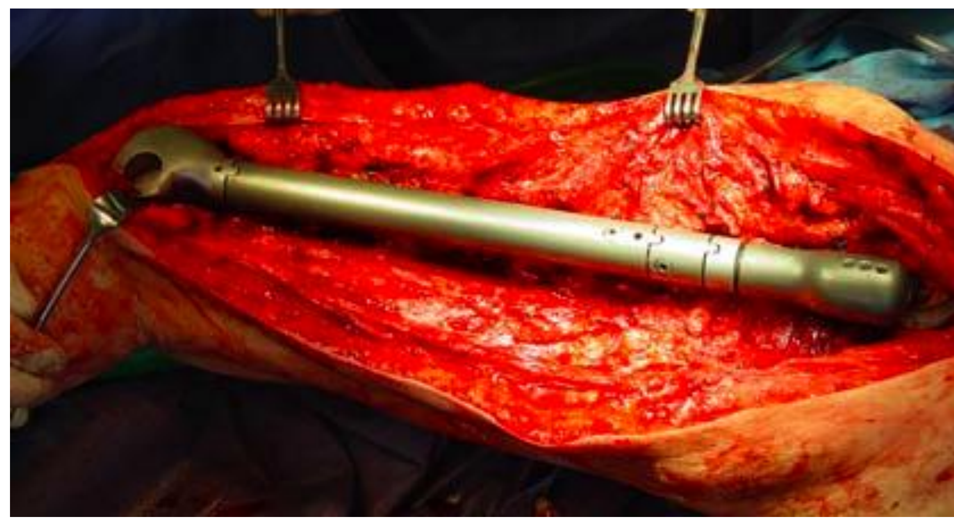
Removal of bone and soft (muscle) tissue



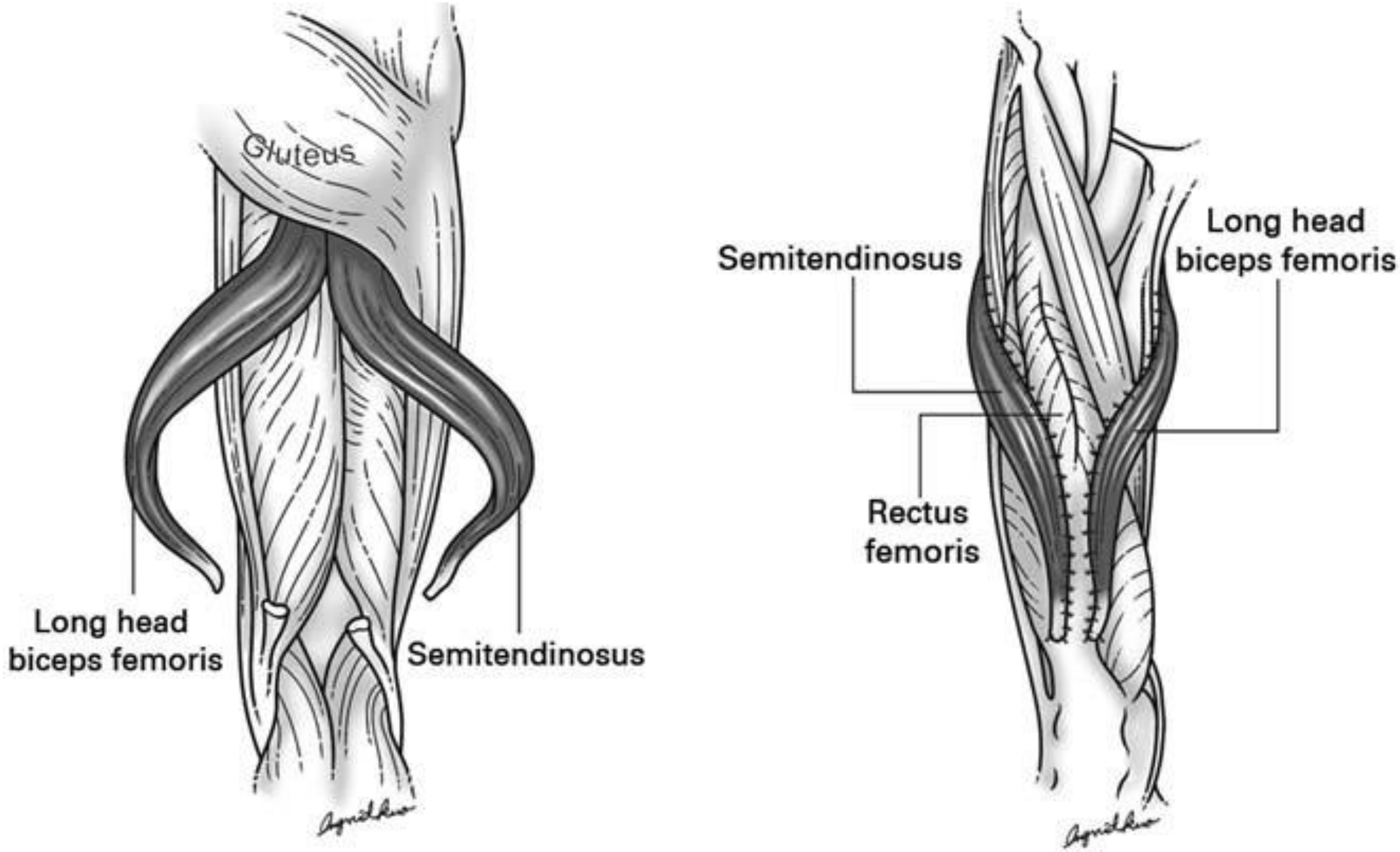
Surgical options: resection of the tumor

Will the patient be able to walk or has the patient more benefit from an amputation?

Can muscles be transposed to improve function ?



Transfer of the biceps femoris tendon



Posterior

Anterior

Lo SJ, Yeo M, Puhaindran M, Hsu CC, Wei FC.
A reappraisal of functional reconstruction of extension of the knee following quadriceps resection or loss.
J Bone Joint Surg Br. 2012 Aug;94(8):1016-23.

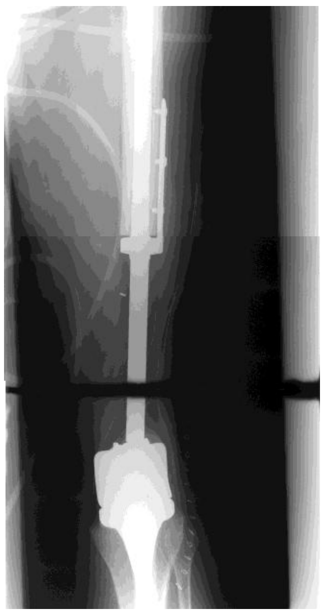
Send in questions for this webcast any time!

RUNMC | Materialise | UT Anybody | WUT | Brainlab | RUNMC

Geometrical and Functional Patient data

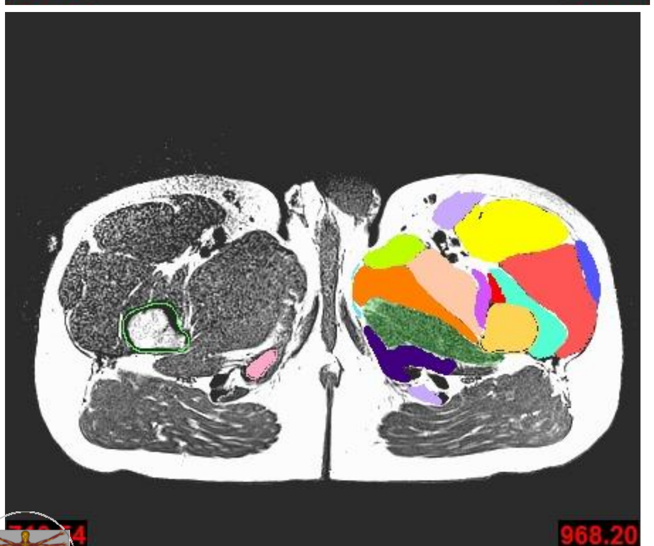
Personalized Advice of Effects of Surgery

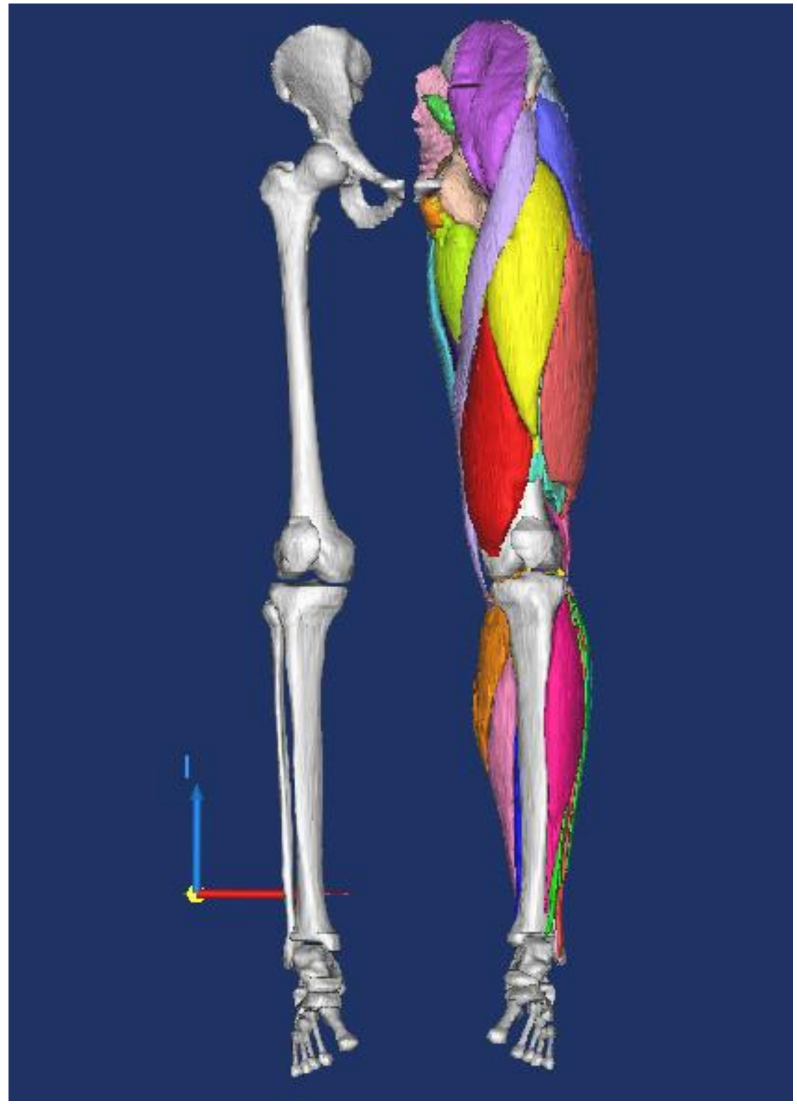
Surgical Navigation System



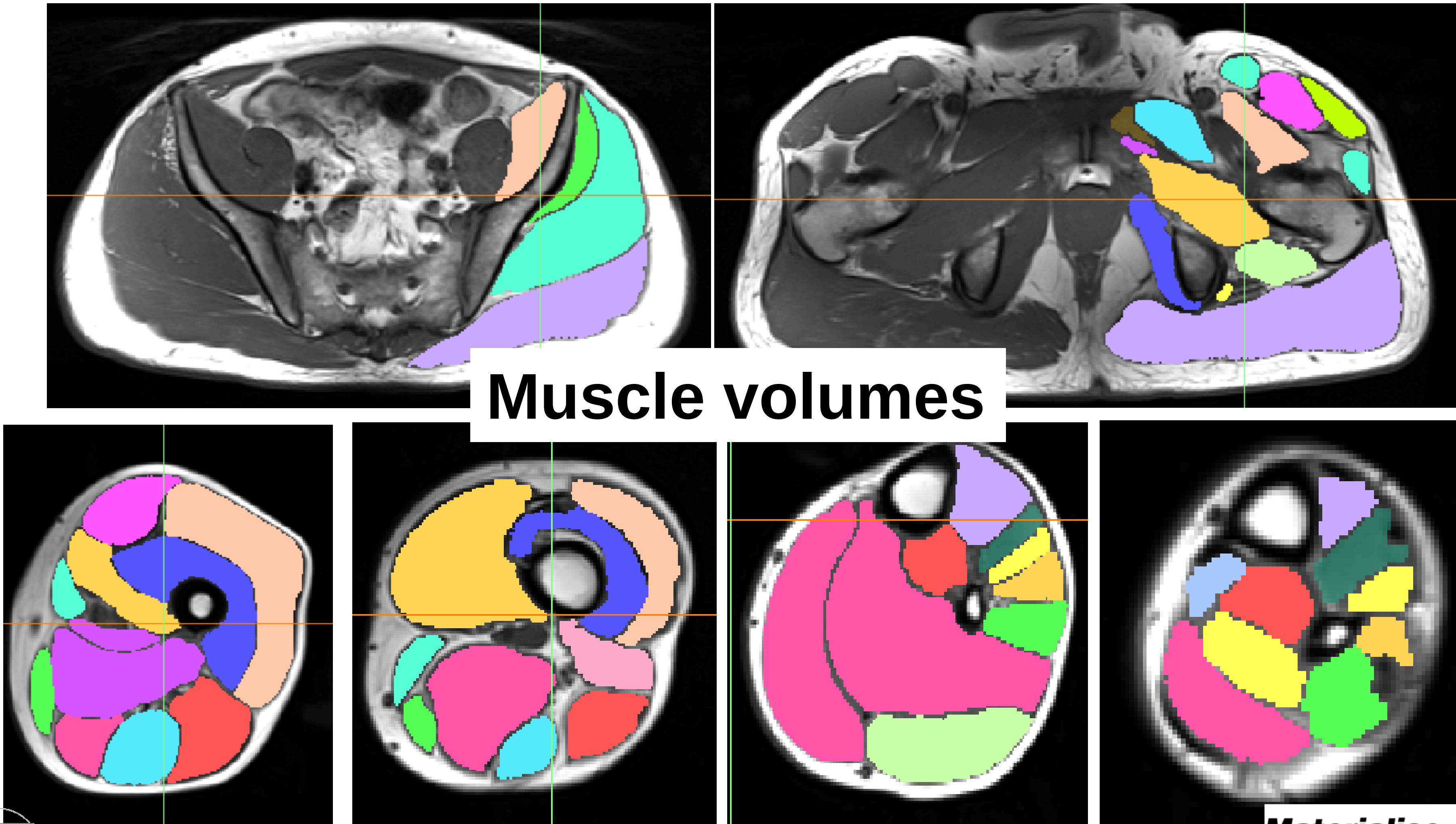
Predict Function; Optimal Functionality

Making MRI-based subject specific musculoskeletal models: definition of the 'ATLAS'

