Towards omni-directional active human body models

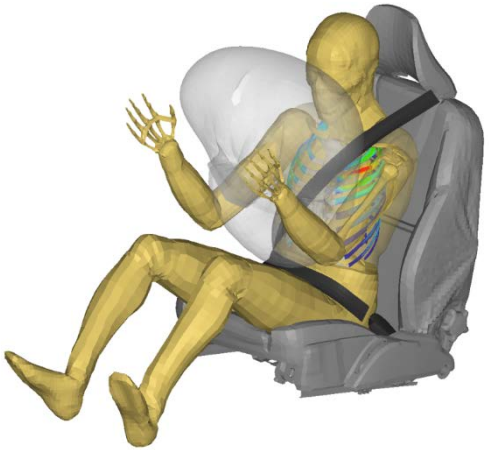
Towards omni-directional active human body models … that predict injury.

Karin Brolin, Jóna Marín Ólafsdóttir, Johan Iraeus, Jonas Östh, Johan Davidsson
Chalmers University of Technology

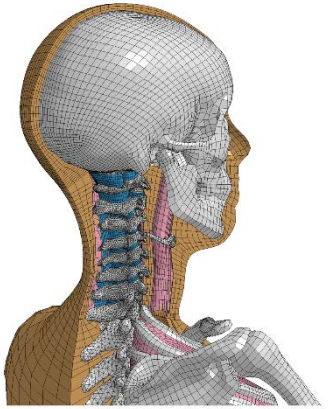
6th International Symposium:
"Human Modeling and Simulation in Automotive Engineering"
October 20 - 21, 2016

Human body modelling (HBM) projects

Active muscles

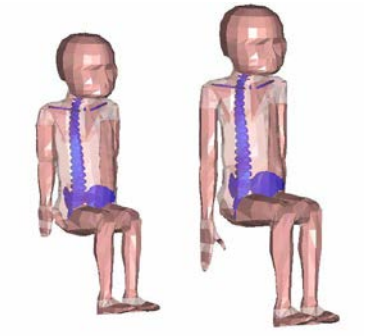


Thoracic injury

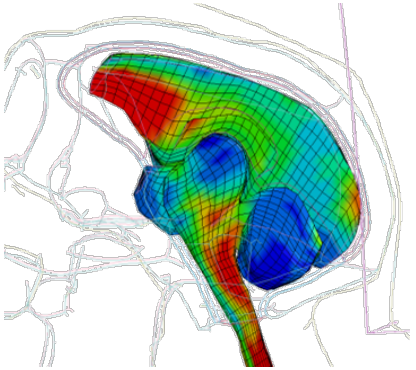


Average female

Adipose tissue

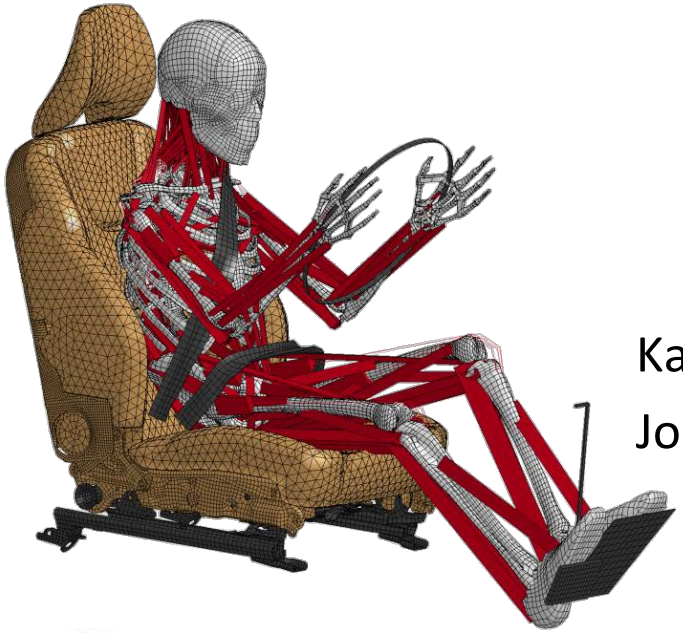


Active child



Brain injury criteria

Active muscle response in HBM, step 3



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Jonas Östh, Ghazaleh Ghaffari

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AIM: SAFER A-HBM

A biofidelic HBM for simulation of sequences of events:

- combined emergency and crash events,
- run off road events, and
- other long duration crash events

Model and methods

HBM:

Total Human Model for Safety (THUMS) version 3.0

(Toyota Motor Corporation, Toyota Central Labs Inc. 2008. Users' Guide of Computational Human Model THUMS – AM50 Occupant Model: Version 3.0–080225)

Finite Element Code:

LS-DYNA v. 970/971 *(LSTC Inc., Livermore, CA, USA)*

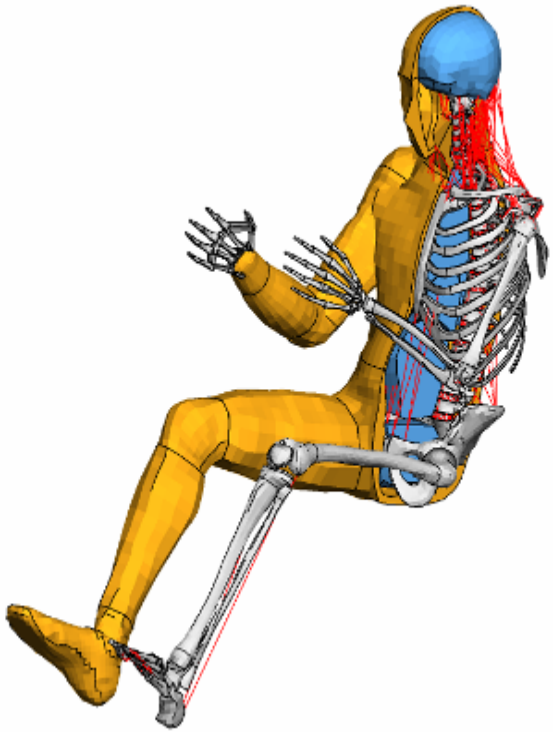
Pre- and post-processing:

Hyperworks *(Altair Engineering Inc., Mich. USA)*

LS-PREPOST *(LSTC Inc., Livermore, CA, USA)*

MatLab *(The Mathworks Inc., Natick, MA, USA)*

Primer *(Oasys Ltd., Sollihull, UK)*



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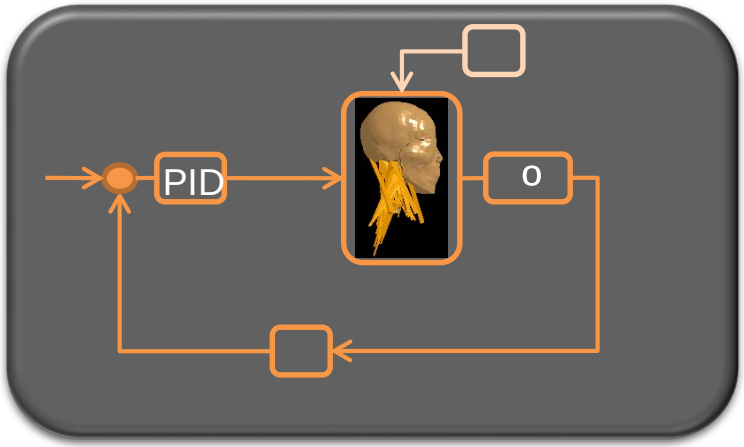
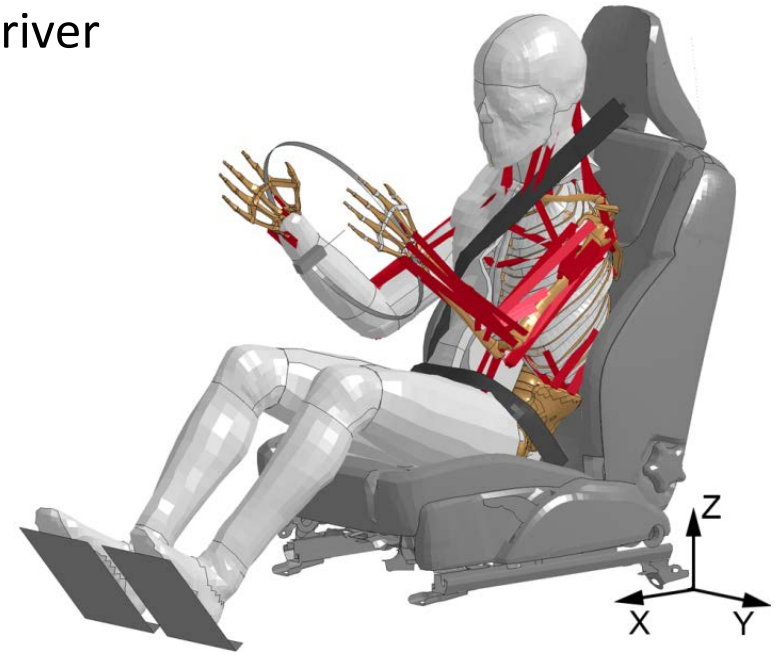
Previous work (A-HBM steps 1-2)

- Implemented muscle control for braking events using feedback control of body angles.
- Provided validation data for autonomous and driver braking.
- Validated the SAFER A-HBM for braking events.





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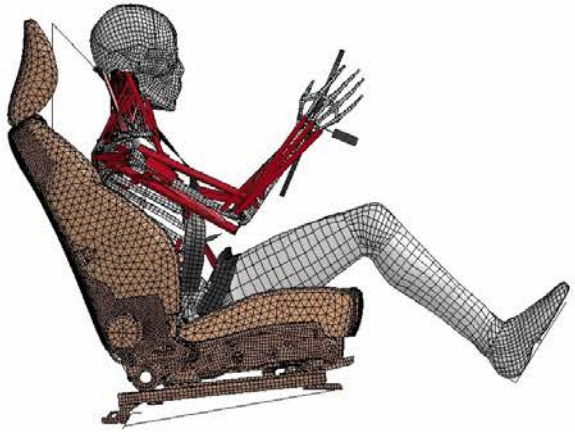
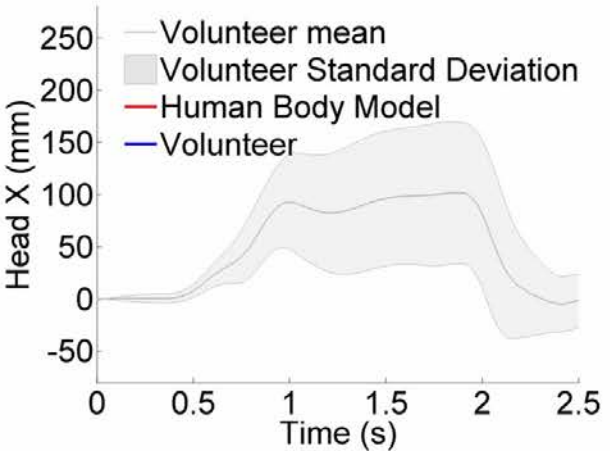
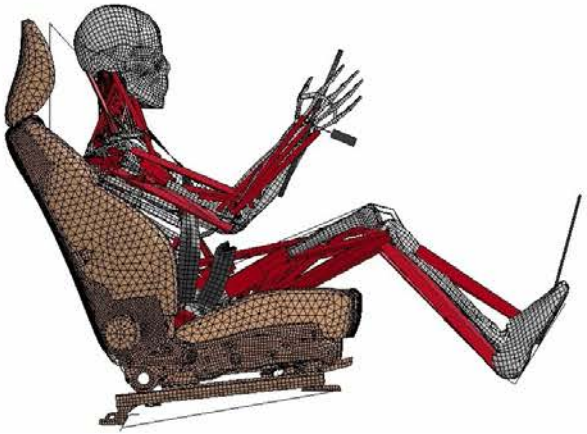
Previous work (A-HBM steps 1-2)

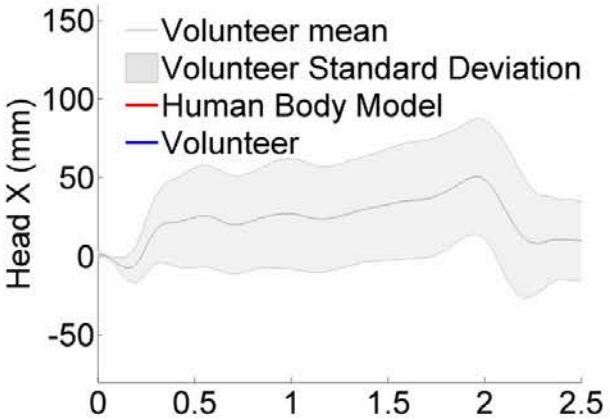
Autonomous braking*





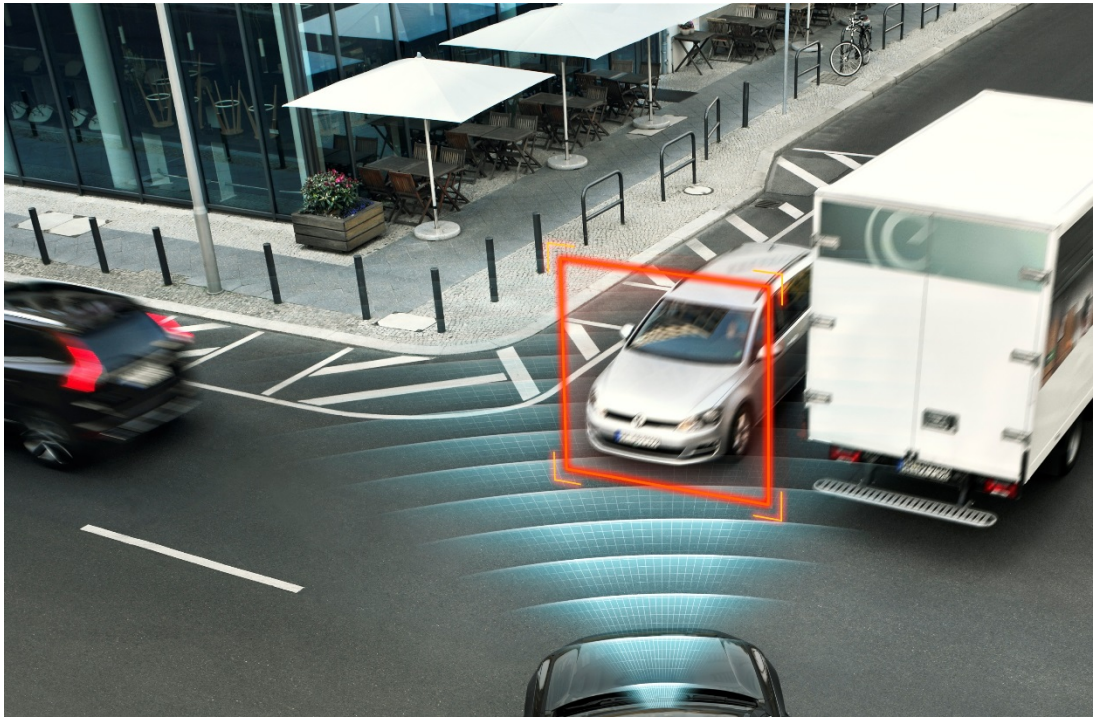
Driver braking**





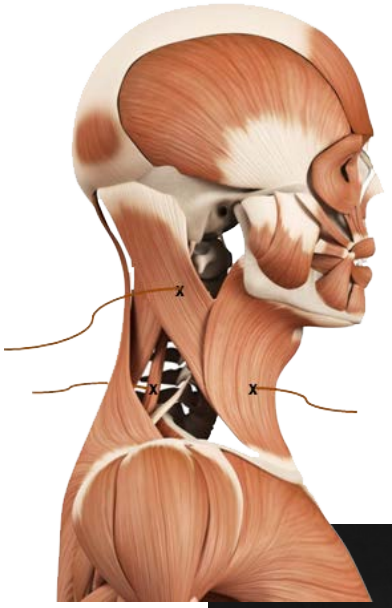
** Östh J, Brolin K, Bråse D. A Human Body Model with Active Muscles for Simulation of Pre-Tensioned Restraints in Autonomous Braking Interventions. Traffic Injury Prevention, 16 (3) s. 304-313, 2015.*

