Biomechanical Responses and Injury Assessment of PMHS in Rear-facing Seating Configurations

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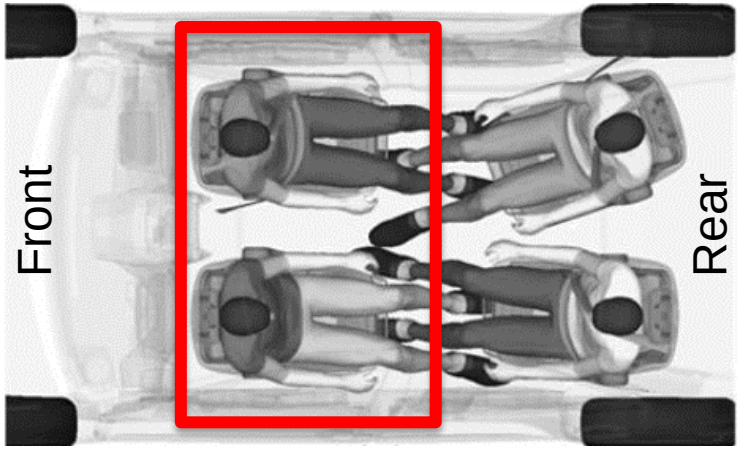
[1]The Ohio State University, [2]TRC Inc., [3]NHTSA/VRTC

Motivation

Non-standard seating configurations for highly automated vehicles (HAV) are likely to be present

- Studies using computational models [Kitagawa et al., 2017; Jin et al., 2018; Katagiri et al., 2018]



Kitagawa et al., 2017

- ATD and FE HBM
  - evaluated and validated only in low speed rear impacts
  - require biomechanical data generated in the desired severity
  - need more biomechanical data in high speed rear impacts with different recline angle

Objective

To investigate biomechanical responses and injury of Post Mortem Human Surrogates (PMHS) in rear-facing seating configuration (high speed rear impacts)

METHODS

Sled Buck Concept

Generate meaningful ATD/HBM targets for use in evaluating future/unknown seat designs

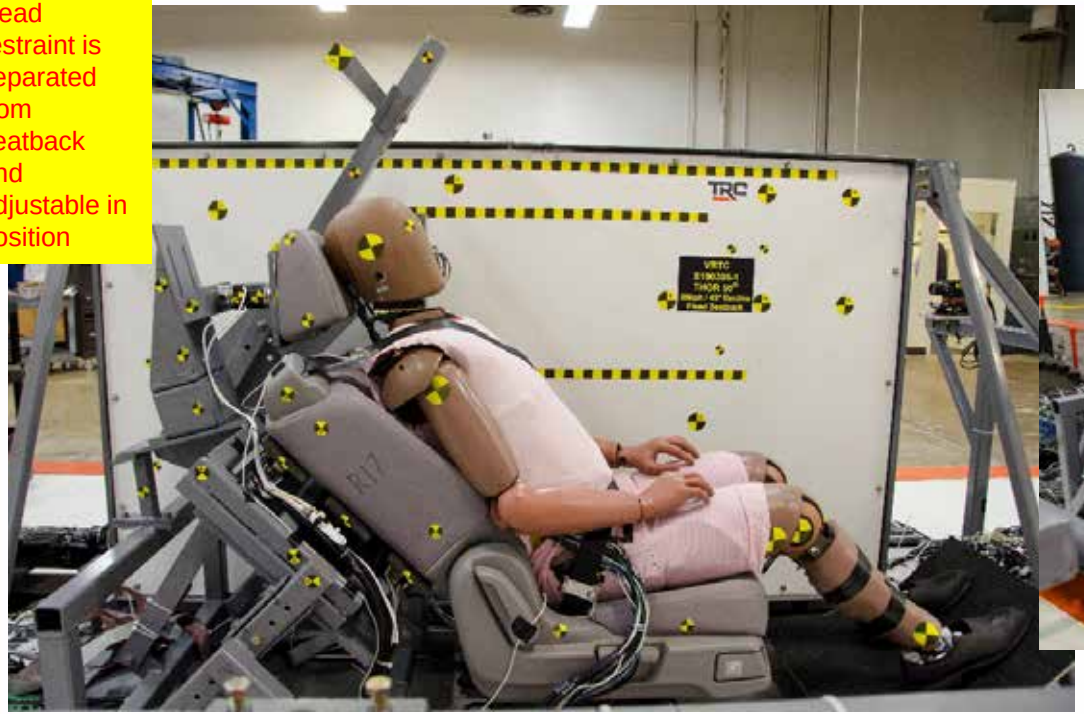
- **Currently, no consensus on future AV seat**

Design criteria:

1) **Repeatable:** rigid support to prevent seat motion
2) **Simulate future AV seat:** current production seat with ABTS
3) **Adjustable:** allow for different recline angles/HR position
4) **Measure reaction loads:** add instrumentation
5) **Various crash directions:** 15° increment