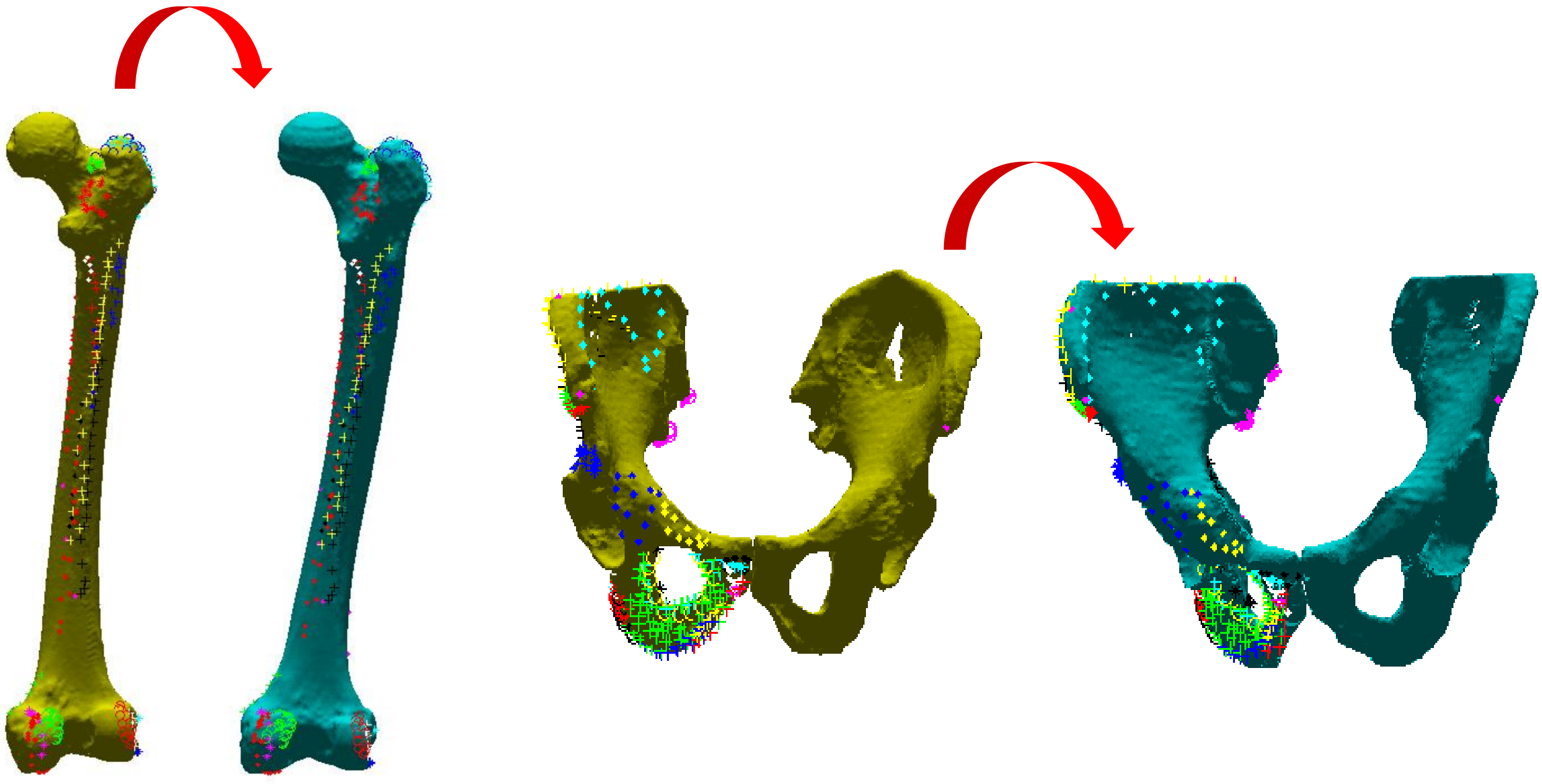




Semi-automatic muscle segmentation for muscle volumes from the ATLAS



Attachment points not visible on MRI → Personalized muscle attachment sites by bone morphing



- **Goal: Develop extensive consistent anatomical data set which can easily be ‘morphed’ to a subject using medical imaging techniques**

- Original TLEM (Martijn Klein-Horsman)

  Problems
  - Bad MRI, no CT -> no bone STLs
  - Formalin preserved body (+- 6 months measurements)

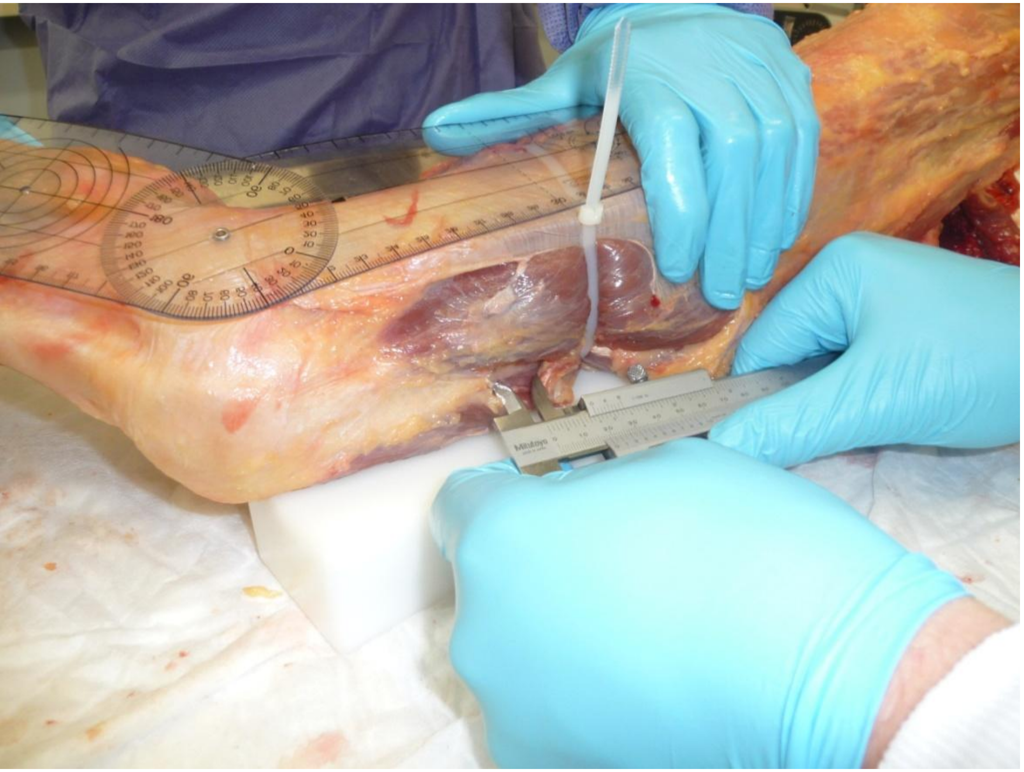
- TLEM*safe* cadaver
  - New anatomical sets for MS geometry
  - Use ‘Original’ TLEM MT parameters
  - MRI and CT available

  - Make an MRI before freezing

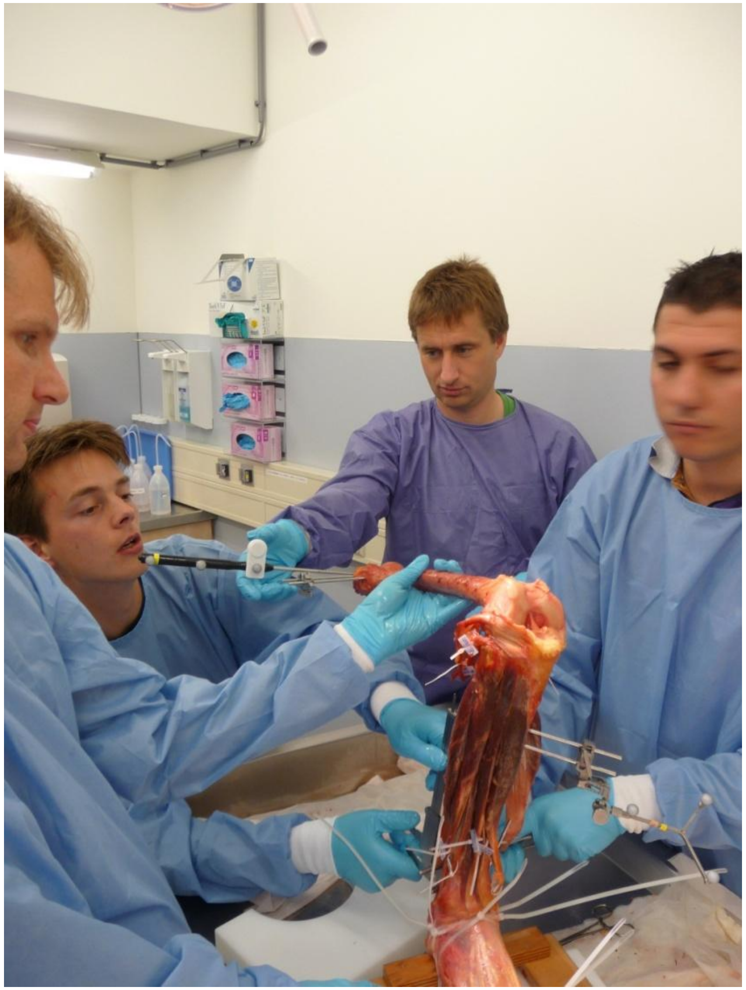
New extensive consistent anatomical data set

We measured muscle moment arms using the tendon excursion method

(An, K.N. et al., *J Biomech*, 16:419-425, 1983)



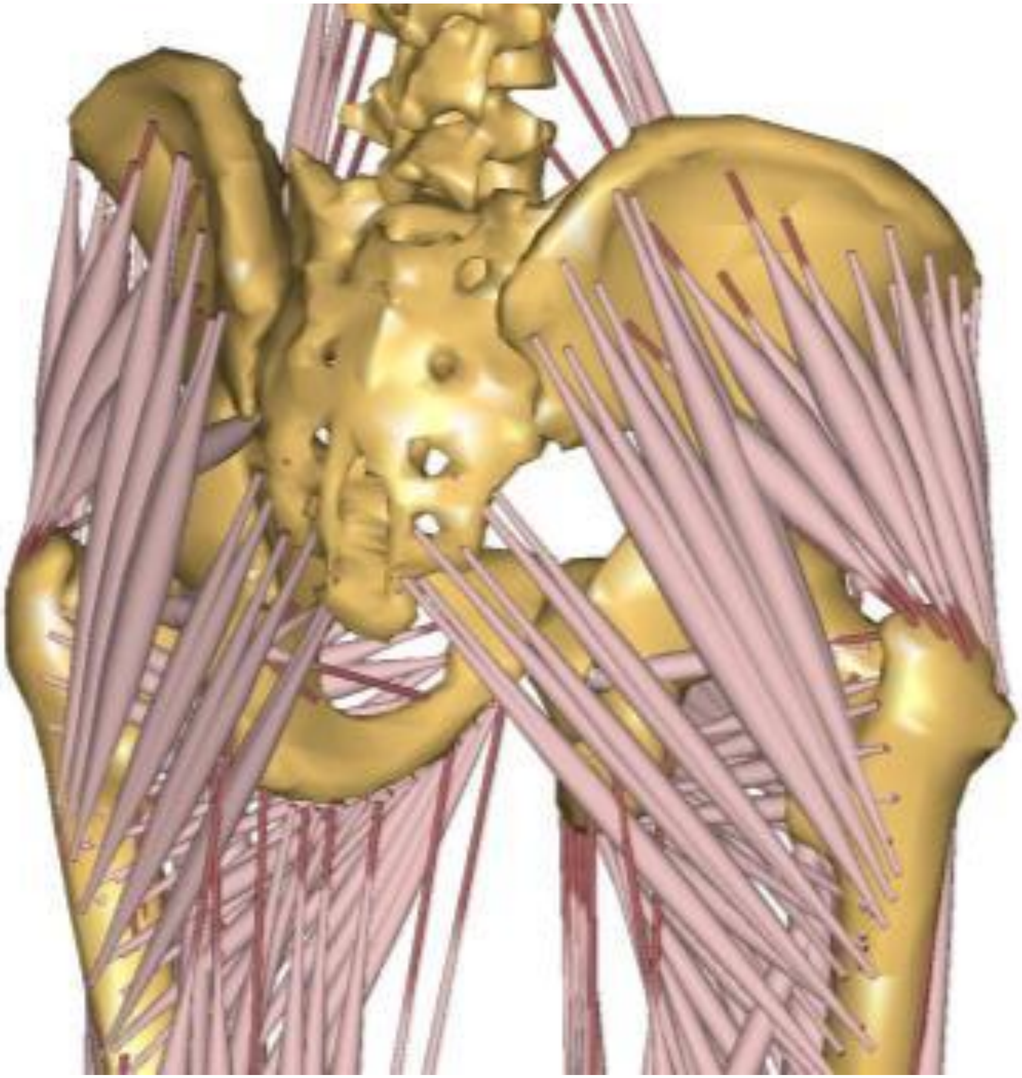
Joint centers and axes (here: knee)

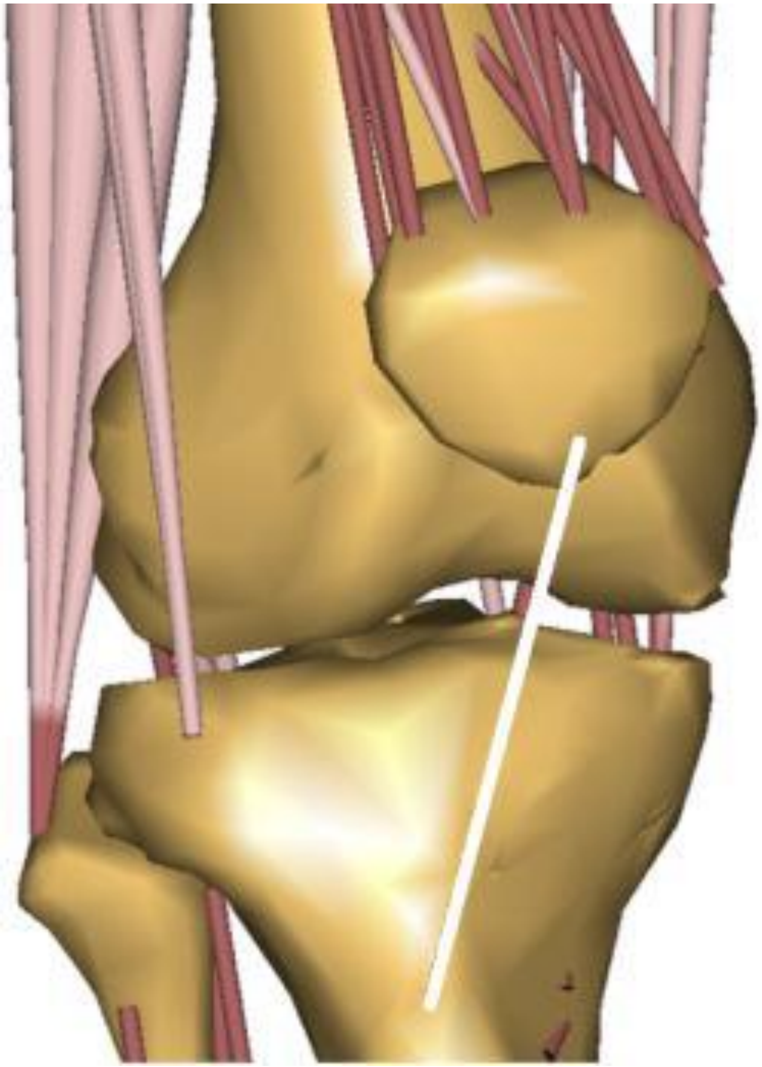


New extensive consistent anatomical data set

Muscle attachment points and volume/ mass

- Attachment points
    - Consistent set of bone geometry and muscle attachment points





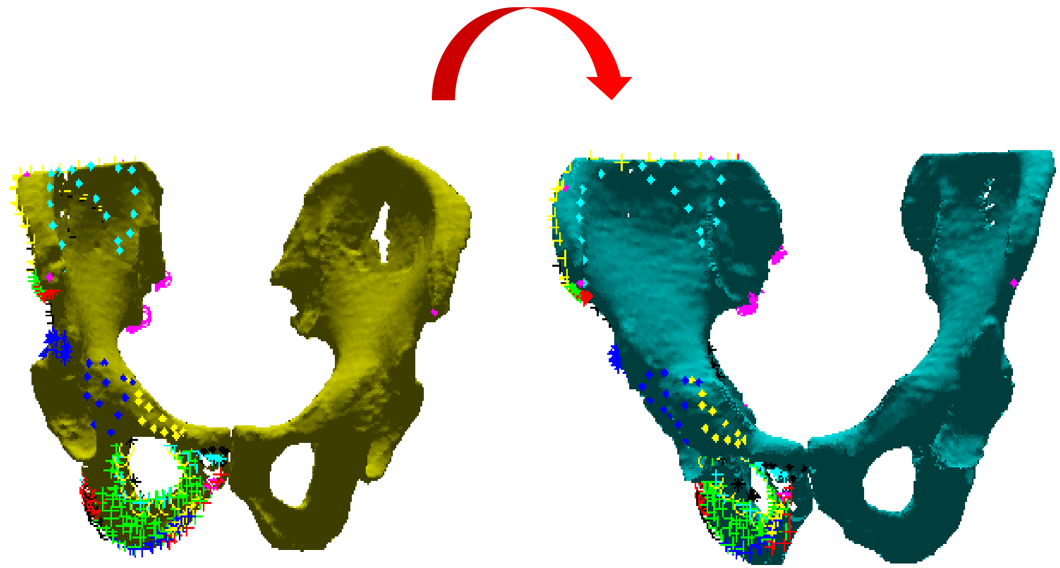
New extensive consistent anatomical data set

- Skin and muscle tissue are also segmented (from MRI)

New TLEM anatomical implemented in Anybody

Personalized muscle attachment sites by bone morphing

Determining patient specific attachment points (one cadaver to the other)



	Source	Target	Result
1	Cadaver 1 ➡	Cadaver 2	Cadaver 1* + cadaver 1 points morphed
2	Cadaver 2 ➡	Cadaver 1	Cadaver 2* + cadaver 2 points morphed