*** Östh J, Eliasson E, Happee R, Brolin K. A Method to Model Anticipatory Postural Control in Driver Braking Events, Gait & Posture. 40 (4) s. 664-669, 2014.*



Omnidirectional active HBM

Volunteer experiment - Multidirectional loading



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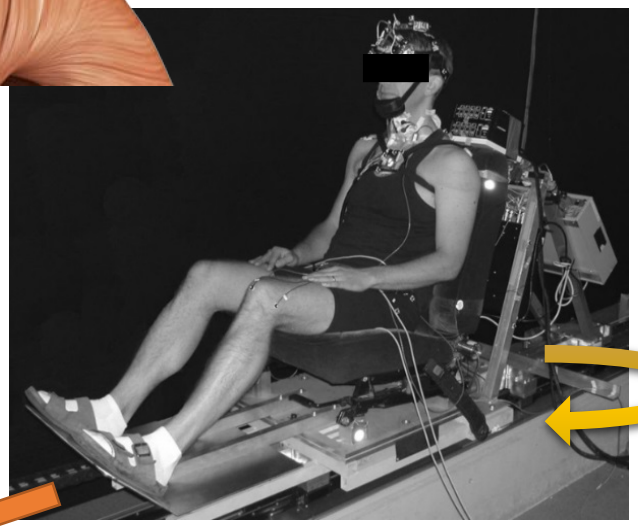
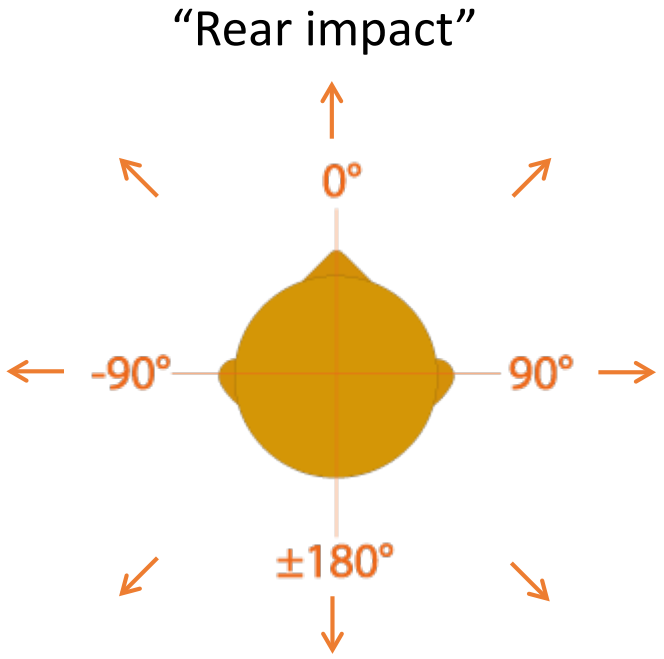
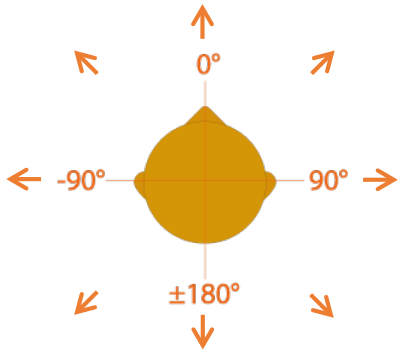


Eight perturbation directions

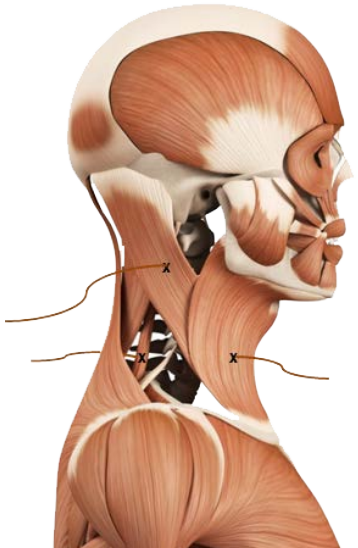


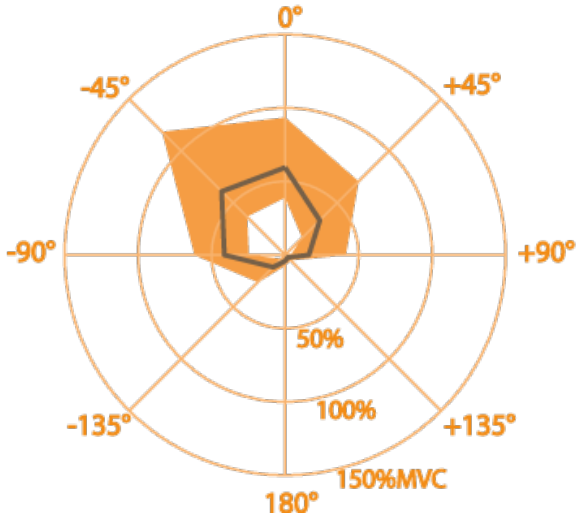
Volunteer experiment – Resulting muscle activity

"Rear impact"

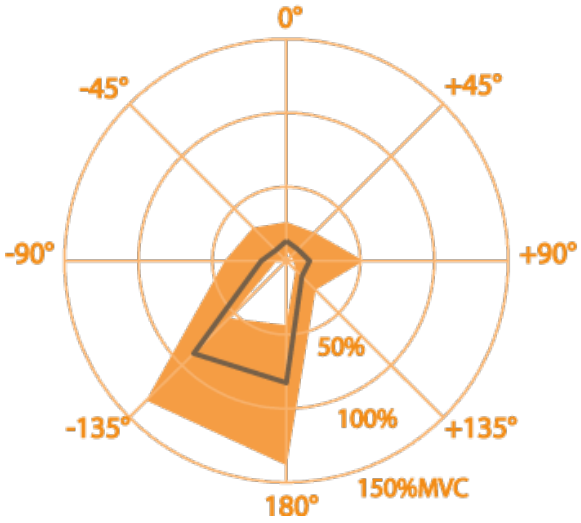


"Frontal impact"





Sternocleidomastoid



Semispinalis capitis

Olafsdottir J, Brolin K, Blouin J-S, Siegmund G. (2015). Dynamic Spatial Tuning of Cervical Muscle Reflexes to Multidirectional Seated Perturbations. Spine. 40 (4) s. E211-E219

