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Paracelsus Medizinische Privatuniversität Salzburg

ANSYS Conference & 32nd CADFEM Users' Meeting 2014

Methodische Aspekte bei der Belastungs-analyse des Hüftgelenks mit MKS und FEA

Methodical Aspects of the Load Analysis of the Hip Joint with MBS and FEA

Varady, P.[1].; Glitsch, U.[2]; Augat, P.[1]

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der Paracelsus Medizinische Privatuniversität Salzburg

[2] Institut für Arbeitsschutz der DGUV, Sankt Augustin

IFA
Institut für Arbeitsschutz der
Deutschen Gesetzlichen Unfallversicherung

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Structure

Introduction	● Hip Osteoarthritis ● Motivation
Methods	● Motion Capture ● Human Multibody Simulation (MBS) ● Segmentation ● Finite Element Analysis (FEA)
Results	● MBS ● FEA
Discussion	
Summary	

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Hip osteoarthritis

- degenerative joint disease
- progressive degradation of cartilage and other structures of the joint
- joint space narrowing, growth of osteophytes
- prevalence 10.9%[1]
- causes: mechanical stress (trauma, incongruency), accompanying other diseases

osteoarthritis of the hip

[1] D. Pereira, B. Peleteiro, et al. The effect of osteoarthritis definition on prevalence and incidence estimates: A systematic review. *Osteoarthritis and Cartilage* 2011, 19(11):1270-1285.

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Motivation

- detrimental to patients‘ health
- 2.6 million work incapacity days in 2011[2]
- €7.6 billion direct costs in the health care system in 2008[2]
- addition costs from early retirements

→ high socioeconomic relevance

- Is there an association between occupational activities and the osteoarthritis of the hip?
- epidemiological evidence can be found in the literature[3]

→ interest of the accident insurers in the safety and health of employees

[2] Robert Koch-Institut (2013) Arthrose, *Reihe Gesundheitsberichterstattung des Bundes*, Heft 54. Berlin. www.gbe-bund.de. Abrufdatum: 24.10.2013
[3] Sulsky, S. I., Carlton, L., Bochmann, F., Ellegast, R., Glitsch, U., Hartmann, B., … Sun, Y. (2012). Epidemiological evidence for work load as a risk factor for osteoarthritis of the hip: a systematic review. PloS One, 7(2), e31521.

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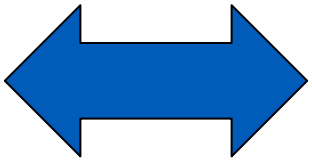
Analysis of occupational and everyday activities

Will certain occupational activities promote the onset of osteoarthritis of the hip?

risk associated activities:

- lifting, carrying und transferring weights (25kg, 40kg, 50kg)
- stair climbing (without weight, with 25kg)
- ladder climbing (angle of 70° and 90°)
- jumping from 430mm height



activities of daily living:

- walking
- sitting down, getting up

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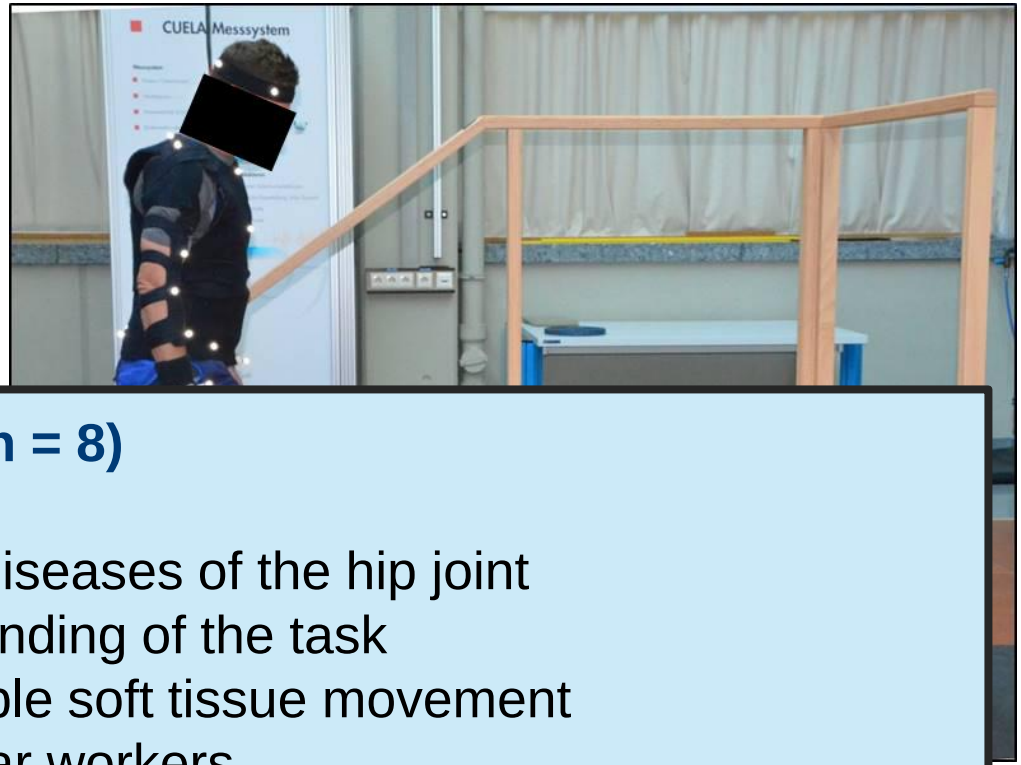
Motion capture, ground reaction forces

- 12-camera-system (Vicon Motion Systems, Oxford, GBR)
- force plates (Kistler Instrumente AG, Winterthur, CH)
- instrumented staircase and ladder (Kistler Instrumente AG, Winterthur, CH)



Subjects (n = 8)

- male
- without diseases of the hip joint
- understanding of the task
- reasonable soft tissue movement
- blue collar workers

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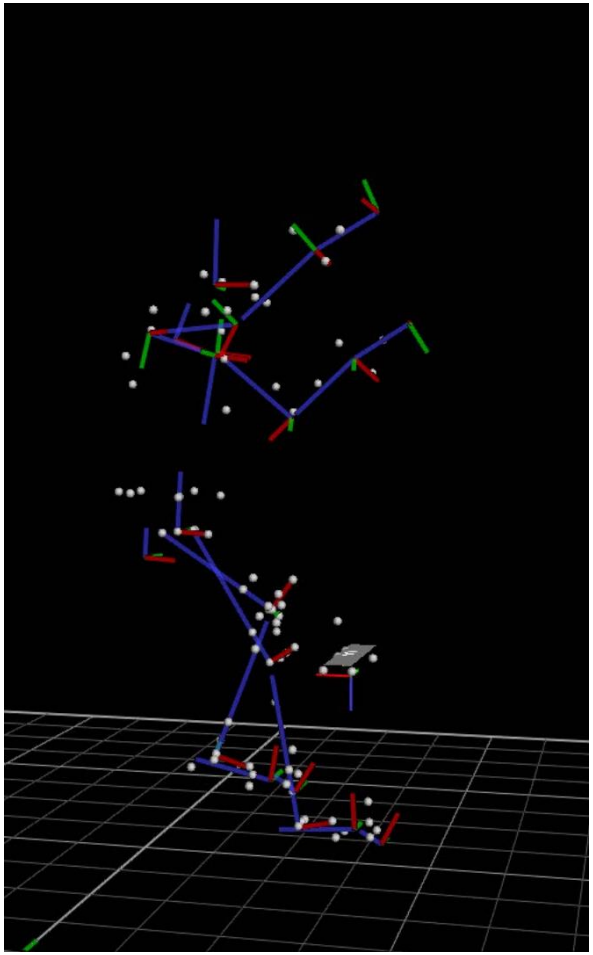
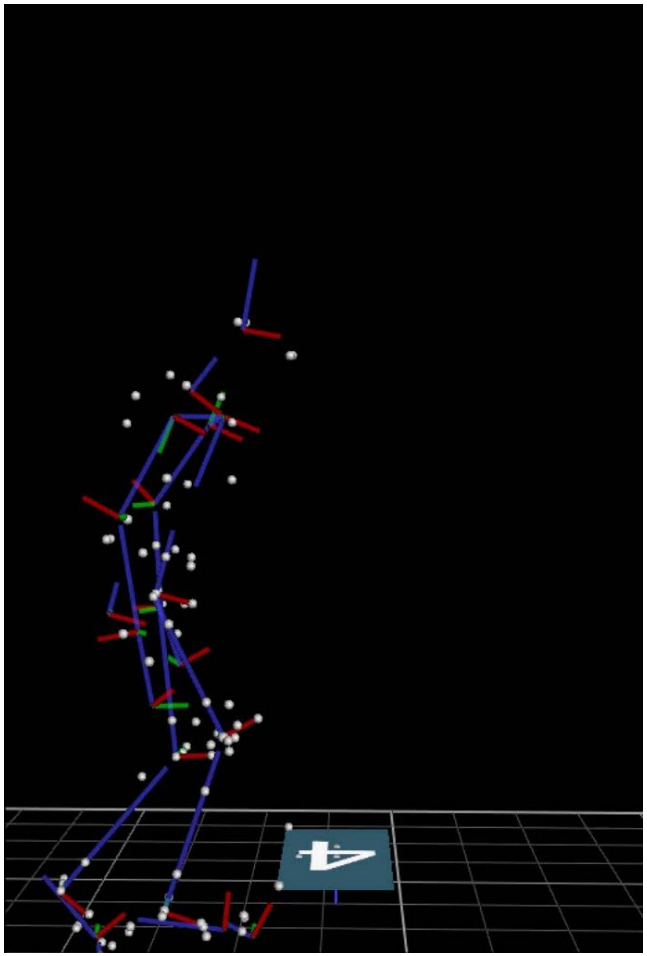
Motion capture, ground reaction forces



