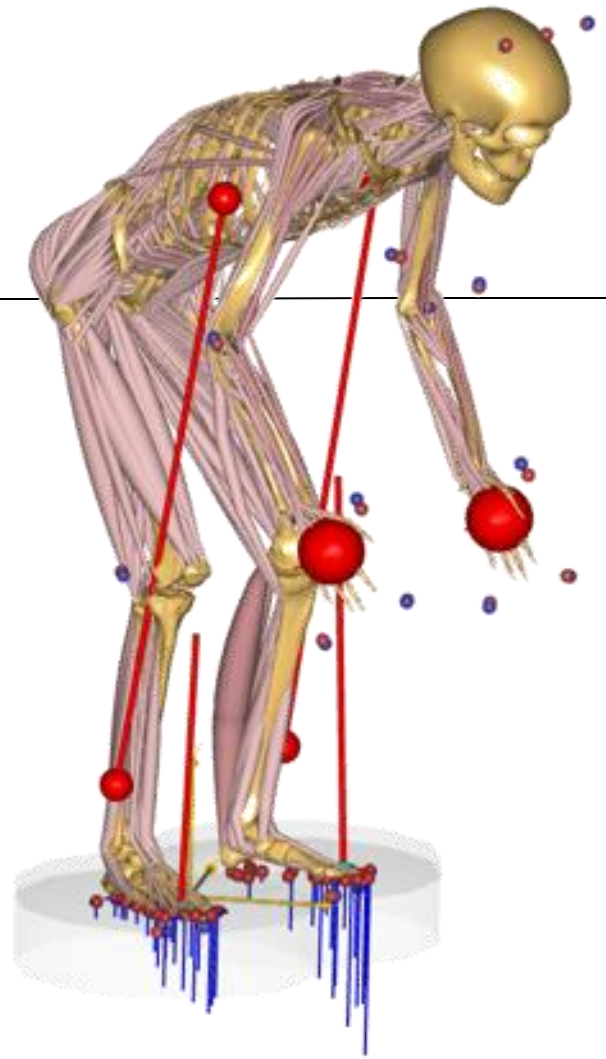
The webcast will begin shortly…

Simulation-Driven Conceptual Design of Exoskeletons

March 28th , 2022



Outline

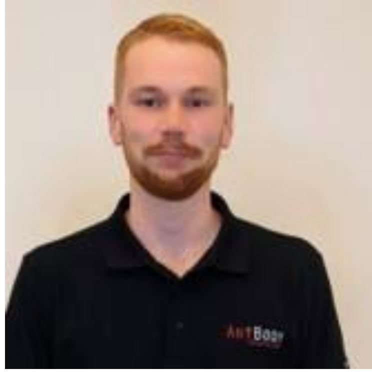
- General introduction to the AnyBody Modeling System
- Presentation by Prof. John Rasmussen
  - *Simulation-Driven Conceptual Design of Exoskeletons*
- Upcoming events
- Question and answer session

Presenter:
Professor John Rasmussen,

Head of the biomechanics research group - Department of Materials and Production,

Aalborg University, Denmark.

AALBORG UNIVERSITY



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

Kristoffer Iversen
Technical Sales Executive

Control Panel

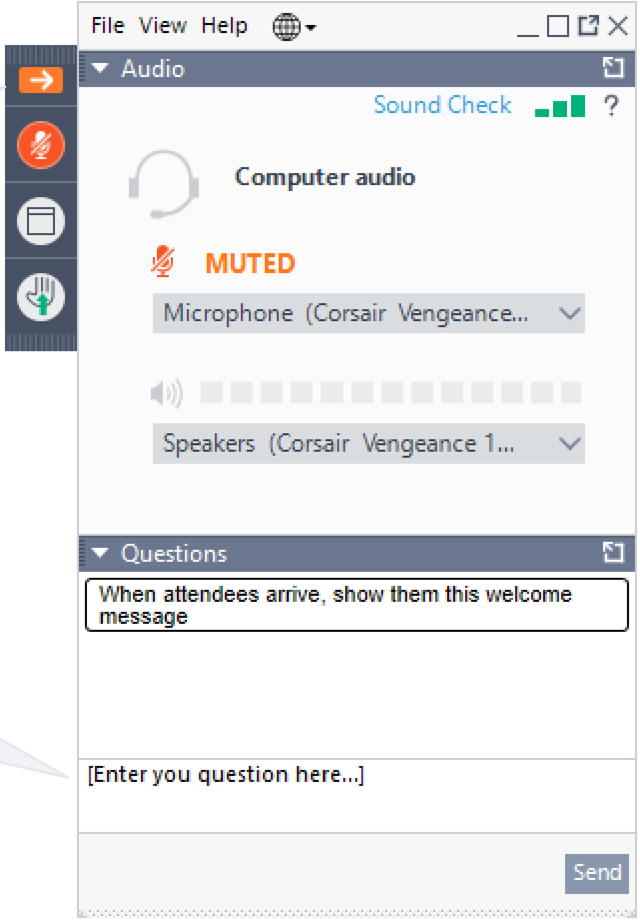
The Control Panel appears on the right side of your screen.

