Human Model Occupant Kinematics in Highly Reclined Seats during Frontal Crashes

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UMTRI-Biosciences

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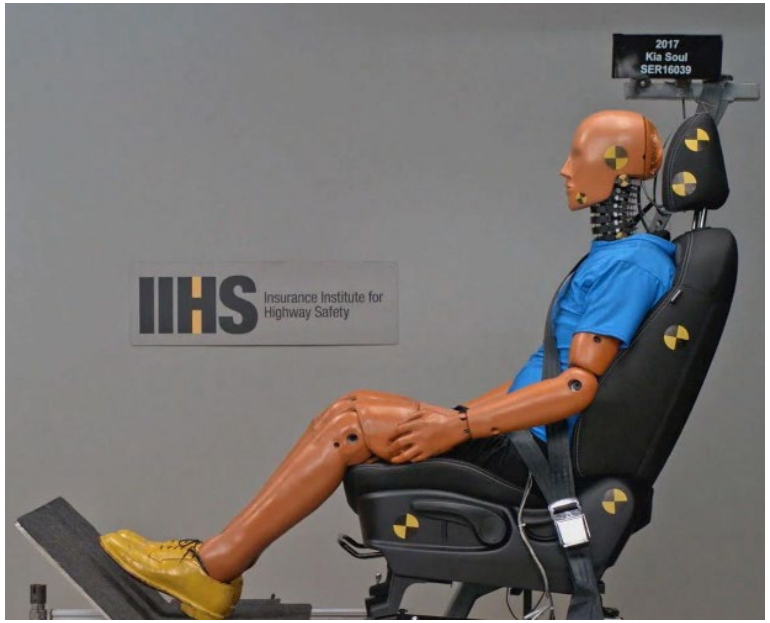
Project Background



Standard automotive posture

Kinematics
Submarining risk
Injury risk
Impact Response

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Concept autonomous vehicle posture

- Current safety standards are based on occupants seated in standard posture (~24°recline)
- Improvements to seats and restraint systems may be needed to ensure good protection for people in alternative postures

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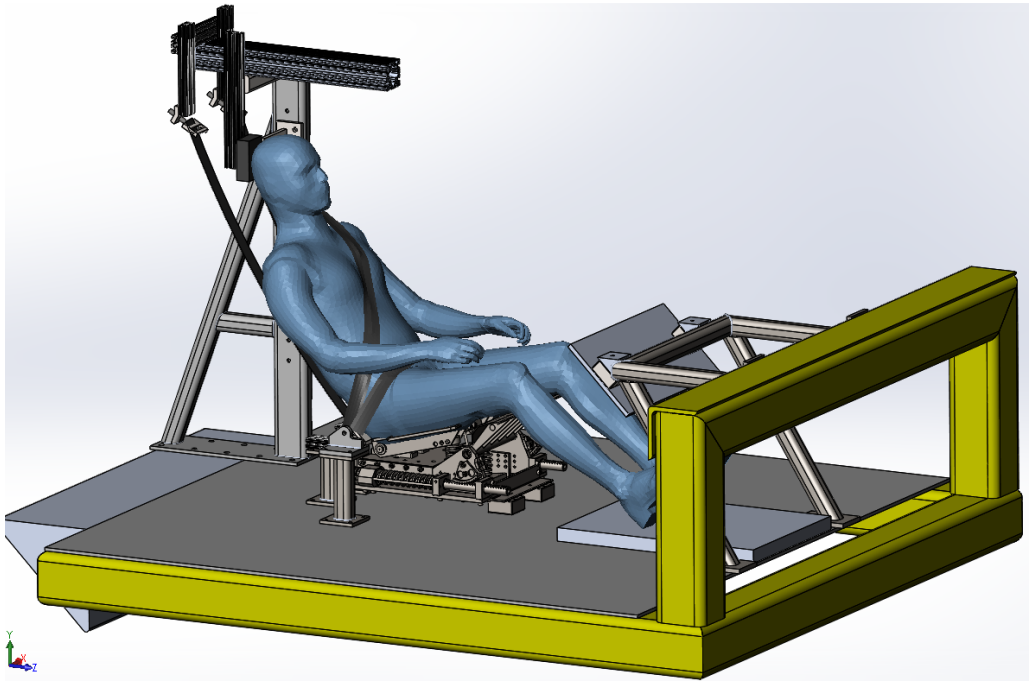
Project Background

- NHTSA-funded PMHS impact tests in vehicles with automated driving systems (ADS)
- Focus will be on highly reclined occupants
- Two populations of interest
  1) 50th percentile male (UMTRI)
  2) Vulnerable occupants: small female, obese (MCW)
- Primary outcome will be a cohesive dataset that can be used for future validation of ATDs and human body models



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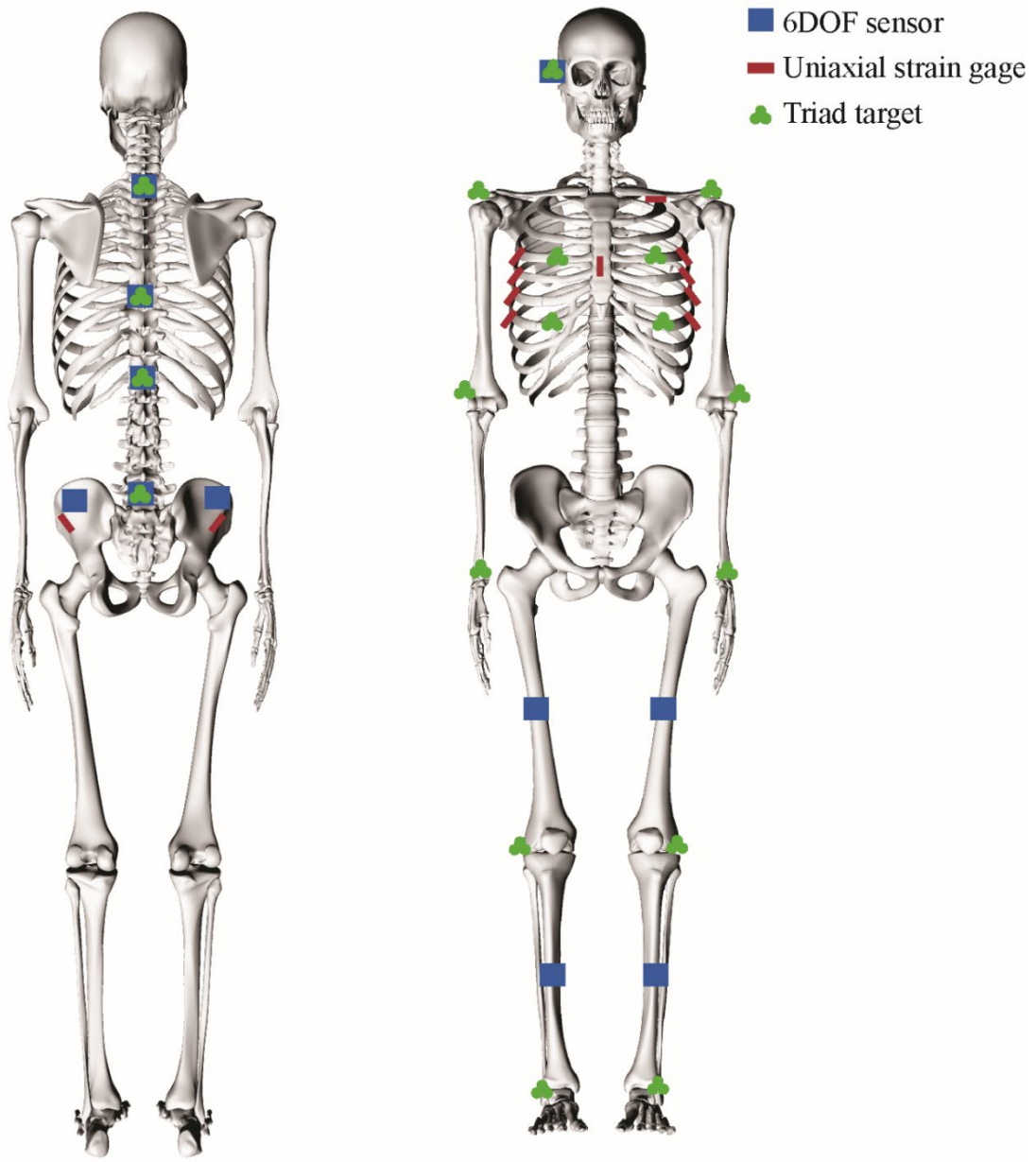
Project Background

- UMTRI/MCW → Similar techniques/philosophies for PMHS instrumentation
- Head, spine, and pelvis kinematics
- Extremity kinematics
- Fracture timing
- Chest deflection