marker movement for
ladder climbing



marker movement for
stair climbing

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AnyBody model

- human multibody simulation with AnyBody 6.01 (AnyBody Technology A/S, Aalborg, DK)
- AMMR v1.6: MocapModel_FullBody
- modified hip extensors
- anthropometric scaling
- limitation of parametric optimisation
- save data in H5-file format

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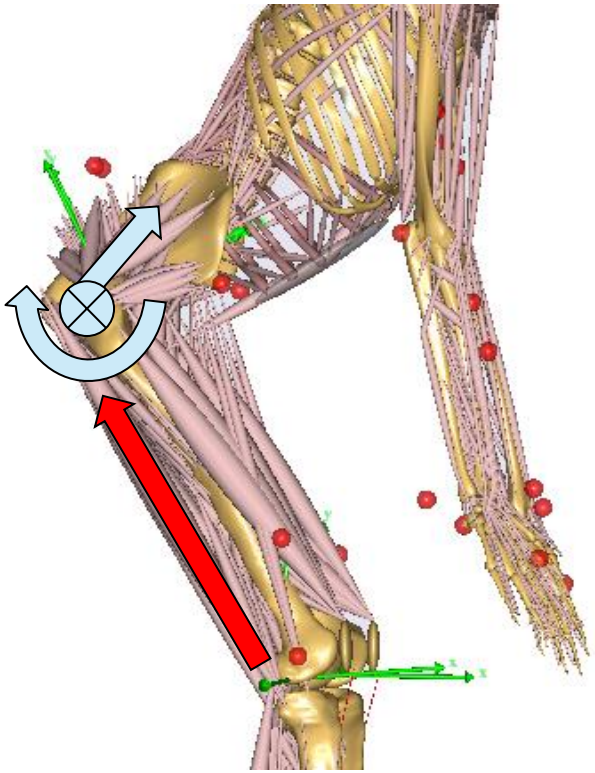
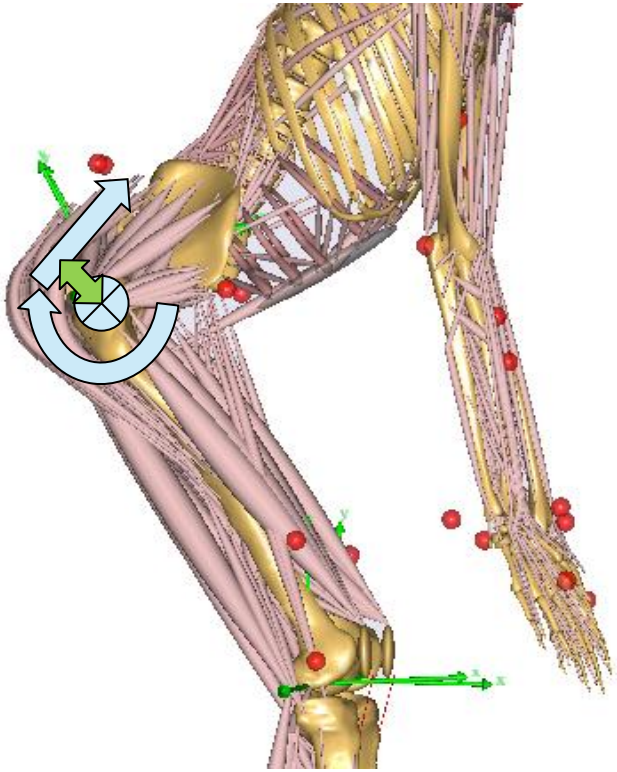
AnyBody model: wrapping extensors



standard model



modified model

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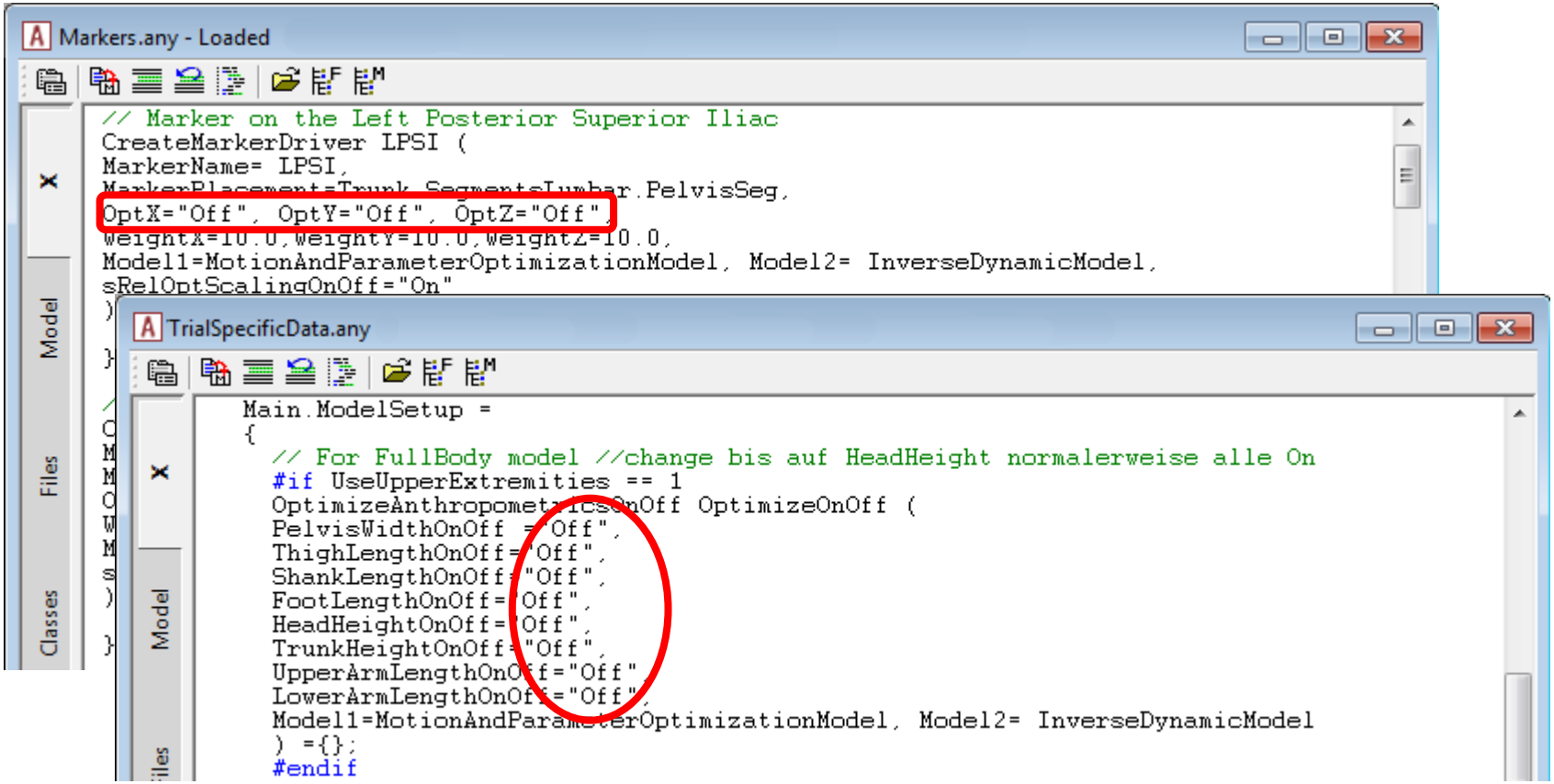
AnyBody model: parameter optimisation

- for one test person the same anthropometry and marker placement was used for every trial



