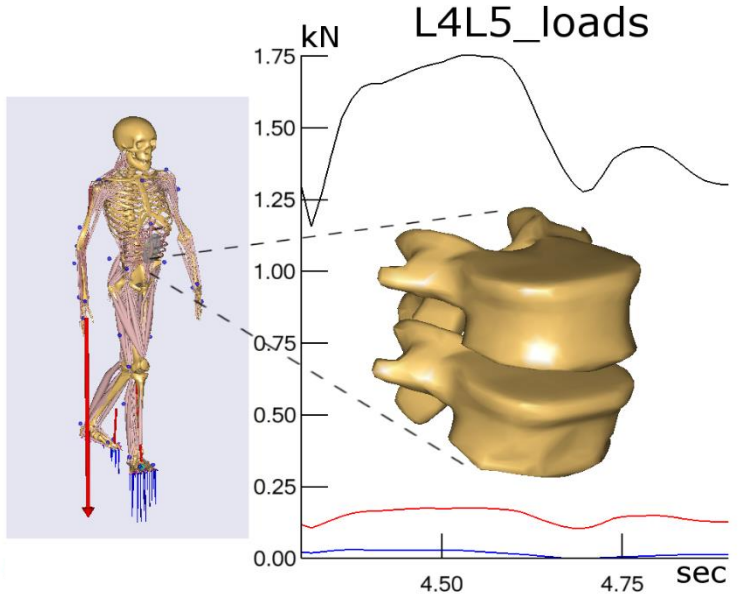
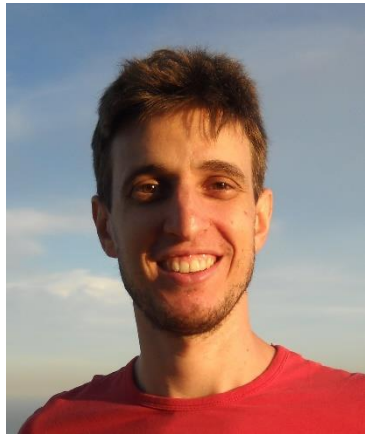
The webcast will start in a few minutes….

Computing realistic loads in the lumbar spine by using the AnyBody musculoskeletal model



Outline

- General introduction to the AnyBody Modeling System
- Background for this webcast
- Computing realistic loads in the lumbar spine by using the AnyBody musculoskeletal model
- Final words and Q&A session.



Tito Bassani
Researcher, PhD
IRCCS Istituto Ortopedico Galeazzi, Milano
LABS – Laboratory of Biological Structures Mechanics

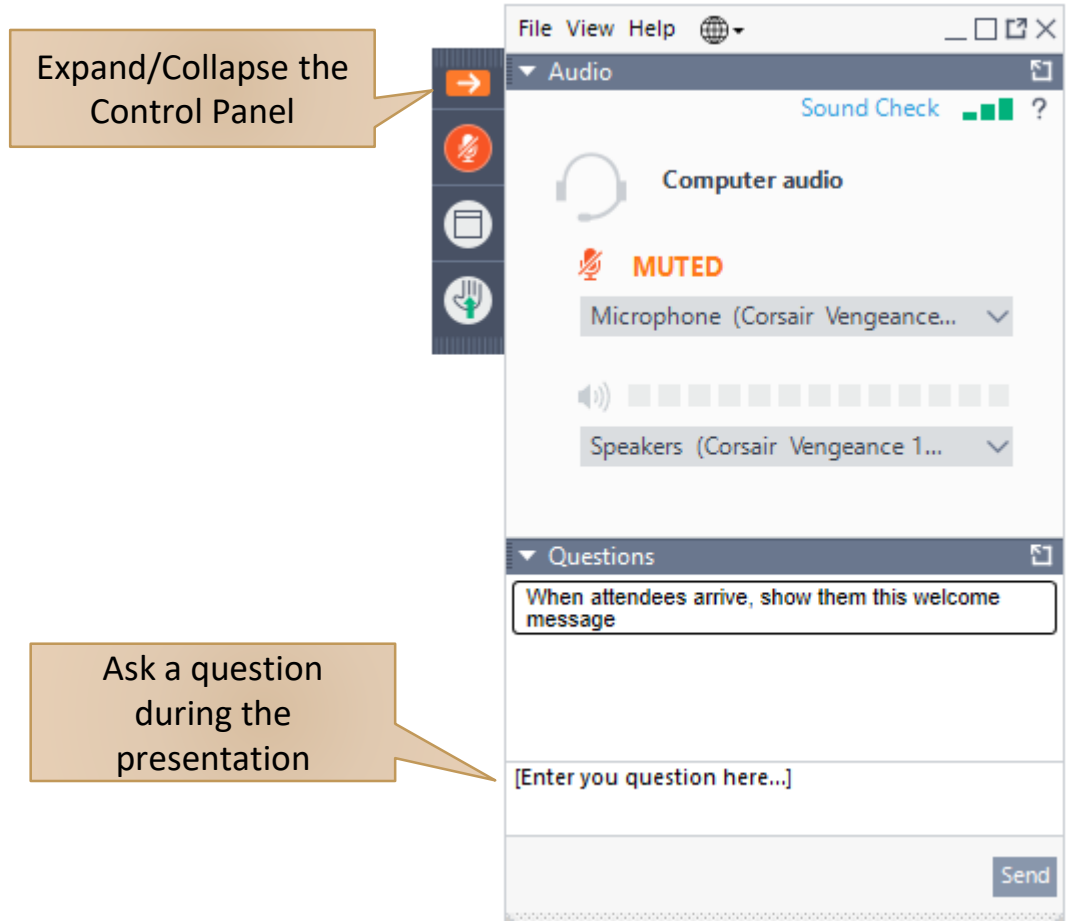
Host:
Pavel Galibarov
Sr. Consultant
AnyBody Technology

Control Panel

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

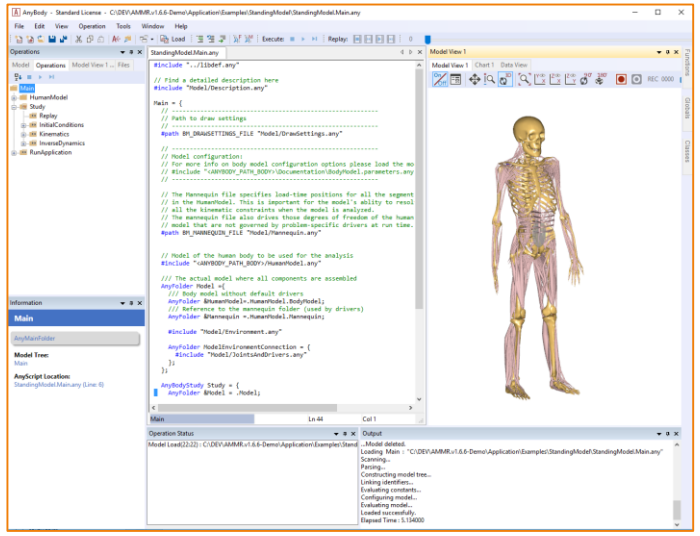
Submit questions and comments via the Questions panel.

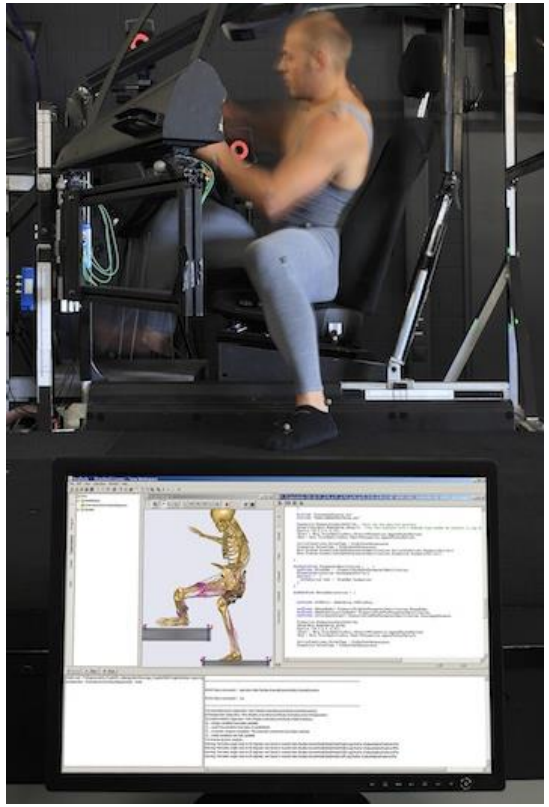
Questions will be addressed at the end of the presentation. If your question is not addressed we will do so by email.



