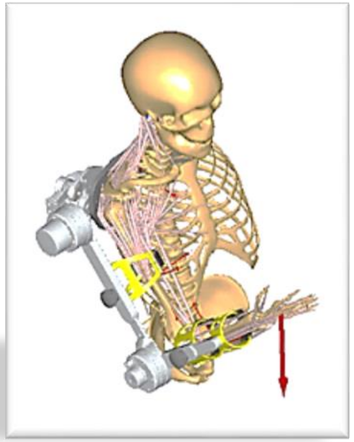
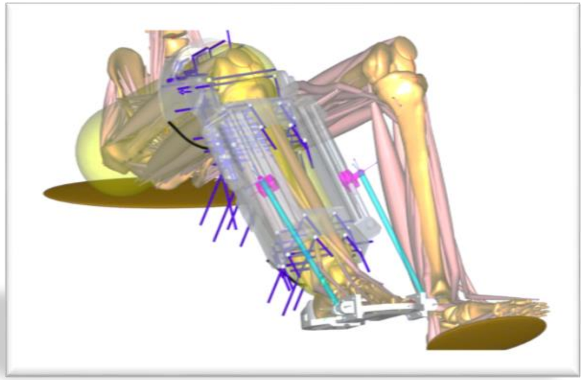




Assistive Devices: Simulating physiological performance

MOHAMMAD S. SHOURIJEH, PHD, R&D ENGINEER

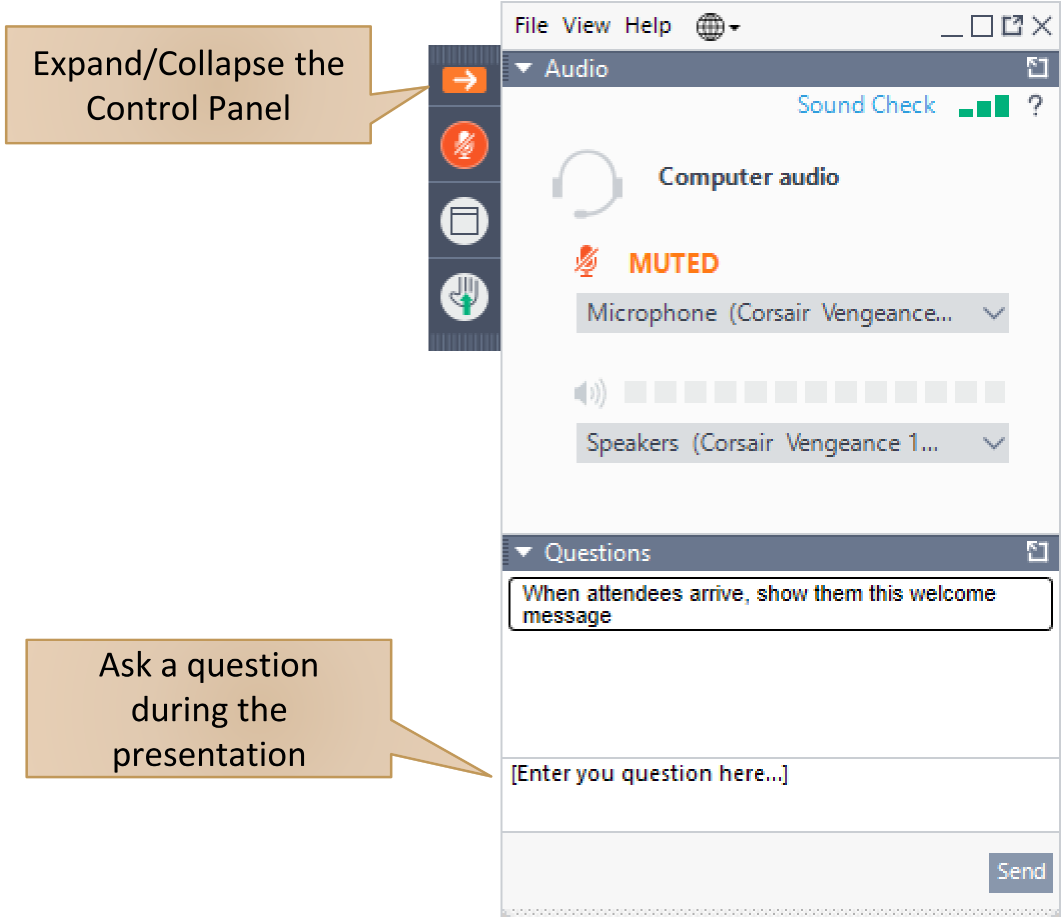
ANYBODY TECHNOLOGY, AALBORG, DENMARK

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.*



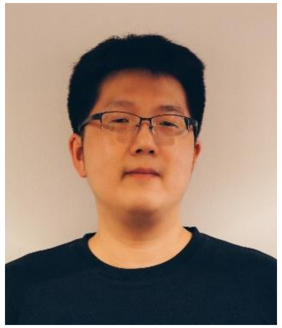
Outline

- Introduction to musculoskeletal modeling with AnyBody
- Physiological design/evaluation criteria of exoskeletons
  - Examples
  - Parametric study
- Final words and Q&A session

Presenter

Mohammad S. Shourijeh
PhD, R&D Engineer,
AnyBody Tech.
mss@anybodytech.com

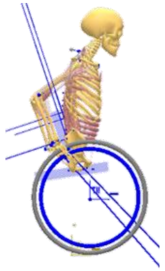
Moderator



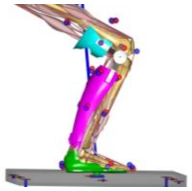
Moonki Jung, PhD
Sr. Application Engineer,
AnyBody Tech.
mj@anybodytech.com