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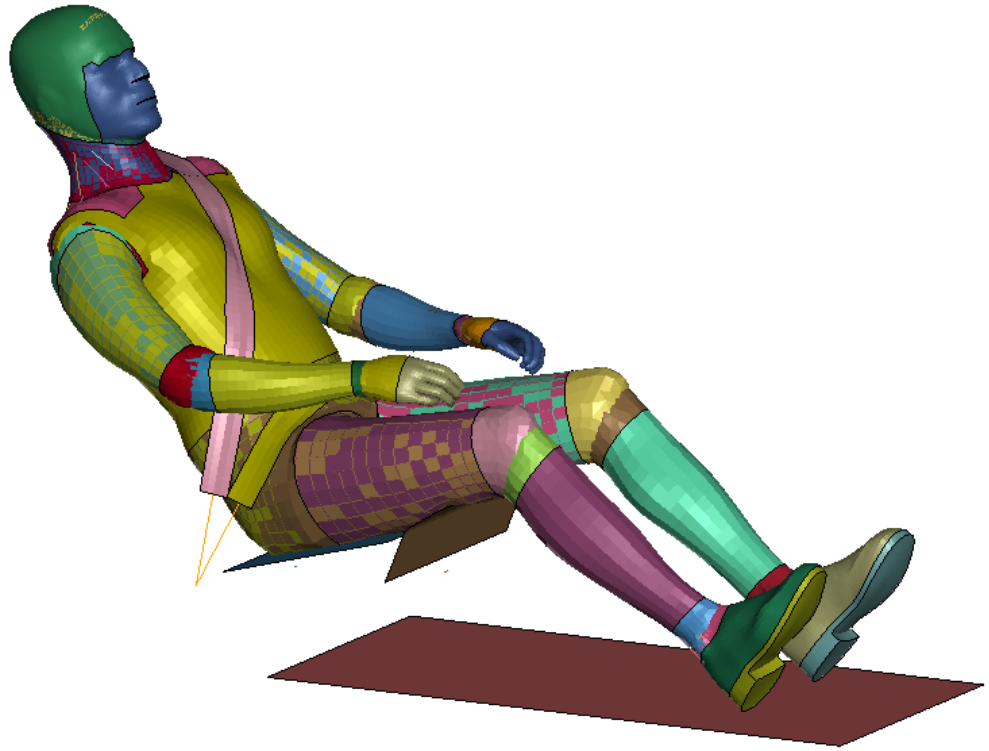
Simulation Strategy

- Predict possible PHMS response / trends
- Examine factors related to submarining
  - Recline angle
  - Seat type
  - Restraint parameters (pre-tensioning, locking tongue belt angle)
- Two parametric studies completed
  - Focused on recline angle and seat type
  - Focused on restraint characteristics
- GHBMC simplified model
- The model is not validated in reclined conditions



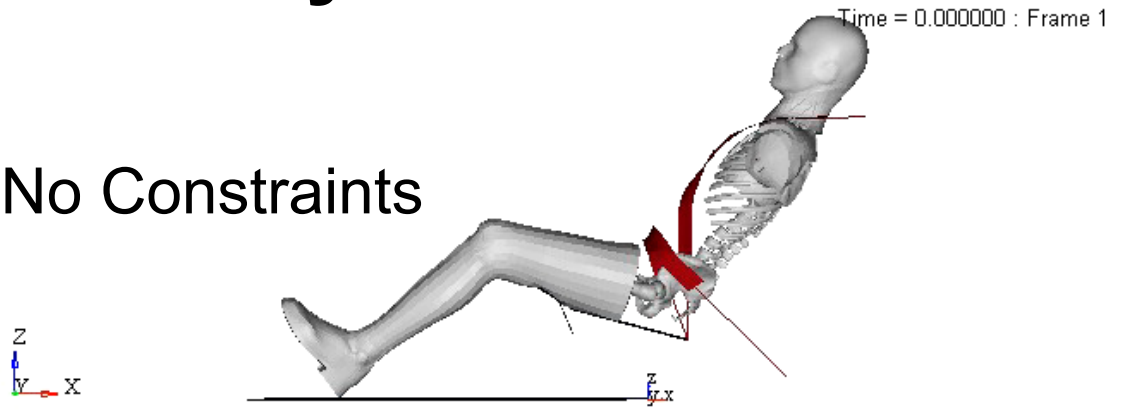
Simulation Setup- Lower Extremity Constraints

- Total LX constraint not realistic
  - Spine buckling
  - Much higher spine forces
- Legs kicking up
  - Does not largely affect pelvis and upper body when compared to heel constraint conditions

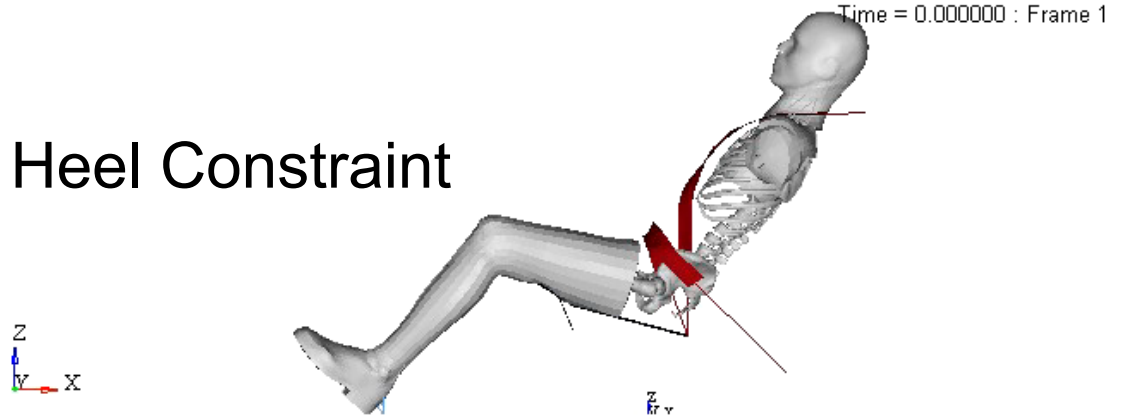
	No Constraints	Heel Constraint	Touching Bolster
HIC	297	332	182
BrIC	0.67	0.68	0.51
Chest D	**27.9**	**27.9**	**21.7**
Head X Exc	783	777	816
Sh X Exc	501	497	600
Pelvis X Exc	**268**	**236**	**30**
Pelvis Z Exc	-4	-10	-31
Pelvis Rot	**54°**	**56°**	**0°**
Lumbar Force	**759**	**917**	**1141**