AnyBody Modeling System

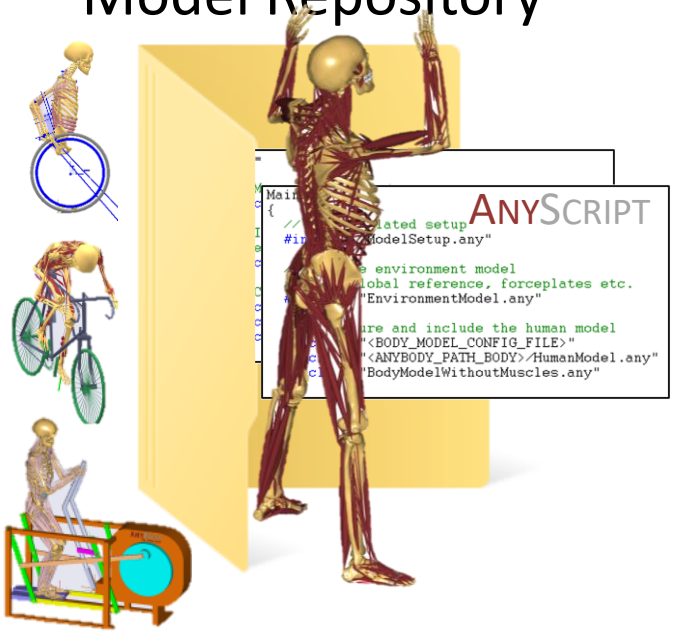
AnyBody Modeling System

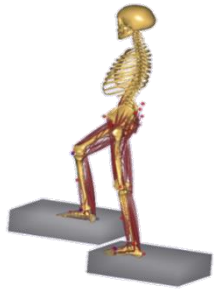




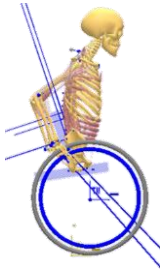
Rasmussen et. al. (2011), ORS Annual Meeting

AnyBody Managed Model Repository





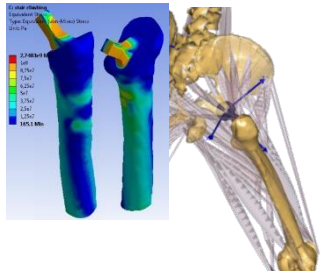
Movement Analysis



Product Design Optimization

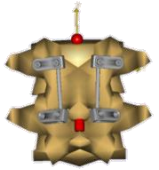
ANYBODY Modeling System

Ergonomic Analysis



Load Cases for Finite Element Analysis

Surgical Planning and Outcome Evaluation

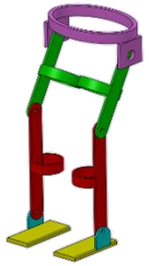


AnyBody Modeling System

Motion and Forces

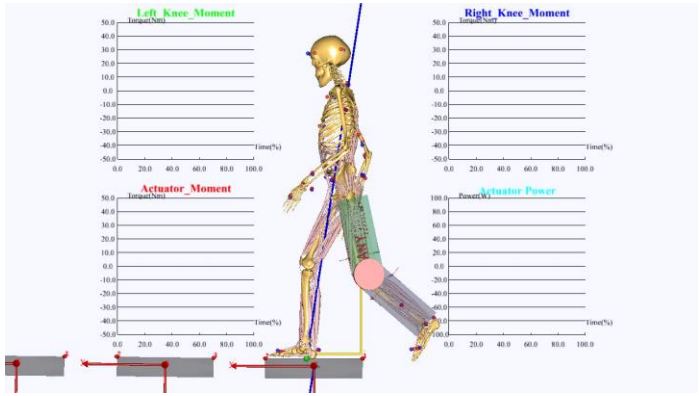
Body model

Environment model



Inverse dynamics
Muscle recruitment

Simulation



Internal body loads

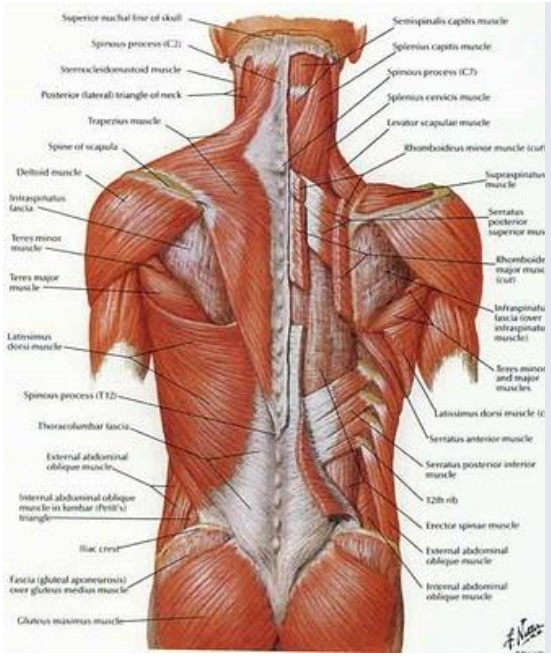
- Muscle forces
- Joint forces

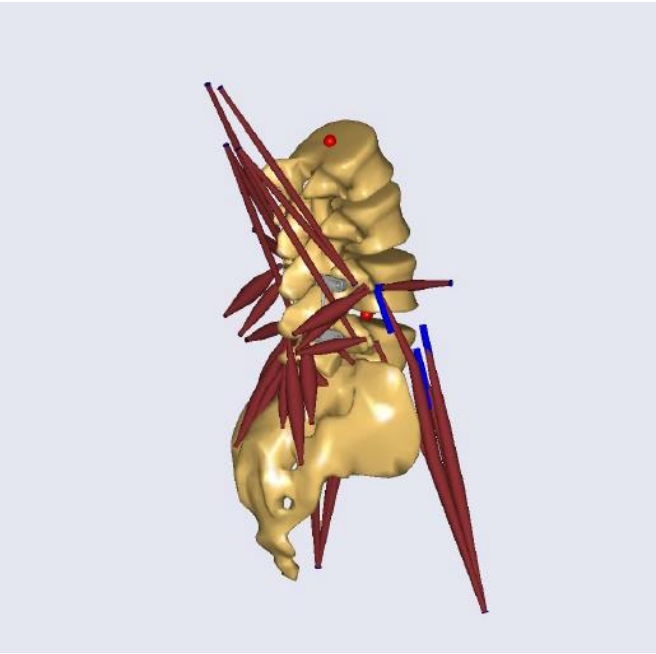
Design Optimization

Post Processing (e.g. FE tools)

Spinal loads

- **Muscle forces**
  - **Unlike muscles of lower/upper extremities difficult to measure individual maximum isometric strength**





- Intervertebral disc pressure
  - Noninvasive methods are limited
  - Difficult for ethical approvals
  - Proximity to spinal canal makes dangerous

- Facet joint contact forces
  - Similar difficulties as with the IVD pressure measurements

Spinal loads

- Muscle forces
  - Unlike muscles of lower/upper extremities difficul
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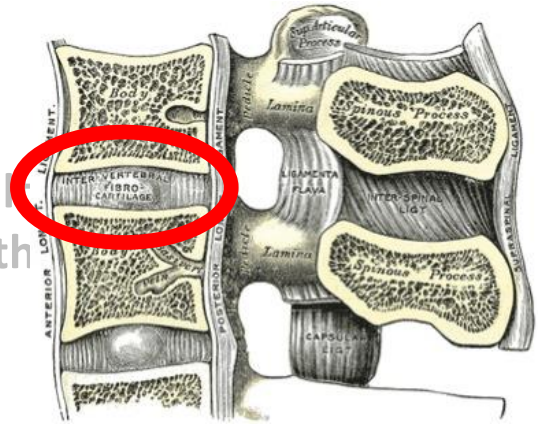
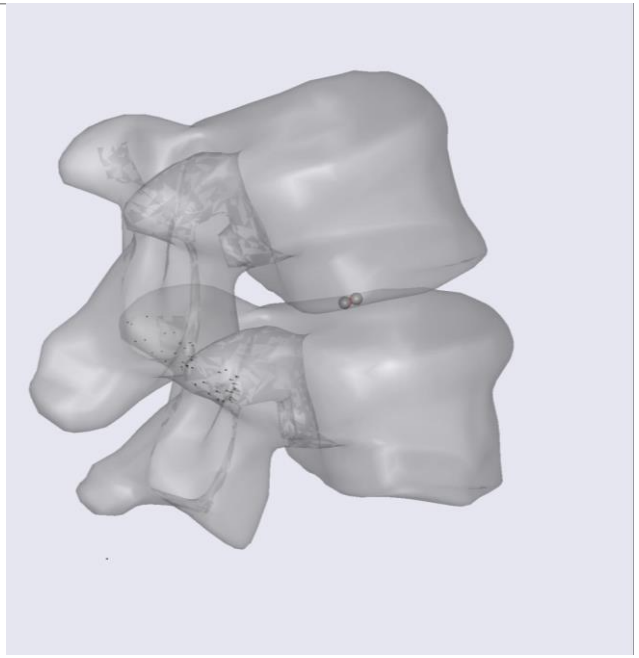
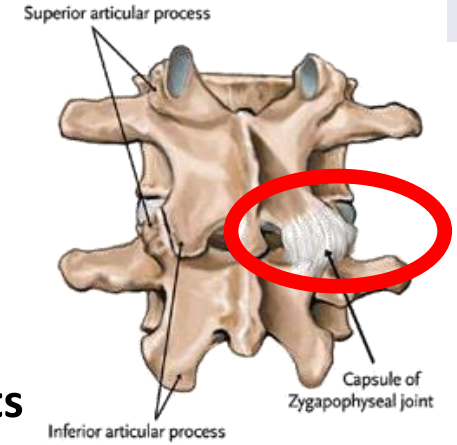




- **Intervertebral disc pressure**
  - **Noninvasive methods are limited**
  - **Difficult for ethical approvals**
  - **Proximity to spinal canal makes dangerous**



