

RCCADS

Research Consortium for Crashworthiness
in Automated Driving Systems



Comparison of Injury Risk Prediction in Reclined Frontal Crashes: Hybrid-III vs THOR

Jeesoo Shin, John-Paul Donlon, Rachel Richardson, Bronislaw Gepner,
Jason Forman, and Jason Kerrigan

University of Virginia Center for Applied Biomechanics

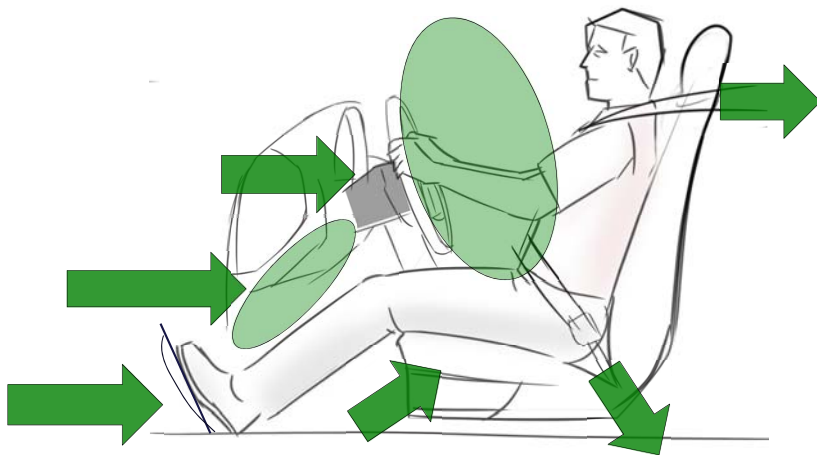


ENGINEERING

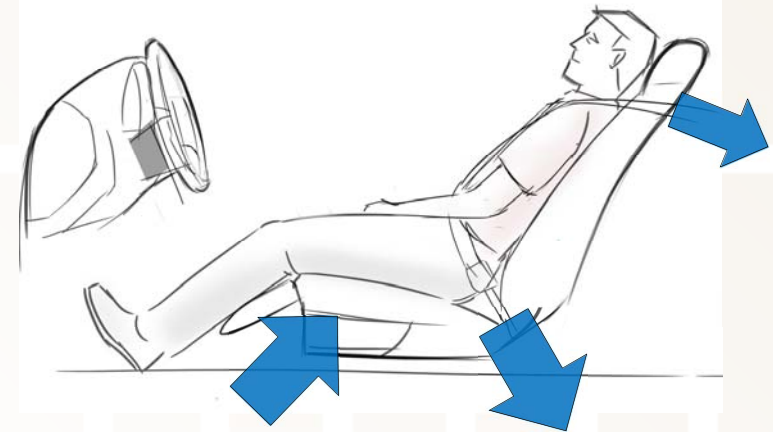
Department of Mechanical and
Aerospace Engineering
Center for Applied Biomechanics

Restraint Systems Adapted to Seating Position

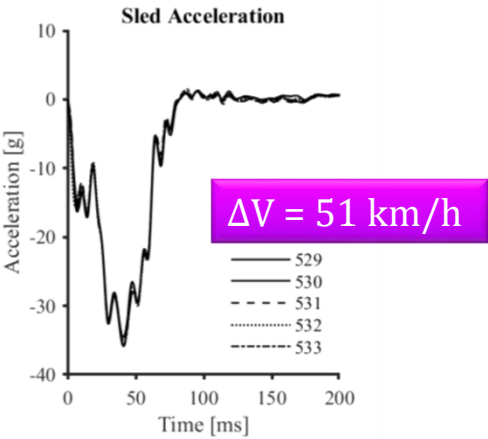
Today:



Tomorrow:



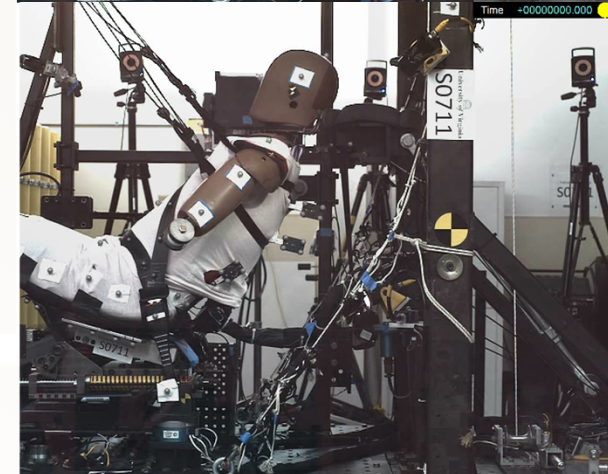
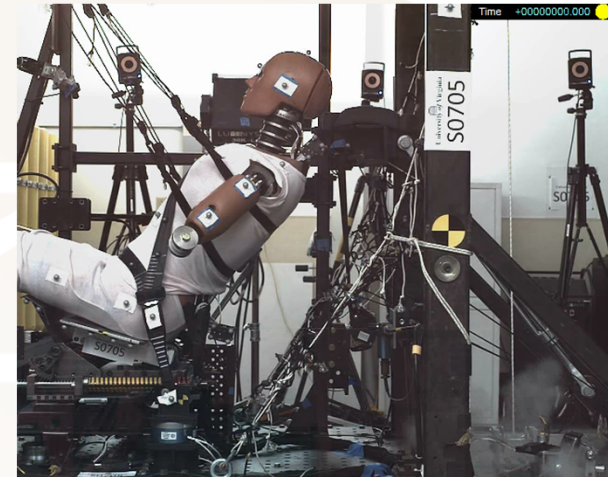
2019: 5 PMHS In Frontal Recline



RESTRAINT SYSTEM:
 Dual retractor
 Triple Pretensioner
 3.5 kN Shoulder Belt LL

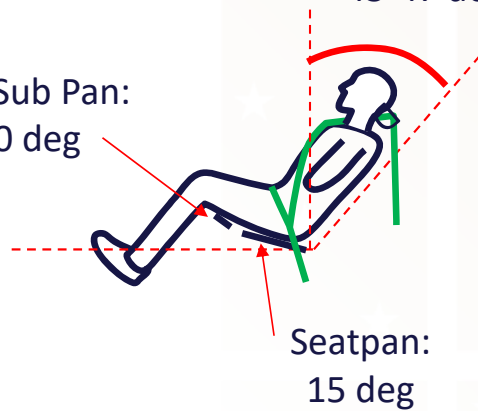
2021: Hybrid III and THOR-50M in Matched Conditions

RCCADS-Funded Study



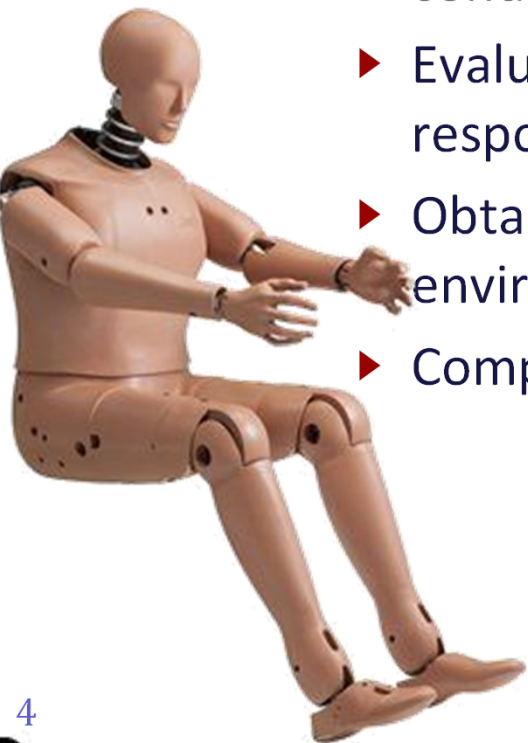
Seatback Recline:
 45-47 deg

Anti-Sub Pan:
 30 deg



Objectives

- ▶ Measure the response of the Hybrid-III 50th Male and THOR-50M ATDs in a reclined frontal sled impact condition
- ▶ Evaluate the biofidelity of the ATDs by comparing their responses to PMHS responses
- ▶ Obtain data that could be used to validate an environment model
- ▶ Compare injury risk predictions from both surrogates



Methodology and Results

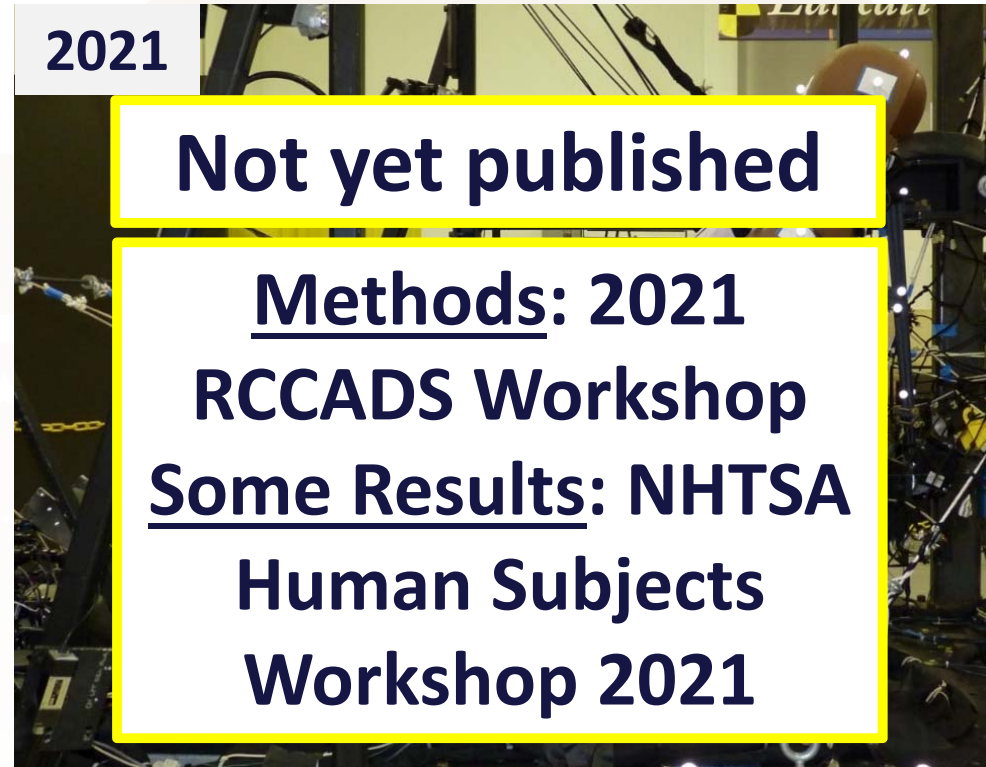
2019



**Published by
Richardson et al. in
Stapp (2020)**

Richardson et al., Stapp, 2020

2021



Not yet published

**Methods: 2021
RCCADS Workshop
Some Results: NHTSA
Human Subjects
Workshop 2021**

Test Matrix for Biofidelity Evaluation

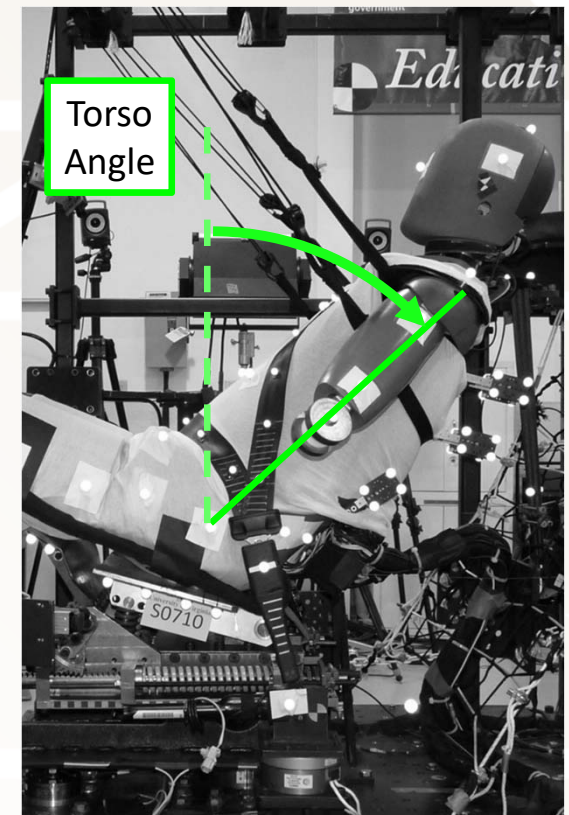
2019 50th Male PMHS Test Series

Test Number	PMHS #	Sagittal Torso Posture
S0529	930	47° recline
S0531	901	46.5° recline
S0532	662	45° recline
S0533	815	46° recline