Sled Buck Description

Head restraint is separated from seatback and adjustable in position



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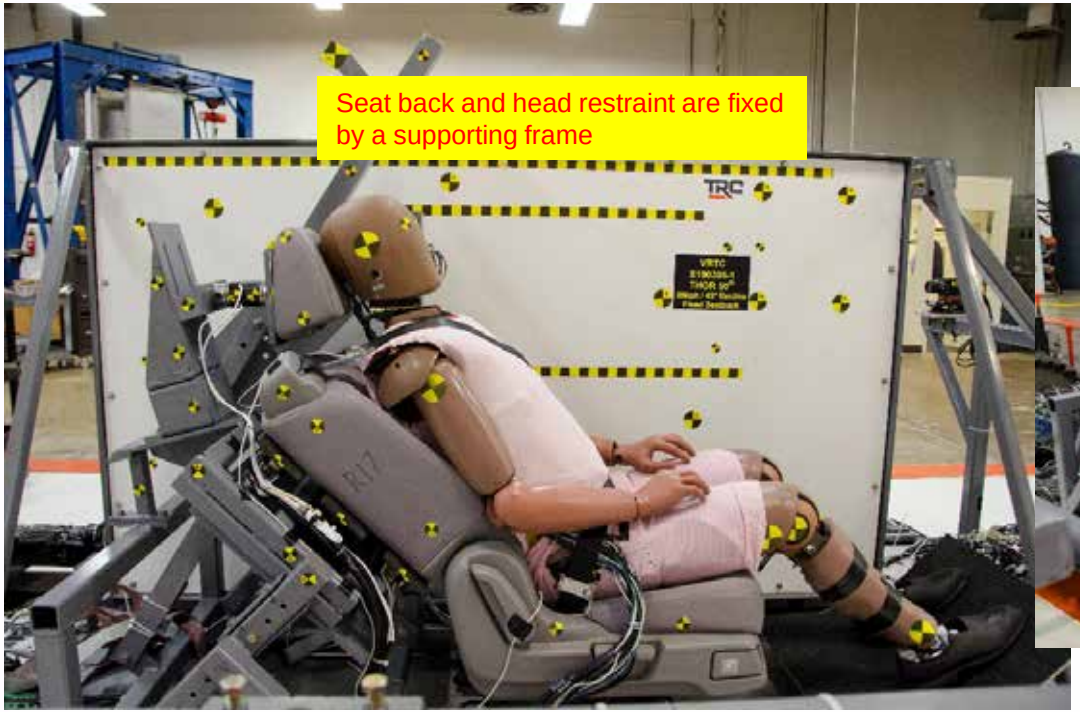

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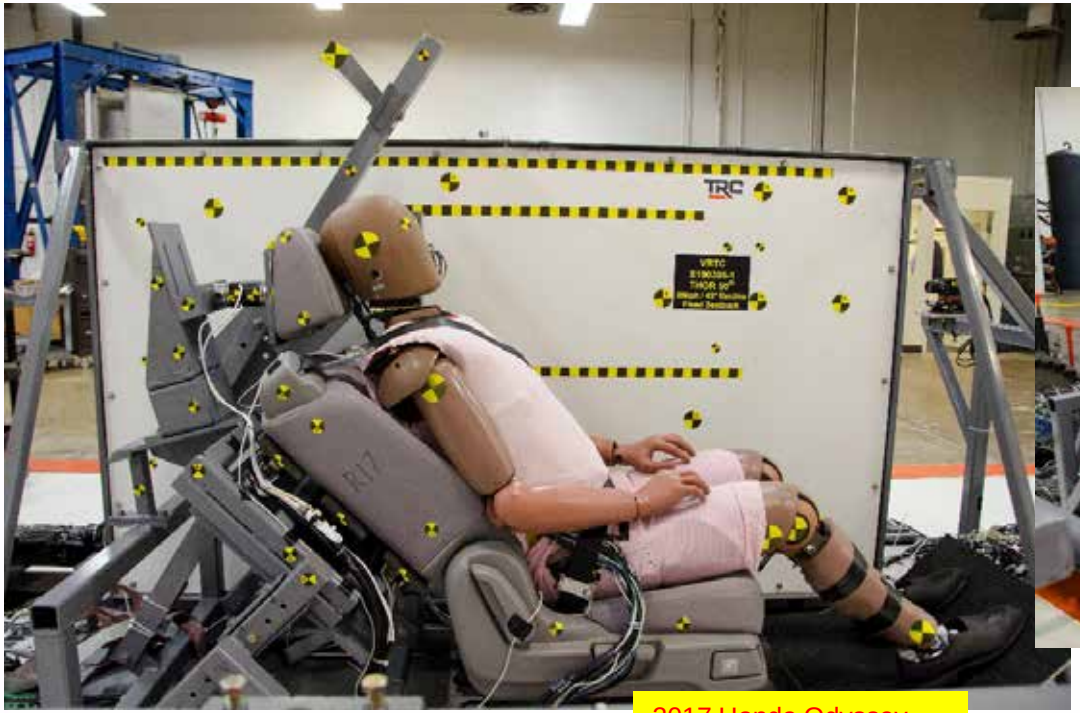
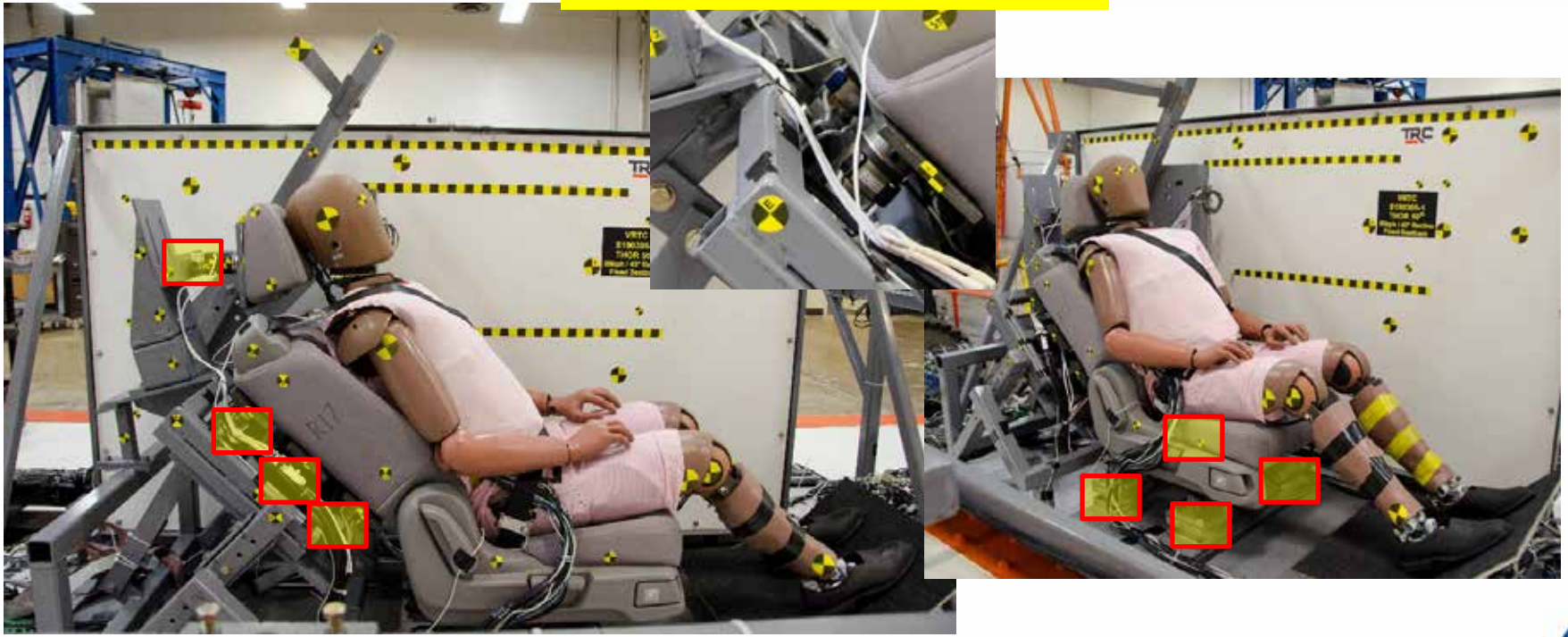