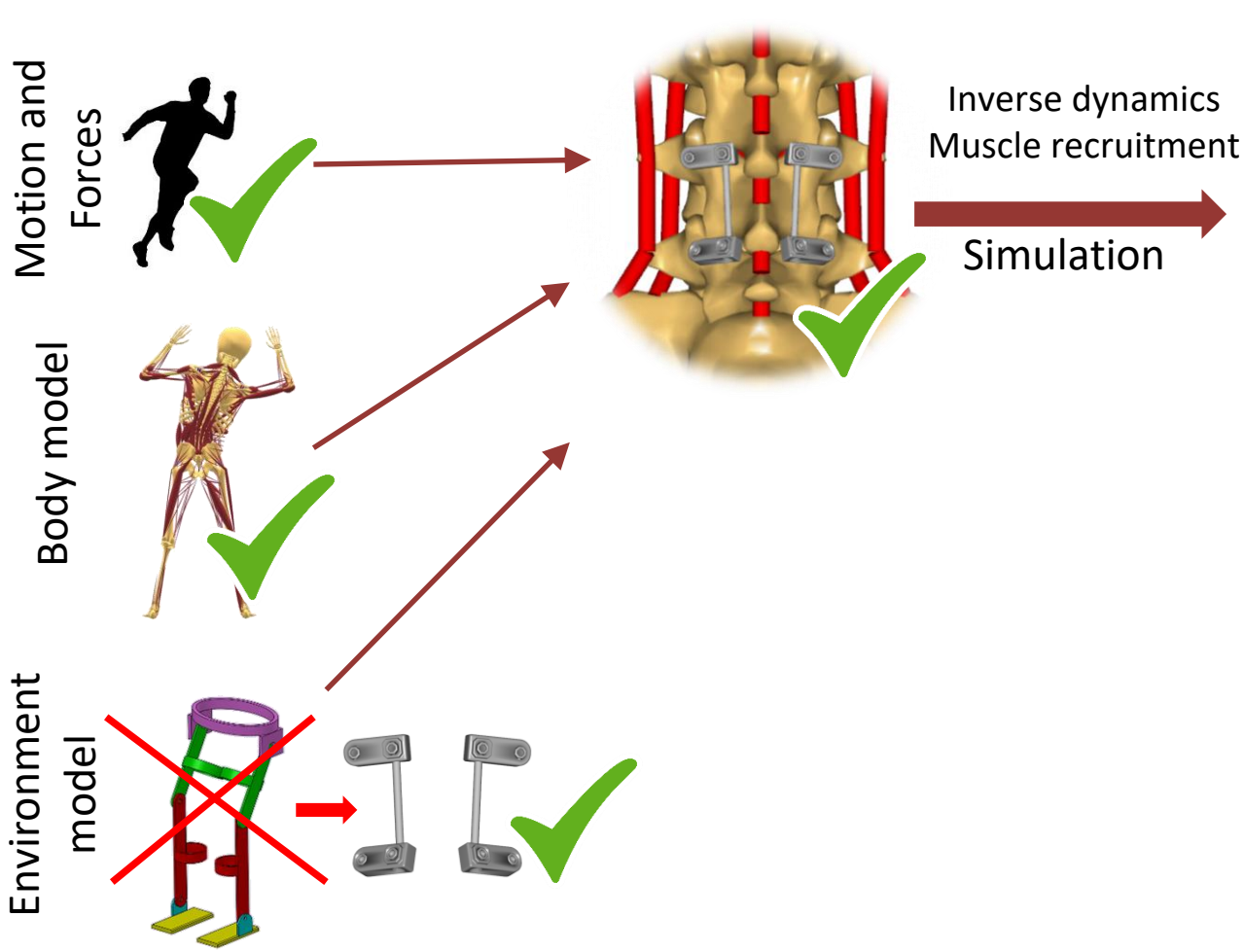
- **Facet joint contact forces**
  - **Similar difficulties as with the IVD pressure measurements**

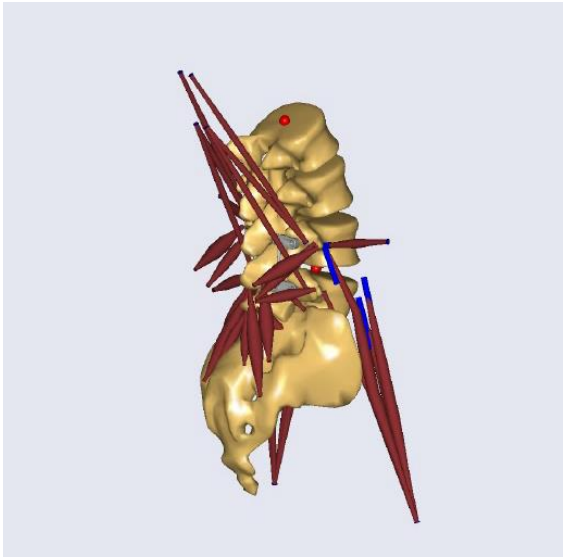
Validation & Verification

Verification of a model is the process of confirming that it is correctly implemented with respect to the conceptual model

Validation checks the accuracy of the model's representation of the real system.

Validation & Verification

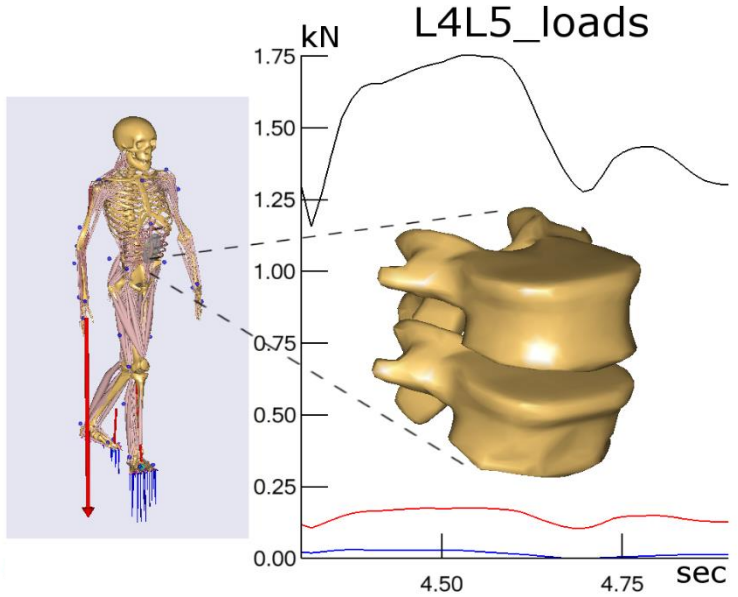




Internal body loads

- Muscle forces
- Joint forces

Computing realistic loads in the lumbar spine by using the AnyBody musculoskeletal model



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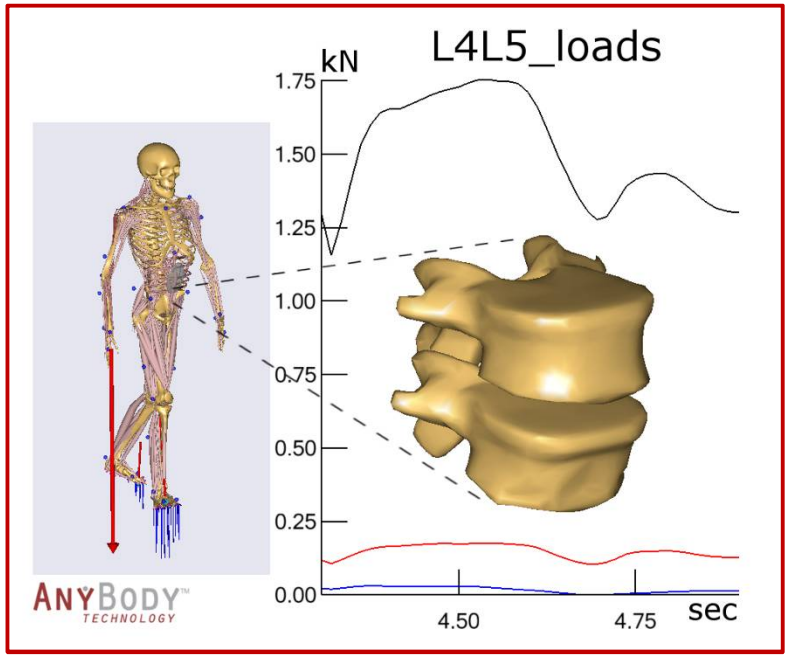

Presenter:
Tito Bassani, PhD
Biomedical Engineer at
Galeazzi Orthopaedic Institute – Milan

www.labsgaleazzi.it

Date:
Wednesday 21 June 2017

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The presentation is based on a recent publication

Journal of Biomechanics 58 (2017) 89–96

Contents lists available at ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech
www.JBiomech.com

Validation of the AnyBody full body musculoskeletal model in computing lumbar spine loads at L4L5 level

Tito Bassani [a,*], Elena Stucovitz [a], Zhihui Qian [b], Matteo Briguglio [a], Fabio Galbusera [a]

[a] IRCCS Istituto Ortopedico Galeazzi, Milan, Italy
[b] Key Laboratory of Bionic Engineering, Jilin University, Changchun, PR China

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The AnyBody AMMR

- AnyBody software provides a full-body musculoskeletal model (AnyBody Managed Model Repository, AMMR).
- The full-body model is increasingly exploited by numerous researchers worldwide.
- More than 50 publication references listed in the AnyBody Technology web site for the year 2016, most of which exploit the full body model from AMMR.

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Computing lumbar loads

When focusing on the characterization of human spine, the model can be accounted to evaluate the lumbar loads during physiological activities (e.g. training, ergonomics and rehabilitation) and pathological scenarios (e.g. spine deformities and surgical fixation strategies).

Does the model provide realistic loads?

Model validation is required!

