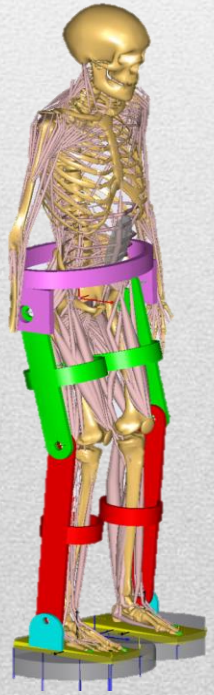
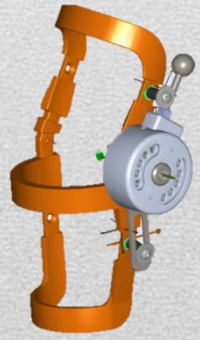
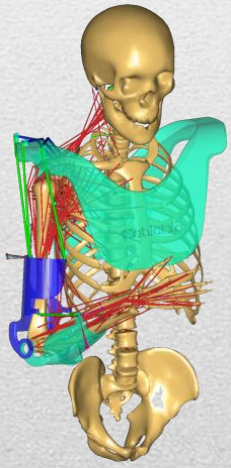
Exoskeletons: Reducing joint and muscle loads while performing difficult tasks







The web cast will start in a few minutes….

Amir Al-Munajjed, Moonki Jung

AnyBody Technology

Outline:

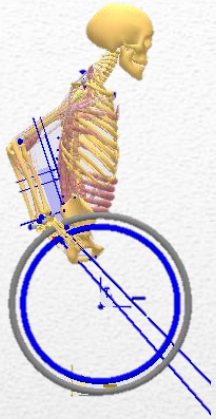
- Who & what is AnyBody?
- What means Exoskeletons?
- Overview: Exoskeletons with AnyBody
  - Shoulder, spine, knee
- Example “reducing knee & hip loads”
  - How to import?
  - How to connect?
  - What results available?
- Questions & answers

Amir Al-Munajjed
(Presenter)

Moonki Jung
(Panelist)

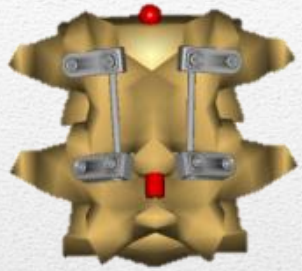
Arne Kiis
(Host)

Who is AnyBody?



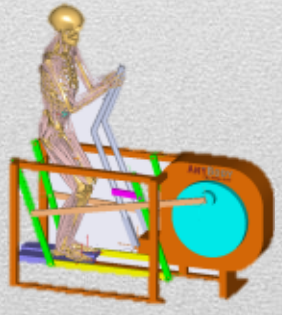
AnyBody Technology
(Aalborg, DK; Boston, US)

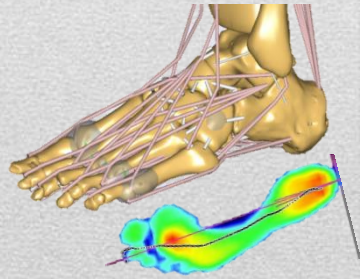
- *AnyBody Modeling System*
- *Licenses, Training, Support*
- *Consulting*



AnyBody Research Group

- *DK: Aalborg University - Prof. Rasmussen*
  - *Biomechanics, Ergonomics, Sport, Automotive*
- *US: Colorado School of Mines – Prof. Patrella*
  - *Biomechanics, Orthopedics, Sport*
- *GER: OTH Regensburg – Prof. Dendorfer*
  - *Biomechanics, Orthopedics, Gait*





What is AnyBody?

AnyBody
Modeling
System

- Software/tool

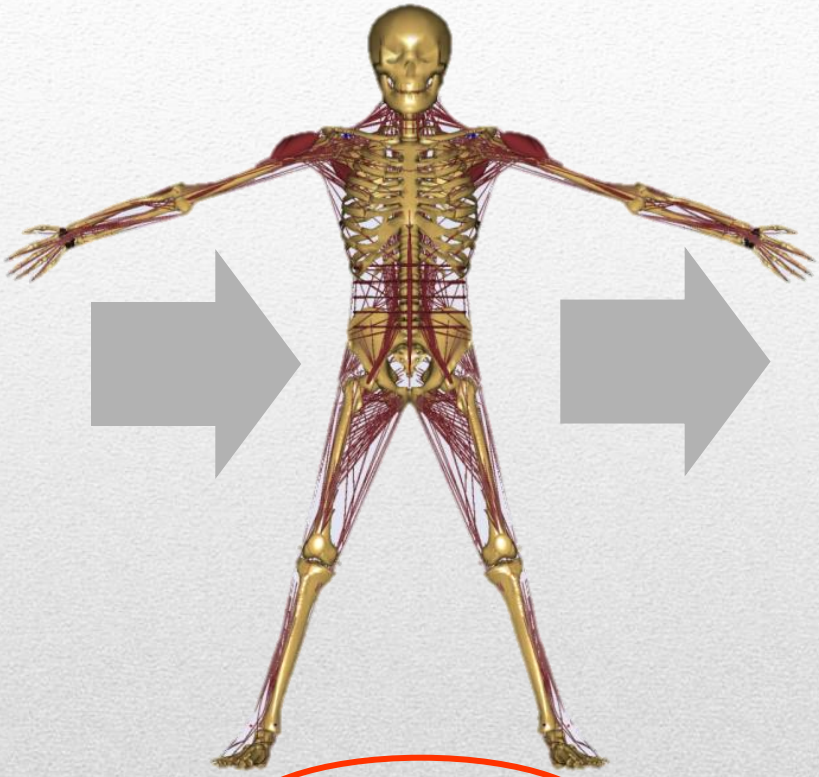
AnyBody
Managed
Model
Repository

- Body Model
- Library of applications

Musculoskeletal Simulation

Input

Activity/
Motion



Output

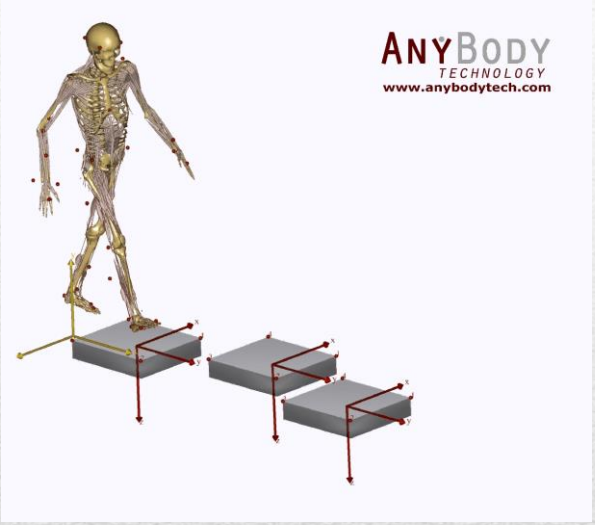
Muscles:
forces, activity, power
Joints:
forces, moments,
...

Body Model

Bones | Joints | Muscles | Ligaments

Inverse Dynamic Analysis

Input:

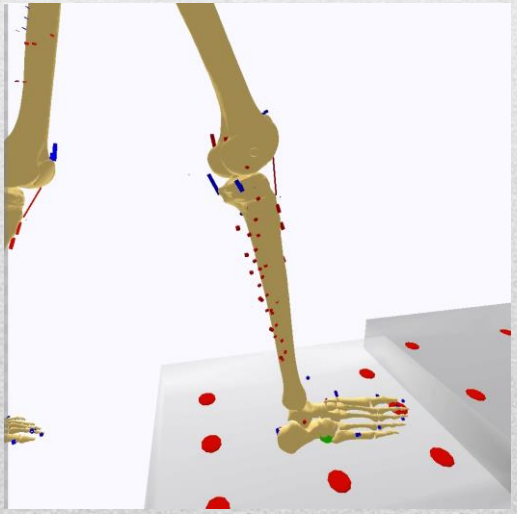


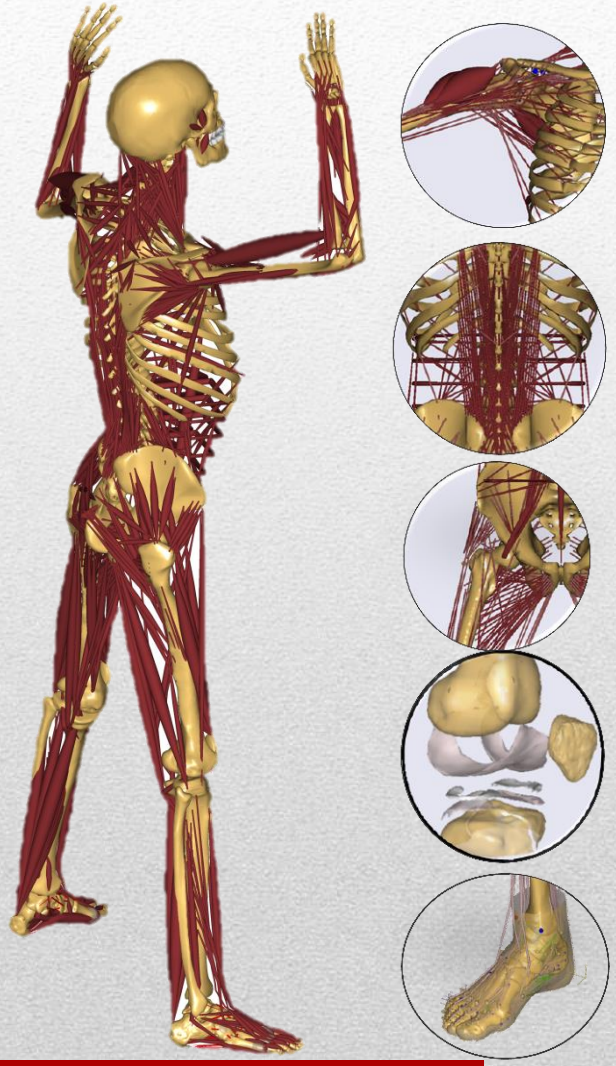
Motion & ext Forces:

- Motion Capture (Vicon, Qualisys, ...)
- Joint Angle Input

Output:

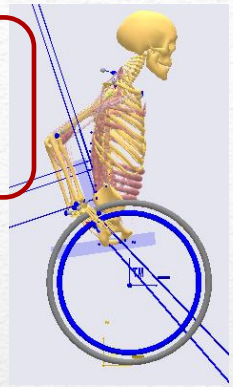
- Muscle Forces (activations)
- Joint Reaction Forces