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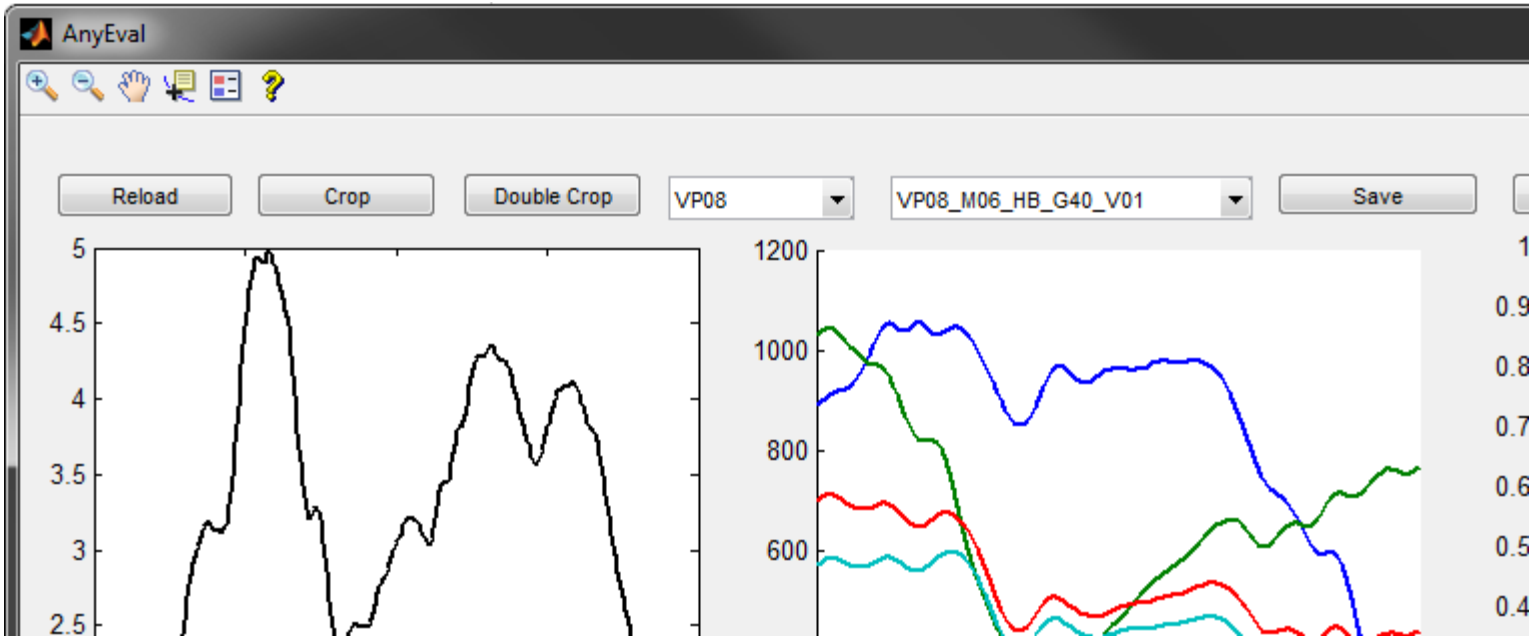
Processing H5-files

- Matlab R2014a (Mathworks Inc., Natick, US-MA)
- import hip joint forces of every H5-file of every test person
- trim the trials to functional time intervalls (e.g. gait cycle, step)
- find maximum loads, calculate means



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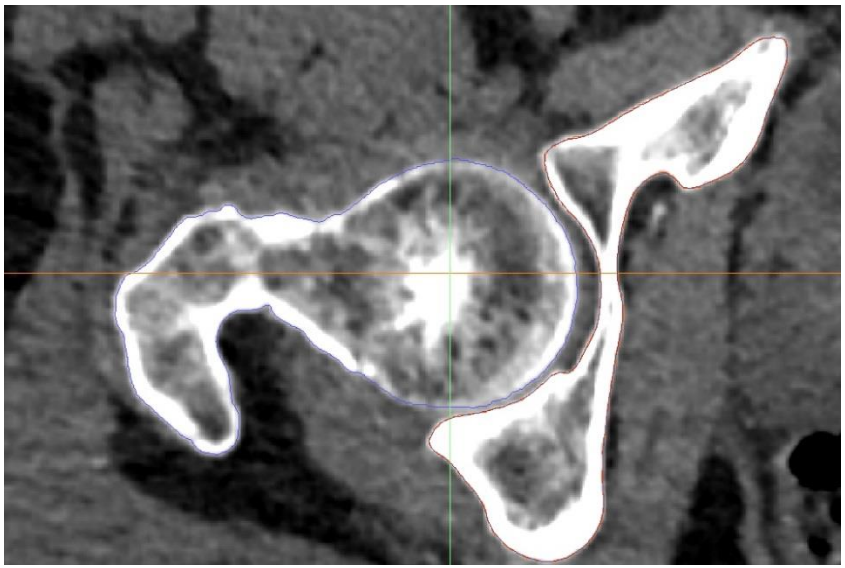
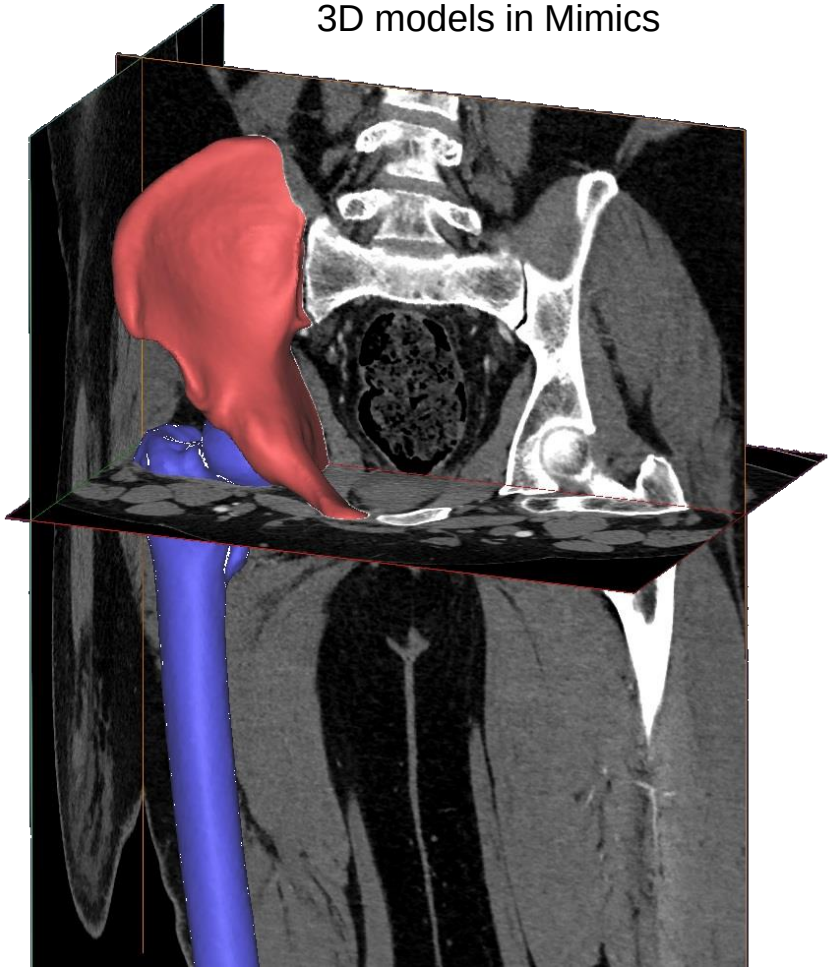
Segmentation of CT data

- Mimics 16.0
  (Materialise NV, Leuven, BE)
- semi automatic segmentation
  (> 200 HU)



model contours in Mimics

3D models in Mimics



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FEA

- simulation of AnyBody load cases in ANSYS Workbench 15.0 (ANSYS Inc., Canonsburg, US-PA)
- AnyBody geometries and segmented geometries were superimposed while maintaining the hip joint rotation center
- this allowed the use of the AnyBody results as parameter sets in ANSYS workbench (rotational orientation, hip joint load)