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.*

Expand/Collapse the Control Panel

Ask a question during the presentation

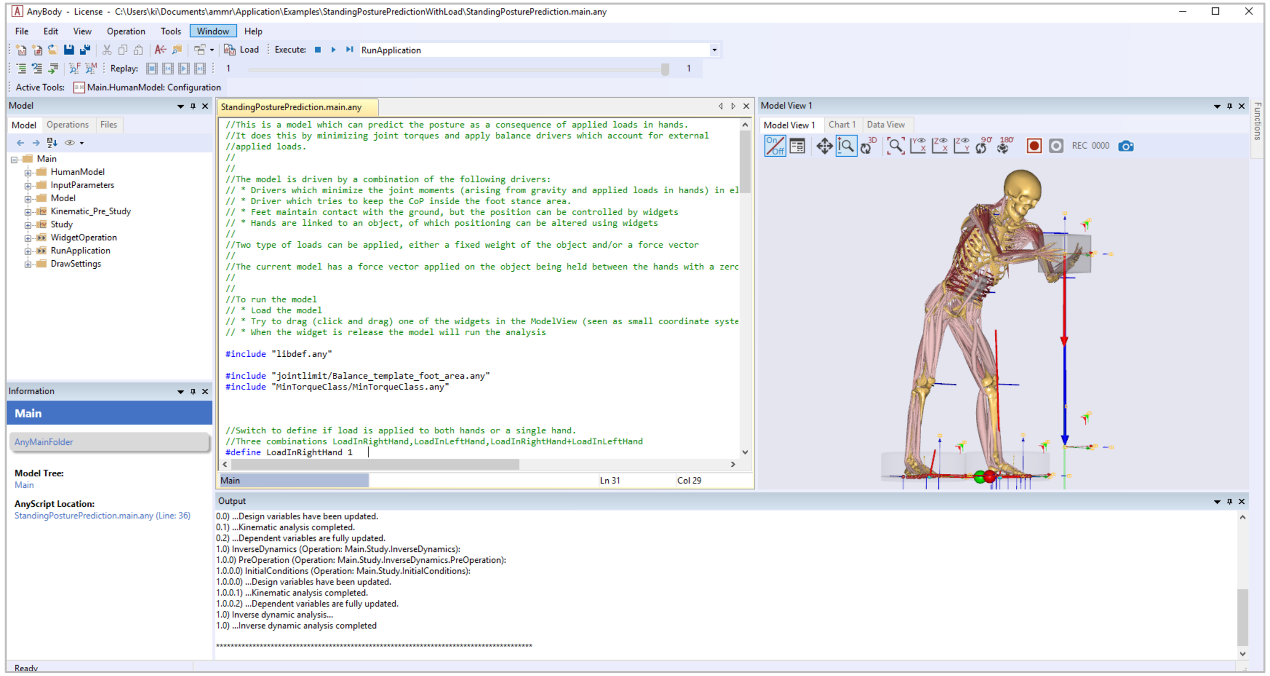


Musculoskeletal Simulation

Motion Data
Kinematics and Forces

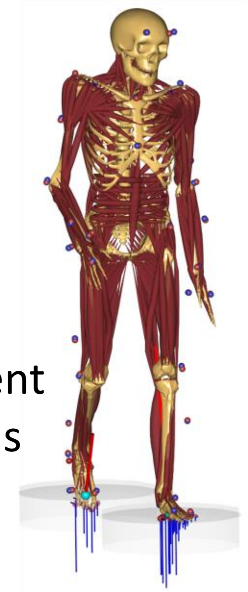
→ **ANYBODY** Modeling System →

Body Loads
- Joint moments
- Muscle forces
- Joint reaction forces

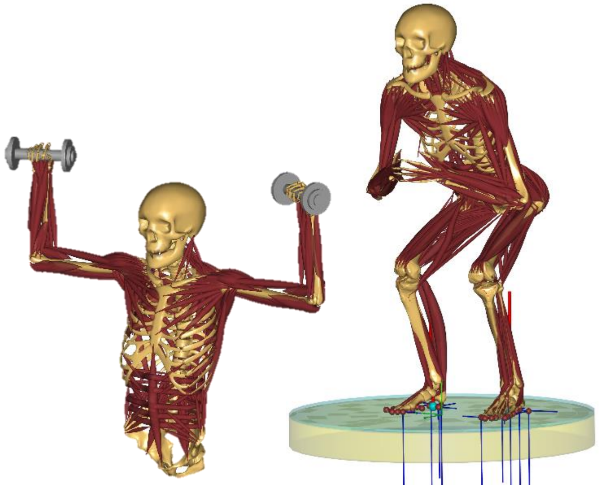


ANYBODY TECHNOLOGY

Product optimization design

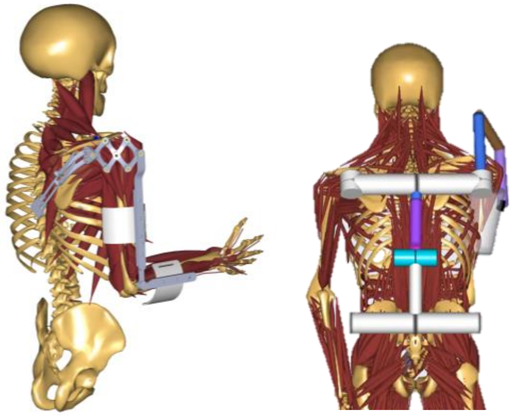


Movement Analysis

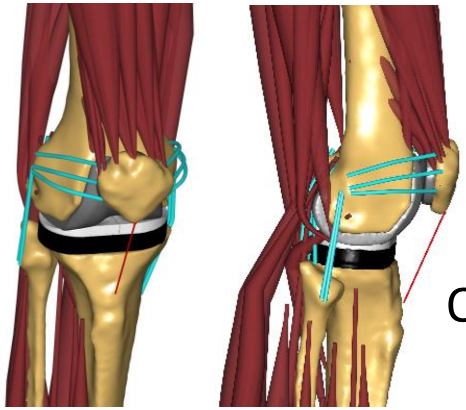


Sports

ANYBODY Modeling System



Assistive Devices



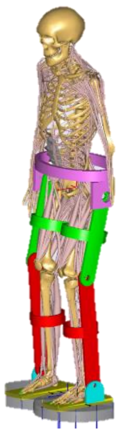
Orthopedics and rehab

AnyBody Modelling System

Motion and Forces

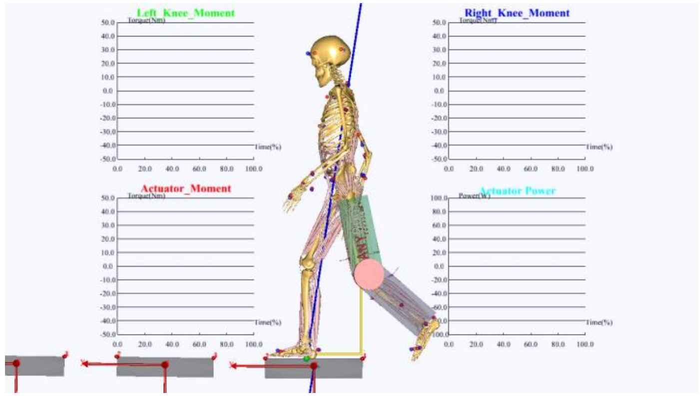
Body model

Environment model



Inverse dynamics
Muscle recruitment

Simulation



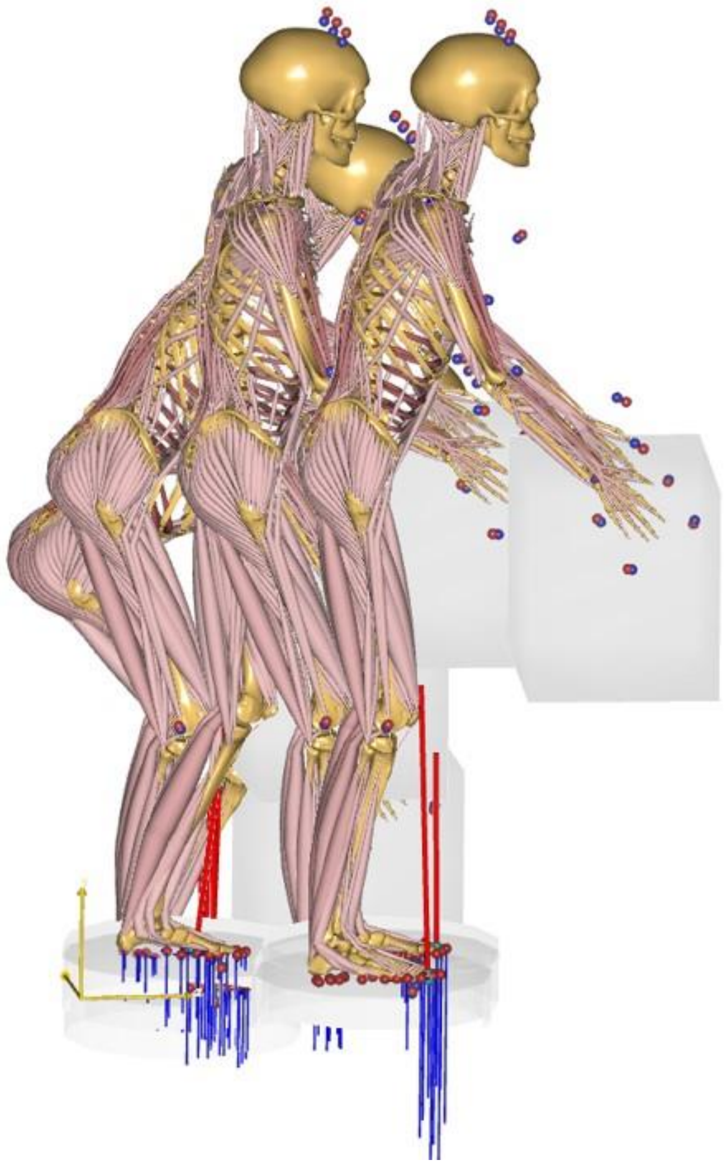
Internal body loads
- Muscle forces
- Joint moments

Design Optimization

Post Processing (e.g. Finite element tools)

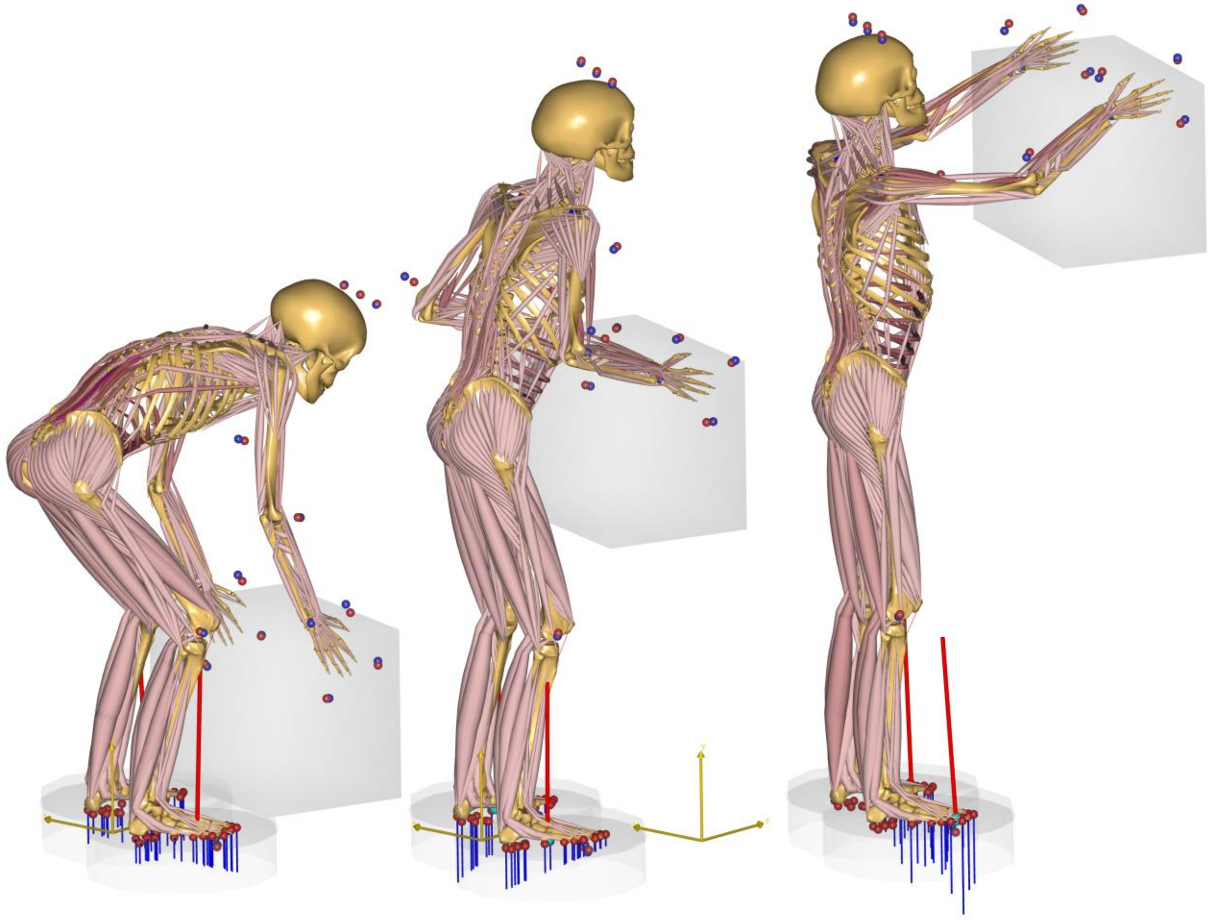
Simulation-Driven Conceptual Design of Exoskeletons

Presented by Professor John Rasmussen



Simulation-based Conceptual Exoskeleton Design

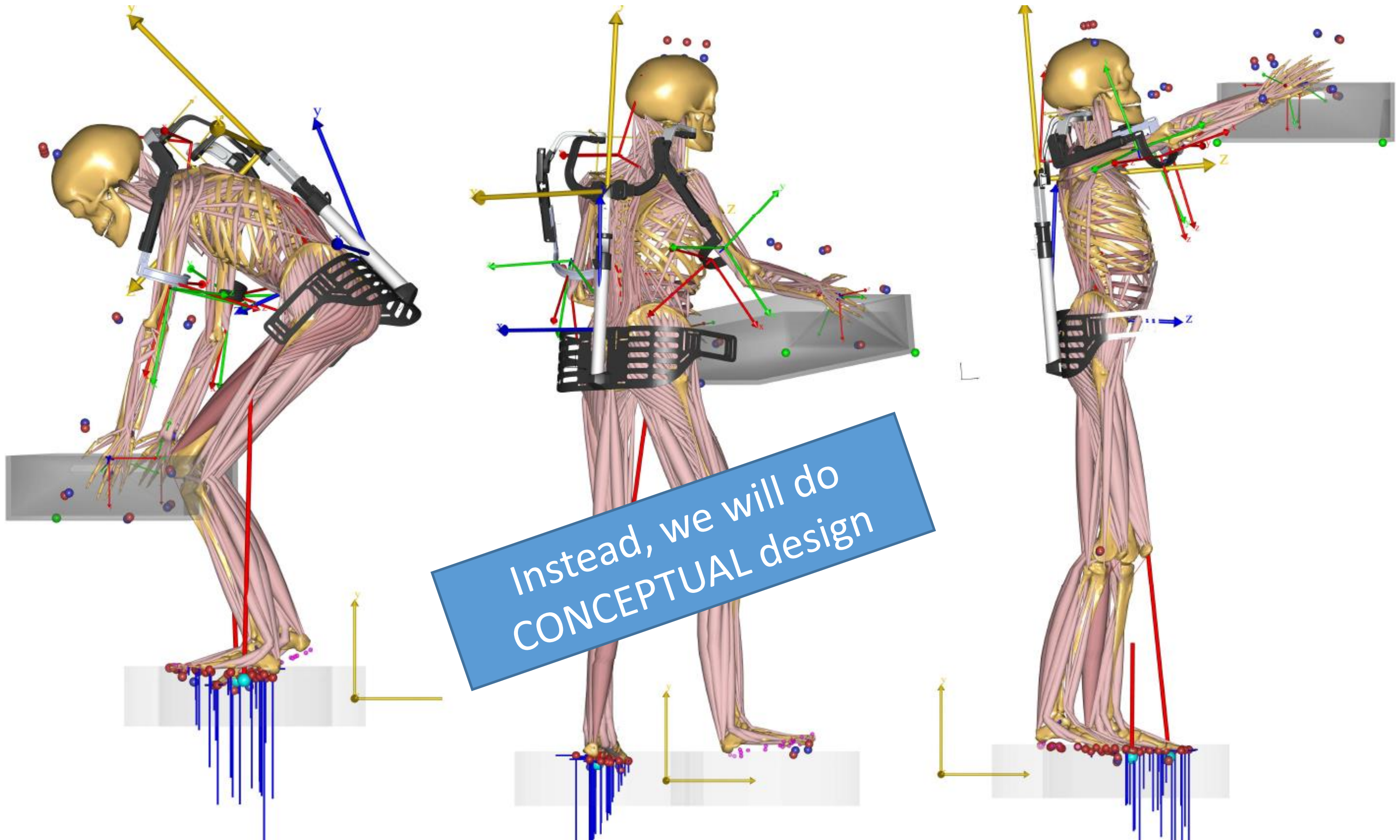
Prof. John Rasmussen
Department of Materials and Production, Aalborg University
Denmark



