LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

International Symposium on Future Mobility Safety Science and Technology

The importance of soft tissue modelling for analysing future seating positions with FE HBMs

Steffen Peldschus, Dustin Draper, Felicitas Lanzl, Julia Muehlbauer

Biomechanics + Accident Analysis

Institute of Legal Medicine

Ludwig Maximilian University Munich

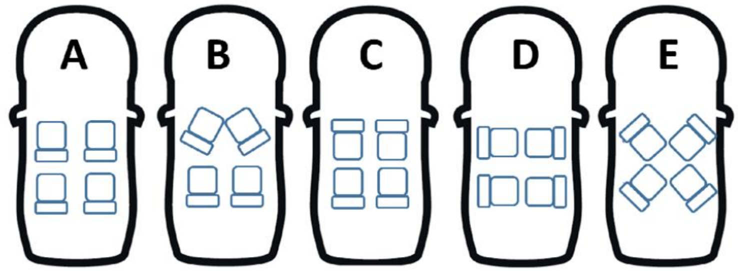
Pilsen, 17 October 2019

Vision

- Multiple Studies have shown that in the context of highly automated vehicles, passengers and drivers expect to be able to sit in new configurations [1] [2]

- One position of particular interest, both for the customer as well as for the safety engineer is the reclined position [3]

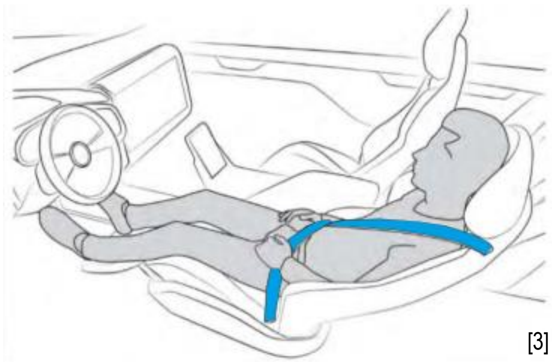
- Automated Driving Systems 2.0: A Vision for Safety



[2]

Section 1: Voluntary Guidance, Subsection 8: Crashworthiness

“In addition to the seating configurations evaluated in current standards, entities are encouraged to evaluate and consider additional countermeasures that will protect all occupants in any **alternative planned seating** or interior configurations during use.[23]”

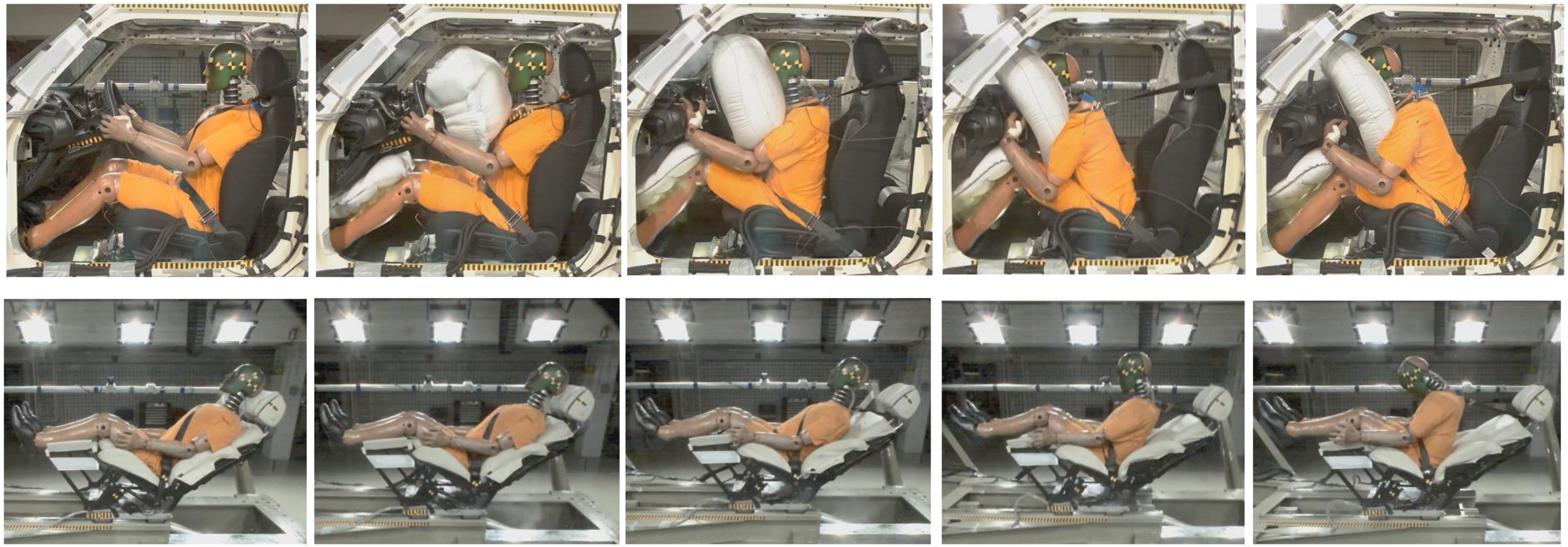


[3]

23) The tools to demonstrate such due care need not be limited to physical testing but also could include virtual tests with vehicle and **human body models.** [4]

[1] Ive, AutomotiveUI 2015 [2] Jorlöv, IRCOBI 2017 [3] Östhling VDI Safety Systems 2018 [4] NHSTA, Automated Driving Systems 2.0 A Vision for Safety 2017

Background



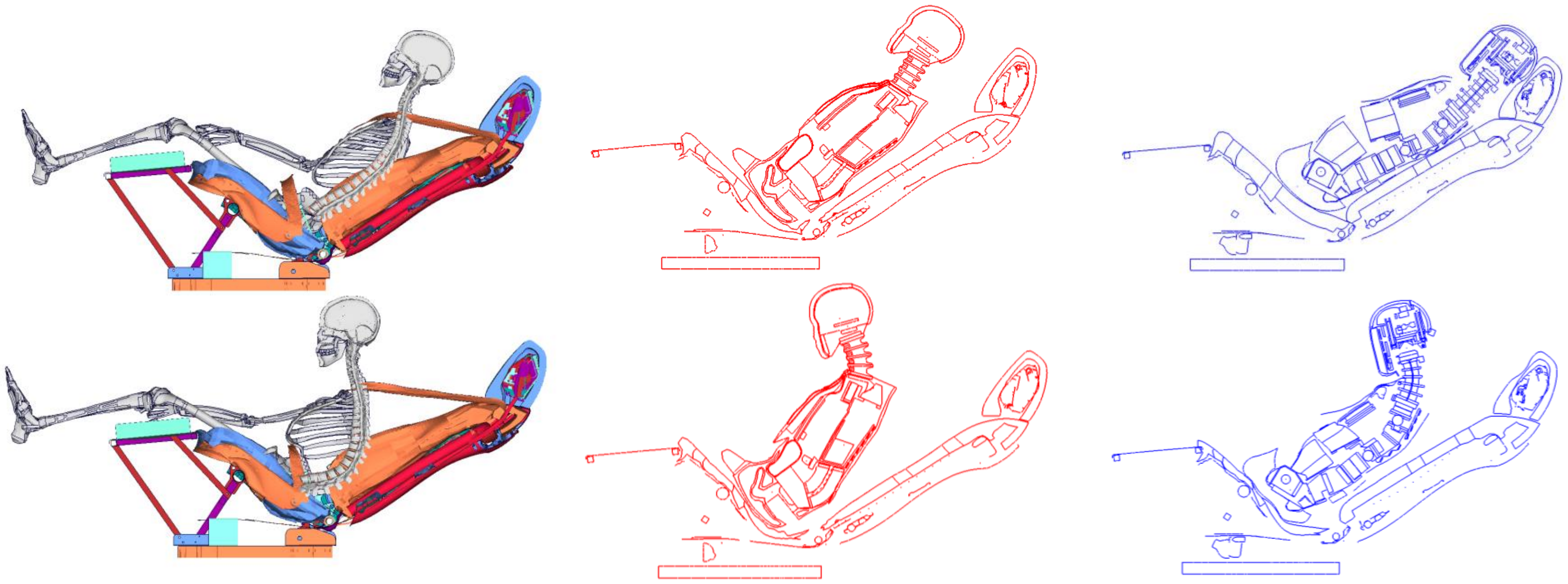
- Hardware tests were performed with both Hybrid III 50th Percentile Male dummy (H350) and the THOR 50th percentile dummy in a concept reclined seating position in a sled environment
- Sled test environment with a USNCAP pulse
- Integrated seat belt, load limiter between the seat and the sled