*All with semi-rigid seat

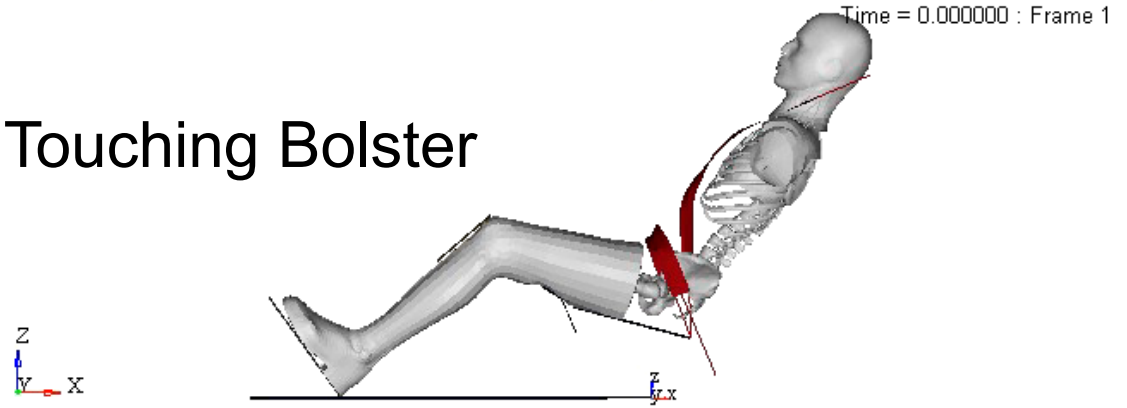
No Constraints



Heel Constraint

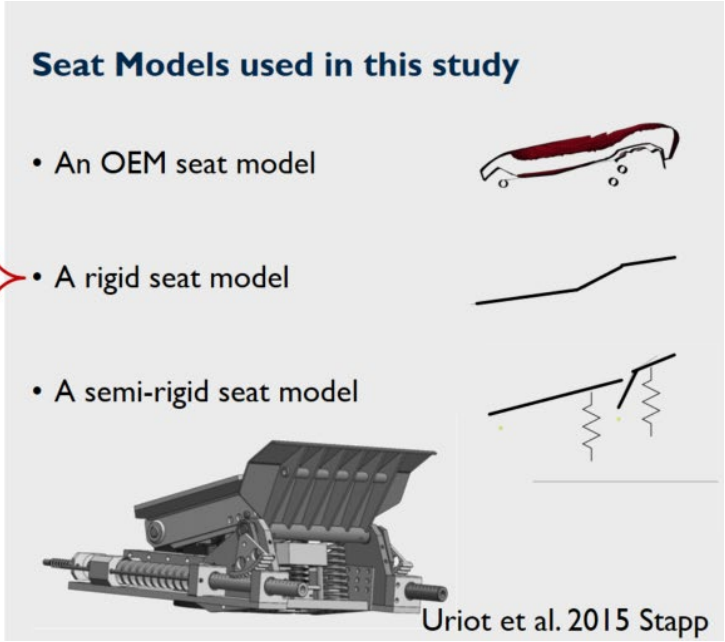


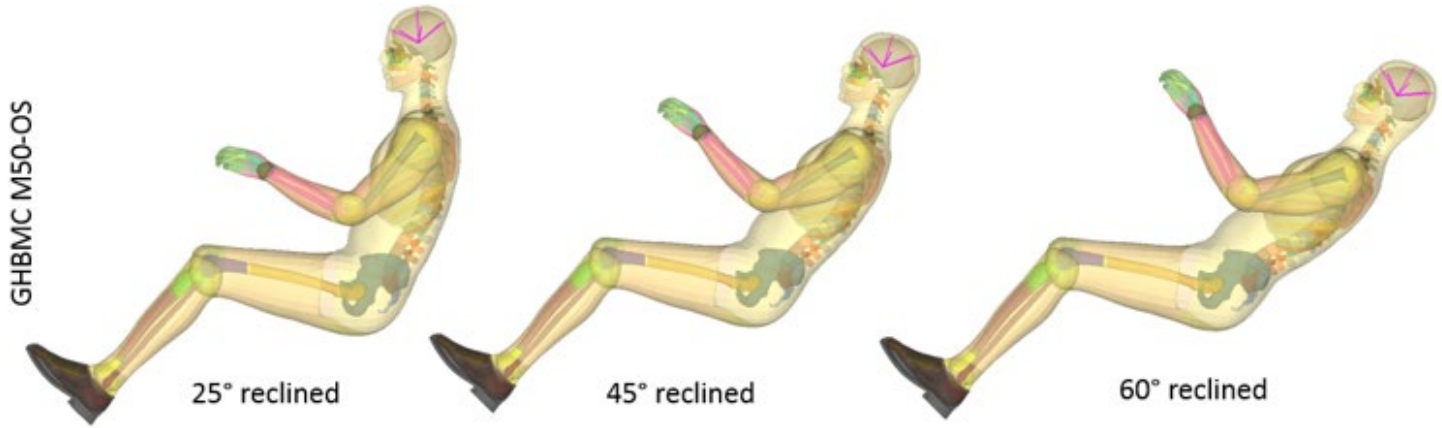
Touching Bolster



Seat and Recline Angle Study

- 35 mph crash pulse
- Simulation Matrix (3x3)
  - 3 seats (Rigid Seat, Semi-rigid, Vehicle OEM seat)
  - 3 recline angle postures (25º, 45º, 60º)
- 3.25 kN shoulder load limit
- 2.5 kN retractor pre-tensioner
- Lap belt angles
  - 65º on the anchor side
  - 70º on the buckle side
- No lower extremity constraints





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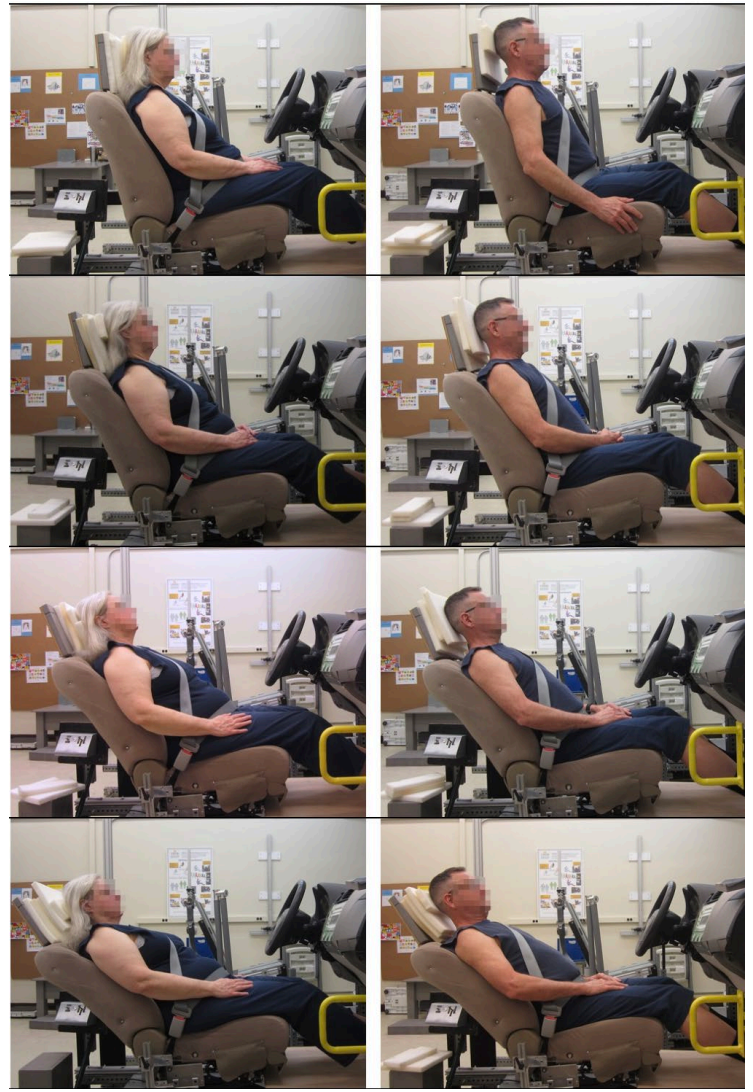
Occupant Positioning: Volunteer Study

How do people sit in highly reclined postures?

UMTRI Study:

- 24 men and women
- laboratory mockup
- 4 seat back angles (23º, 33º, 43º, 53º)
- sitter-selected head support
- posture measurement using FARO Arm



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Occupant Positioning: Posture Model

Posture Prediction:

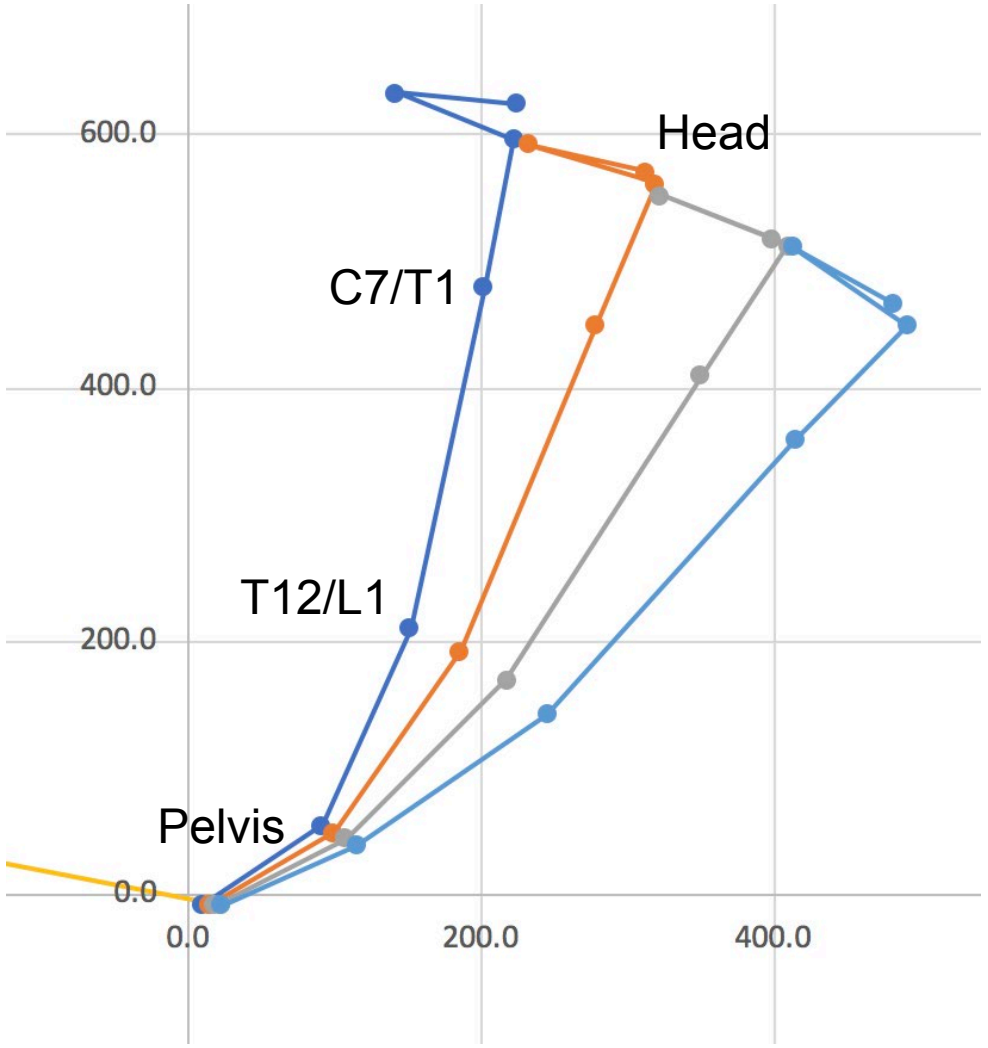
Statistical modeling of torso posture

Inputs:

- Stature
- Erect Sitting Height
- Body Weight
- Seat Back Angle

Outputs:

- Head and torso landmarks
- Torso joint center locations
- Pelvis angle



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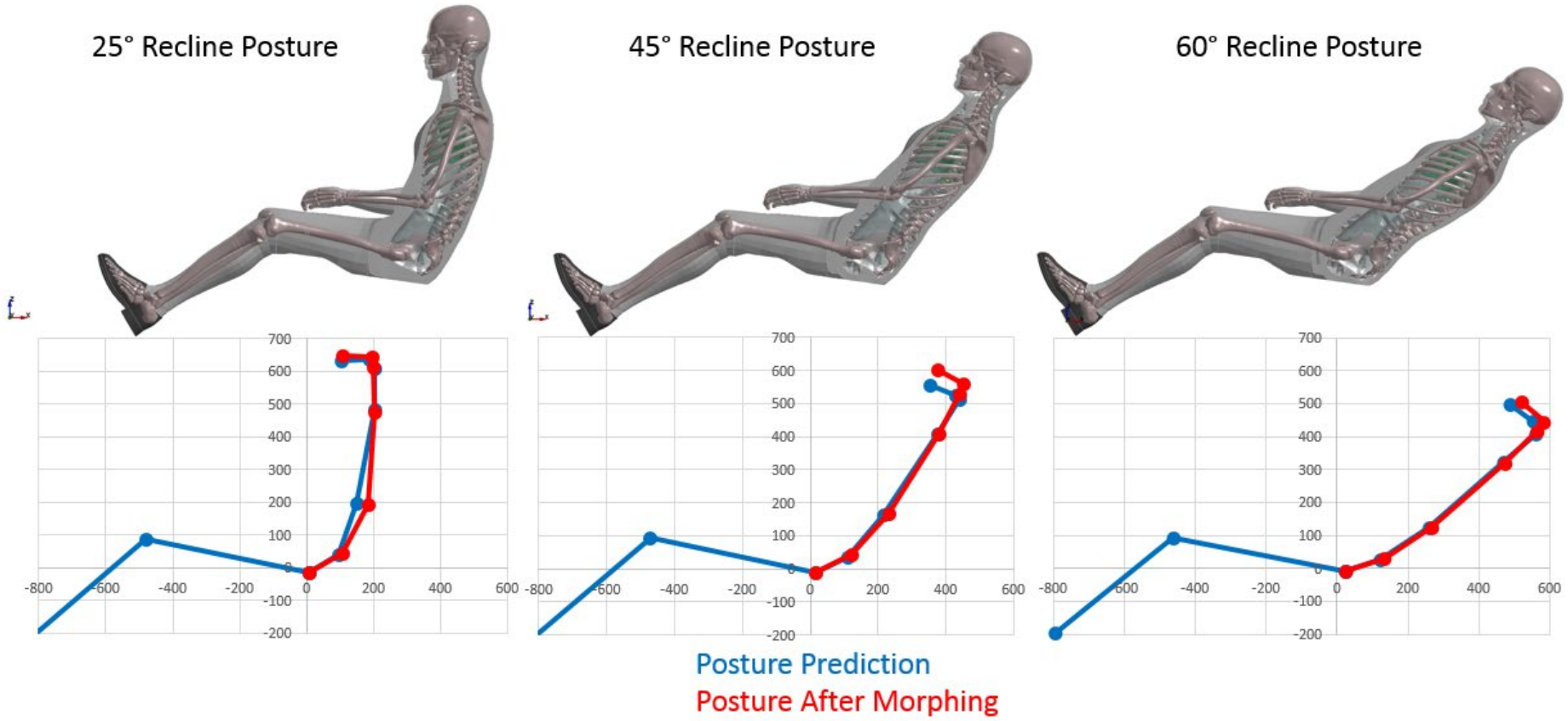
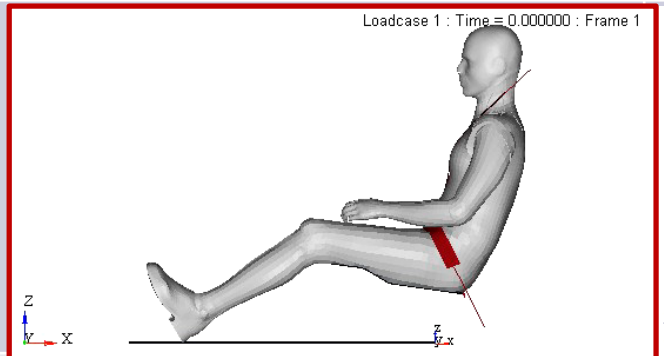
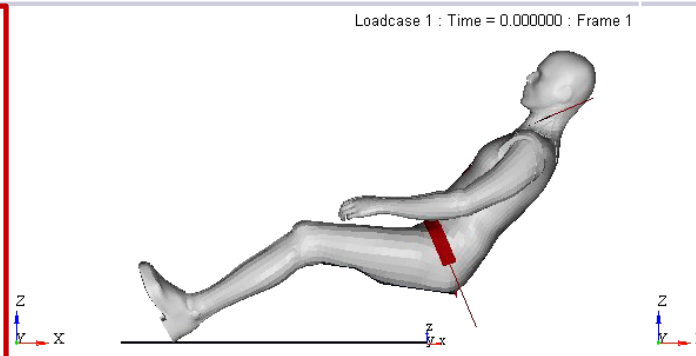
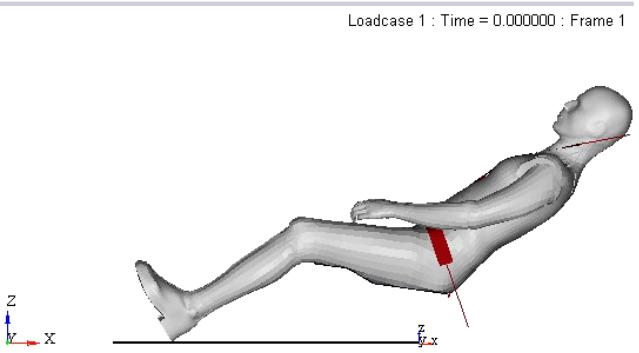
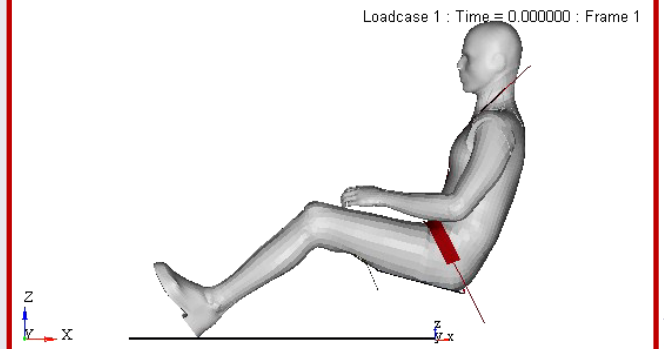
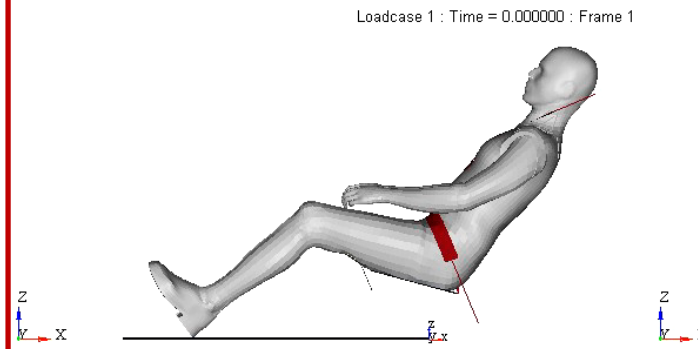
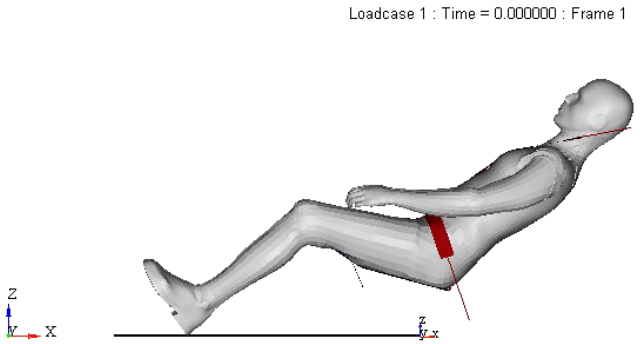
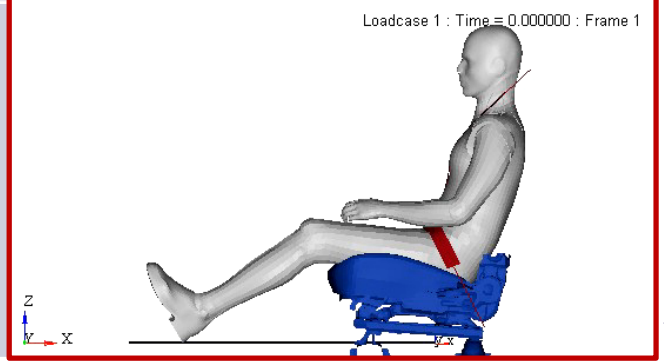
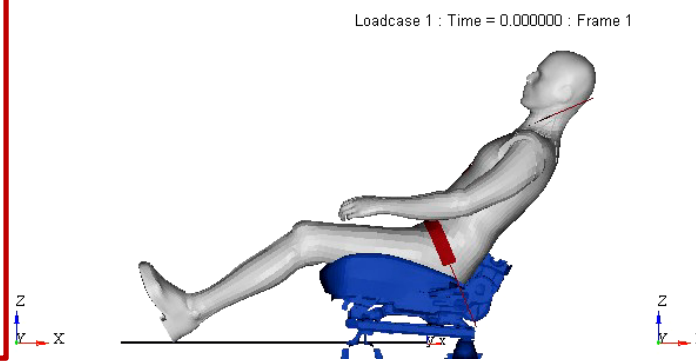
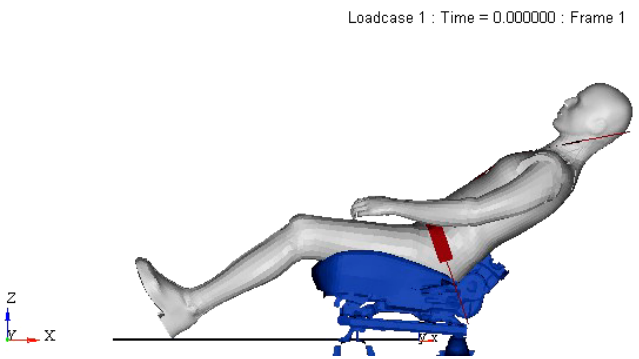
Occupant Positioning: Morphing