The AnyBody Modeling System, www.anybodytech.com

Part 1/3: Setting the scene

We are not going to do this

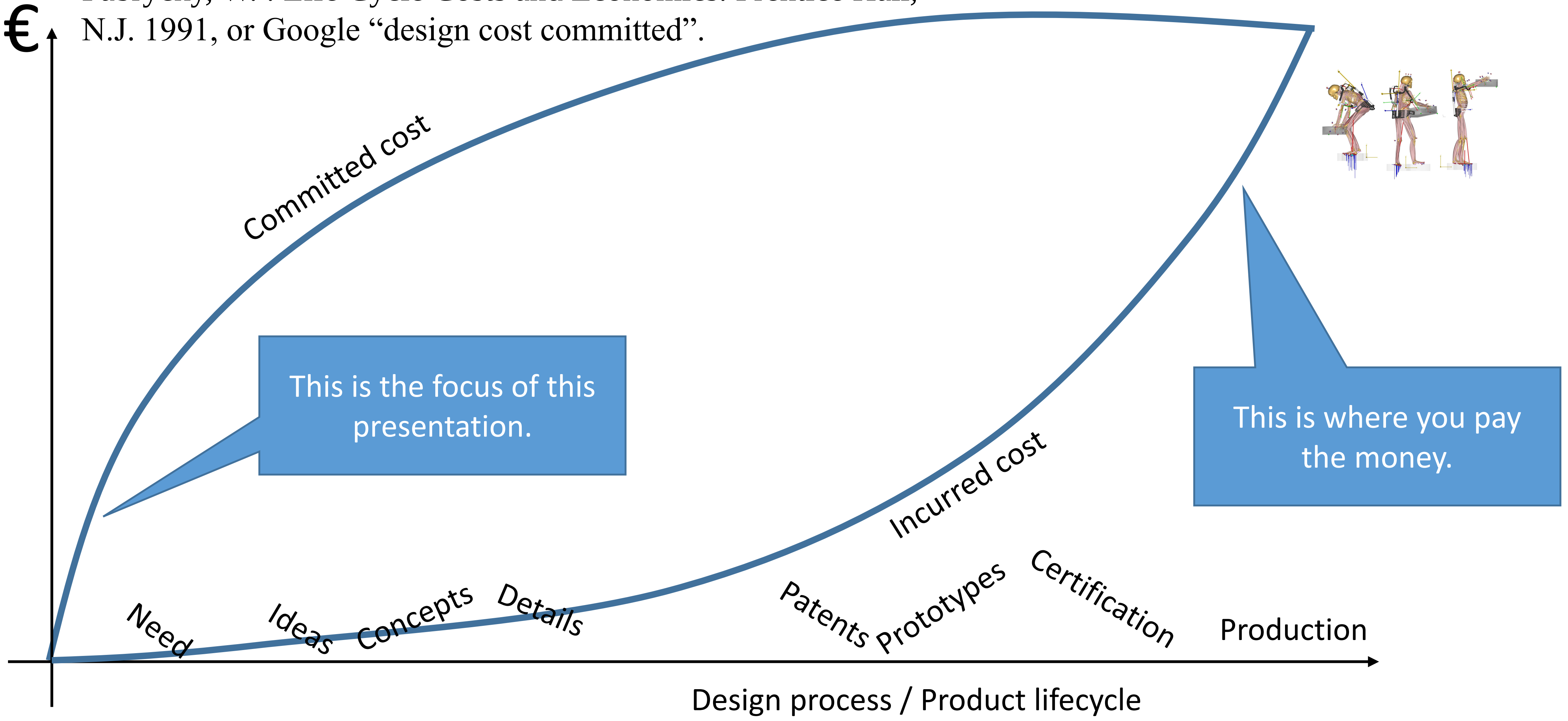


Instead, we will do CONCEPTUAL design

The AnyBody Modeling System + SuitX shoulder exo
Seiferheld et al.

Design science folklore

Fabrycky, W. : Life Cycle Costs and Economics. Prentice Hall, N.J. 1991, or Google “design cost committed”.



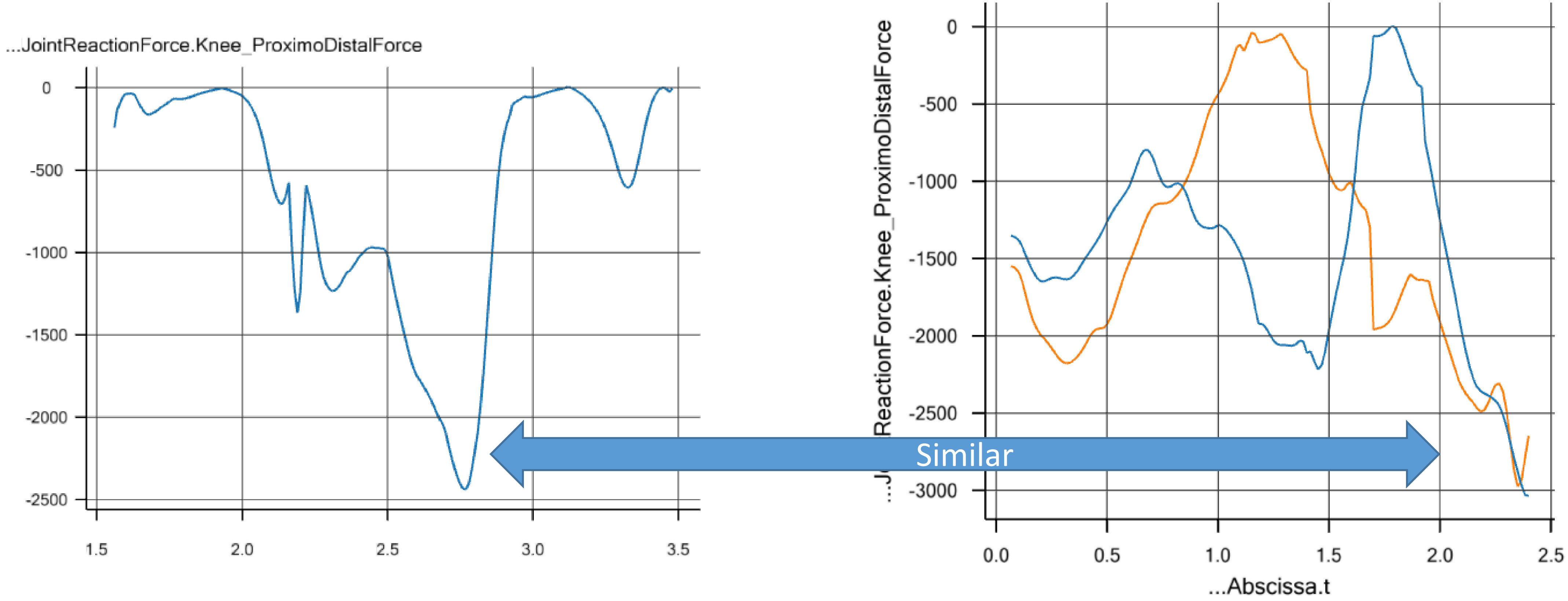
Part 2/3: Load analysis

The two models to compare

Baseline: Gait

Actual working task

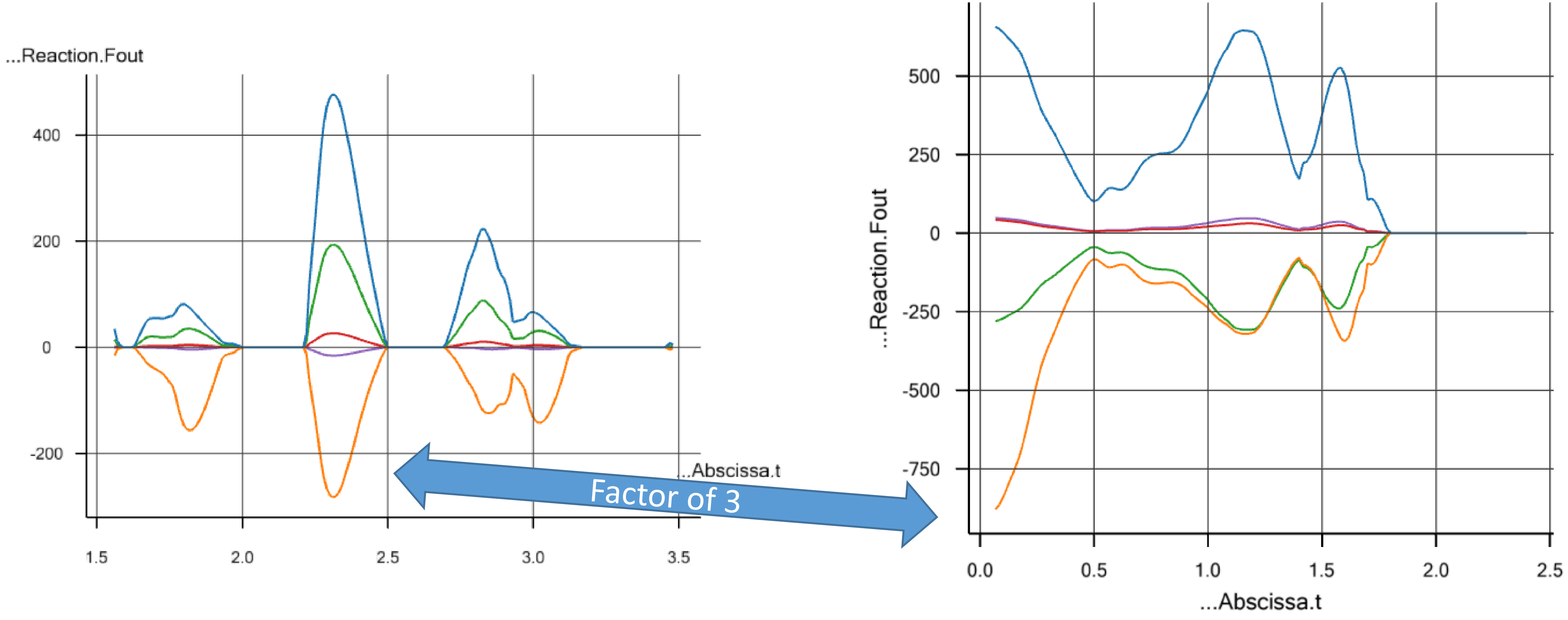
Knee compression force



Baseline: Gait

Actual working task

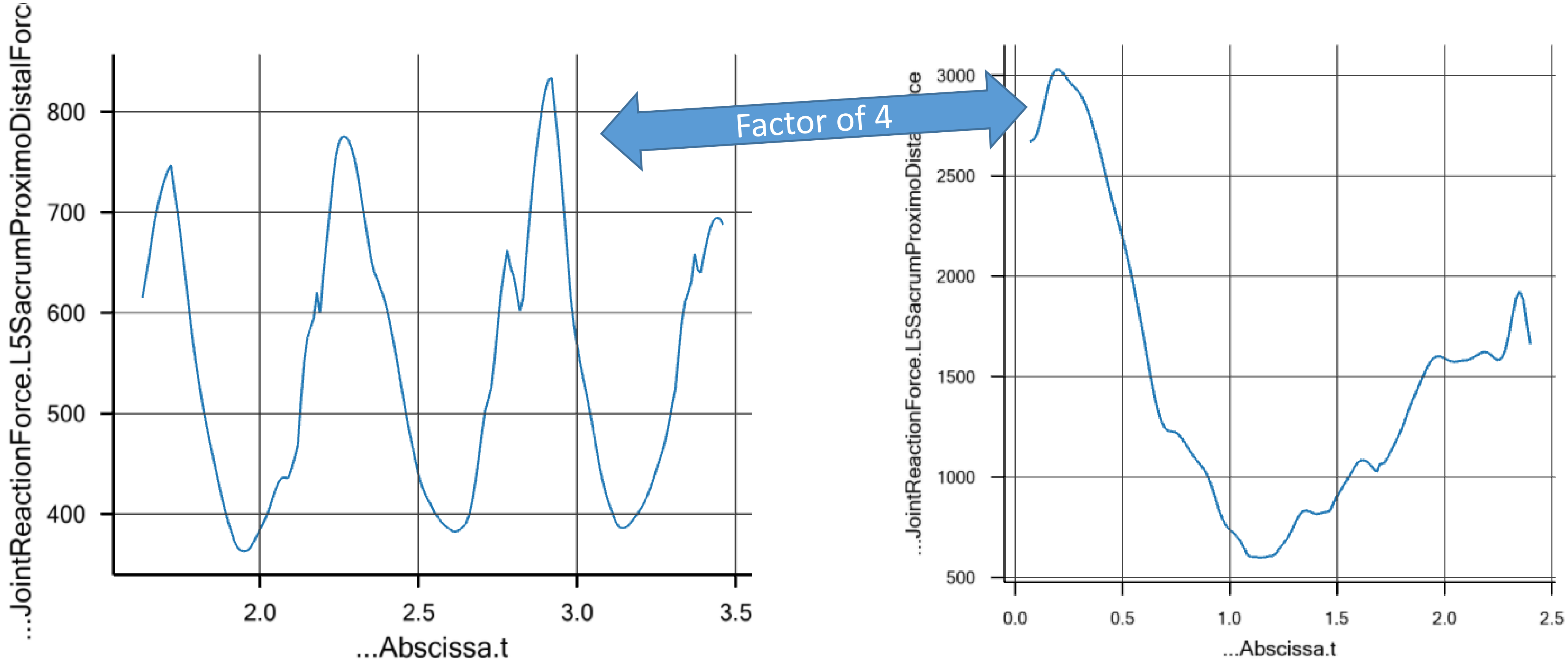
Patellofemoral reactions



Baseline: Gait

Actual working task

Lumbar spine compression



Baseline: Gait

Actual working task

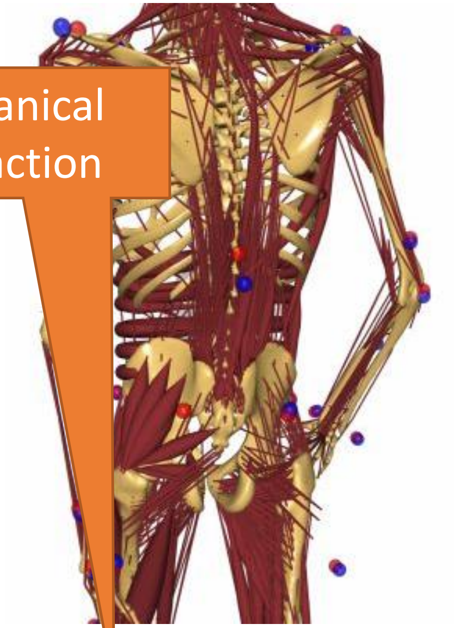
Part 3/3: Conceptual design

There is a mathematical trick inherent to inverse dynamics that can compute an ideal force anywhere in the system.