Huf et al. 2018, Draper et al. 2019

Background

Human body model simulation – Comparison to dummy

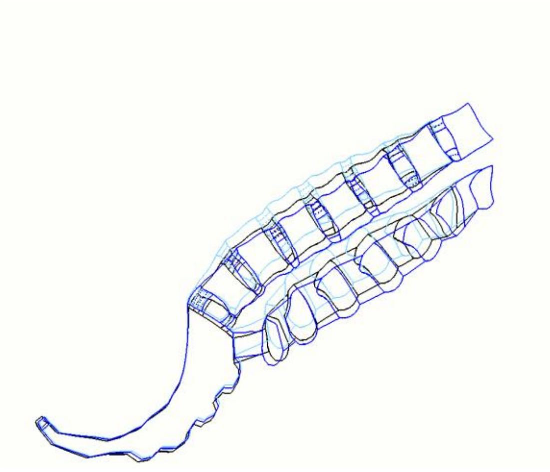
- The HBM spine develops a curvature during the pulse event, whereas the dummy lumbar spines remain straight



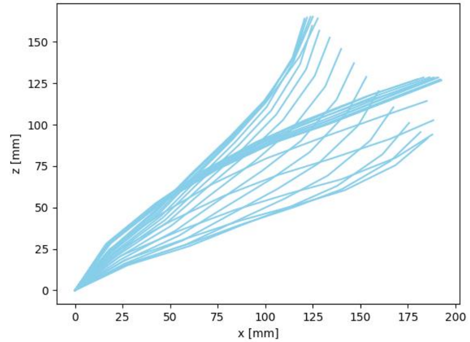
Draper et al. 2019

Lumbar spine positioning

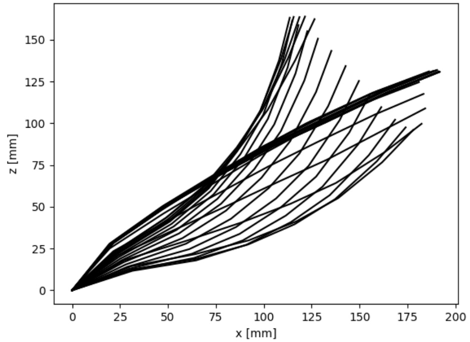
- A sensitivity study was made only varying lumbar spine position:
- Differences in the kinematic response can clearly be seen
  - Difference in the location of buckling
  - Difference in the timing of buckling
  - Difference in the timing of axial loading transitioning into flexion



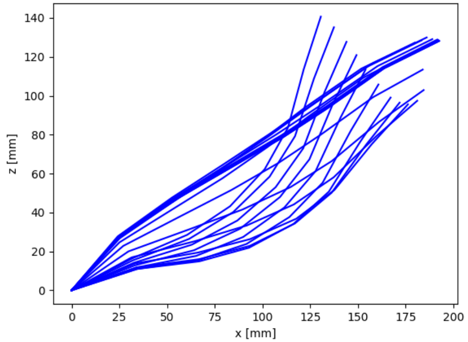
Lordodic Position



Basis Position



Kyphotic Position



Draper et al. 2019

Iterative multimodal approach

condition A (baseline)

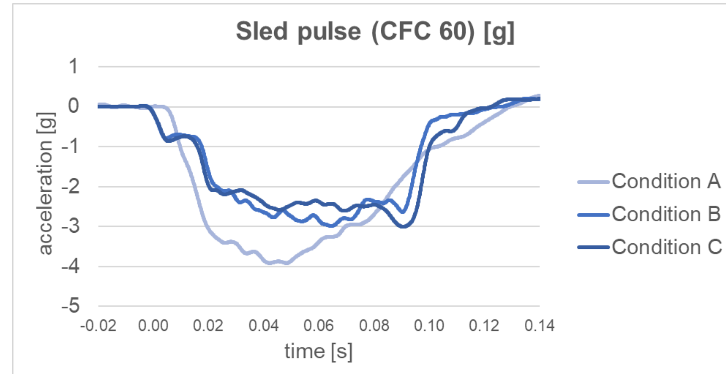
How does condition affect
- lumbar intervertebral disk displacement peak lumbar and pelvis force

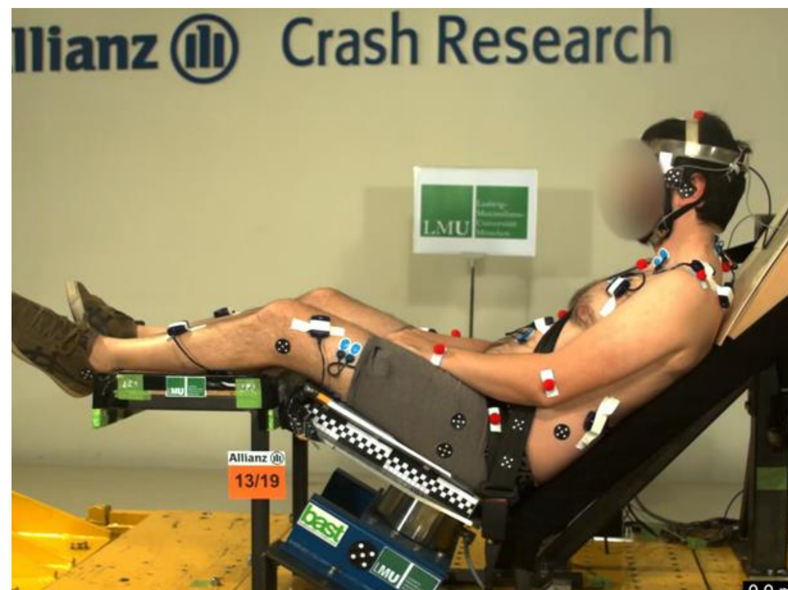
Conclusion:
- **Baseline pulse scaled down by ~20 %**
- **Removal of footrest for condition C**

Condition B: backrest 30° **Condition C: backrest 50°**

Volunteer Testing

condition A (baseline) [5]

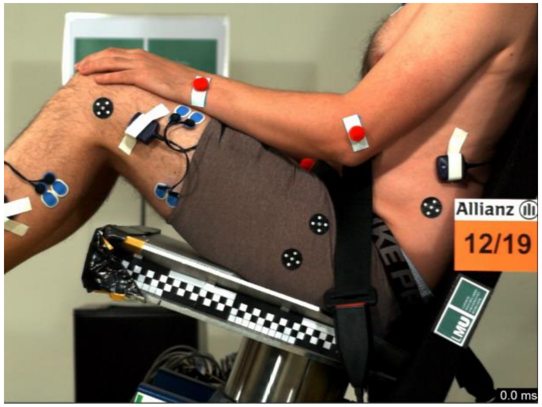
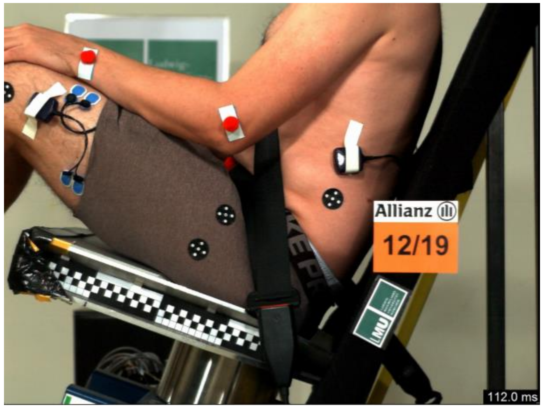
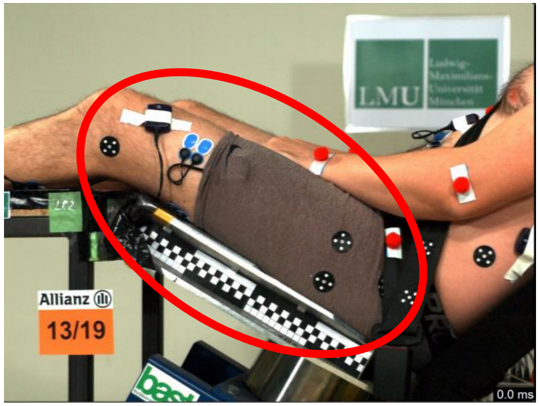
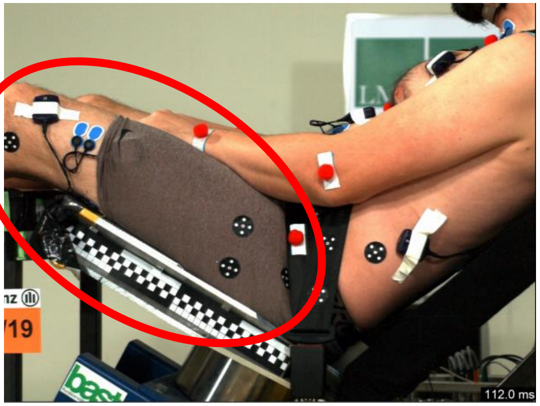