- Posture applied to Simplified GHBMC model using mesh morphing technique
  - Rotation of upper body and abdomen bones around pelvis and lumbar joint centers
  - Morphing of surrounding abdomen flesh

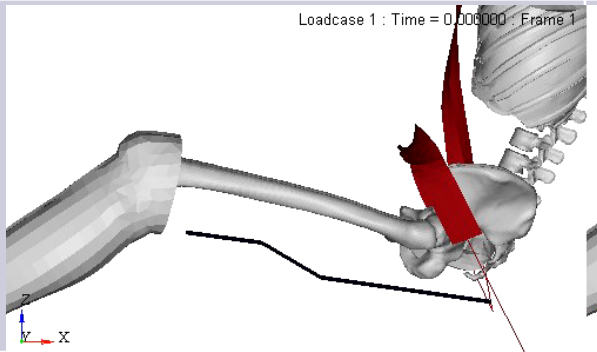
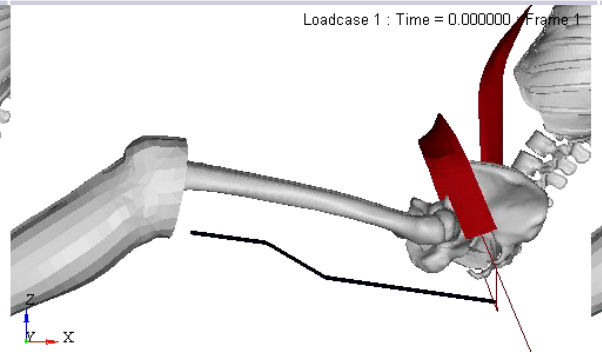
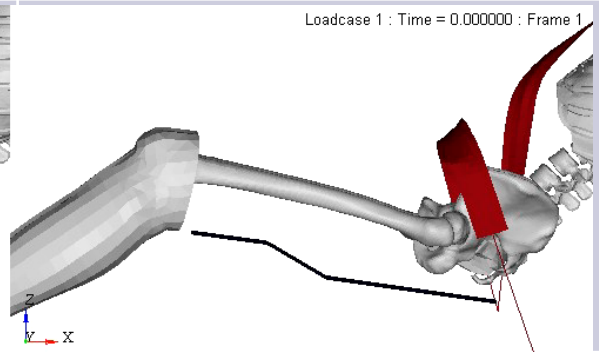
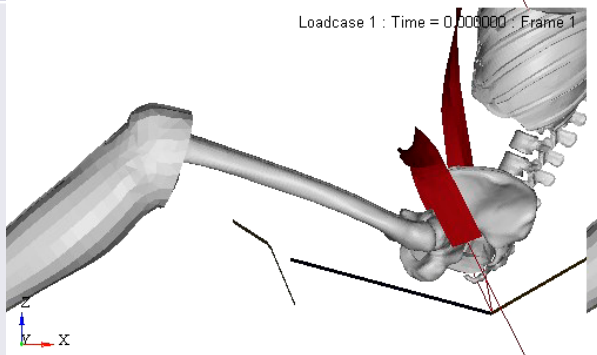
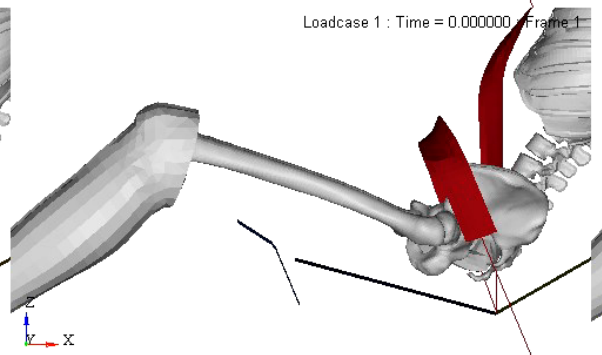
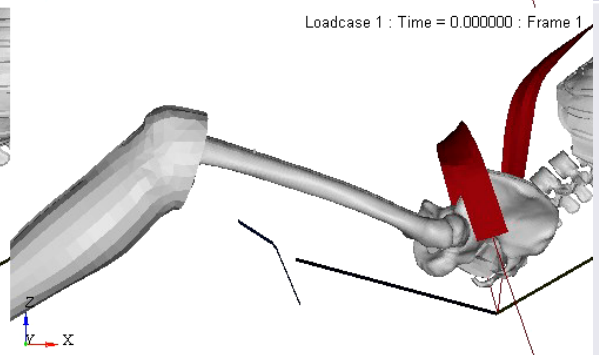
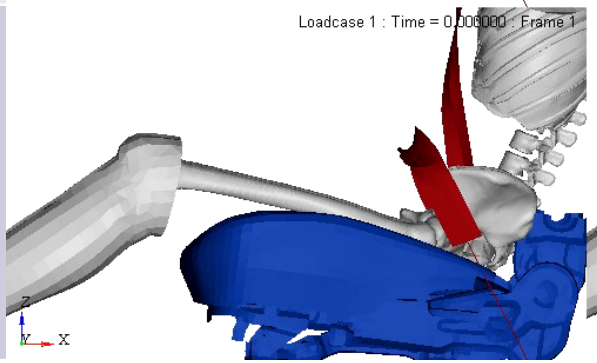
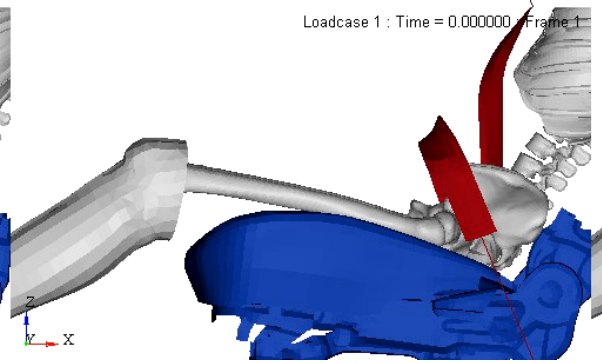
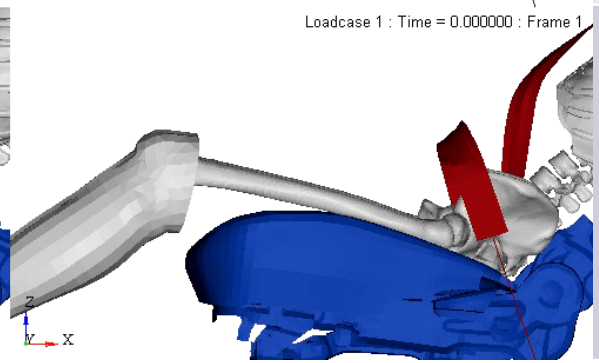