2017 Honda Odyssey
2nd row seat with ABTS

Sled Buck Description

Load cells at head restraint (1), seat back (6), and seat anchors (4) to measure reaction loads



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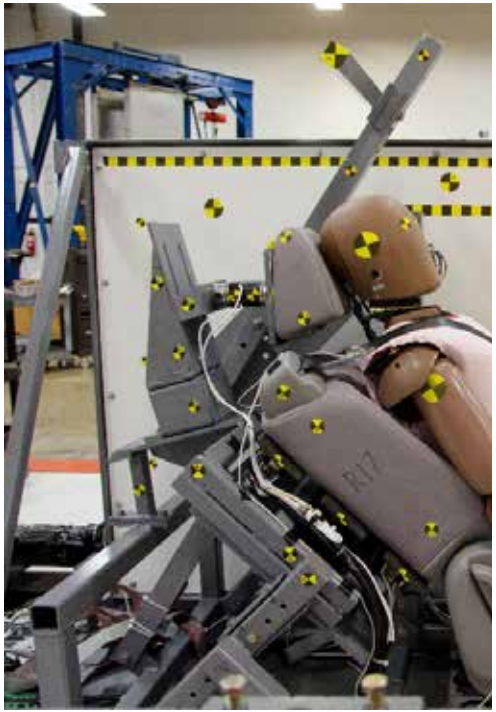
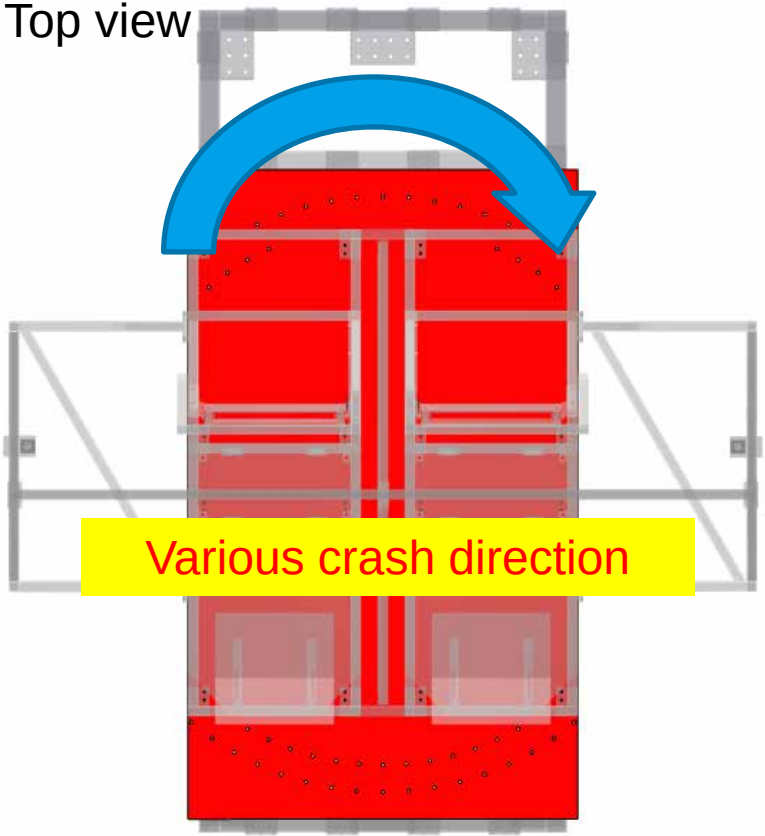
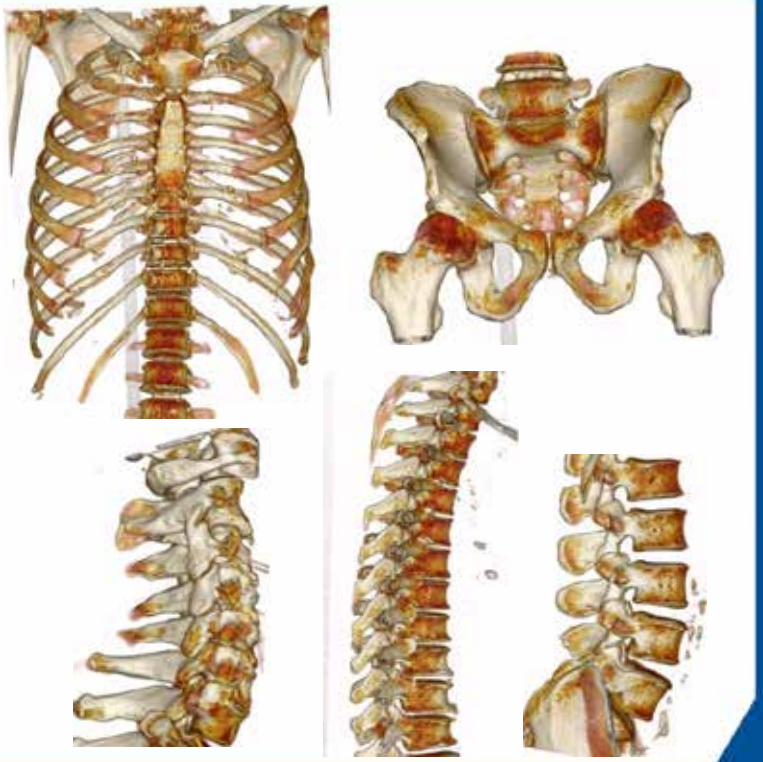