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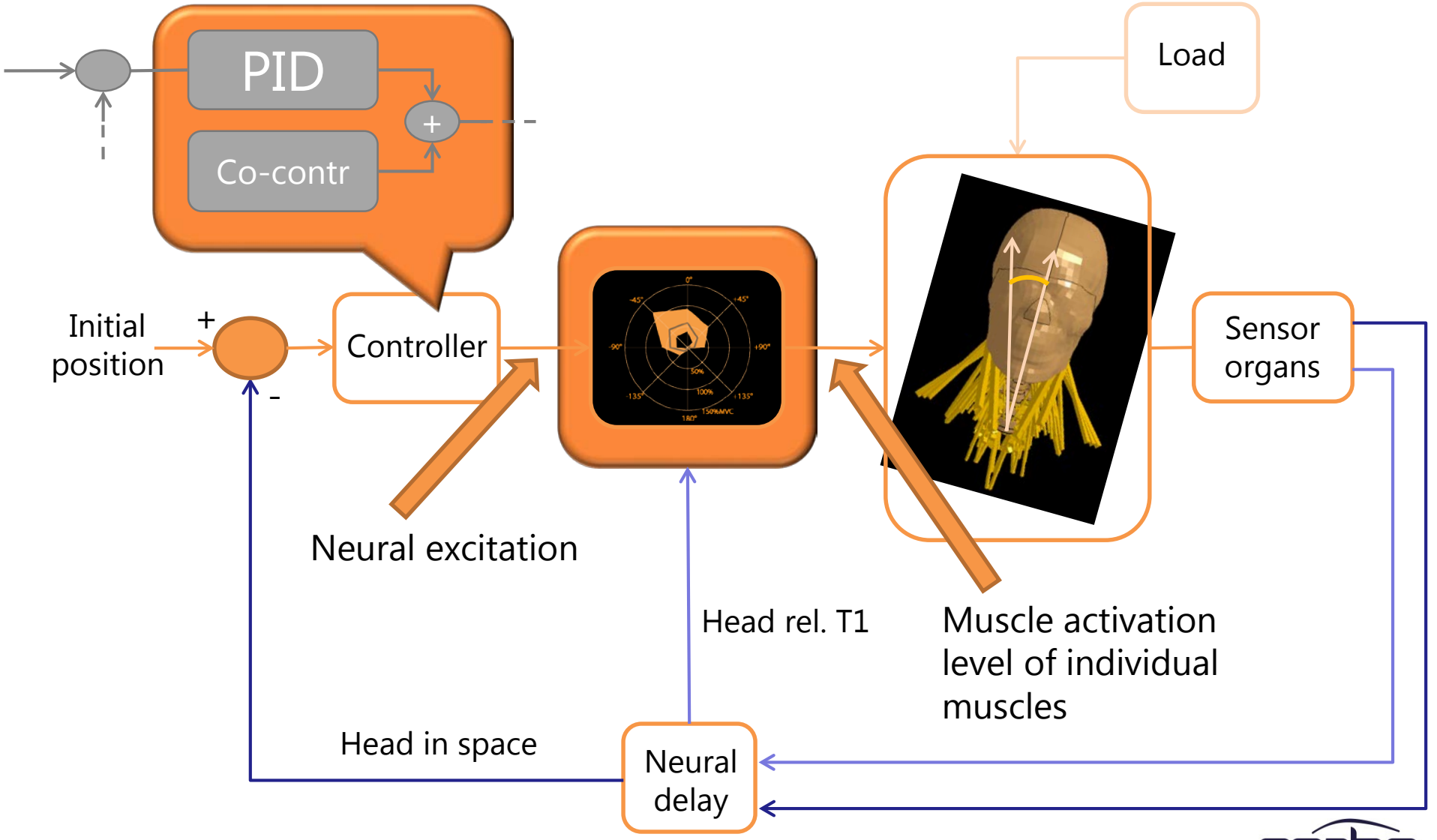
Neuromuscular control scheme



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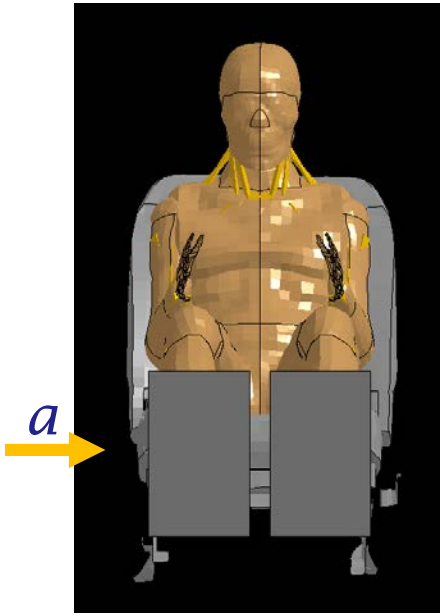
Model verification



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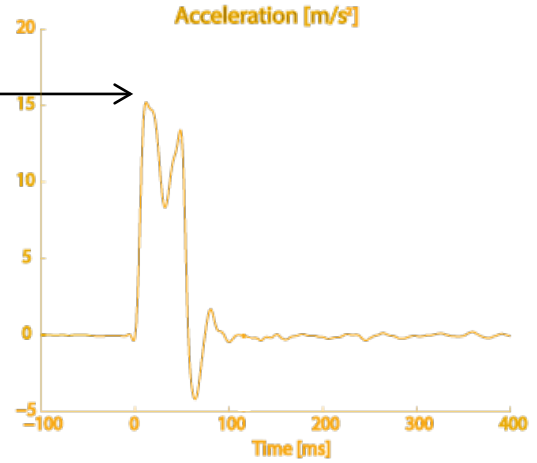