Seat and Recline Angle Study

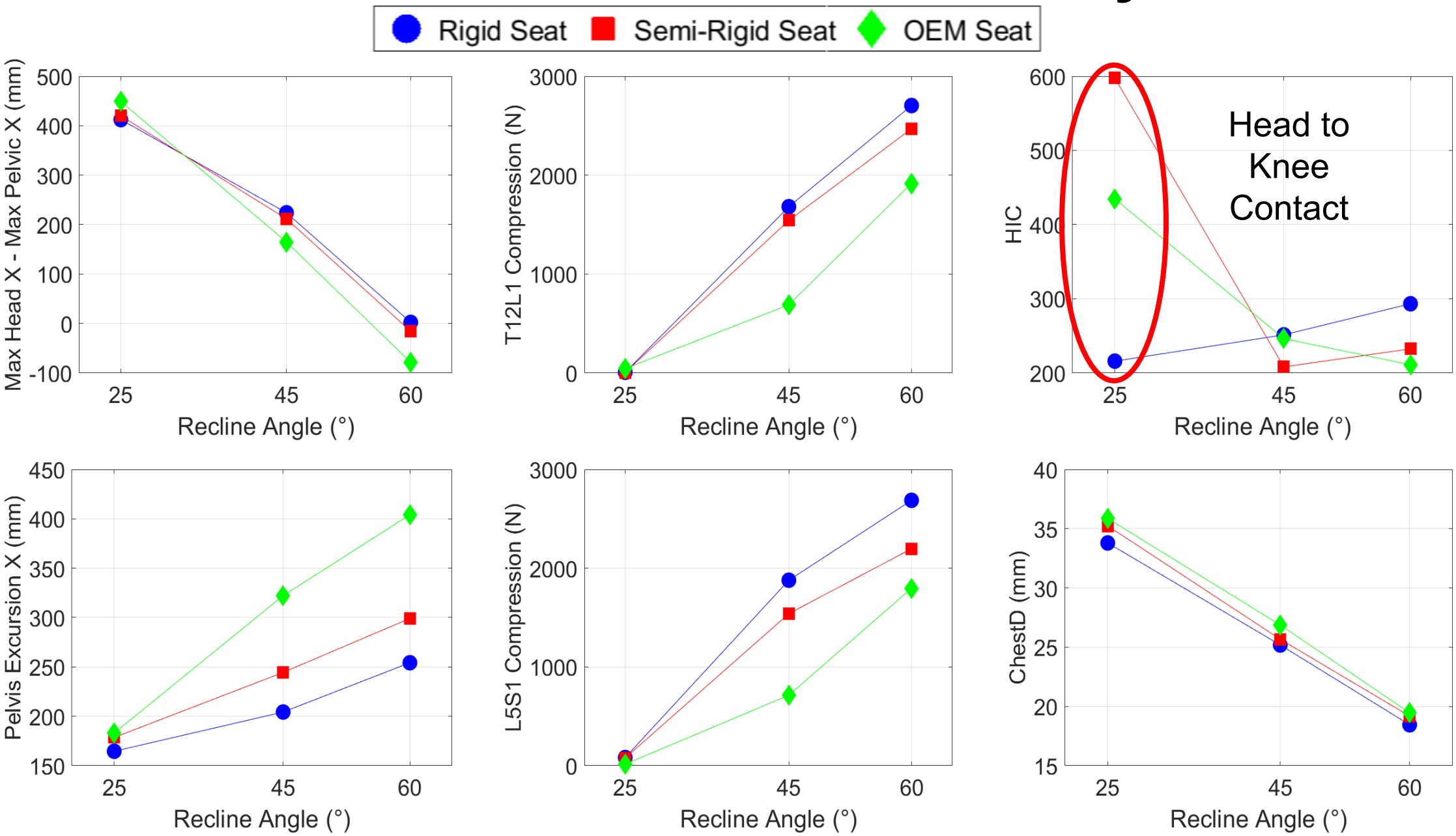
	25º Recline	45º Recline	60º Recline
Rigid Seat			
Semi-rigid Seat			
OEM Seat			

Head to knee contact

Seat and Recline Angle Study

	25º Recline	45º Recline	60º Recline
Rigid Seat			
Semi-rigid Seat			
OEM Seat			

Seat and Recline Angle Study

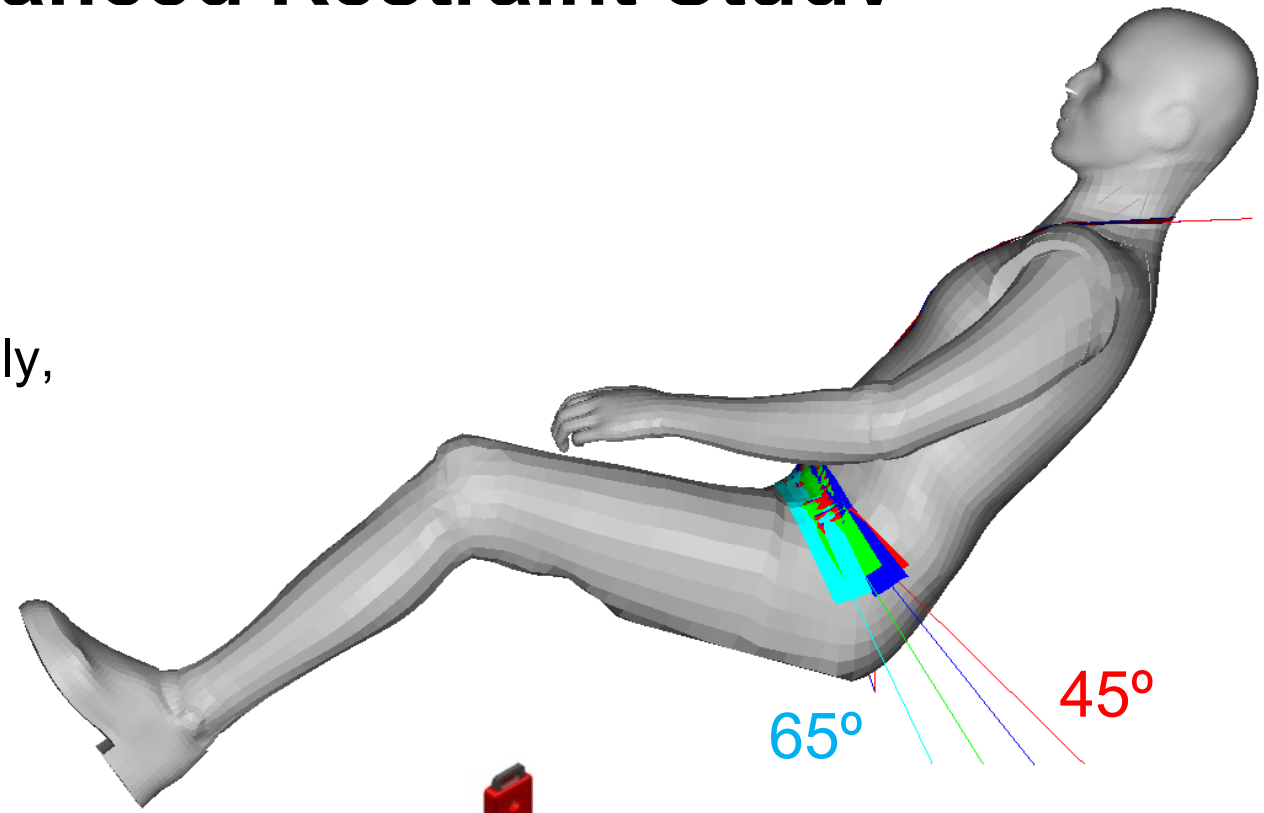


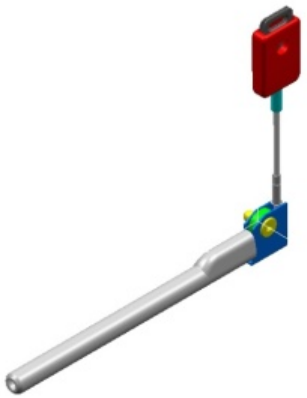
Seat and Recline Angle Study

- Submarine issues at high recline angles
- Torso does not pitch forward at higher recline angles
- Head to knee contact possibilities at lower recline angles
- Higher lumbar compression loads with higher recline angles
  - Scale of loads seems low, could be issue with HBM definitions

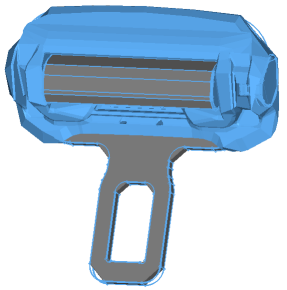
Belt Angle and Advanced Restraint Studv

- Simulation Matrix (4x4)
  - 4 belt angles (45º, 51º, 58º, 65º)
  - 4 restraint conditions (No AP/DLT, AP only, DLT only, both AP and DLT
- 3.25 kN shoulder load limit
- 2.5 kN retractor pre-tensioner
- 45º recline angle
- 35 mph crash pulse
- No lower extremity constraints