Richardson et al., Stapp, 2020

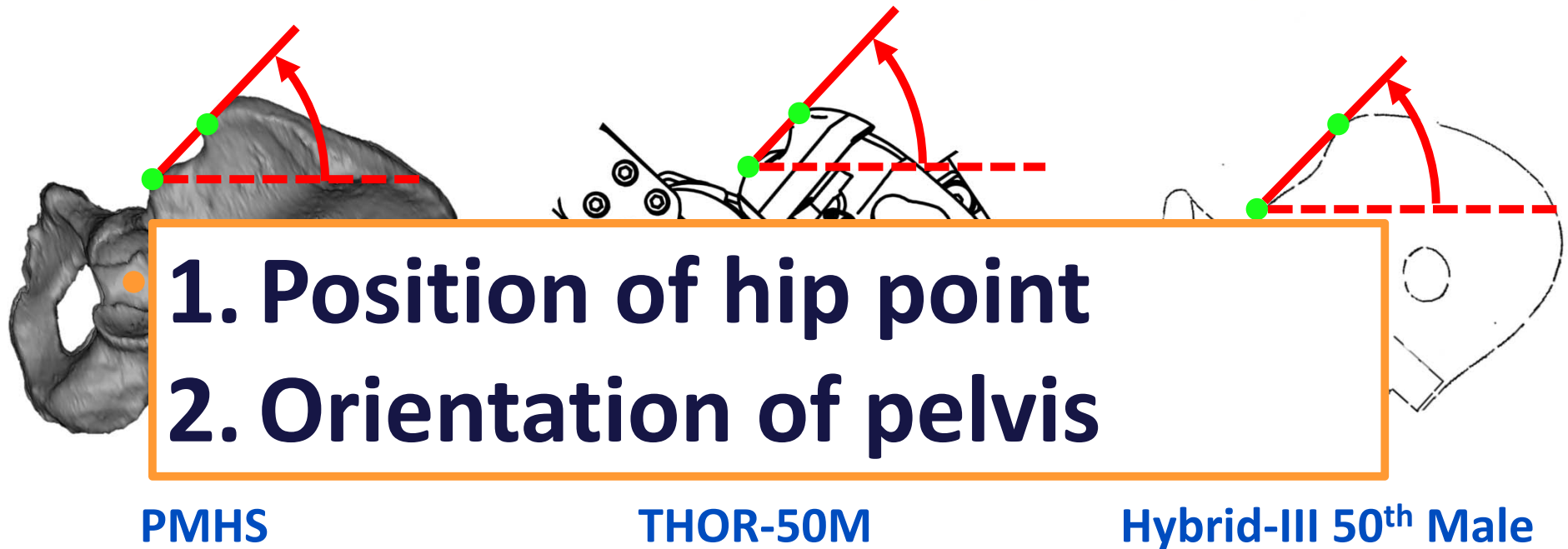
2021 50th Male ATD Test Series

Test Number	Subject	Sagittal Torso Posture
S0702	HIII-50M	48° recline
S0705	HIII-50M	49° recline
S0706	HIII-50M	48° recline
S0709	THOR-50M	47° recline
S0710	THOR-50M	49° recline
S0711	THOR-50M	49° recline



Center for Applied Biomechanics

Pelvis Positioning

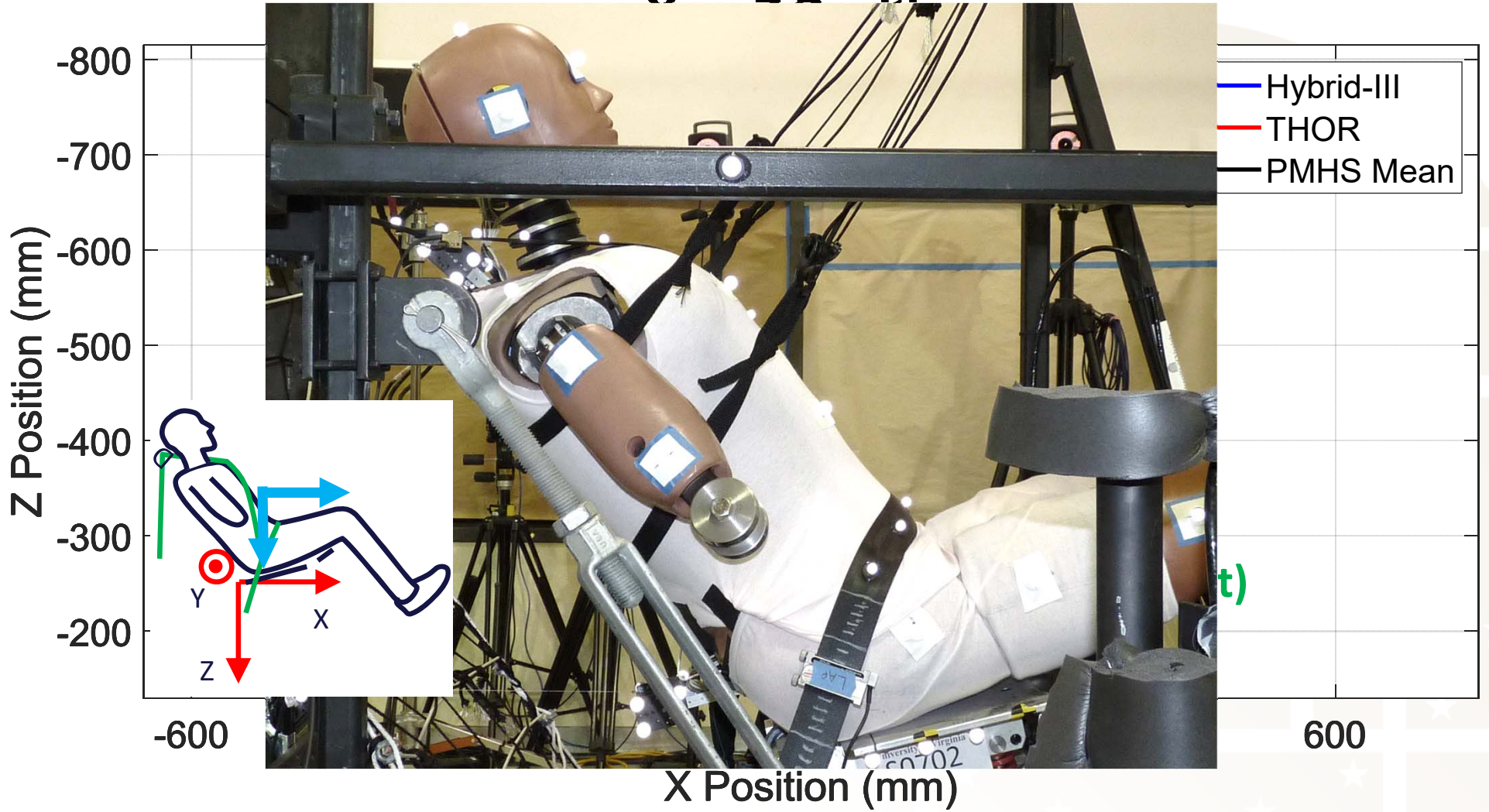


Pelvis Positioning

Target Pelvis Notch Angle: 40°~49°

Test Number	Subject	Pelvis Notch Angle
S0702	HIII-50M	42°
S0705	HIII-50M	42°
S0706	HIII-50M	41°
S0709	THOR-50M	42°
S0710	THOR-50M	44°
S0711	THOR-50M	43°

Super-slouched



Evaluating the Biofidelity of Hybrid-III 50th Male and THOR-50M in Reclined Frontal Impact Sled Tests

Jee Soo Shin, John-Paul Donlon, Rachel Richardson, Bronislaw Gepner, Jason Forman, and Jason Kerrigan

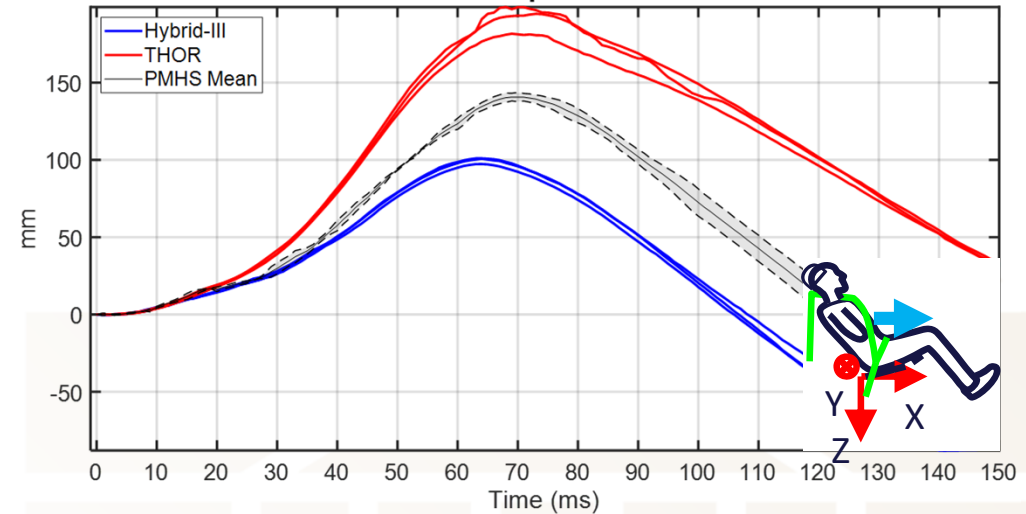


49th NHTSA Workshop on Human Subjects for Biomechanical Research
Tuesday, October 26, 2021

This content has not been screened for accuracy nor refereed by any body of scientific peers and should not be referenced in the open literature.

Center for Applied Biomechanics

Pelvis Displacement X



INTERNATIONAL RESEARCH COUNCIL ON BIOMECHANICS OF INJURY

Biofidelity Evaluation of Hybrid-III 50th Male and THOR-50M in Reclined Frontal Impact Sled Tests

Jeesoo Shin, John Paul Donlon, Rachel Richardson, Bronislaw Gepner, Jason Forman, Martin Ostling, Jason Kerrigan

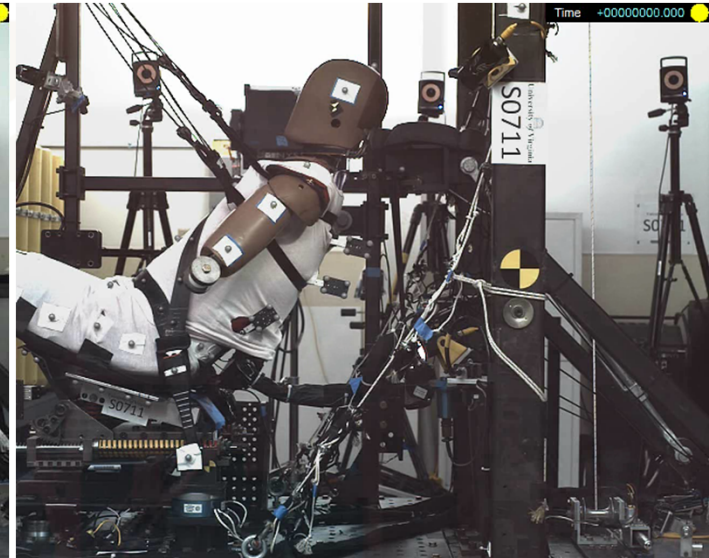
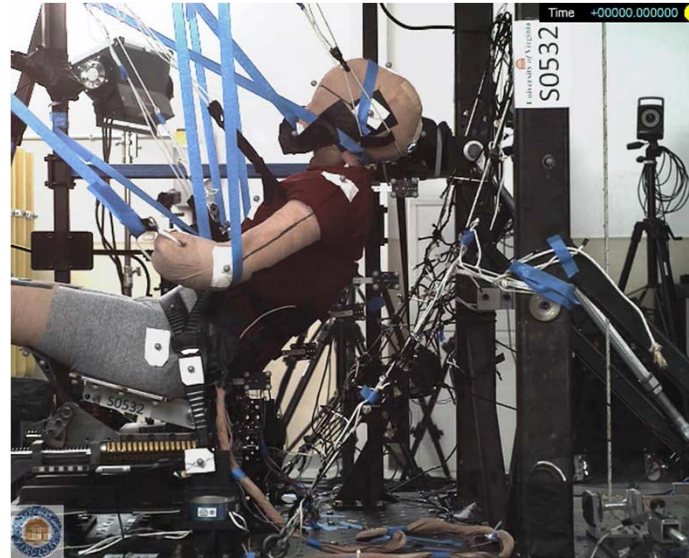
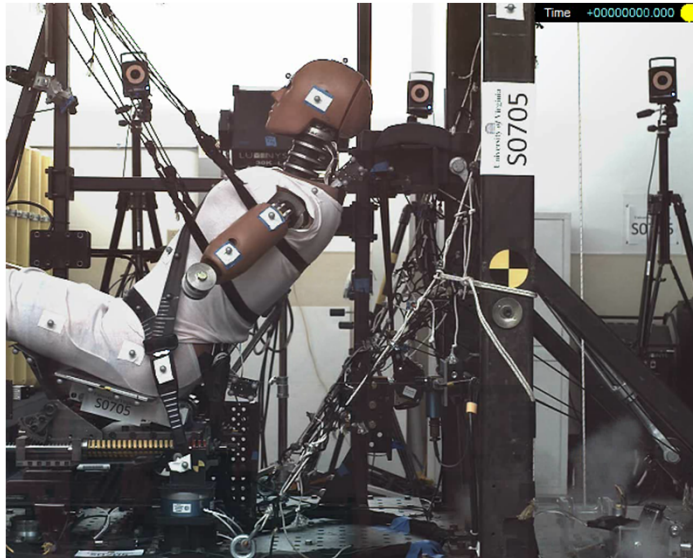