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Model validation: previous works

ELSEVIER

Journal of Biomechanics 40 (2007) 1219–1227

JOURNAL OF BIOMECHANICS

www.elsevier.com/locate/jbiomech
www.JBiomech.com

A generic detailed rigid-body lumbar spine model

Mark de Zee[a,*], Lone Hansen[b], Christian Wong[c], John Rasmussen[a], Erik B. Simonsen[b]

Applied Ergonomics 48 (2015) 22–32

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

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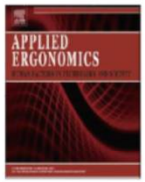

Comparative evaluation of six quantitative lifting tools to estimate spine loads during static activities

Mohammad Ali Rajaee [a], Navid Arjmand [a,*], Aboulfazl Shirazi-Adl [b], André Plamondon [c], Hendrik Schmidt [d]

CrossMark

XXIInd Congress of the International Society of Biomechanics 2009

VALIDATION OF A BIOMECHANICAL MODEL OF THE LUMBAR SPINE

[1]John Rasmussen, [1,2]Mark de Zee and [3]Sylvain Carbes

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Previous works: limitations

The previous works compared the lumbar loads with reference measurements obtained *in vivo*, but held some **limitations**:

- arbitrarily imposed kinematics
- only static postures, no motion conditions
- only static lifting activities

Need for a comprehensive validation!

- setting kinematics from motion capture data
- evaluating motion conditions
- assessing dynamic lifting activities

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In vivo measurements of the L4L5 disc nucleus pressure

ELSEVIER

Clinical Biomechanics 16 Supplement No. 1 (2001) S111–S126

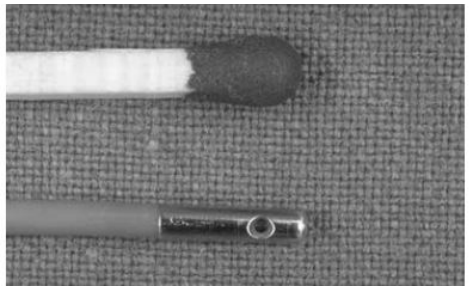
CLINICAL BIOMECHANICS

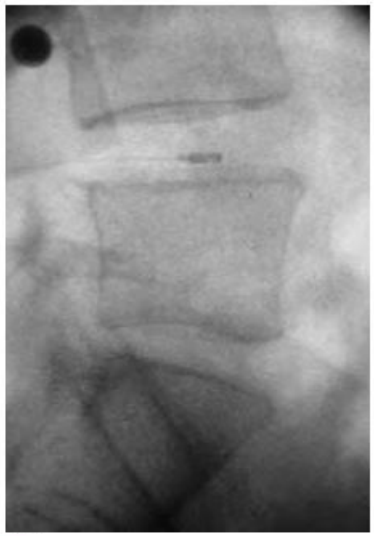
www.elsevier.com/locate/clinbiomech

Intradiscal pressure together with anthropometric data – a data set for the validation of models

Hans-Joachim Wilke [a,*], Peter Neef [b], Barbara Hinz [c], Helmut Seidel [c], Lutz Claes [a]

[a] *Institute for Orthopaedic Research and Biomechanics, University of Ulm, Helmholtzstrasse 14, 89081 Ulm, Germany*
[b] *Gesundheitspark, Ulm, Germany*
[c] *Federal Institute for Occupational Safety and Health, Berlin, Germany*





L4L5 disc

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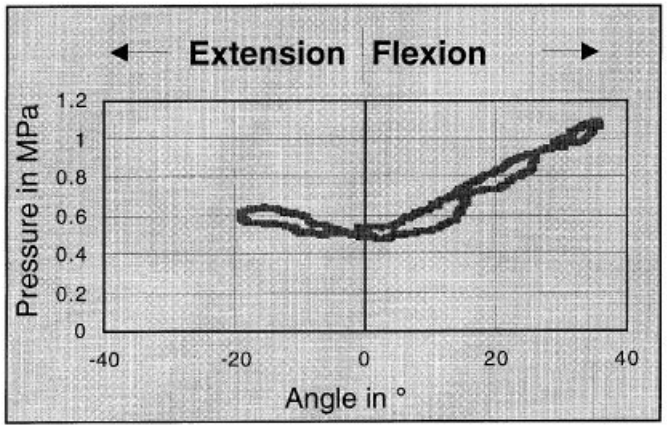
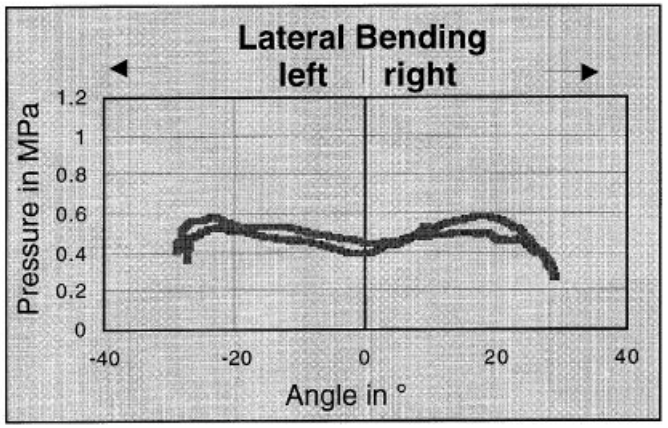
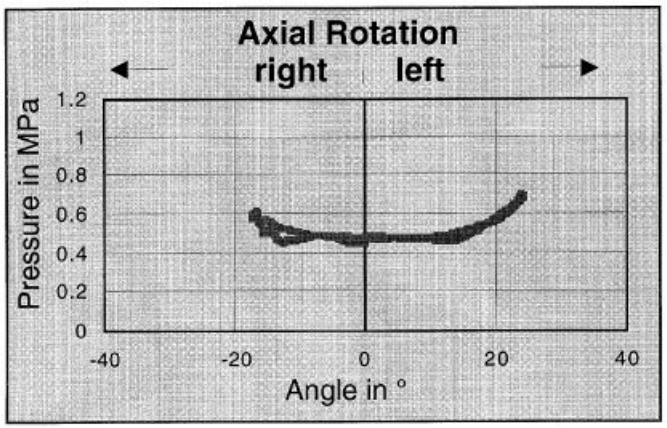
In vivo disc nucleus pressure and motion angle

Intradiscal pressure in function of the motion angle between thorax and pelvis. Evaluated in continuous dynamic fashion.







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In vivo pressure during exercise tasks

- Exercise conditions accounting for the lifting of a crate of beer of 19.8 kg.
- Other conditions: standing, sitting, walking.

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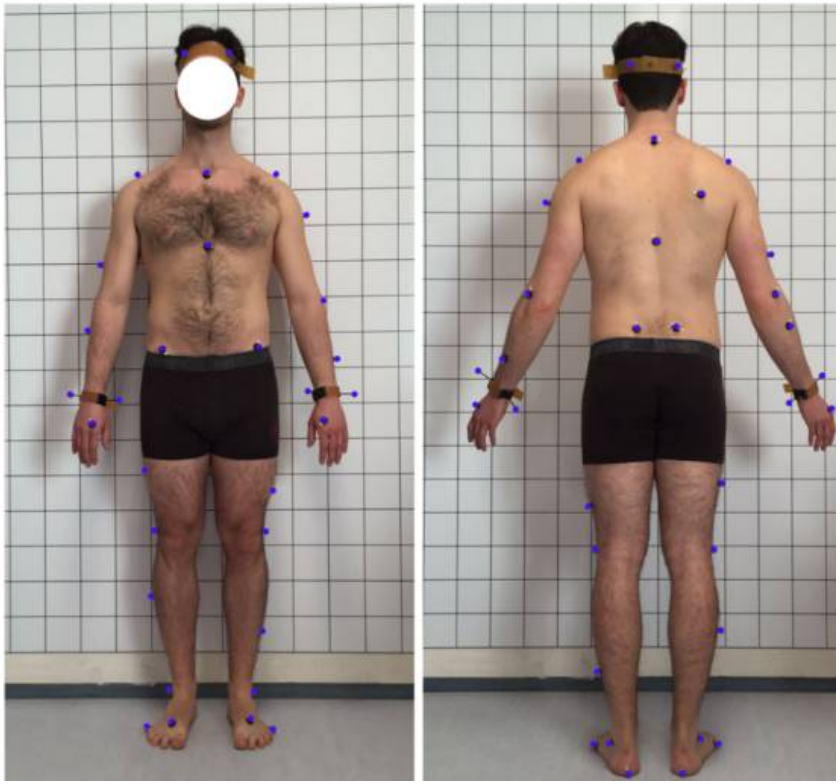
Subject enrolled in the present study



- One male subject (28 years), same weight (72 kg) and height (174 cm) of the volunteer evaluated by Wilke et al. in 2001.
- 41 passive markers placed on skin (VICON Plug-in-Gait protocol).
- Motion capture data acquired with 8 cameras optoelectronic system (BTS Bioengineering, Italy).
- Marker trajectories acquired at 70 Hz.