Condition B: backrest 60°

Condition C: backrest 40°

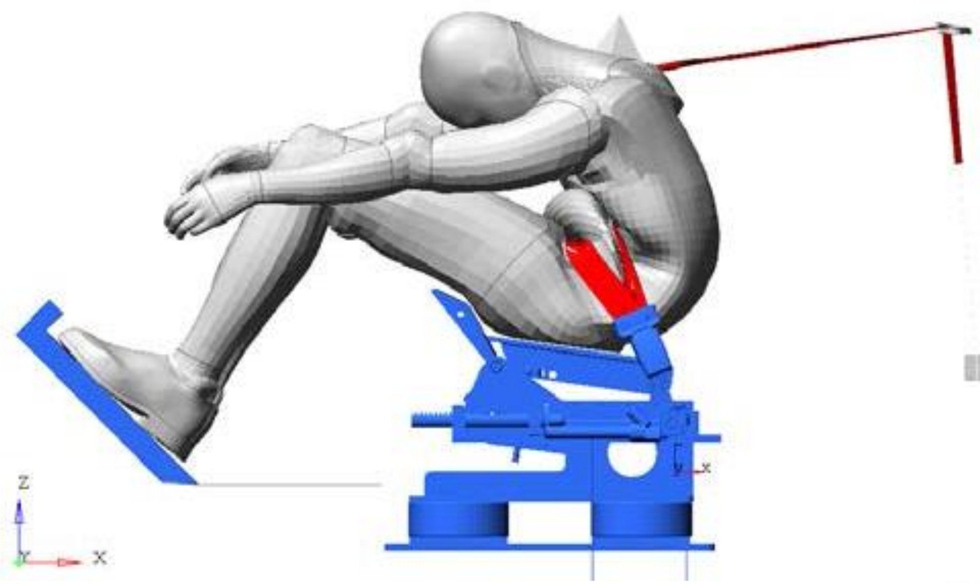
Initial observations

	t = 0	maximum pelvis excursion
Condition B		
Condition C		

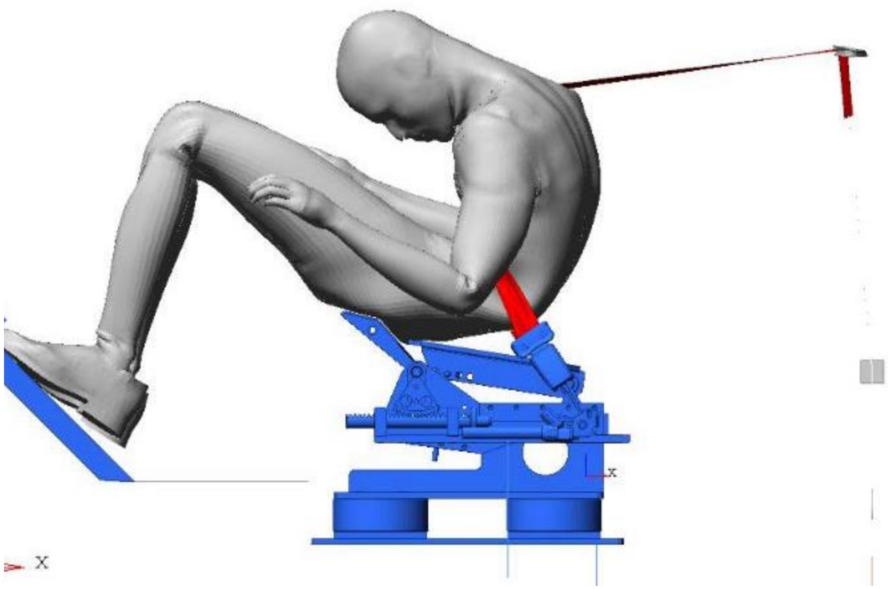
Submarining

- Multi-model analysis of reclined position
- Smaller seat cushion angle
- Multiple pre-tensioning

GHBMC-S



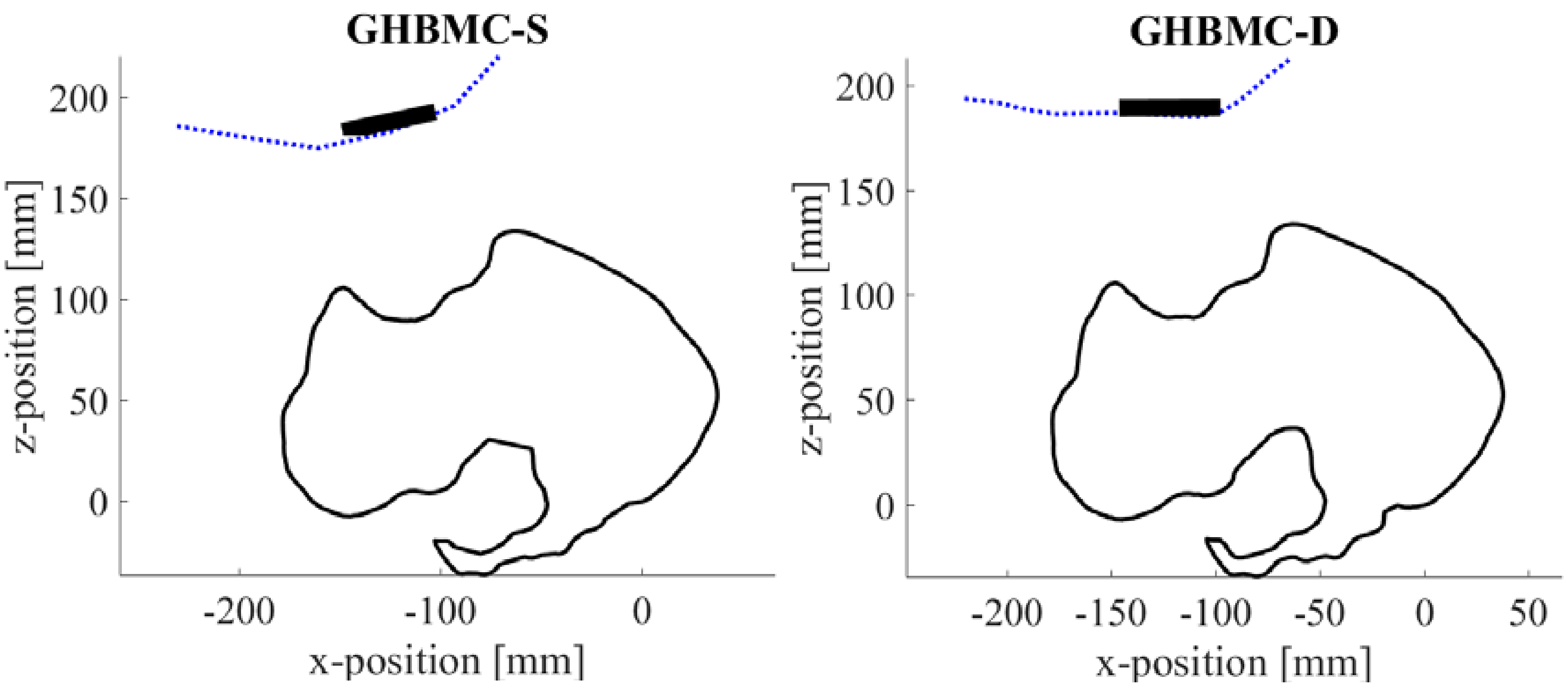
GHBMC-D



Gepner, Draper et al. 2019

Submarining

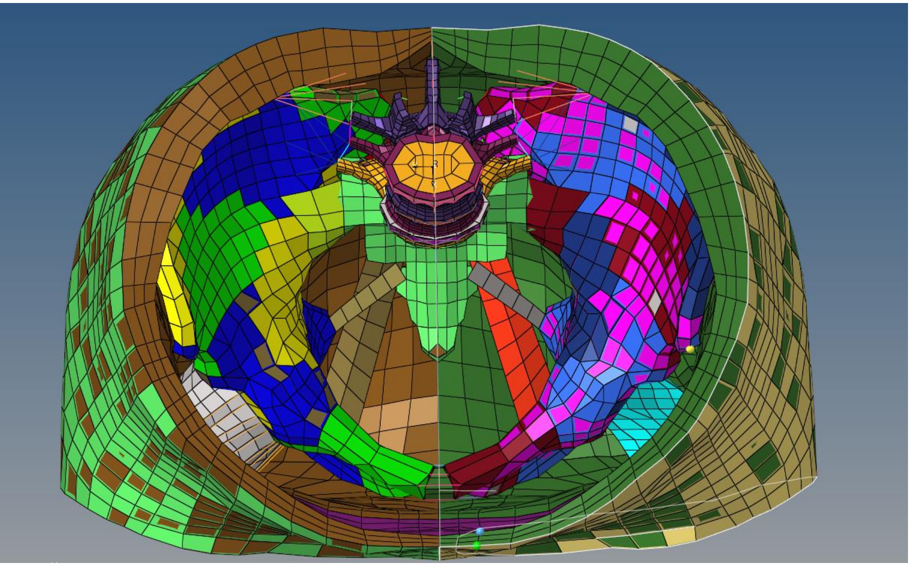
- Lap belt positioning
- Same procedures enforced