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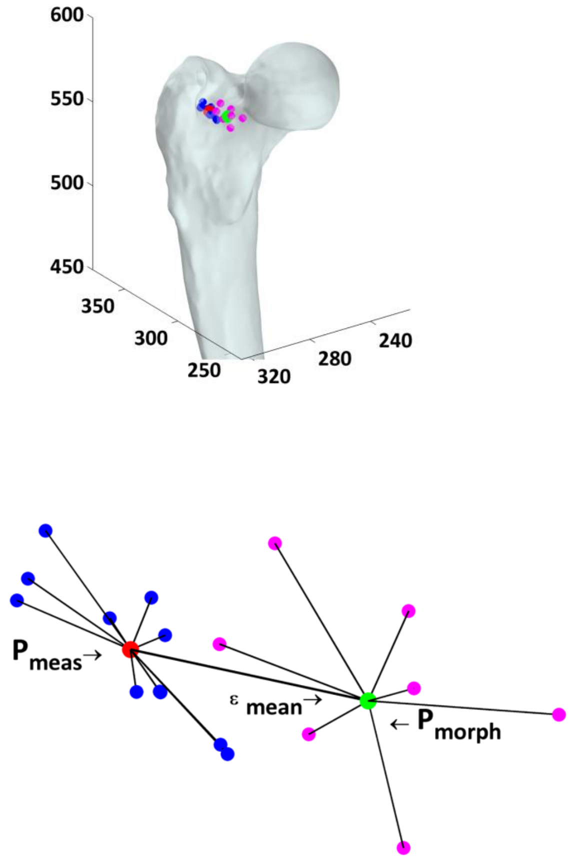
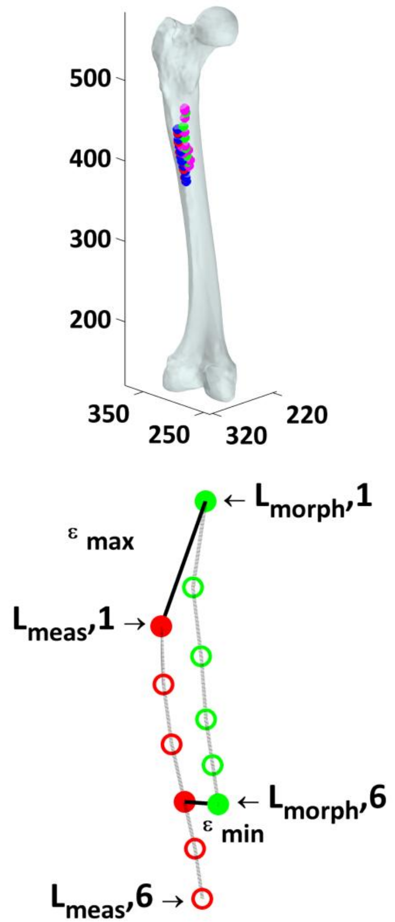
Errors of muscle attachment sites after morphing

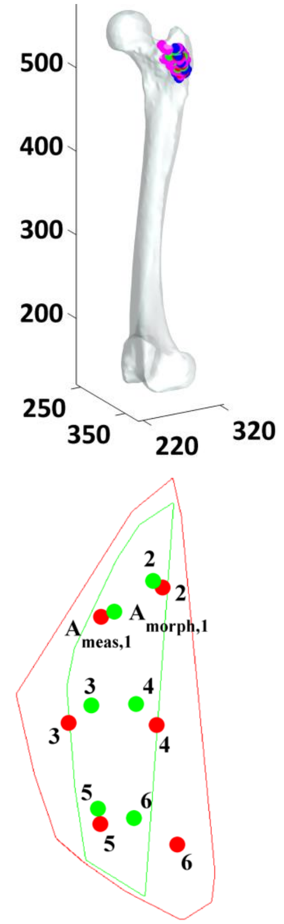
Point



Line

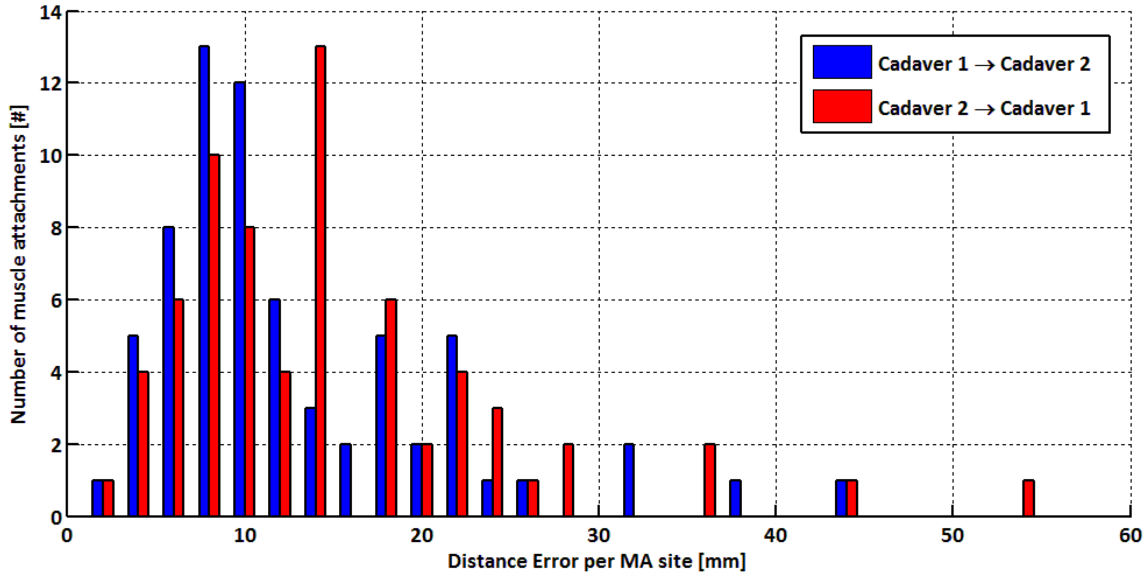


Area

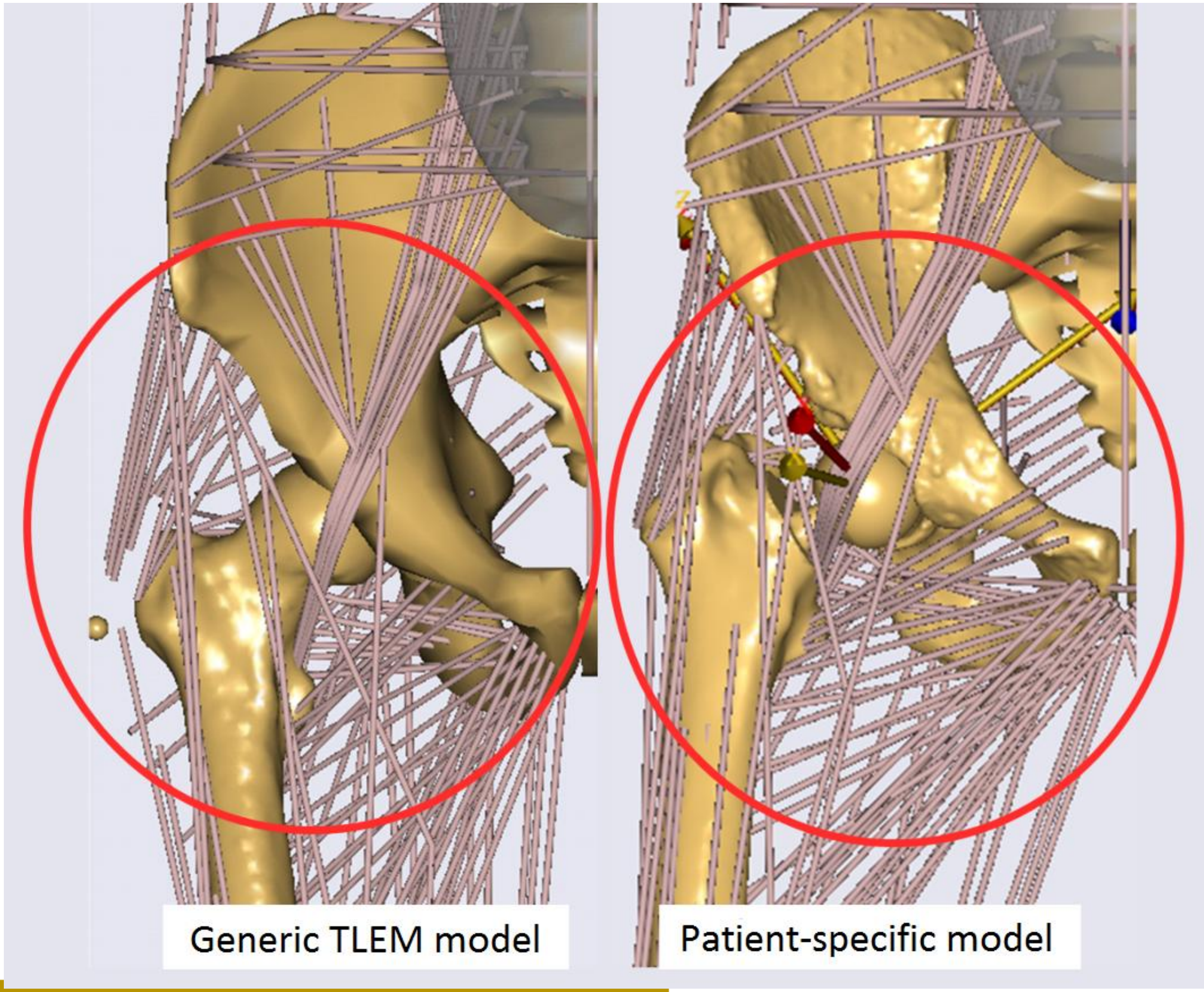


Errors of muscle attachment sites after morphing

- 68 MA sites
- 69% of the MA sites showed a small (<10mm) or medium (<15mm) distance error
- Mean distance error for all MA sites was:
  - 12.8 $\pm$ 8.3 mm for cadaver 1 morphed to cadaver 2
  - 14.7 $\pm$ 9.5 mm for cadaver 2 morphed to cadaver 1
- Smallest: pectineus insertion (line) and Obturator internus insertion (point)
- Largest: Tibialis Anterior insertion



So we are able to generate a subject specific musculoskeletal model (muscle volumes and attachment sites) … takes still a few days

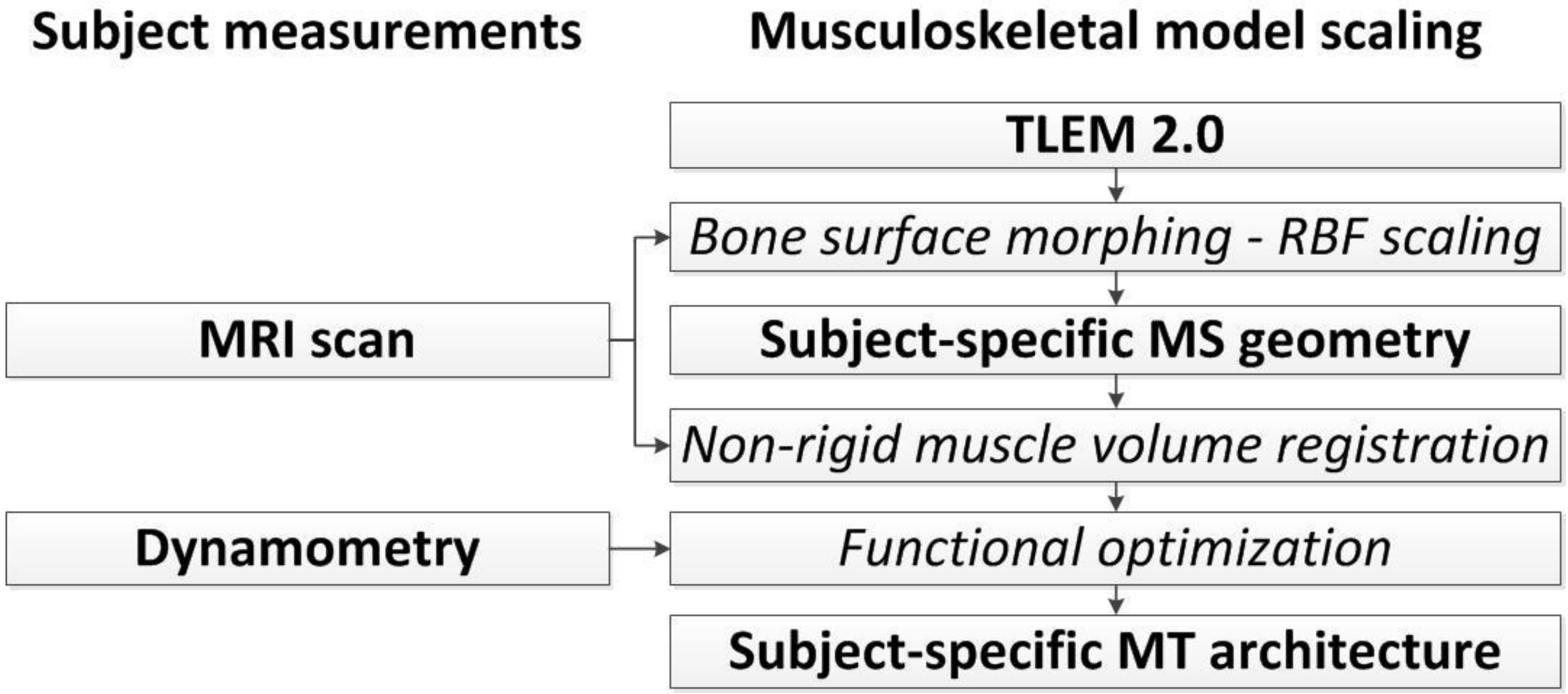


Subject specific data collected during the project

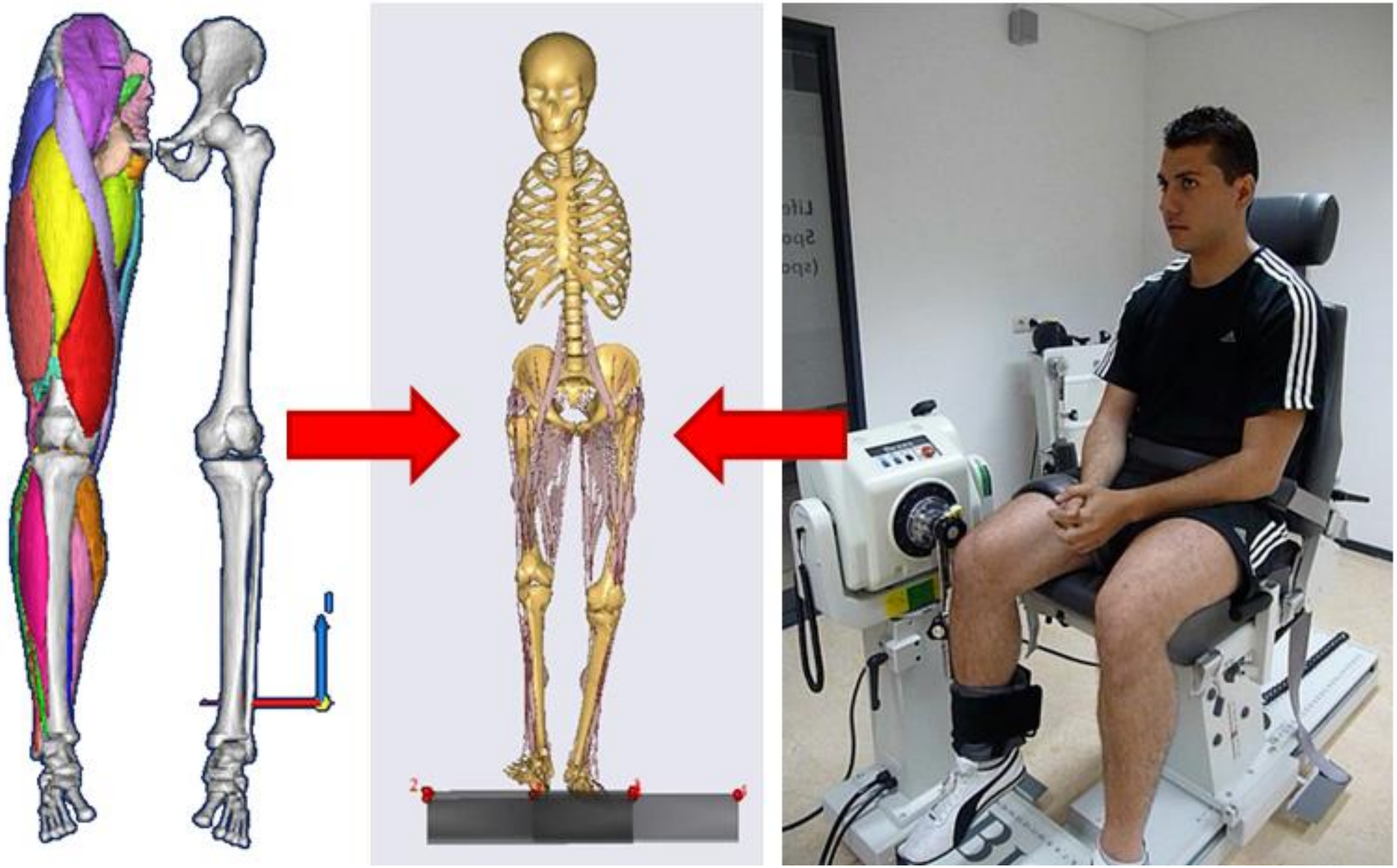
- 10 healthy subjects
  - MRI scans
  - MVC and isokinetic
  - Gait, chair, stair, squat, lunge, obstacle
  - EMG and PET-CT