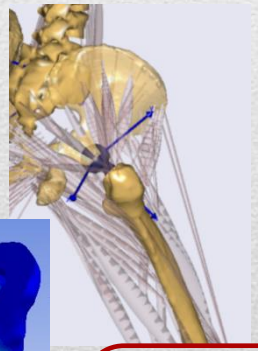
Gait Application
AnyGait

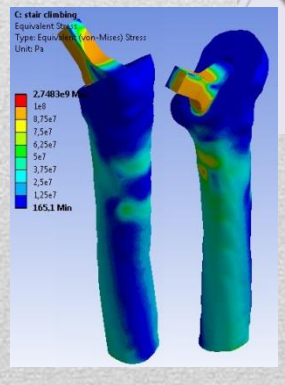
Product Design
Optimization



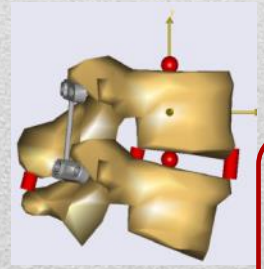
Ergonomic Analysis
and Documentation

ANYBODY
Modeling System



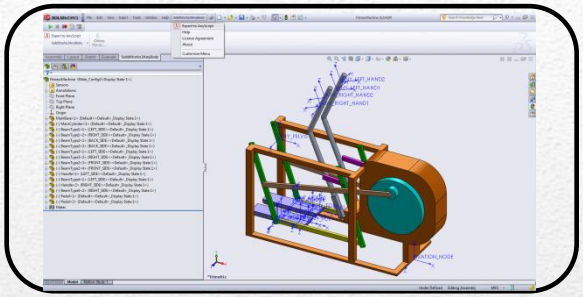


Physiological Load
Cases for Finite
Element Analysis



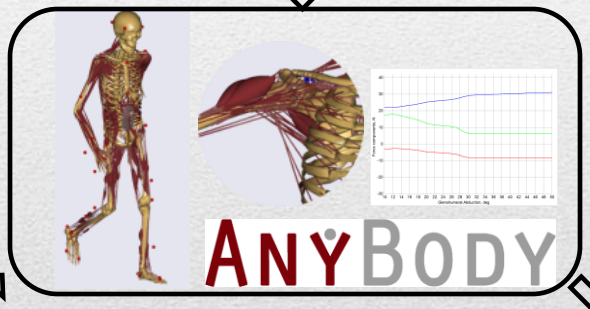
Surgical Planning, -
Evaluation & -Failure
Analysis

Advanced Work flow



CAD environment model
(SolidWorks2AnyBody)

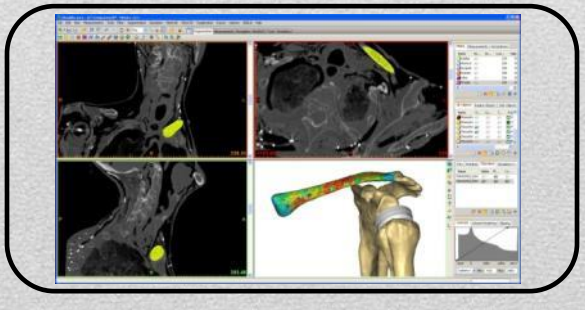
Applications: Activities of daily living



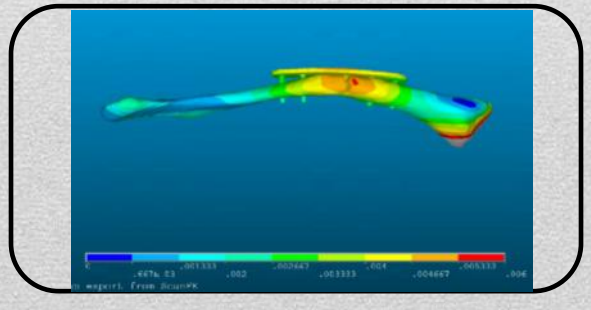
Processing workflows:

- Scripting e.g. Python, Matlab.
- Optimization software

Subject information



FE-model



What means Exoskeleton?

An exoskeleton is a wearable robot attached to the human body to influence or assist human motion.

- Motion assistance for patients in rehab.
- Muscular enhancement of industrial workers or soldiers .

- Active engine to provide torque/force for joints.
- Passive stiffness to support/limit body motion.

Exoskeleton in rehab

Patients with no or low functionality in extremities:

- Stroke patients
- Paraplegic patient

Learn to walk again.

ReWalk exoskeleton

Argo Medical Technologies

Exoskeleton in work environment

Lift heavy loads, perform difficult tasks while:

- Keep low joint reaction forces.
- Limit muscle activations/ limit muscle fatigue.

Honda

HAL 5: CYBERDYNE

Exoskeleton in military

Support soldiers:

- Better endurance
- Carry heavy equipment
- Cover long distances

”future soldier” US Army

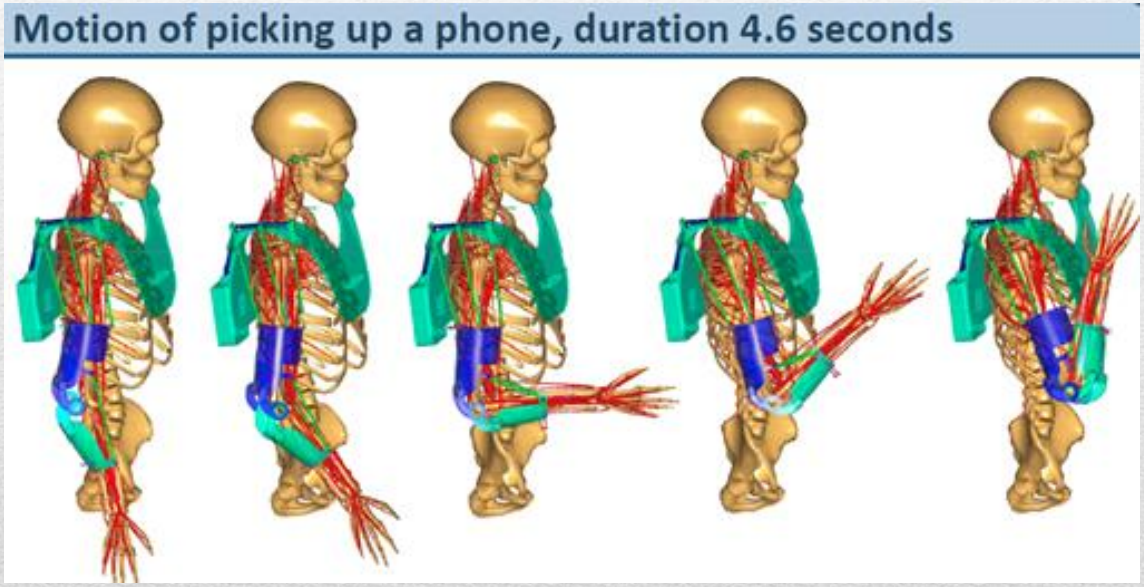
Exoskeletons and AnyBody

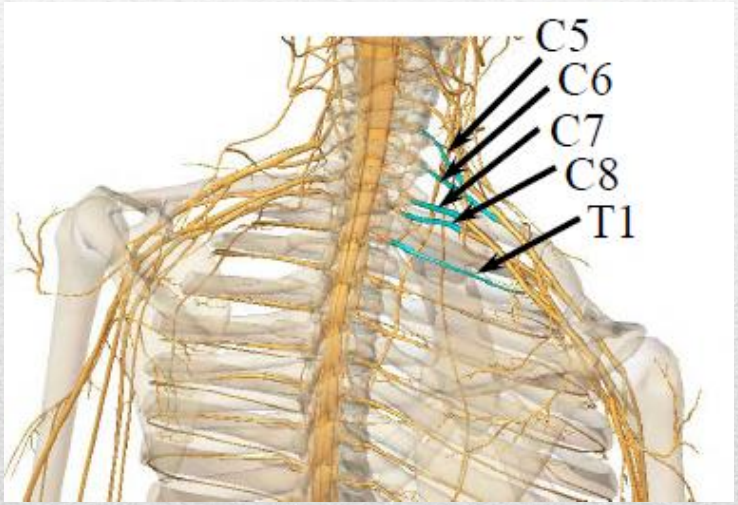
AnyBody simulations help to:

- Find optimal parameters of exoskeleton
  - Torque
  - Power
  - Kinematics
  - Stiffness
  - ...
- Analyze effect of exoskeleton on human
  - Joint loads
  - Muscle activations (injured/non-active)

Bai & Rasmussen 2011

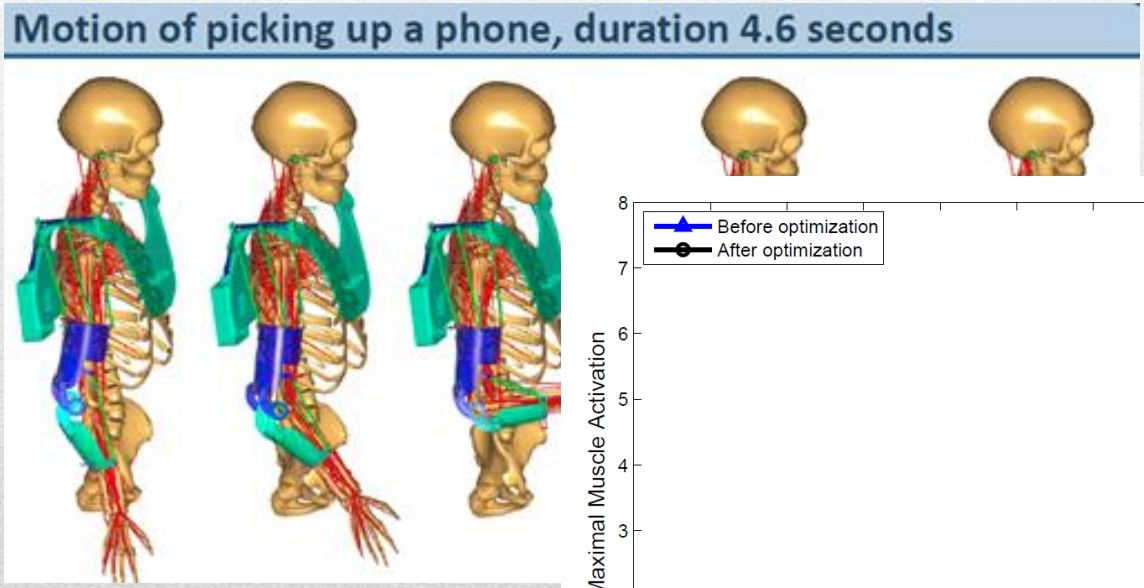
Assistive shoulder orthoses for brachial plexus injury