AnyBody femur and segemented femur superimposed in ANSYS Design Modeler

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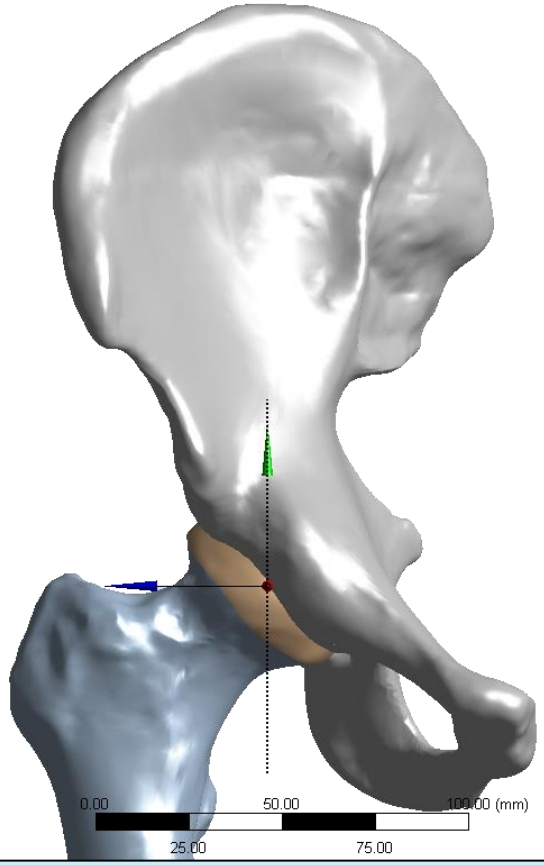
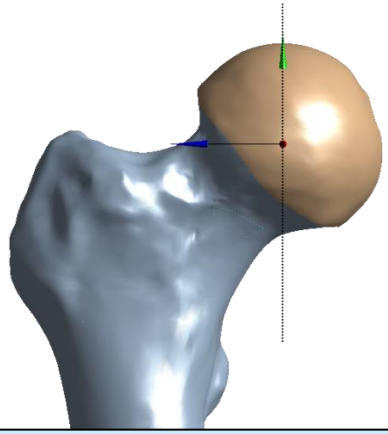
FEA



alignment of the femur in the hip joint rotation center according to the orientation calculated in AnyBody



femur cartilage was applied as a 1.4mm layer on the femoral head and the acetabulum

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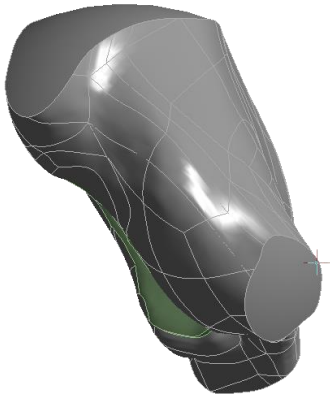
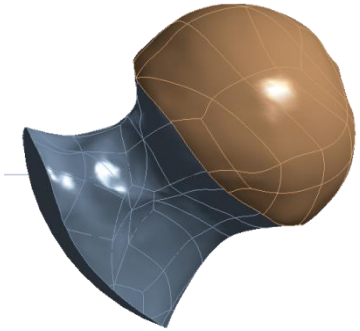
FEA

- limit the model to the region of interest
- pelvis with fixed support
- remote load on the cut surface of the femur located as remote point in joint rotation center
- 1.4mm cartilage on both parts
- cartilage: linear isotropic (E=11.85MPa, ν=0.45)[4]
- bone: linear isotropic (E=12.4GPa, ν=0.3)
- contacts: bonded and frictional (μ=0.04)



trimmed pelvis in ANSYS



trimmed femur in ANSYS

[4] Yoshida, H., Faust, A., Wilckens, J., Kitagawa, M., Fetto, J., & Chao, E. Y.-S. (2006). Three-dimensional dynamic hip contact area and pressure distribution during activities of daily living. *Journal of Biomechanics*, *39*(11), 1996–2004.

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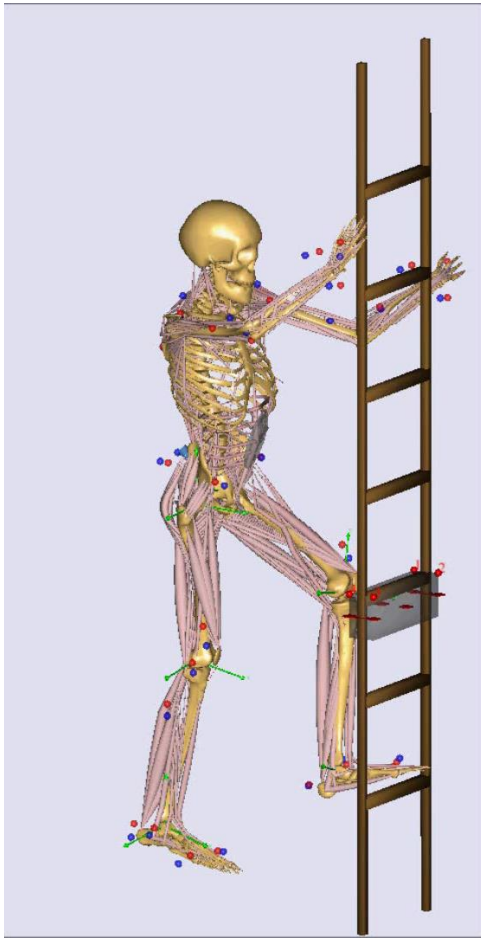
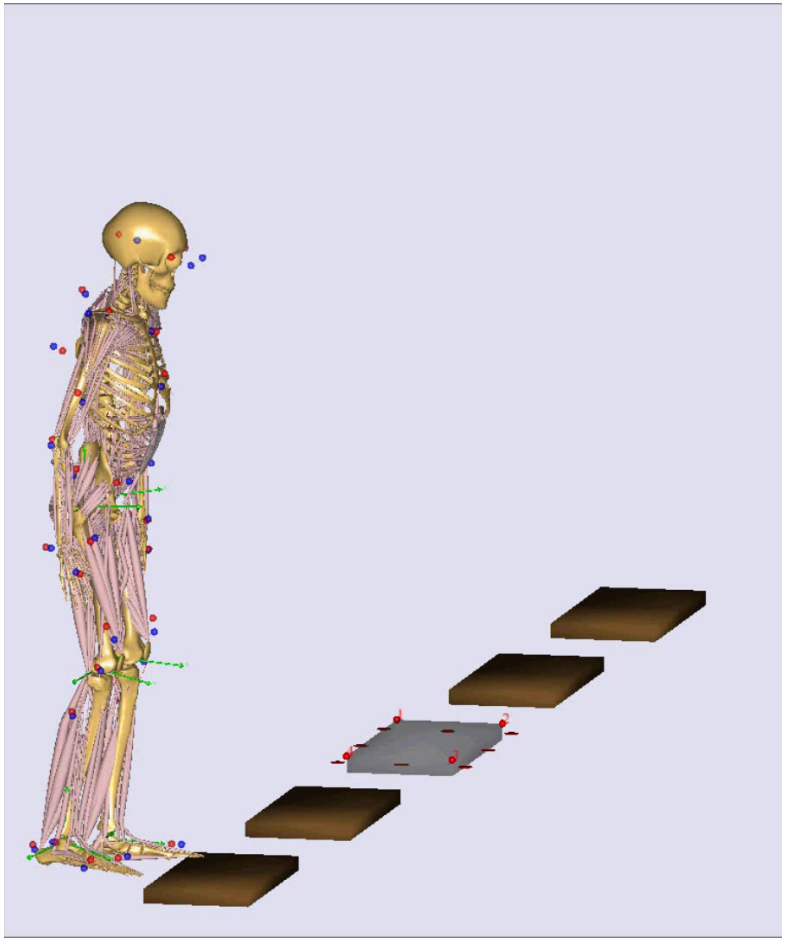
AnyBody multibody simulation