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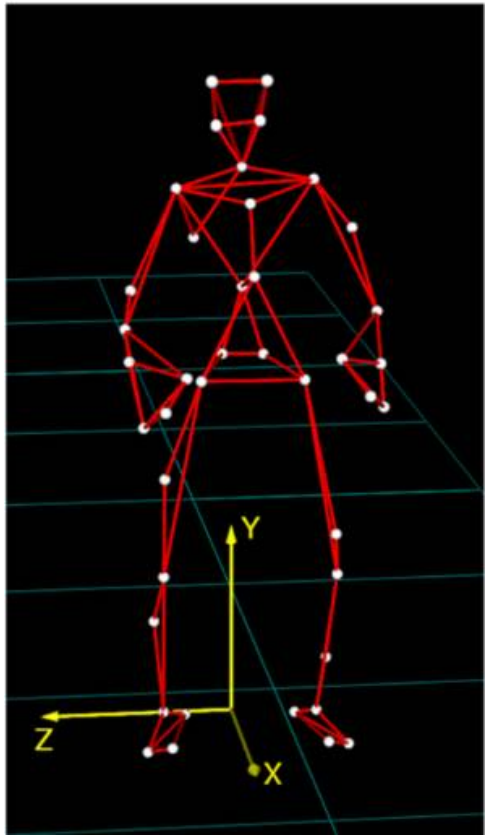
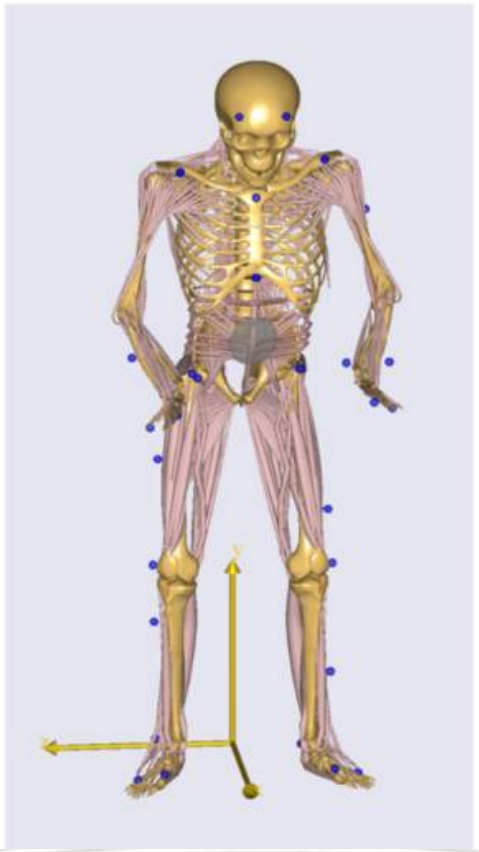
From motion capture to model kinematics

The markers trajectories in the 3D space were exported as *.c3d files and then loaded into AnyBody software to set mannequin kinematics.





ANYBODY™ TECHNOLOGY

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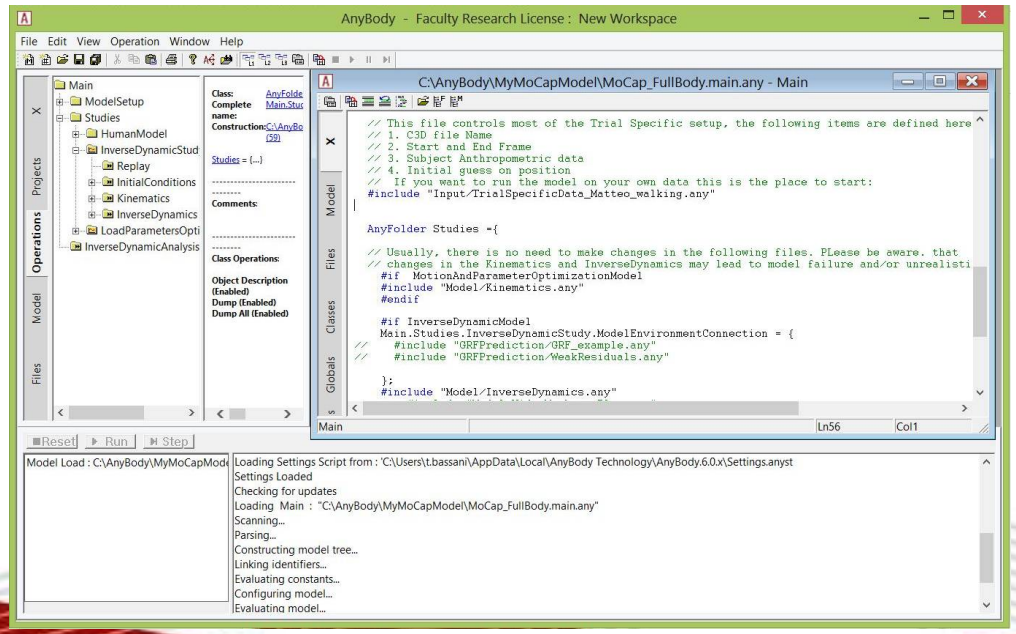
AnyBody setting

- AnyBody v.6.0 and full-body model from AMMR v.6.1.3
- MoCap model (motion optimization followed by inverse dynamic analysis)
- Markers trajectories low pass filtered (10 Hz)
- Length-mass-fat scaling and anthropometrics data were accounted
- Default lumbar spine rhythm assumption
- Ground reaction force prediction
- Muscle recruitment criterion: 'MR_Polynomial'



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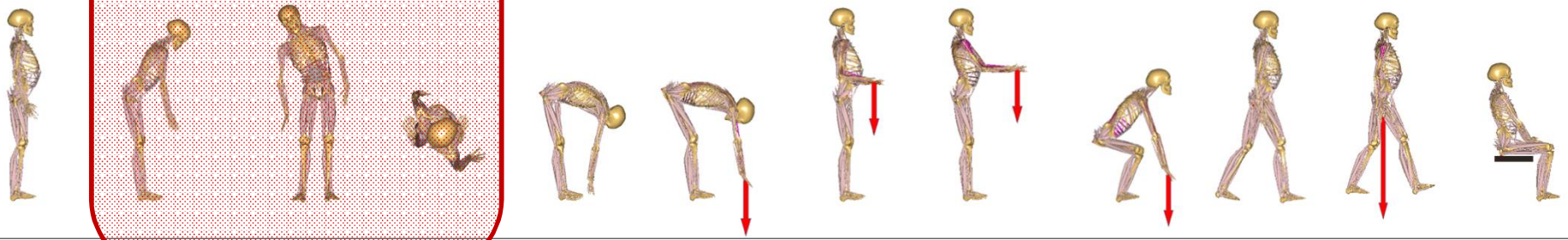
Exercise tasks

Twelve exercise tasks were performed to accurately replicate the corresponding conditions evaluated by Wilke et al. in 2001.

i	ii	iii	iv	v	vi	vii	viii	ix	x	xi	xii
standing	flexion-extension	lateral bending	axial rotation	fingers to floor	lifting load* knees extended	arms at chest holding load*	arms extended holding load*	squat lifting load*	walking	walking carrying load#	sitting (on stool, straight back)



*, lifting with both hands a barbell loaded at the center with 20 kg.

#, carrying with the right hand a dumbbell loaded with 20 kg.

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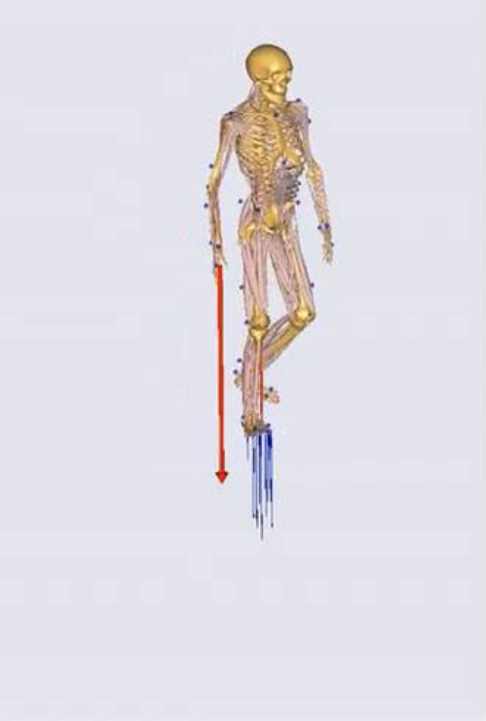
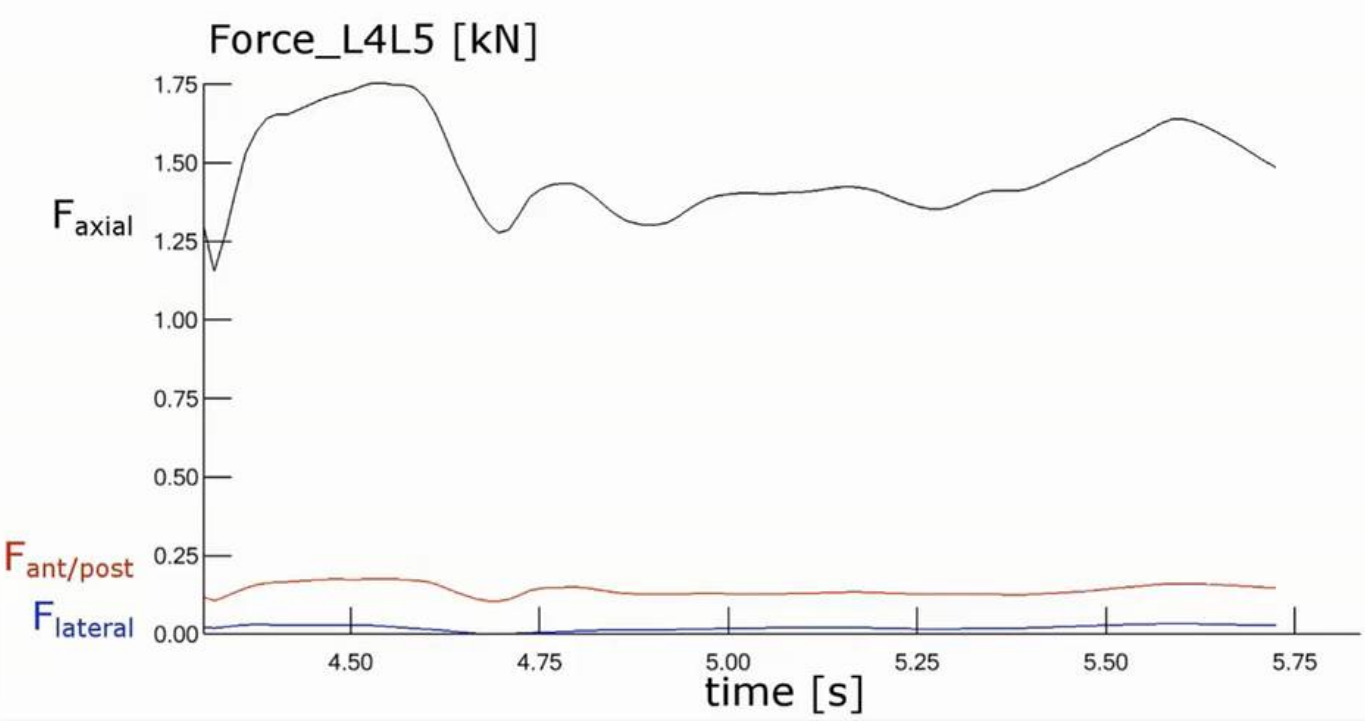
Walking carrying 20 kg with the right hand