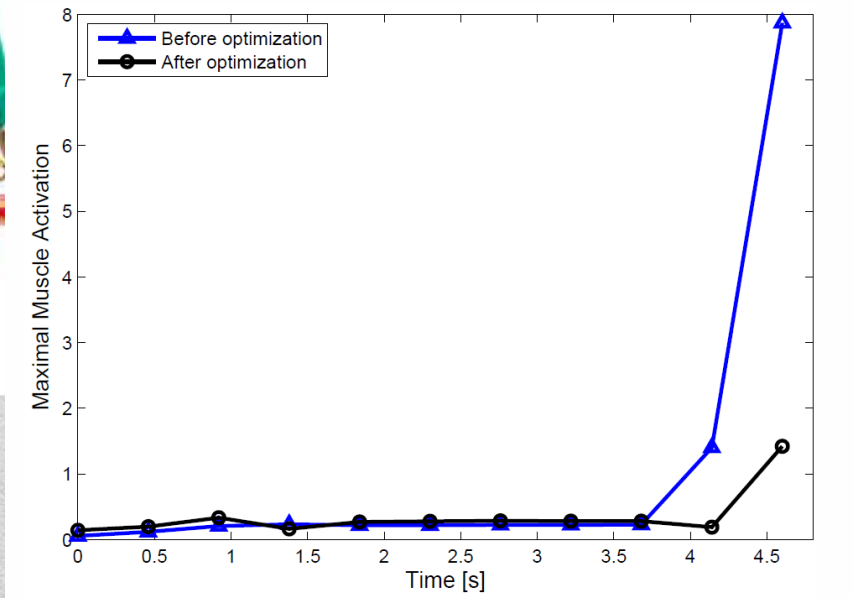


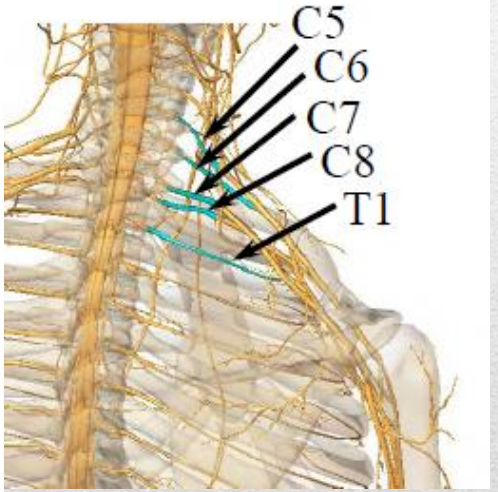


Zhou et al. 2012, AAL Forum 2012

Assistive shoulder orthoses for brachial plexus injury



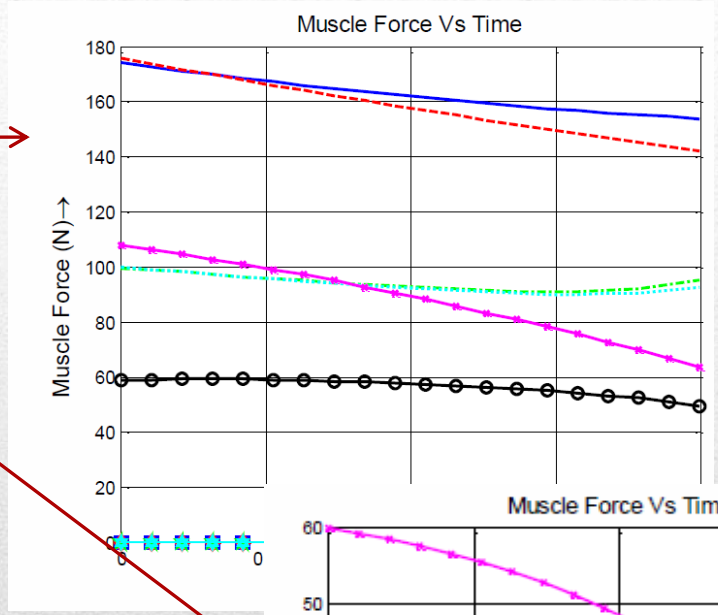


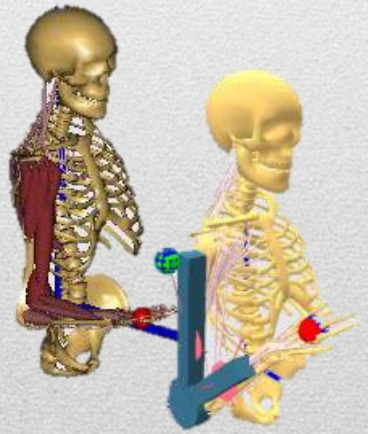


Zhou et al. 2013

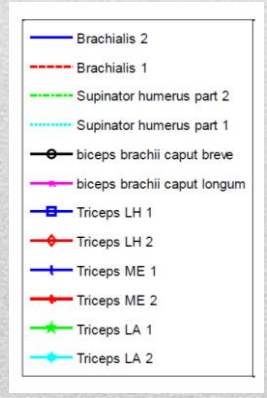
Effect of Actuator Moment on ind. muscles

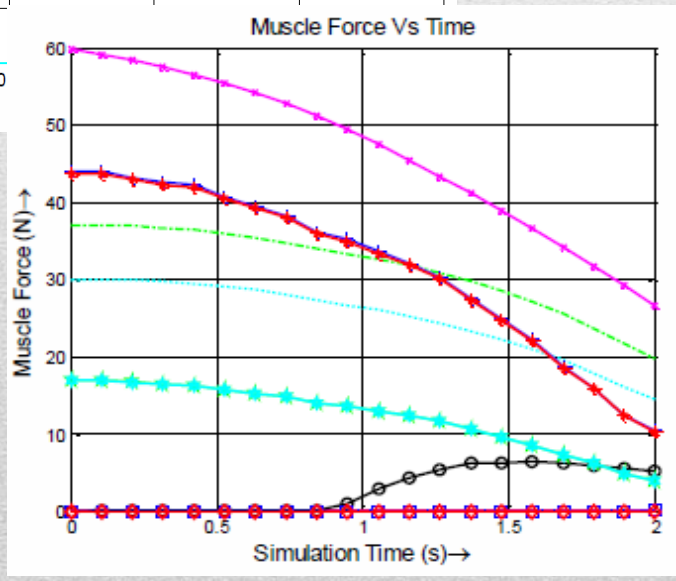
1. Standard Control
2. Exoskeleton with:
   - constant assistive moment
   - variable assistive moment
   - assistive moment