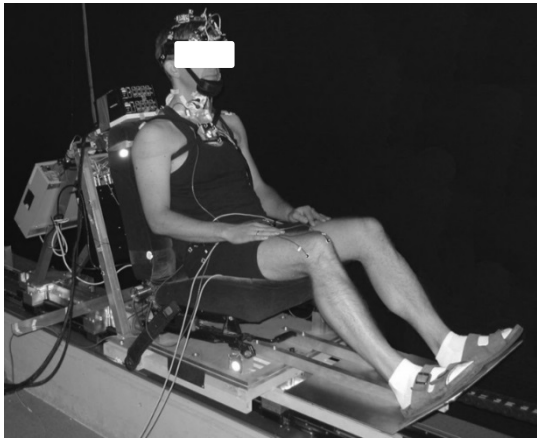

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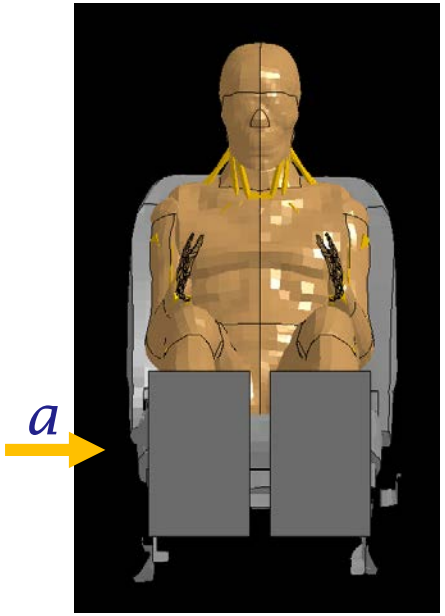
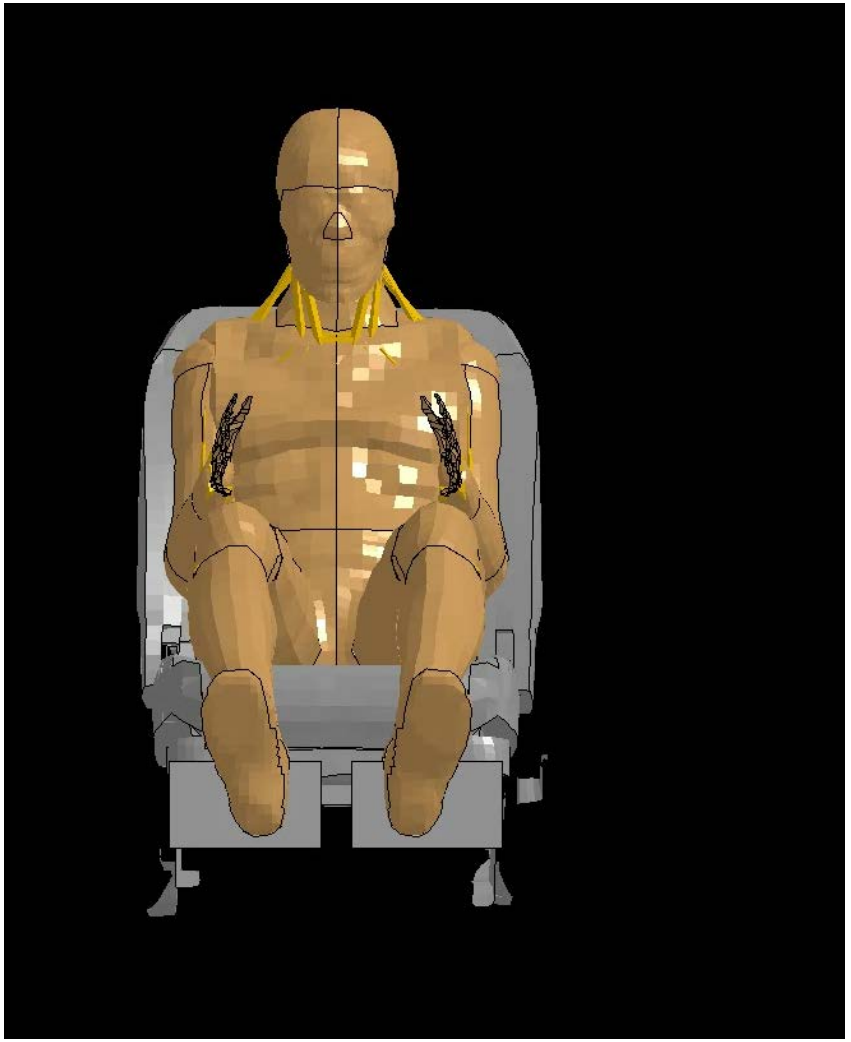




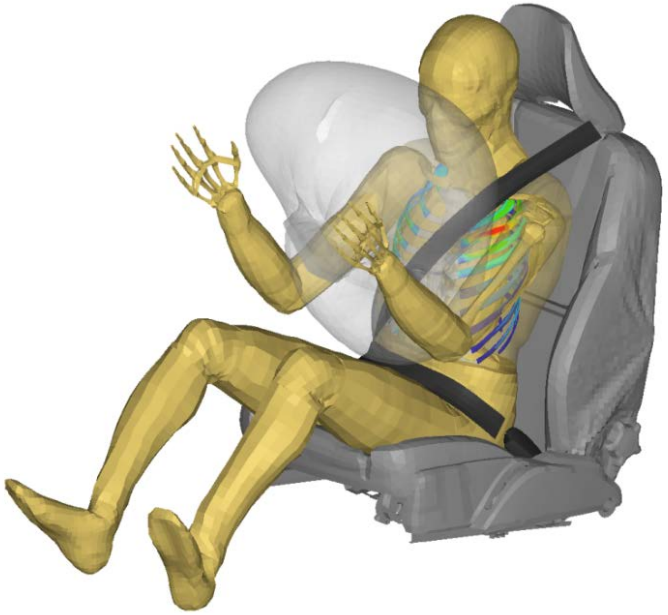
Model validation - ongoing

New experimental series:

- Volunteer drivers and passengers in test vehicle
- Muscle activity measured with electrodes
- 3-D kinematics with video tracking
- Collect vehicle data
- Events and voluntary driving:
  - Lane change,
  - U-turns,
  - Braking.

All data collected and data analyses about to begin.

Improved injury prediction using HBM, step 3



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Previous research (I-HBM, steps 1-2)

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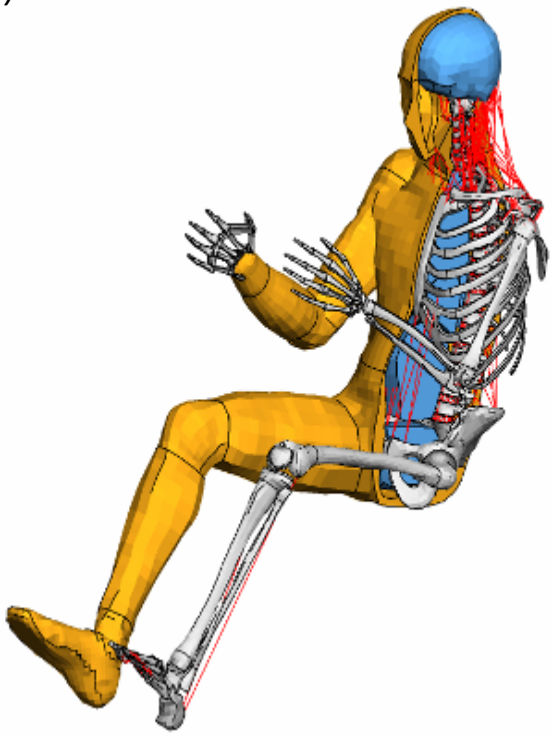
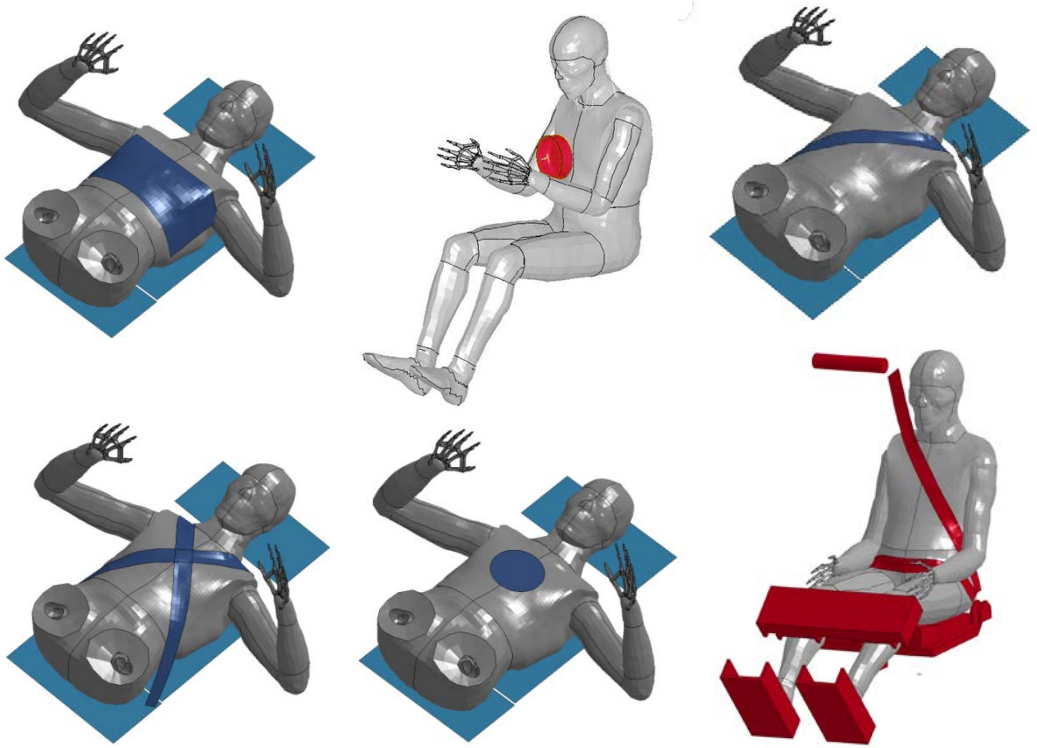
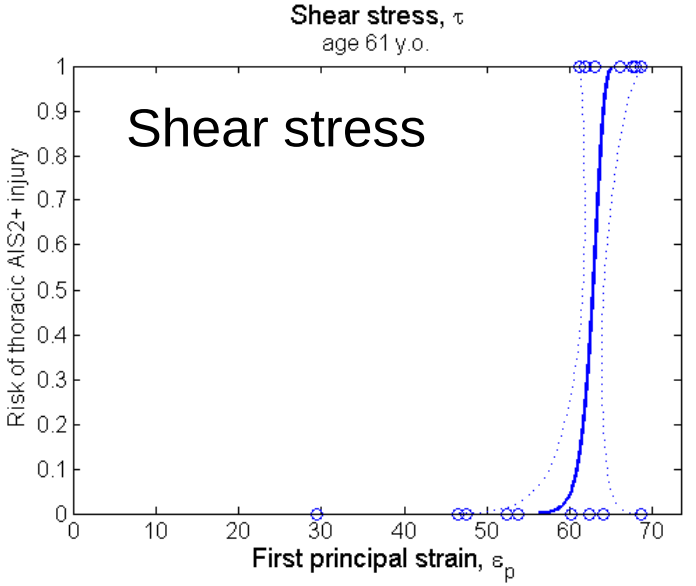