ladder climbing in AnyBody



stair climbing in AnyBody

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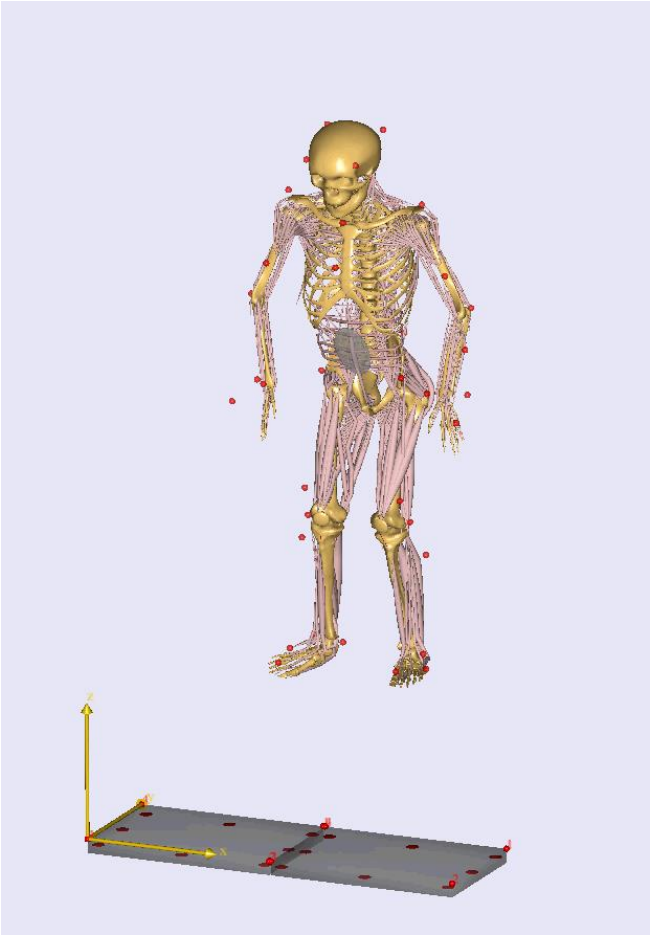
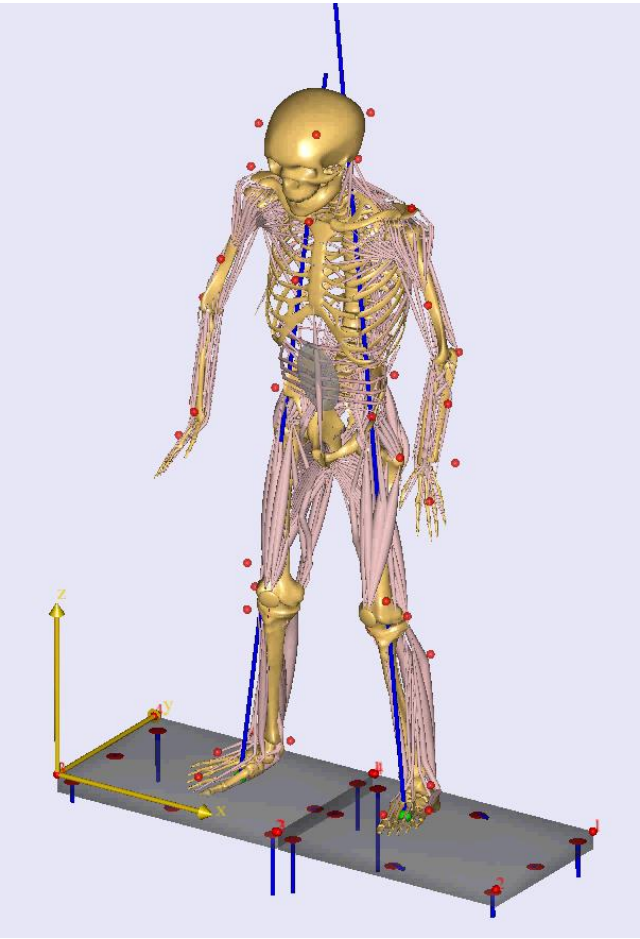
AnyBody multibody simulation



jumping in AnyBody



sitting down in AnyBody

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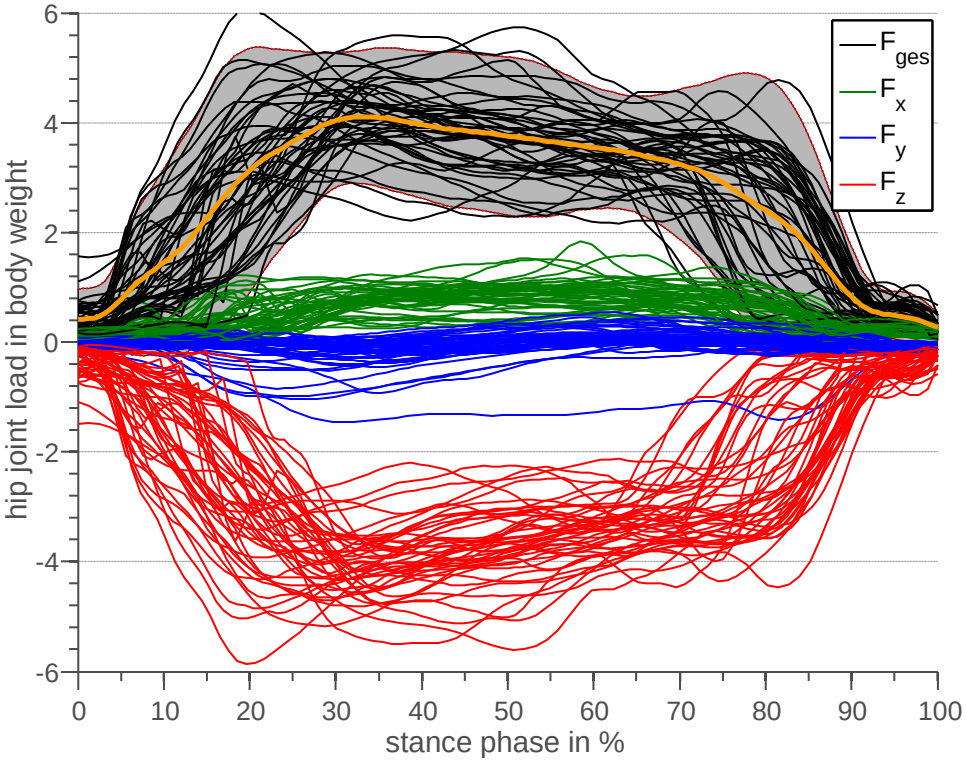
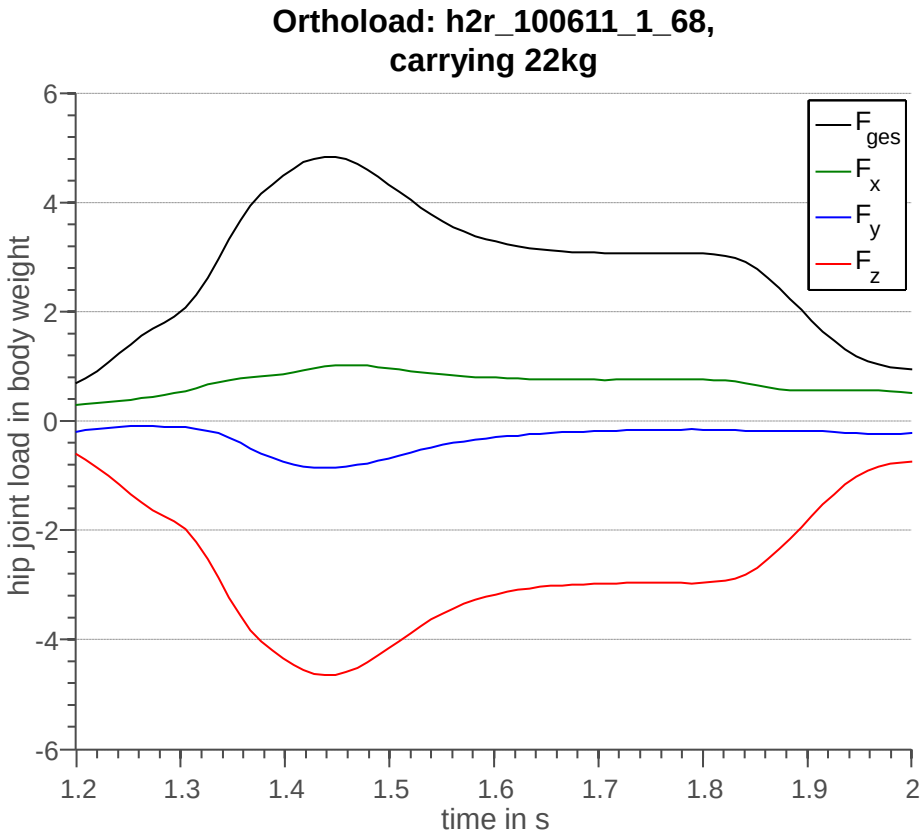
Lifting & carrying