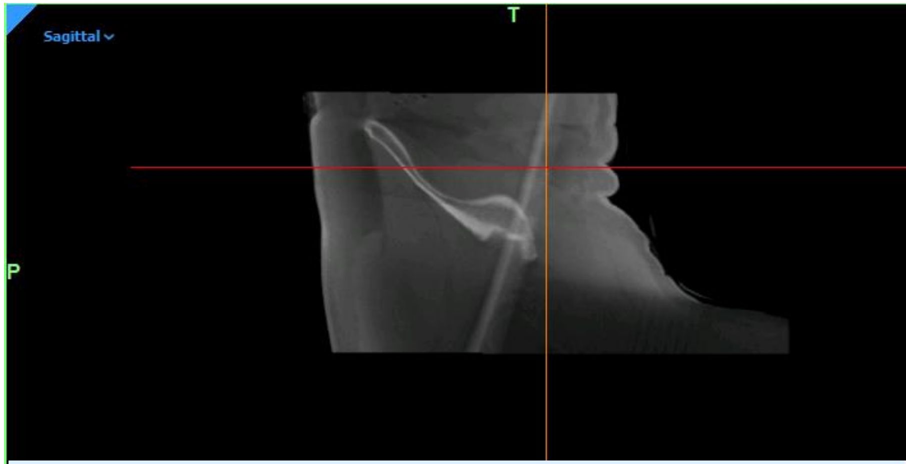


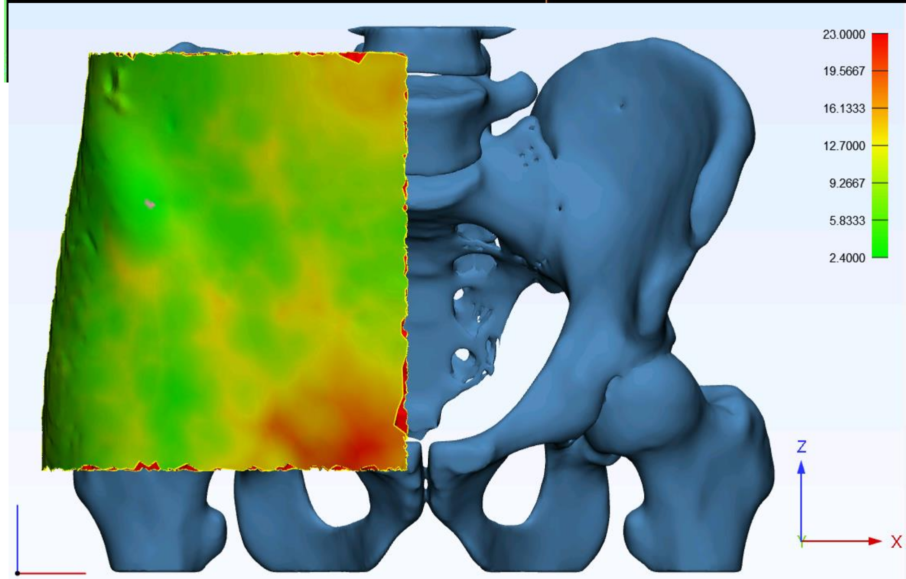
Gepner, Draper et al. 2019

Soft tissue geometry

- Human anatomy variance
- Model adaption







OSCCAR Project

PROJECT PARTNERS

AUSTRIA

- KOMPETENZZENTRUM – DAS VIRTUELLE FAHRZEUG, FORSCHUNGS GMBH
- TECHNISCHE UNIVERSITÄT GRAZ

BELGIUM

- SIEMENS INDUSTRY SOFTWARE NV
- TOYOTA MOTOR EUROPE

CHINA

- TSINGHUA UNIVERSITY
- CHINA AUTOMOTIVE TECHNOLOGY AND RESEARCH CENTER

FRANCE

- ESI GROUP
- UNIVERSITE DE STRASBOURG

GERMANY

- BUNDESANSTALT FUER STRASSENWESEN
- ROBERT BOSCH GMBH
- DAIMLER AG
- LUDWIG-MAXIMILIANS-UNIVERSITAET MUENCHEN
- RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN
- UNIVERSITAET STUTTGART
- ZF GROUP, PASSIVE SAFETY SYSTEMS, TRW AUTOMOTIVE GMBH

NETHERLANDS

- SIEMENS DIGITAL INDUSTRIES SOFTWARE

SPAIN

- IDIADA AUTOMOTIVE TECHNOLOGY SA

SWEDEN

- AUTOLIV DEVELOPMENT AB
- CHALMERS TEKNISKA HOEGSKOLA AB
- VOLVO PERSONVAGNAR AB

PROJECT COORDINATOR: virtual vehicle

PROJECT FACTS

PROJECT COORDINATOR: WERNER LEITGEB

INSTITUTION: VIRTUAL VEHICLE RESEARCH CENTER

EMAIL: OSCCAR@V2C2.AT

WEBSITE: WWW.OSCCARPROJECT.EU

START: JUNE 2018 **DURATION:** 36 months

PARTICIPATING ORGANISATIONS: 21

Follow us on Twitter
https://twitter.com/OscarProject

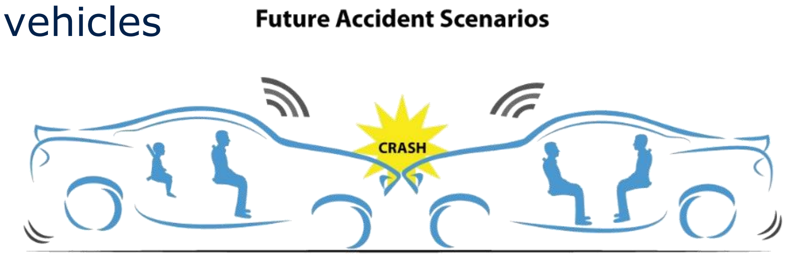
Become OSCCAR member on LinkedIn
https://www.linkedin.com/groups/13655575/

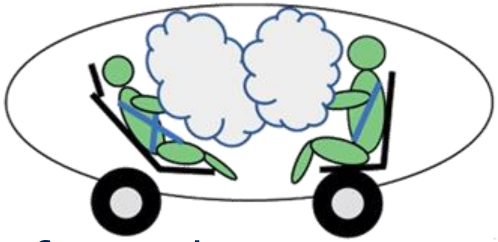
OSCCAR has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 768947.

WWW.OSCCARPROJECT.EU

OSCCAR – Highlights

- Future relevant accident scenarios for automated vehicles
  - ☐Consideration of mixed traffic influence
  - ☐Intersection Scenarios
  - ☐Highway Scenarios

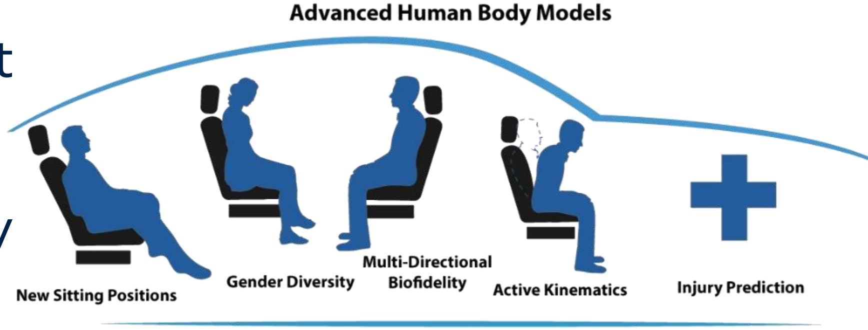




- Selected occupant UseCases for future sitting positions
  - ☐User studies on future sitting position preferences performed at RWTH Aachen
  - ☐1st physical test series for future sitting positions performed at BAST
  - ☐Restraint principles for new sitting positions under investigation

OSCCAR – Highlights

- Advances in human body modelling (HBM):
  - ☐Injury criteria development and harmonization
  - ☐Active HBMs for pre-crash assessment
  - ☐Tissue, fat and muscle modelling
  - ☐Advances in omnidirectional biofidelity



  - ☐Workshop on “Virtual Testing and Open Source Human Body Modelling” @ IRCOBI 2019

http://www.ircobi.org/wordpress/downloads/VIRTUAL-OSCCAR-workshop-20190329.pdf

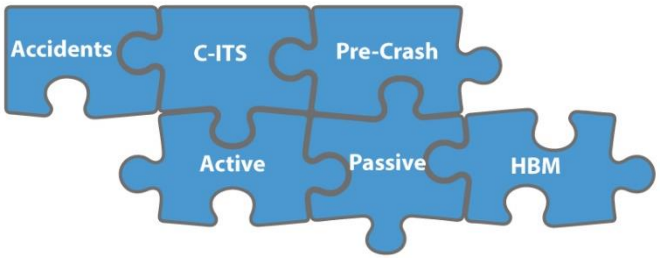
  - ☐International cooperations and exchange planned with
    - VIRTUAL Project
    - TRC ADS Safety project
    - Euro NCAP
    - NHTSA & IIHS

OSCCAR – Highlights

- Continuous virtual assessment of advanced protection principles
  - Using diverse HBM occupants
  - Common assessment methodology
  - Considering accident scenario, pre-chrash & incrash phases