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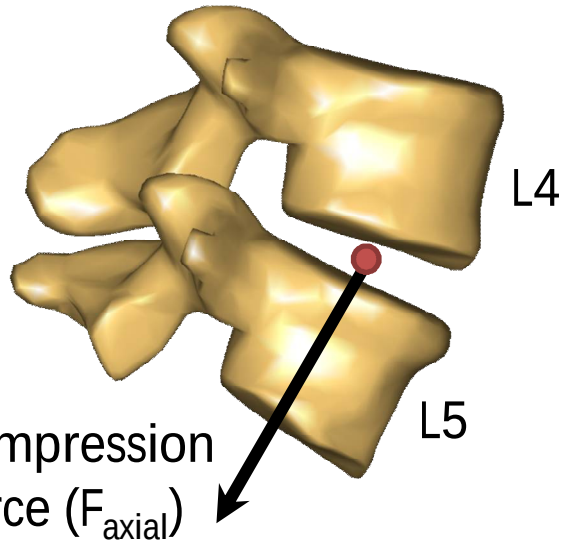
From intersegmental load to average disc pressure



$$\text{Average disc pressure} = \frac{\text{compression force}}{\text{L5 upper endplate area (from Wilke et al., 2001)}}$$

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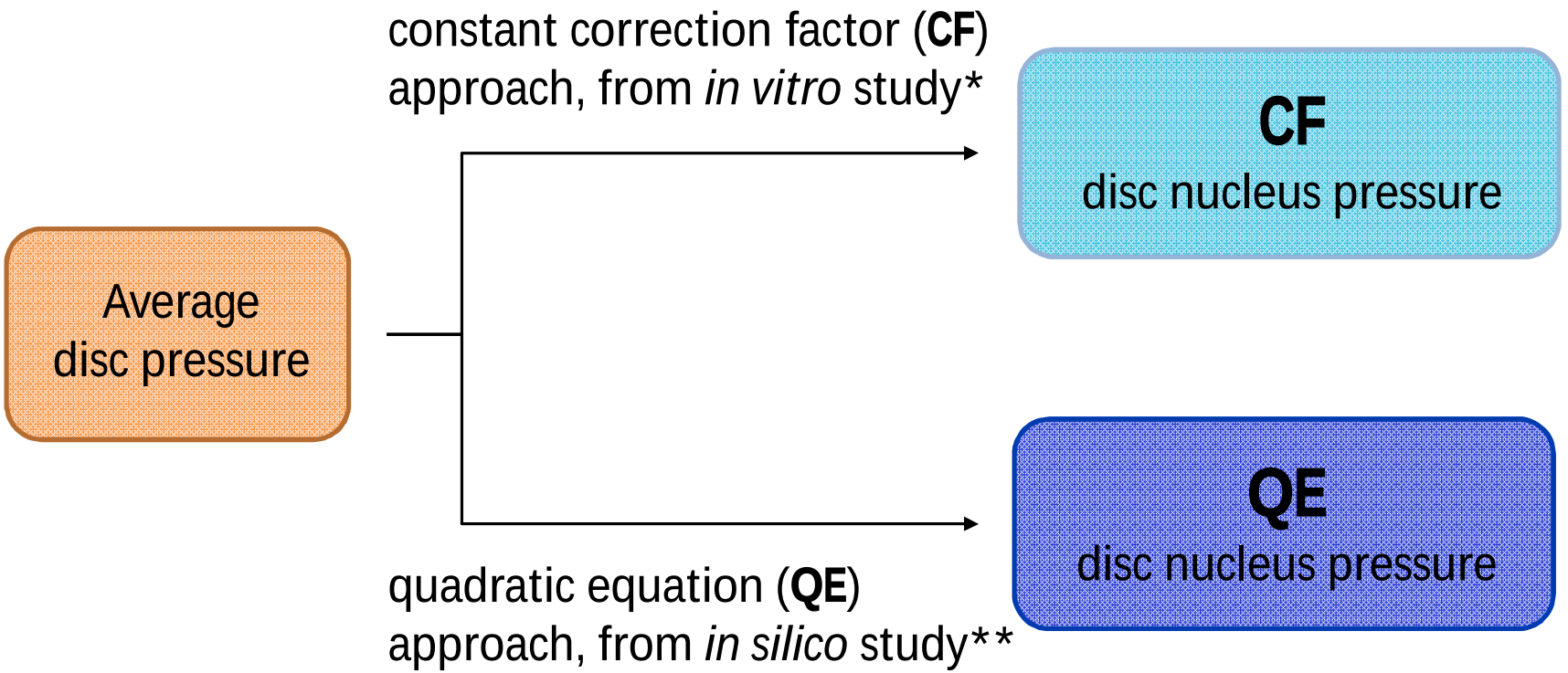
From average disc pressure to disc nucleus pressure



*Brinckmann P et al., 1991. *Spine (Phila Pa 1976)* 16(6):641–646.
**Ghezelbash F et al., 2016. *Biomech Model Mechanobiol* 15(6):1699-1712.

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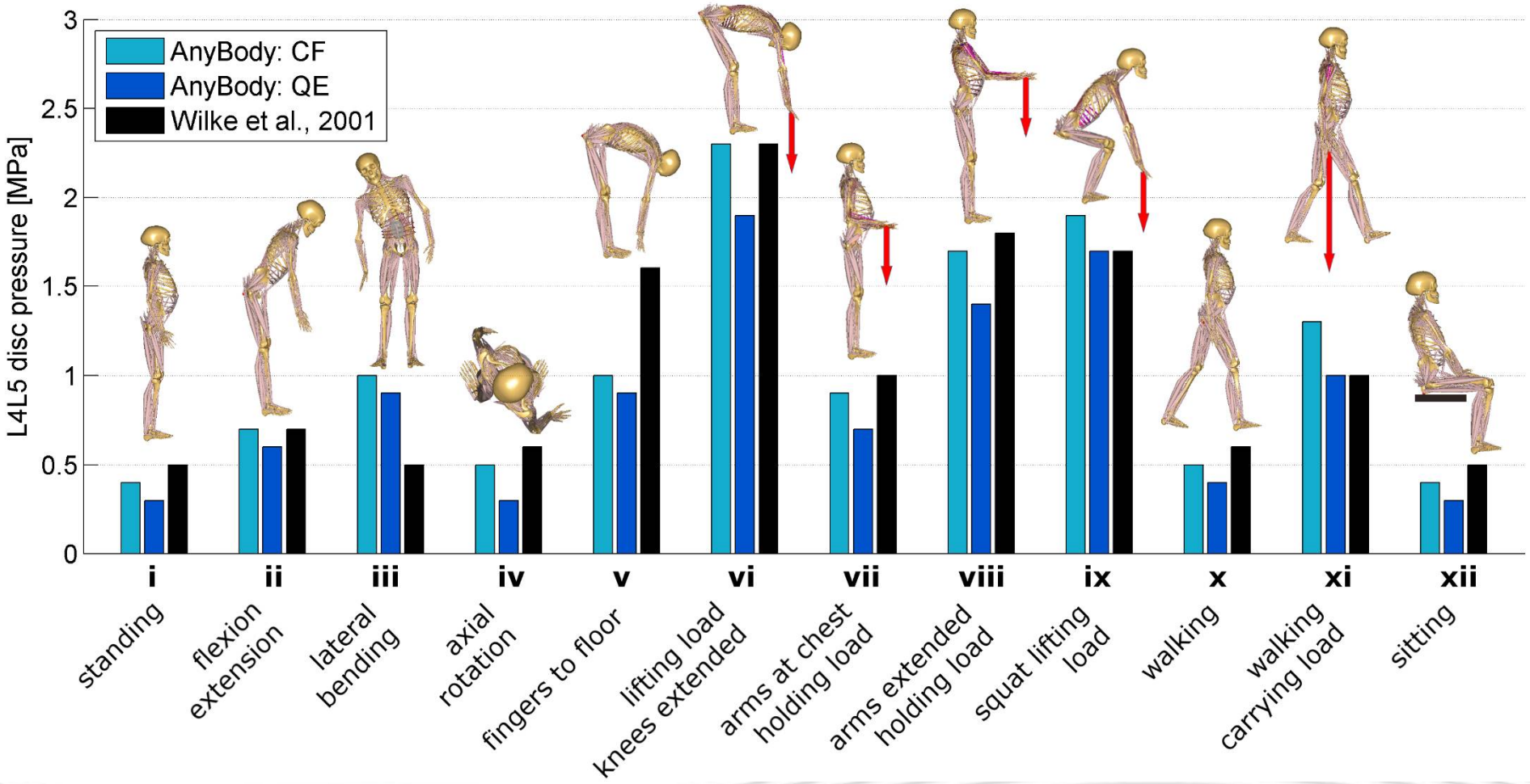
Results