Quelle: www.orthoload.de

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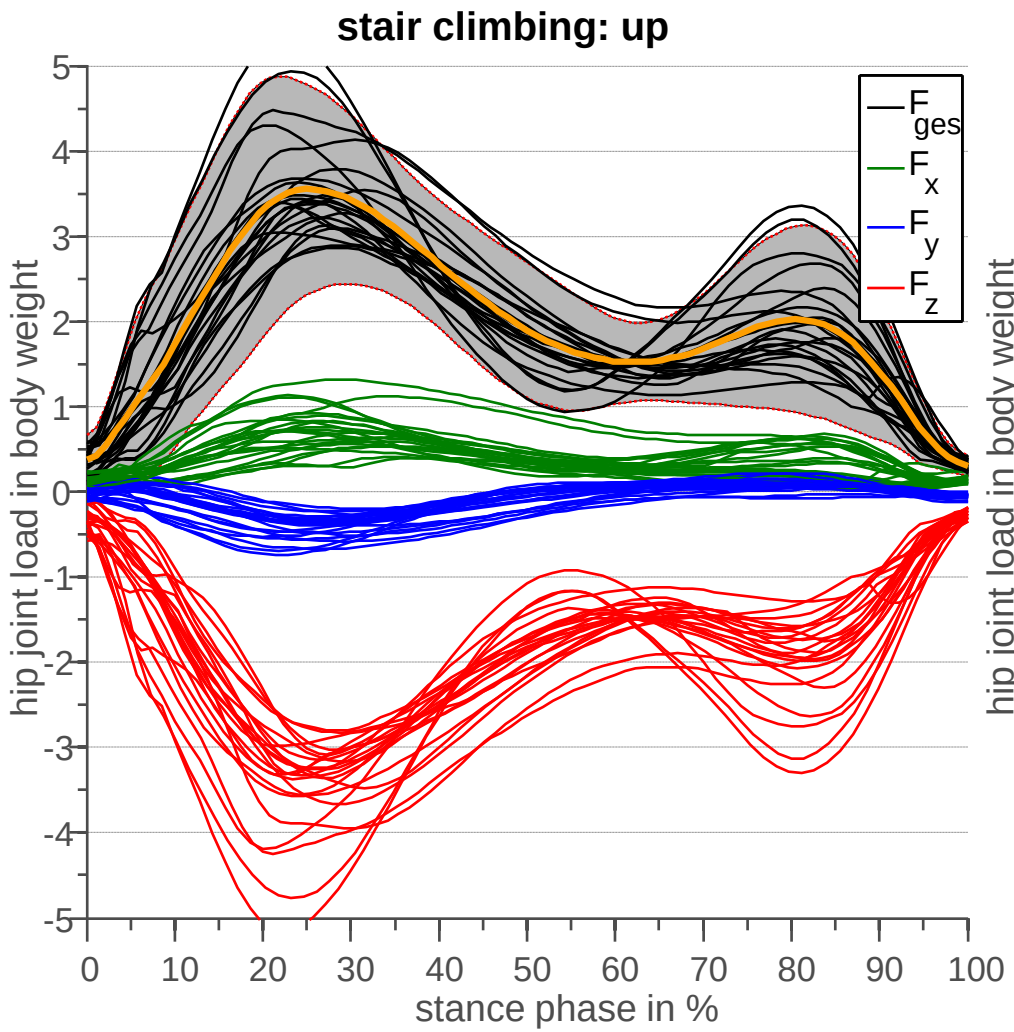
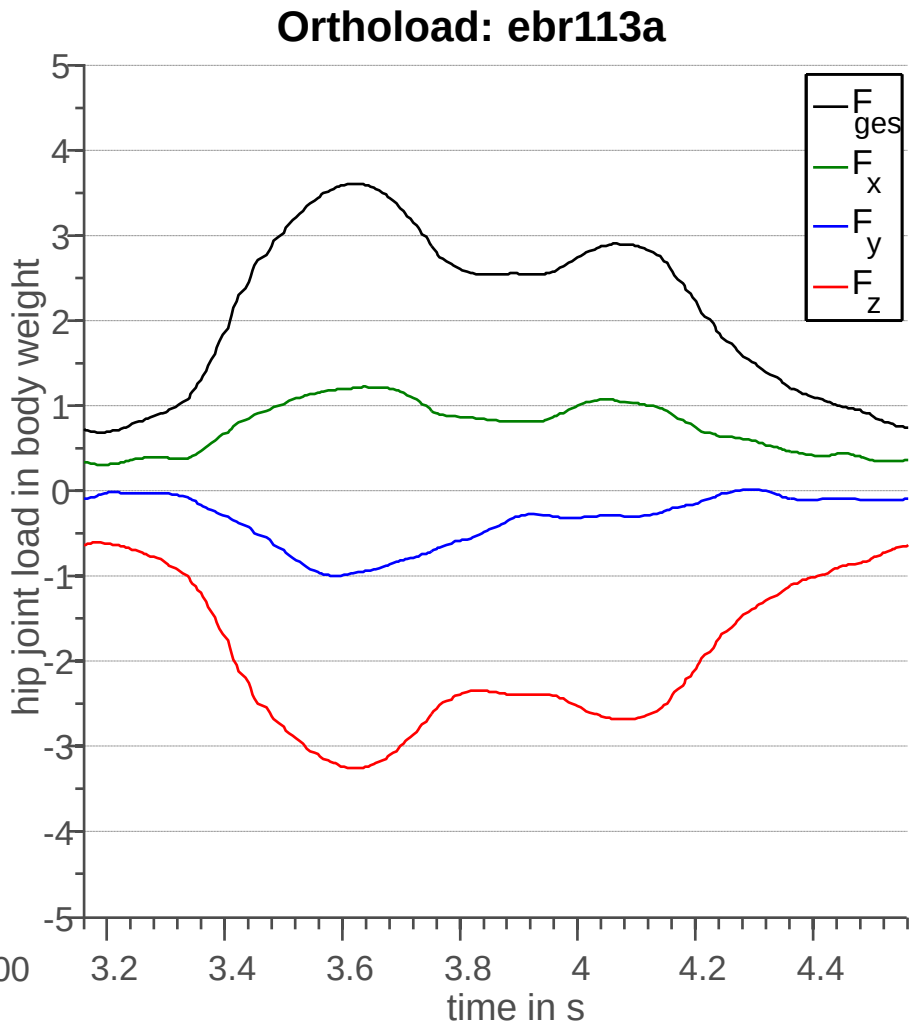
Stair climbing: up





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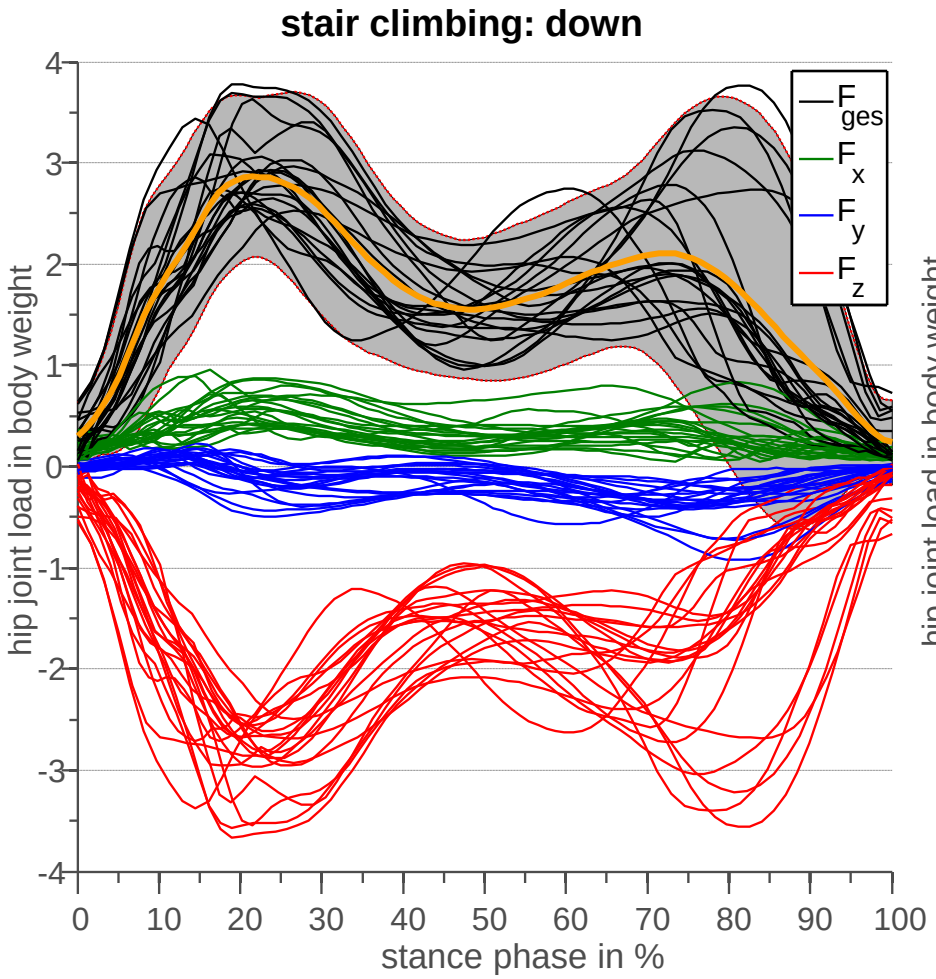
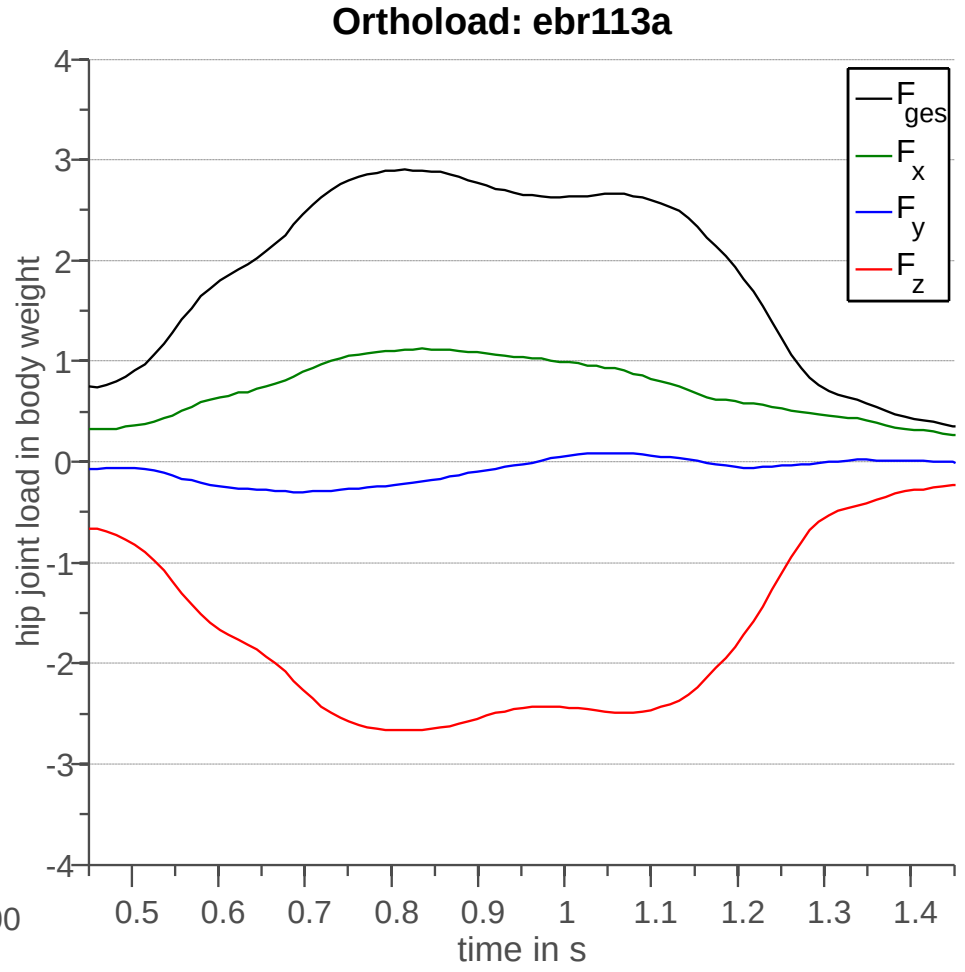
Stair climbing: down