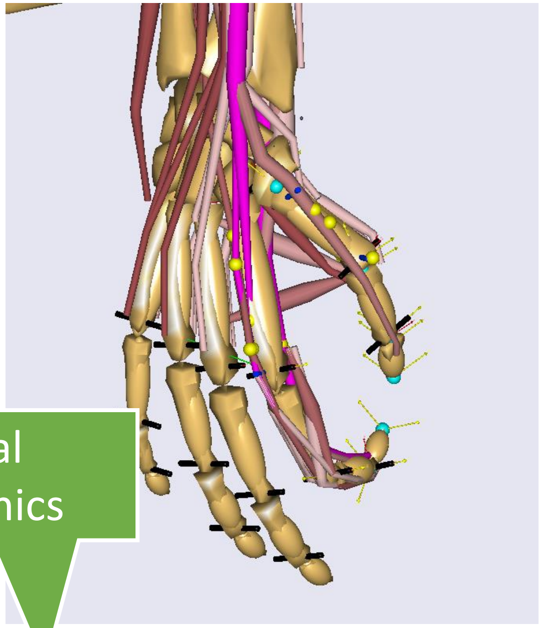
Model constraints

Kinematics — Kinetics

Mechanical abstraction



Actual mechanics



Mechanical abstraction

AnyReacForce

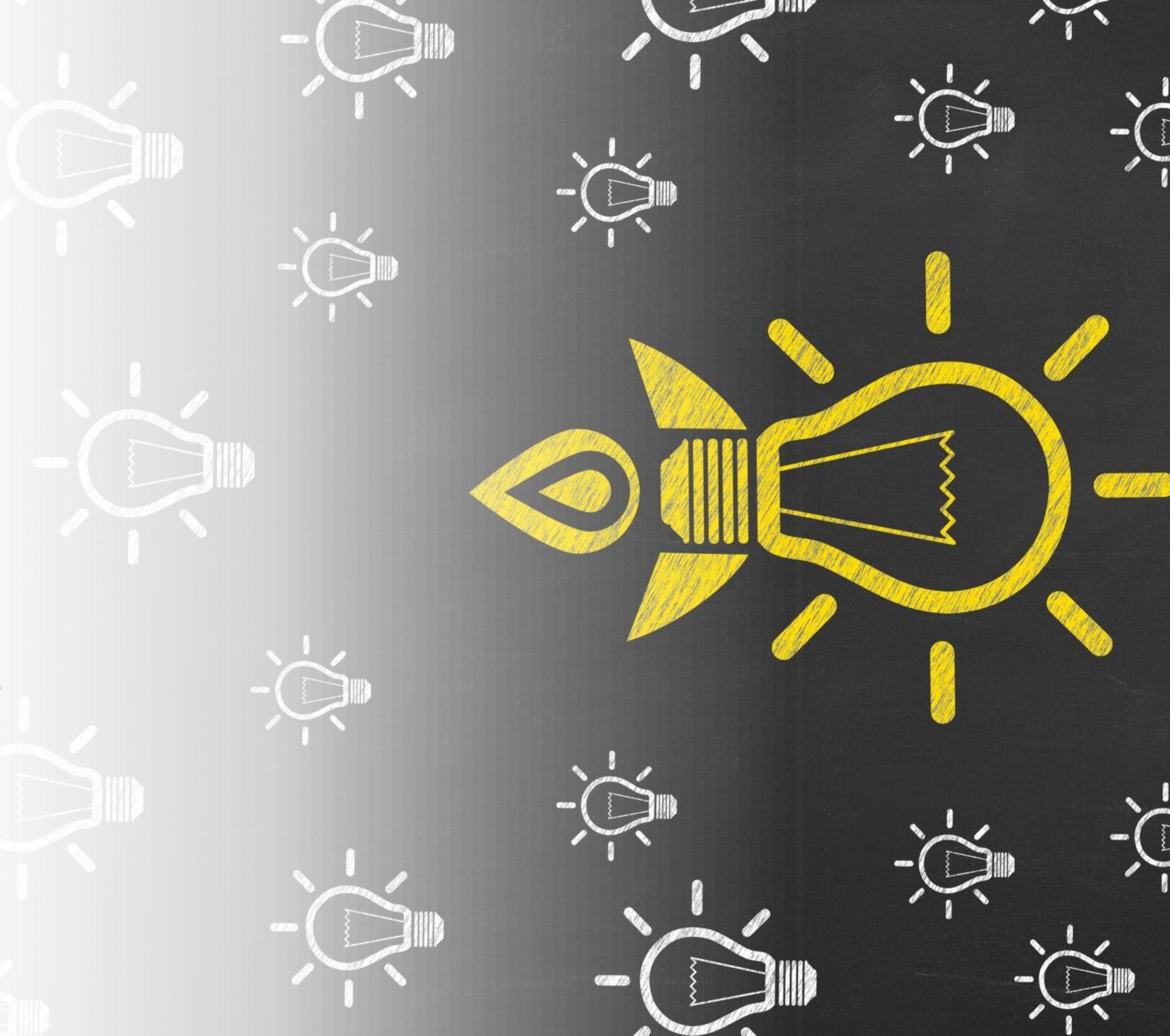
Mocap markers:
Provide position only

Joints:
Provide position and reaction

AnyReacForce:
Provides reaction only

First idea:

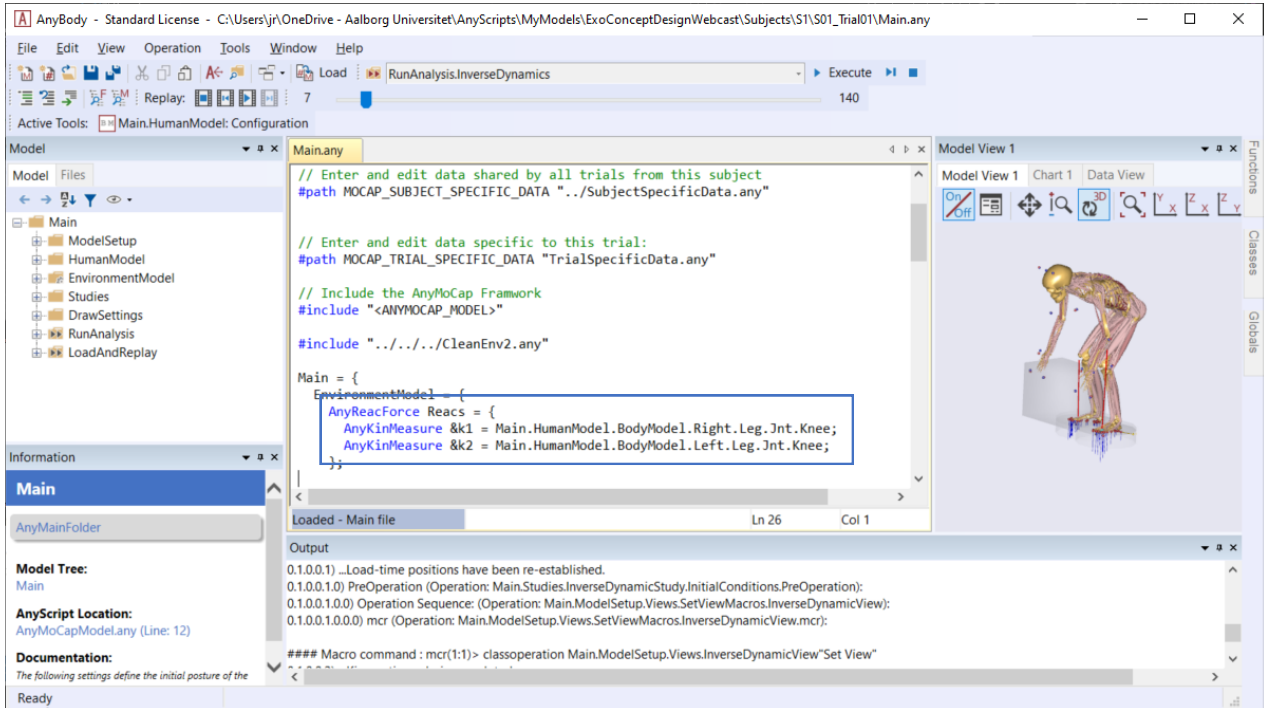
Patella-femoral loads was a problem. Can we fix this with an exo that helps extend the knee?



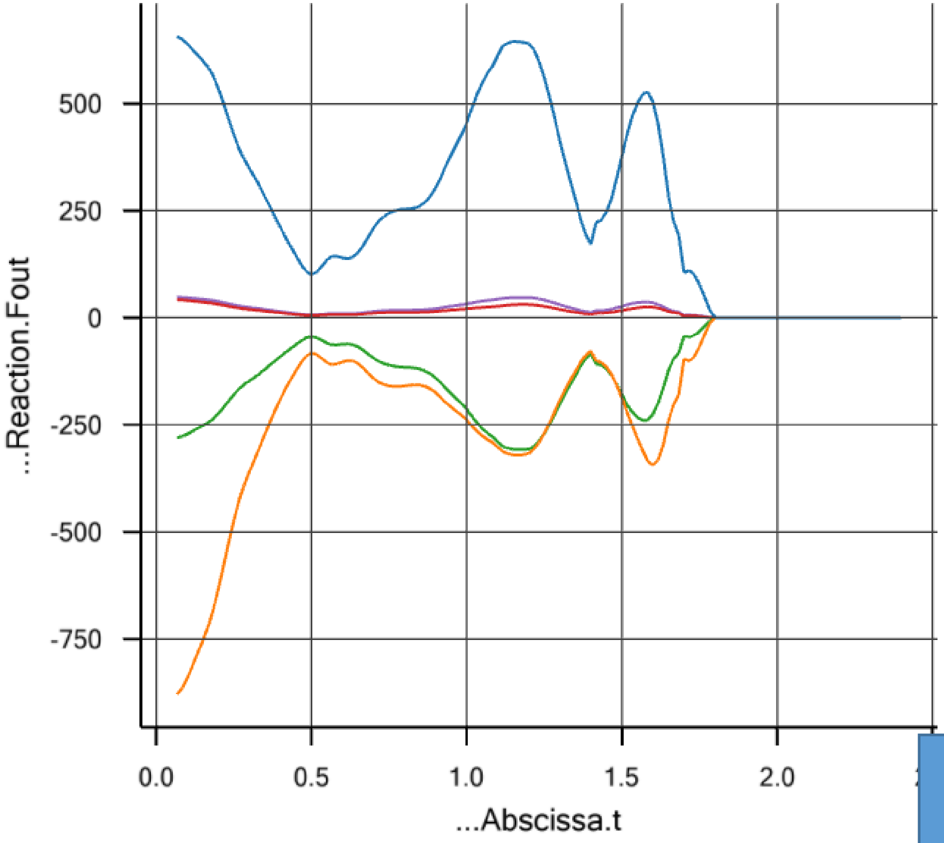
Reaction forces for knee extension

We add the following to the model:

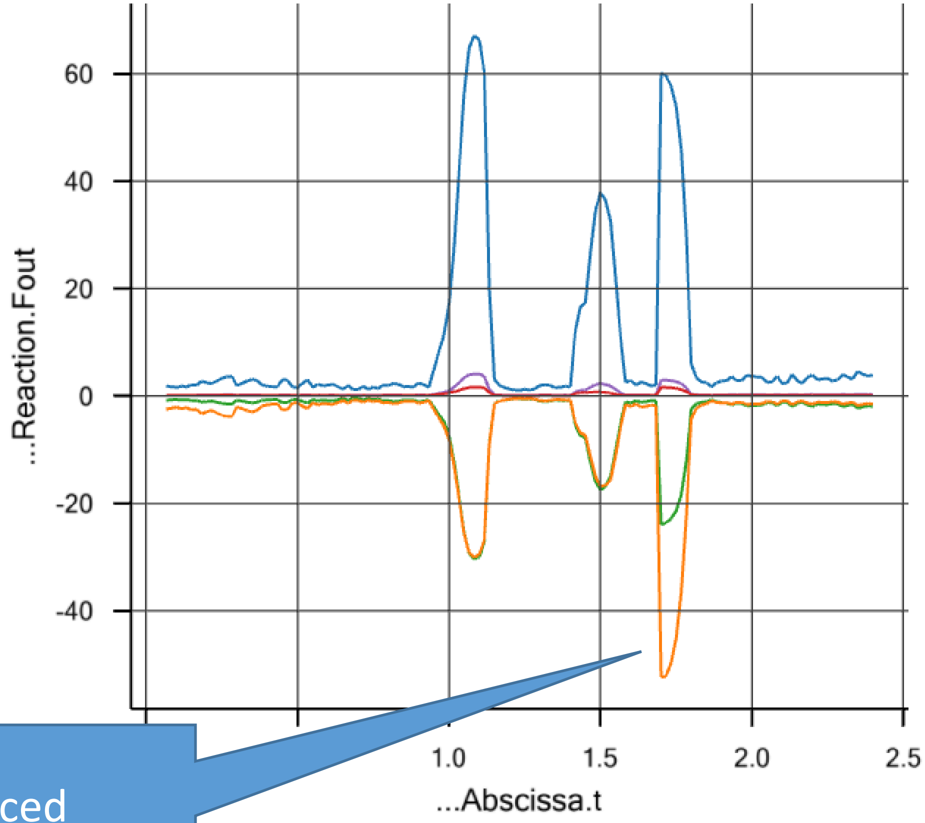
```
AnyReacForce Reacs = {
 AnyKinMeasure &k1 =
Main.HumanModel.BodyModel.Right.Leg.Jnt.Knee;
 AnyKinMeasure &k2 =
Main.HumanModel.BodyModel.Left.Leg.Jnt.Knee;
};
```



Patellofemoral reactions without and with AnyReacForce



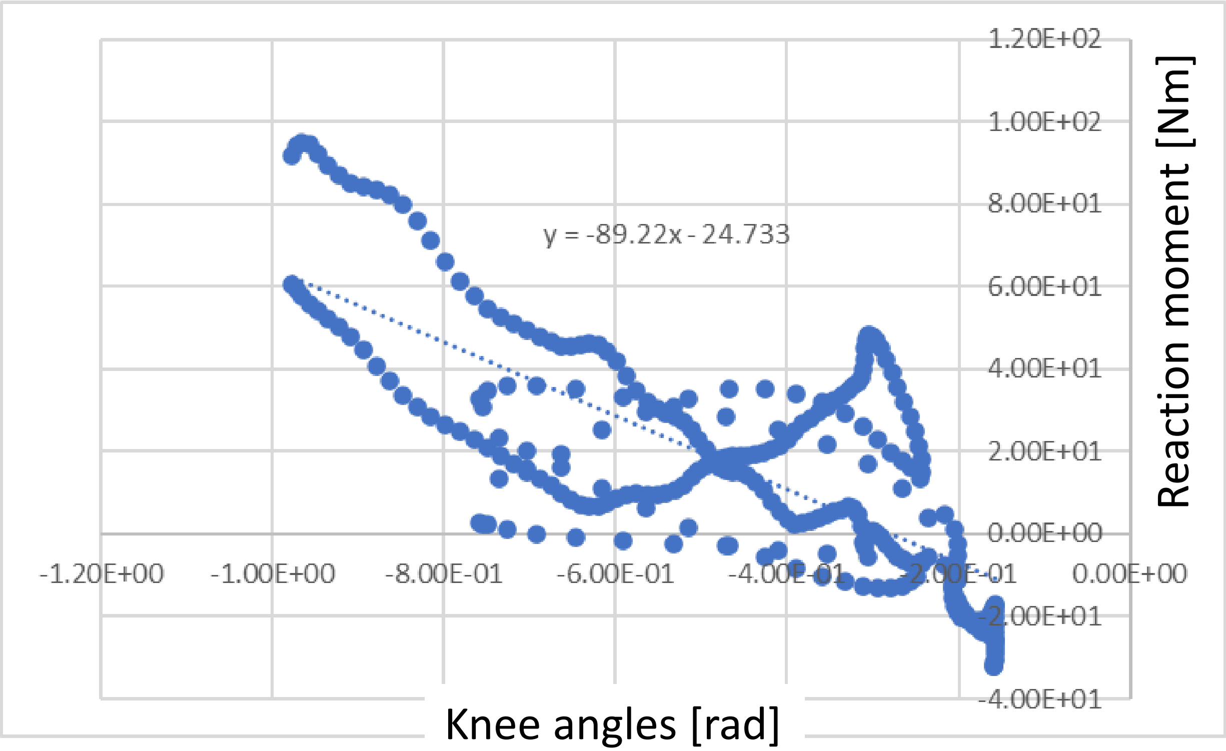
Without exo



Reduced
(no shit, Sherlock!)

With ”knee extension” exo

Ideal assistive knee moment as a function of angle

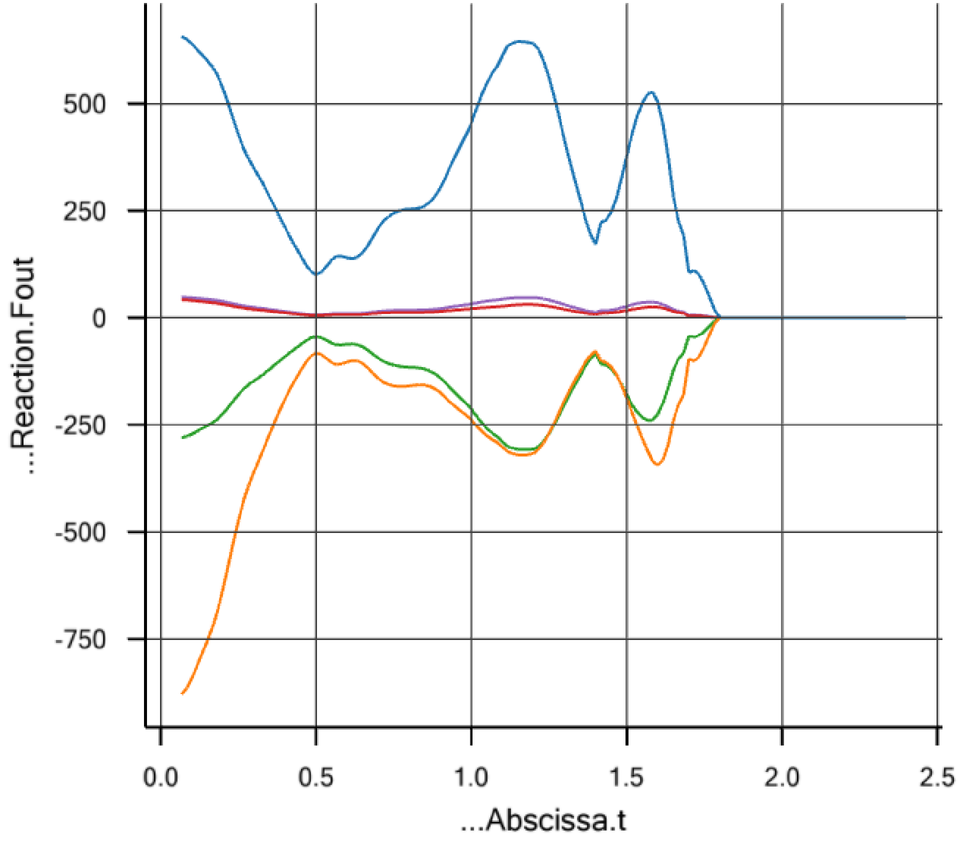


The linear regression is a perfect spring, which we can build into an exo.
If the approximation is good enough, we should get a reduction of patella-femoral force

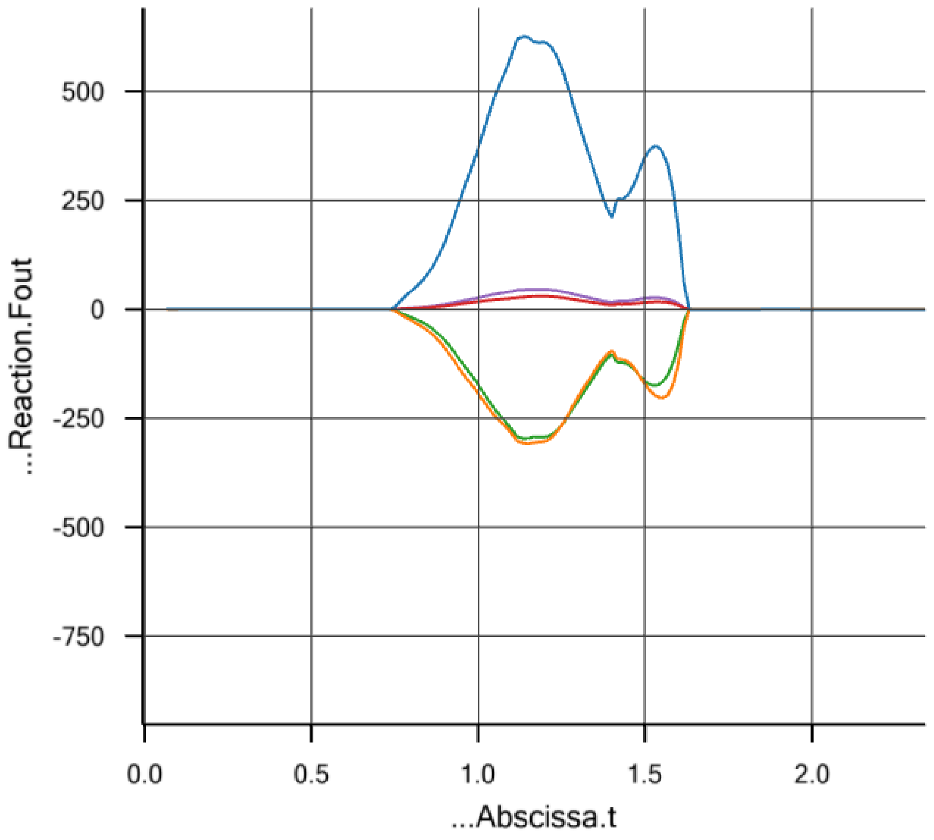
Spring definition

```
AnyVar k = -89.22;
AnyForce rSpring = {
  AnyKinMeasure &k1 = Main.HumanModel.BodyModel.Right.Leg.Jnt.Knee;
  F = .k*k1.Pos-24.73;
};
AnyForce lSpring = {
  AnyKinMeasure &k1 = Main.HumanModel.BodyModel.Left.Leg.Jnt.Knee;
  F = .k*k1.Pos-24.73;
};
```