For what we need musculoskeletal modeling

Gait Analysis
AnyGait

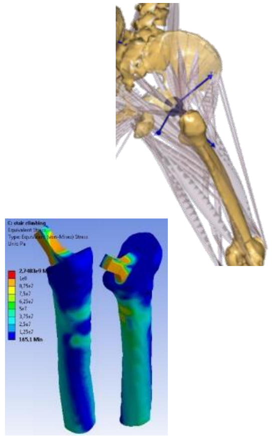


Product Design
Optimization



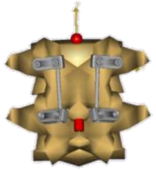
Ergonomic
Analysis

ANYBODY
Modeling System

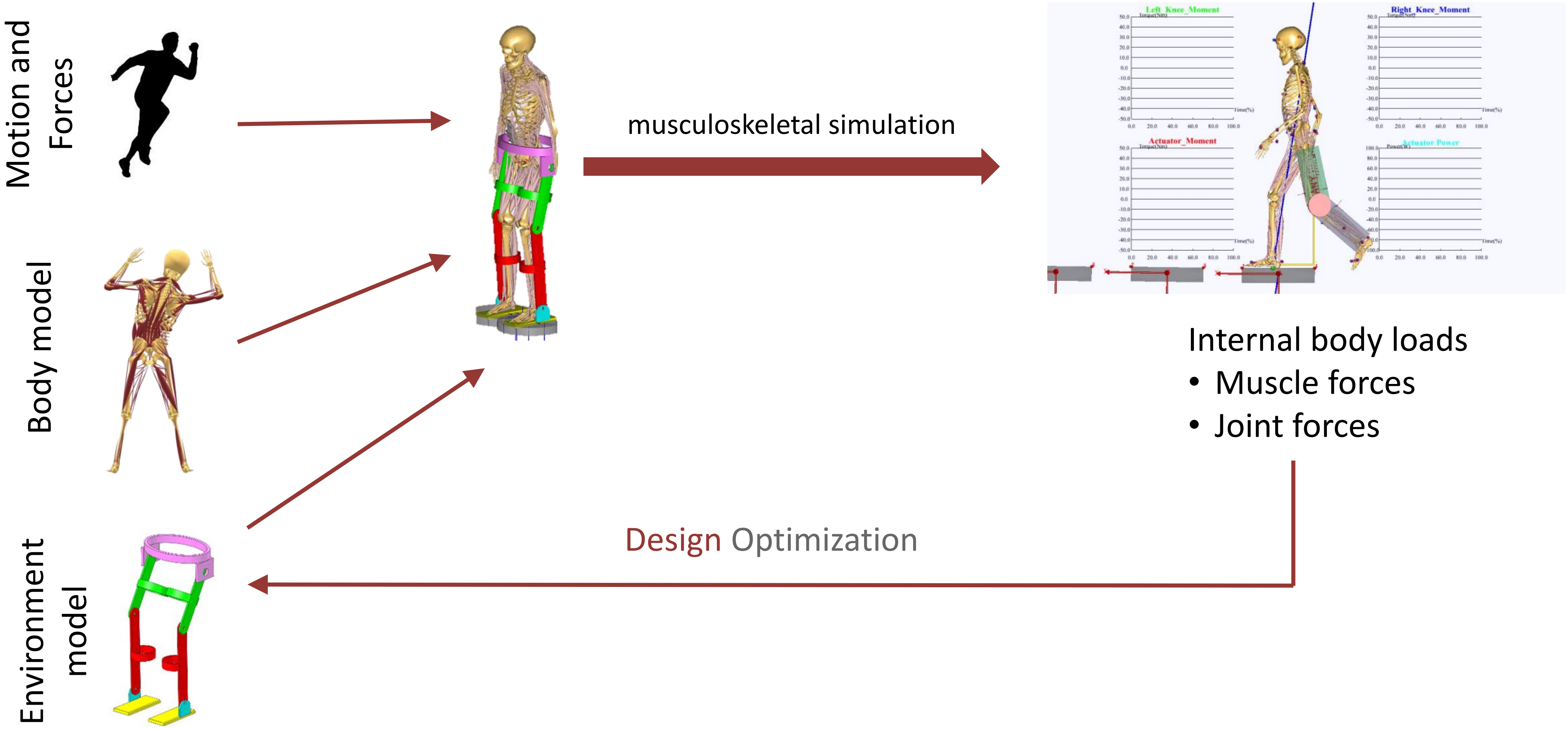


Load Cases for
Finite Element
Analysis

Surgical Planning and
Outcome Evaluation

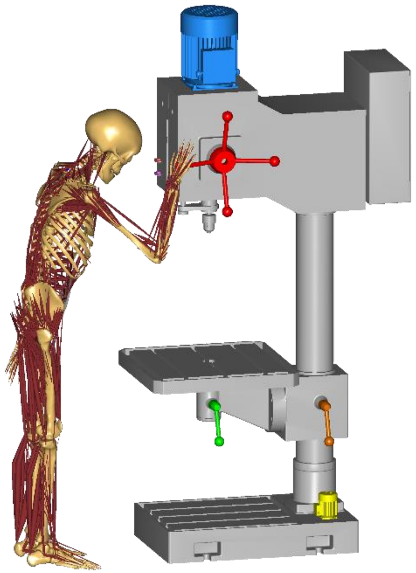


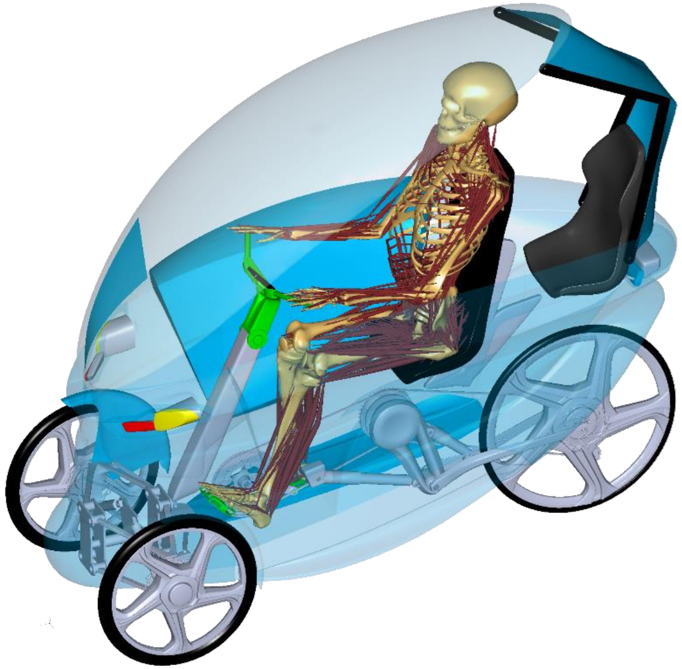
AnyBody Modeling System



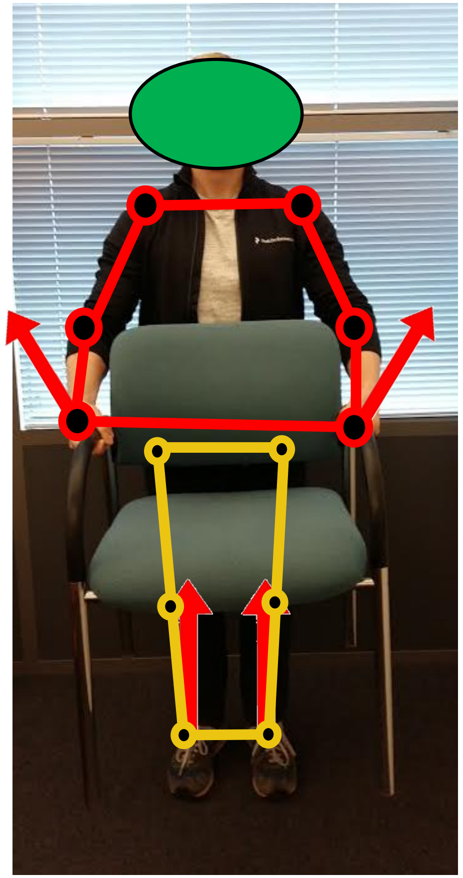
Machine Design and Optimization

- AnyBody Exporter for SOLIDWORKS®
  - Plugin for SolidWorks
  - Export your machine's design from SolidWorks
  - Run Man-Machine simulations

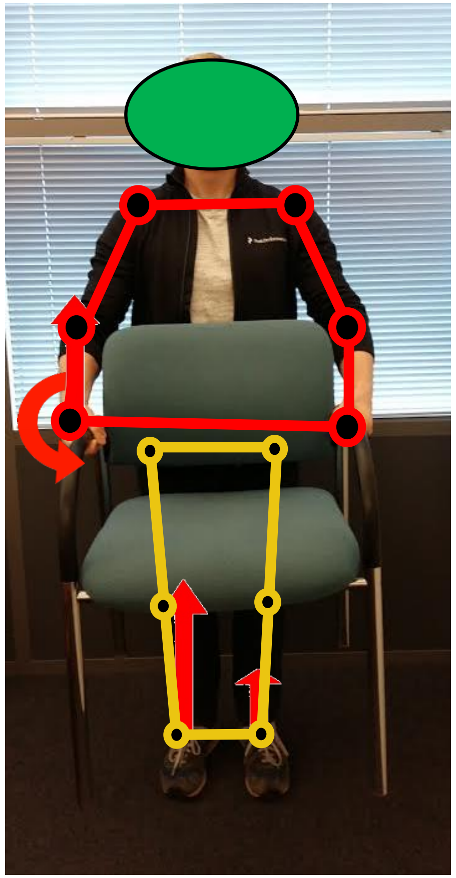




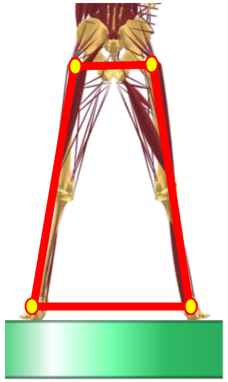
Body-Device Closed Kinematic Chains

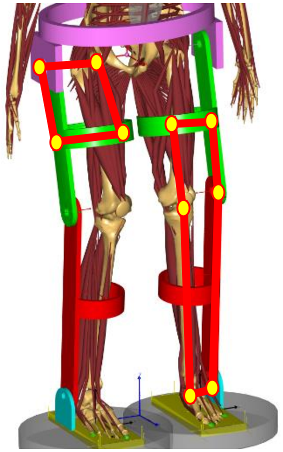


- Measure kinematics ONLY
- Infinite possibilities for
  - Joint moments
  - Muscle forces
  - Interaction forces

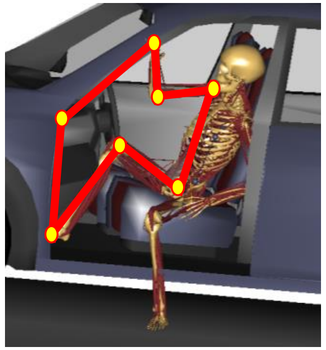


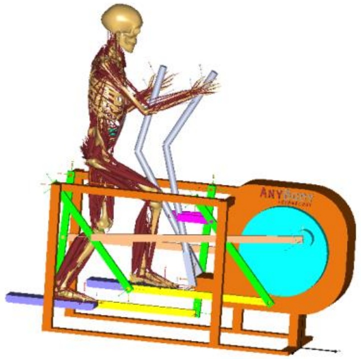
Body-Device Closed Kinematic Chains





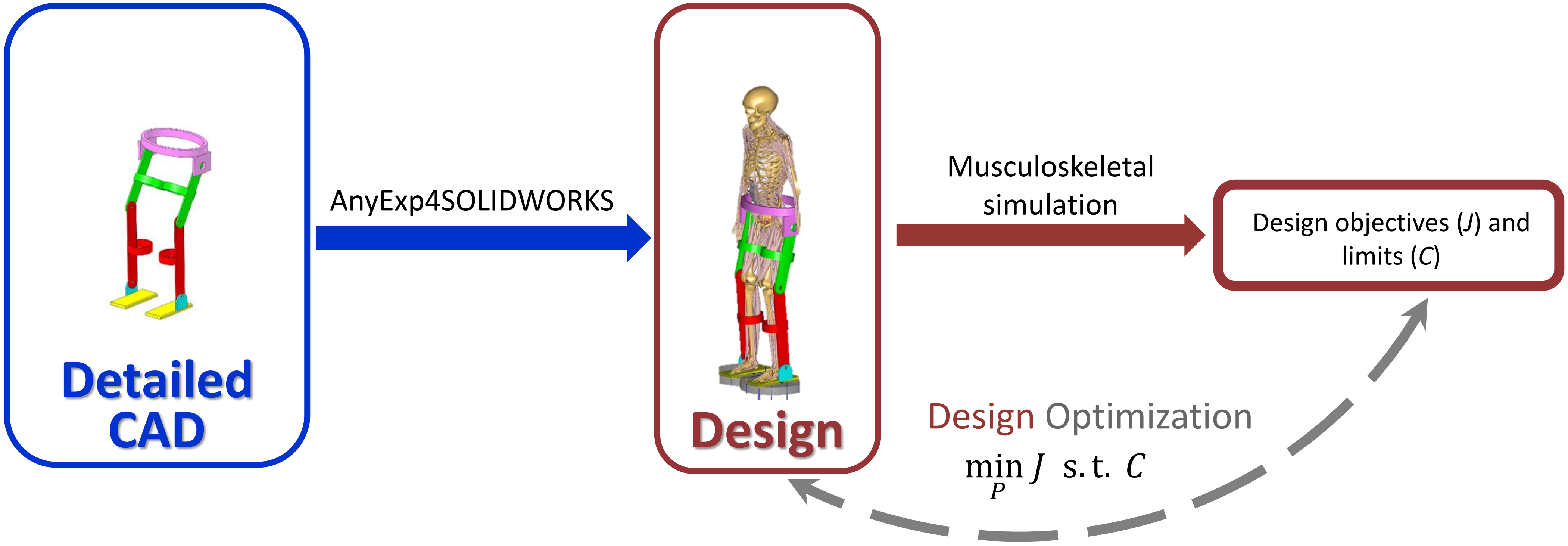
- Inverse Dynamics with Joint Coordinates
  - Leads to extra effort for closed loops
  - Might not be able to access reaction forces instantly
- AnyBody Inverse Dynamics (Cartesian Coordinates)
  - Full dynamic detail
  - Handles closed kinematic chains





- Control of Man-Machine interaction forces
  - Contact forces on the human
  - Control of normal and shear forces (e.g. how tight the straps are)

Design framework



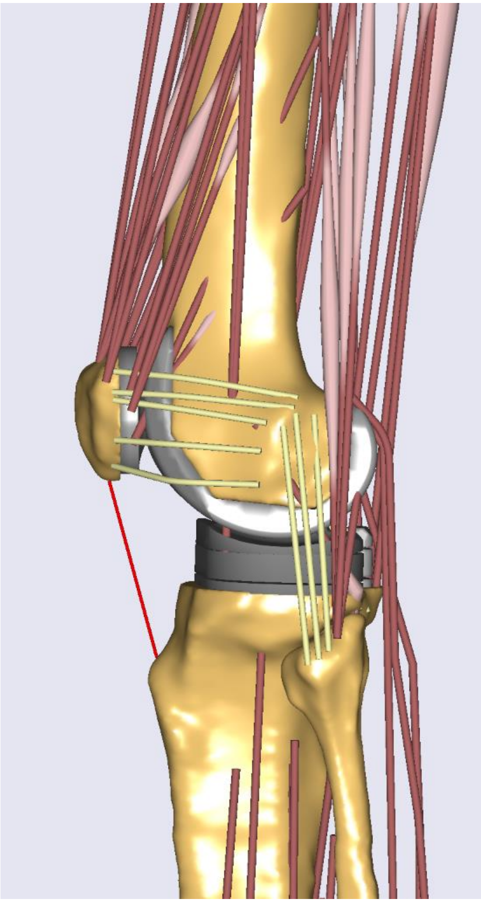
Physiological objectives

- Metabolic cost
  - What about individual muscles?
  - What about joints?
  - Cause-effect?

Physiological objectives

- Metabolic cost

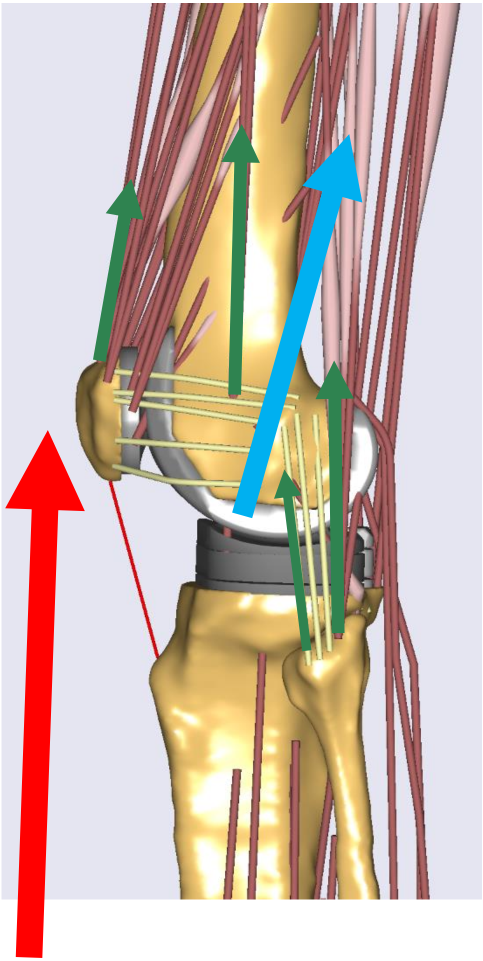
- Activation effort
    - How to combine individual quantities?