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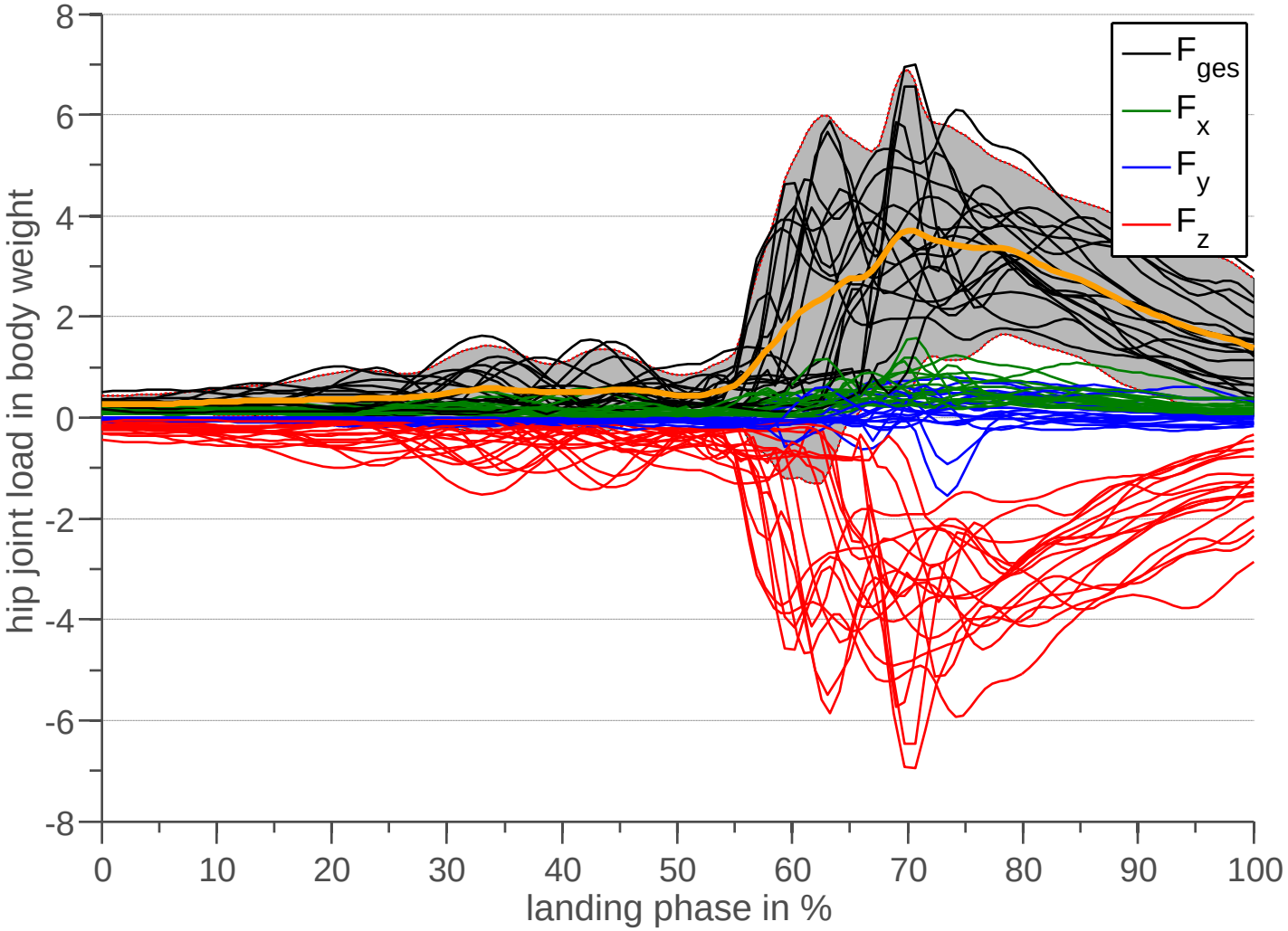
Jumping



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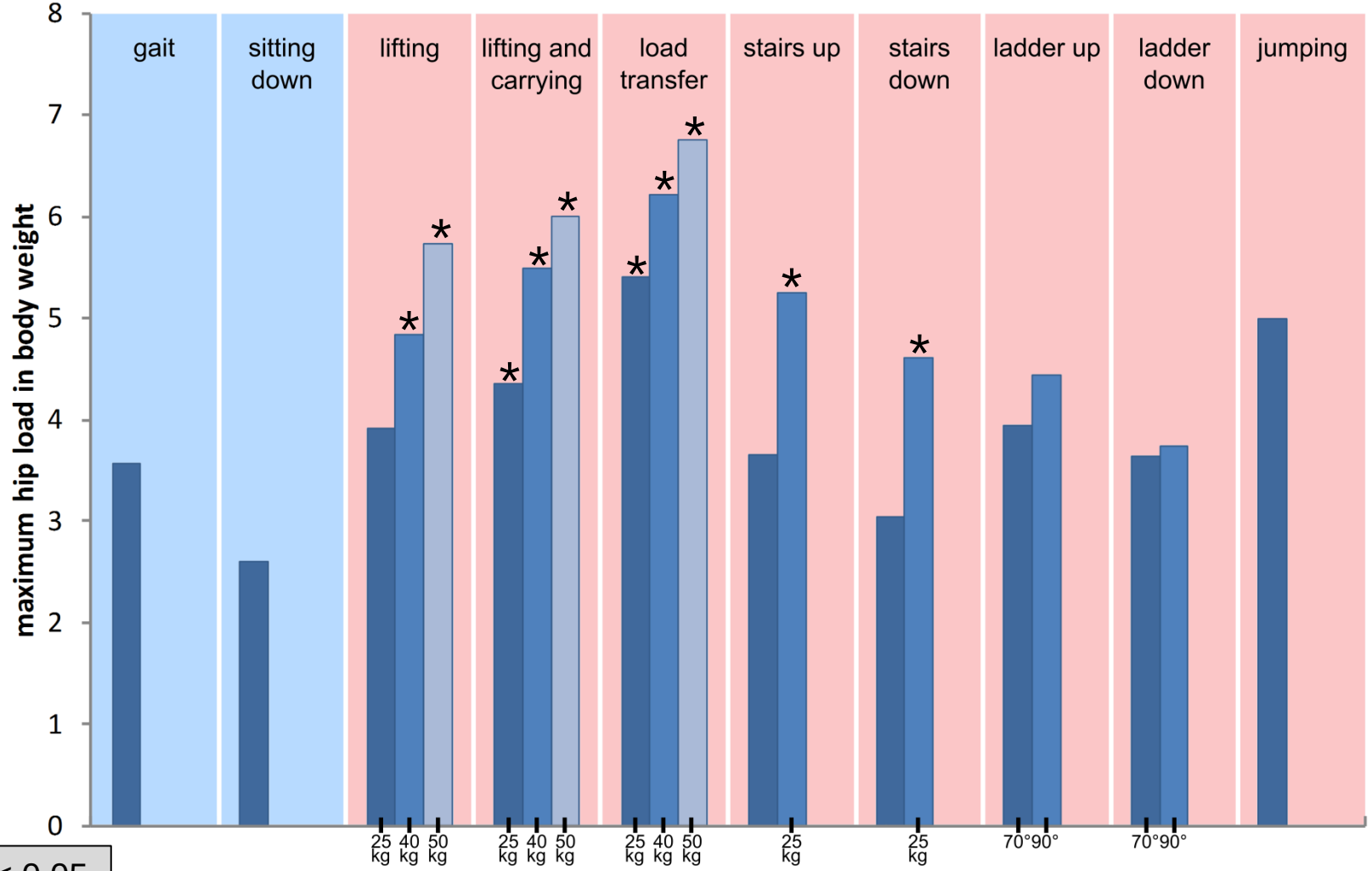
Overview of all activities