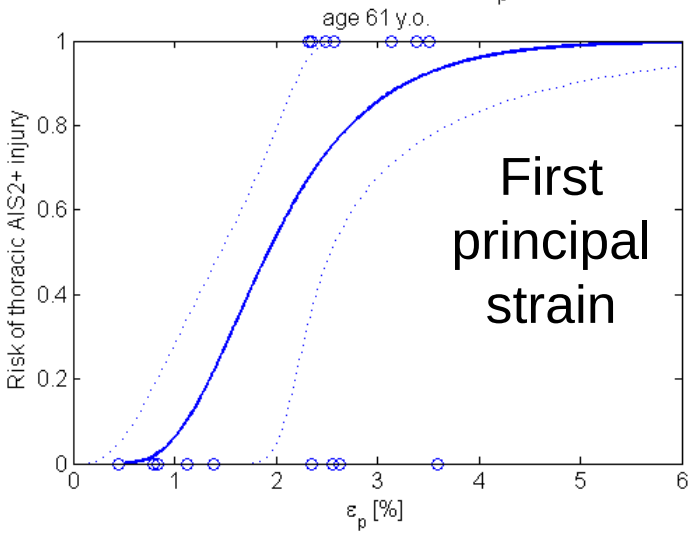
Previous research (I-HBM, steps 1-2)

AIS2+ injury risk curves created based on simulations of 23 PMHS tests.

Mendoza-Vazquez M, Davidsson J, Brolin K. Construction and evaluation of thoracic injury risk curves for a finite element human body model in frontal car crashes. Accident Analysis and Prevention. 2015;85:73-82.



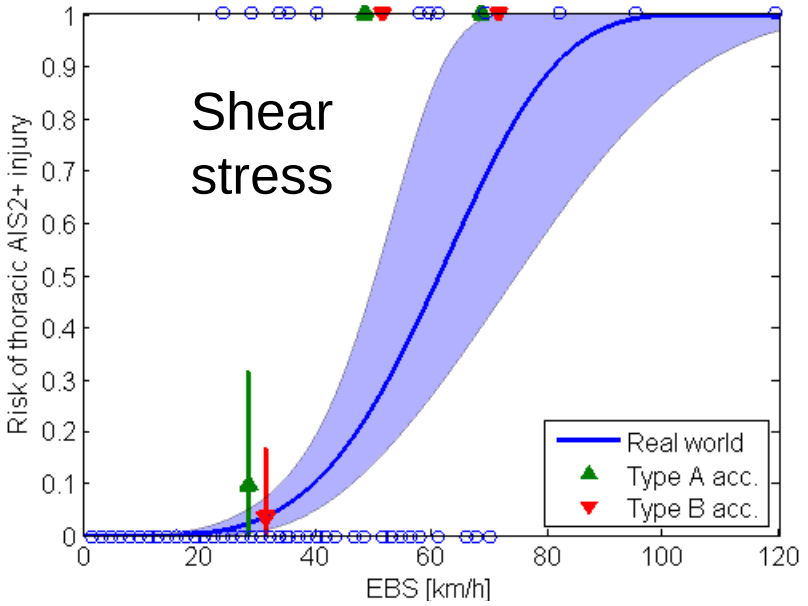


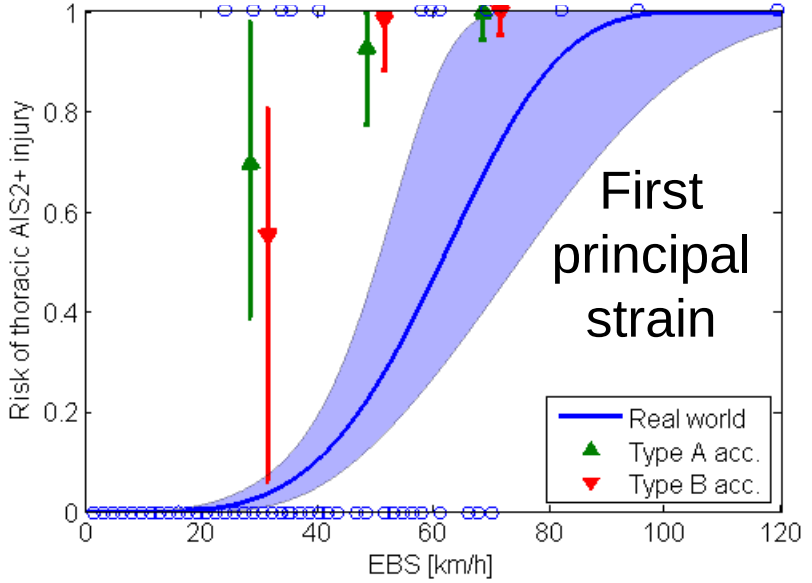


Previous research (I-HBM, steps 1-2)

Accident reconstructions

Mendoza-Vazquez M, Jakobsson L, Davidsson J, Brolin K, Östmann M. Evaluation of Thoracic Injury Criteria for THUMS Finite Element Human Body Model Using Real-World Crash Data. I: IRCOBI Conference Proceedings - International Research Council on the Biomechanics of Injury, 10-12 September, Berlin, Germany . 2014. 528-541.





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Previous research (I-HBM, steps 1-2)

The HBM was over predicting injury risk in real world accidents.

How can we improve the biofidelity of injury predictions?

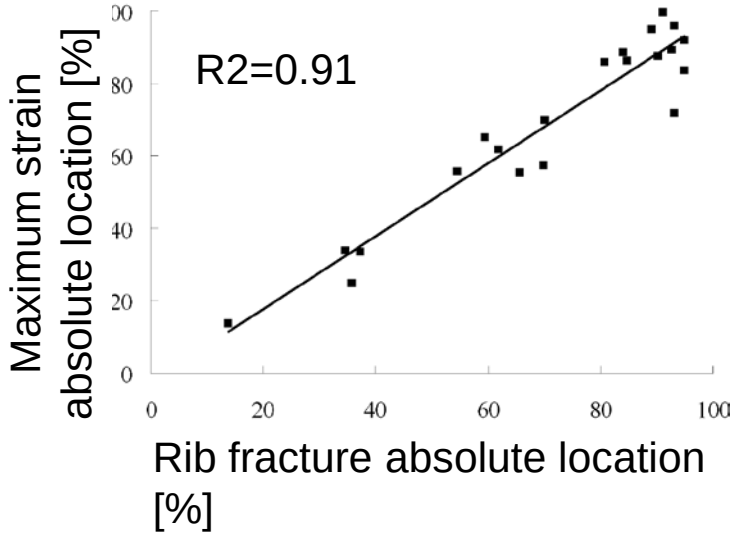
Improved injury prediction using HBM, step 3

Enhanced prediction of rib fracture risk using HBMs

Hypothesis:
Rib fracture is strain controlled.