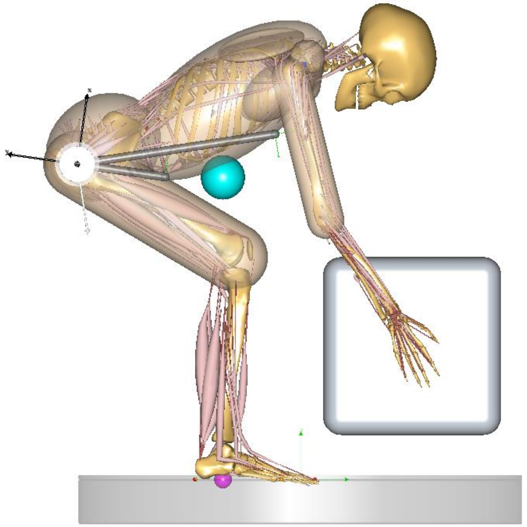


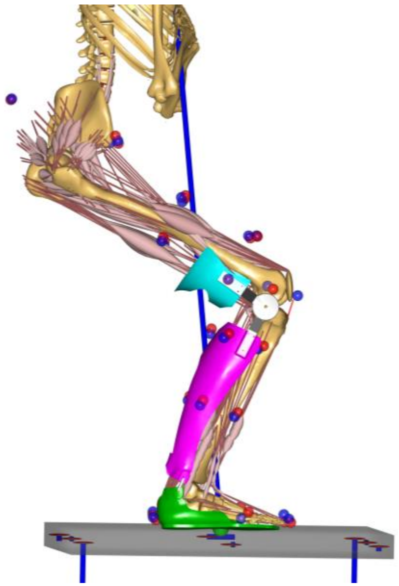
Physiological objectives

- Metabolic cost
- Activation effort
  - How to combine individual quantities?
- Joint reaction force
  - How to combine individual quantities?

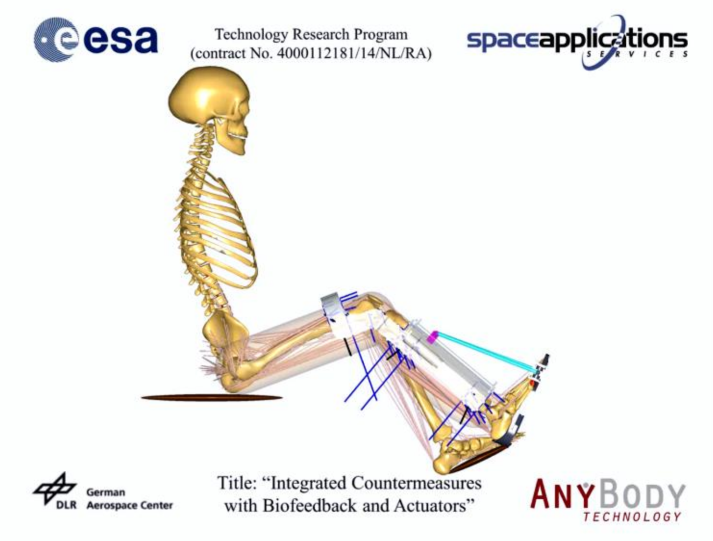
- Muscle and ligament forces
- Net ground reaction force
- Net joint reaction force

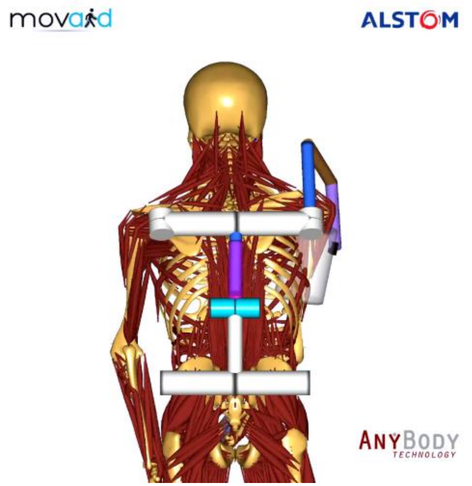


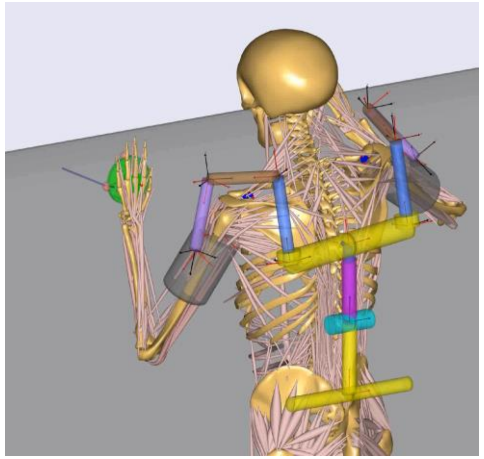




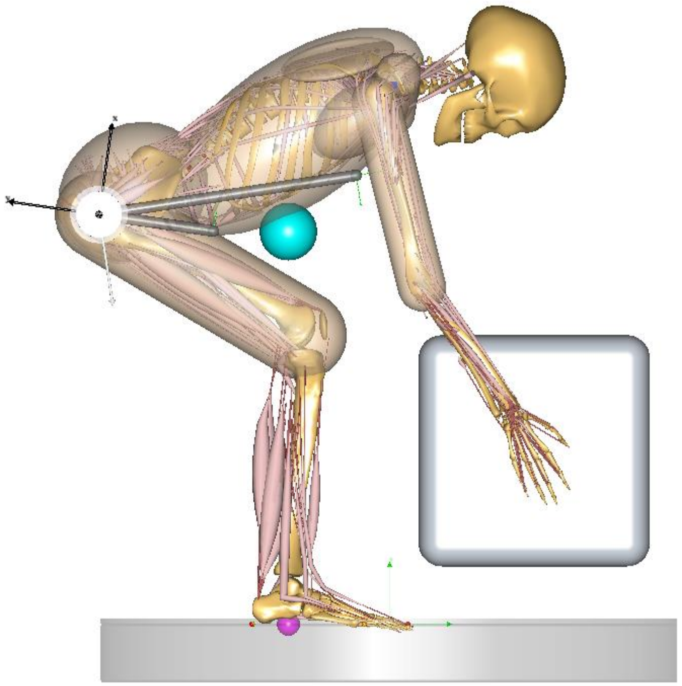
Examples:

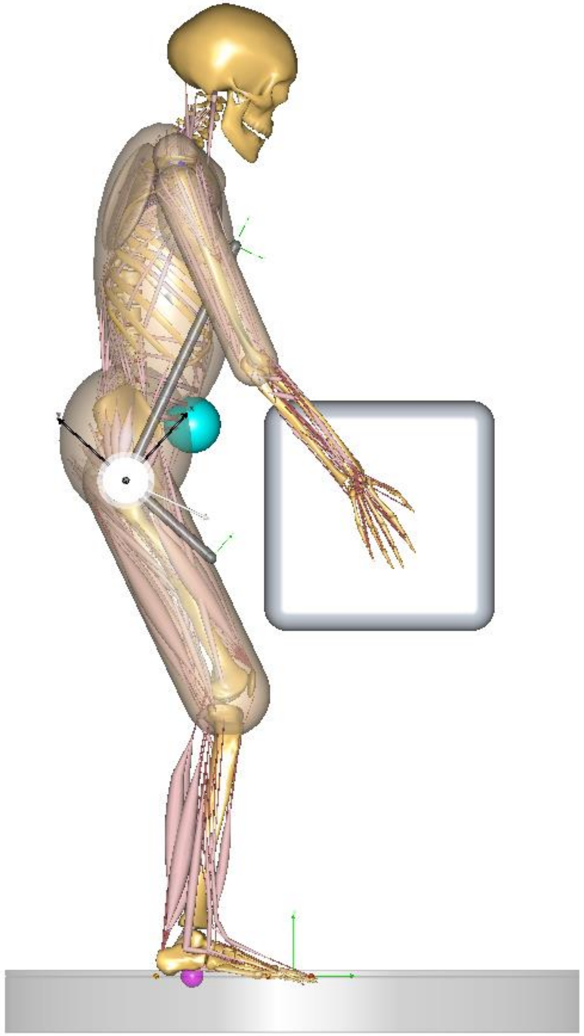

esa
Technology Research Program
(contract No. 4000112181/14/NL/RA)
spaceapplications
SERVICES
DLR
German Aerospace Center
Title: "Integrated Countermeasures
with Biofeedback and Actuators"
ANYBODY
TECHNOLOGY


movaid
ALSTOM
ANYBODY
TECHNOLOGY



Femur-Thorax Flexion/Extension Support





Box-lifting study

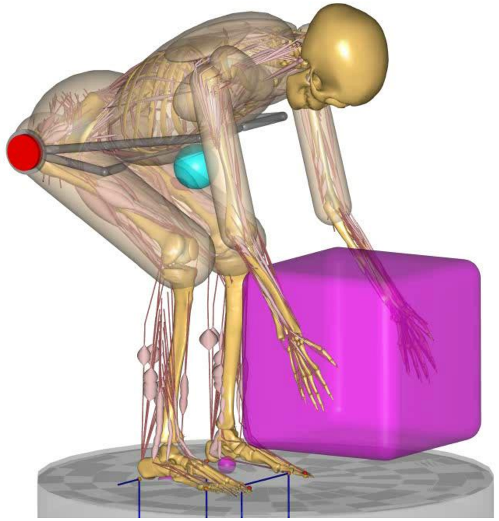
- No motion capture data used.

- Motion generated based on requirements
  - Balance – Projected net CoM lies between feet
  - Duration – 3 sec
  - Posture – Attains standing posture
  - Box motion – Polynomial trajectory in time

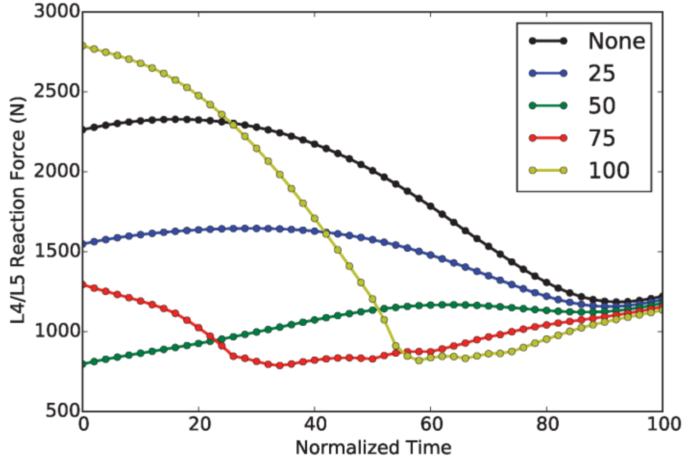
- Ground reaction forces were predicted

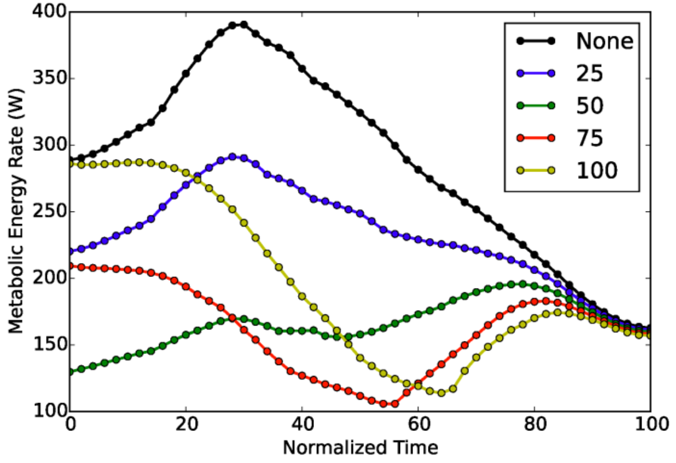
Parametric Study:
$0 \leq K \leq 100$

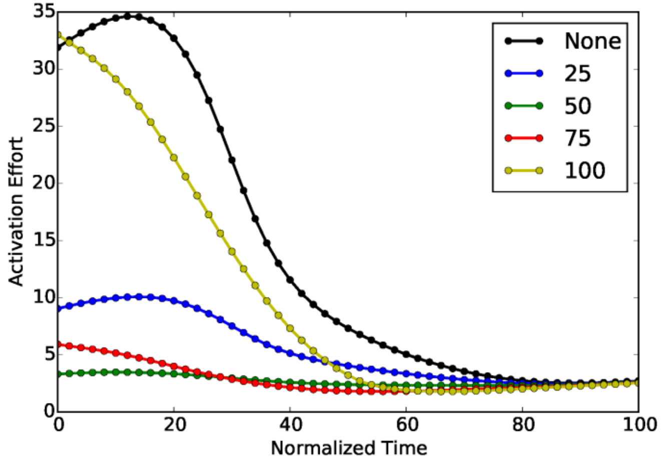
$$T_{Assist} = -\boxed{K.}(\theta - \theta_{ref})$$