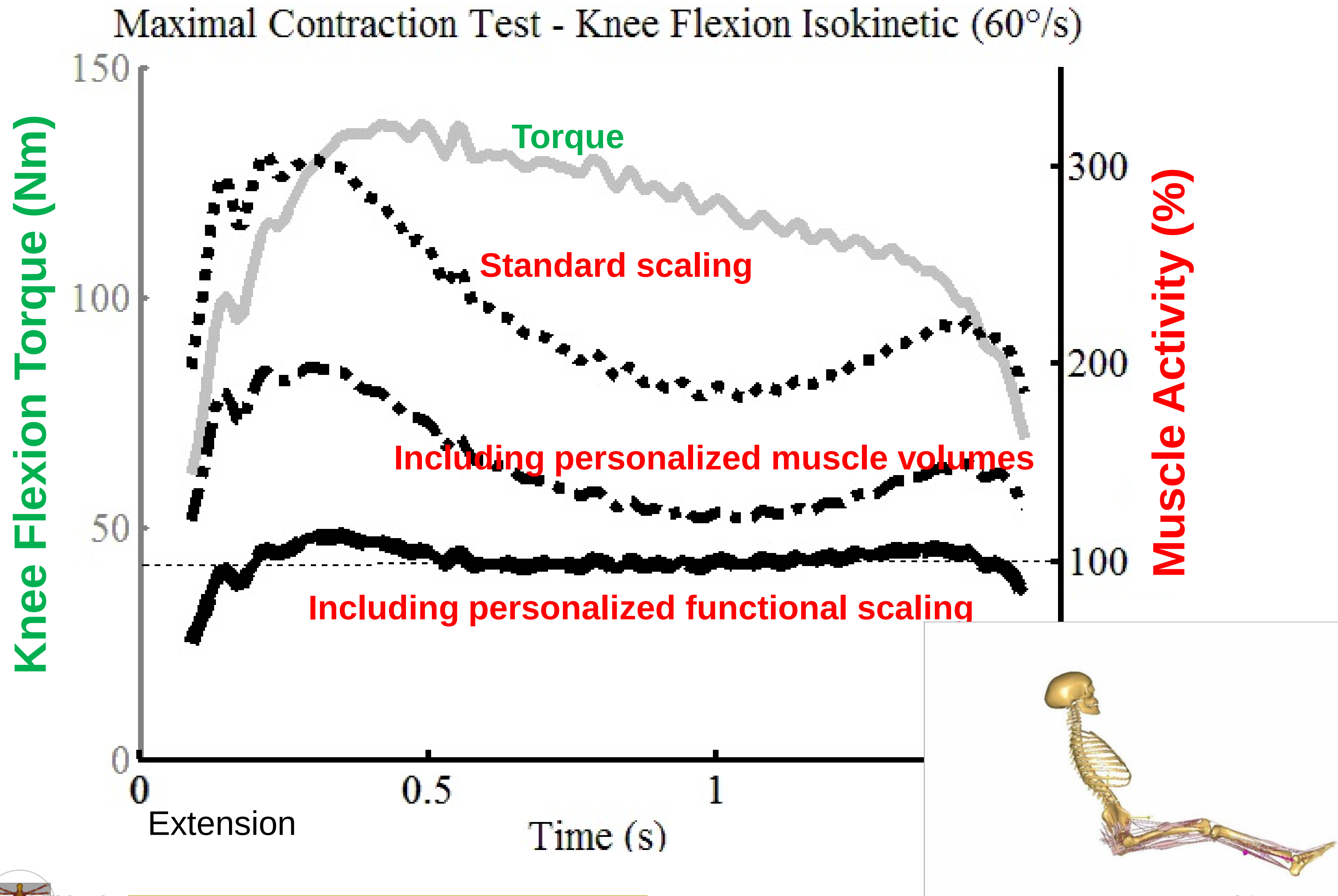
- 30 patients (pre-op and post-op)
  - 15 hip patients; 15 tumor patients
  - MRI scans (pre-op and post-op)
  - MVC and isokinetic (adapted to patient)
  - Gait, chair, stair, squat, lunge, obstacle (adapt to patient)
  - EMG

Functional effect of subject-specific modeling

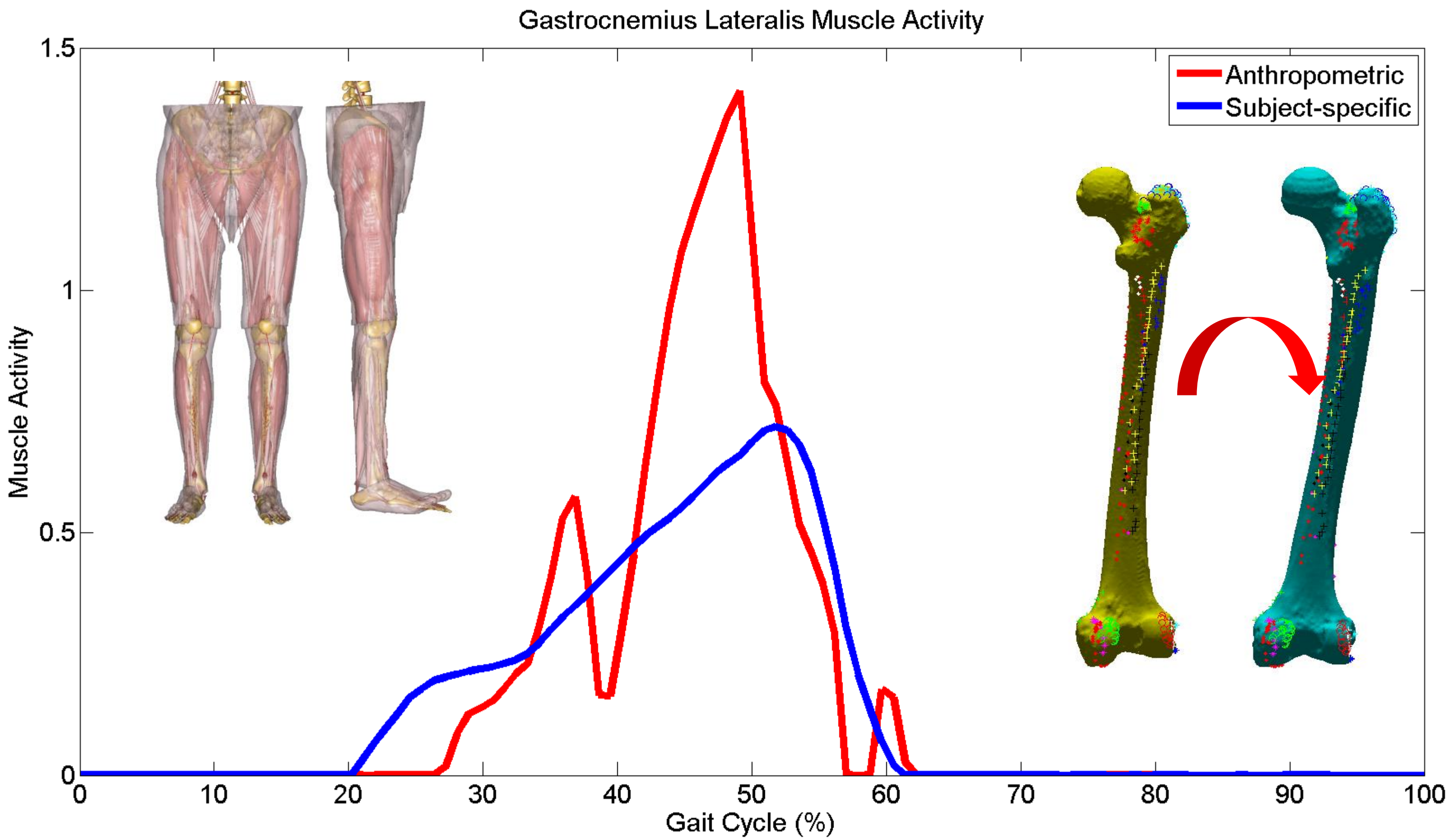


Using muscle volume and functional data in a personalized model (not muscle attachment points)




Maximal Contraction Test - Knee Flexion Isokinetic (60°/s)
Knee Flexion Torque (Nm)
150
100
50
0
Torque
Standard scaling
Including personalized muscle volumes
Including personalized functional scaling
300
200
100
Muscle Activity (%)
0
0.5
1
Extension
Time (s)

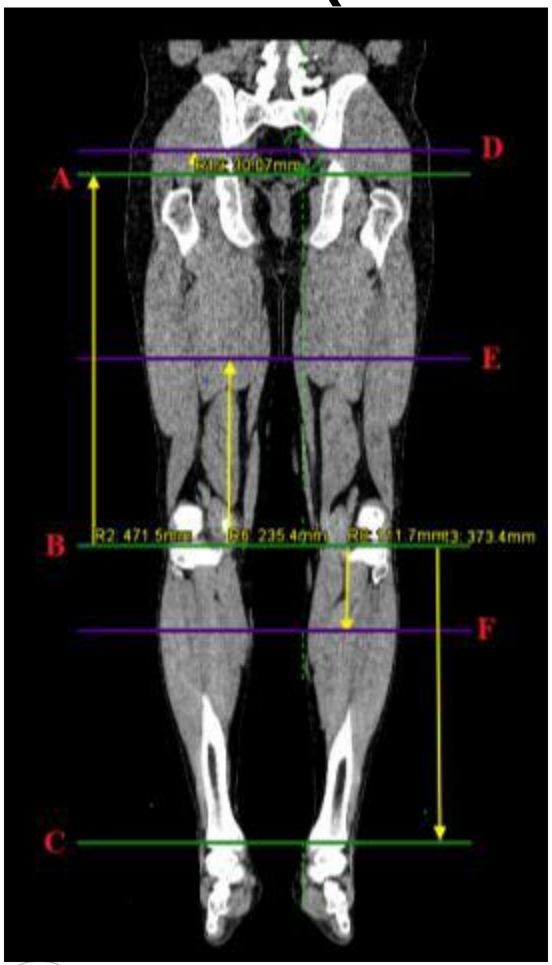
More realistic muscle activity predictions after subject-specific scaling of muscle attachment points

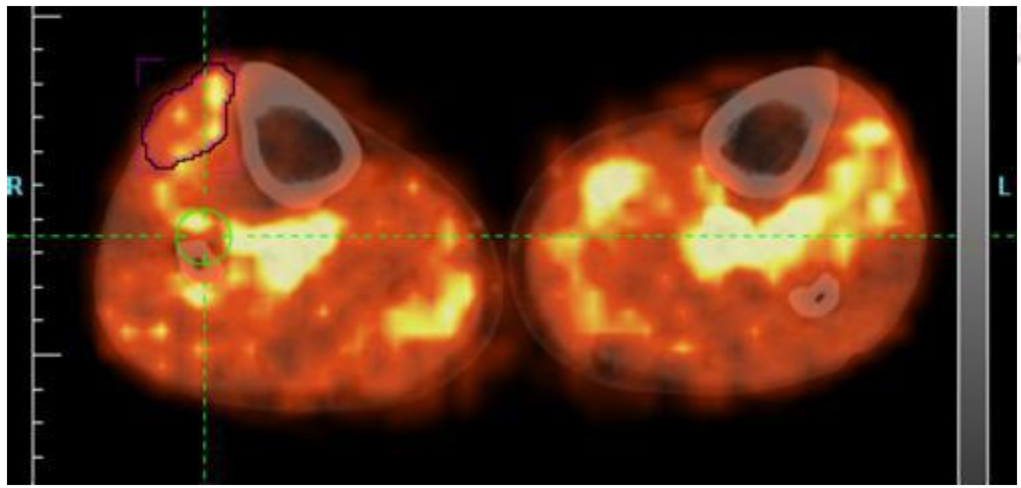


Validation and verification of activity predictions

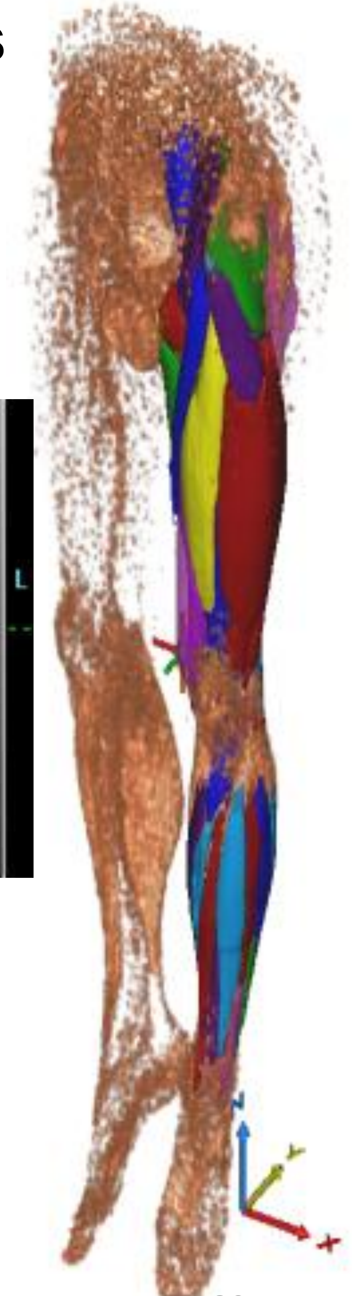
EMG

PET CT (10 healthy subjects)





Determination of energy consumption of the muscles of the lower extremity during walking using FDG-PET