Method:

- Understand influence of geometry and material properties
  - Develop a generic rib cage
- Validate distribution of rib strain in load configurations of increasing complexity
  - Evaluate rib strain as indicator of rib fracture
- Evaluate how PMHS results relates to real world accident data.



Adopted from: Trosseille, X., Baudrit, P., Leport, T., Vallancien, G., (2008). Rib cage strain pattern as a function of chest loading configuration. Stapp car crash journal 52, 205-231.

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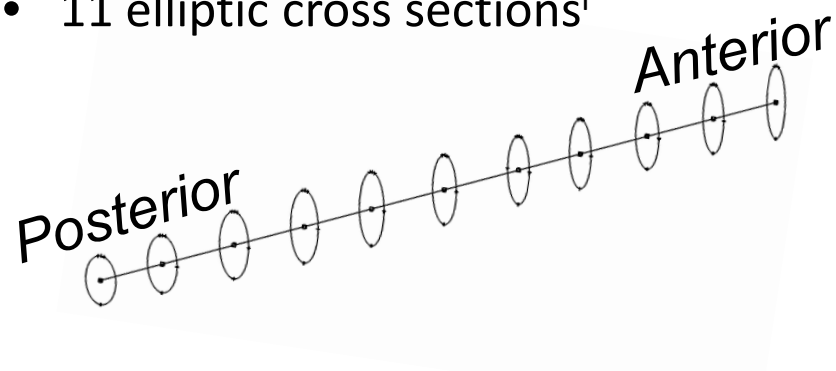
Development of a generic ribcage

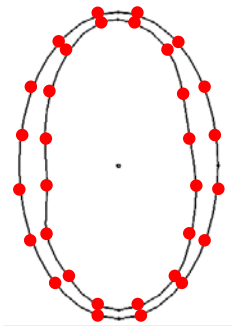
1. Each rib defined using:

- Rib chord length[i]
- 11 elliptic cross sections[i]



2. Each cross section defined using:

- 16 cortical thickness measurements[i]

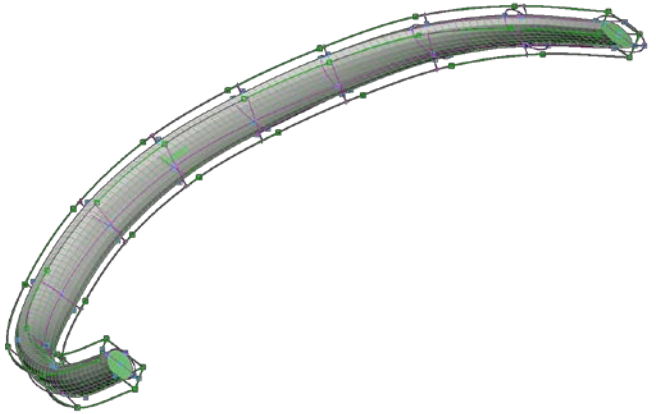


3. Create surface and mesh

- First all solid mesh
- Convert outer solids to thin shells

4. Fit to 3-D shape using morphing

- Both curvature and twist assigned[ii]



i. Choi, H.-Y., Kwak, D.-S., (2011). Morphologic characteristics of korean elderly rib. J Automotive Safety and Energy, 2011, Vol. 2 No. 2

ii. Shi, X., Cao, L., Reed, M.P., Rupp, J.D., Hoff, C.N., Hu, J., (2014). A statistical human rib cage geometry model accounting for variations by age, sex, stature and body mass index. Journal of biomechanics 47 (10), 2277-2285.

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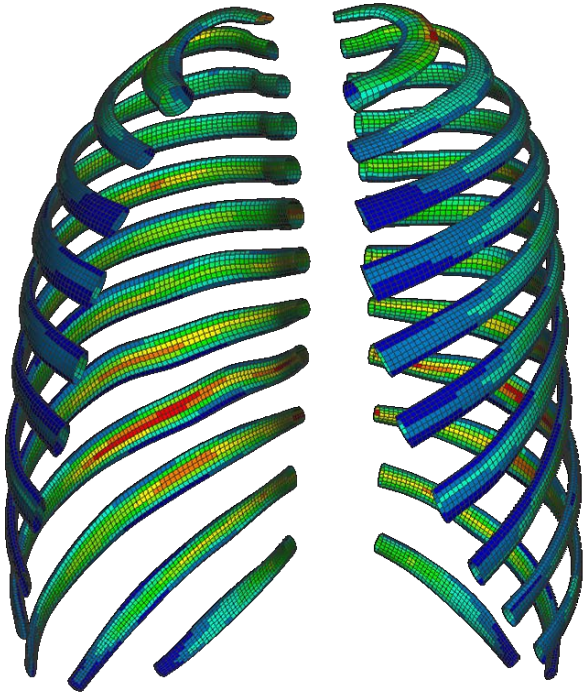
Development of a generic ribcage

5. Assemble all ribs:

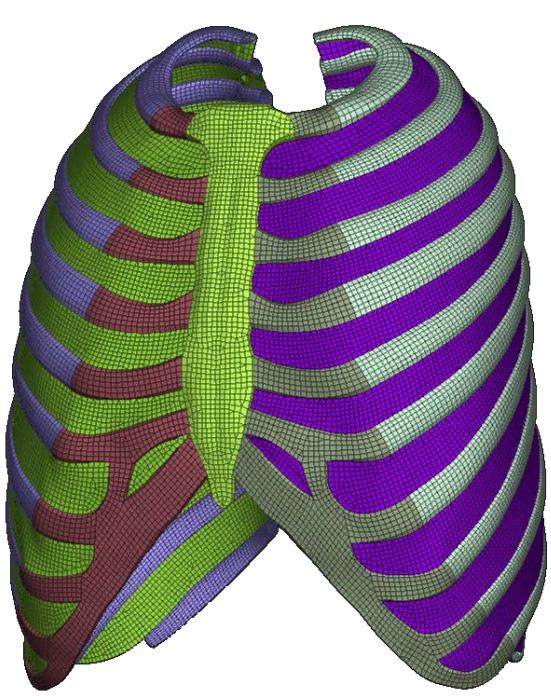
- Ribs location given by Shi study[ii]