Top view



PMHS Information

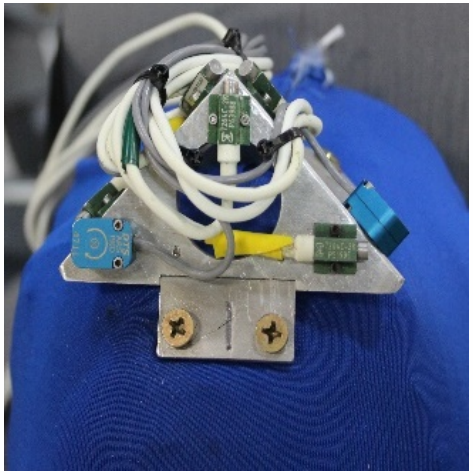
	PMHS01	50th male
Sex	M	M
Age	57	45
Cause of Death	COPD	N/A
Height (cm)	167	175
Weight (kg)	63.0	78.2
Head mass (kg)	3.8	4.5
Seated Height (cm)	90.0	90.7
Chest Depth (cm)	20.7	22.9
Chest Breadth (cm)	30.3	33.0

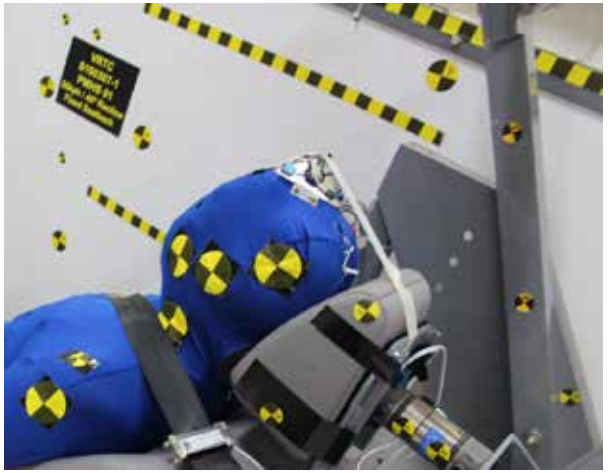


PMHS Instrumentation

6aw

	PMHS
Head	
Chest	
C2/4/6	
T1	
T4	
T8	
T12	
S1	
Pelvis	
Femur	
Tibia	





Kang et al., 2011 & 2015; Yoganandan et al., 2006

PMHS Instrumentation

6aw

Chestband

Strain Gauges

	PMHS
Head	
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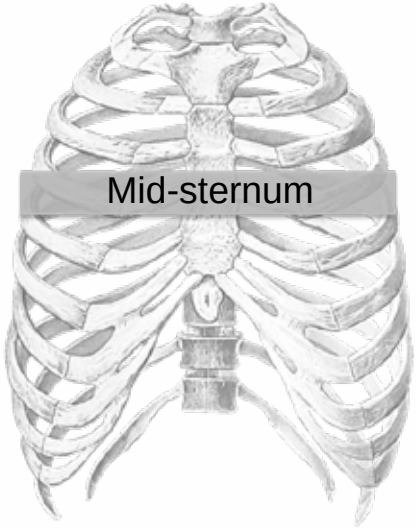

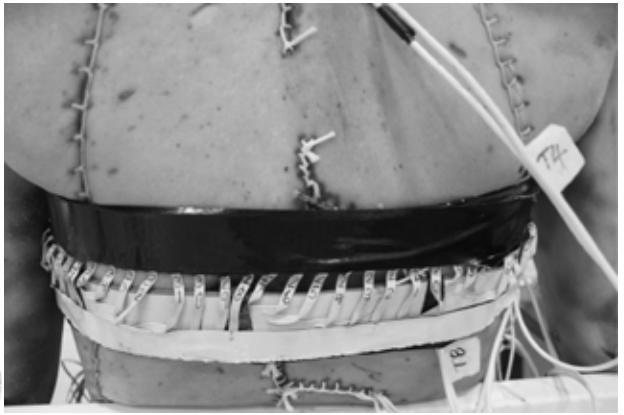

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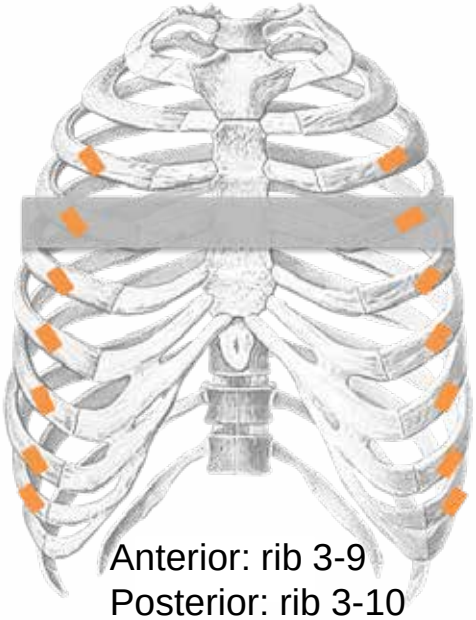