Parametric Study

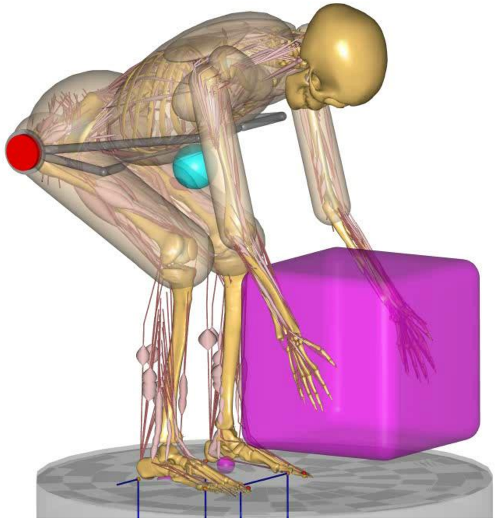




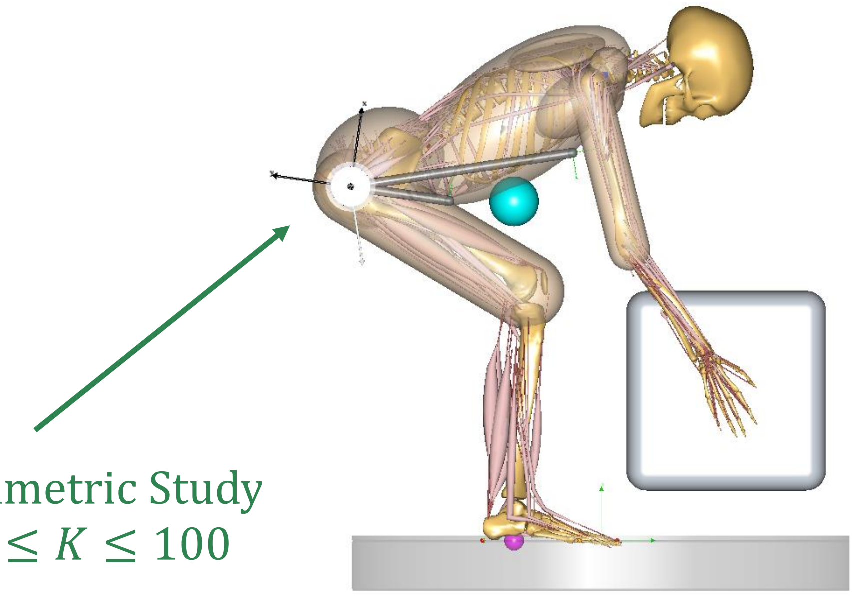


$$T_{Assist} = -\boxed{K.}(\theta - \theta_{ref})$$

Parametric Study:
$0 \leq K \leq 100$

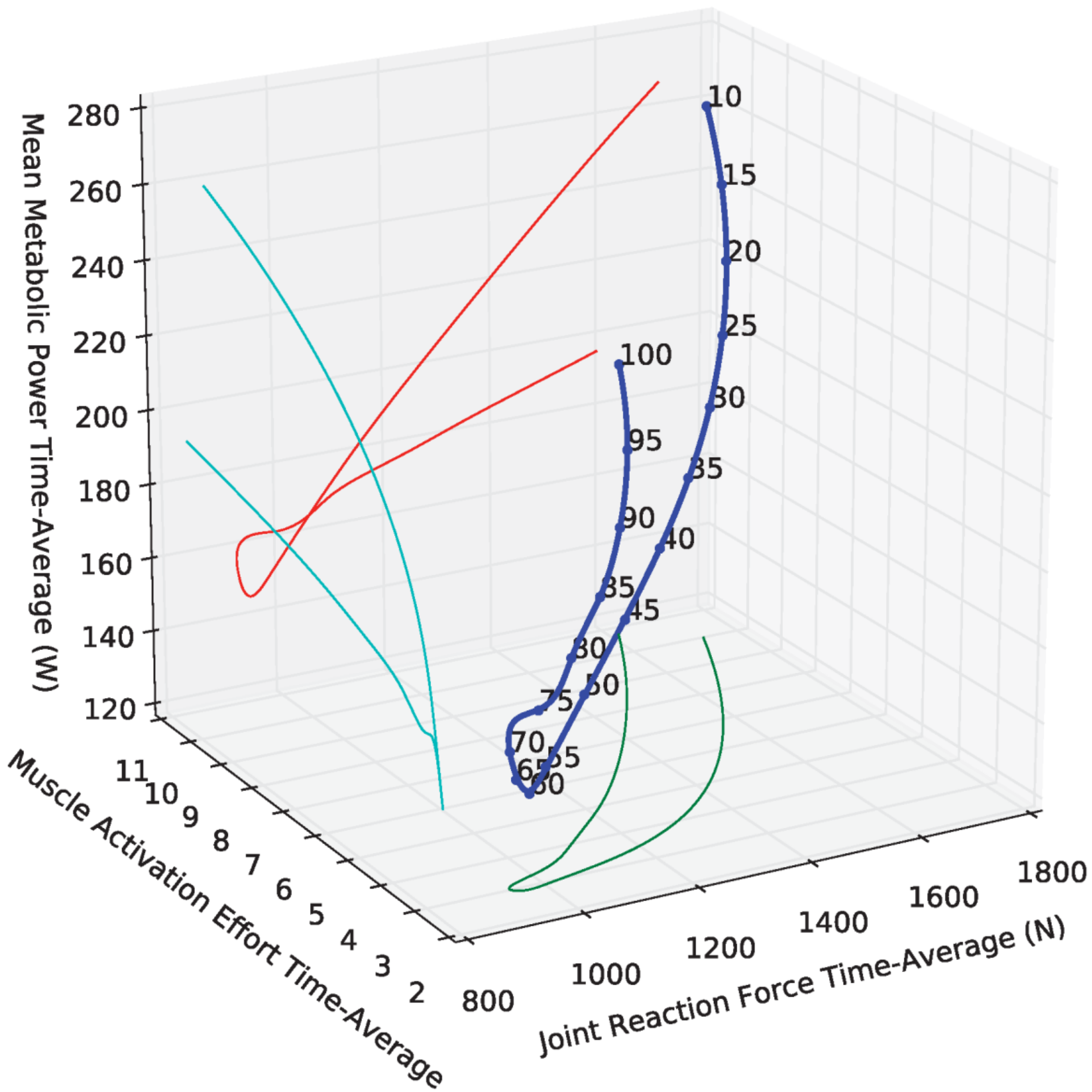


Parametric Study



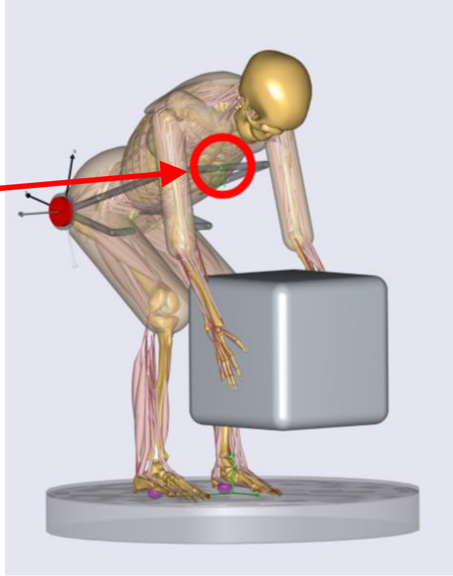
Parametric Study
$0 \leq K \leq 100$

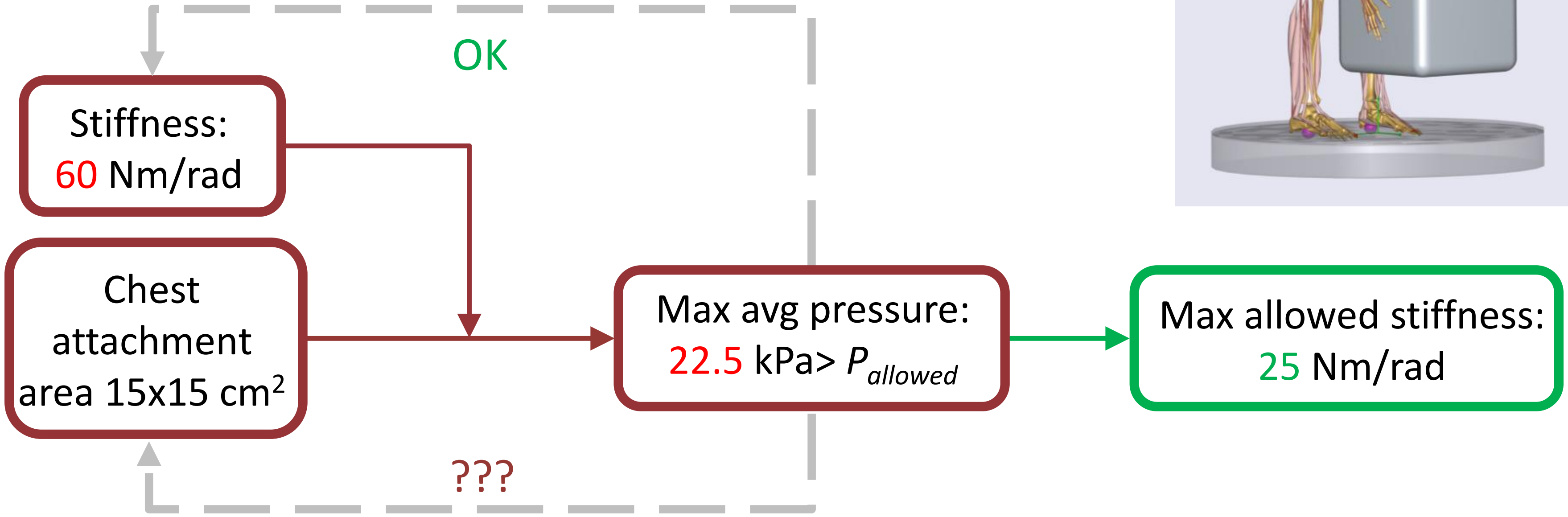
$$T_{Assist} = -\boxed{K.}(\theta - \theta_{ref})$$



Design check (iteration) with limits

- Max skin pressure $P_{allowed}$ = 70 mmHg ≈ 9.3 kPa*
- Assume chest attachment area to be 15x15 cm^2





* Lyder, C.H. Pressure Ulcer Prevention and Management. *JAMA-J. Am. Med. Assoc.* 2003