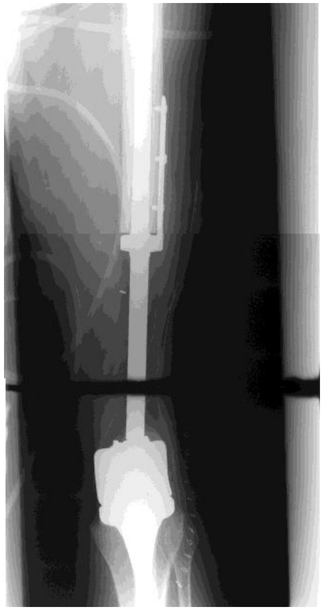


Surgeon has to be able to operate on the model

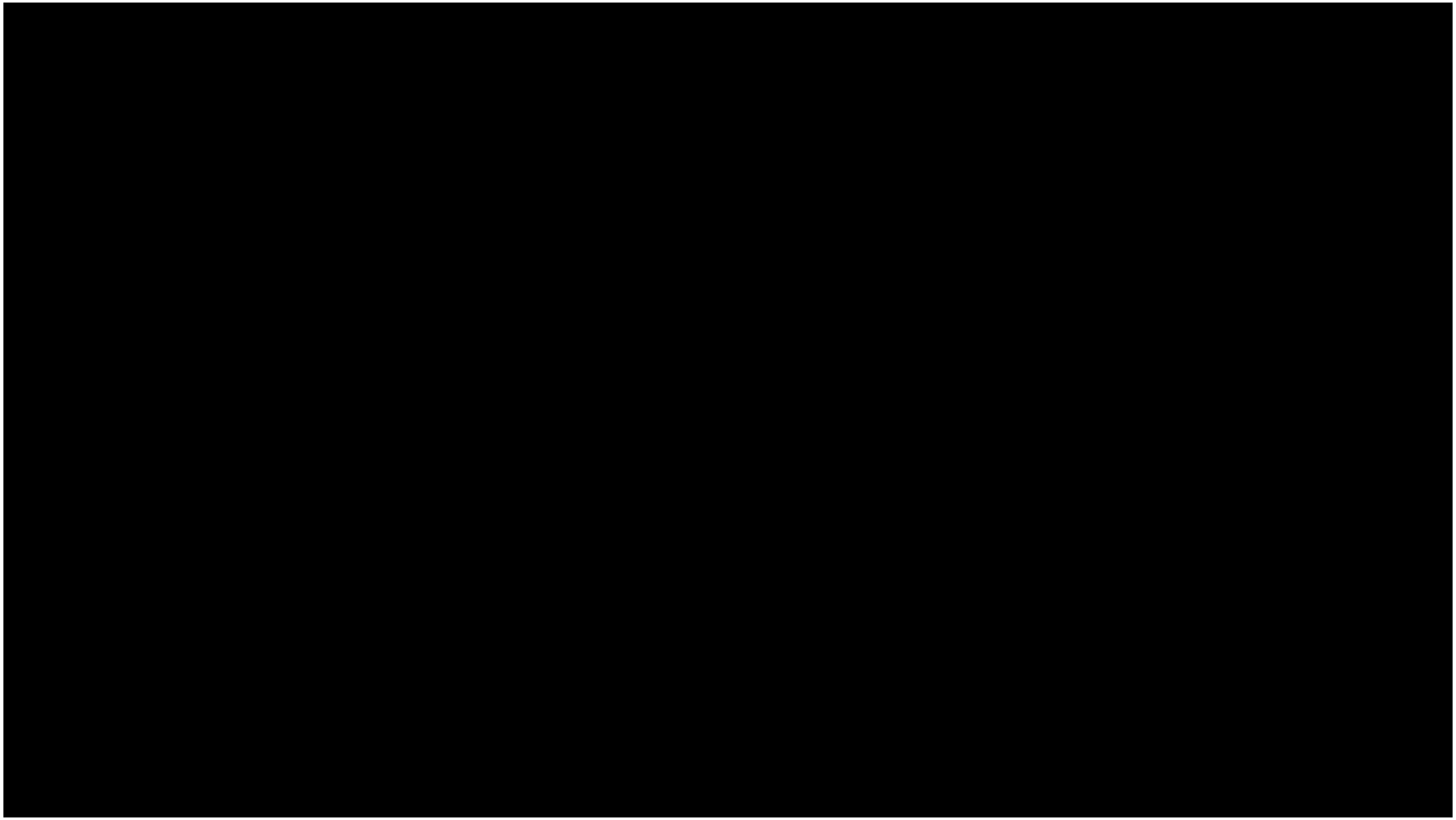
Geometrical and Functional Patient data

Personalized Advice of Effects of Surgery

Surgical Navigation System



Predict Function; Optimal Functionality

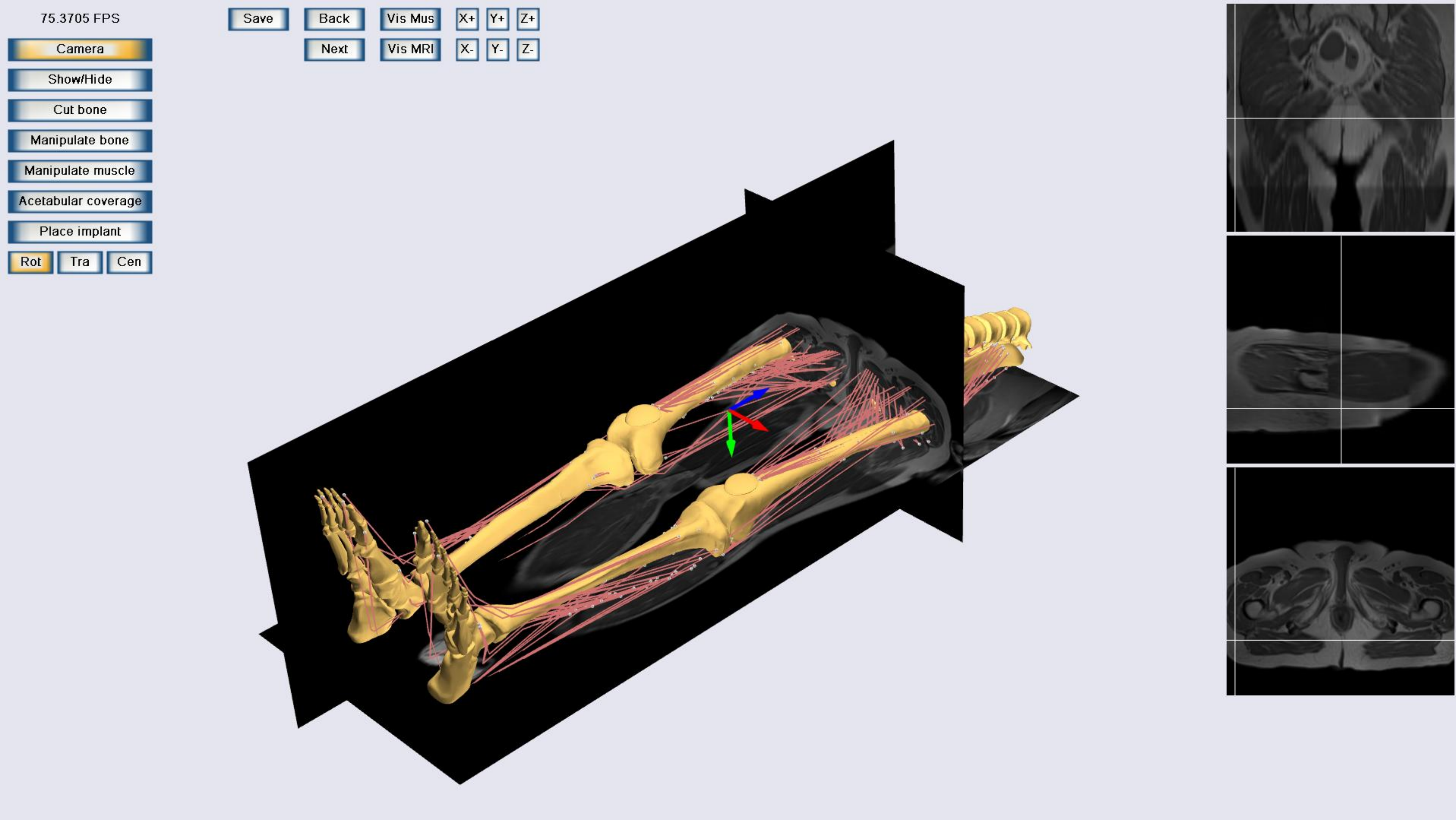


Marcin Witkowski, Robert Sitnik, Janusz Lenar

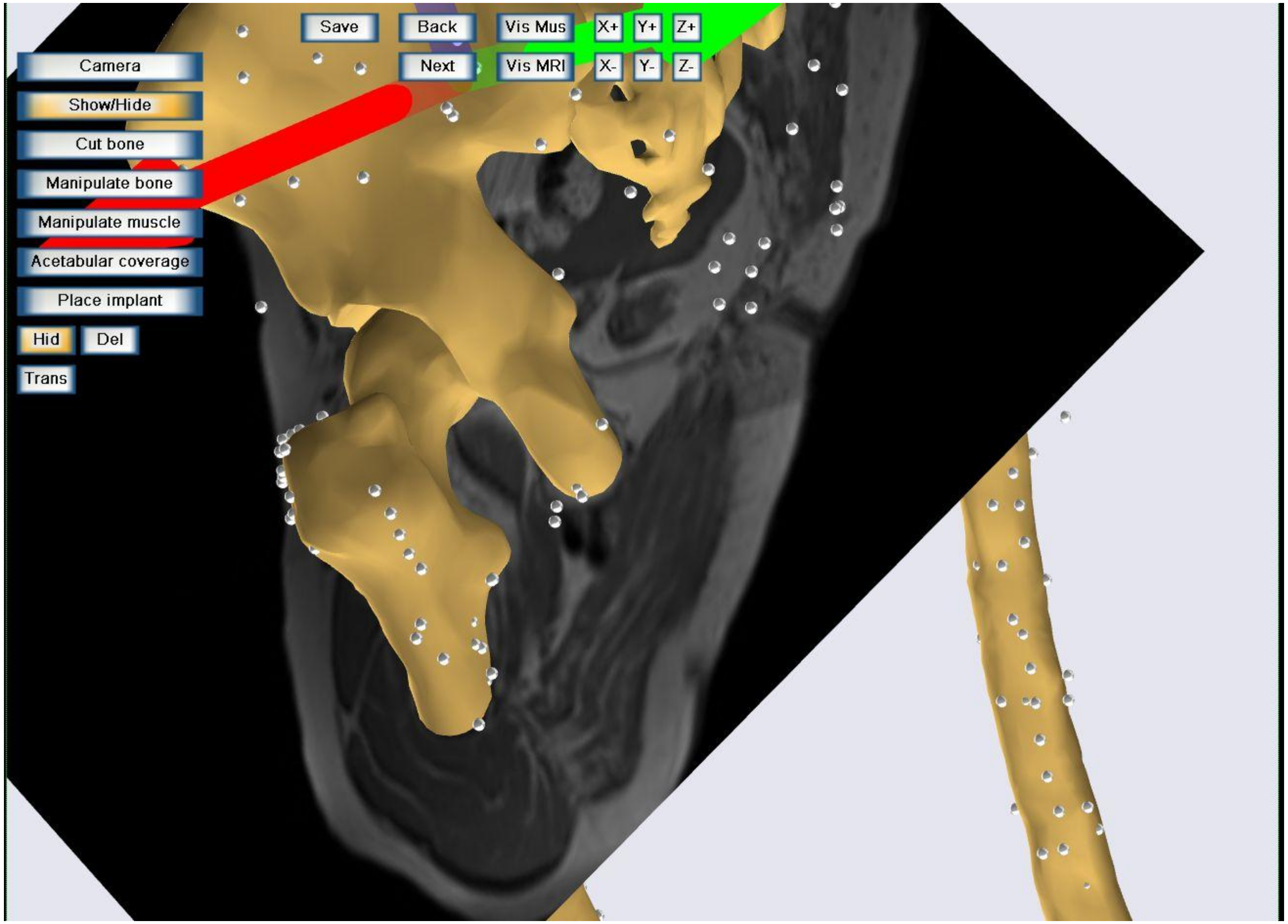
OGX|OPTOGRAPHX

Institute of Micromechanics and Photonics, Warsaw University of Technology

Fusion of MRI with Anybody



Arbitrary MRI cross-section may be directly used to plan the osteotomy

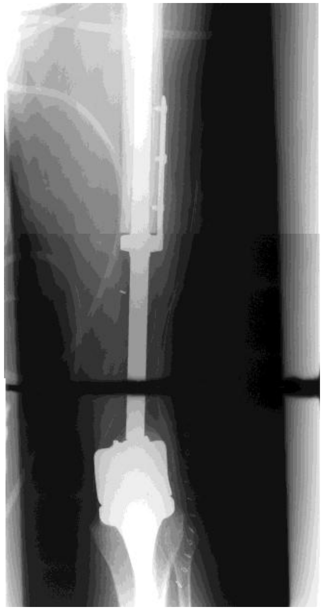


Surgeons need to understand the modeling results

Geometrical and Functional Patient data

Personalized Advice of Effects of Surgery

Surgical Navigation System



Predict Function; Optimal Functionality

Functional Outcome Evaluation Tool

Models

Healthy: Healthy person of same size as subject
PreOp: Model of subject before surgery
PostOp: Models of subject after surgery

Cases	Healthy	PreOp	PostOp1	PostOp2
Rectus femoris strength	390 N	300 N	250 N	200 N
Hip joint center position	Original	Original	Moved 1cm	Moved 1cm

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Functional Outcome App

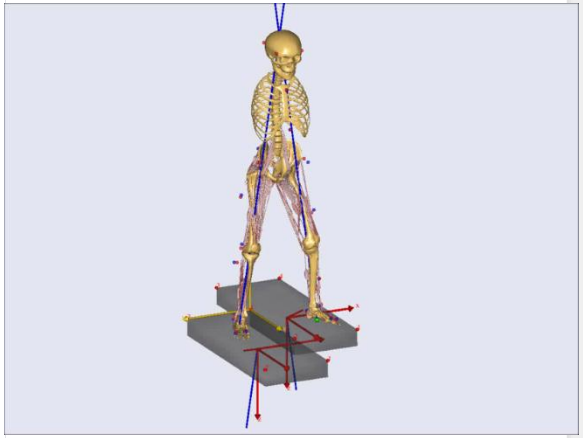
Start | Overview | Activities | Joint Strength | Muscle | AnyBody Output

PostOp Case Selection:

PostOp1

Currently displayed PostOp cases:

The description of the currently displayed PostOp cases goes here



Activity Strength Measure:

Activity	PostOp1	PostOp2
DeepKneeBend.Main	36.5%	39.3%
LGModel.Main	57.5%	60.3%

Parameterized activities

Activity Quality Measure:

Activity	PostOp1 RelHealthy	PostOp1 RelPreOp	PostOp2 RelHealthy	PostOp2 RelPreOp
DeepKneeBend.Main	104.2%	101.5%	153.4%	152.4%
LGModel.Main	102.2%	100.8%	108.8%	107.2%

Muscle Configuration Status:

DoF	MuscleGroup	PostOp1 EMMC: Rel.PreOp	PostOp1 EMMCR: Rel.PreOp	PostOp2 EMMC: Rel.PreOp	PostOp2 EMMCR: Rel.PreOp
Right.Leg.HipAbduction	RectusFemoris	3.0781%	2.8634%	1.8631%	3.4387%
Right.Leg.HipFlexion	GluteusMediusAnterior	1.0191%	2.0705%	1.9463%	3.8502%
Right.Leg.HipFlexion	GluteusMinimusMid	0.8546%	1.7443%	3.1230%	3.2603%
Right.Leg.HipFlexion	AdductorBrevis	1.0212%	2.0705%	11.6504%	8.8893%
Right.Leg.HipFlexion	GluteusMinimusAnterior	0.9015%	1.8240%	2.0394%	3.4983%
Right.Leg.HipFlexion	IliacusLateralis	0.8000%	1.5487%	10.6452%	8.9591%
Right.Leg.HipExternalRota...	RectusFemoris	8.5708%	8.2999%	3.7549%	8.5141%
Right.Leg.HipFlexion	TensorFasciaeLatae	0.8983%	1.8196%	3.6020%	2.2438%
Right.Leg.HipFlexion	GemellusInferior	1.0212%	2.0705%	4.6578%	5.1040%

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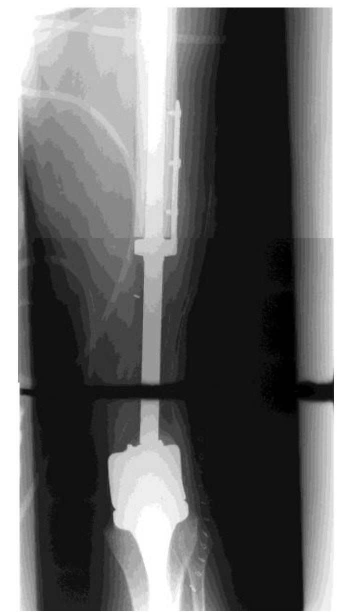
Surgeons need to be able to perform the surgery as planned

Geometrical and Functional Patient data

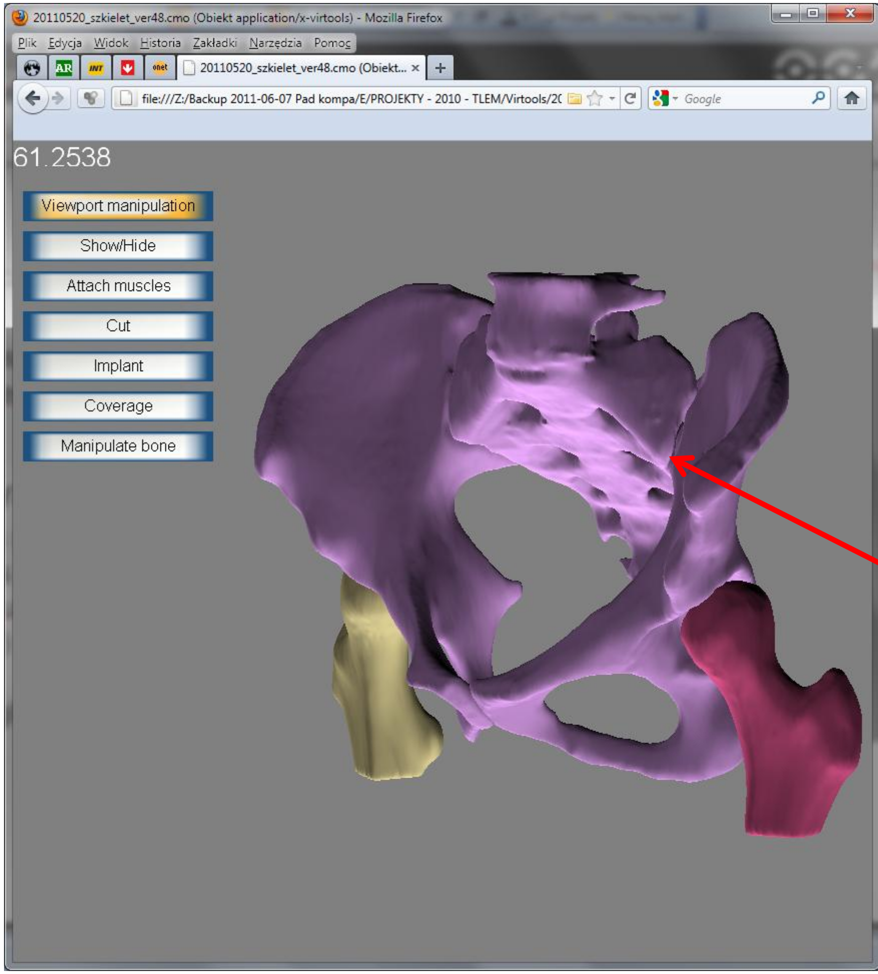
Personalized Advice of Effects of Surgery