Anterior: rib 3-9
Posterior: rib 3-10

PMHS Instrumentation

6aw
Chestband
Strain Gauges
3aw

	PMHS
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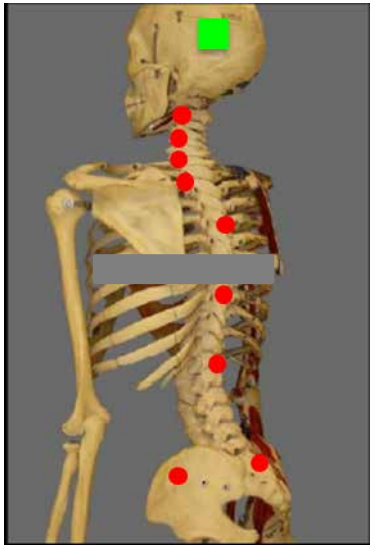

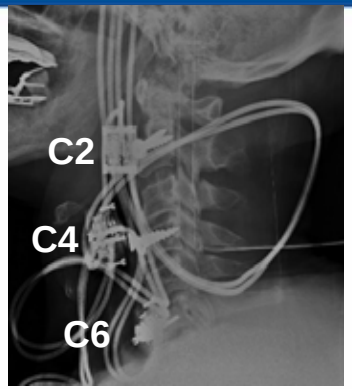

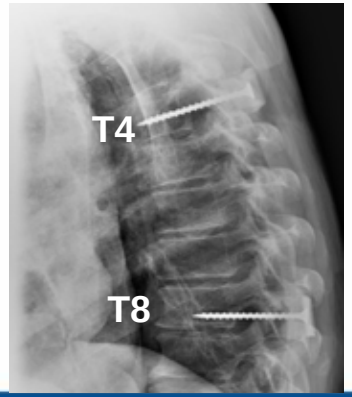

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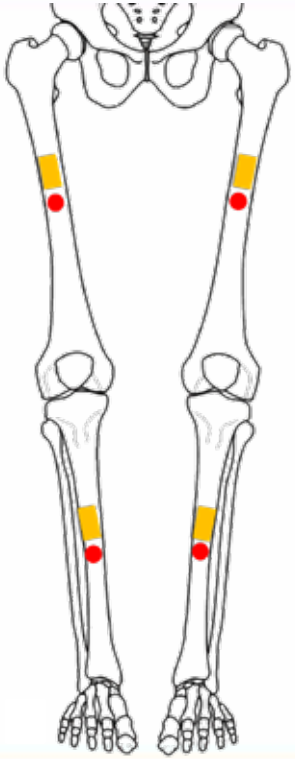
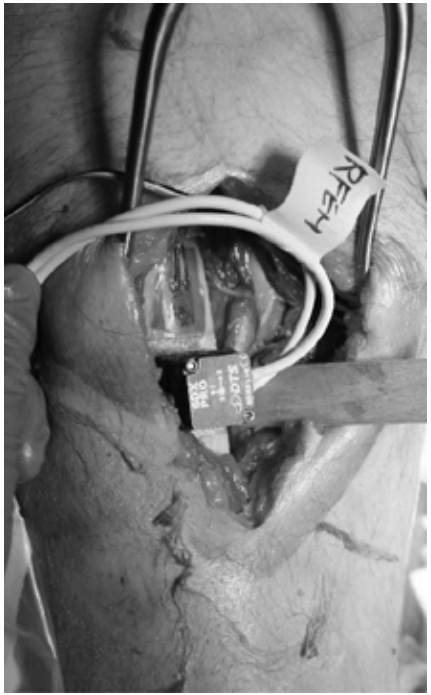
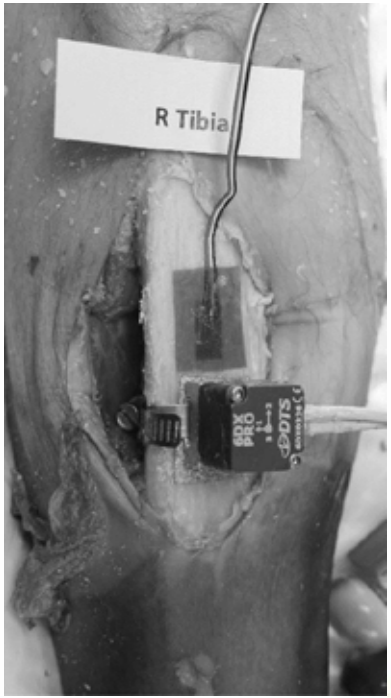
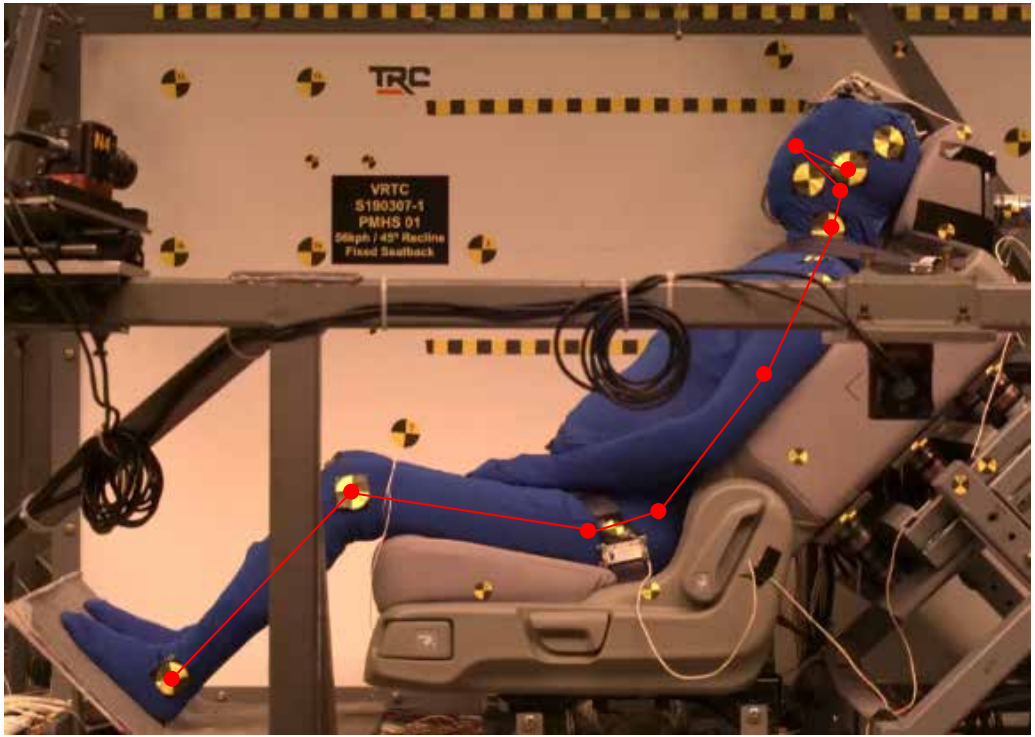