Design check (iteration) with limits

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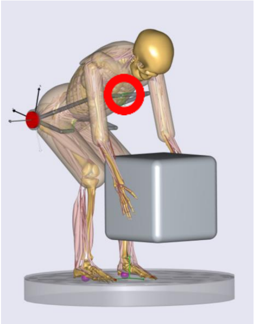
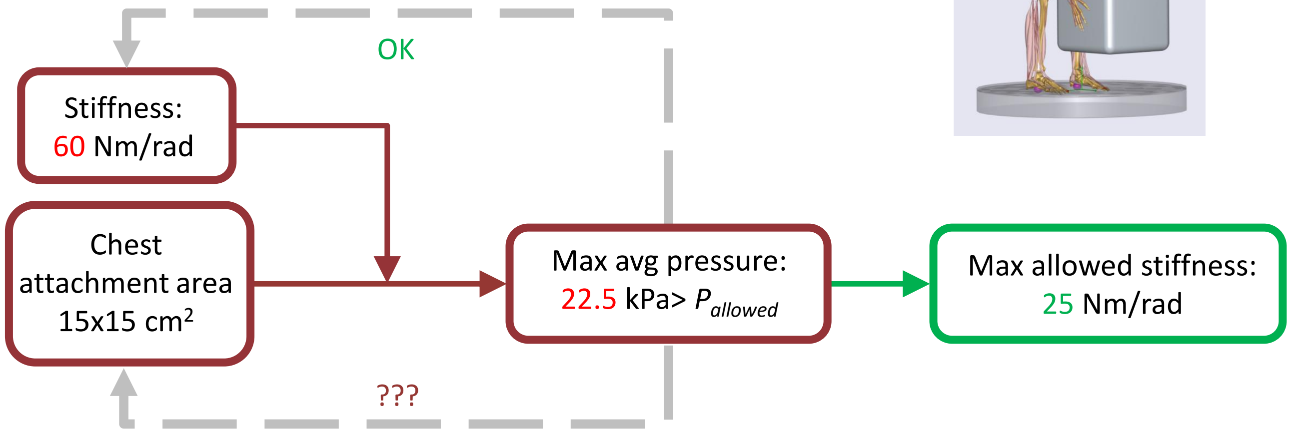
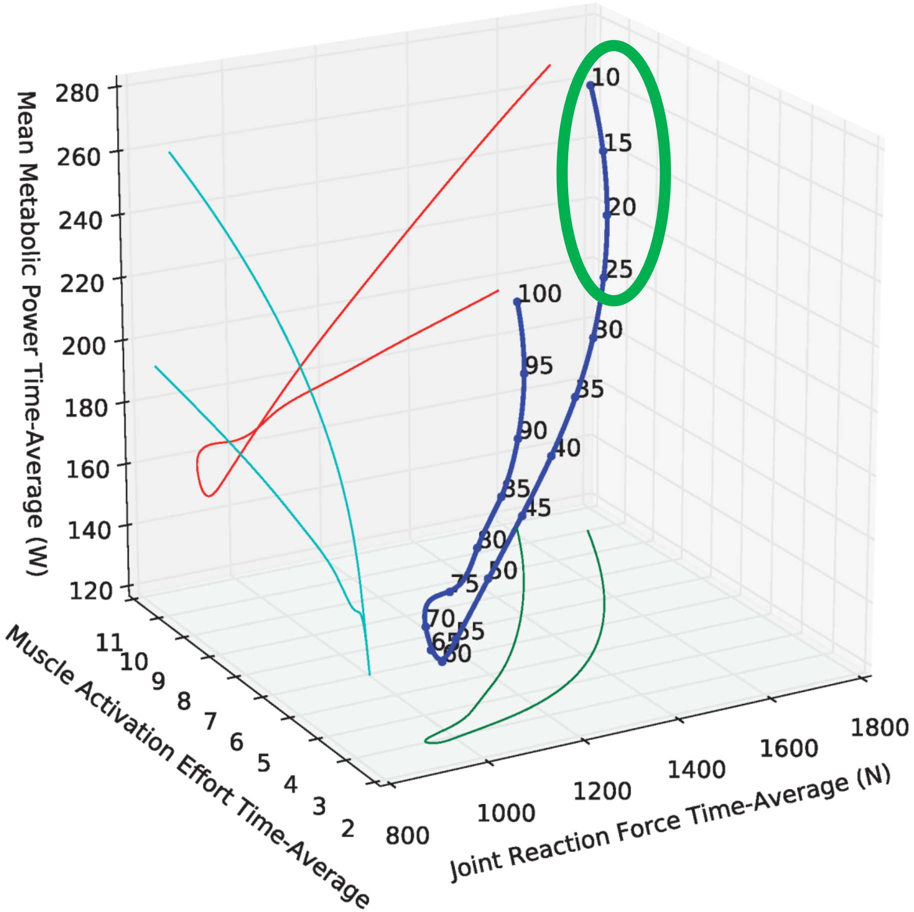
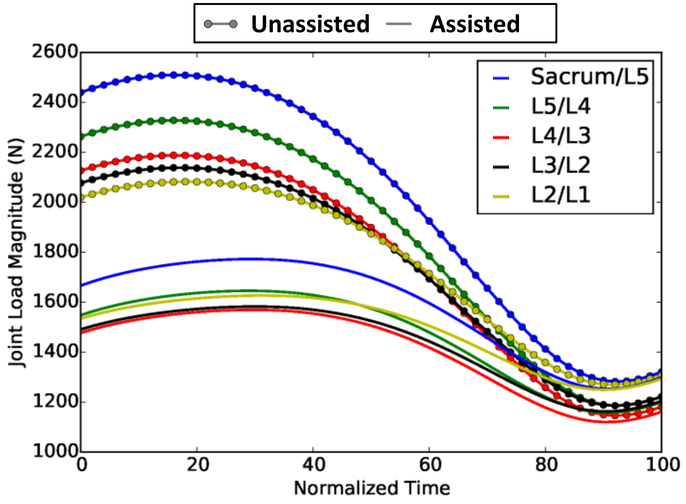
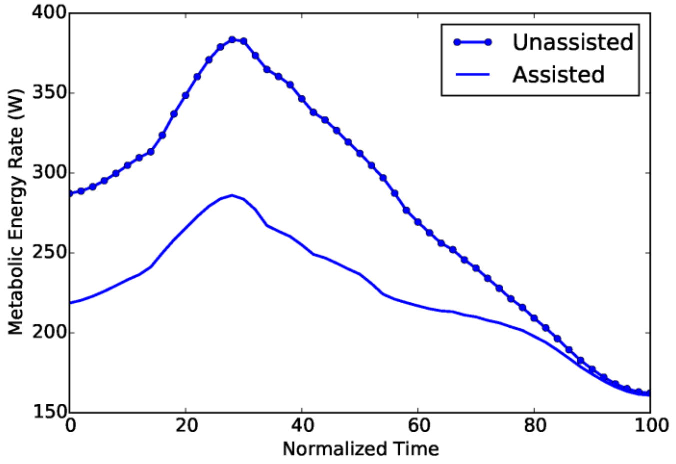


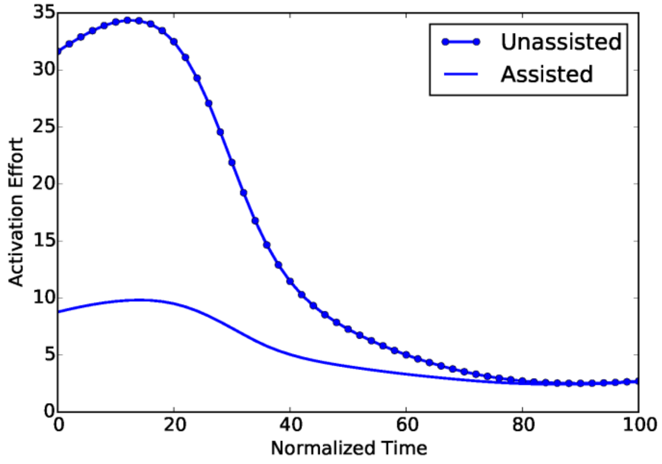




Results (25 Nm/rad)





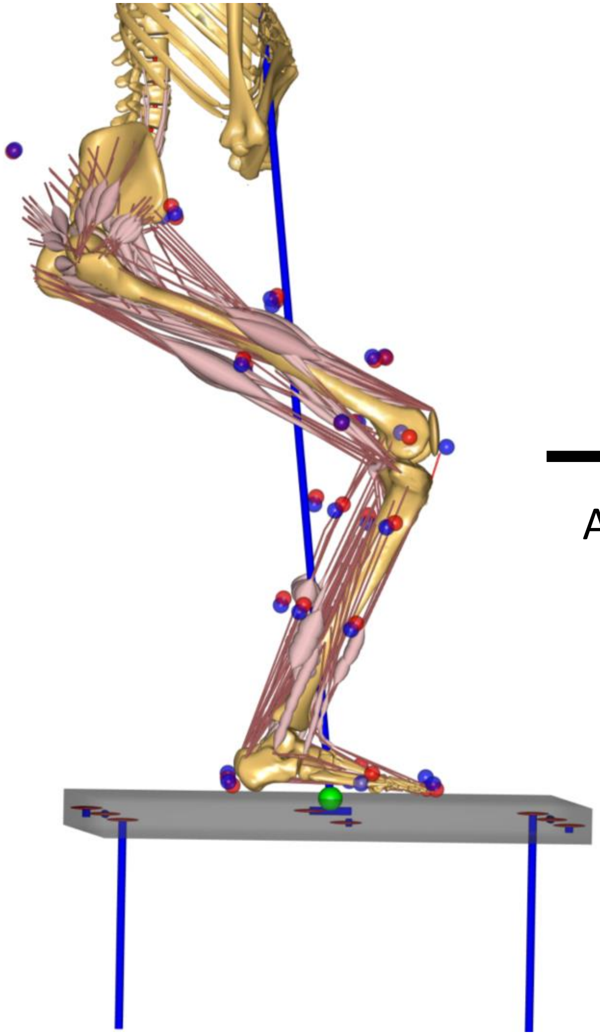


% Device Benefit	Joint Reaction (L4/L5)	Activation Effort	Metabolic Cost
Box-lifting	21.4	62.2	19.6