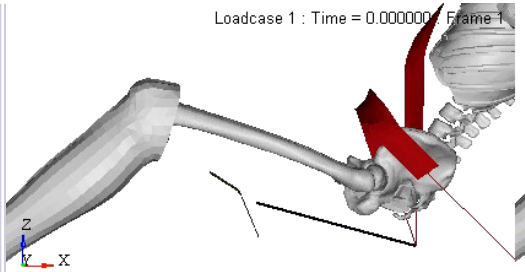
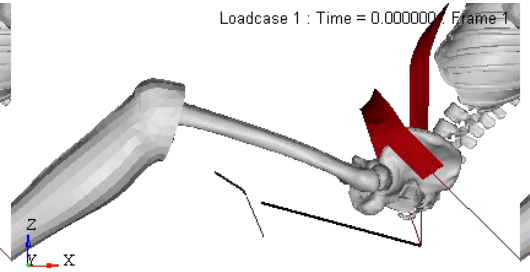
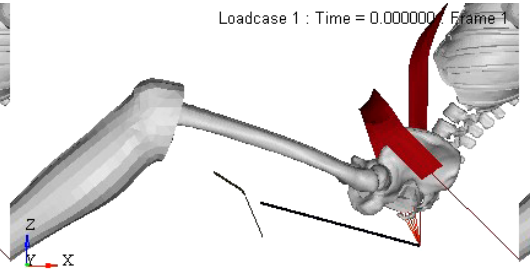
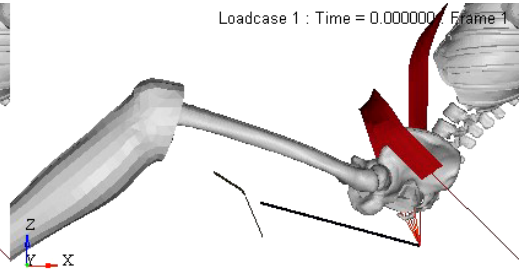
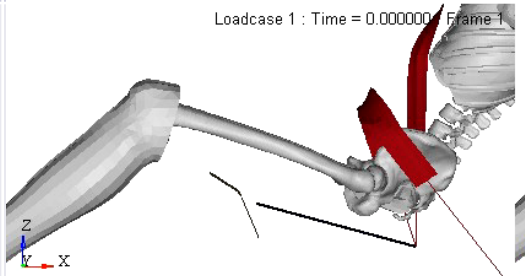
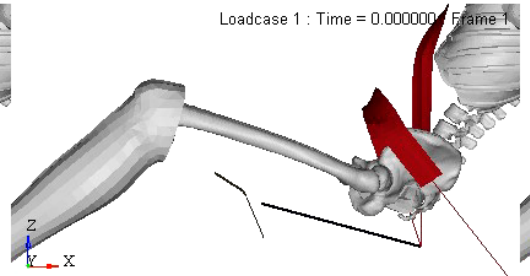
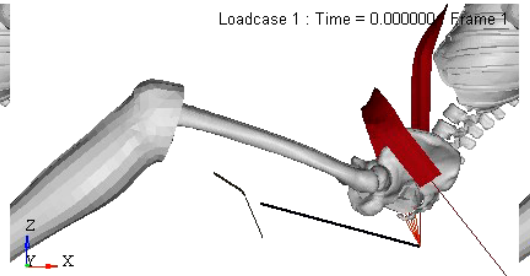
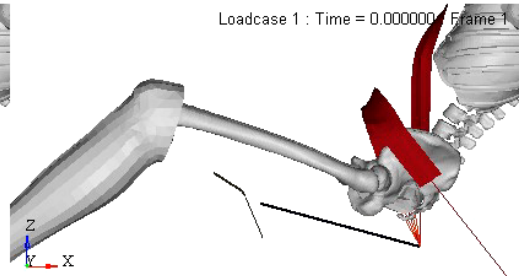
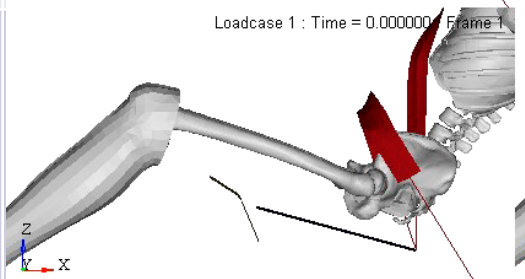
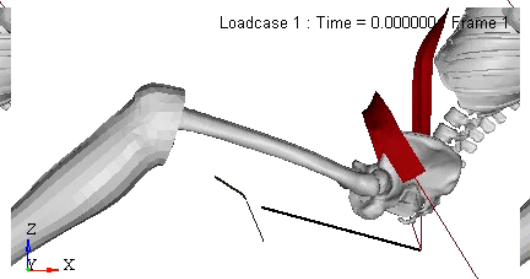
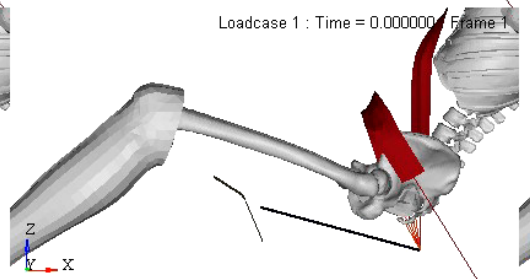
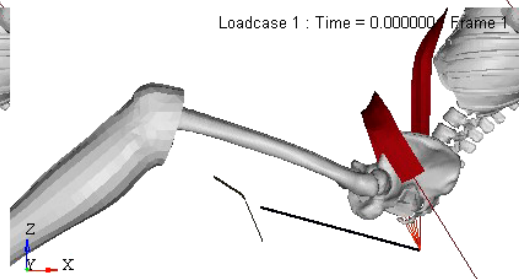
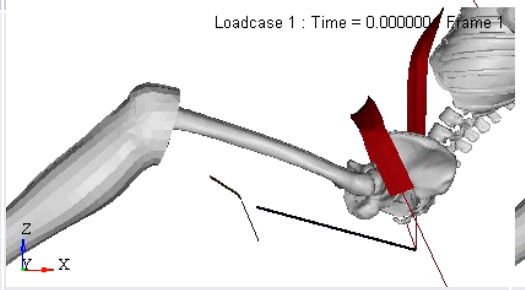
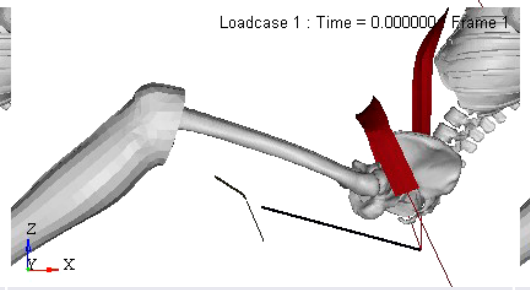
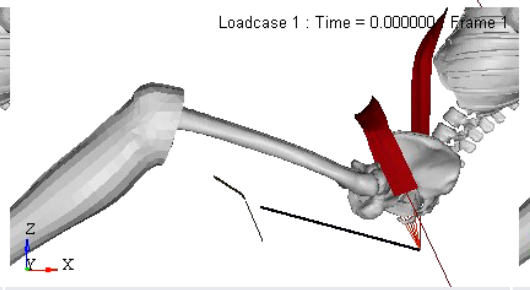
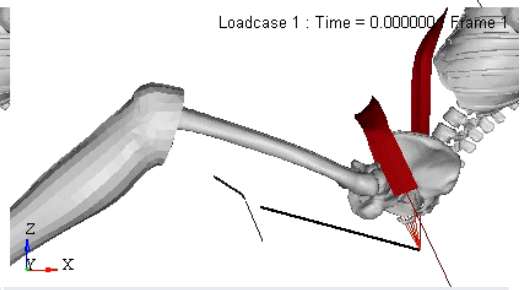