- Requirements for virtual testing and harmonization
  - Harmonization of virtual testing procedures
  - Demonstration homologation scenario in development

Fully Integrated Assessment Tool Chain



Harmonization of Virtual Testing

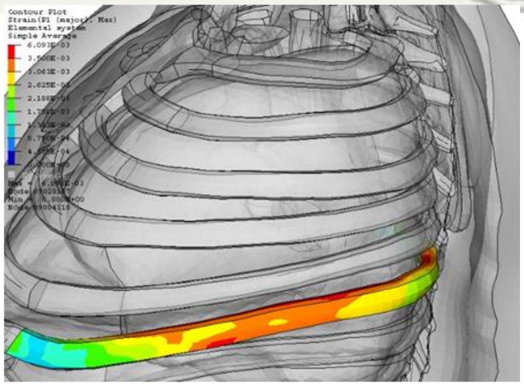
Rib Fracture Risk Assessment

Definition of output request of full model simulations

Simulation

Input for RSP

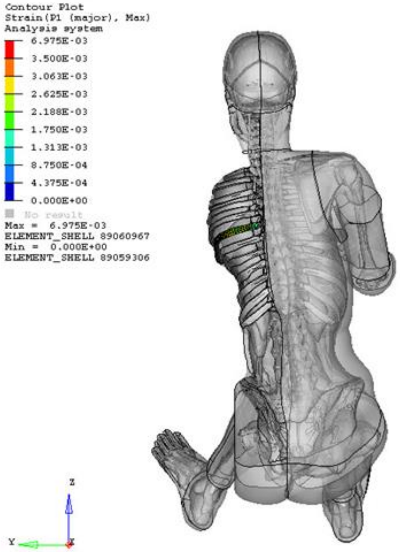
Rib Strain Processor

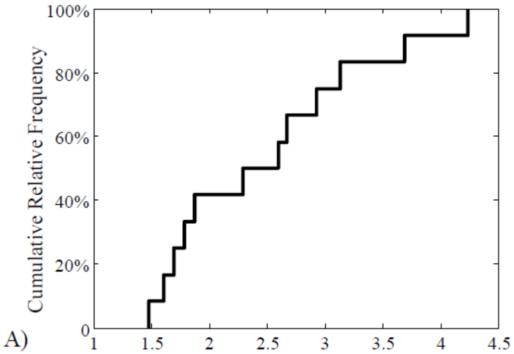


ASCII file containing peak strain values

Output of RSP
=
Input for RFRP

Rib Fracture Risk Predictor





A)

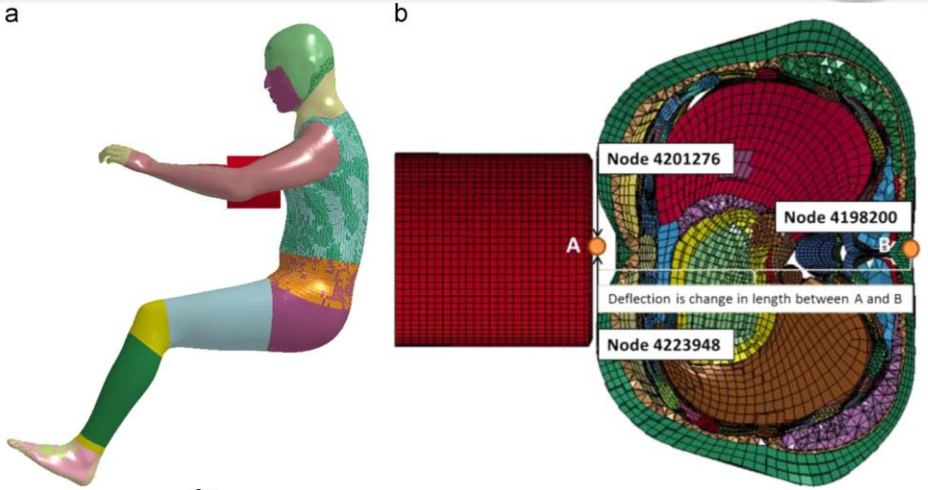
Output of RFRP

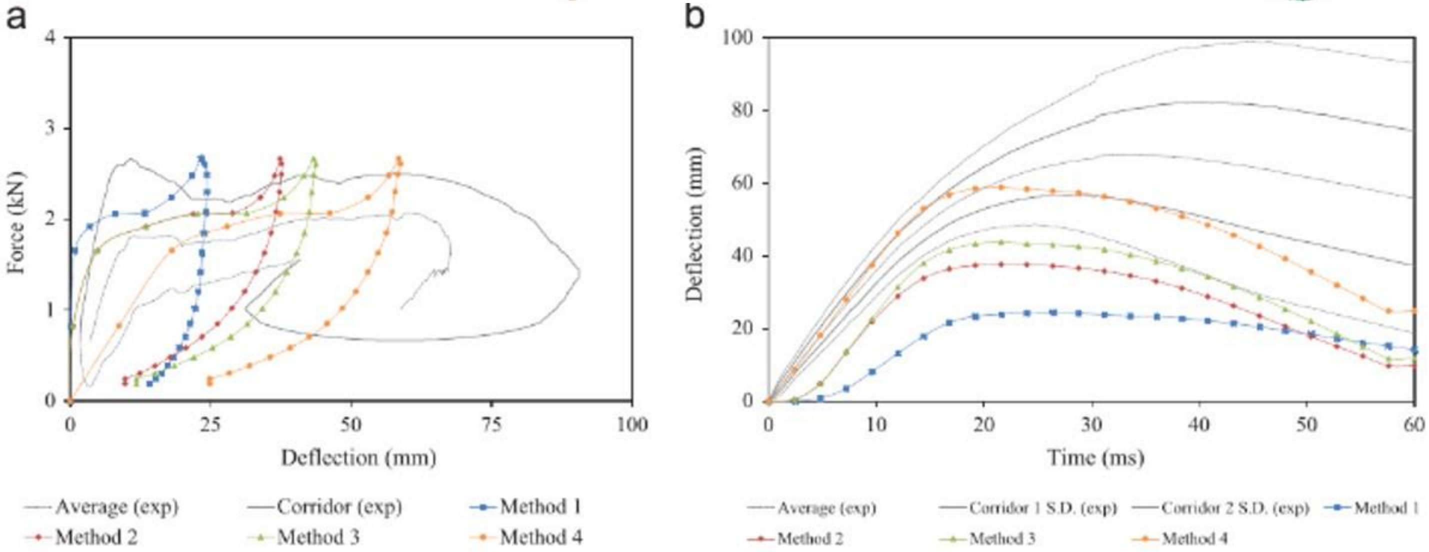
Predicted risk of a person of target age sustaining specific number of fx

Validation - Example

Poulard et al. 2015:

- Kroell tests
- (not) including soft tissue in calculation of deflection



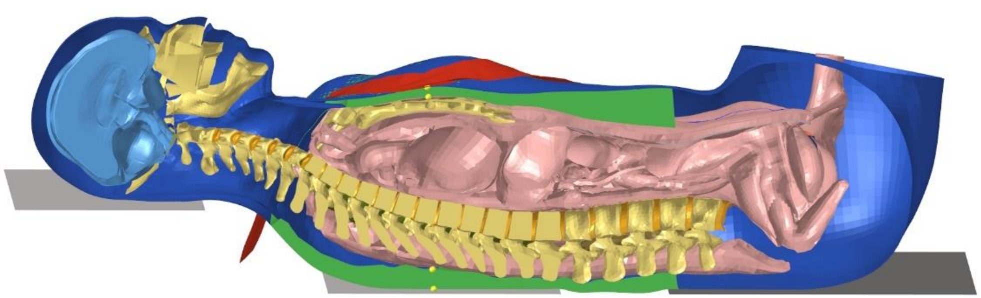


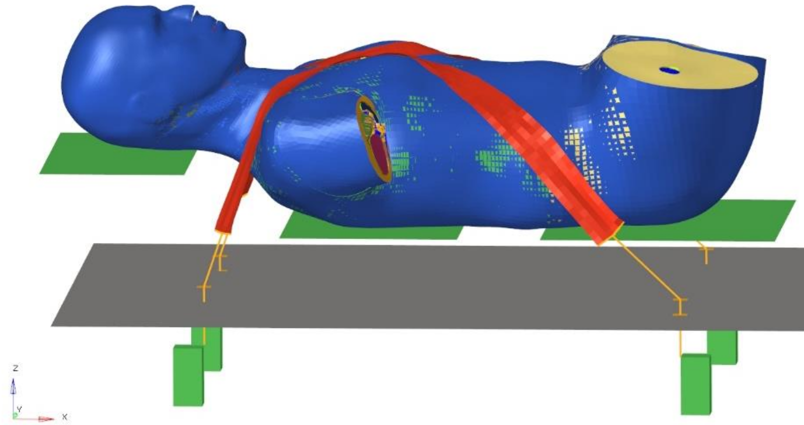
Validation example

- Kent table top experiments
- GHBM, Version 4.3

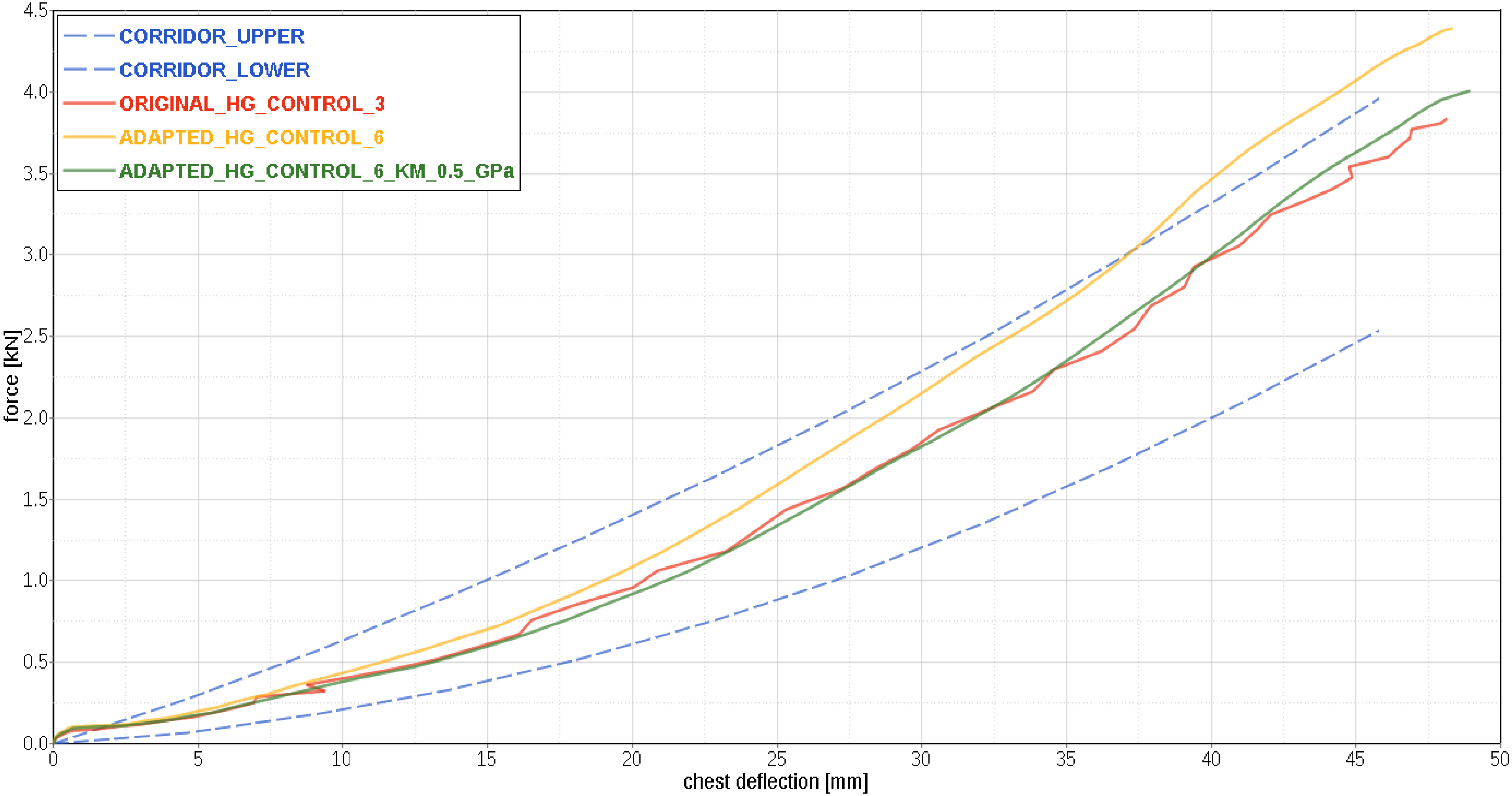
“*FLESH*”

less than 15% of thorax depth

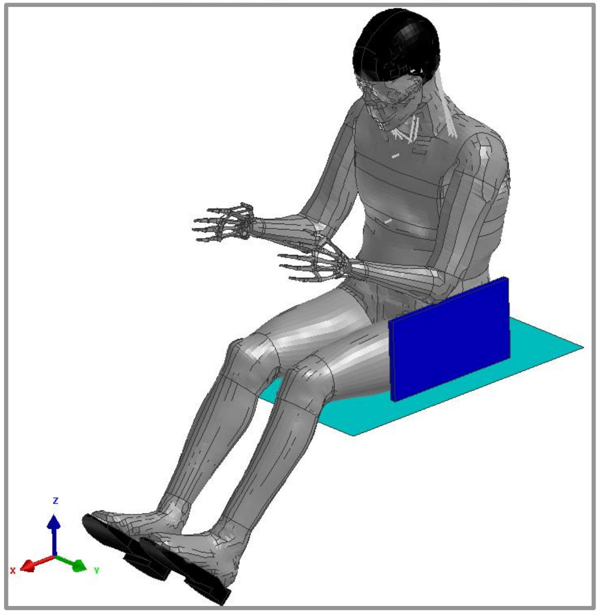




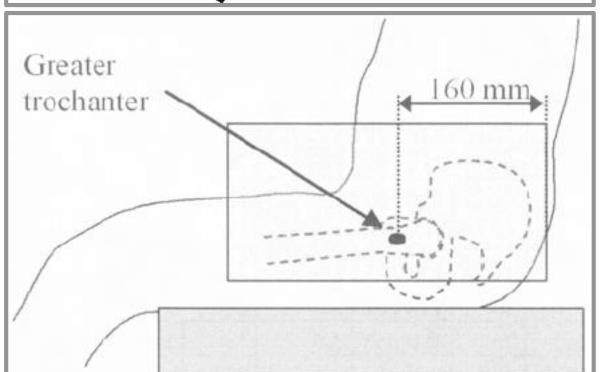
Challenges – Hourglass Control

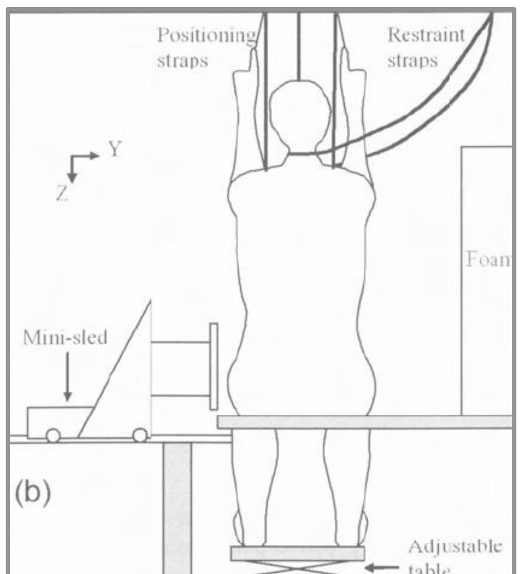


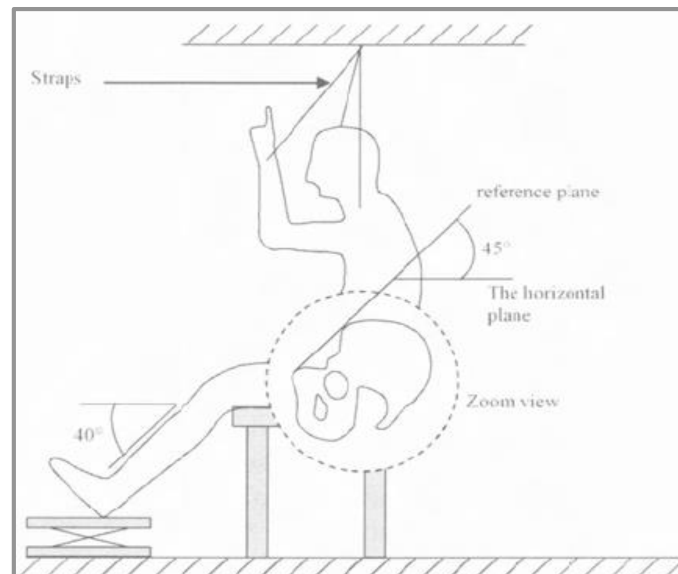
Validation - Example



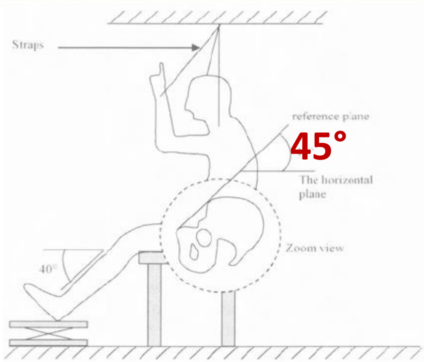
Body region	Pelvis
Level	Full Scale
Load case	Lateral sled
References	Leport et al. (2007): *Assessment of the pubic force as a pelvic injury criterion in side impact.* SAE Technical Paper, no. 2007-22-0019