Focus on Injury Risk Prediction

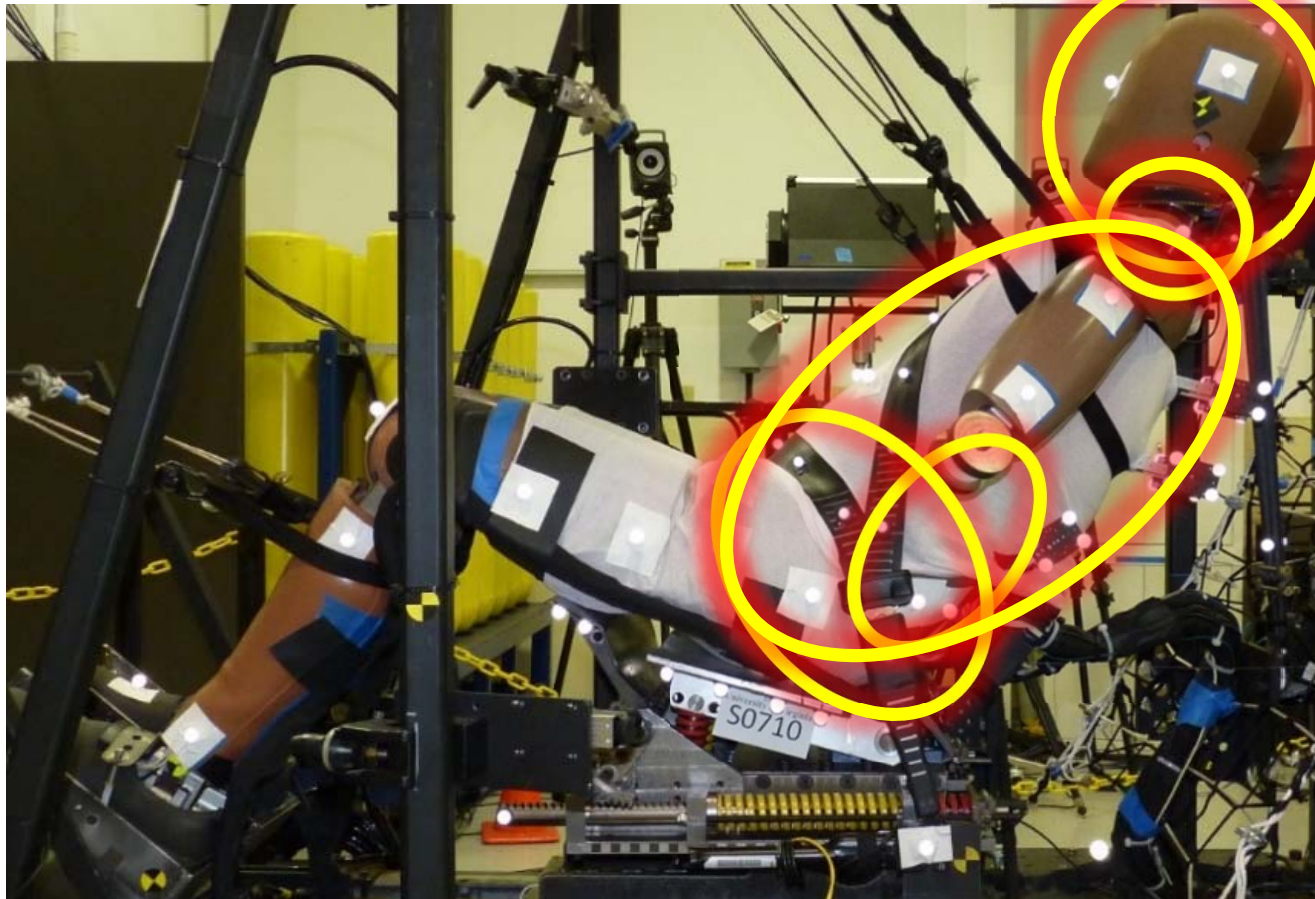
Hybrid-III 50th Male

PMHS

THOR-50M



Injury Risk Prediction: Hybrid III vs. THOR vs. PMHS



HEAD

NECK

THORAX

LUMBAR
SPINE

PELVIS

Injury Risk Prediction: HEAD

PMHS:

- No Skull Fractures,
- N/A for Brain Injury



Hybrid III-50M:

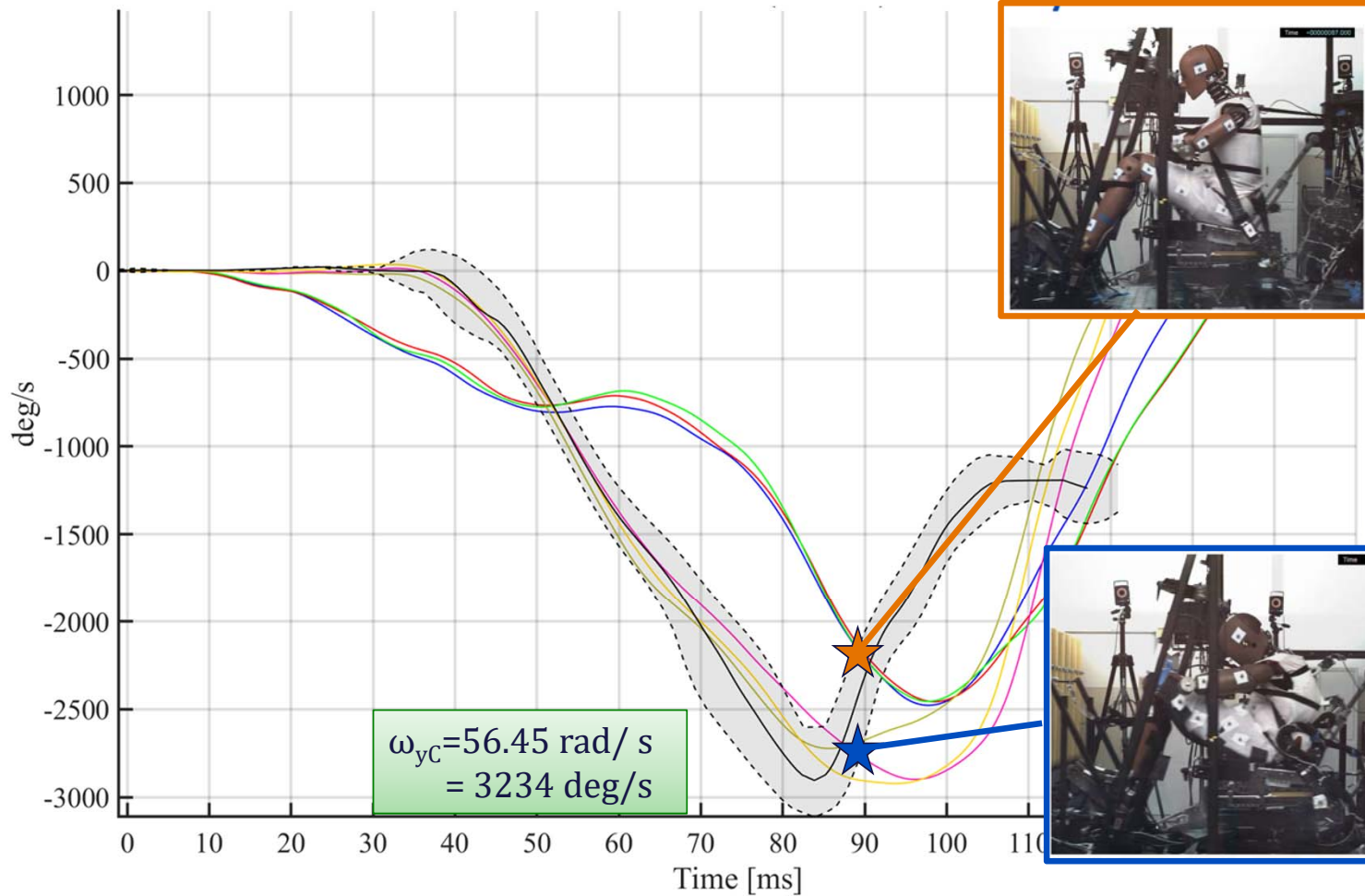
HIC₁₅*: P(AIS3+) = 3%
 BrIC**: P(AIS3+) = 24%

THOR-50M:

HIC₁₅** : P(AIS3+) = 20%
 BrIC** : P(AIS3+) = 43%

*NHTSA (2008);
 Craig et al. (2020)

Head Angular Rate Sensor Y



Hybrid III-50M:

HIC₁₅*: P(AIS3+) = 3%
 BrIC (MPS)**: P(AIS3+) = 24%

- S0702 [H-III]
- S0705 [H-III]
- S0706 [H-III]
- S0709 [THOR]
- S0710 [THOR]
- S0711 [THOR]

THOR-50M:

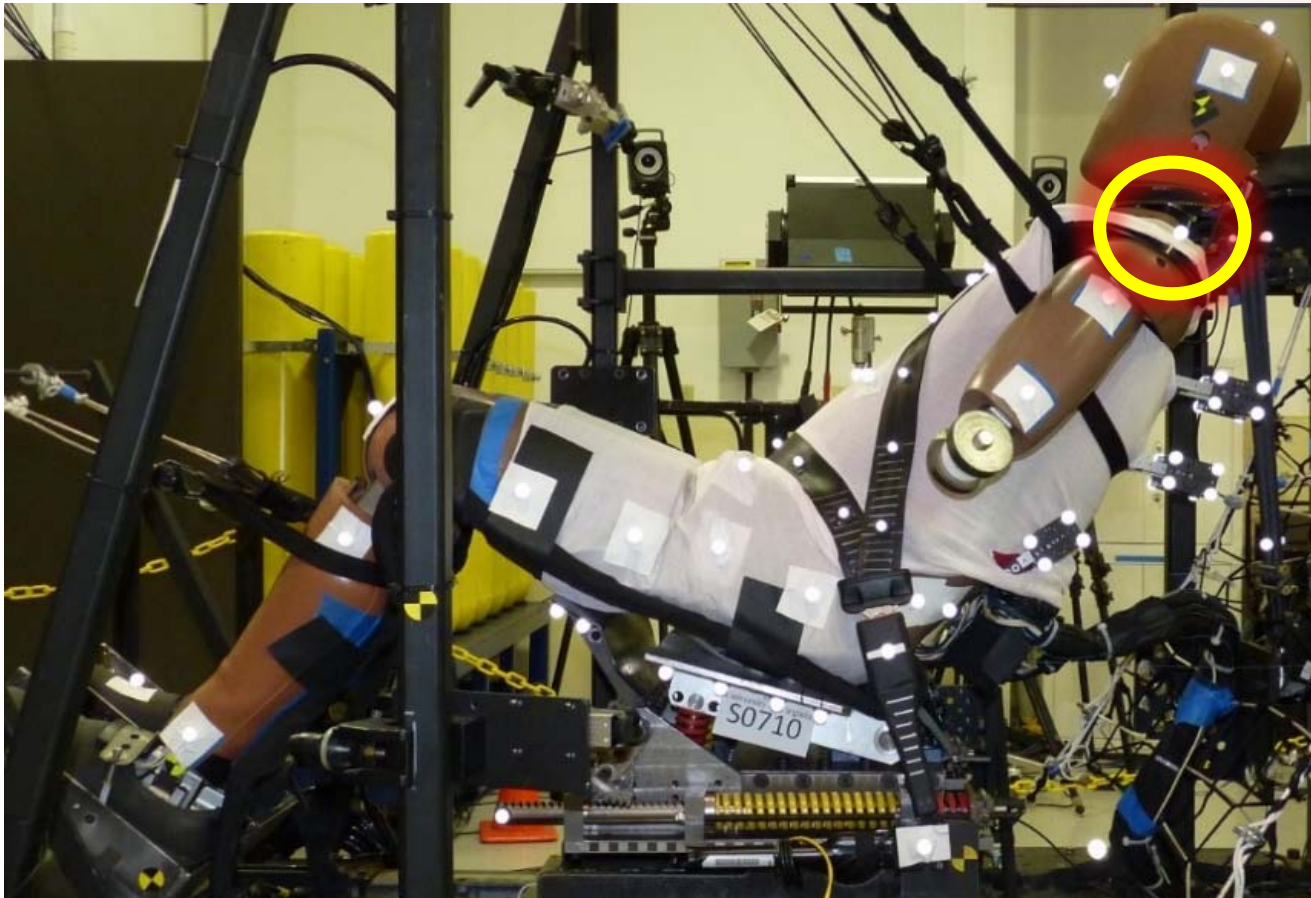
HIC₁₅** : P(AIS3+) = 20%
 BrIC (MPS) **: P(AIS3+) = 43%

*NHTSA (2008);
 **Craig et al. (2020)

Injury Risk Prediction: NECK

PMHS:

- No Neck Injuries



Hybrid III-50M*:

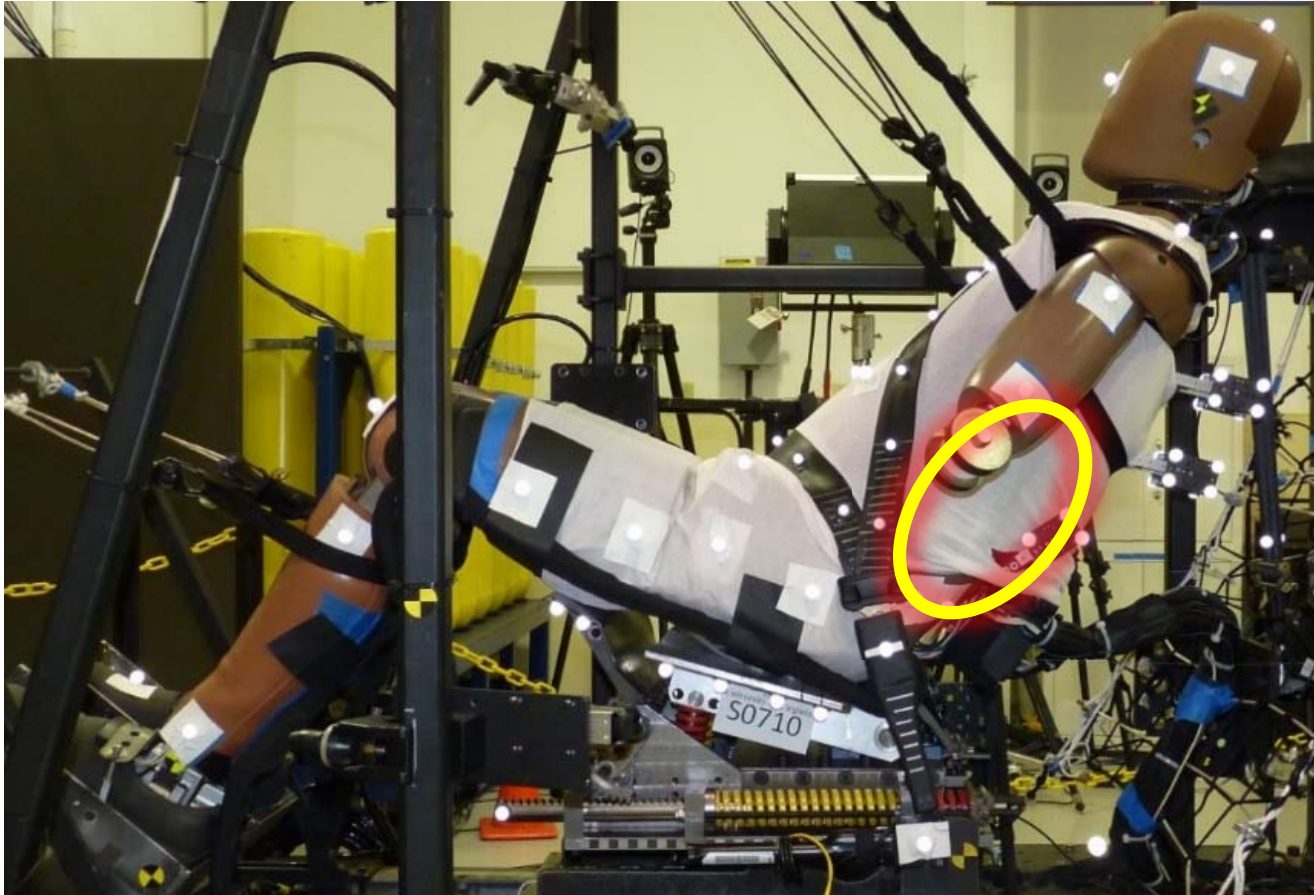
N_{ij} : P(AIS3+) = 26%
Flexion/Tension
Extension/Tension