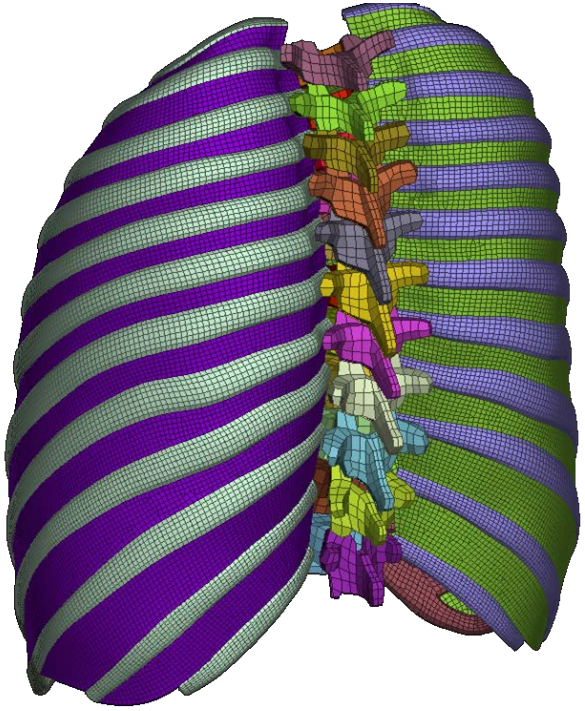


Fringe=cortical thickness

6. Adapt boundaries to THUMS:

- Adapt costal cartilage
- Reshape ribs locally at spine





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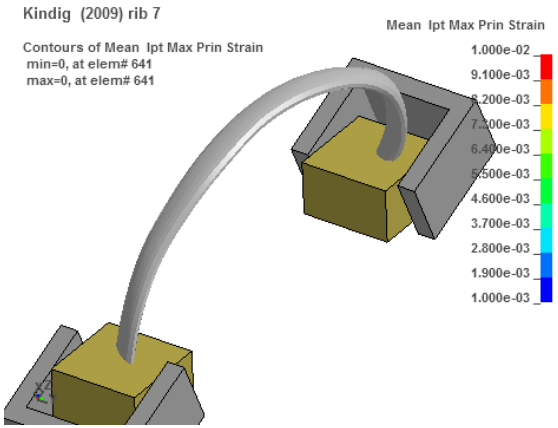
Rib strain validation

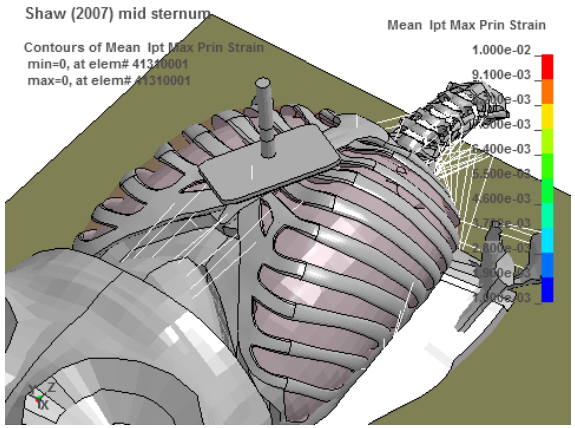
1. Single rib tests



Fringe=maximum principal strain

Kindig, M.W., (2009). Tolerance to failure and geometric influences on the stiffness of human ribs under anterior-posterior loading, Thesis, School of Engineering and Applied Science University of Virginia.

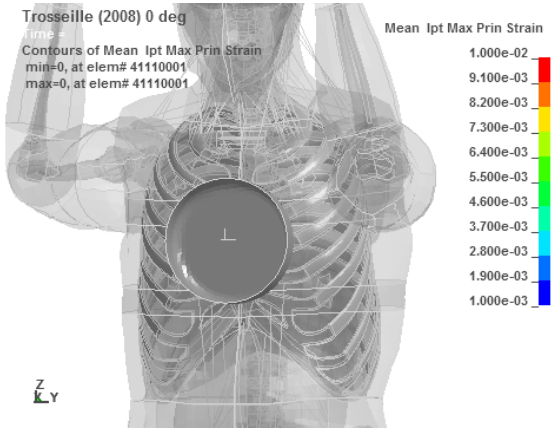
2a. Table top tests



Fringe=maximum principal strain

Shaw, C.G., Lessley, D., Evans, J., Crandall, J.R., Shin, J., Portier, P., Paolomi, G., (2007). Quasi-static and dynamic thoracic loading tests: Cadaveric torsos. In: Proceedings of the Proceedings of the International Research Council on the Biomechanics of Injury conference.

2b. Impactor tests

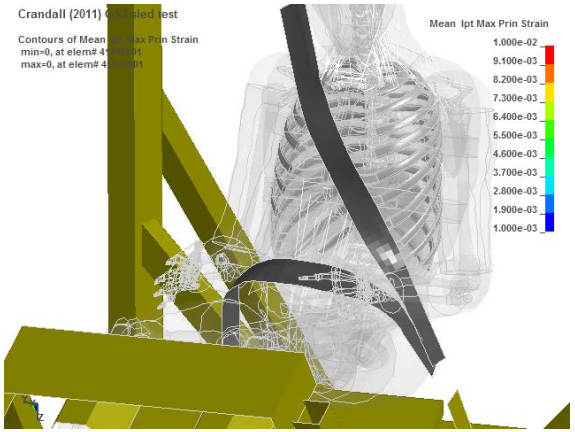


Fringe=maximum principal strain

Trosseille, X., Baudrit, P., Leport, T., Vallancien, G., (2008). Rib cage strain pattern as a function of chest loading configuration. Stapp car crash journal 52, 205-231.

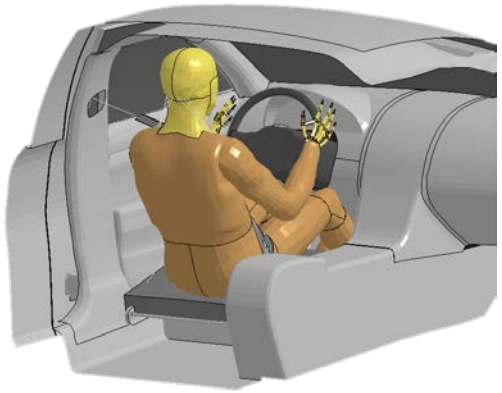
Rib strain validation / Injury criteria evaluation

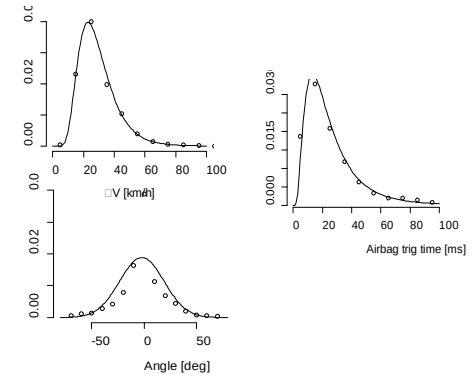
3. Sled tests → 4. Accident reconstructions → ...back to 1

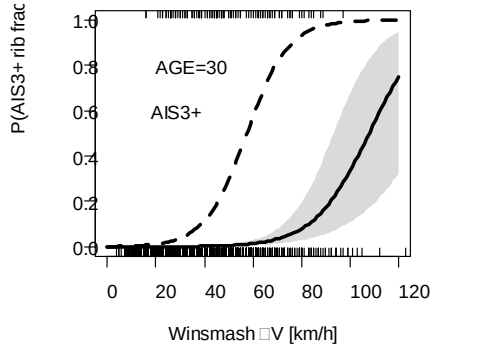


Fringe=maximum principal strain

Crandall, J., (2012). Atd thoracic response test development - gold standard buck condition 2: Force limited belt, 30 km/h frontal (Report), Charlottesville, Virginia, University of Virginia.







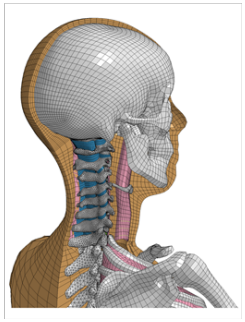
Iraeus, J., (2015). Stochastic finite element simulations of real life frontal crashes. Doctoral thesis, comprehensive summary. Umeå University.

carhs.

Questions?

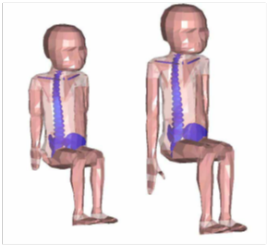
Active muscles

Thoracic injury

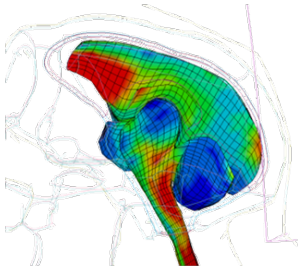


Average female

Adipose tissue



Active child



Brain injury criteria

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