Surgical Navigation System

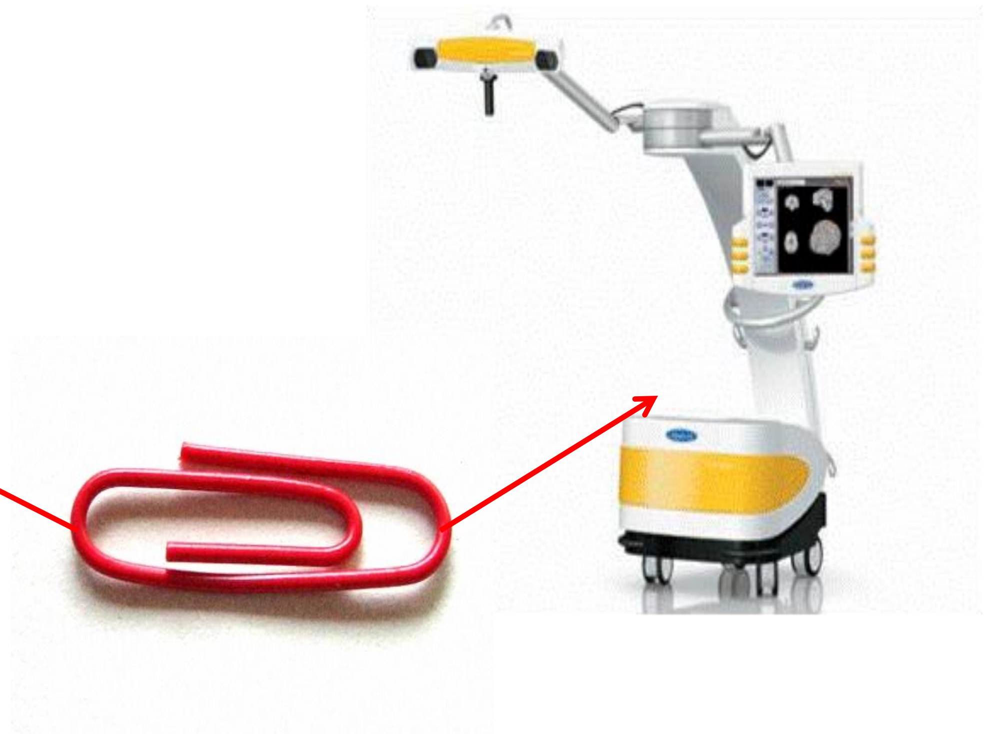


Predict Function; Optimal Functionality

Virtual pre-planning system



Surgical navigation system



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BRAINLAB

Cadaver experiment to test the whole pipe line

Surgical Procedures

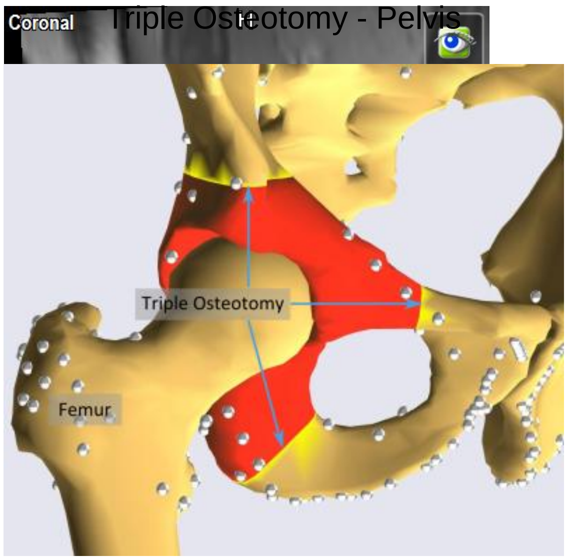
Over the course of two days several different surgical procedures were planned and performed using navigation guidance.

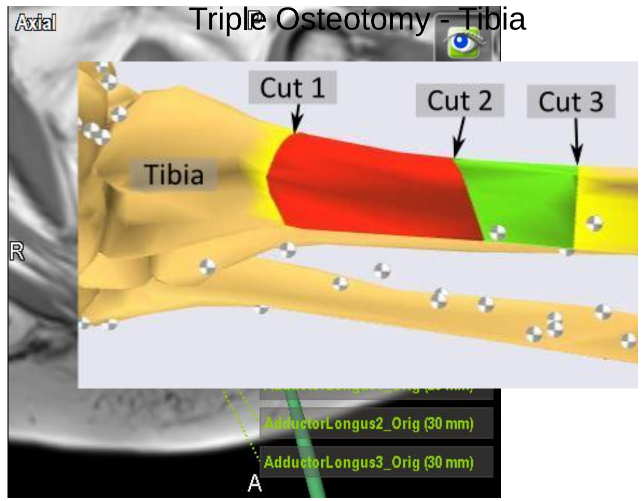
Muscle Removal

Muscle Transfer

Triple Osteotomy - Pelvis

Triple Osteotomy - Tibia





We succesfully performed all steps of the whole pipe line

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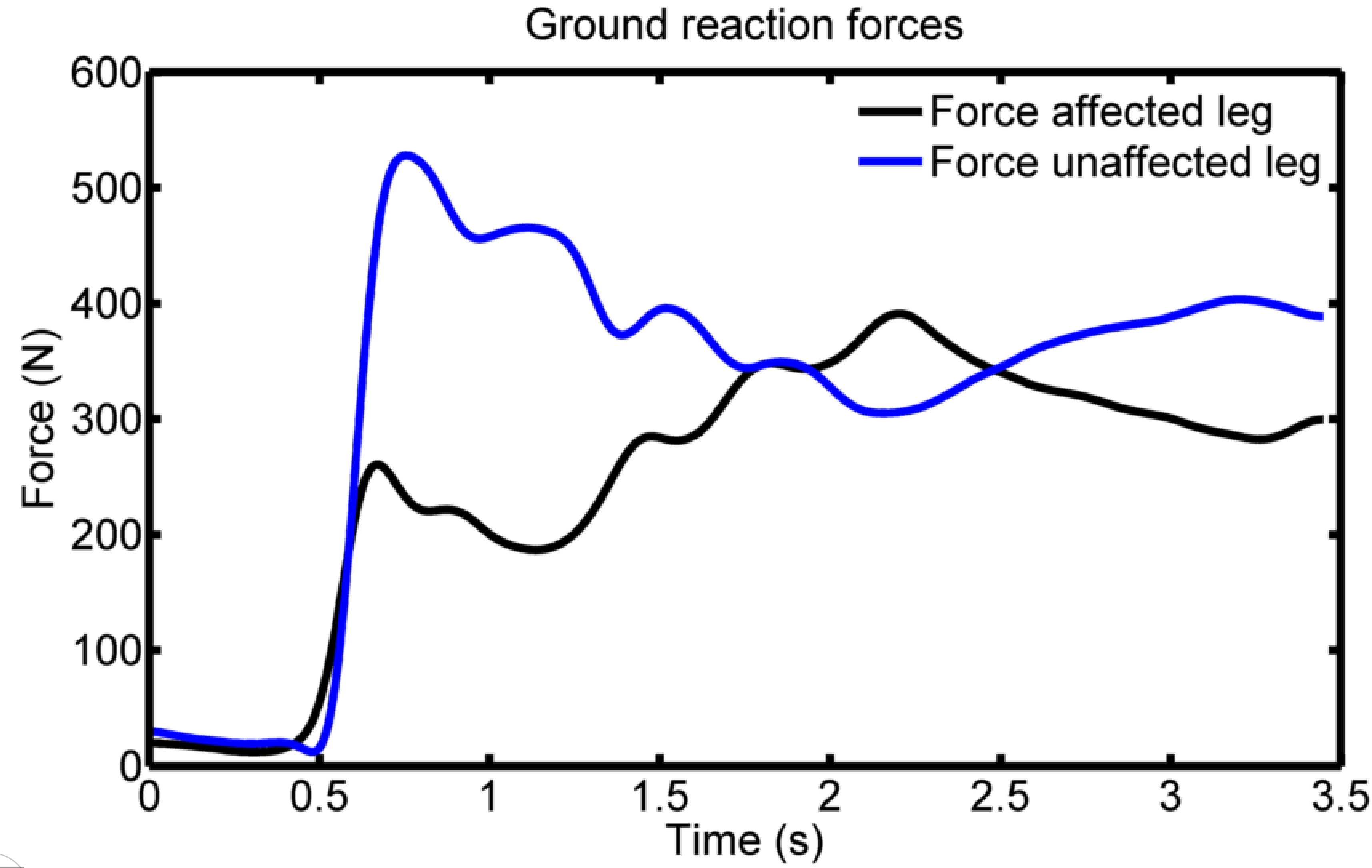
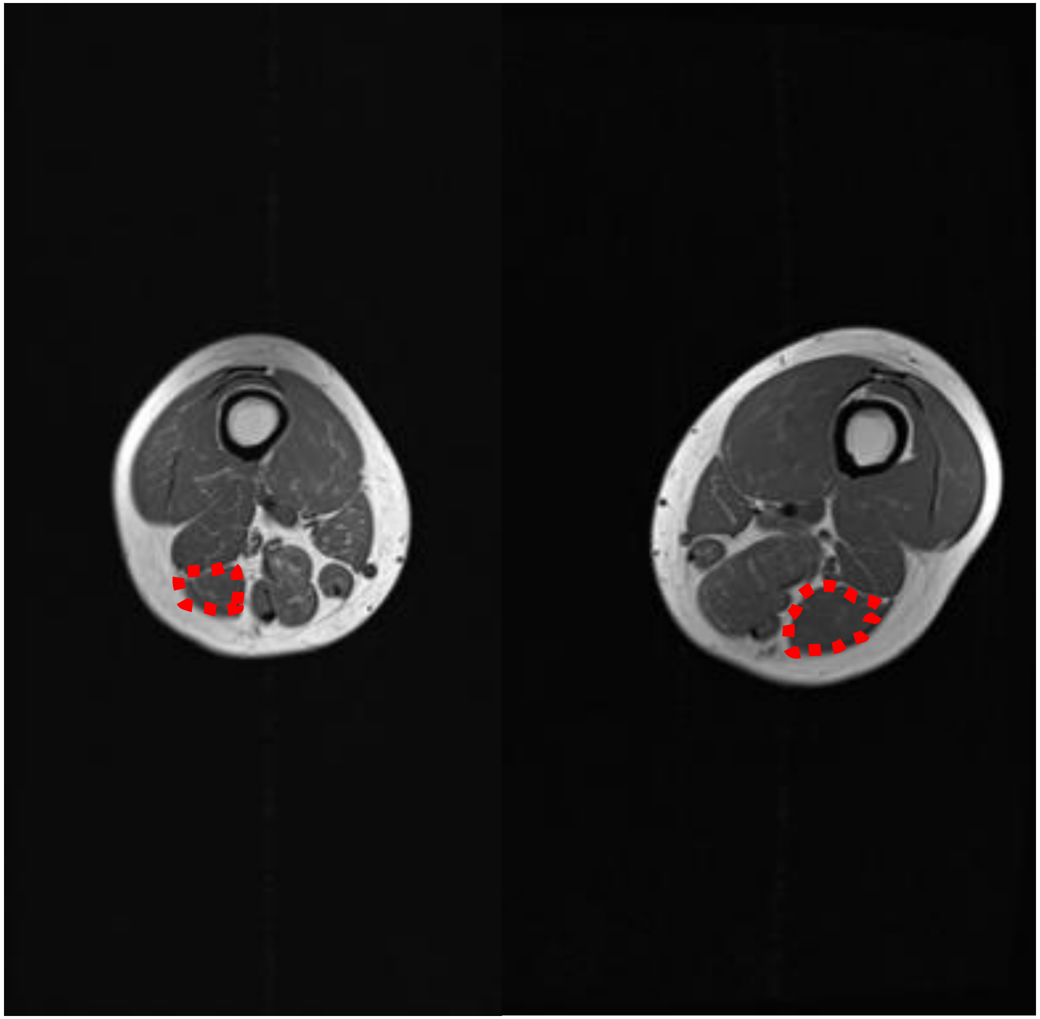
Example: hip dysplastic patient

Example: hip dysplastic patient

Example: hip dysplastic patient



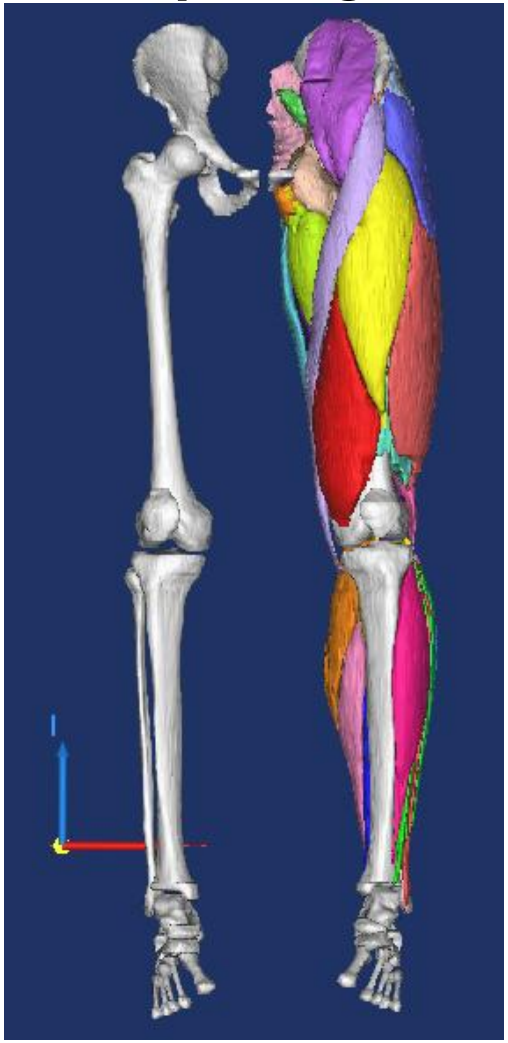
Making MRI-based subject specific musculoskeletal models to predict individualized functional outcome