THOR-50M**:

N_{ij} : P(AIS3+) = 24%
Flexion/Tension

*NHTSA (2008);
Craig et al. (2020)

Injury Risk Prediction: LUMBAR



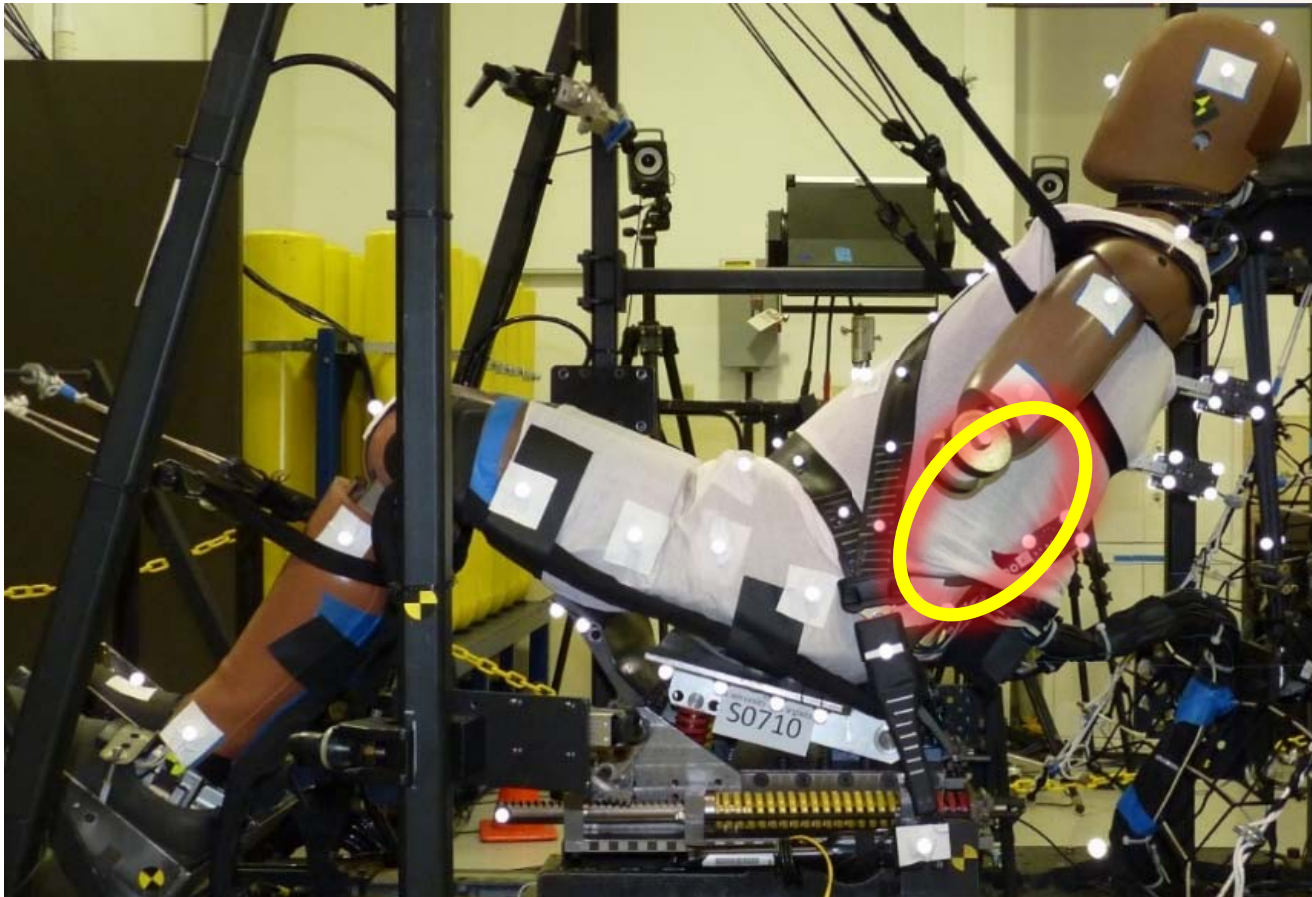
PMHS Injuries: Lumbar Spine

Compression and burst fractures of lumbar spine are generally caused by:

- Axial Compression,
- Flexion Bending, or
- Compression + Flexion

Subject 4 and Subject 5:
NO INJURY

ATD Injury Risk Prediction: Lumbar Spine



Hybrid III-50M:

Avg. max compression= 4.07 kN

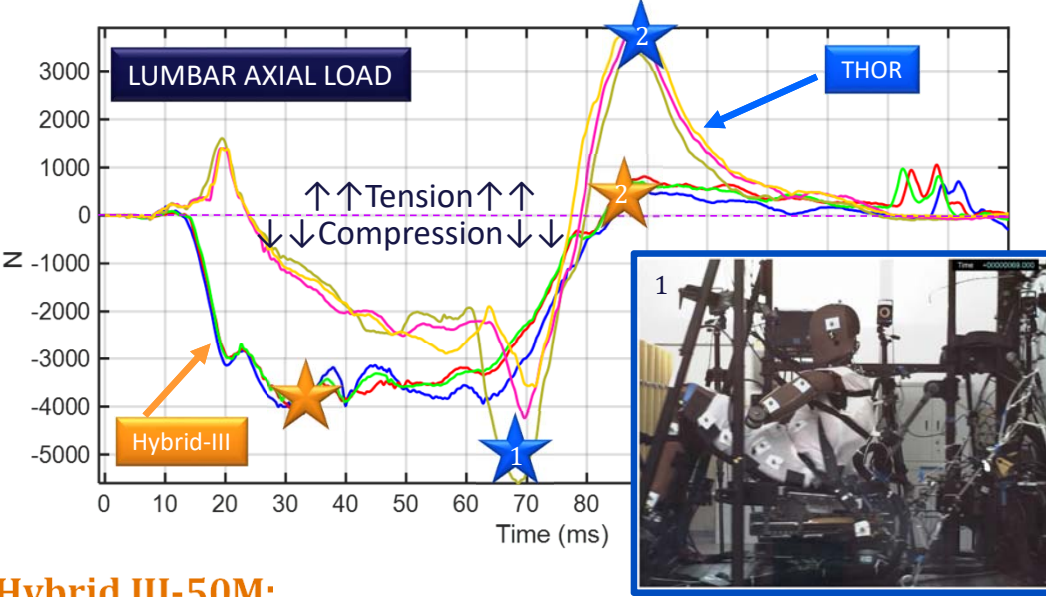
Avg. max flexion= 186 Nm

THOR-50M:

Avg. max compression= 4.48 kN

Avg. max flexion= 408 N m

ATD Injury Risk Prediction: Lumbar Spine

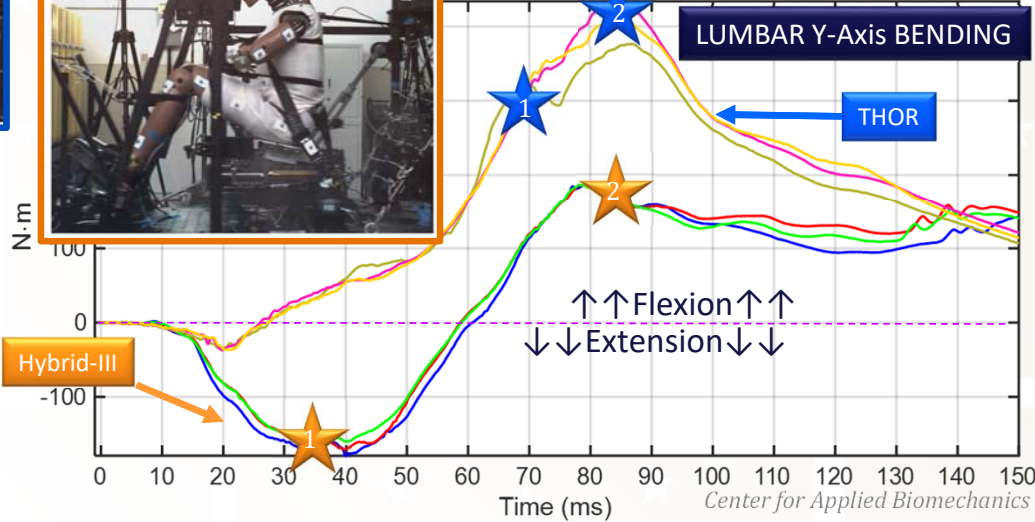
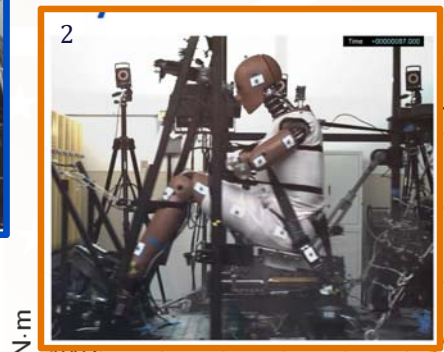


THOR-50M:

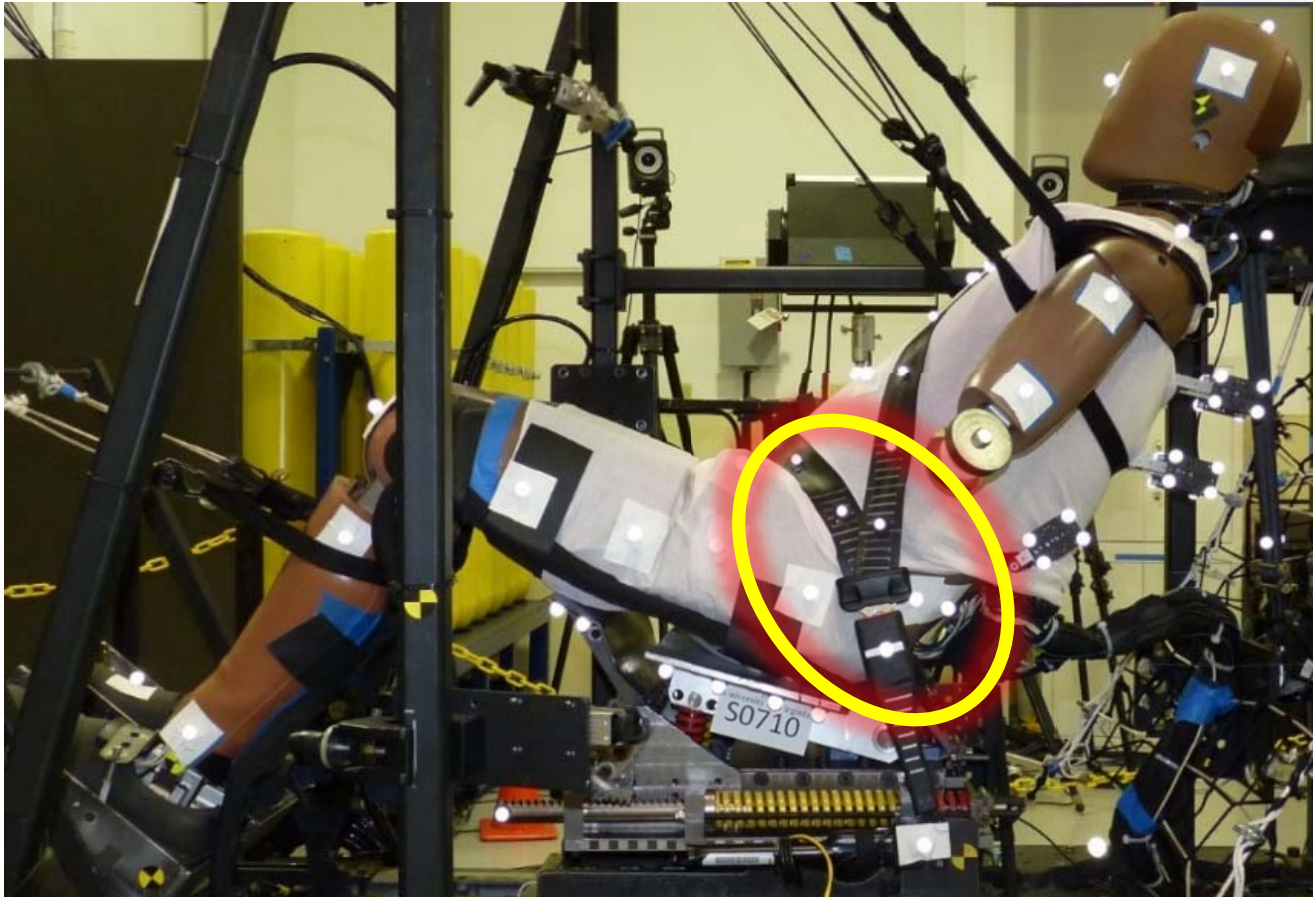
- Avg. max compression= 4.48 kN
- Avg. max flexion= 408 Nm
- Time (MaxComp) = Time (HighFlex)
- Time (MaxFlex) = Time (MaxTension)

Hybrid III-50M:

- Avg. max compression= 4.07 kN
- Avg. max flexion= 186 Nm
- Max. Comp. Very Early ~35 ms and with extension
- Max Flexion occurs later, and with NO compression
- Time (MaxFlex) ≠ Time (MaxComp)