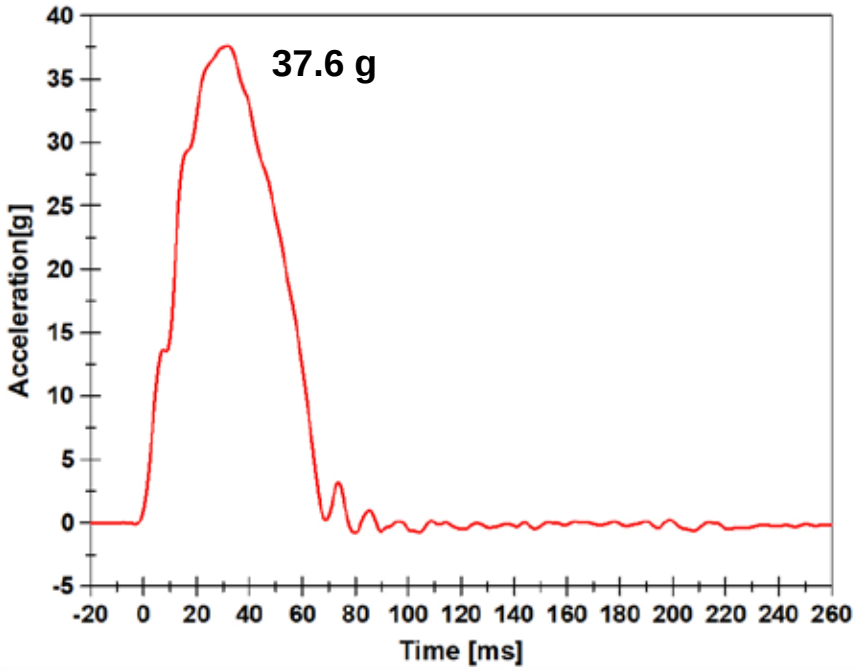
PMHS Positioning

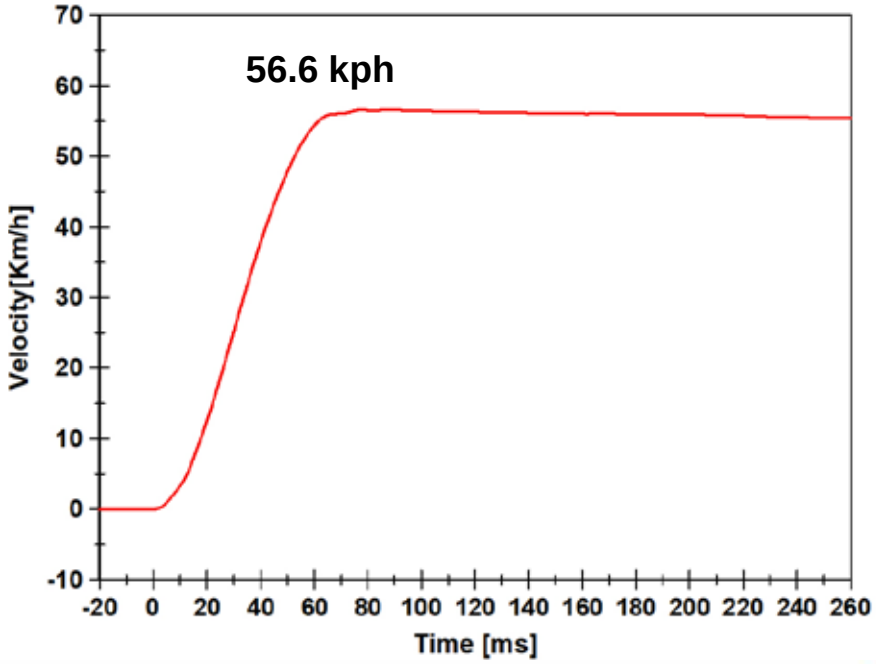


	UMTRI Target[1]	PMHS
Head Angle	22.3 ± 2º	22.0º
Pelvic Angle	21.1 ± 5º	25.0º
Thigh Angle	11.1 ± 2º	10.0º
Leg Angle	45.9 ± 2º	46.0º
Hip-to-Eye Angle	31.6± 5º	26.0º
Back set	0 mm	0 mm
Top set	---	46 mm
Hip X	+55 ± 10 mm	+60.4 mm
Hip Z	-375 ± 10 mm	-366 mm

[1]Reed M, Ebert S. "Effects of Recline on Passenger Posture and Belt Fit" UMTRI Report 2018-2