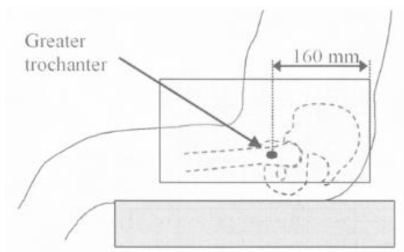




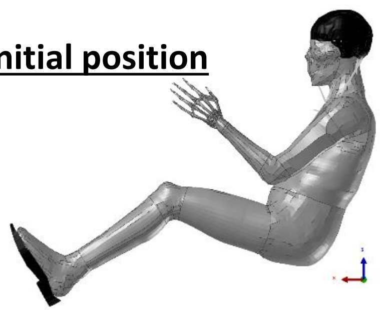


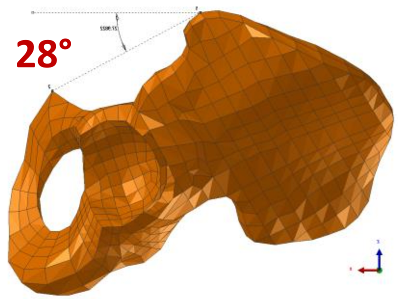
Validation - Example



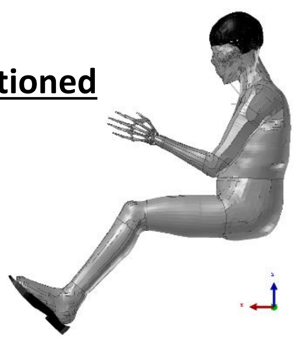


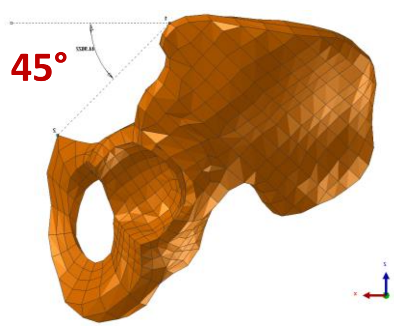
Initial position

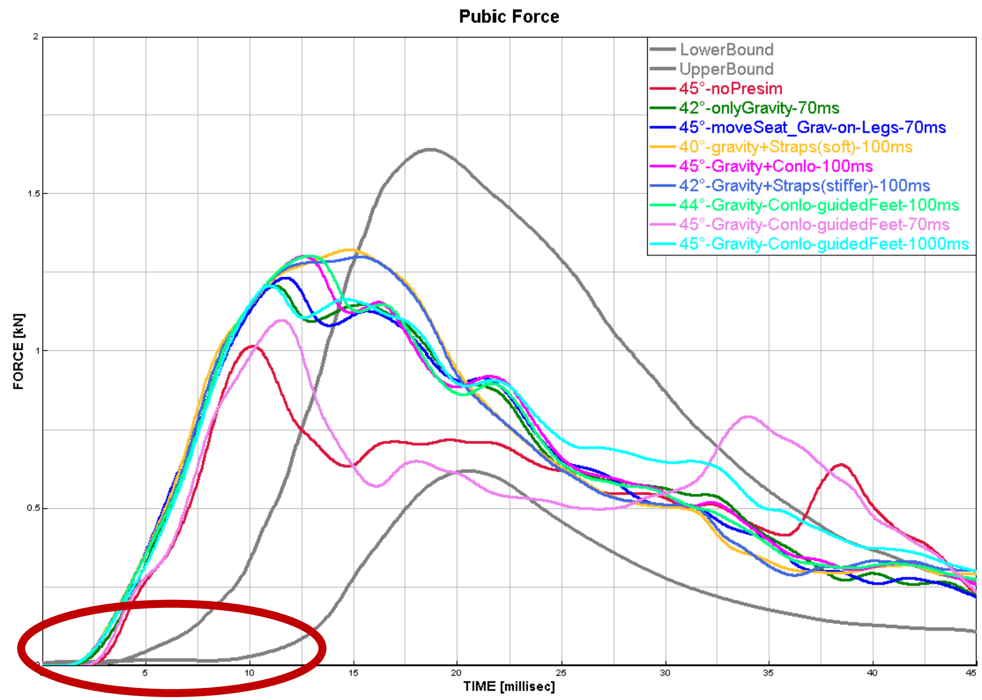




Positioned







THUMS User Community

Core Partners

Technical Advisor

Coordinator

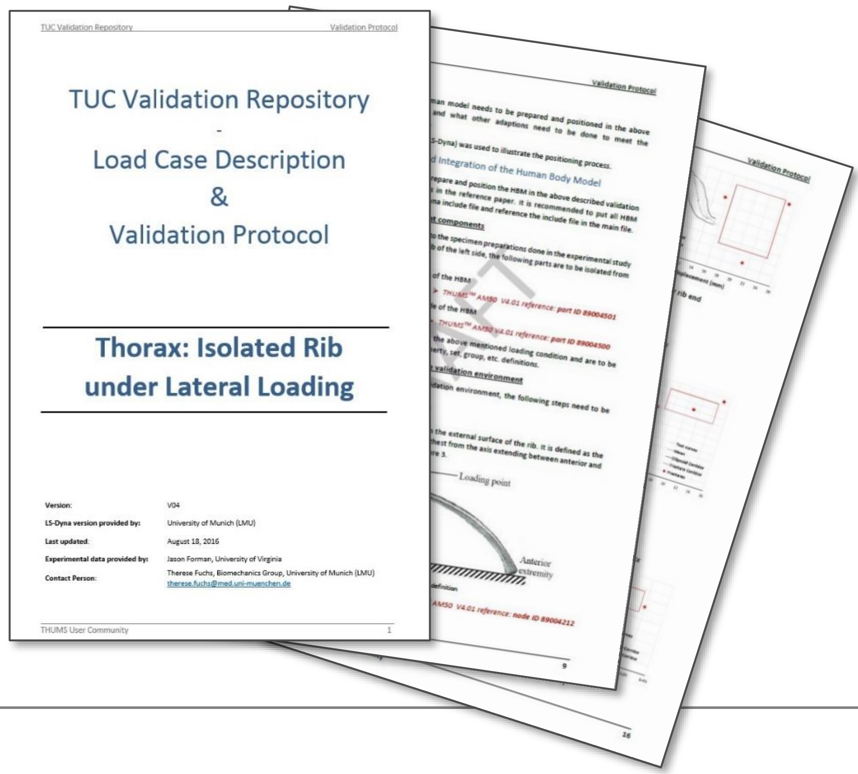
Associated Partners

Development Partners

TUC Validation Repository

- **Database with FE models of validation setups of state-of-the-art load cases for validating HBMs**
- **Precise documentation for a consistent application when evaluating HBMs**
- **Experimental data / validation parameters provided by institutions where testing was conducted**
- **Available in different crash codes (Abaqus, LS-Dyna, Radioss, VPS)**
- **Numerical check by Development Partners (DYNAmore, ESI)**

www.tuc-project.org/validation-repository


TUC Validation Repository Validation Protocol

TUC Validation Repository
-
Load Case Description
&
Validation Protocol

Thorax: Isolated Rib under Lateral Loading

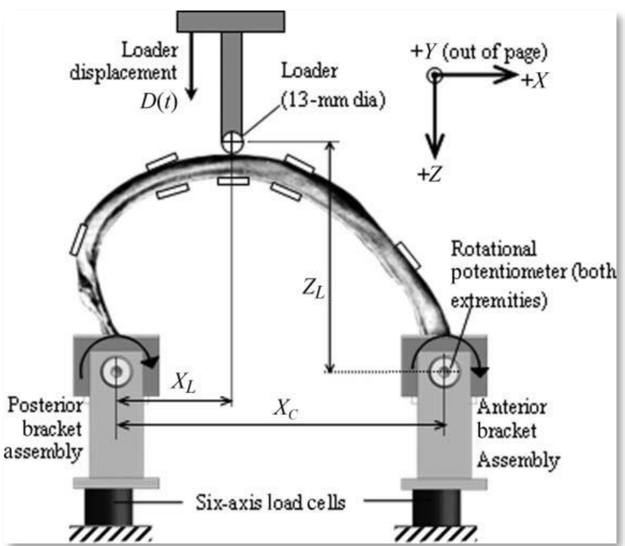
Version: V04
LS-Dyna version provided by: University of Munich (LMU)
Last updated: August 18, 2016
Experimental data provided by: Jason Forman, University of Virginia
Contact Person: Therese Fuchs, Biomechanics Group, University of Munich (LMU) therese.fuchs@med.uni-muenchen.de