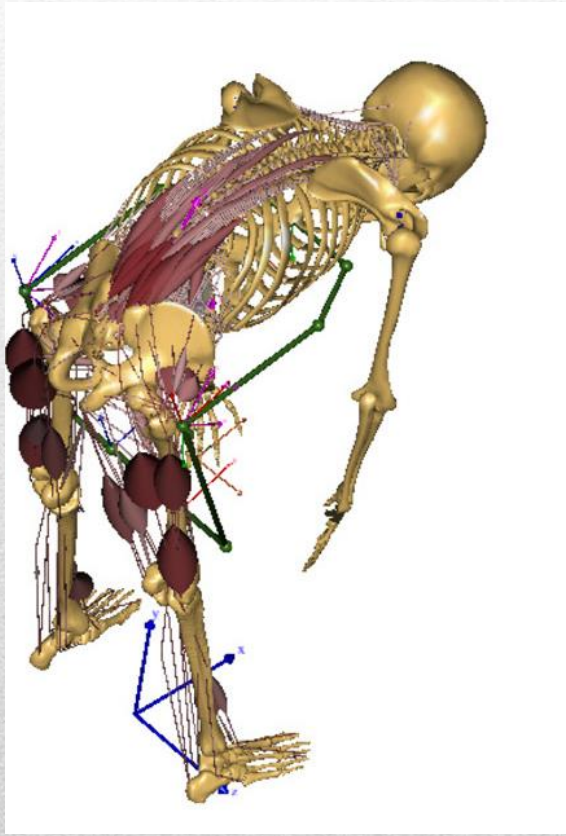


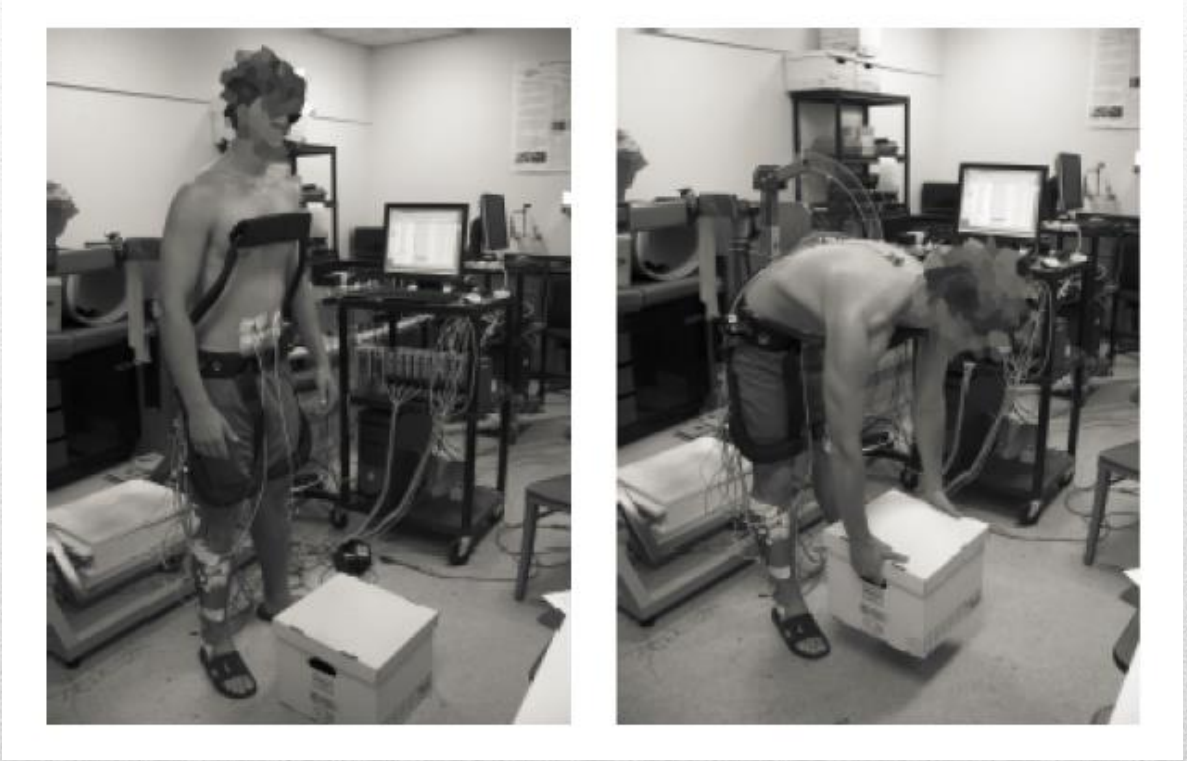
Agarwal et al. 2010





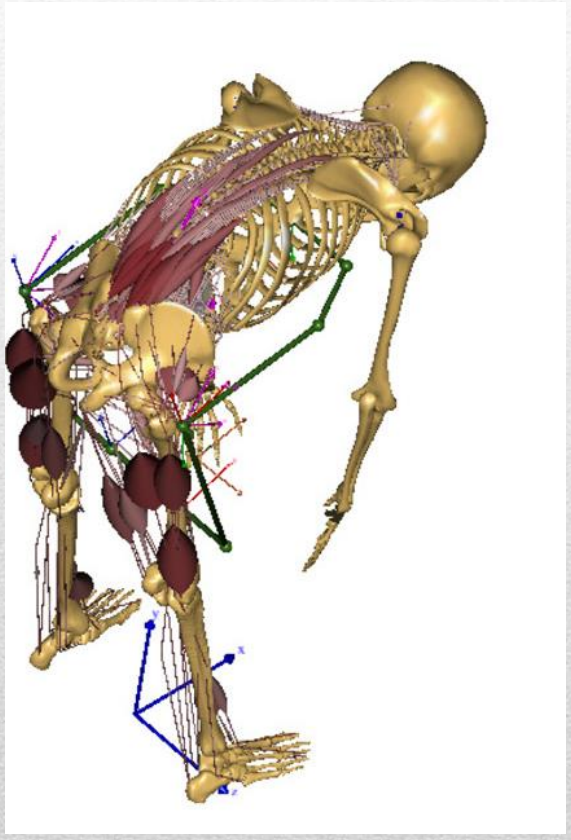
Stooped posture with a personal weight transfer device

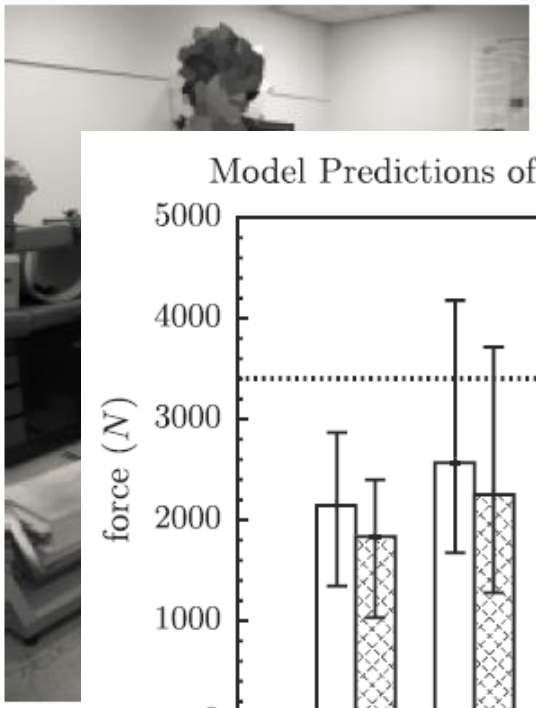


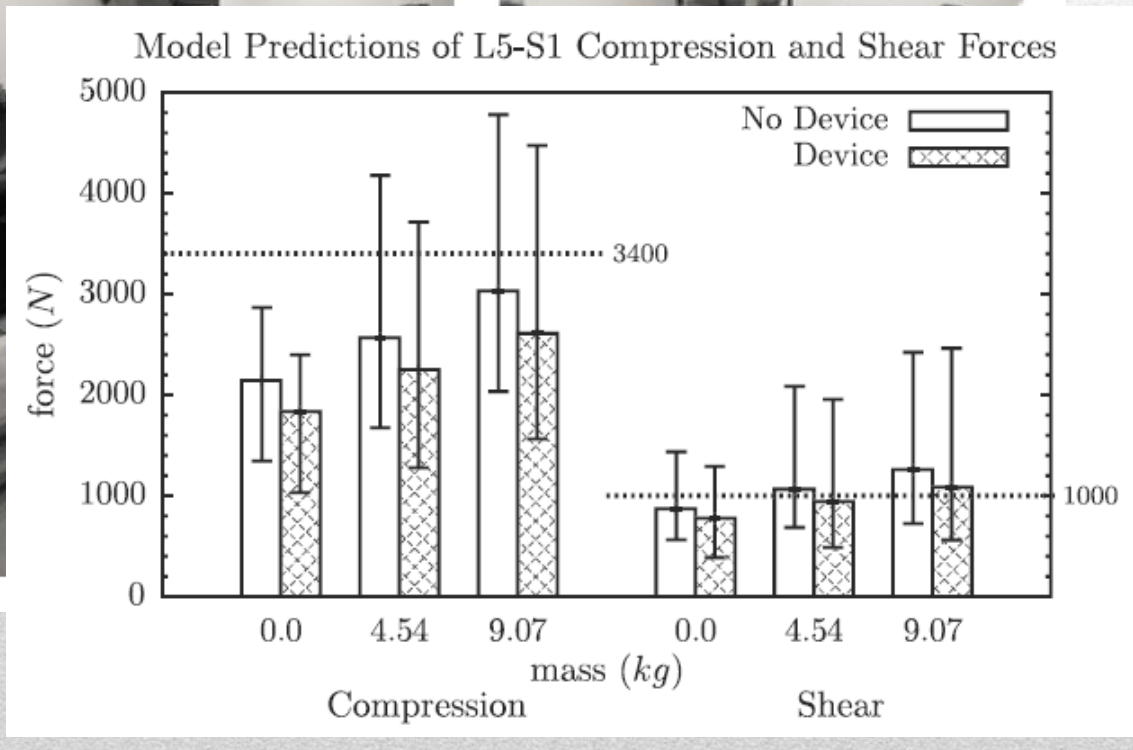


Ulrey & Fathallah 2012, J Electro. Kinesiol

Stooped posture with a personal weight transfer device

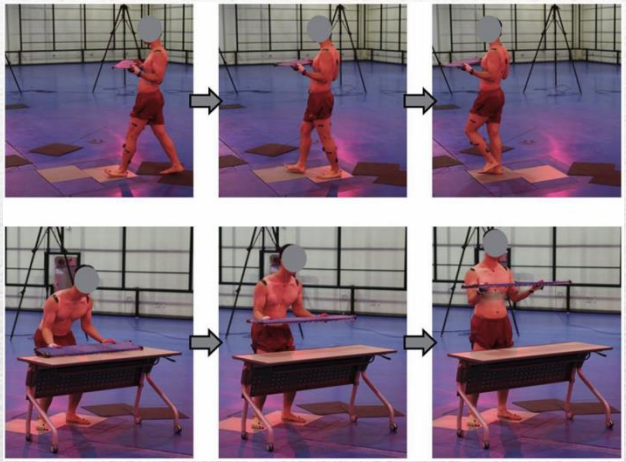


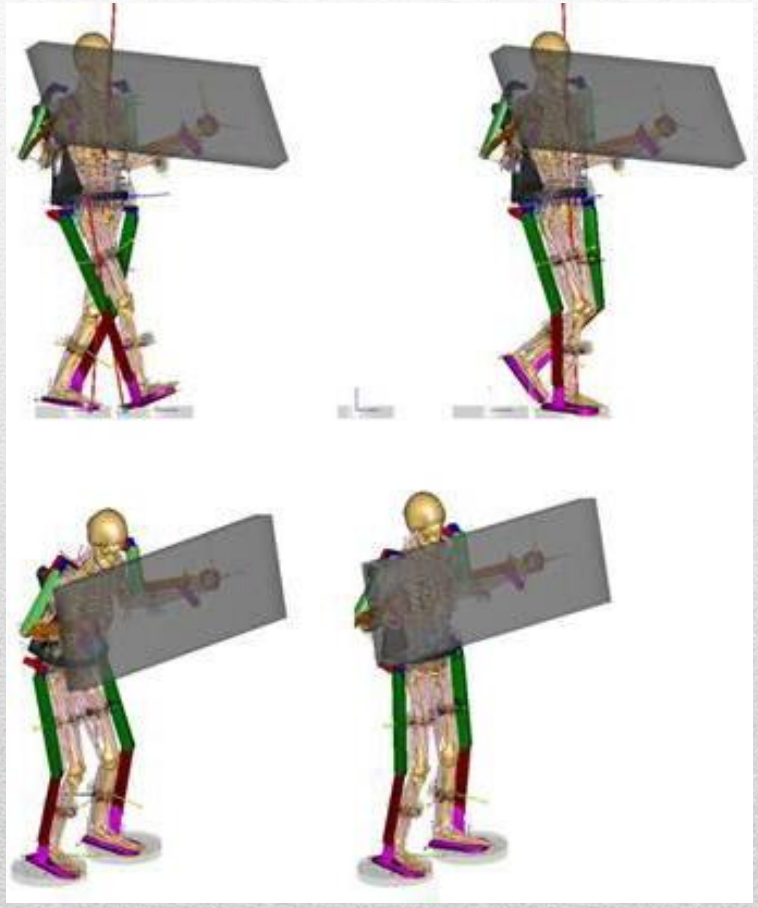




Ulrey & Fathallah 2012, J Electro. Kinesiol

Lifting different weights with a wearable robot using different constraints



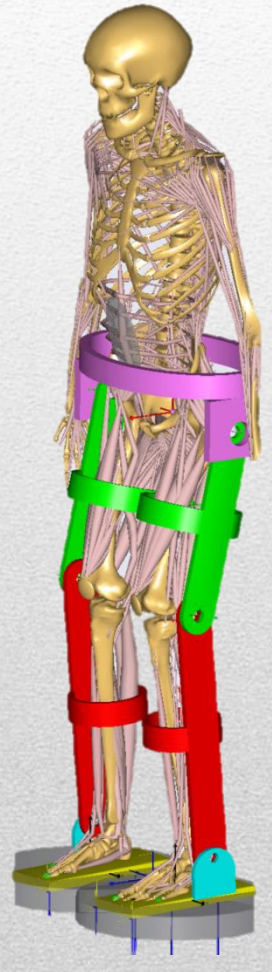


How to attach a exoskeleton to the human?