Sled Pulse

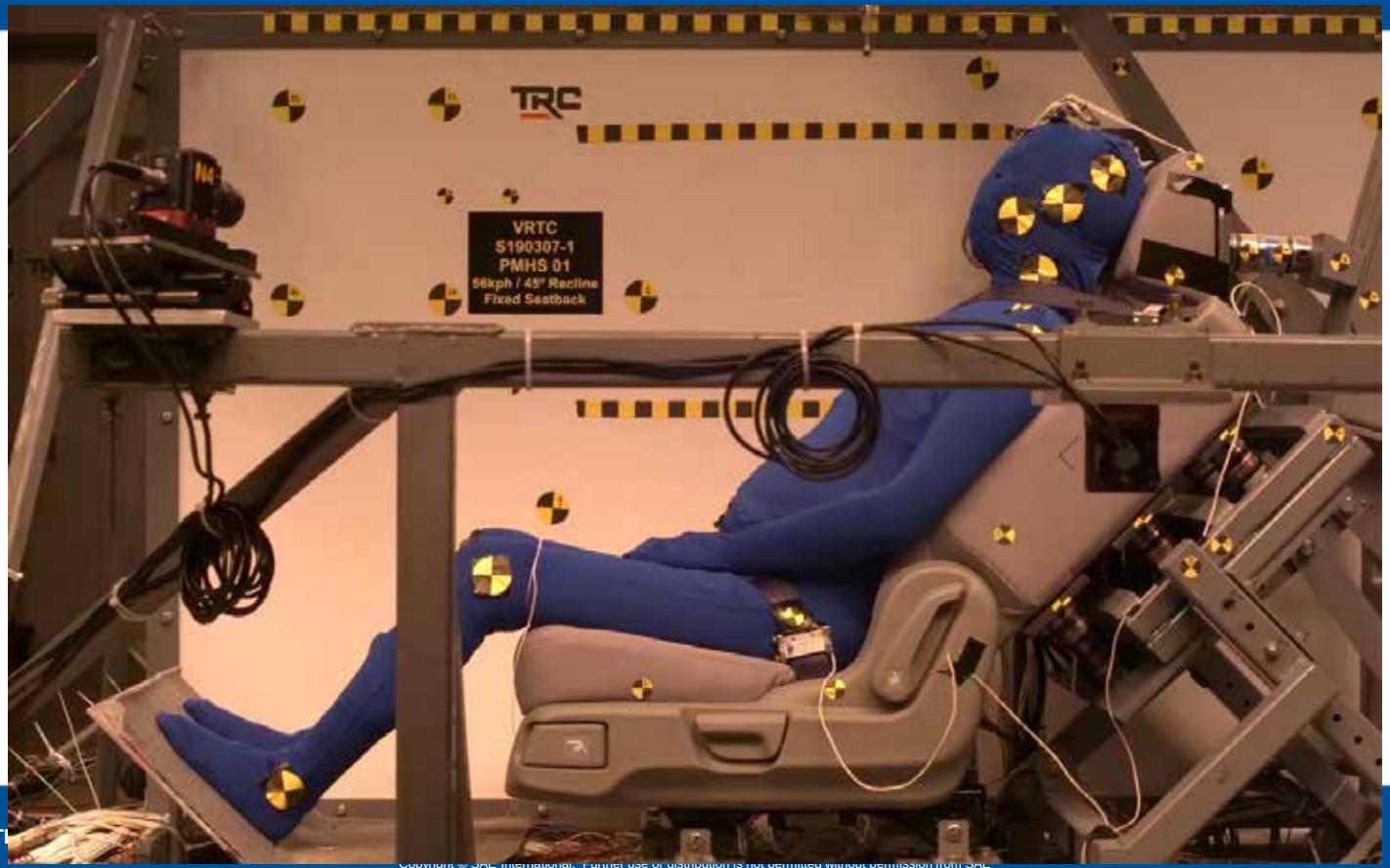




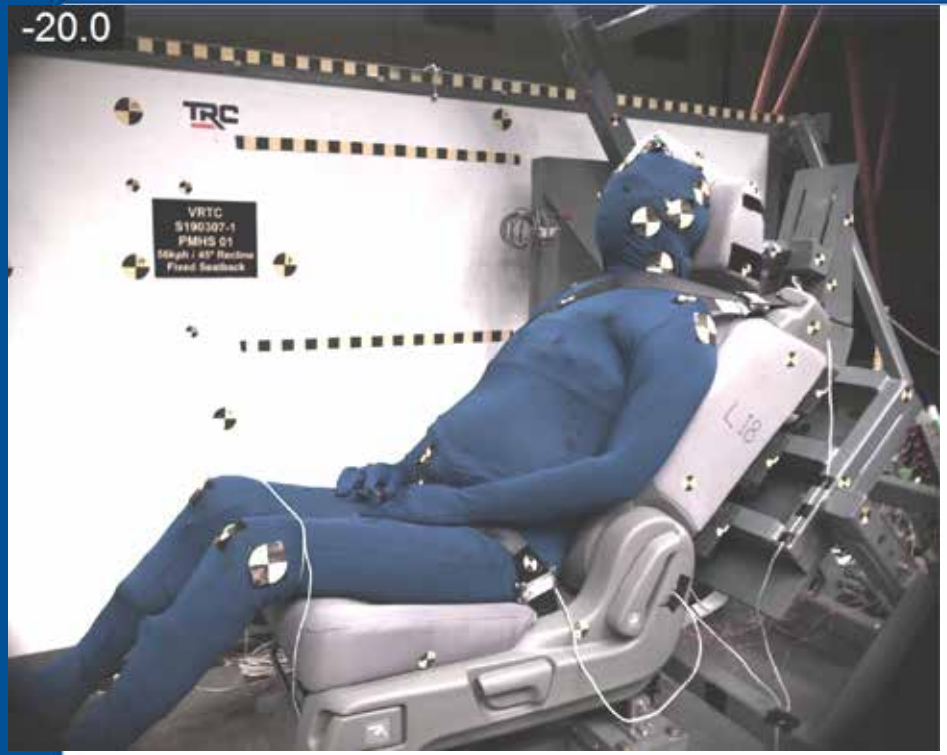
RESULTS

PRELIMINARY RESULTS

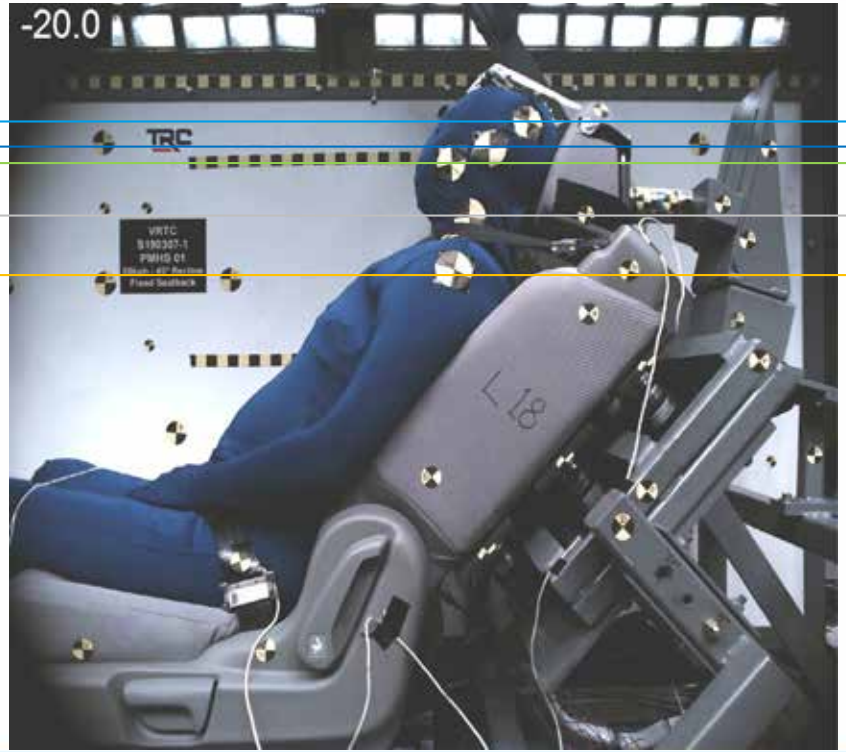
Offboard HS Video

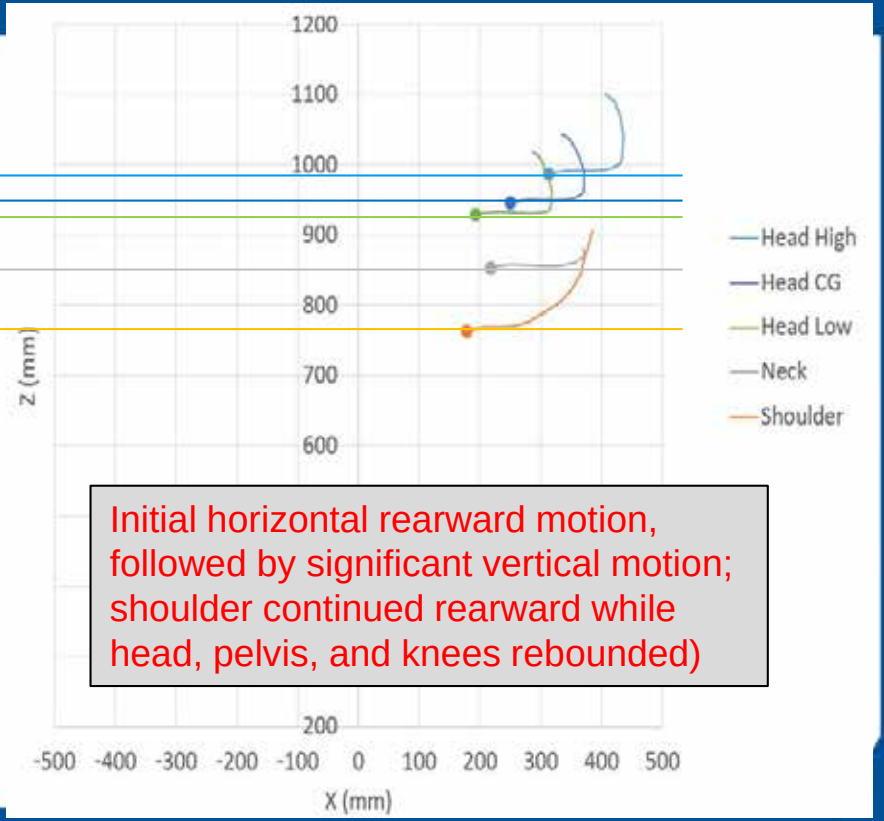


Onboard HS Video



Kinematics