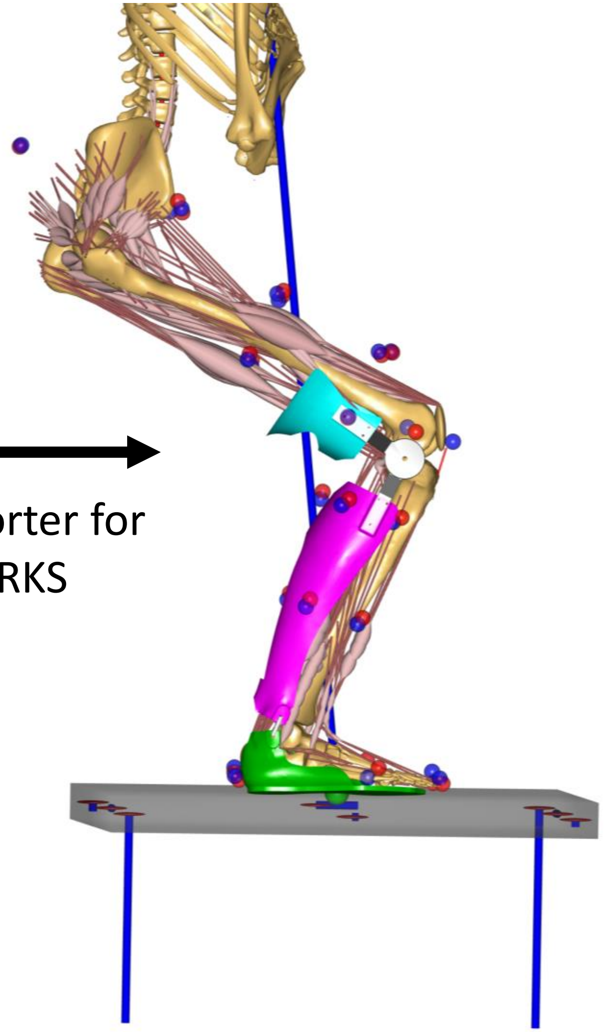
Example 2: KAFO

CAD model in SolidWorks

+

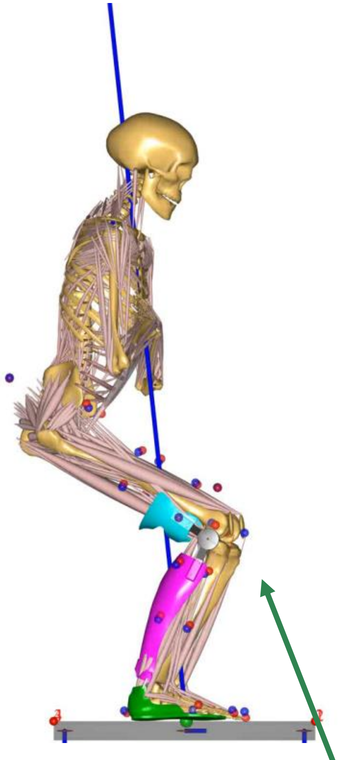


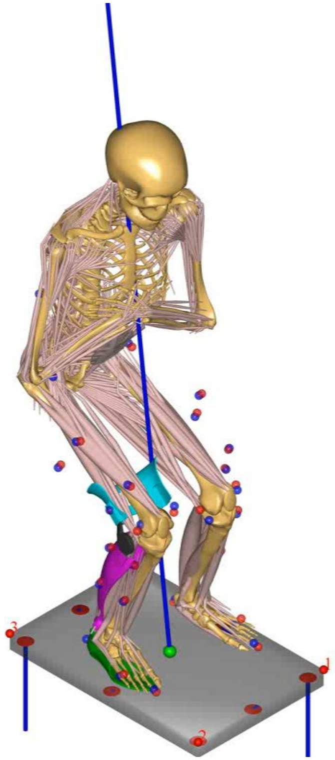
AnyBody Exporter for SOLIDWORKS



Example 2: KAFO

- Combining motion capture with exo design, using motion cameras

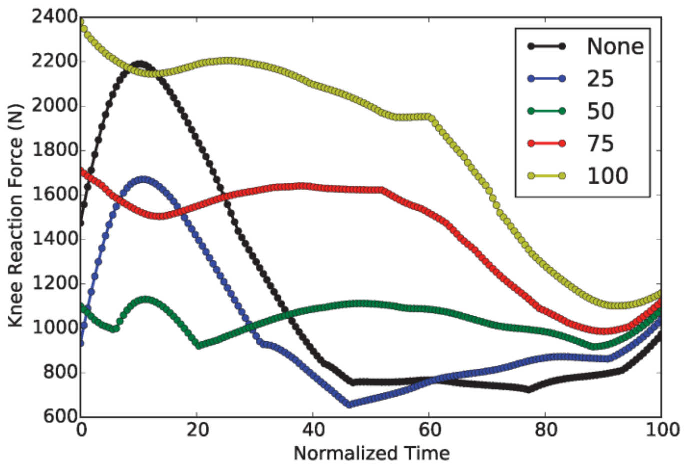


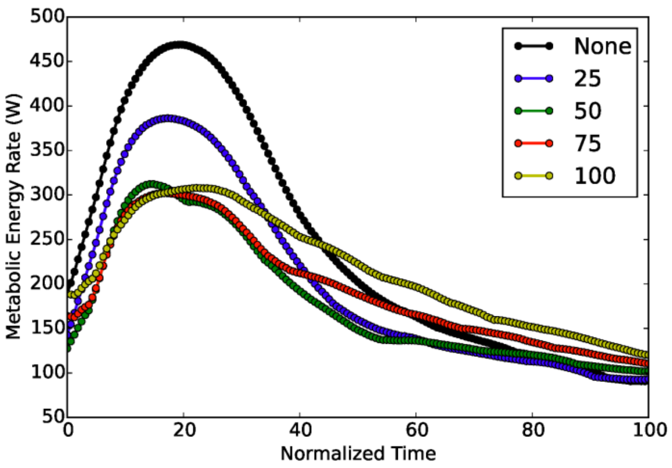


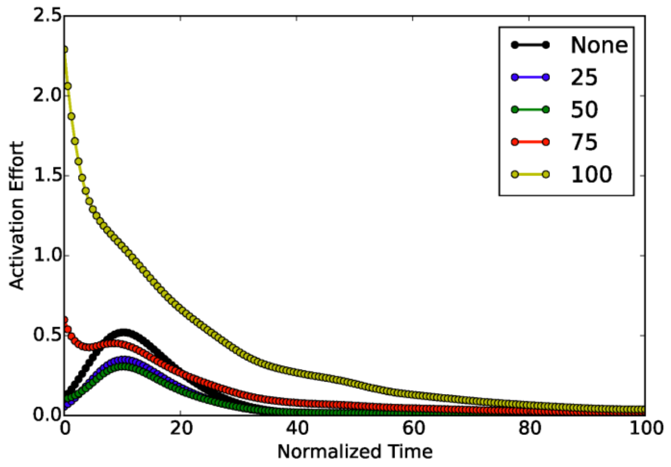
Parametric Study:
$0 \leq K \leq 100$

$$T_{Assist} = -\boxed{K.}(\theta - \theta_{ref})$$

Parametric Study



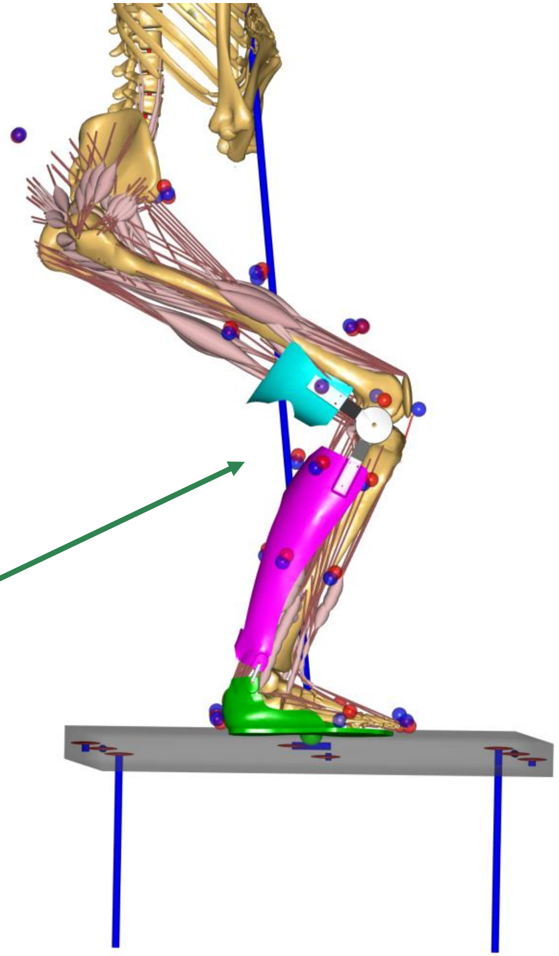




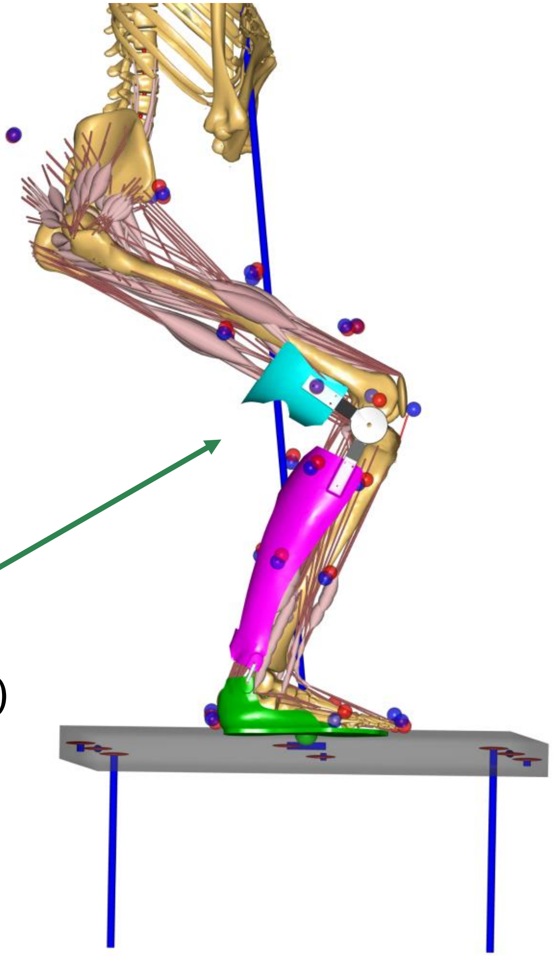
$$T_{Assist} = -\boxed{K}.(\theta - \theta_{ref})$$

Parametric Study:

$0 \leq K \leq 100$

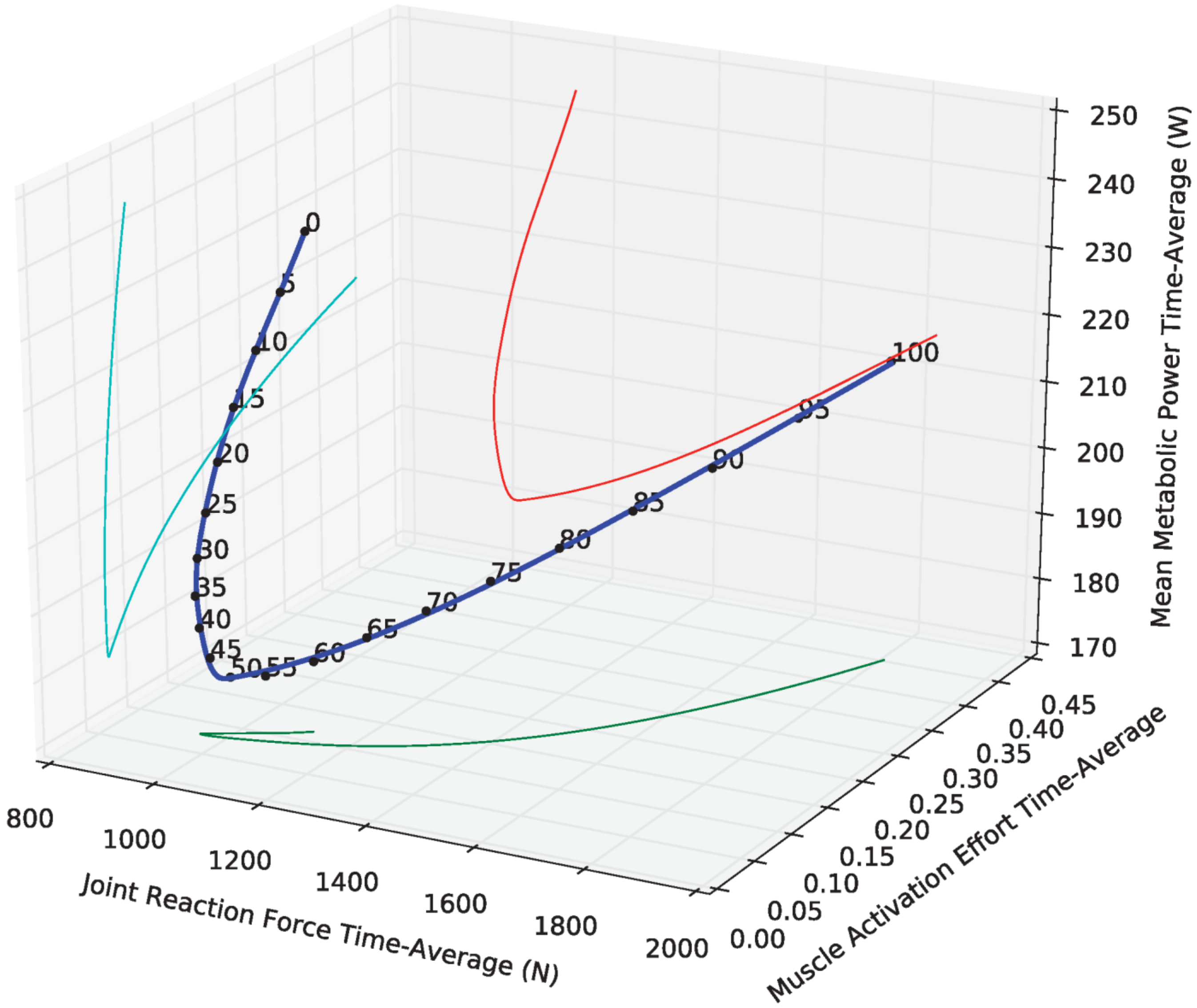


Parametric Study

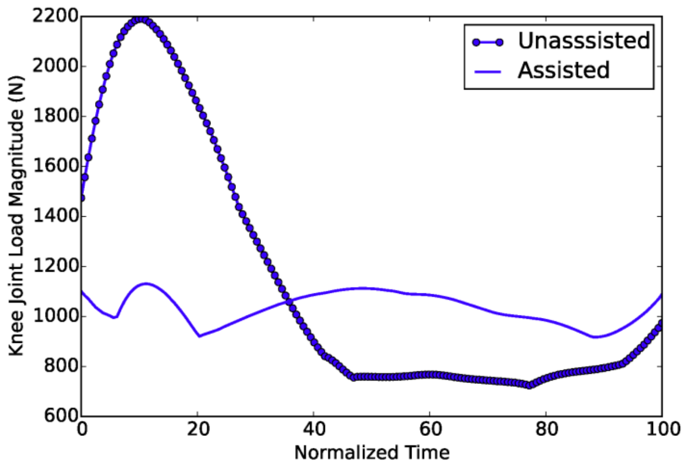


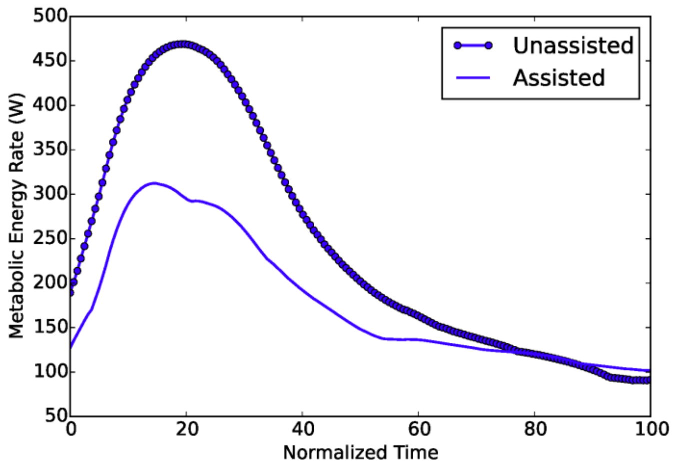
$$T_{Assist} = -\boxed{K}.(\theta - \theta_{ref})$$

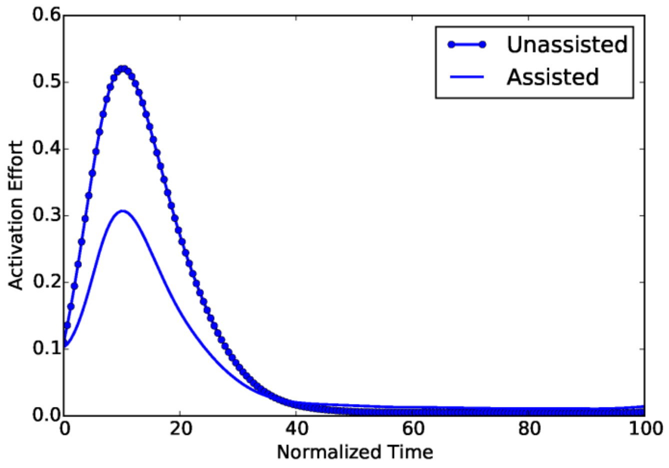
Parametric Study:
$0 \leq K \leq 100$



Optimal results

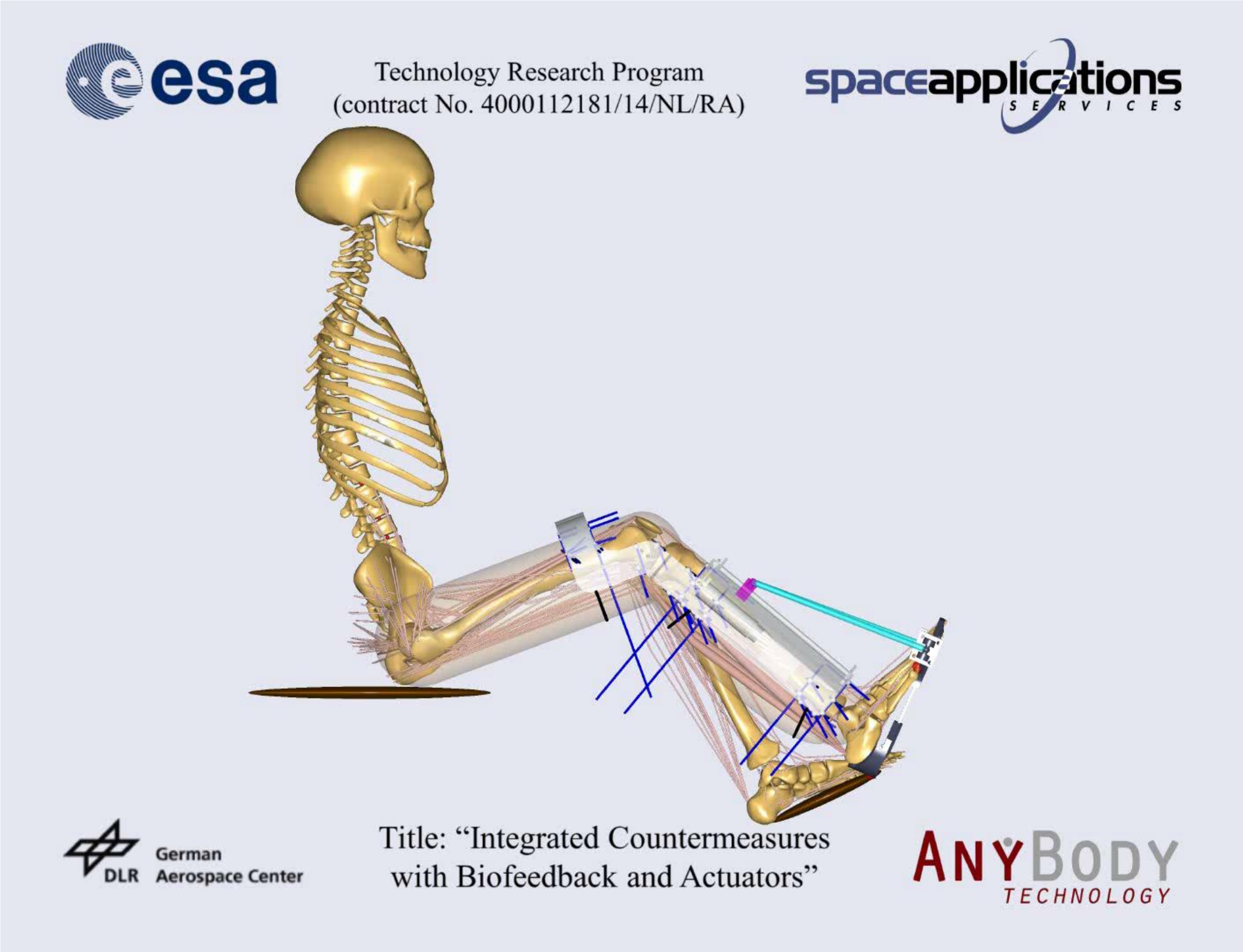






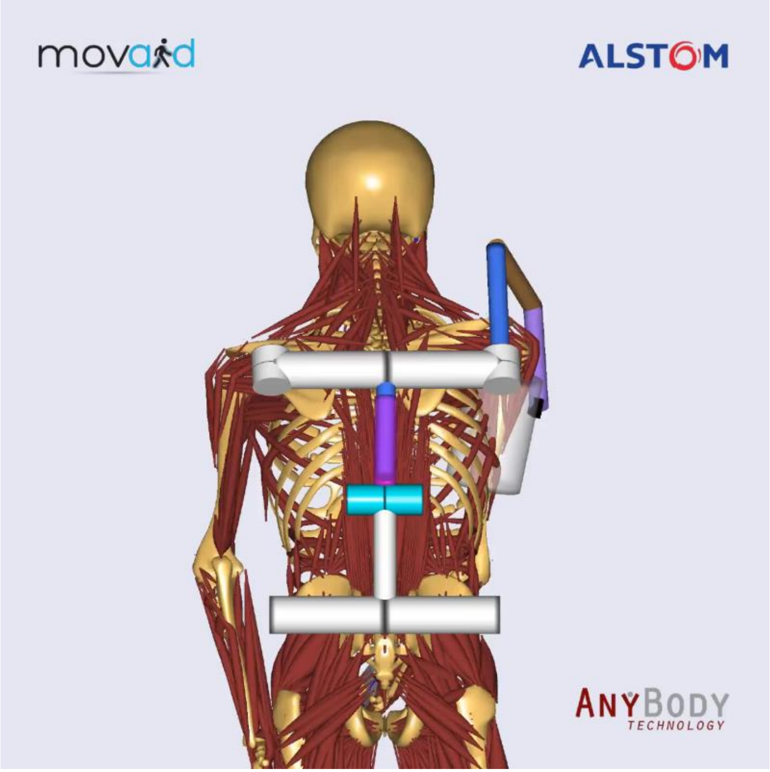
% Device Benefit	Joint Reaction (Knee)	Activation Effort	Metabolic Cost
Sit to stand	**9.2**	33.9	26.4

Example 3: Plantarflexor exercise machine

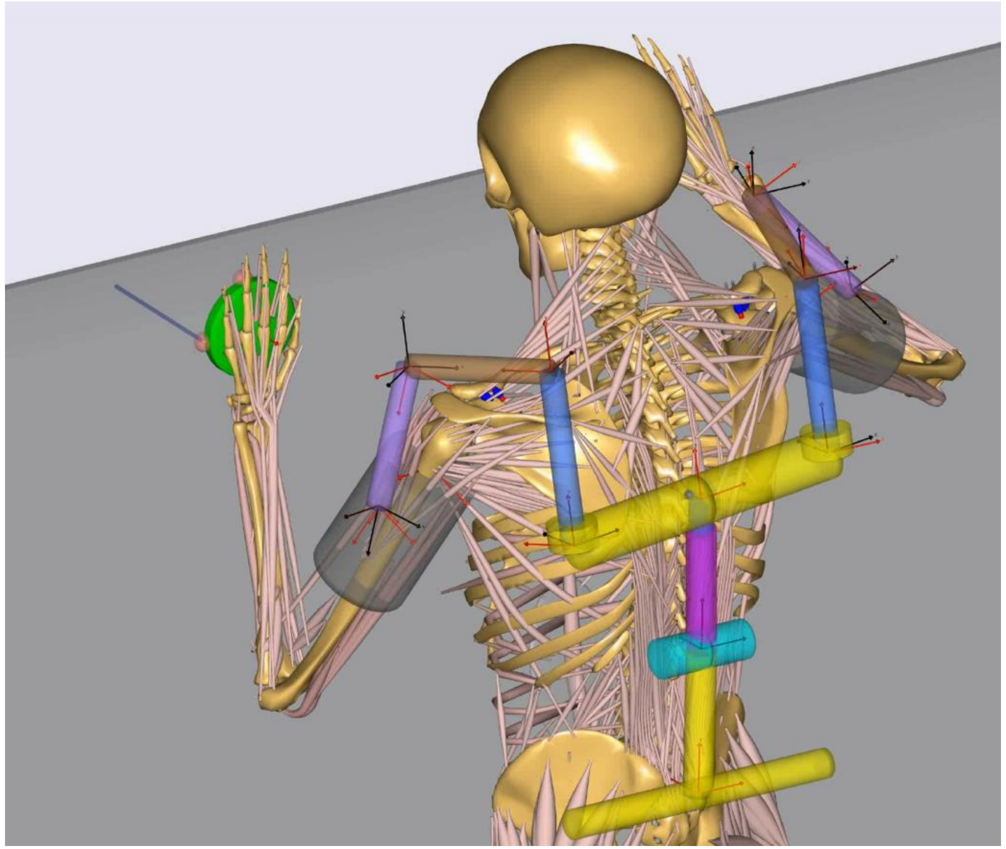


Example 4: Shoulder support device

- Combining motion capture with exo design, using Xsens



Example 5: Polishing Task Support



Discussion

- The changes might be pronounced or suppressed

Device Benefit %	Joint Reaction	Activation Effort	Metabolic Cost
Box-lifting	21.4	62.2	19.6
Sit to stand	9.2	33.9	26.4