Cho et al. 2012

Human-Exoskeleton example

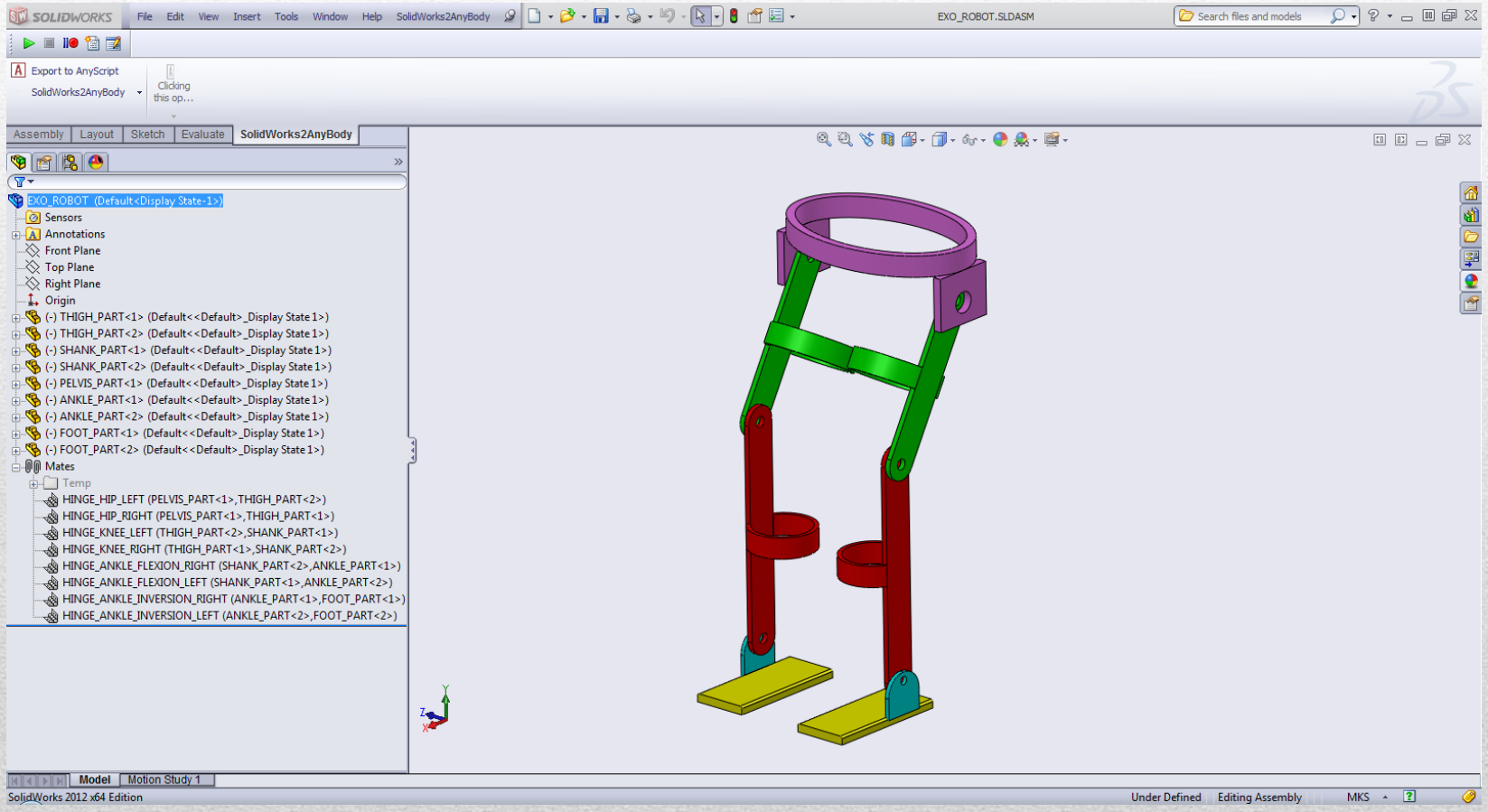
- “I have designed an exoskeleton, how will it affect a human subject?”