Patellofemoral reactions without and with imaginary exo springs



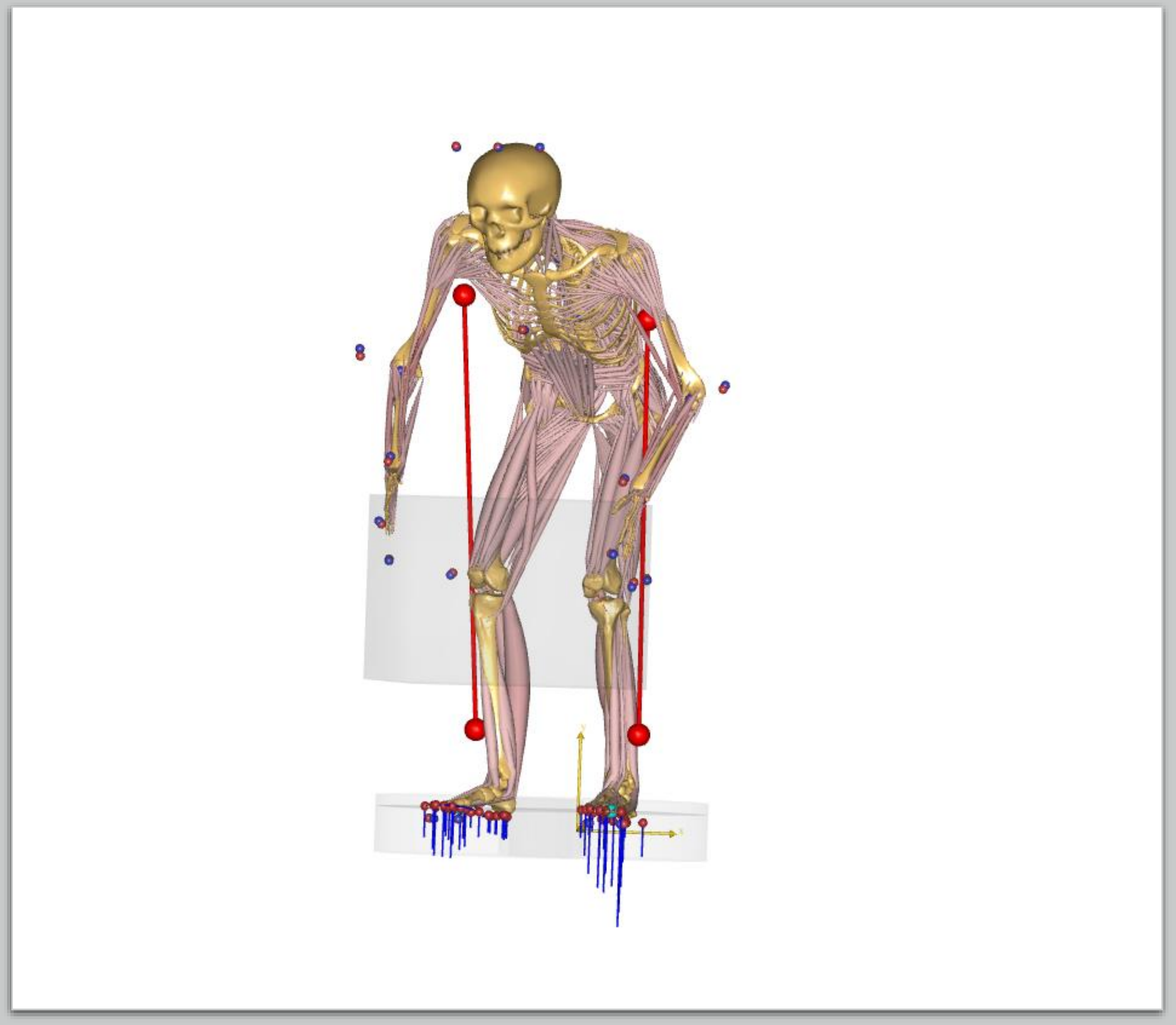
Without exo



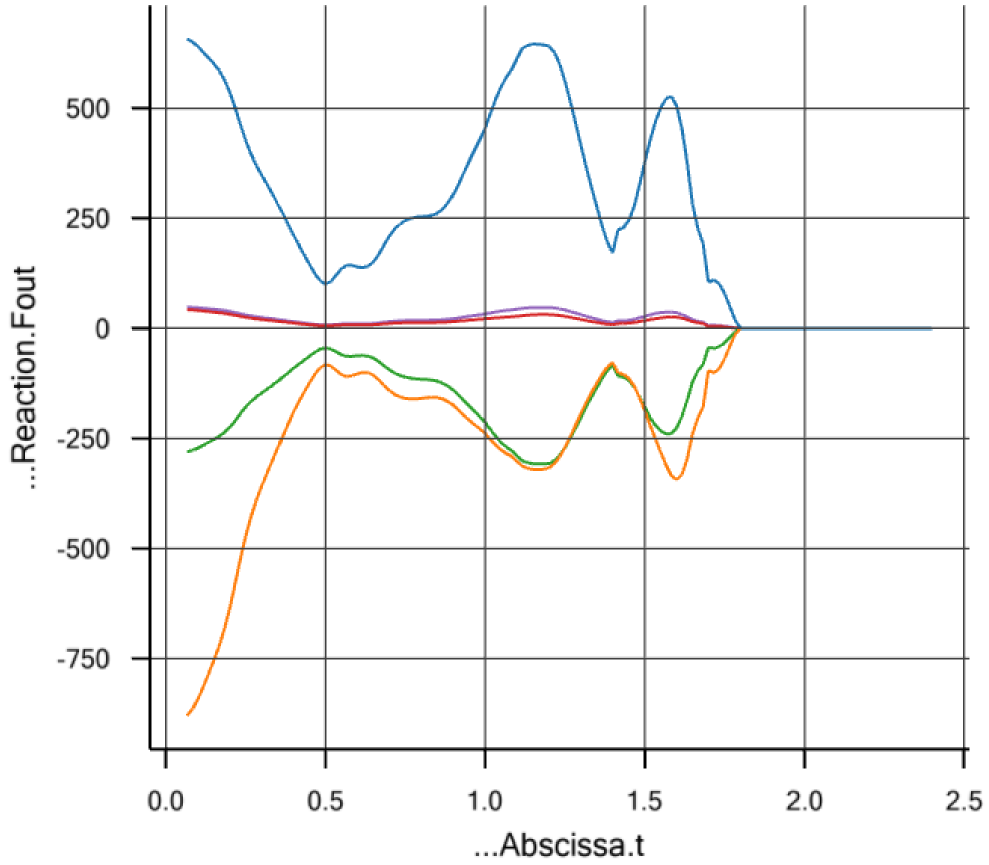
With ”knee spring” exo

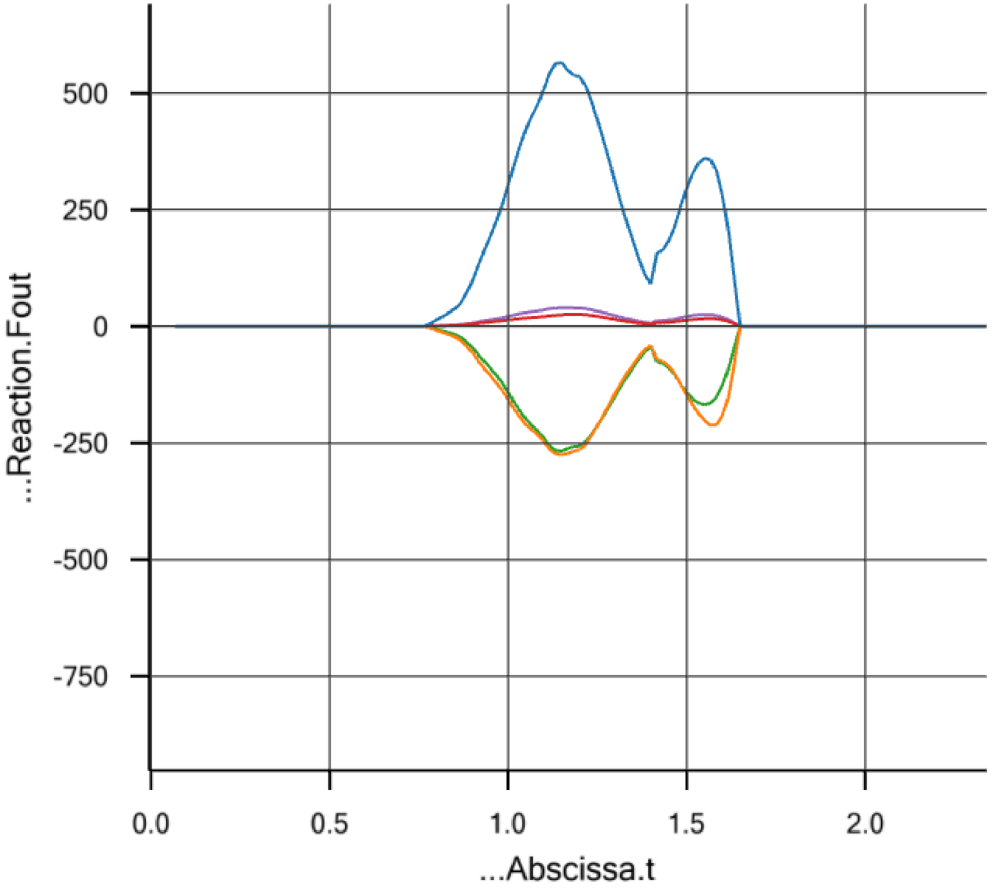
Second idea

- We define extensible rods crossing the knees, hips and lumbar spine.
- We equip the rods with AnyReacForces to provide ideal but unrealistic support.
- We perform the same investigation as before.