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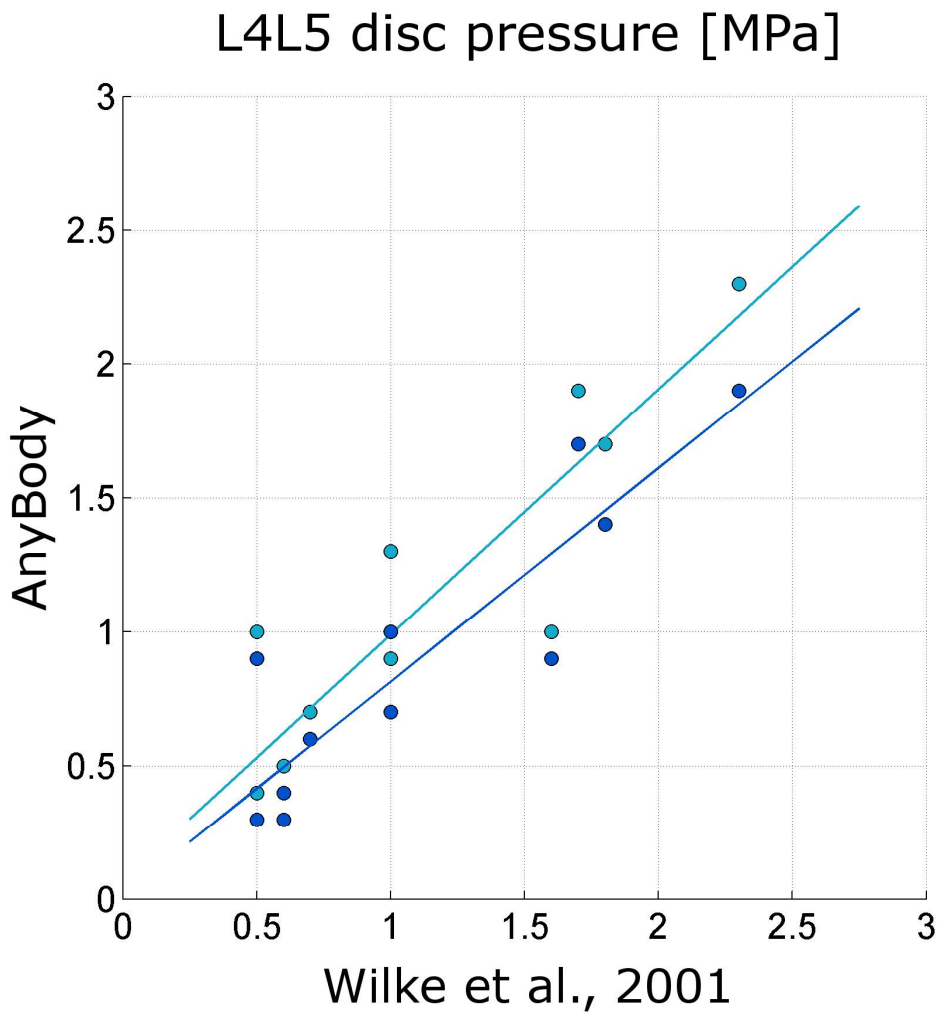
Correlation between computed and *in vivo* pressure



CF

corr. coeff:	0.91
p-value:	<0.001
line slope:	43°
intercept:	0.07 MPa
RMSE:	0.24 MPa

QE

corr. coeff:	0.90
p-value:	<0.001
line slope:	39°
intercept:	0.02 MPa
RMSE:	0.22 MPa

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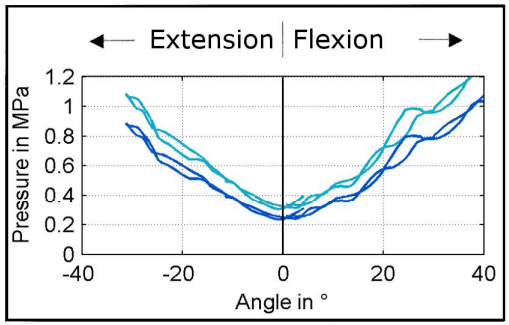
Disc nucleus pressure in function of the motion angle between thorax and pelvis

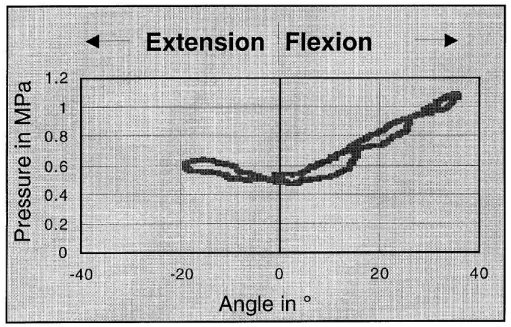
AnyBody

CF: — QE: —

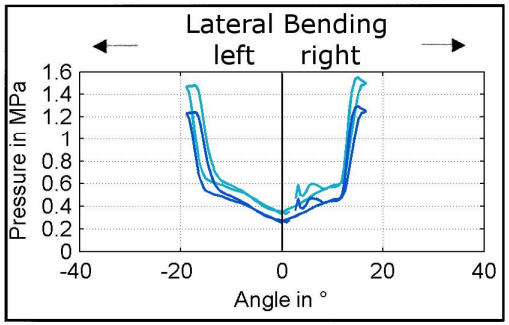
Wilke et al., 2001

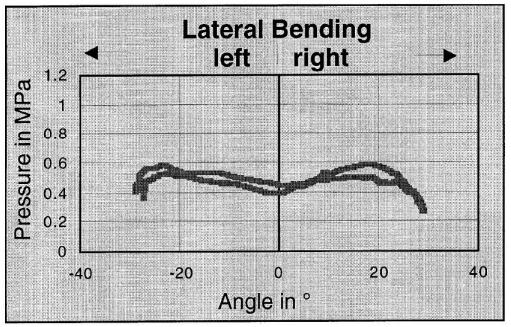
flexion-extension



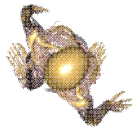


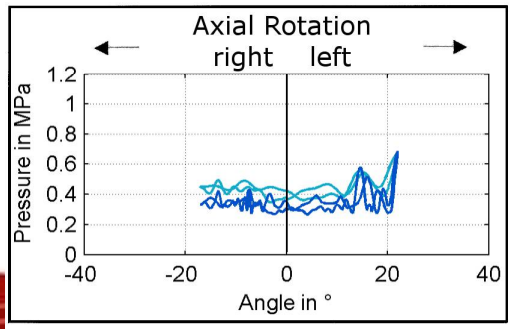
lateral bending

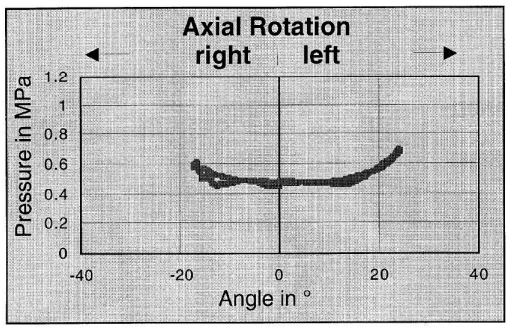




axial rotation







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Discussion

- The results demonstrated the **suitability** of the AnyBody model in computing **lumbar spine loads** at L4L5 level.
- **Caution** needs to be taken only when considering postures characterized by **large lateral displacements**.
- The findings promote the AnyBody model as an **appropriate tool** to non-invasively evaluate lumbar loads in **physiological activities**.
- **Future studies** can be aimed at evaluating the use of AnyBody modeling in pathological conditions known altering spine alignment, such as spine deformities and spine fixation strategies.

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Limitations of the present study

- **One subject** and **one repetition** of the tasks.
- Subject was **28 years** old whereas the one enrolled by Wilke et al. in 2001 was **45 years** old.

- The AnyBody model has **several limitations**:
  - rigid rib cage and thoracic spine
  - no facet joints and ligaments
  - lumbar discs simply described as spherical joints
  - lumbar spine rhythm based on literature assumption*

*Wong KW et al., 2006. *Spine (Phila Pa 1976)* 31(4):414–19.