Moonki Jung

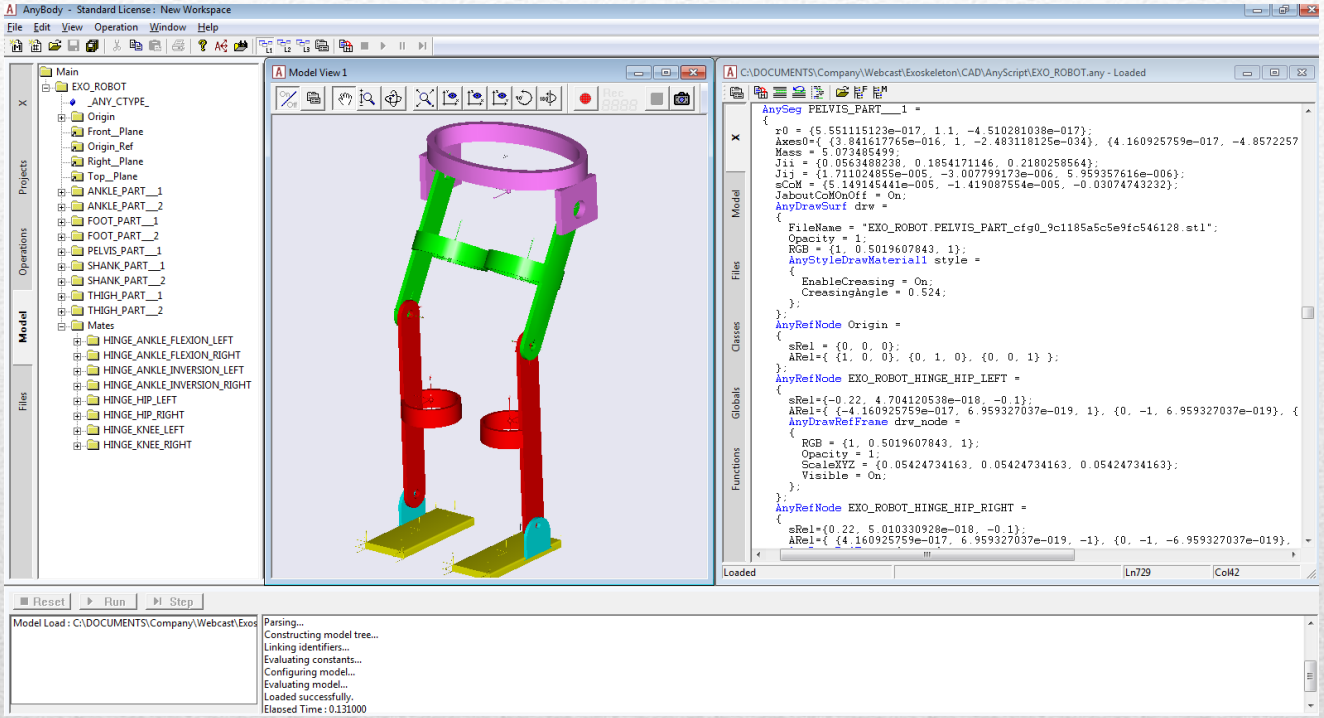
SolidWorks to AnyBody

- Translation of your CAD model into AnyBody



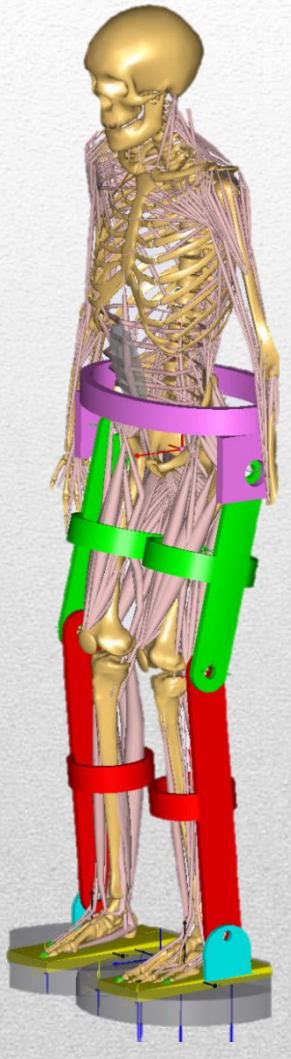
SolidWorks to AnyBody

- Geometry
- Weight
- Inertia
- Joints
- Reference nodes
- …



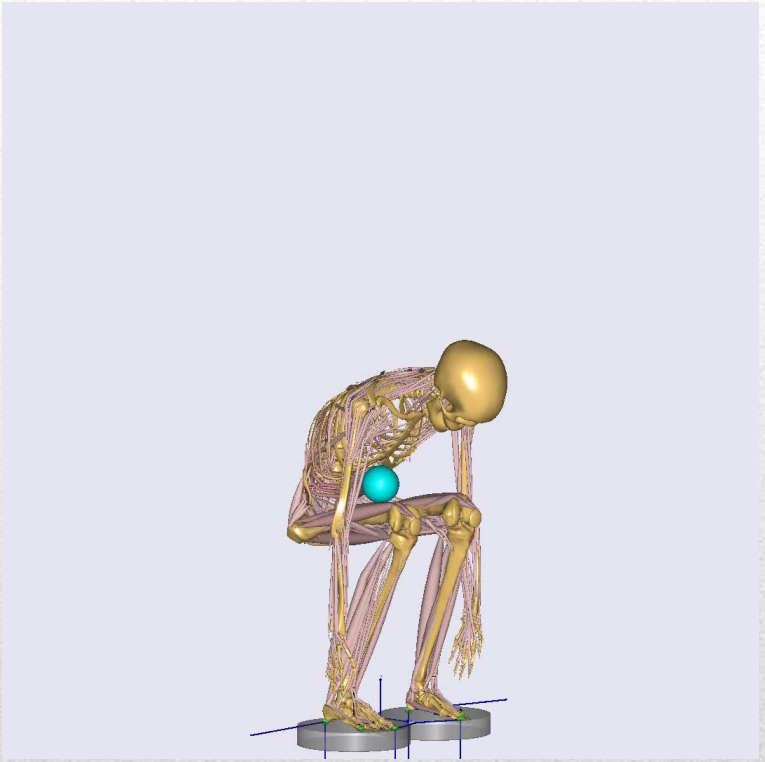
Human-Exoskeleton model

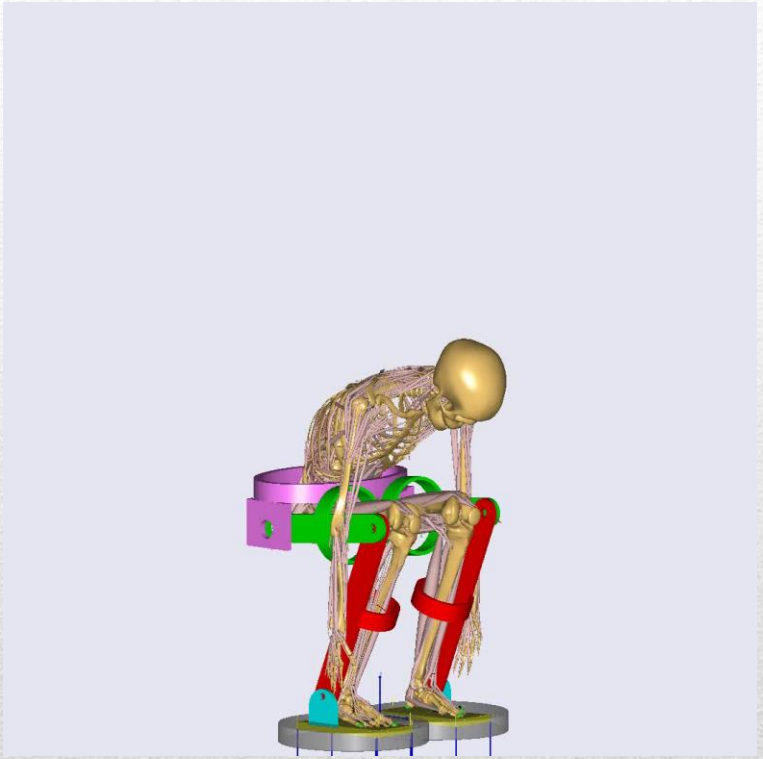
- What actuator in exoskeleton?
  - 6 actuators (hip, knee and ankle)
  - 2 different actuators types (strong and medium)
- How to attach exoskeleton to human?
  - Pelvis, both of thighs, both of shanks



Moonki Jung

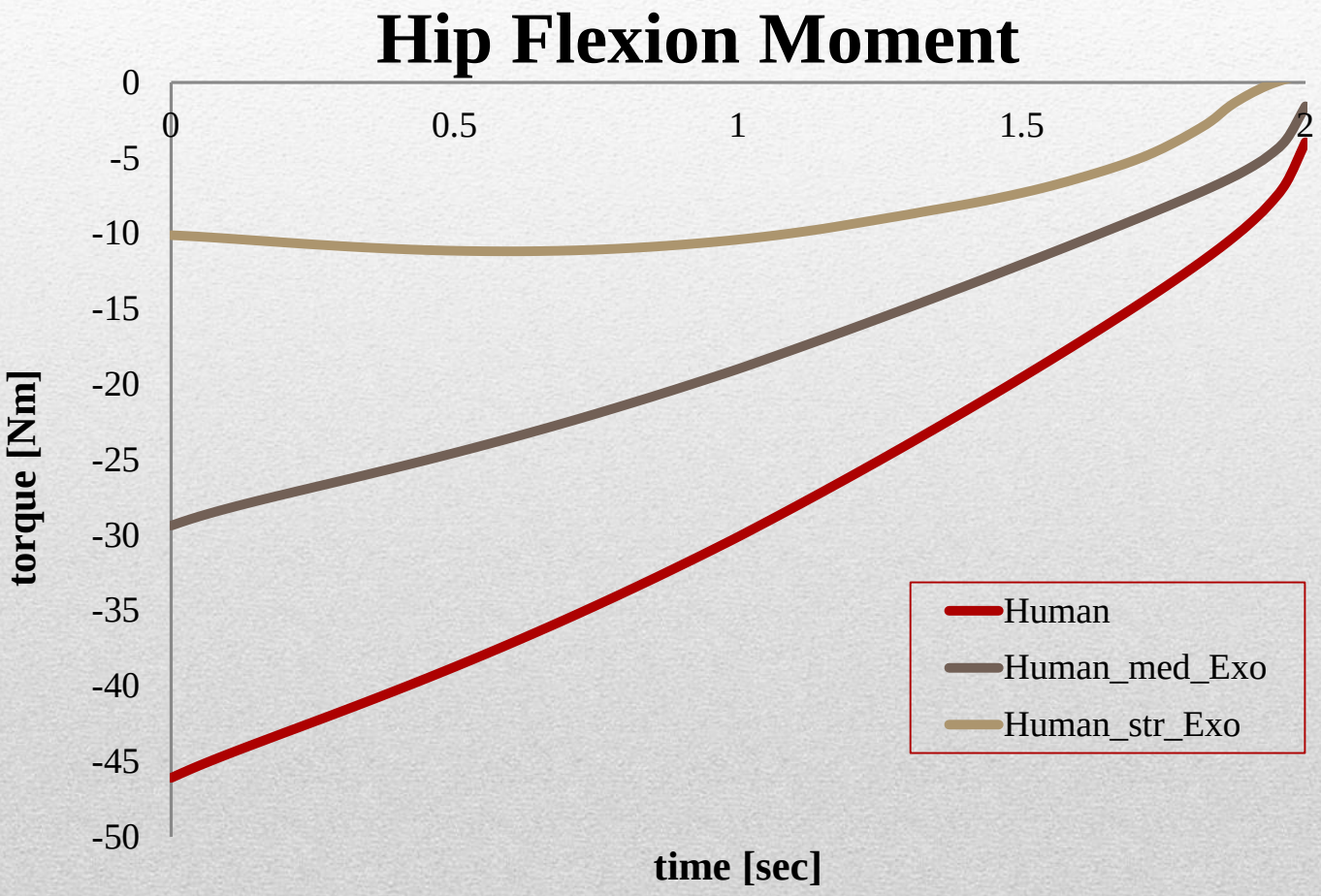
Human-Exoskeleton model

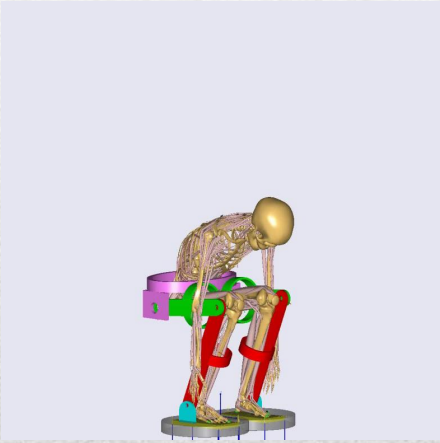




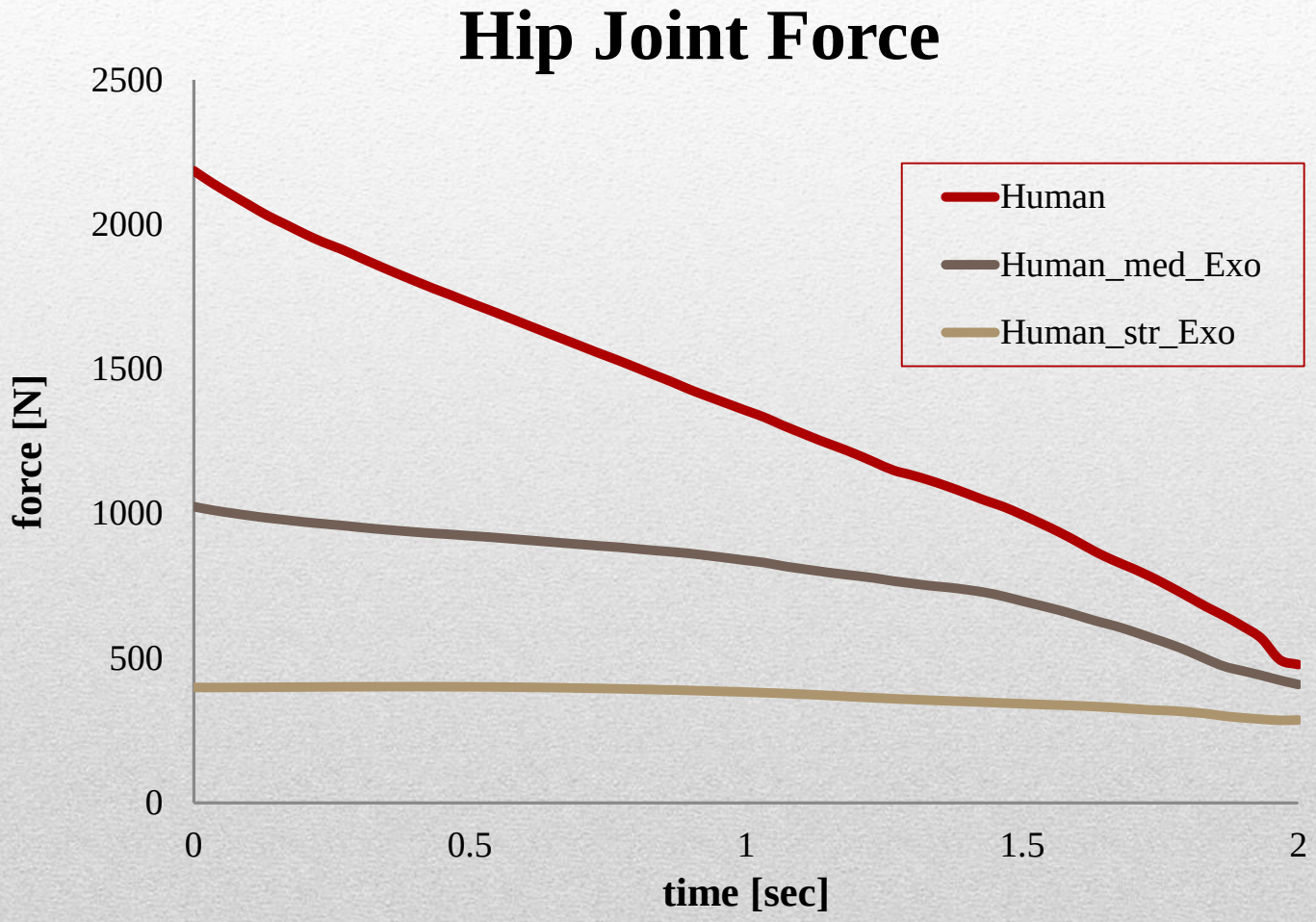
- Definition of motion
  - Parameterized joint angle definition available
- External forces
  - Prediction of ground reaction forces