- How collectively quantify activation and joint reaction?
  - Otherwise it is based on luck to capture the comfort/discomfort

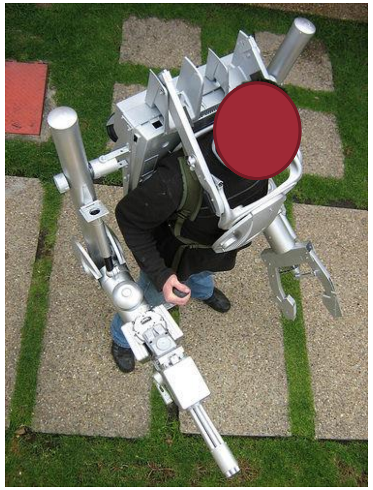
- Short term vs long term?

$$\text{Act Effort} \stackrel{?}{=} \sum_j \sum_i a_{ij}^3$$

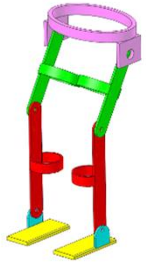
$$\text{JR}_{\text{effort}} \stackrel{?}{=} \sum_j \sum_i JRF_{ij}^2$$

Discussion

- Other criteria?

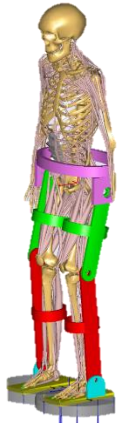


Design framework (another look)



Detailed CAD

AnyExp4SOLIDWORKS



Design

Musculoskeletal simulation

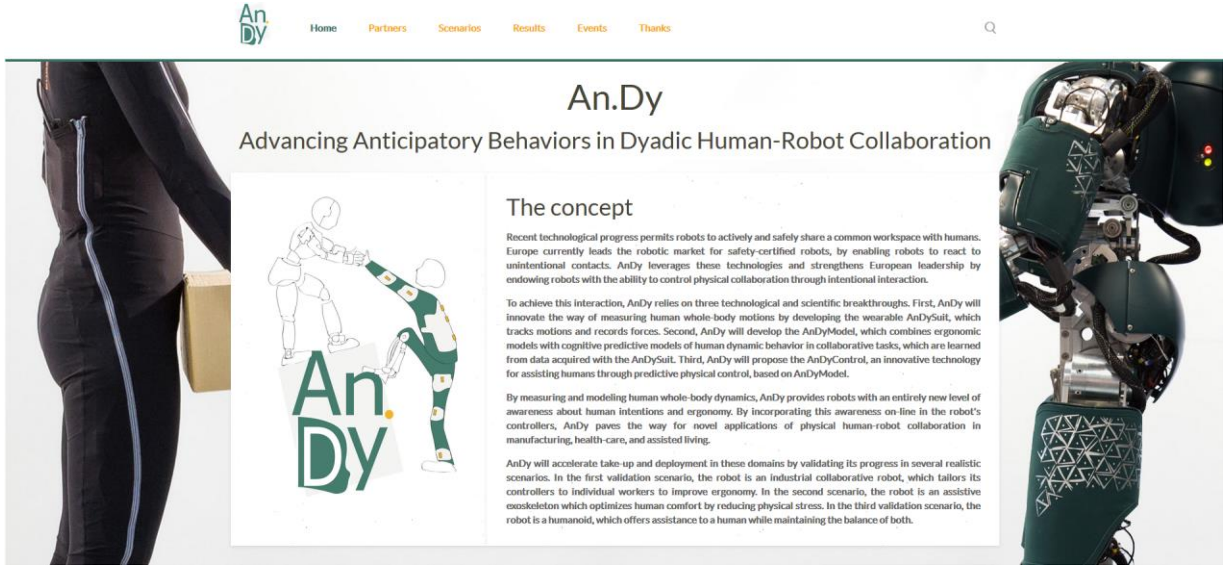
Design objectives (J) and limits (C)

Design Optimization

$$\min_{P} J \ \text{ s.t. } C$$

Acknowledgments

This work has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreements
No. 680754 (The MovAiD project, www.movaid.eu) and
No. 731540 (The AnDy Project, www.andy-project.eu).



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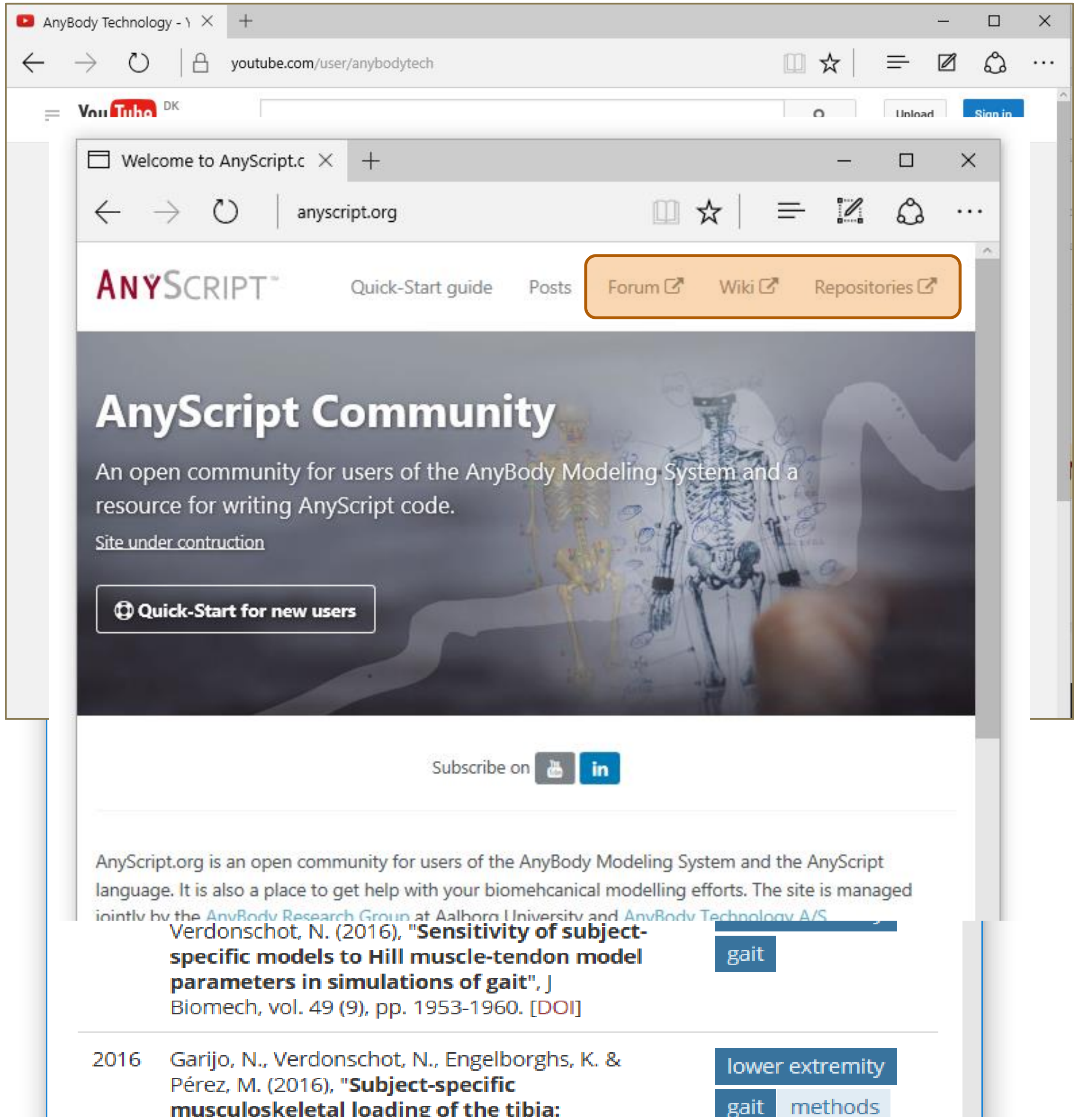
- Check our YouTube channel

www.anybodytech.com

- Events, dates, publication list, ...

www.anyscript.org

- Wiki, Forum, Repositories



Events:

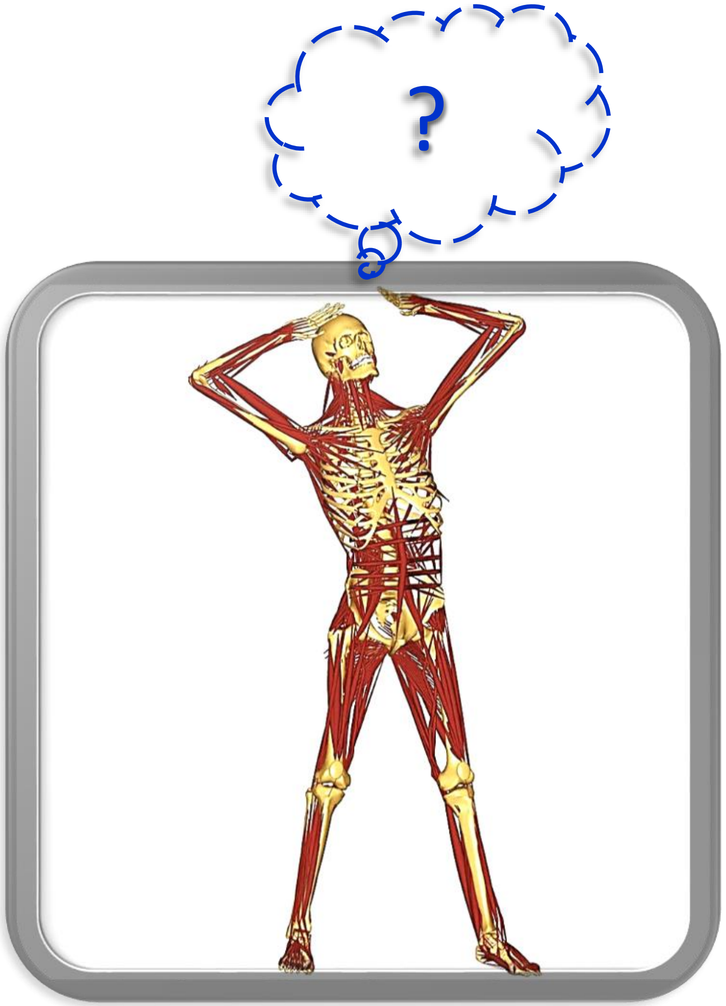
14-17 Jun: CAOS International 2017, Aachen, Germany

14-18 Jun: ISBS 2017, Cologne, Germany

21 Jun Webcast: Computing realistic loads in the lumbar spine by using the AnyBody musculoskeletal model

Meet us? Send email to sales@anybodytech.com

Time for questions



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