*: $p < 0.05$

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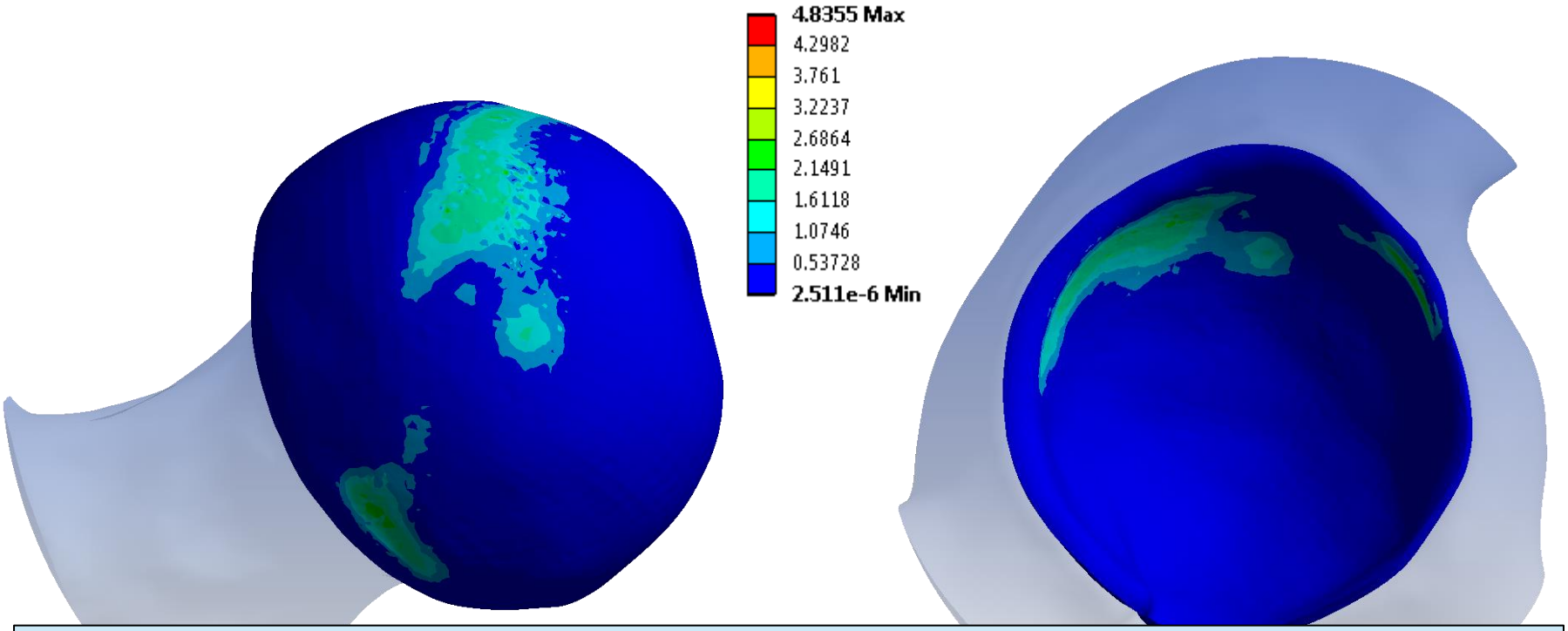
FEA: First results - stresses



experimental data: maximum contact stress 8 to 9 MPa[5]

[5] Von Eisenhart-Rothe, R., Eckstein, F., Müller-Gerbl, M., Landgraf, J., Rock, C., & Putz, R. (1997). Direct comparison of contact areas, contact stress and subchondral mineralization in human hip joint specimens.*Anatomy and Embryology*, *195*(3), 279–88.

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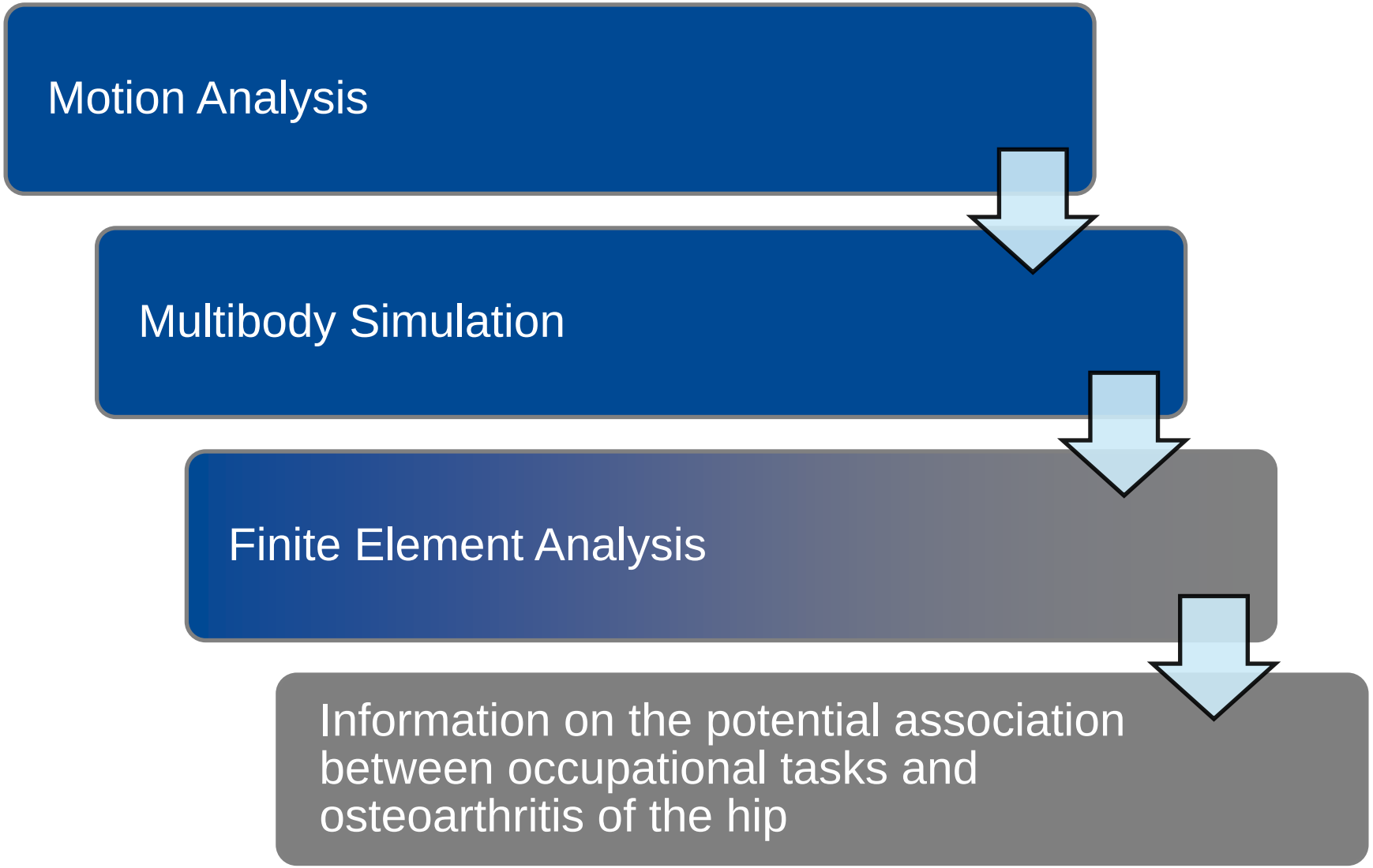
Discussion

- number of test persons
  - ⇒ additional test persons will follow
- dose dependency
- simplified finite element model
  - ⇒ incremental improvements
    - ⇒ hyperelastic materials
    - ⇒ division of the bone (cortical, trabecular and subchondral bone)

Summary


Motion Analysis
Multibody Simulation
Finite Element Analysis
Information on the potential association between occupational tasks and osteoarthritis of the hip

Thank you for your attention!

This research project was supported by a grant provided by the German Social Accident Insurance.