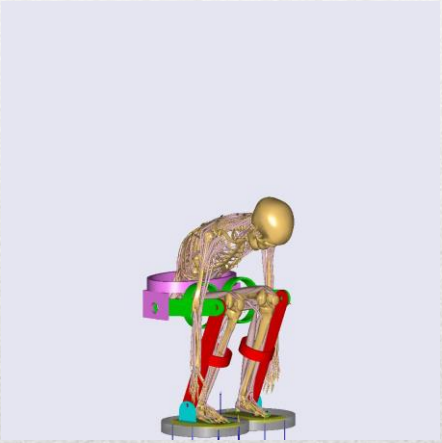
Results in Human



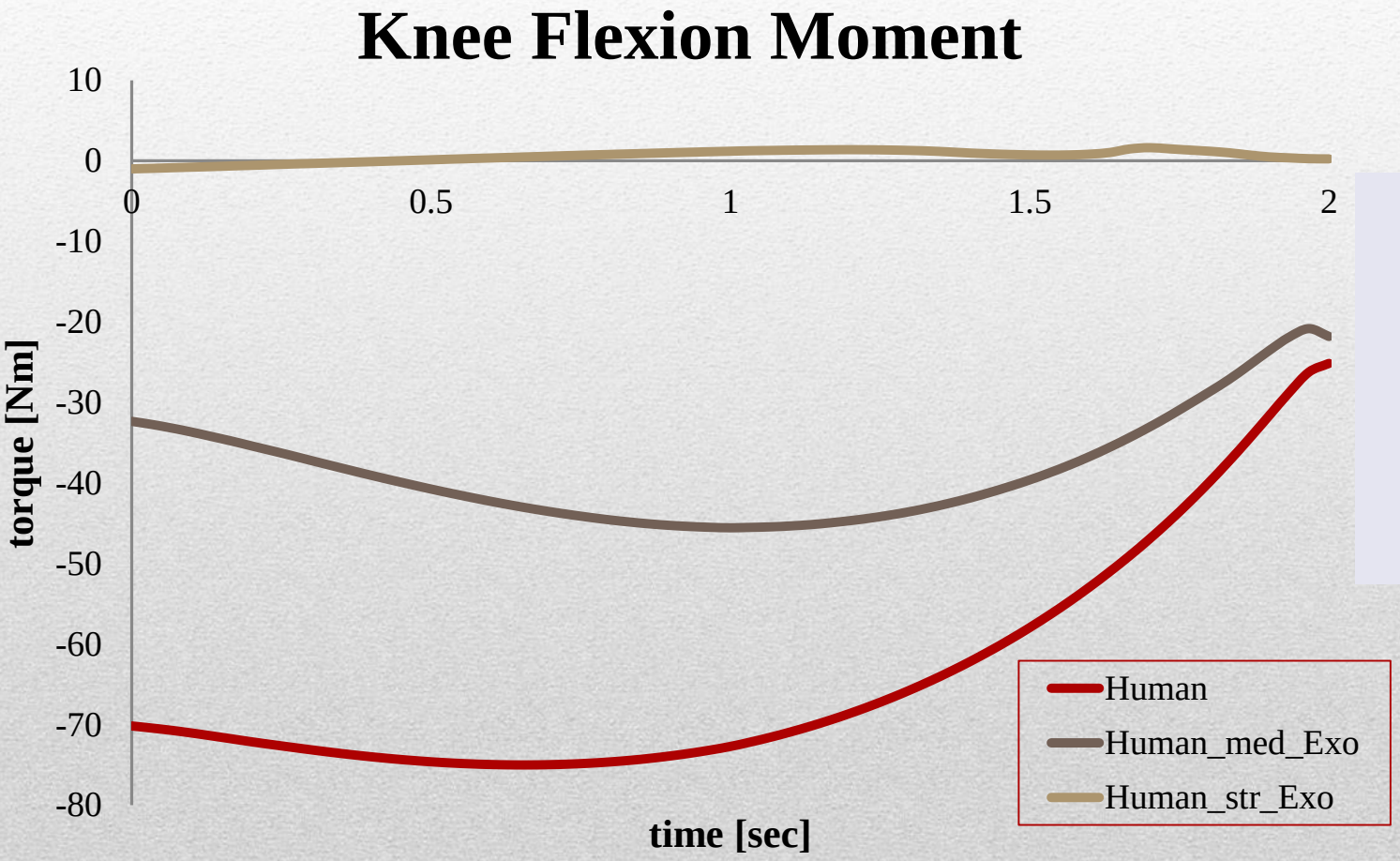


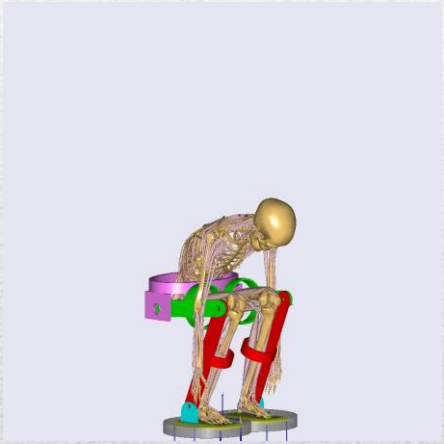
Results in Human



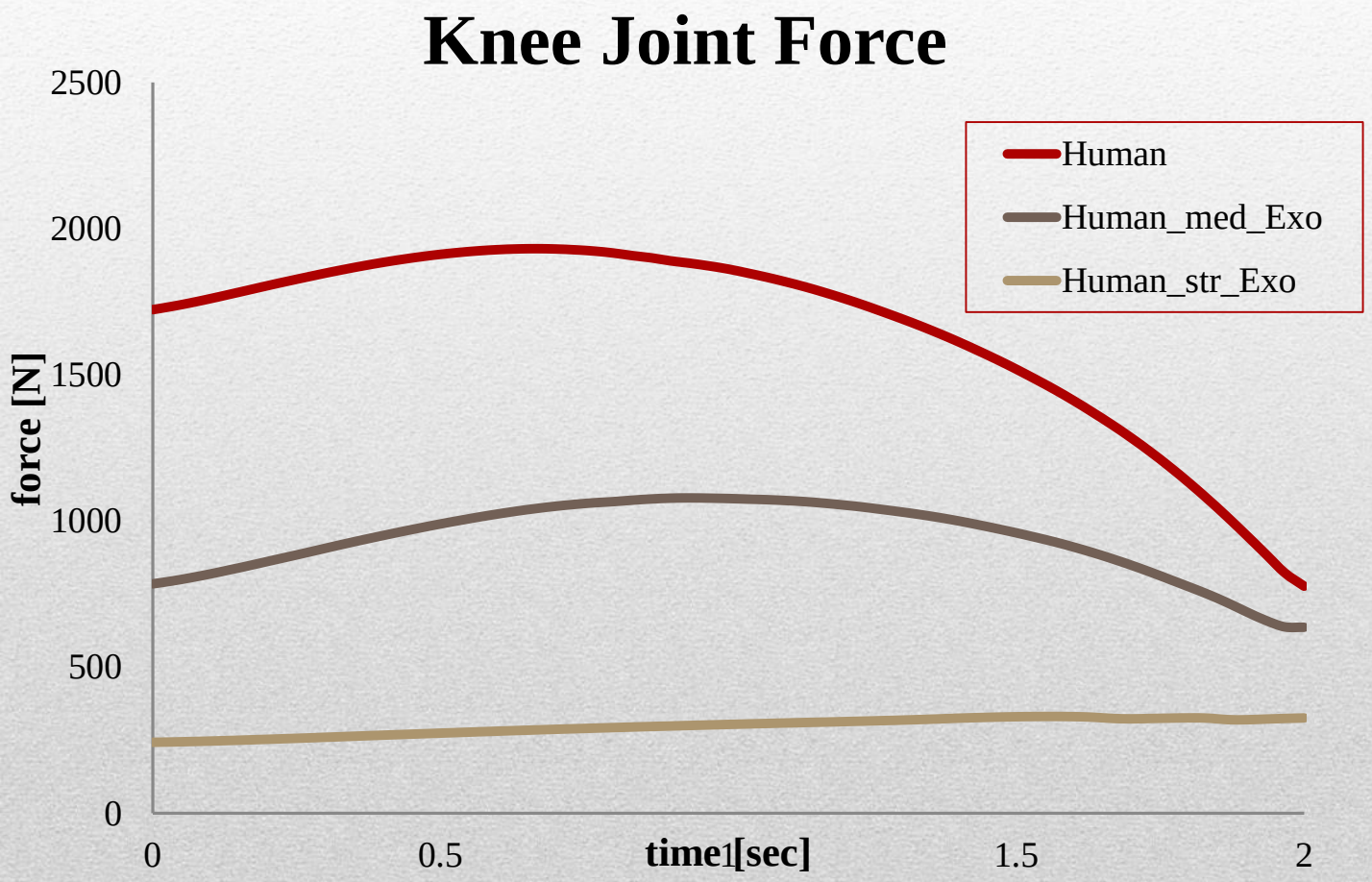


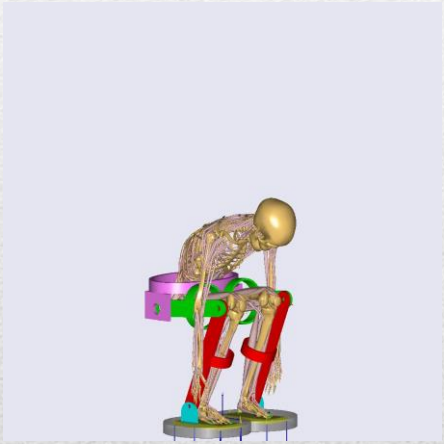
Results in Human





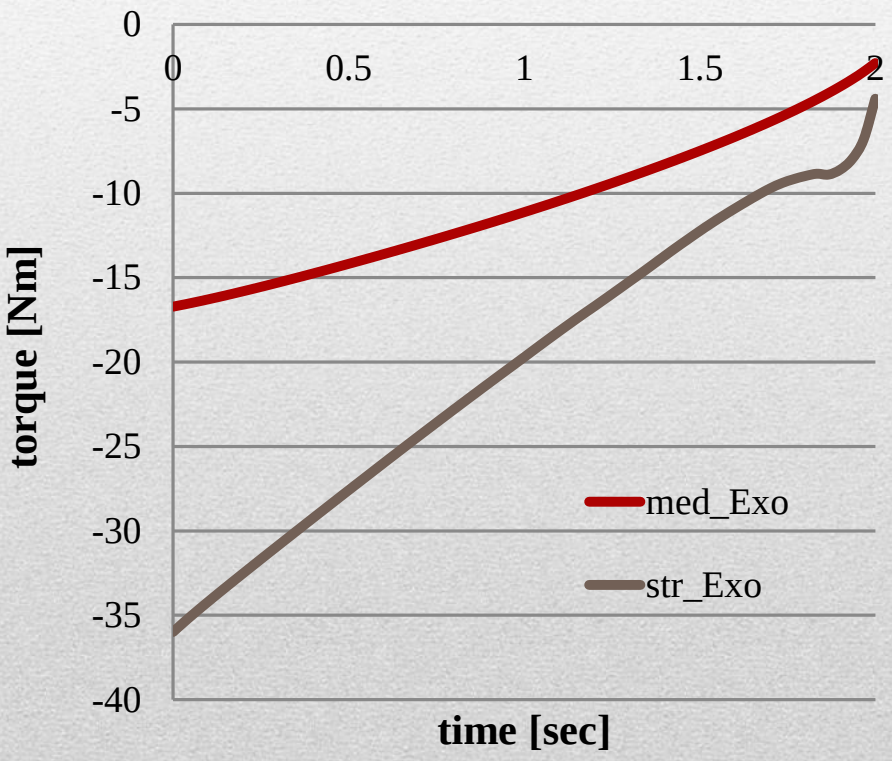
Results in Human



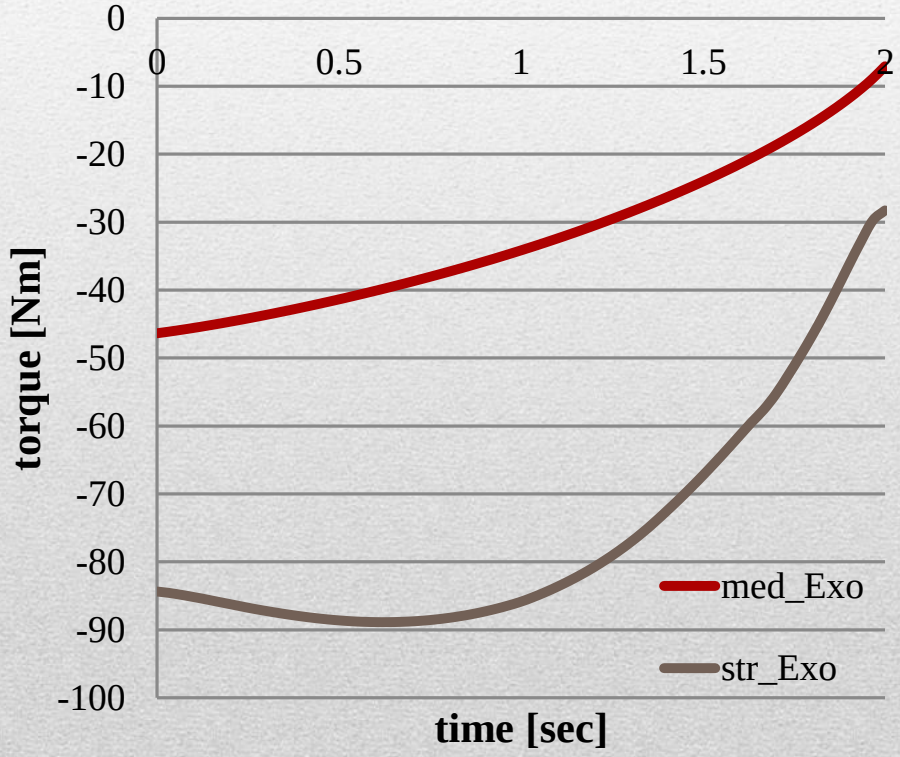


Results in Exoskeleton

Hip Actuator Moment

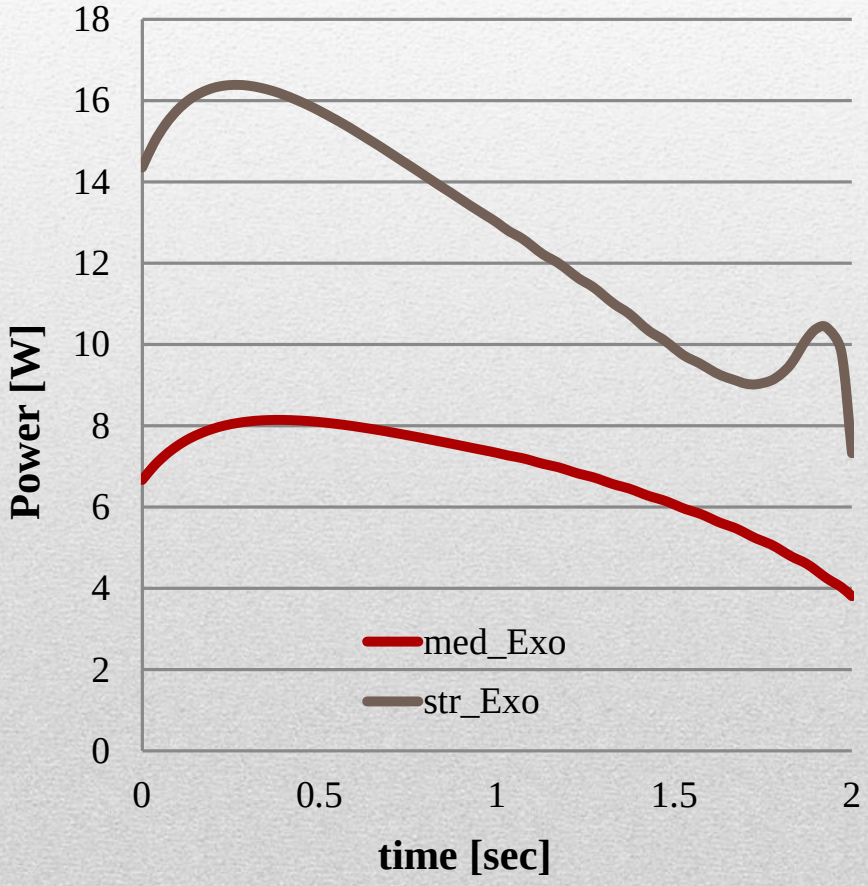


Knee Actuator Moment

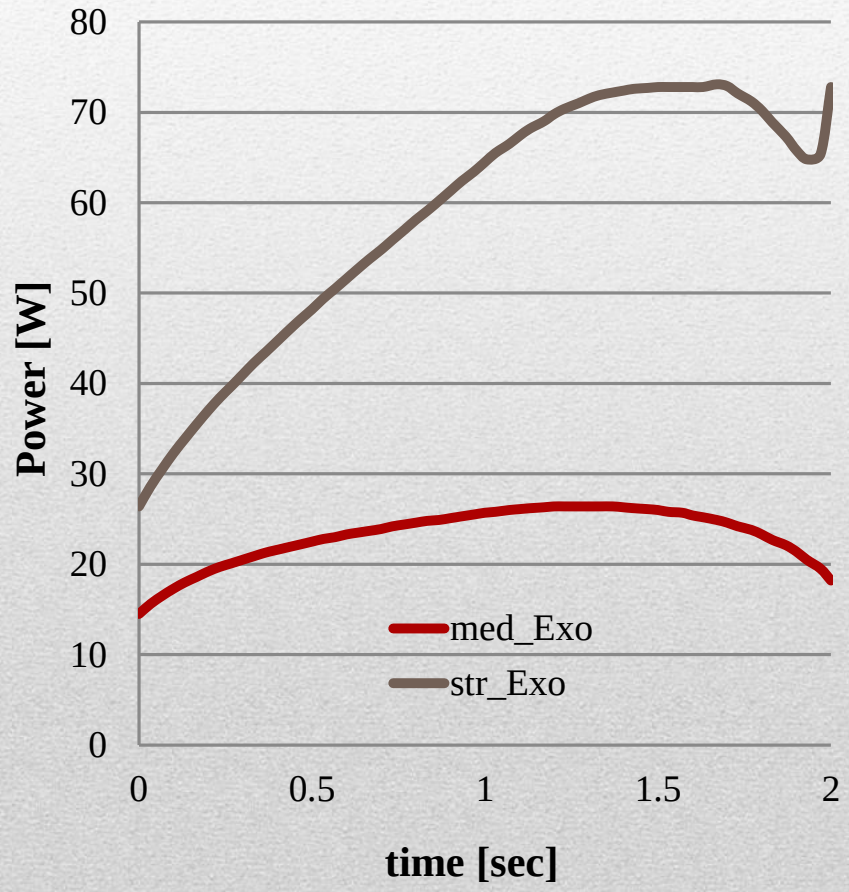


Results in Exoskeleton

Hip Actuator Power

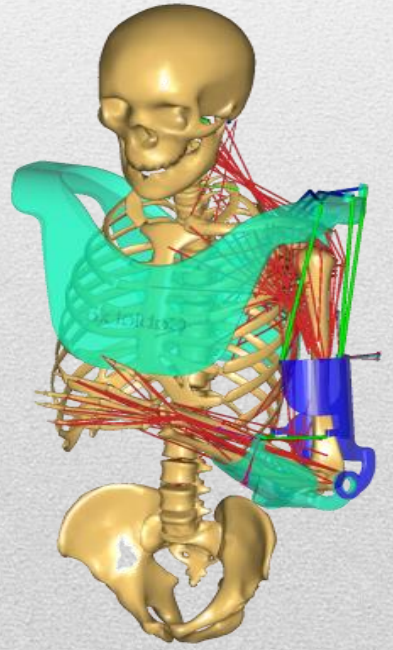


Knee Actuator Power

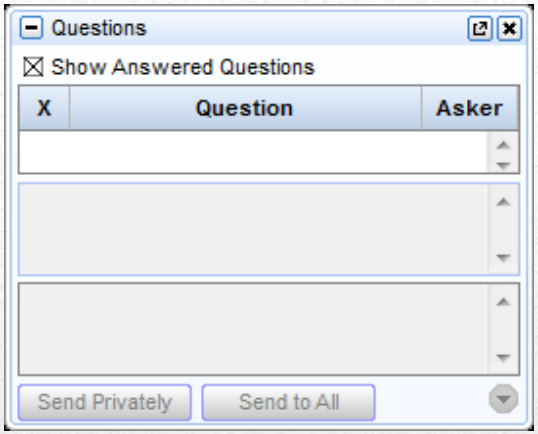


Conclusion

- AnyBody simulation can help during
  - development of exoskeleton (Optimize key parameters)
  - evaluation of exoskeleton (effect on human body)
- How to fix the exoskeleton to human body?
  - Rigid
  - Elastic springs (force dependent kinematics)
- A lot more possibilities:
  - Healthy subjects or Patients
  - Single muscle activations
  - Metabolic / Mechanical Power
  - ...



- You can write your questions in the Q&A panel.



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- Meet us at:
  - 11-15 March: ORS/AAOS: New Orleans, USA
  - 2 April: AnyBody Intro Event, Regensburg, Germany
  - 8 April: Webcast – lumbar spine
- www.anybodytech.com
  - Events, dates, publication list, ...
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