Anchor Pre-tensioner

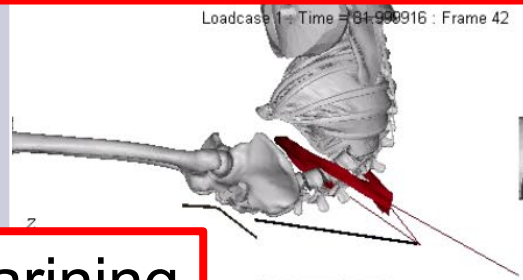
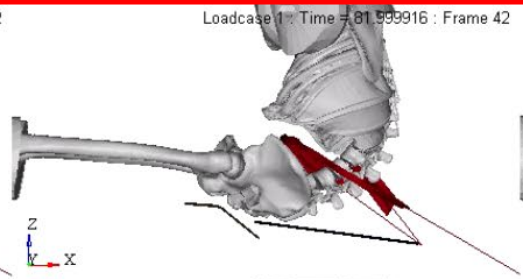
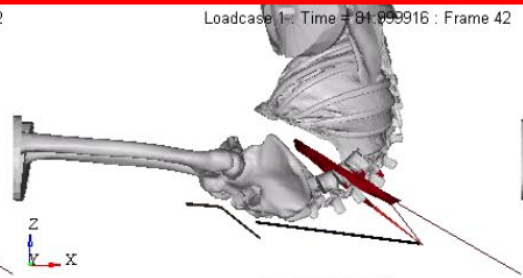
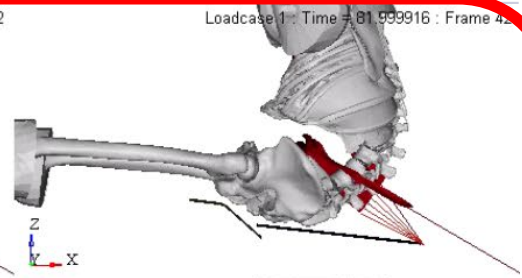
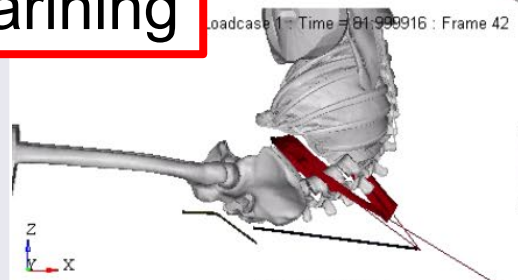
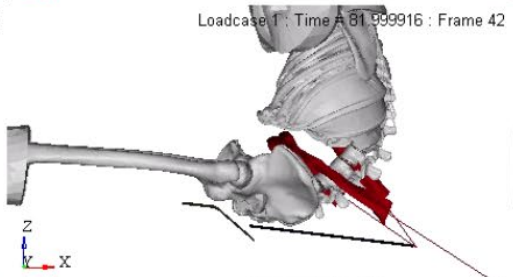
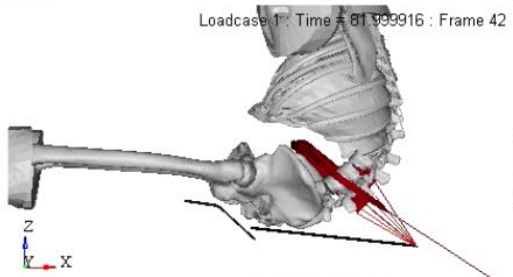
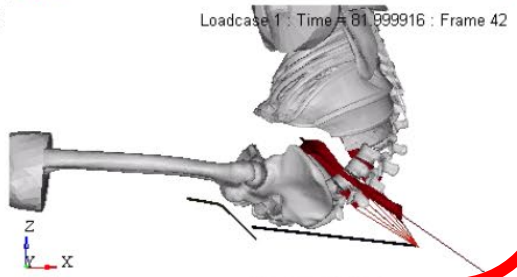
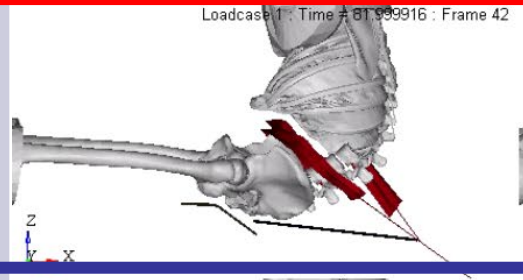
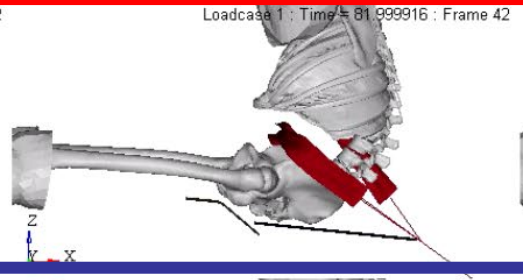
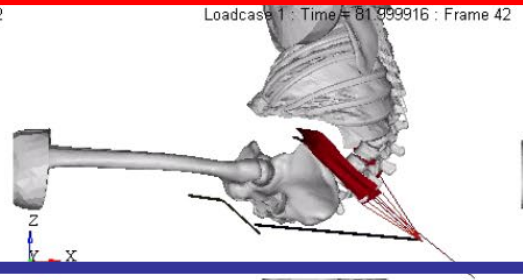
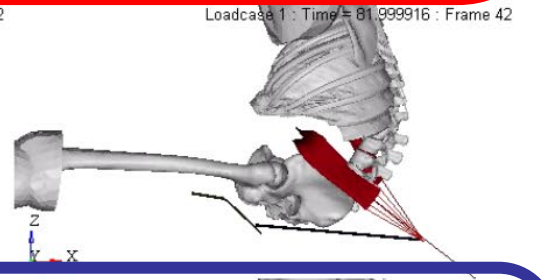
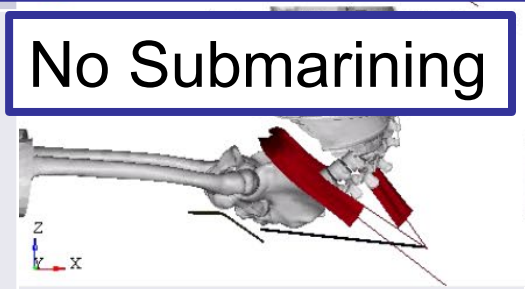
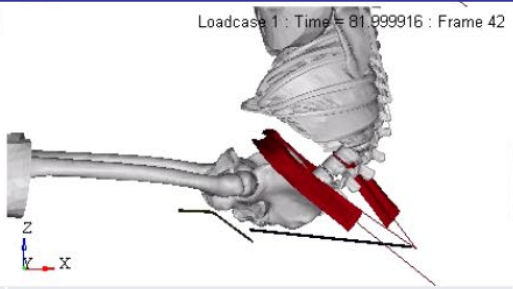
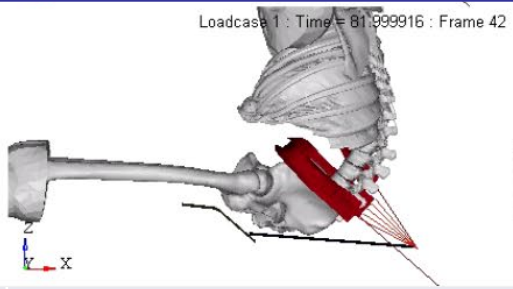
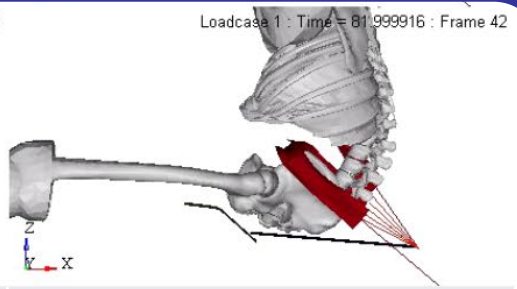


Dynamic Locking Tongue

Belt Angle and Advanced Restraint Study

	No AP/DLT	AP Only	DLT Only	AP and DLT
45º Belt				
51º Belt				
58º Belt				
65º Belt				

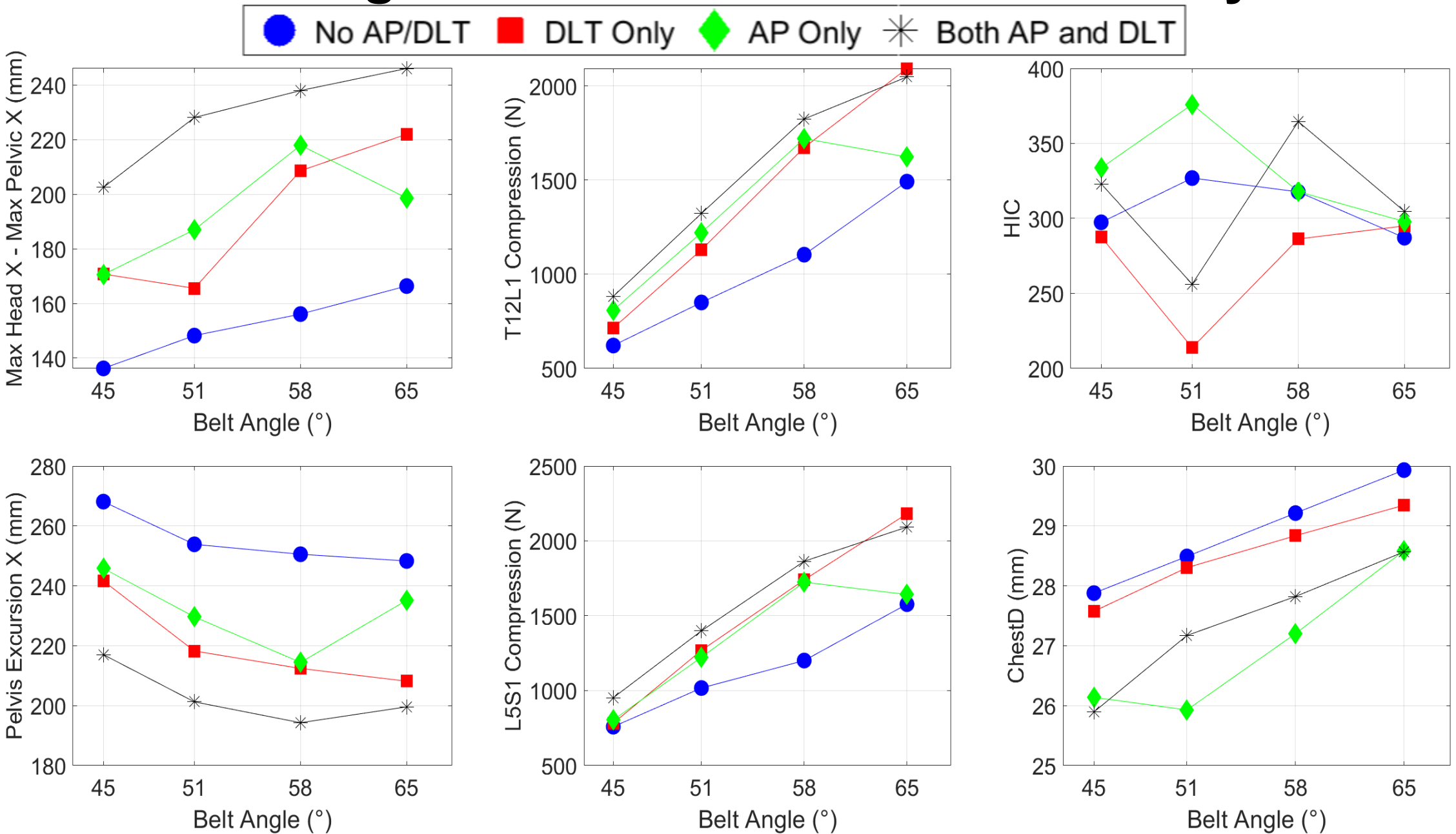
Belt Angle and Advanced Restraint Study

	No AP/DLT	AP Only	DLT Only	AP and DLT
45º Belt				
51º Belt				
58º Belt				
65º Belt				

Submarining

No Submarining

Belt Angle and Advanced Restraint Study



Belt Angle and Advanced Restraint Study

- Submarine issues at lower belt angles
- Use of AP and DLT
  - Each reduces pelvis X excursion
  - Can reduce risk of submarining although not as effective as changing belt angle
- Higher lumbar compression loads when pelvis is better constrained
  - Scale of loads seems low, could be issue with HBM definitions

Summary

- Human models at highly reclined angles were developed by morphing the GHBMC model into postures calculated by a volunteer data set.
- Frontal crash simulations were conducted with these morphed models considering differences in seat and restraint types.
- The simulations suggested that:
  - Recline angle significantly changes occupant kinematics
  - Recline angle and belt angle both largely affect submarining risk
  - There is a risk of head to knee contact at lower recline angles without airbag / IP
  - There is a conflict between submarining risk and lumbar force in highly reclined postures.

Acknowledgements

- NHTSA
- GHBMC
- Altair
- LSTC

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