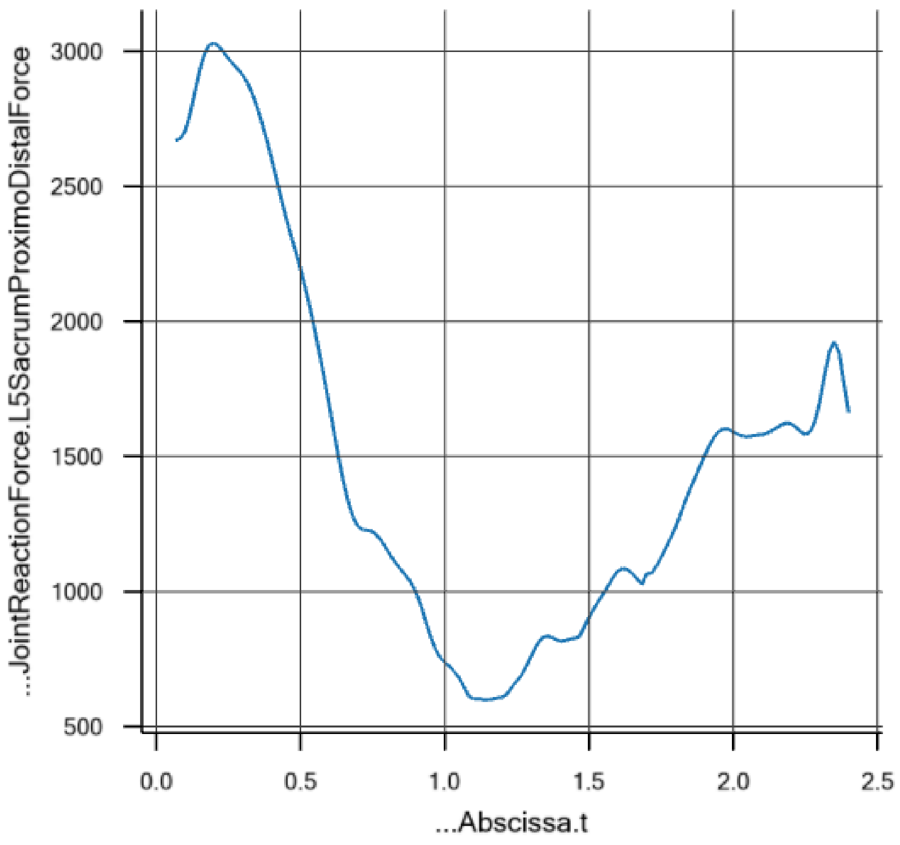


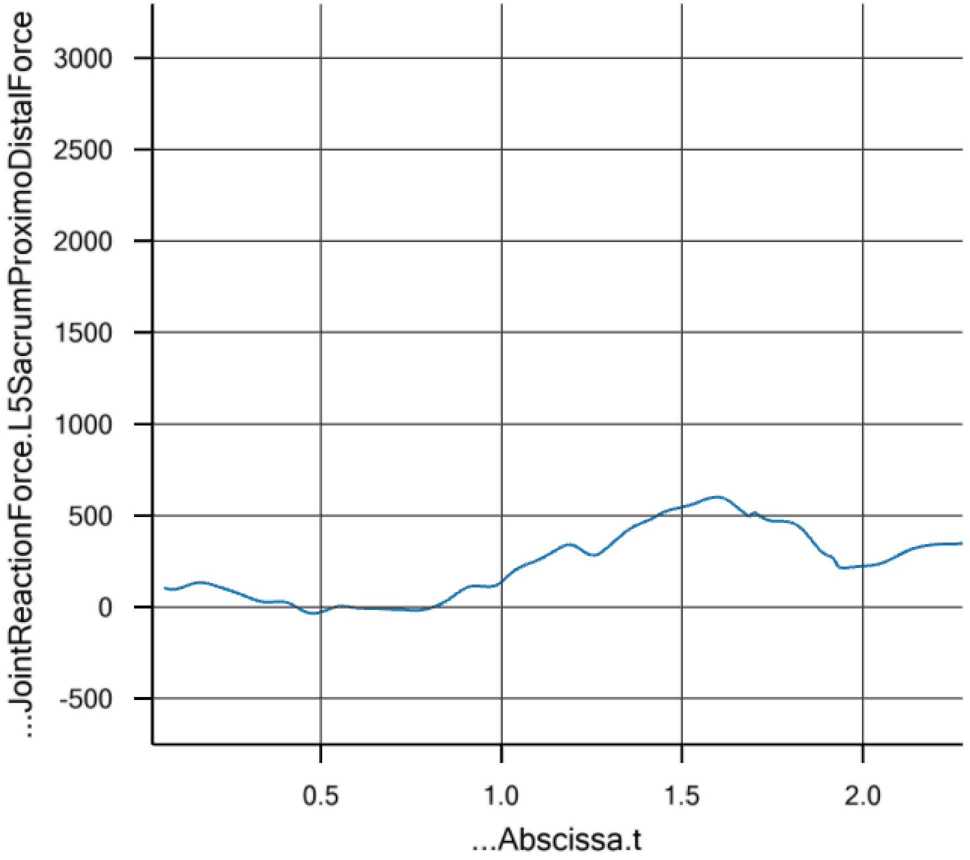
Without and with ideal extension rods (patella-femoral forces)

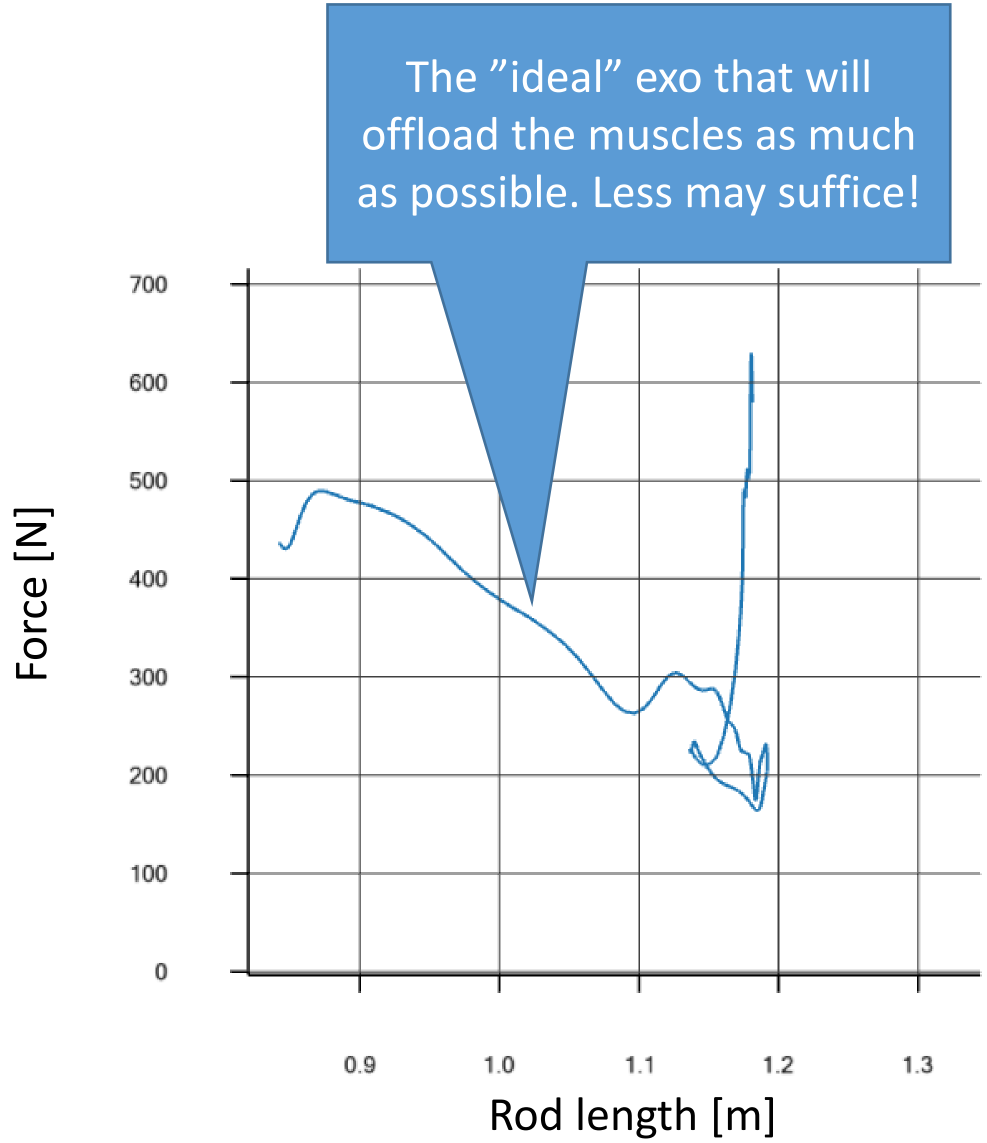


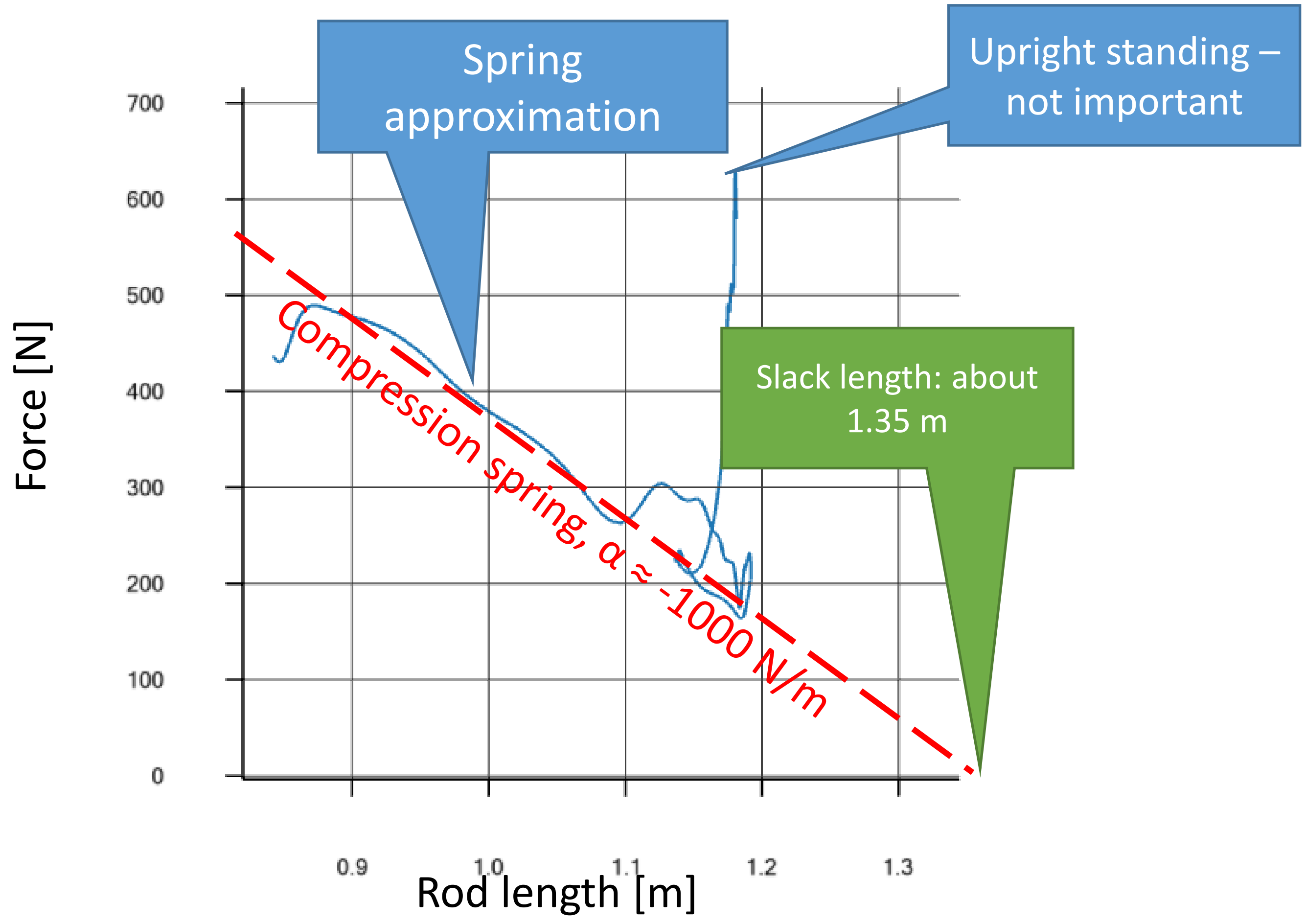


Without and with ideal extension rods (L5-S1 forces)



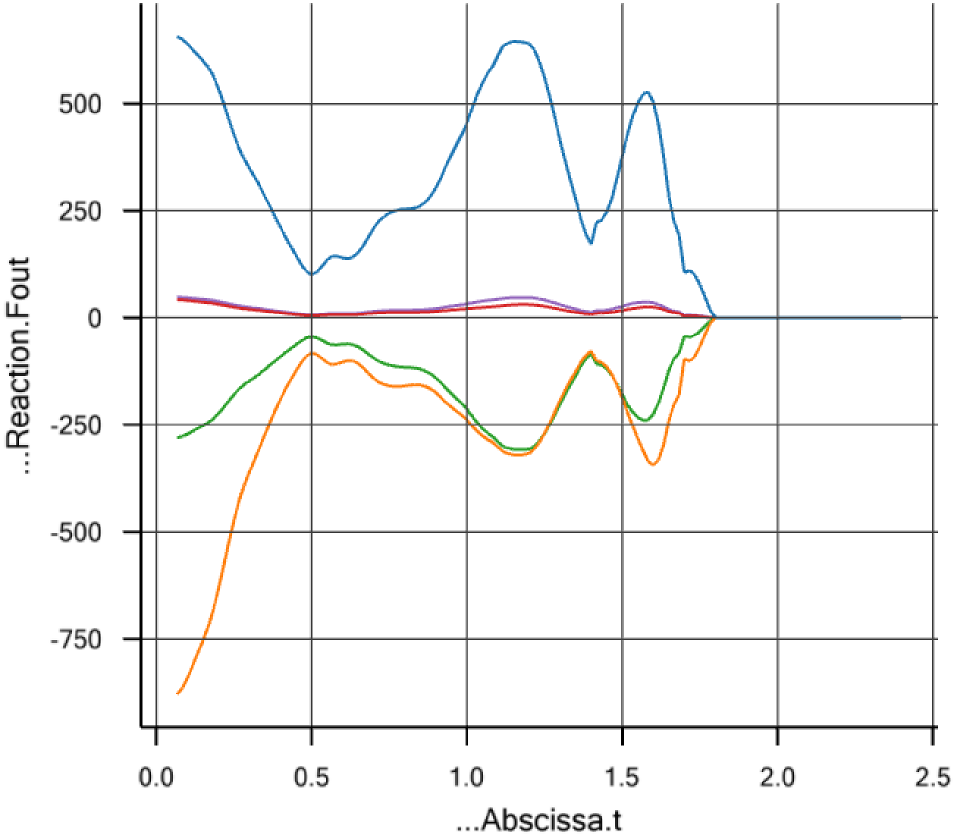



The ”ideal” exo that will offload the muscles as much as possible. Less may suffice!
700
600
500
400
300
200
100
0
0.9
1.0
1.1
1.2
1.3
Force [N]
Rod length [m]