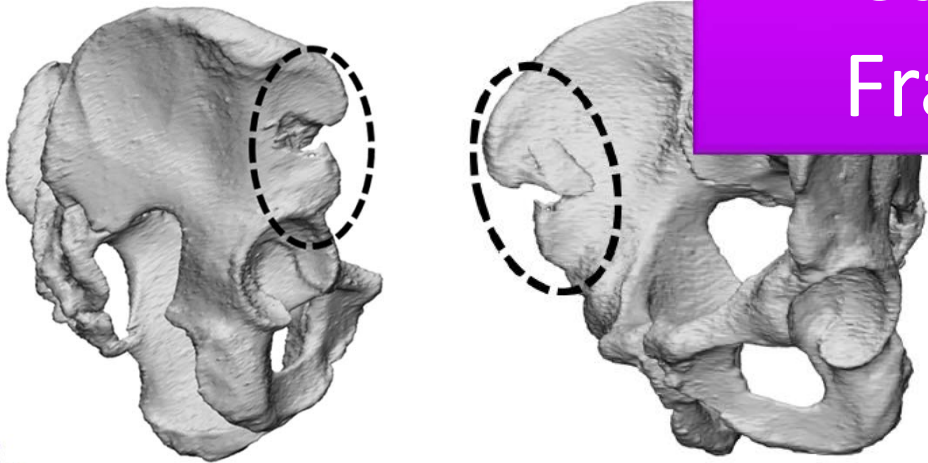
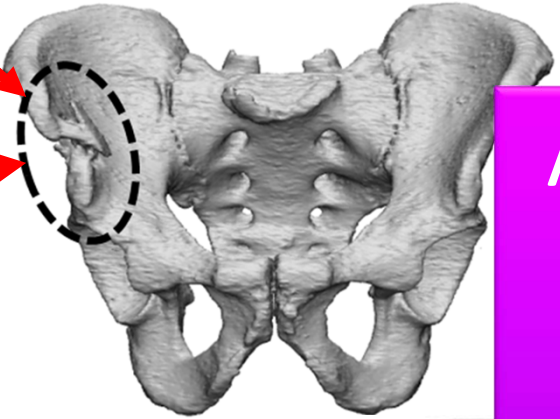
Injury Risk Prediction: PELVIS



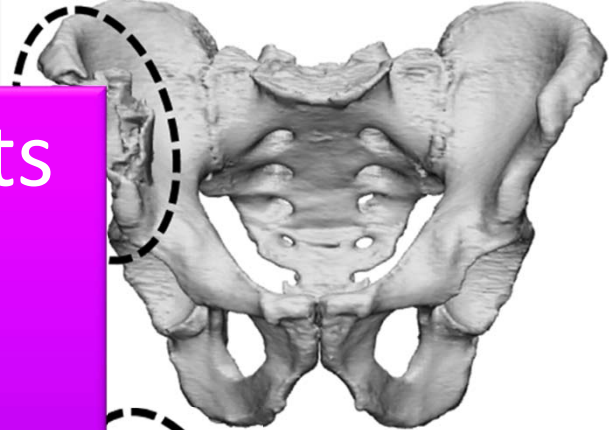
PMHS Injuries: Pelvic Wings

PMHS 1

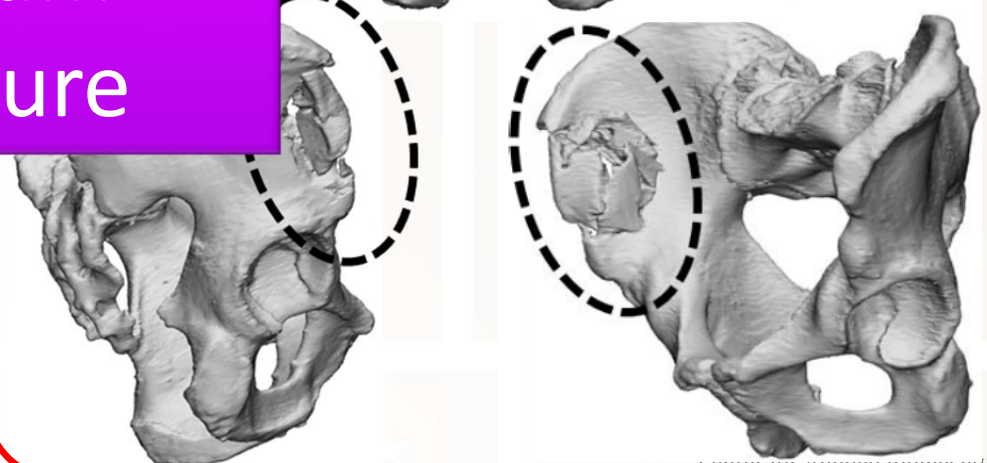
ASIS
AIIIS



PMHS 3

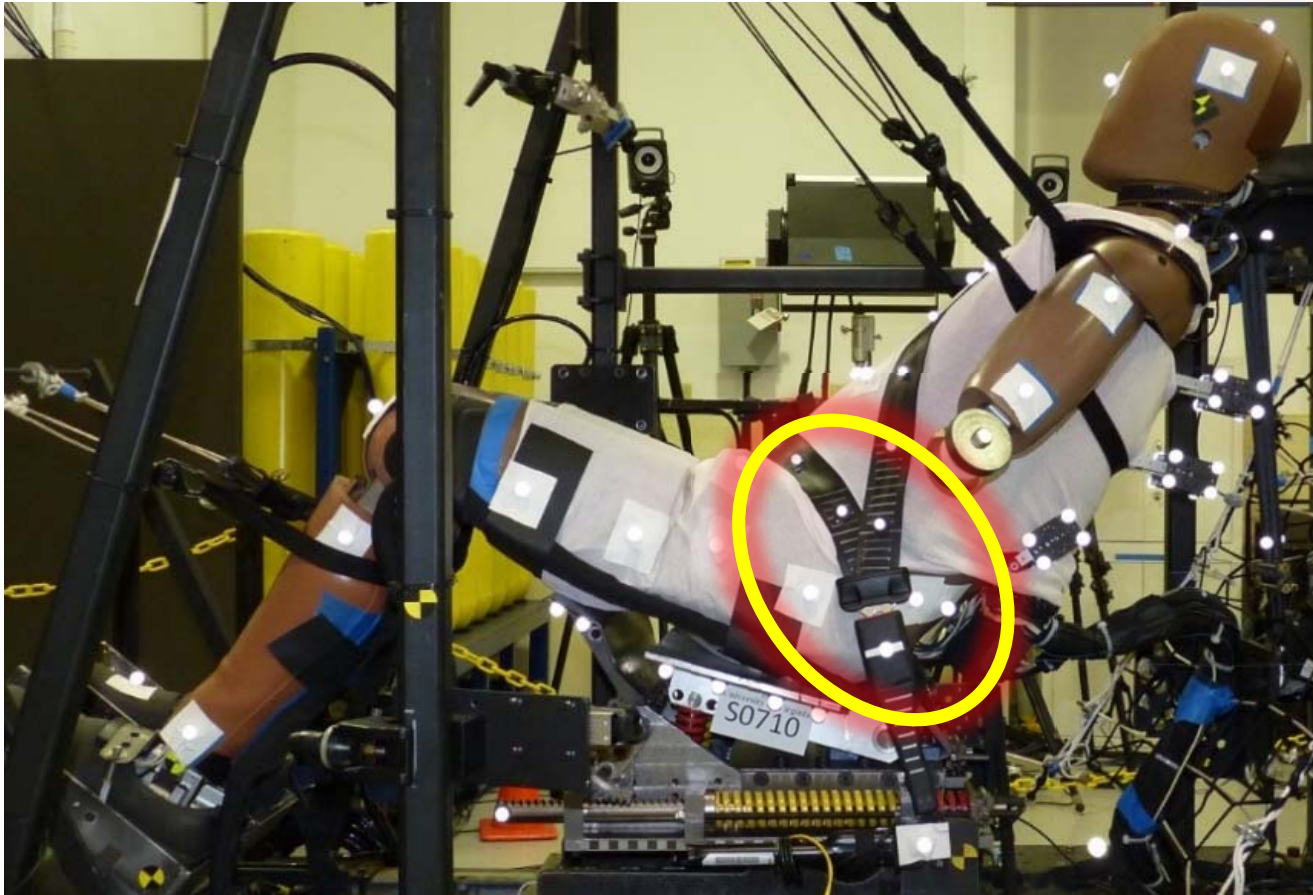


AIS 2



All 5 Subjects Sustained Sacrum Fracture

ATD Injury Risk Prediction: Pelvis Injury



Hybrid III-50M:

Pelvic Wing: No Measurement

Sacrum: No Measurement

THOR-50M:

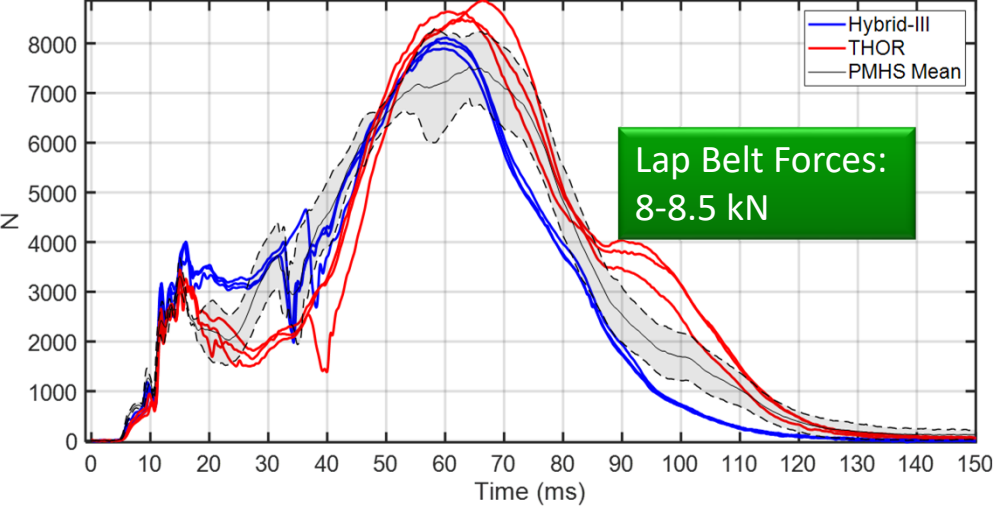
Pelvic Wing: 5-6 kN

Sacrum: No Measurement

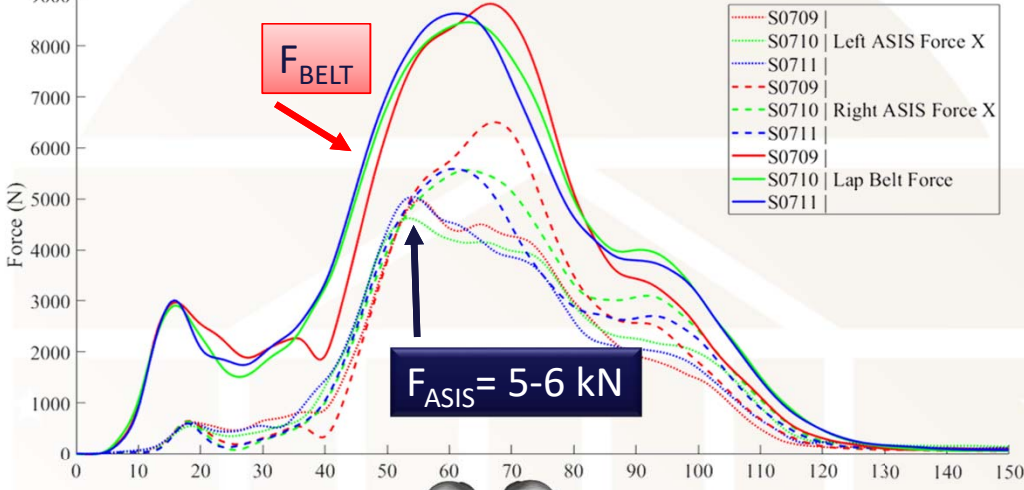
*NHTSA (2008);
Craig et al. (2020)

Injury Risk Prediction: PELVIS

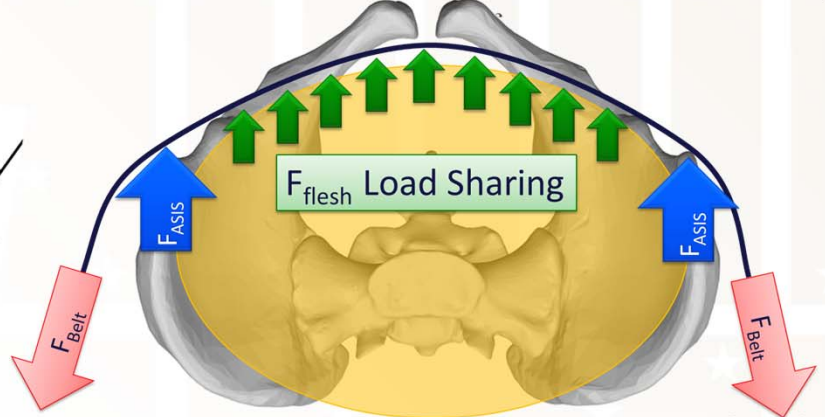
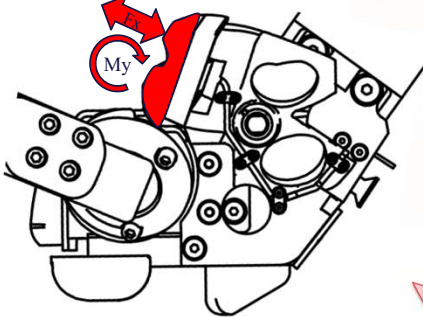
Lap Belt Force (CFC 600)