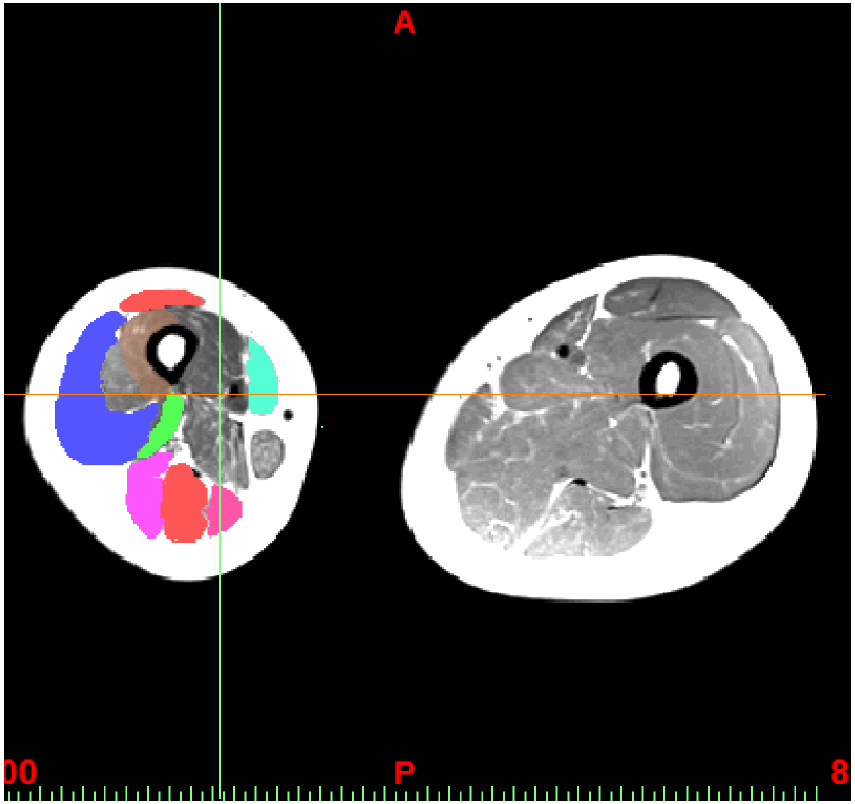


Affected side

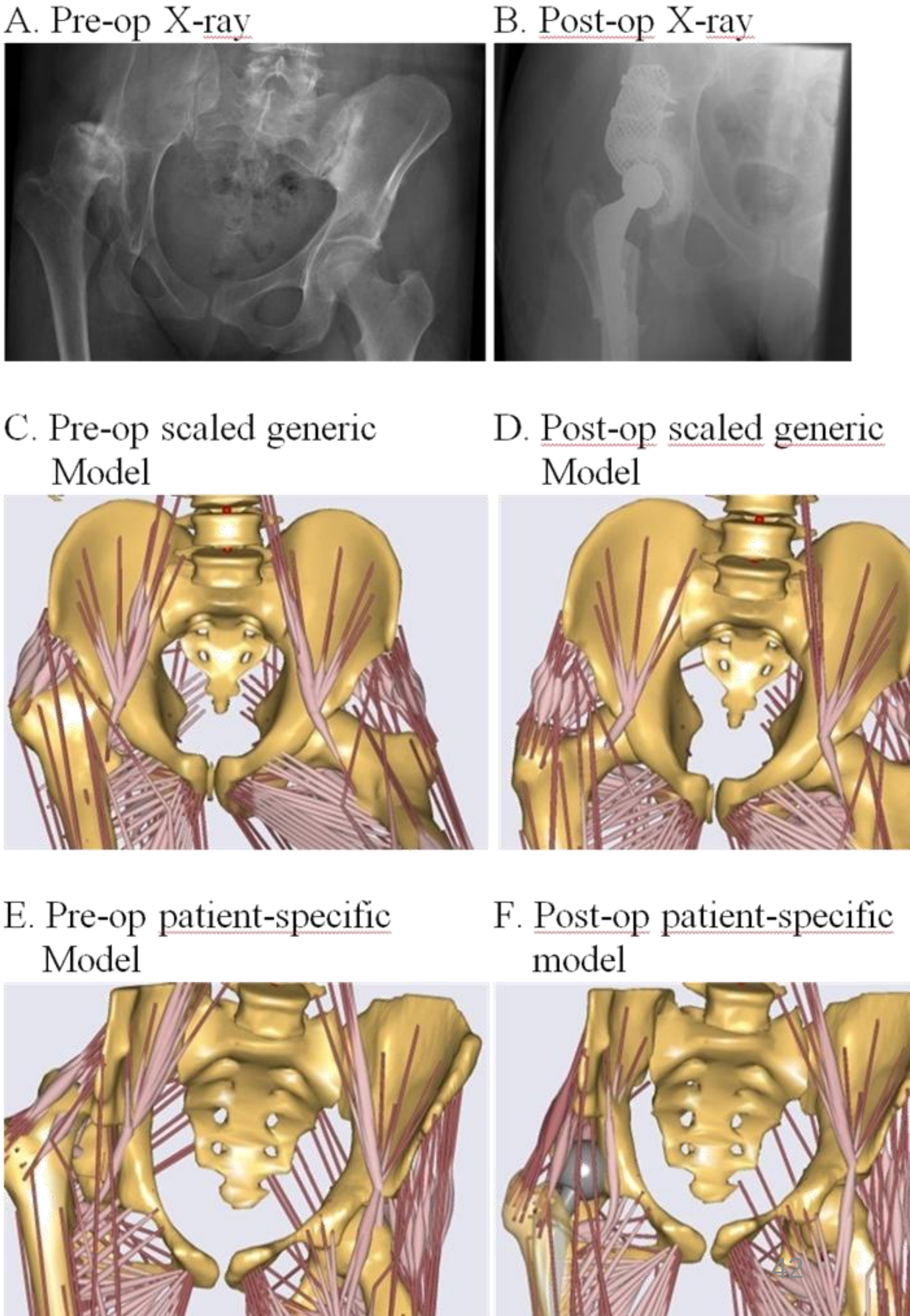
unaffected side

Pre-op Muscle segmentation of dysplastic patiënt requiring manual correction in Mimics





Hip dysplastic patient



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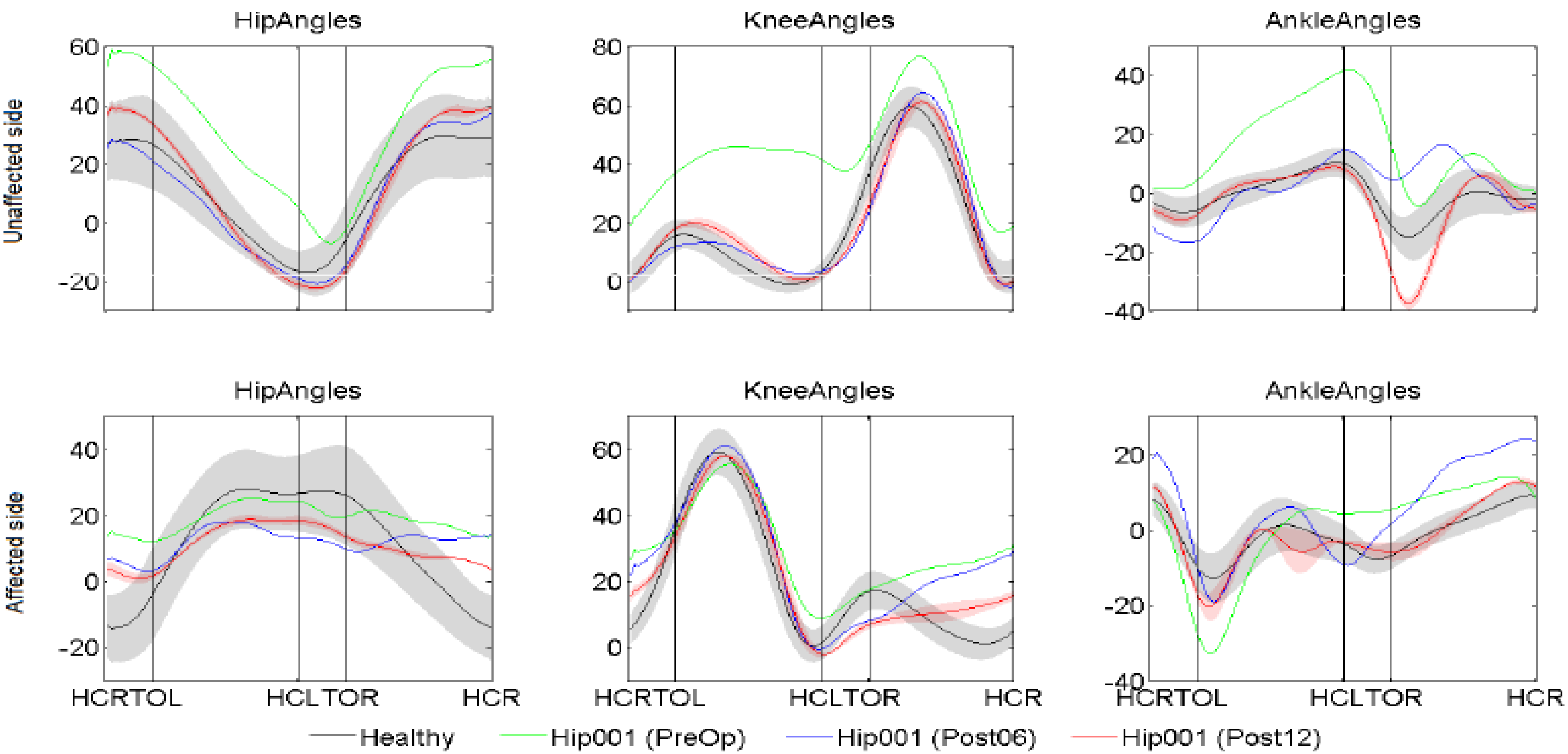
PATIENT SIMULATION

RESULTS

- Joint angles (hip flexion, knee flexion, ankle plantar flexion)

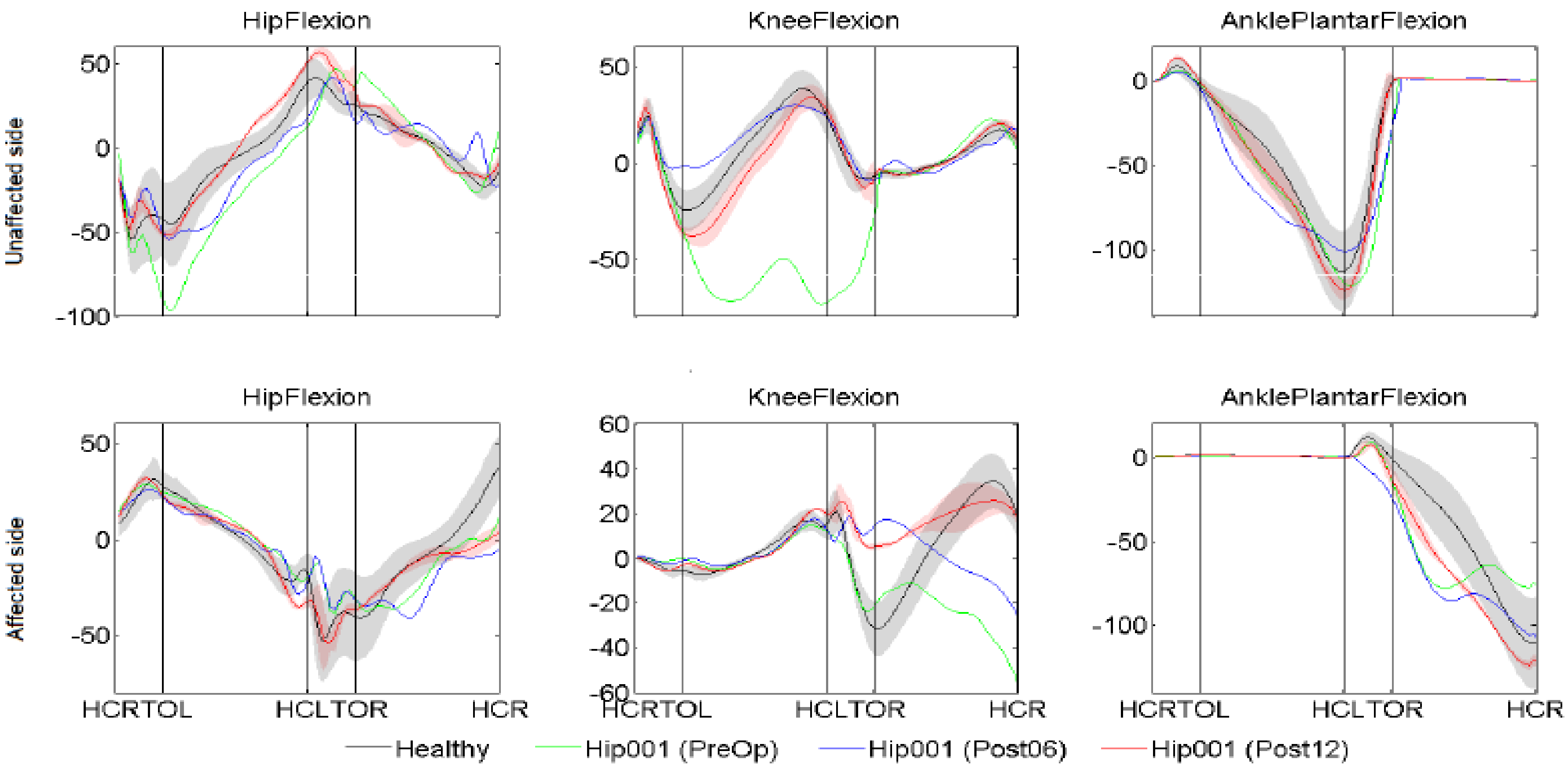


UNIVERSITY OF TWENTE.

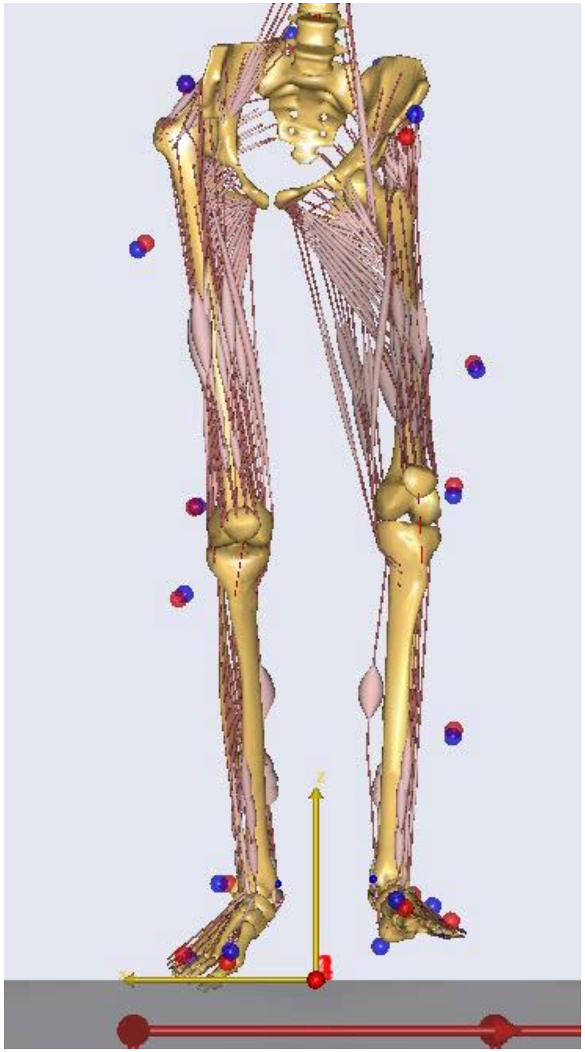
PATIENT SIMULATION

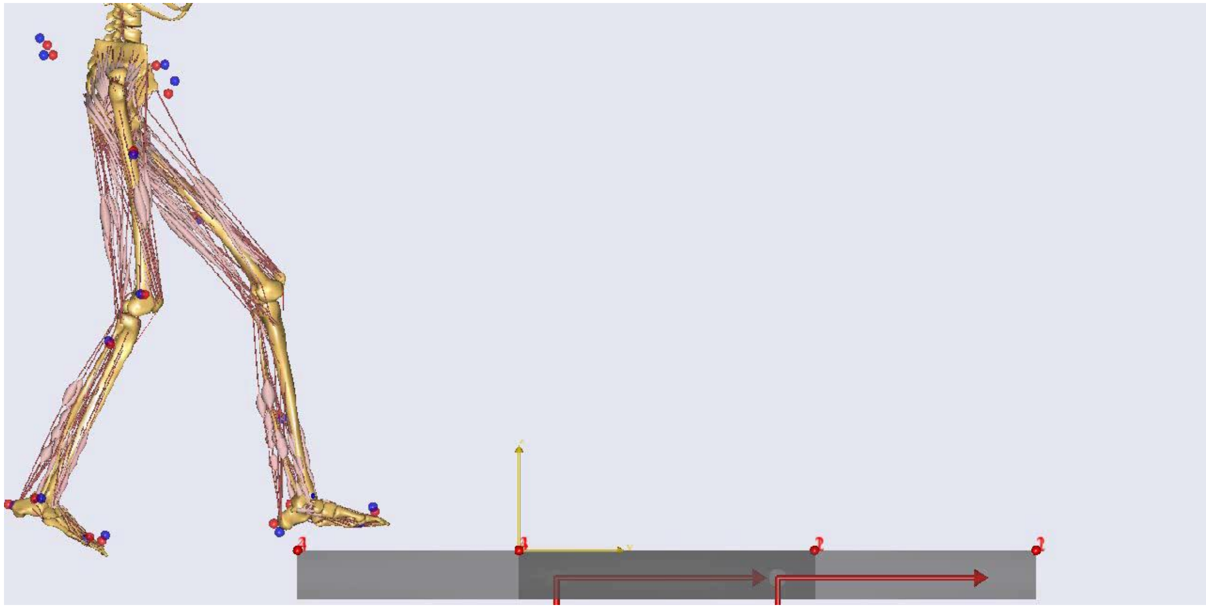
RESULTS

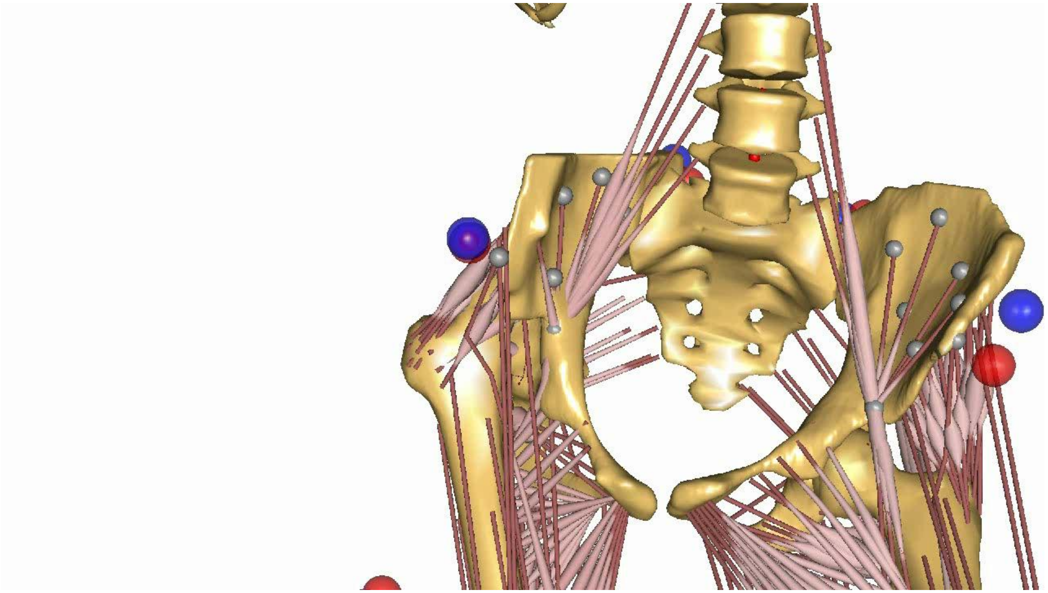
- Joint Moments (hip flexion, knee flexion, ankle plantar flexion)