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Markers placement

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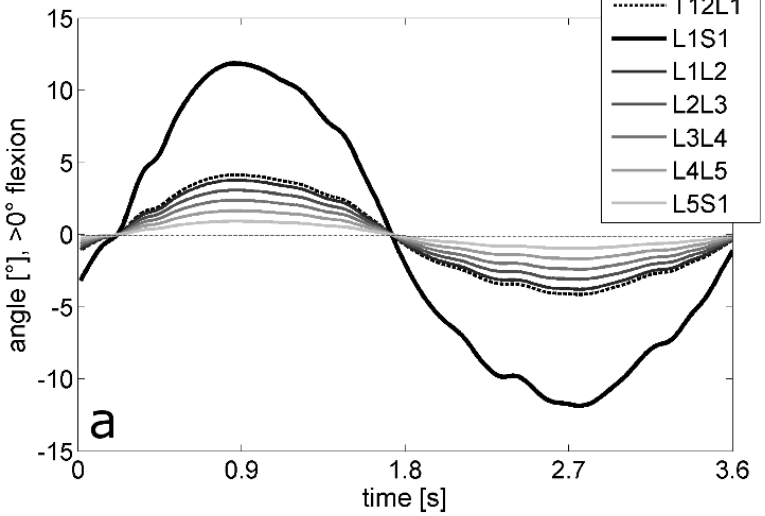
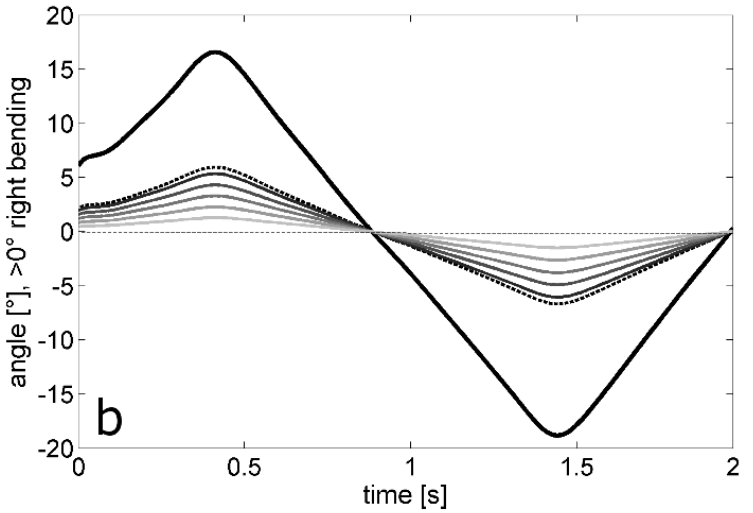
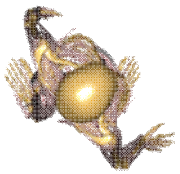
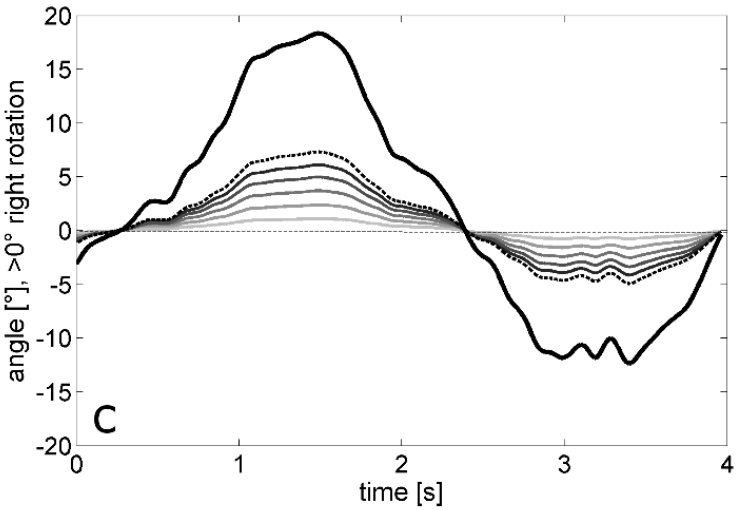
Lumbar spine rhythm









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In conclusion: take-home message

The AnyBody full-body musculoskeletal model is suitable in computing realistic lumbar loads in physiological conditions.

- kinematics from motion capture data
- motion conditions in continuous dynamic fashion
- lifting activities during motion

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Thanks for your attention

Acknowledgements

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Previous webcasts

- Check our YouTube channel

www.anybodytech.com

- Events, dates, publication list, ...

www.anyscript.org

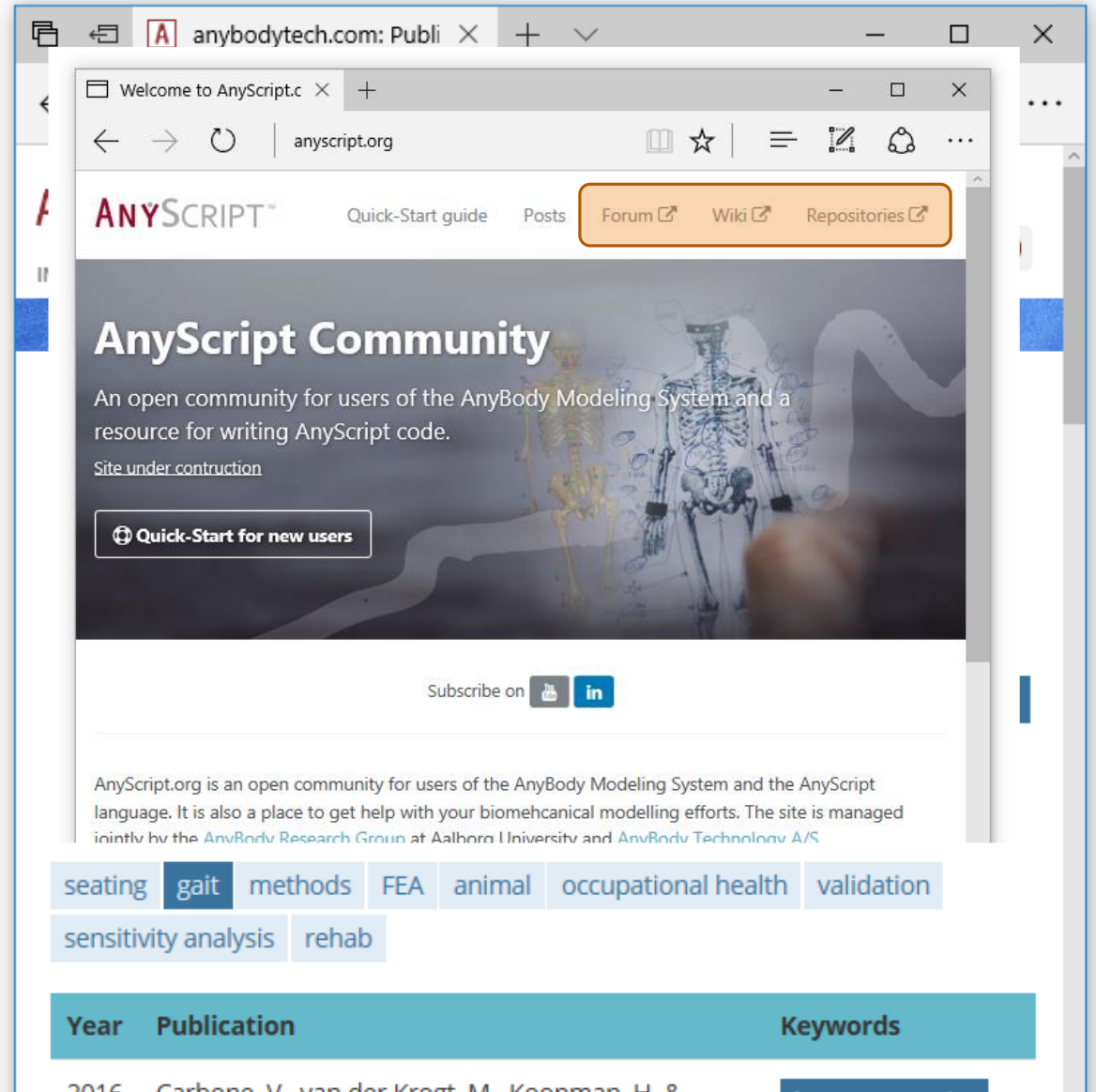
- Wiki, Forum, Repositories

Events:

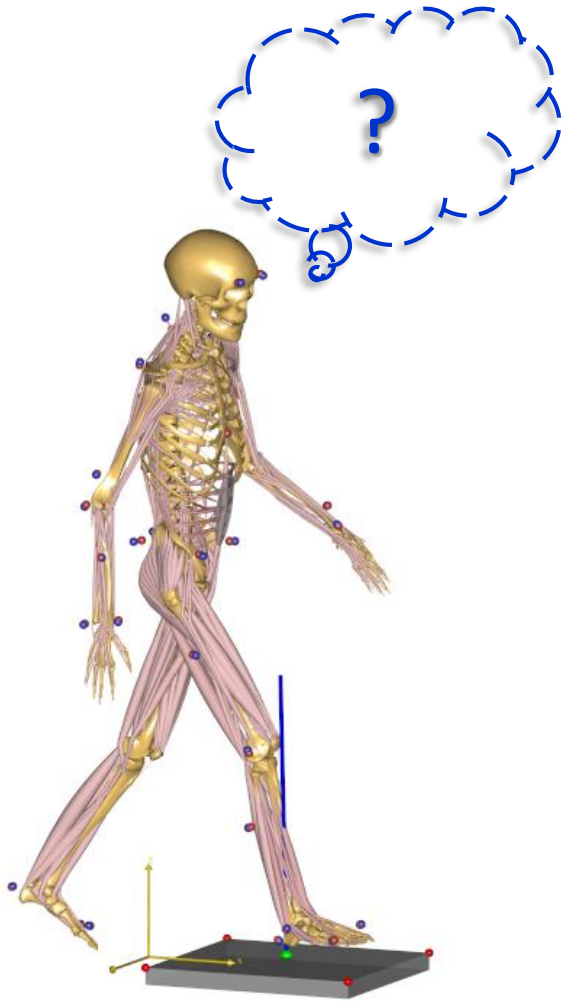
- 29 Jun: *Webcast* – New AnyBody Modeling System: Tour and overview of version 7.0
- 2-5, July: 23rd Congress of the ESB, Sevilla, Spain

🤝 **Meet us?** Send email to sales@anybodytech.com

💡**Note:** Close to 500 AnyBody related publications.



Time for questions:



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