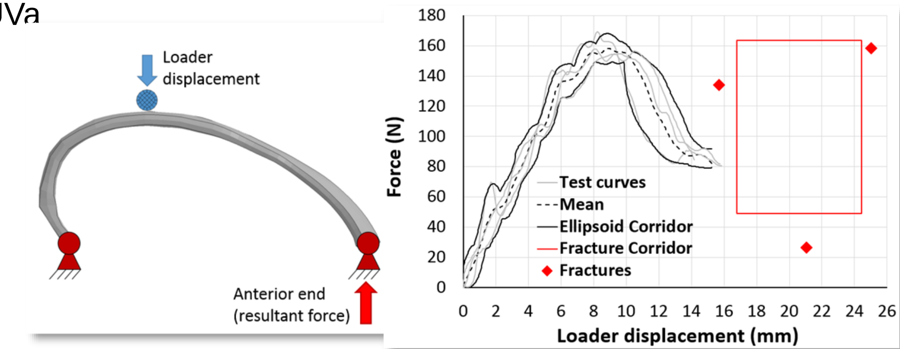
THUMS User Community 1

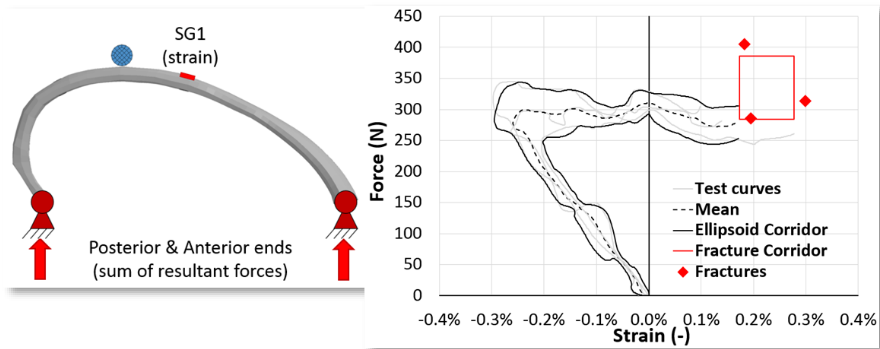
TUC Validation Repository

- **Available in three crash codes:**
  - Isolated Rib under Lateral Loading
  - Experiments published by Del Pozo et al. (2011)
  - Validation Setup developed in cooperation with University of Virginia (UVa)
  - Experimental data / corridors provided by UVa

University of Virginia
Center for Applied Biomechanics







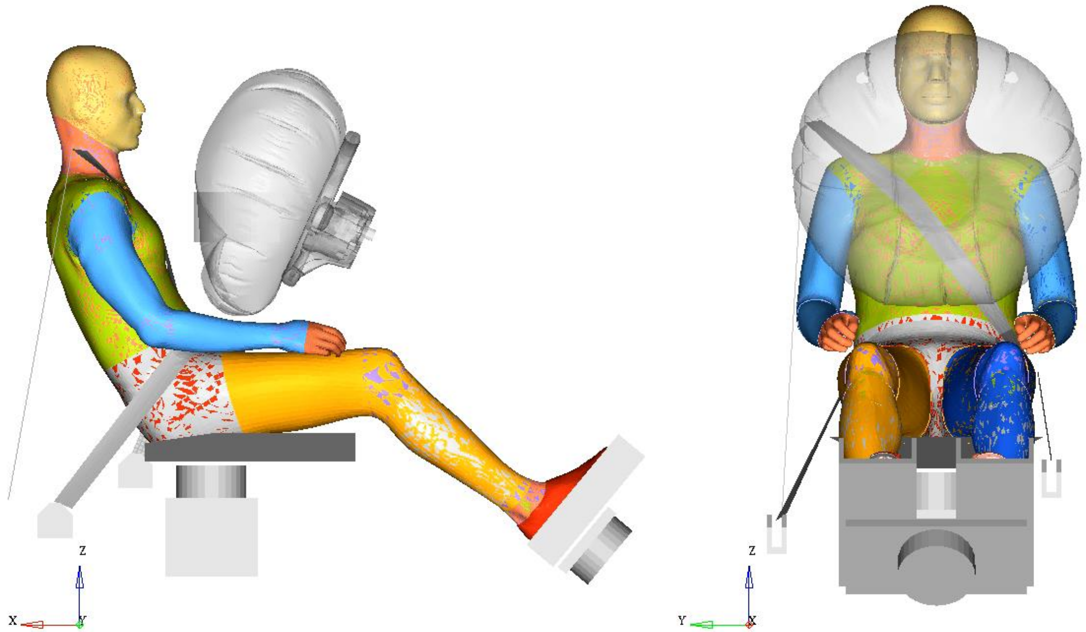
Del Pozo et al. (2011)
Toczynski et al. (2016)

TUC

www.tuc-project.org/validation-repository

TUC Validation Repository

- **Work in progress**
  - Frontal sled using a generic test rig
  - Experiments conducted within SENIORS EU project
  - Experimental data published by Francisco J. Lopez-Valdes
  - Validation Setup developed in cooperation with SENIORS

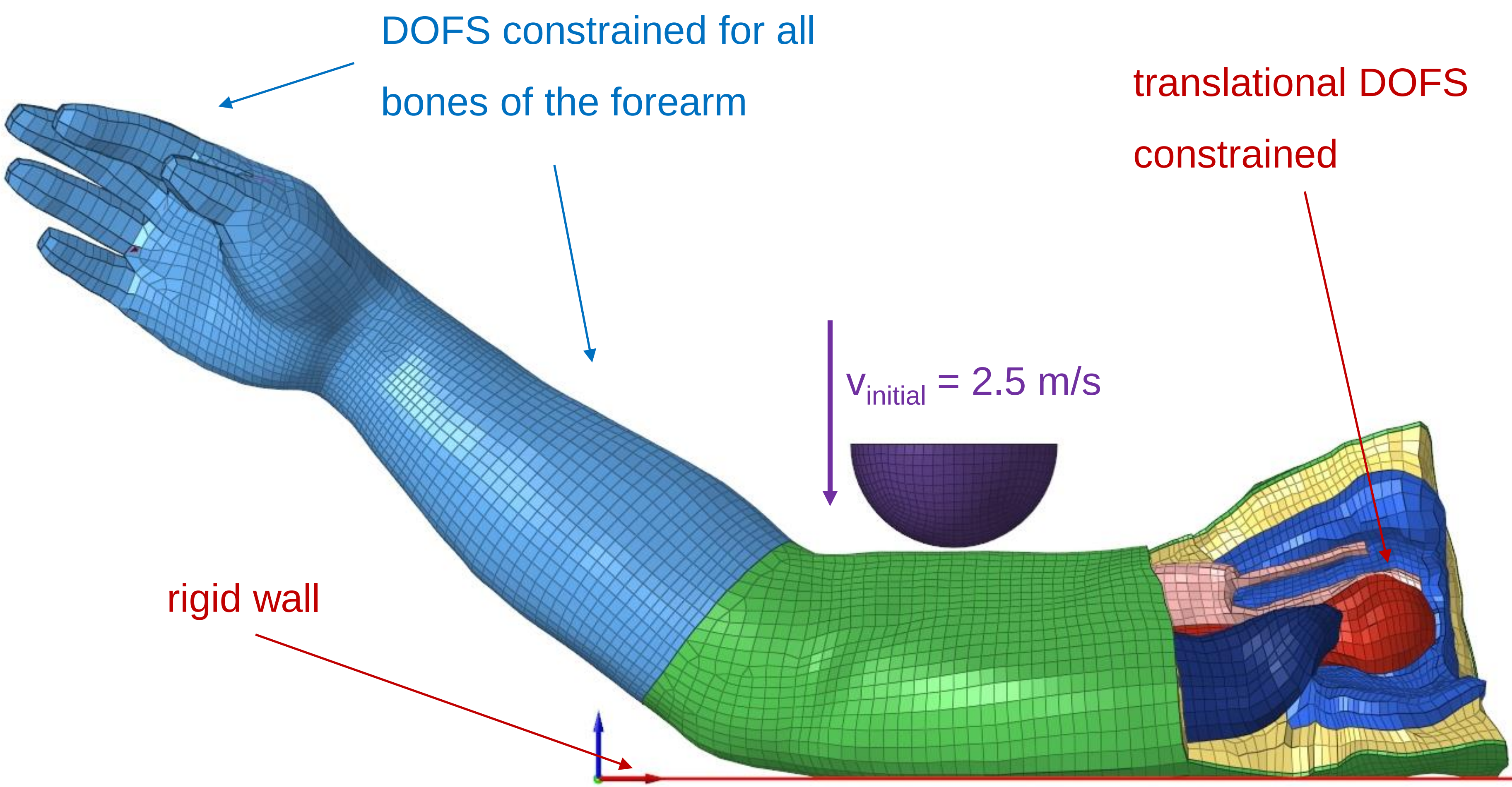


Lopez-Valdez et al. (2017)

www.tuc-project.org/validation-repository

Validation

Validation


DOFS constrained for all bones of the forearm
translational DOFS constrained
$v_{initial}$ = 2.5 m/s
rigid wall

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Thank you for your attention!

Contact: steffen.peldschus@med.lmu.de