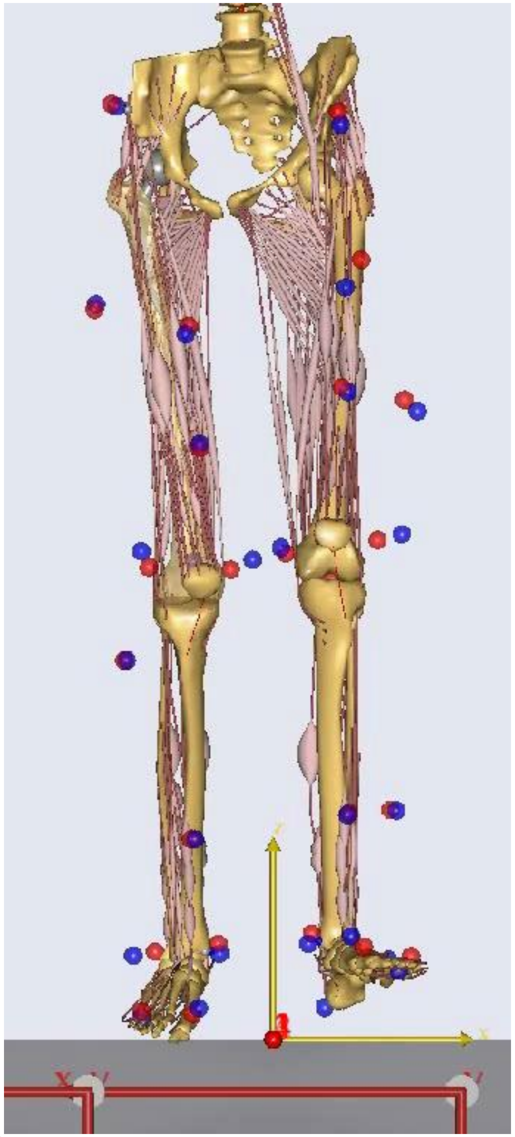
- AnyBody simulation of the hip patient (pre-op), ‘normal’ gait

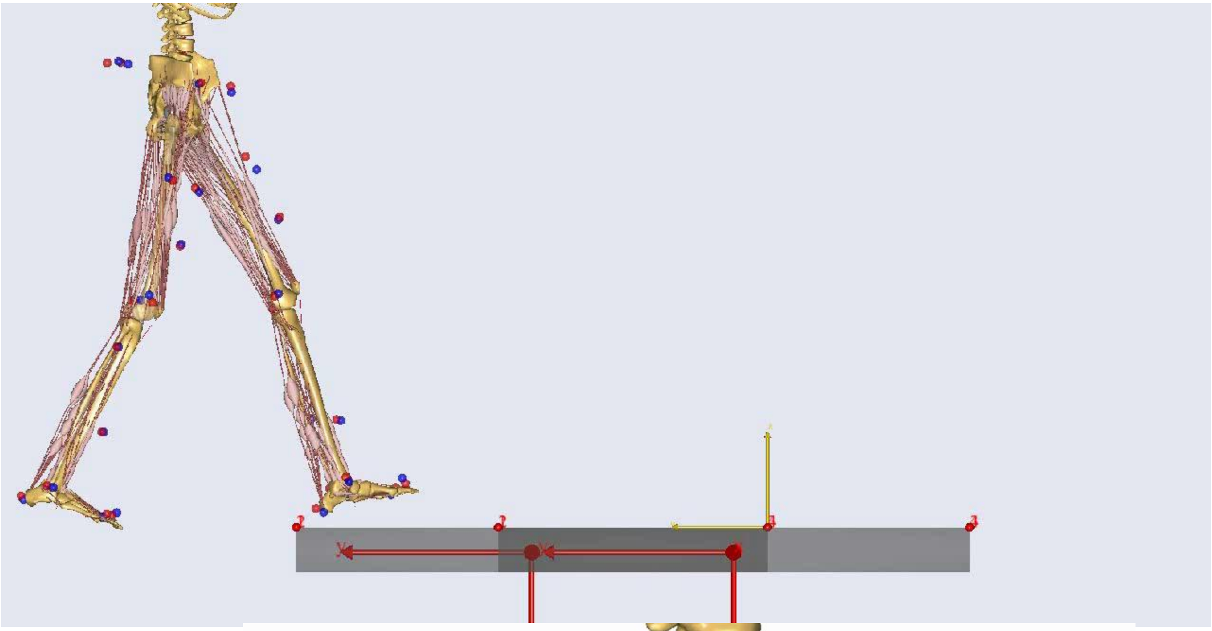


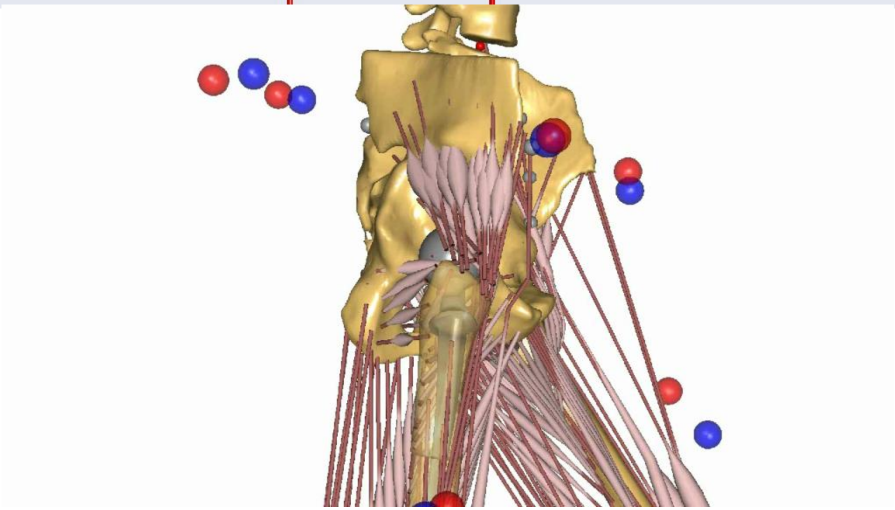




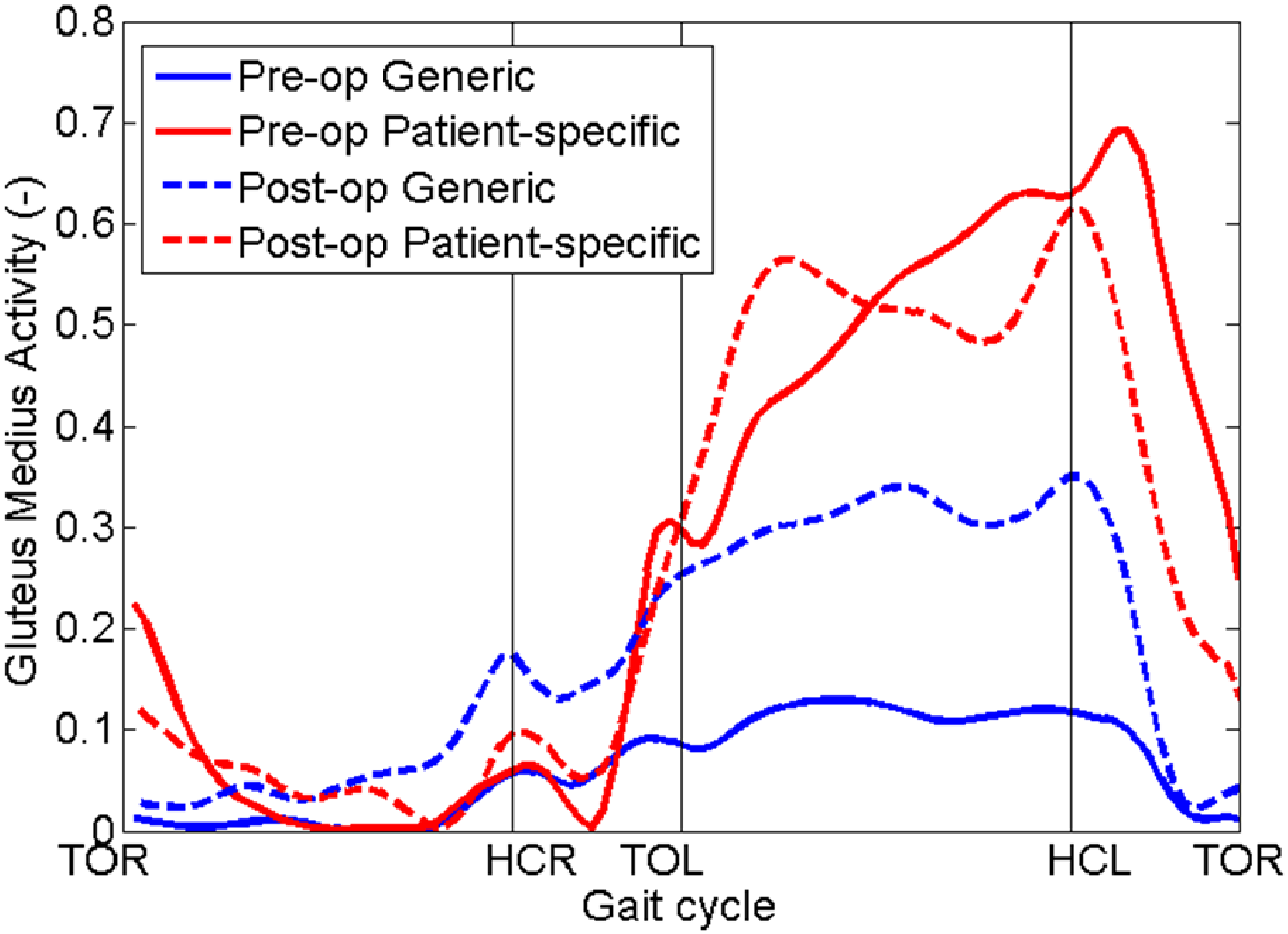
- AnyBody simulation of the hip patient (post-op)
- Based on ‘virtual surgery’ of the pre-op model







- Large differences also in predicted muscle activity
- Goal: validate personalized models with EMG



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Optimizing complex musculo-skeletal surgery using a patient-specific navigation system

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Conclusion:

•We can make personalized models in a semi-automated manner
•Have collected data of 10 healthy individuals
•Have demonstrated the links between different steps

Current targets (18 mos):

•Collect functional and MRI data of patients
•Generate methods to quickly make patient specific models
•Determine accuracy of functional preditions and quantify improvement due to personifications

SEVENTH FRAMEWORK PROGRAMME

Scientific & Clinical Application:

Interested in application of the methods??
Visit our website: www.tlemsafe.eu
Email: n.verdonschot@orthop.umcn.nl

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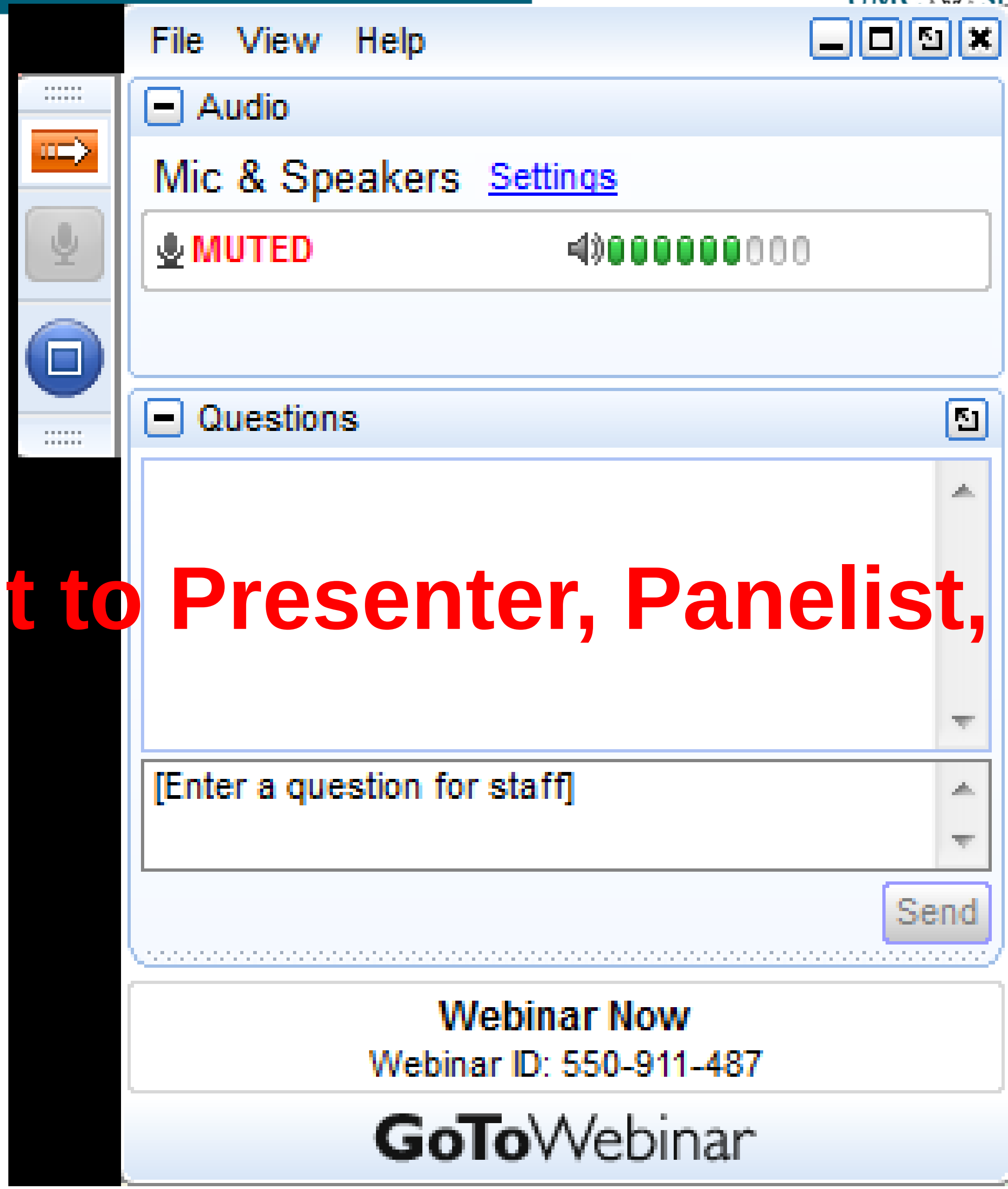

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Resources Q & A

- http://www.anybodytech.com/publications.html
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Meet AnyBody Technology…

- AAOS, Chicago, 19-23 March
- Symposium on Computational Biomechanics, Ulm, 13-14 May
- ISB, Natal, 4-9 August
- APCB, Seoul, 29-31 August
- Workshop, Aalborg, 29 April-3 May

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