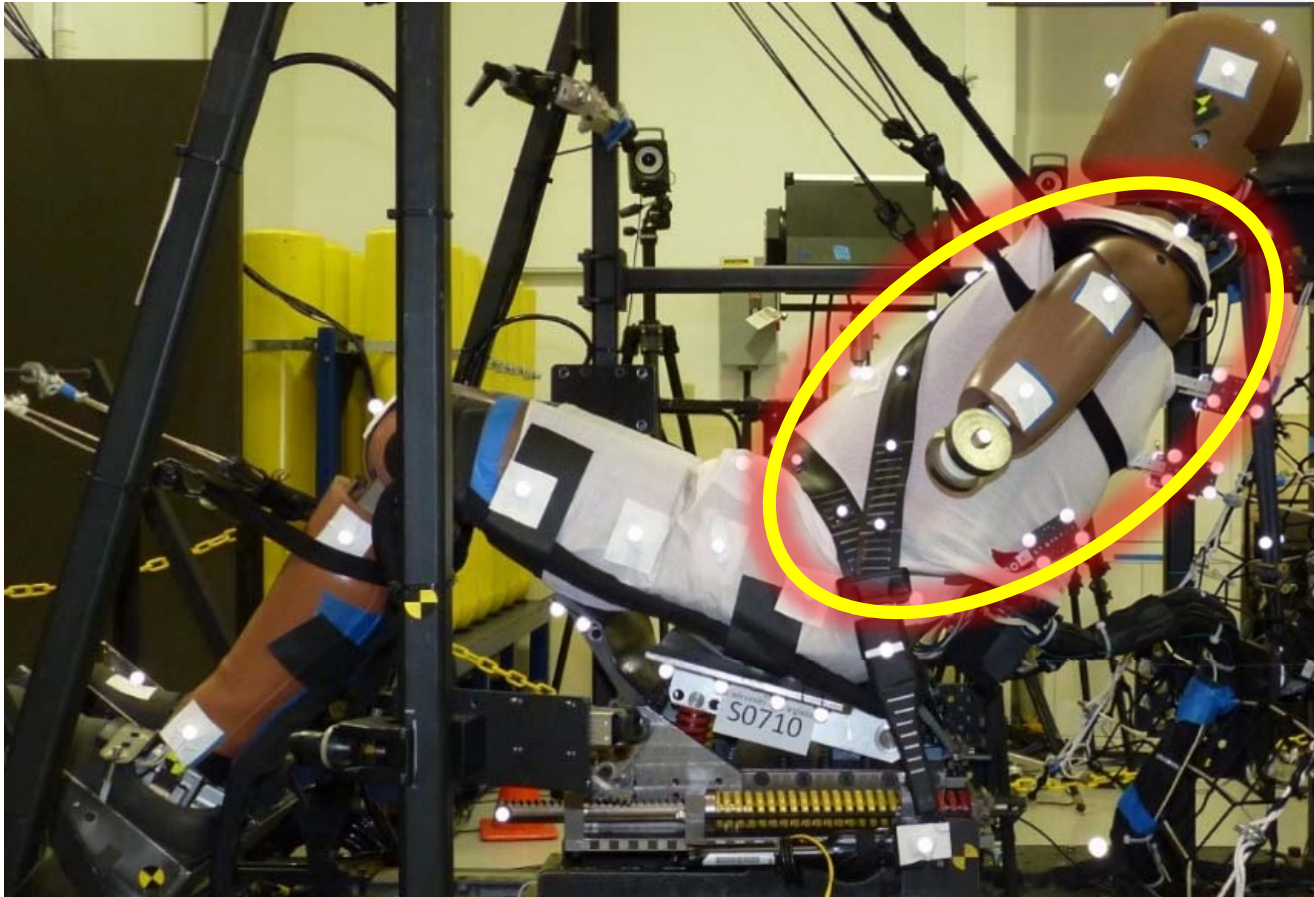
THOR ASIS Force vs. Lap Belt Force



THOR ASIS Load Cells

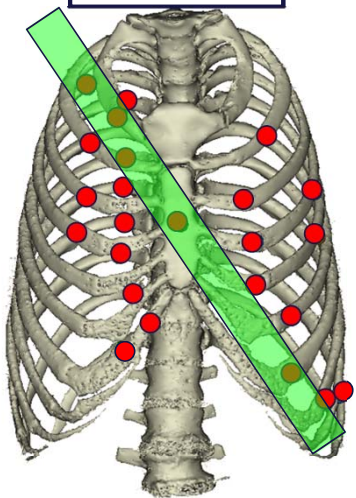


Injury Risk Prediction: Thorax



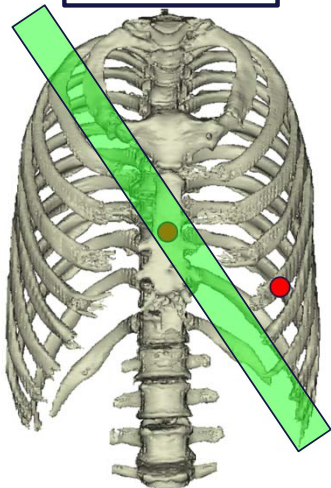
Injury Risk Prediction: THORAX

Subject 1:
66 YO
74 kg
1.1 g/cm²



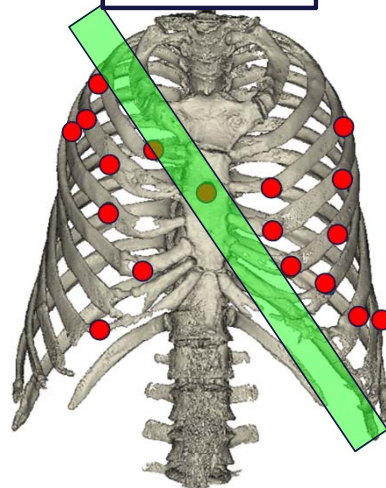
23 rib fractures
Sternal fracture

Subject 2:
53 YO
57 kg
1.4 g/cm²



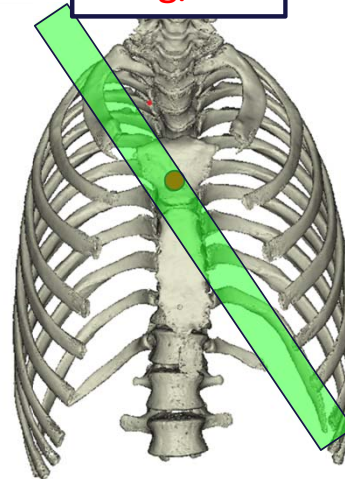
1 rib fracture
Sternal fracture

Subject 3:
72 YO
74 kg
1.1 g/cm²



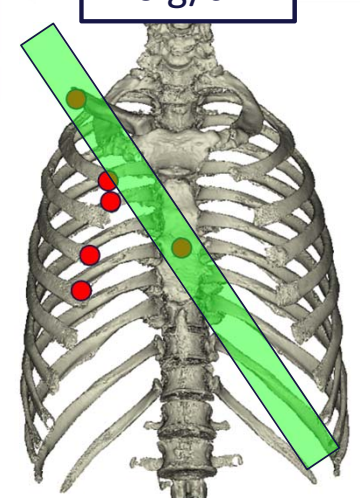
18 rib fractures
Sternal fracture

Subject 4:
25 YO
75 kg
1.2 g/cm²



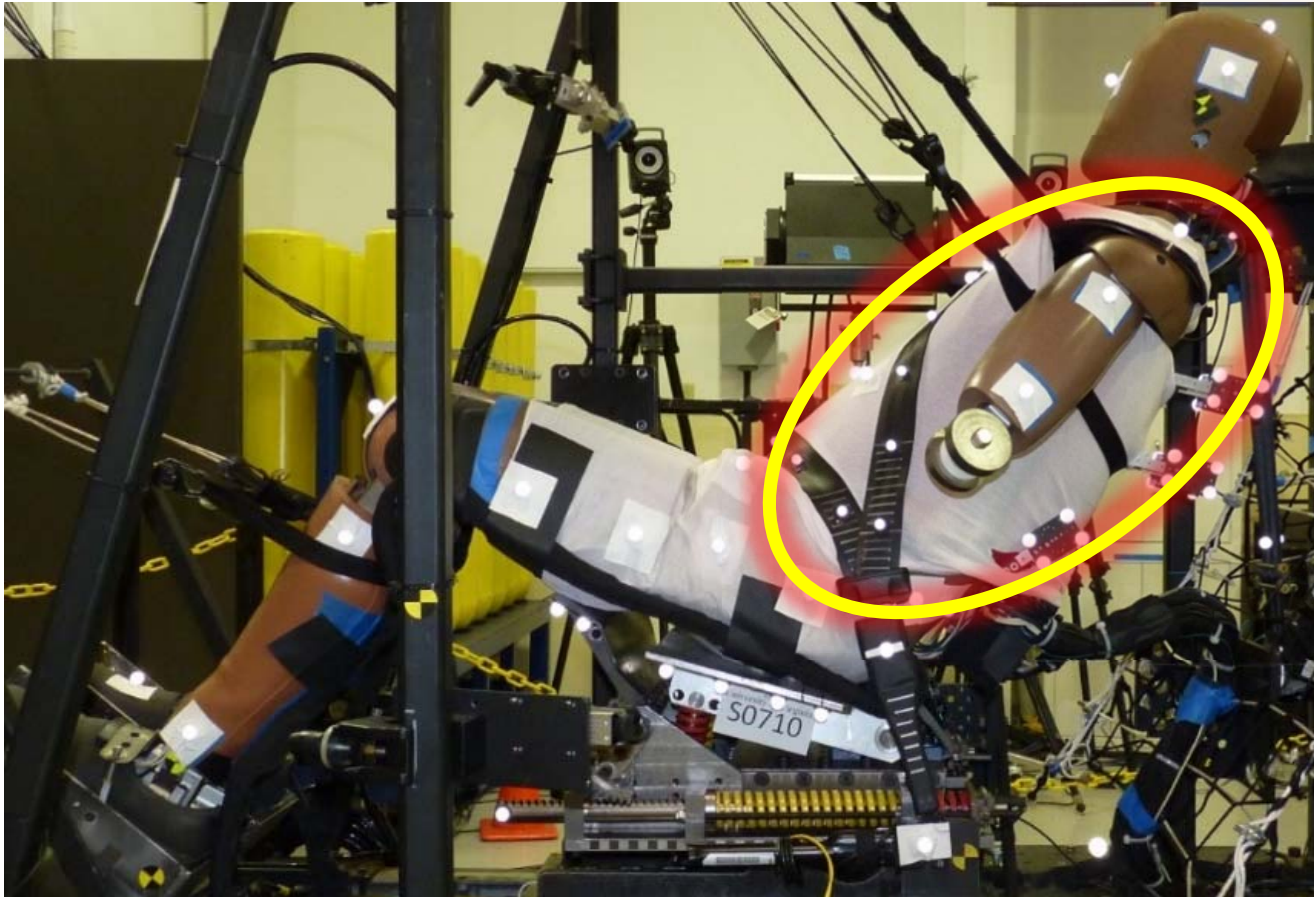
No rib fractures
Sternal fracture

Subject 5:
55 YO
74 kg
1.0 g/cm²



6 rib fractures
Clavicle fracture
Sternal fracture

ATD Injury Risk Prediction: Thoracic Injury



Hybrid III-50M*:

Peak resultant chest deflection:
P(AIS3+) = 2%

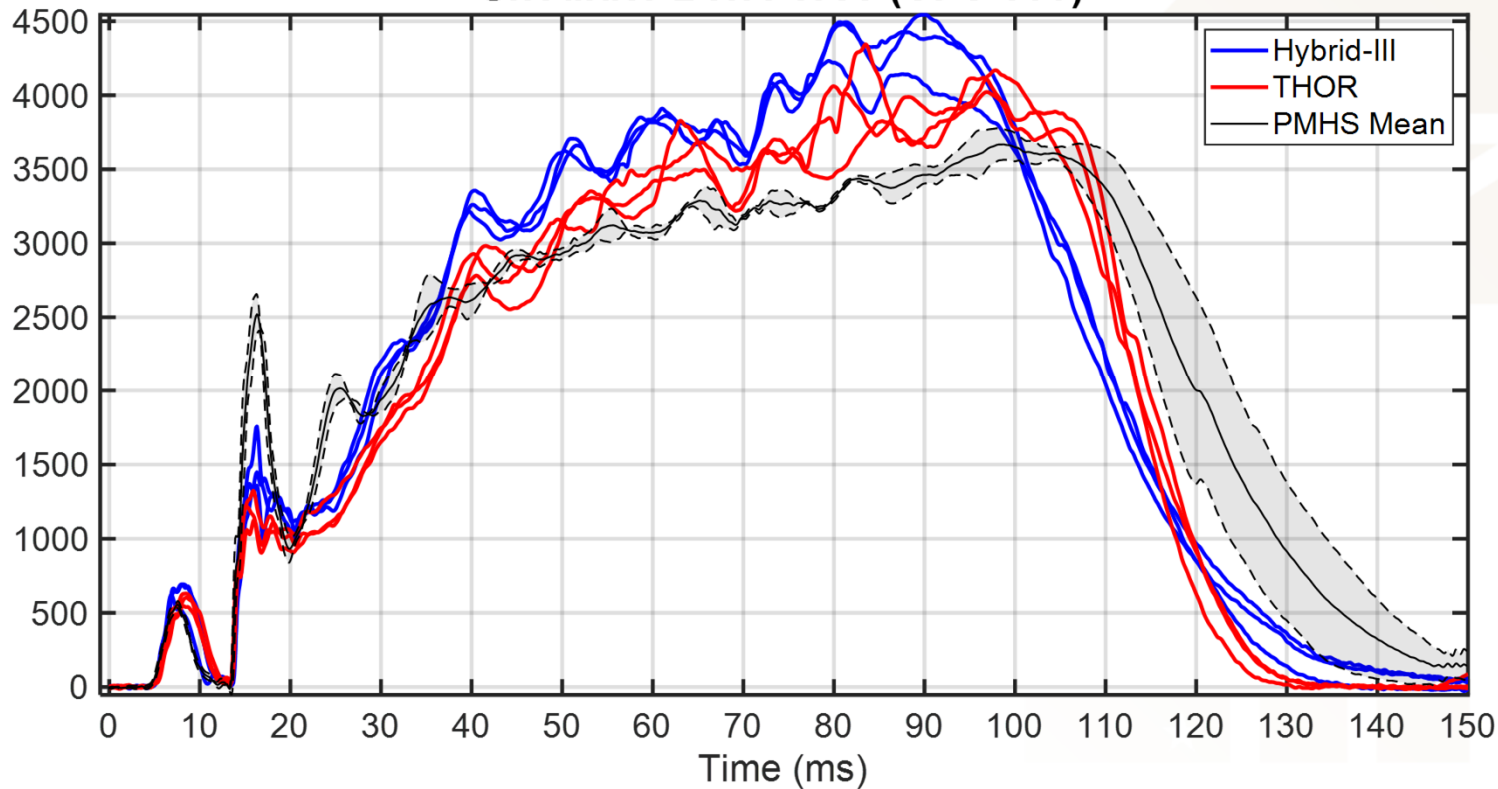
THOR-50M:**

Peak resultant chest deflection:
P(AIS3+) = 45%

*NHTSA (2008);
**Craig et al. (2020)