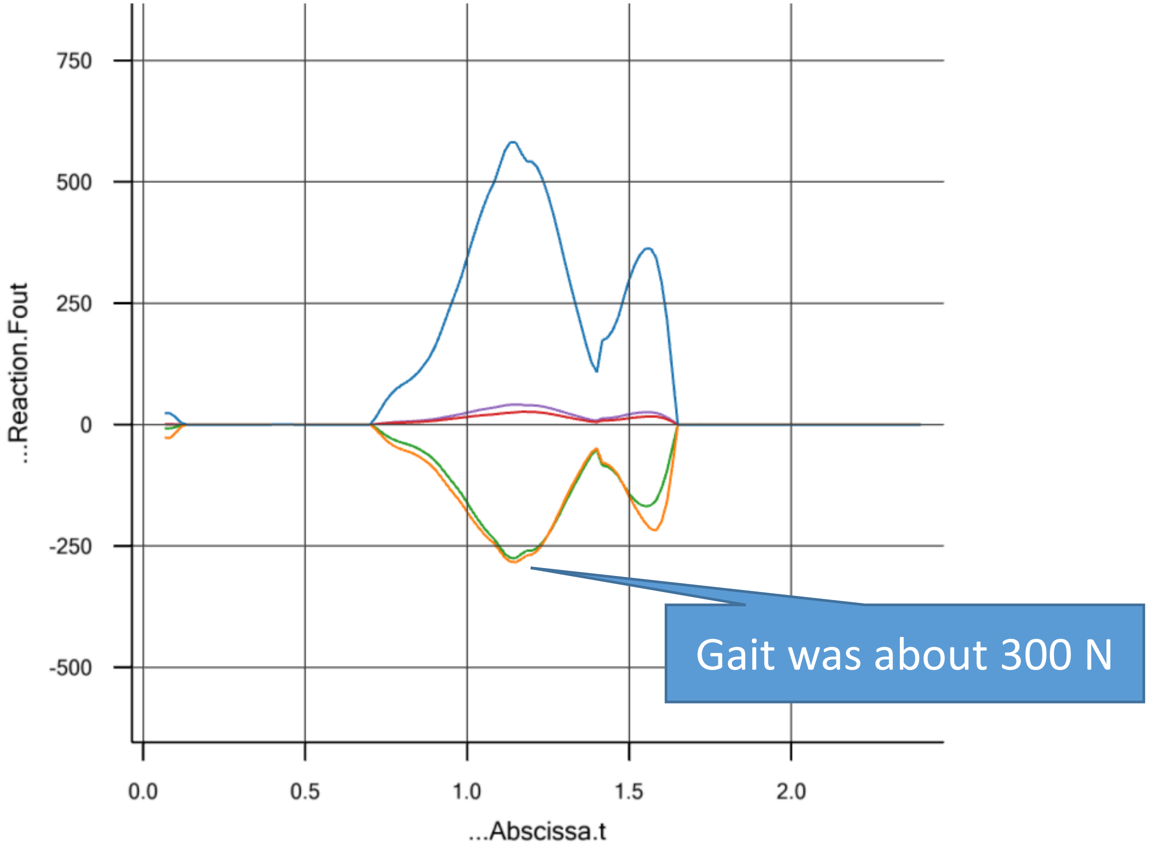


Spring approximation
Upright standing – not important
Slack length: about 1.35 m
Compression spring, α ≈ -1000 N/m
Force [N]
Rod length [m]
700
600
500
400
300
200
100
0
0.9
1.0
1.1
1.2
1.3

Patella-femoral reactions

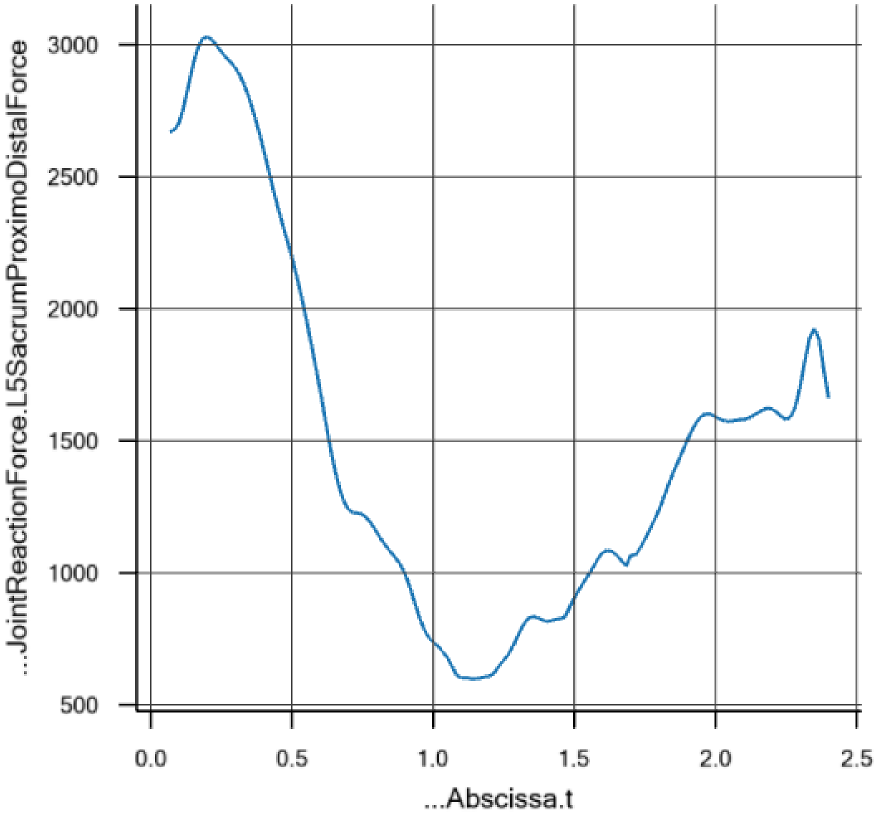


Without exo

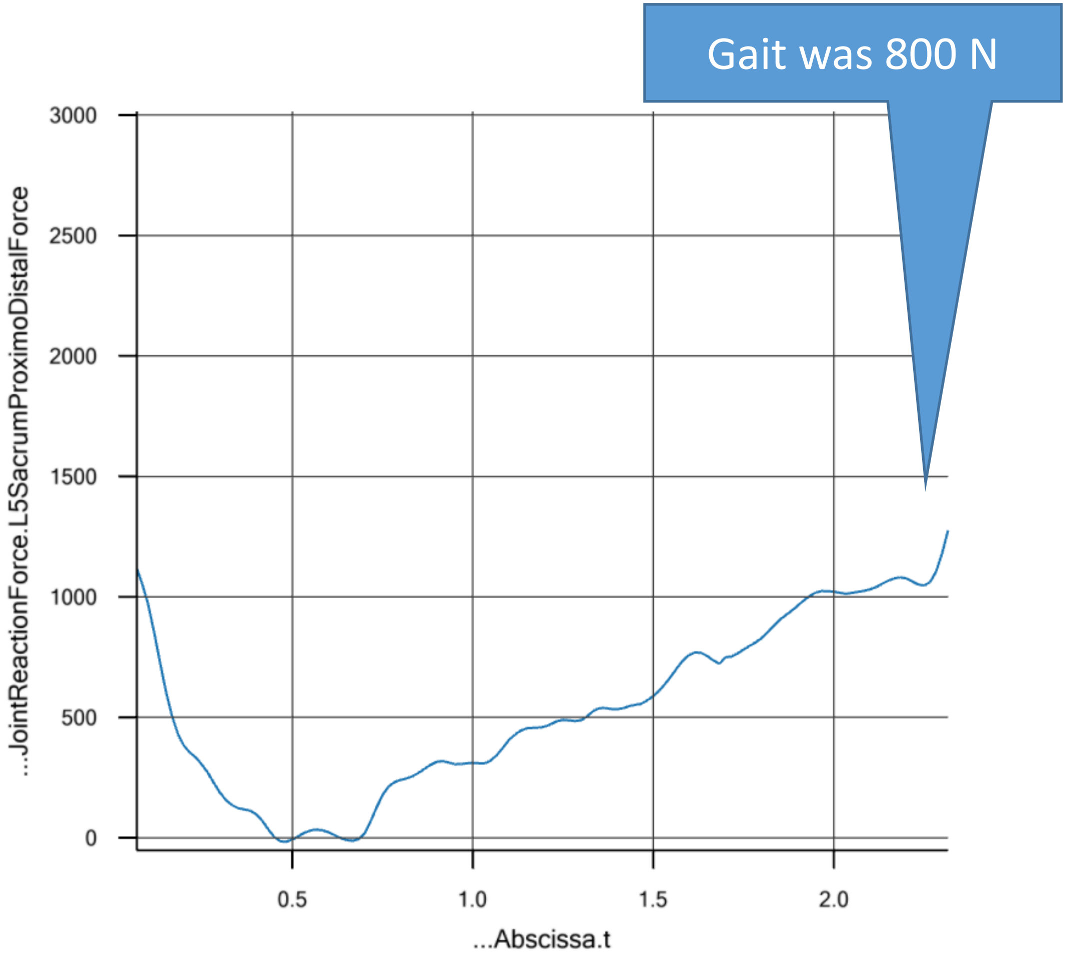


With ”spring rod” exo

Lumbar spine compression



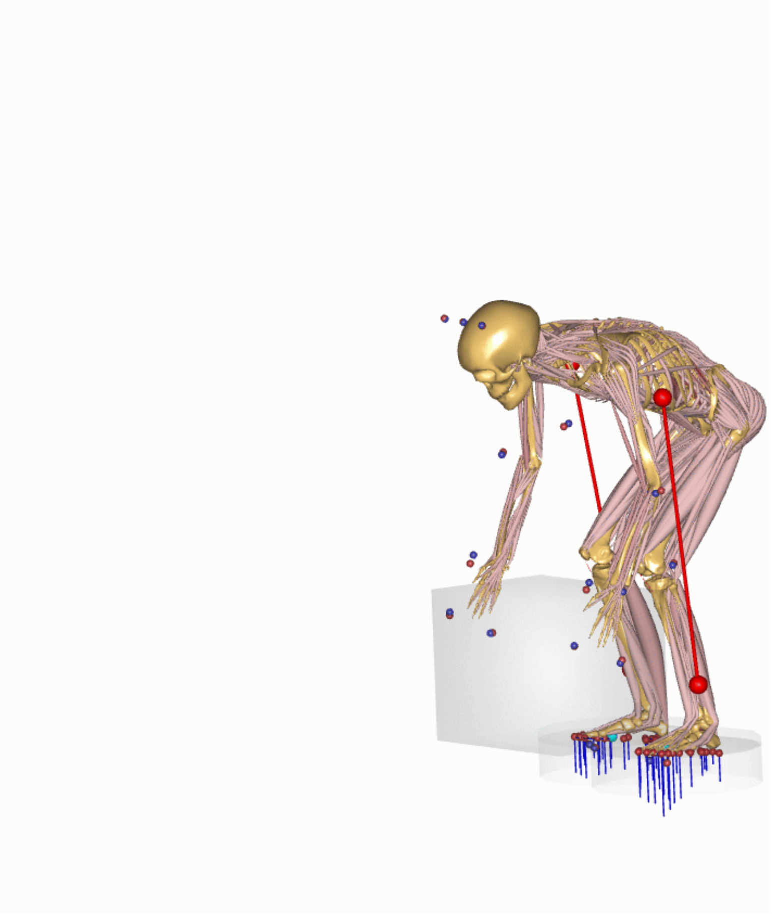
Without exo



With ”spring rod” exo

Conclusions

- Simulation-based conceptual design of exoskeletons is possible (with AnyBody).
- In the absence of biomechanical ergonomic guidelines, use a baseline model of a safe activity, e.g., gait.
- Use idealized AnyReacForces to investigate potential of improvement and get parameters for passive actuators.
- You can go a long way with a few iterations.



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<u>Events</u>

- Let's meet at WearRAcon 2022
  - April 25-26, 2022 - Scottsdale, Arizona

Meet us? Send email to sales@anybodytech.com

Want to present? Send email to ki@anybodytech.com

Thank you for your attention - Time for questions