ATD Injury Risk Prediction: Thoracic Injury

Shoulder Belt Force (CFC 600)



Hybrid III-50M:

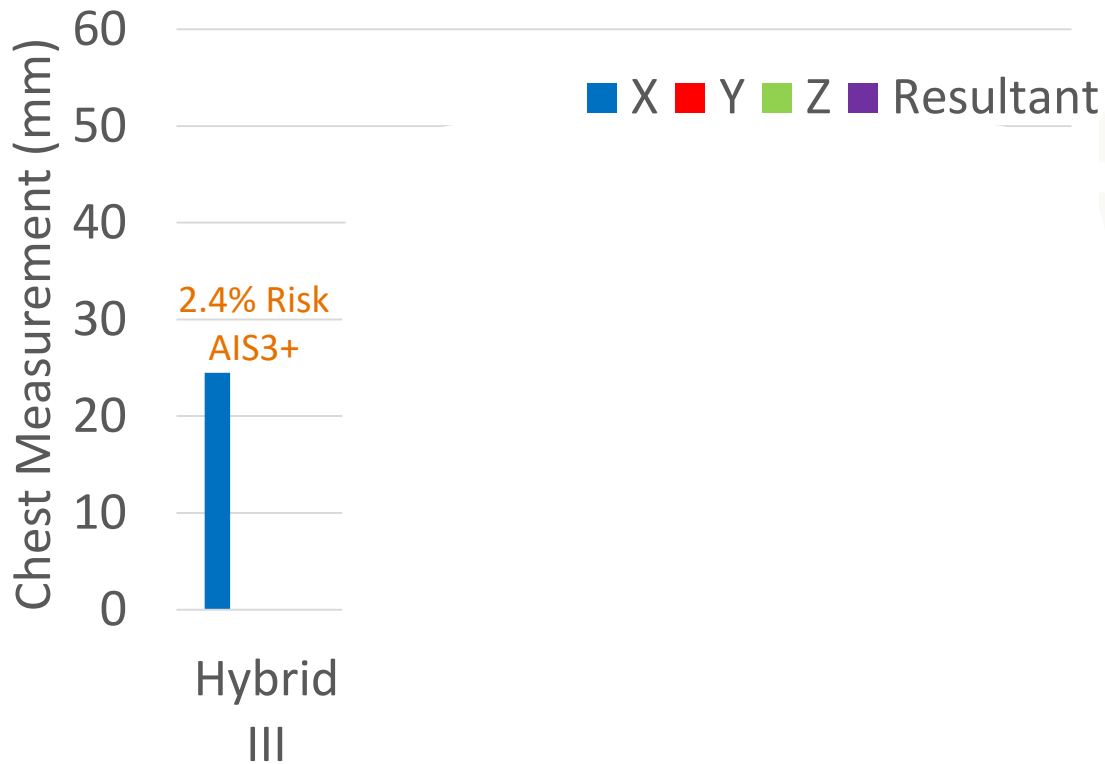
Peak resultant chest deflection:
P(AIS3+) = 2%

THOR-50M:

Peak resultant chest deflection:
P(AIS3+) = 45%

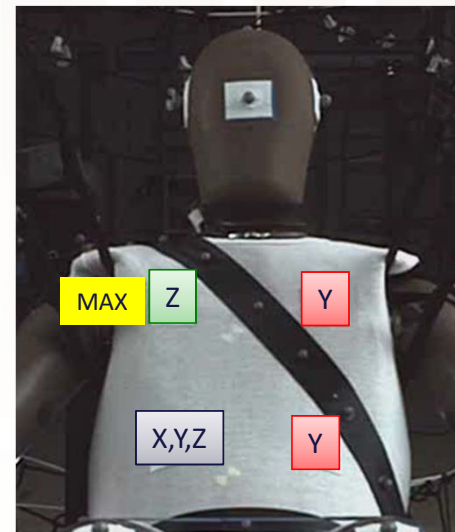
*NHTSA (2008);
Craig et al. (2020)

ATD Injury Risk Prediction: Thoracic Injury

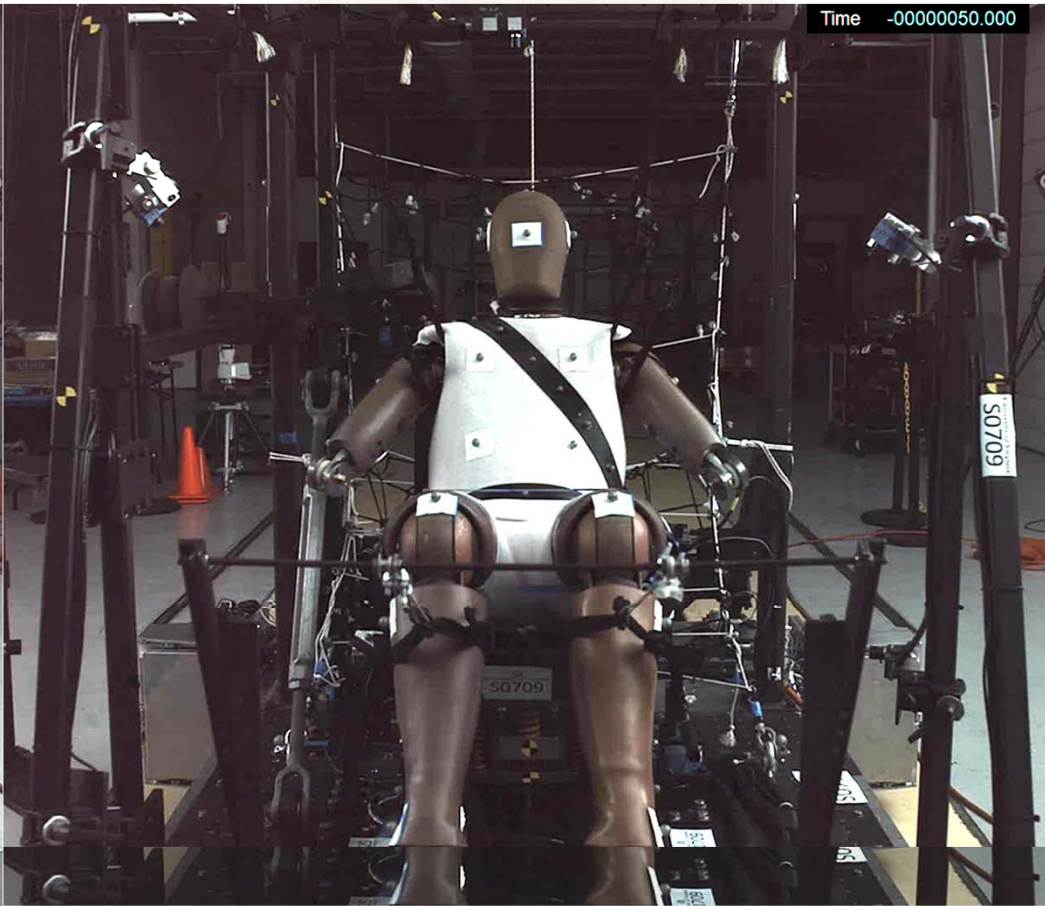
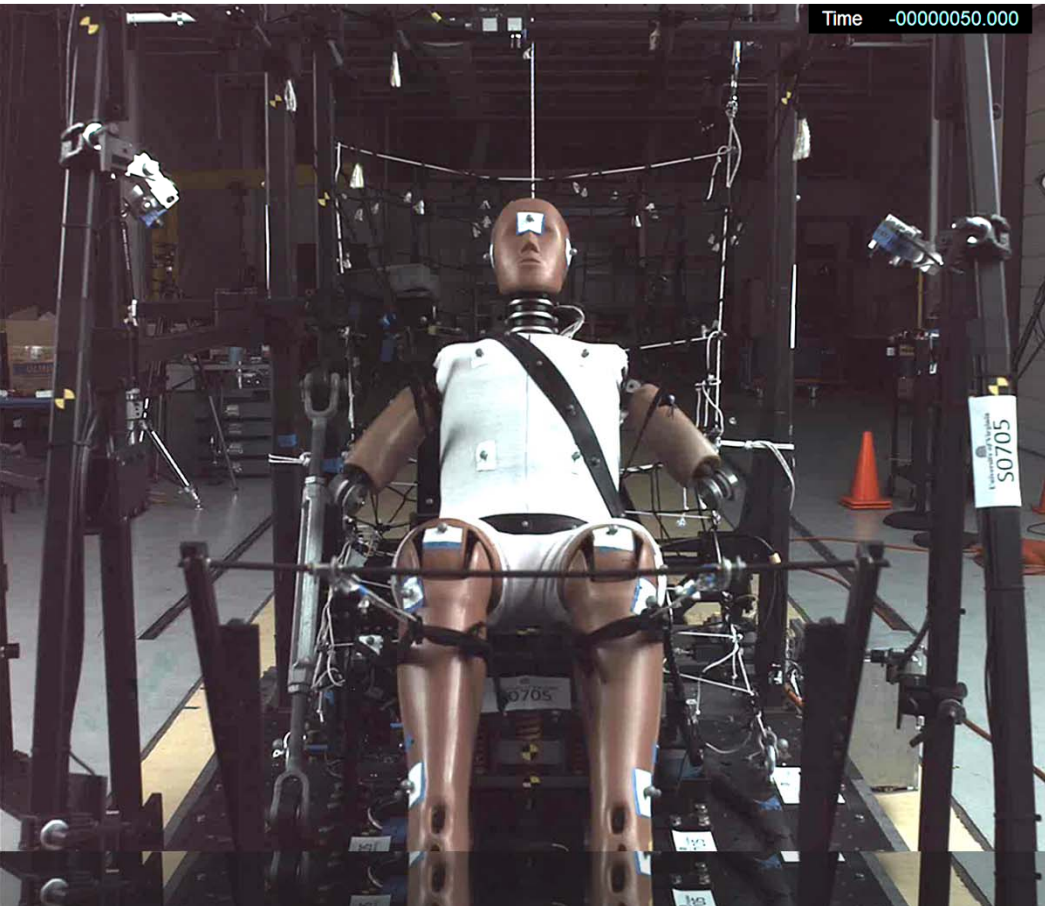


Hybrid III-50M*:
 Peak resultant chest deflection:
 P(AIS3+) = 2%

THOR-50M:**
 Peak resultant chest deflection:
 P(AIS3+) = 45%

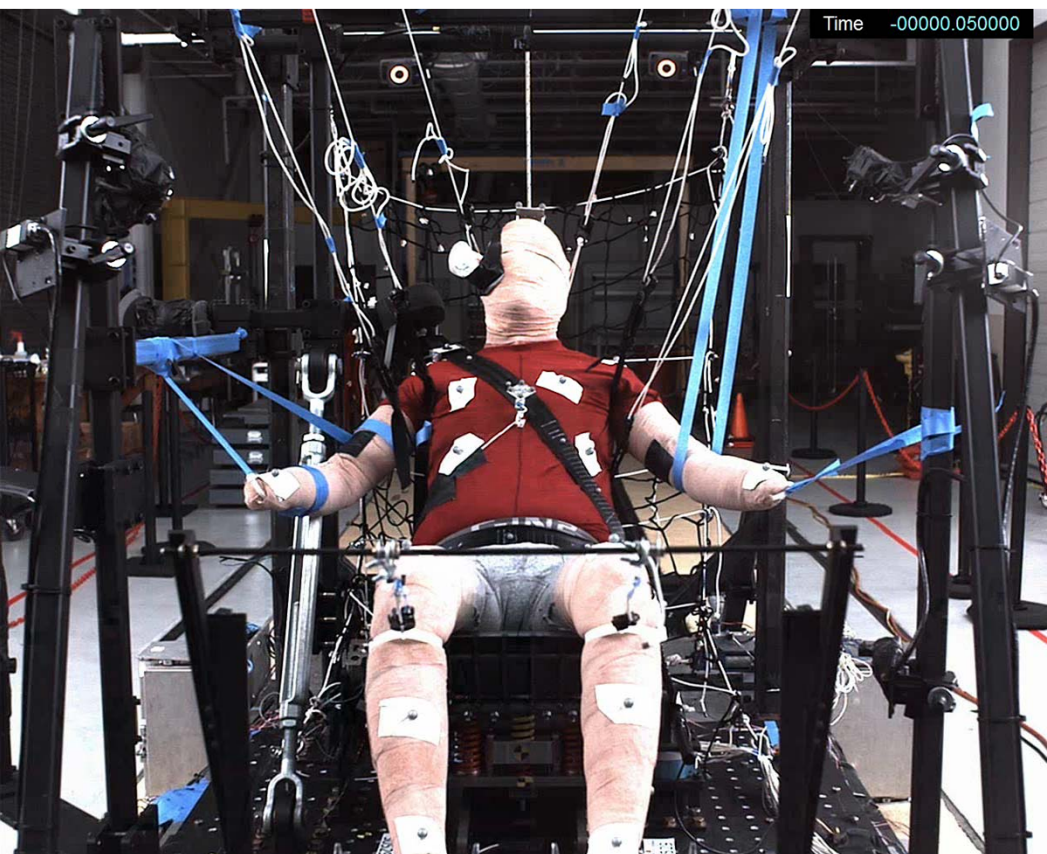


*NHTSA (2008);
 **Craig et al. (2020)

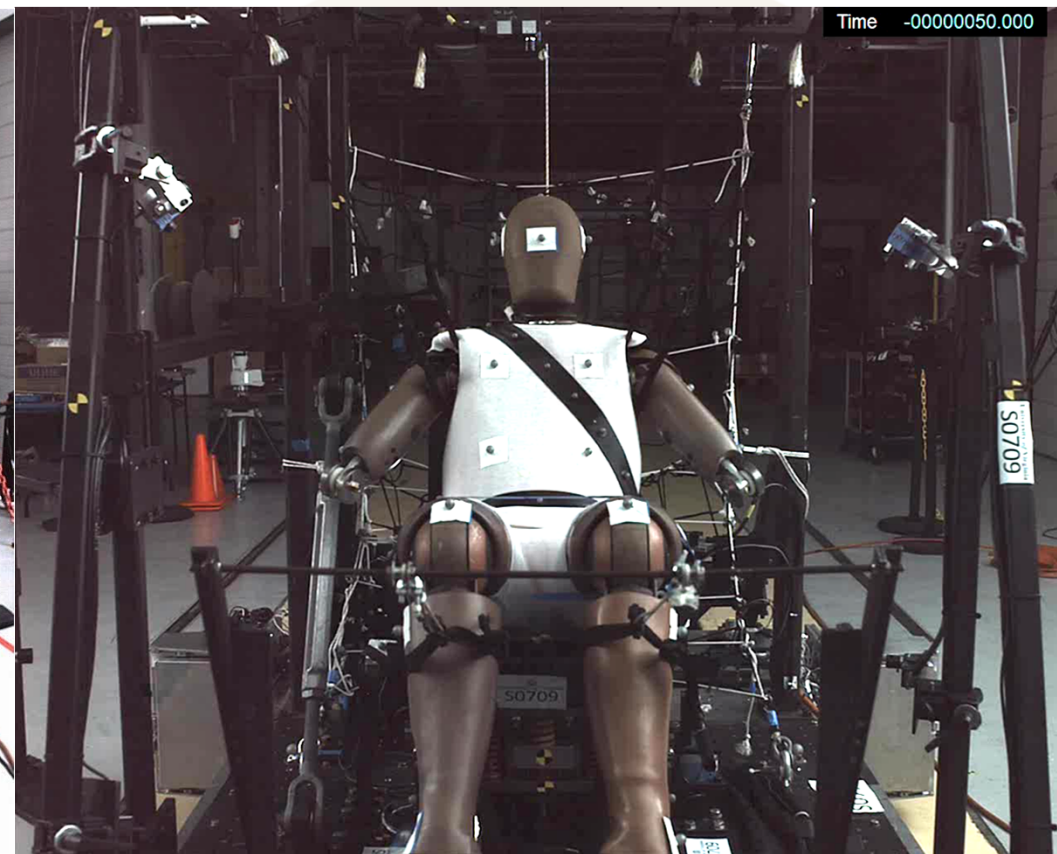


Hybrid-III 50th Male

THOR-50M



PMHS



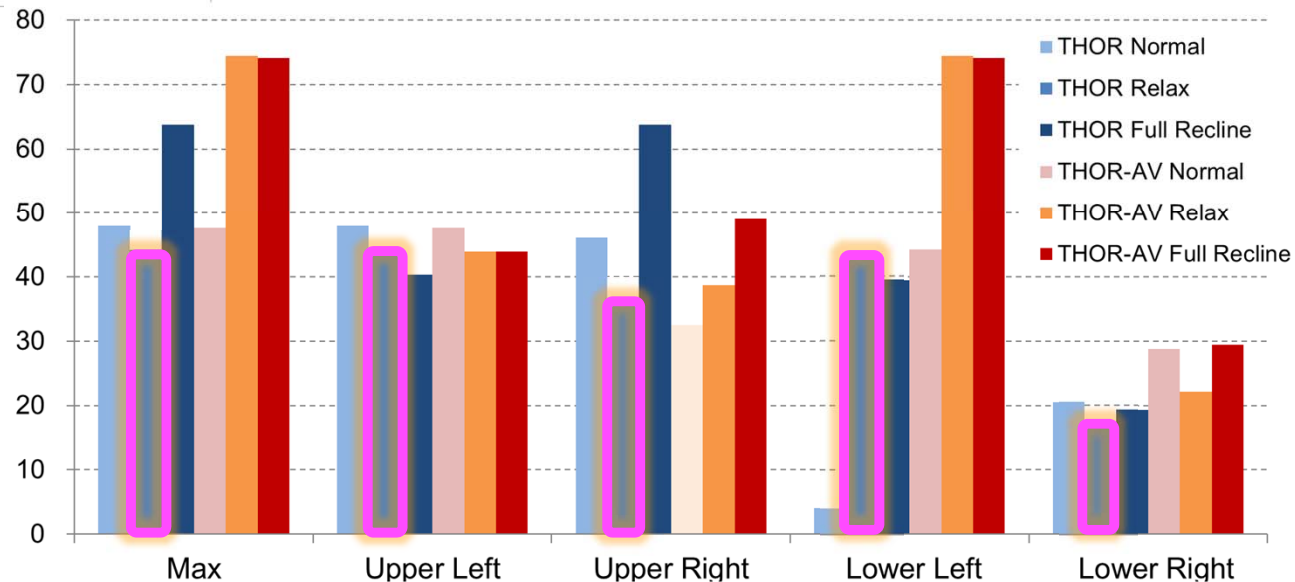
THOR-50M

Thoracic Injury Risk: Kapseong Jeong, SAE Government/Industry Meeting, Feb 2021

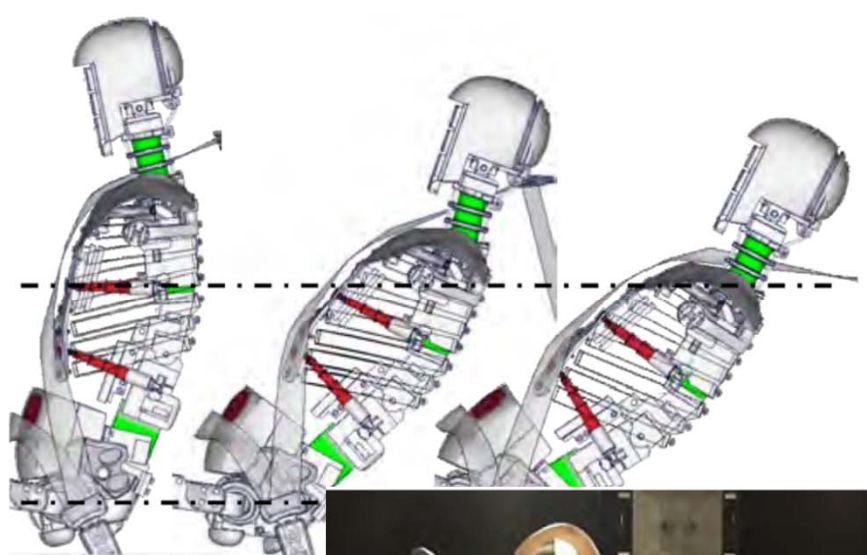
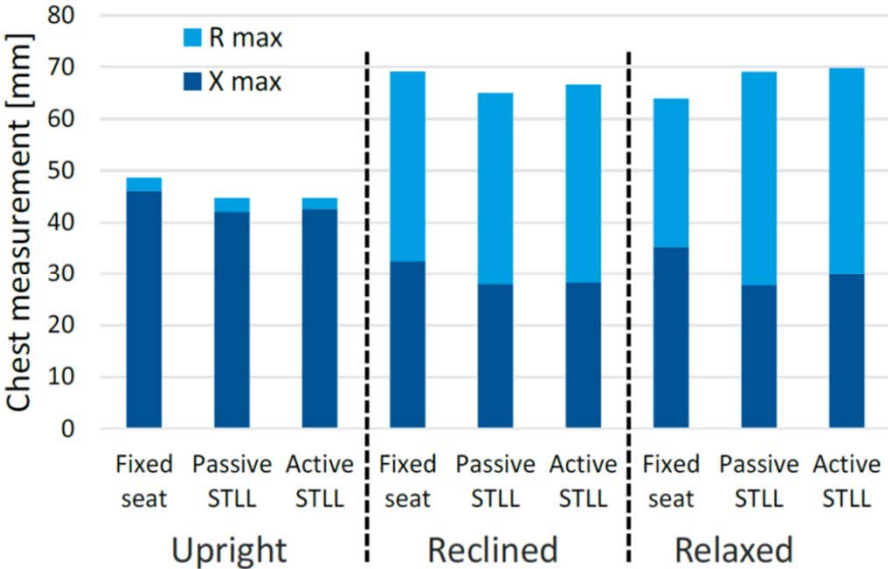


THOR-50M
 “Relax” condition: 45 deg recline
 ~45 mm Rmax

Seatback Angle	25°	45°	60°
Pelvis Tilt Angle	33.2°	39.9°	44.8°

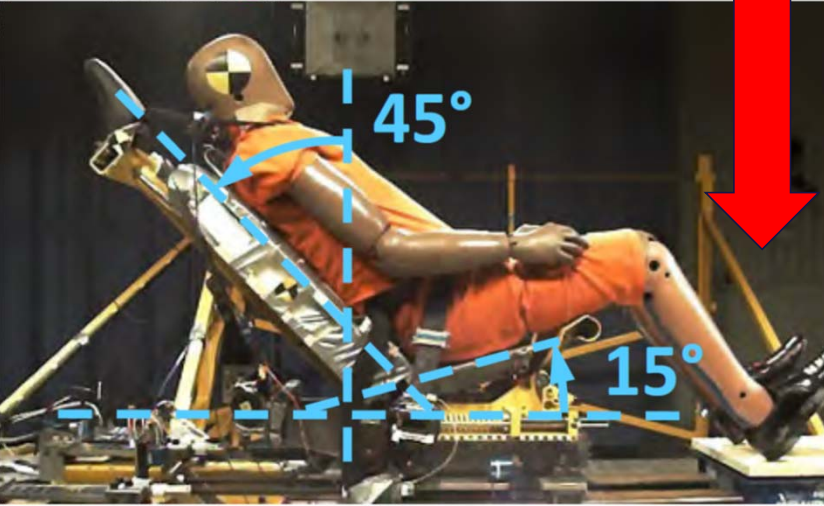


Thoracic Injury: Ostling et al. 2021 IRCOBI



No
Toe
Pan

Similar Configuration and Belt
Higher Injury Risk
Higher Amount of X-component



Conclusions

- ▶ ATD-predicted BrIC varies only a little between ATDs
 - 20%-40% Risk of AIS3+, with no head contact.
- ▶ Lumbar
 - Similar Axial Compression Prediction (~4 kN)
 - THOR predicts higher flexion (408 Nm vs. 186 Nm)
 - Only THOR predicts high compression occurring simultaneously to high flexion
 - Injury Risk
 - Compression + Flexion test data: *Tushak et al. 2022 Journal of Biomechanics*
 - Injury Risk Functions
 - Presented at AAAM 2021
 - Currently under review



- ▶ Pelvis
 - THOR ASIS load cell measures lower forces than lap belt
- ▶ Thorax
 - THOR predicts much higher risk of thoracic injury than Hybrid-III
 - Hybrid-III low prediction may be belt location
 - THOR compression peak is in Z-direction
 - Peak is upper right, under shoulder belt



Acknowledgements

RCCADS | **Research Consortium for Crashworthiness
in Automated Driving Systems**

Autoliv



kerrigan@virginia.edu

Comparison of Injury Risk Prediction in Reclined Frontal Crashes: Hybrid-III vs THOR

Jeesoo Shin, John-Paul Donlon, Rachel
Richardson, Bronislaw Gepner, Jason Forman,
and Jason Kerrigan

University of Virginia Center for Applied Biomechanics



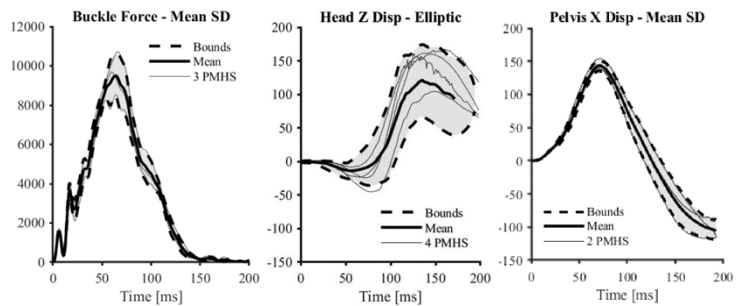
**Biofidelity Evaluation of Hybrid-
III 50th Male and THOR-50M in
Reclined Frontal Impact Sled
Tests**

Comparison of Injury Risk Prediction in Reclined Frontal Crashes: Hybrid-III vs THOR

Jeesoo Shin, John-Paul Donlon, Rachel Richardson, Bronislaw Gepner, Jason Forman, and **Jason Kerrigan**

Special Announcement:
PMHS Corridor Package

Autoliv  UNIVERSITY of VIRGINIA 2019 HAV Recline Test Series



Richardson et al., Stapp, 2020

In 2020, Richardson et al. published PMHS response corridors for a 50th percentile male occupant in a reclined position.

Corridors we used to evaluate the two ATDs have been made public. This data is available at:

<https://engineering.virginia.edu/cab-downloads>

Thank You!

kerrigan@virginia.edu

 **IRCOBI** Shin et al. 2022

INTERNATIONAL RESEARCH COUNCIL ON BIOMECHANICS OF INJURY

Biofidelity Evaluation of Hybrid-III 50th Male and THOR-50M in Reclined Frontal Impact Sled Tests