Initial horizontal rearward motion, followed by significant vertical motion; shoulder continued rearward while head, pelvis, and knees rebounded)

Injuries

Cervical spine (640284.1)

- C3/C4 and C4/C5 moderate laxity

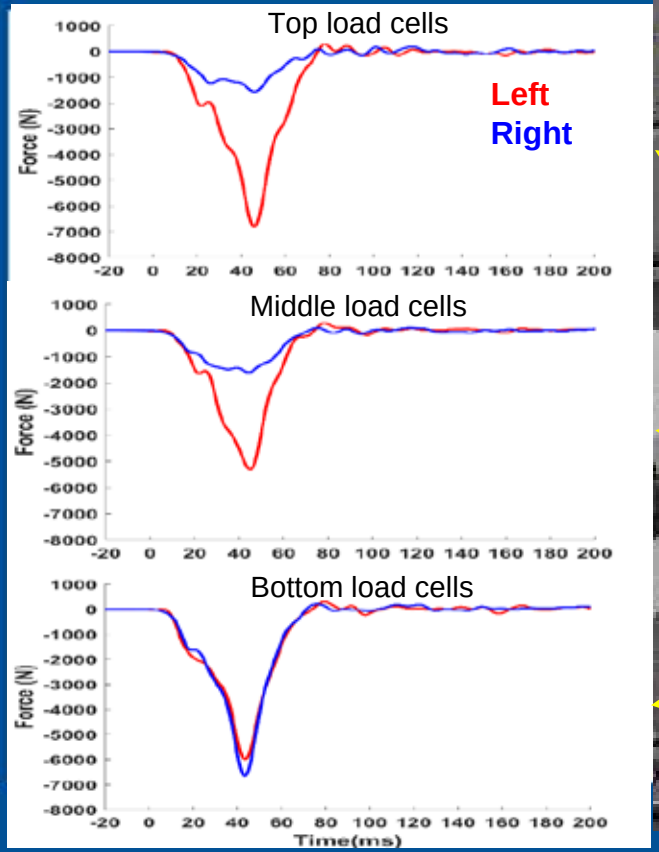
Scapula (750952.2)

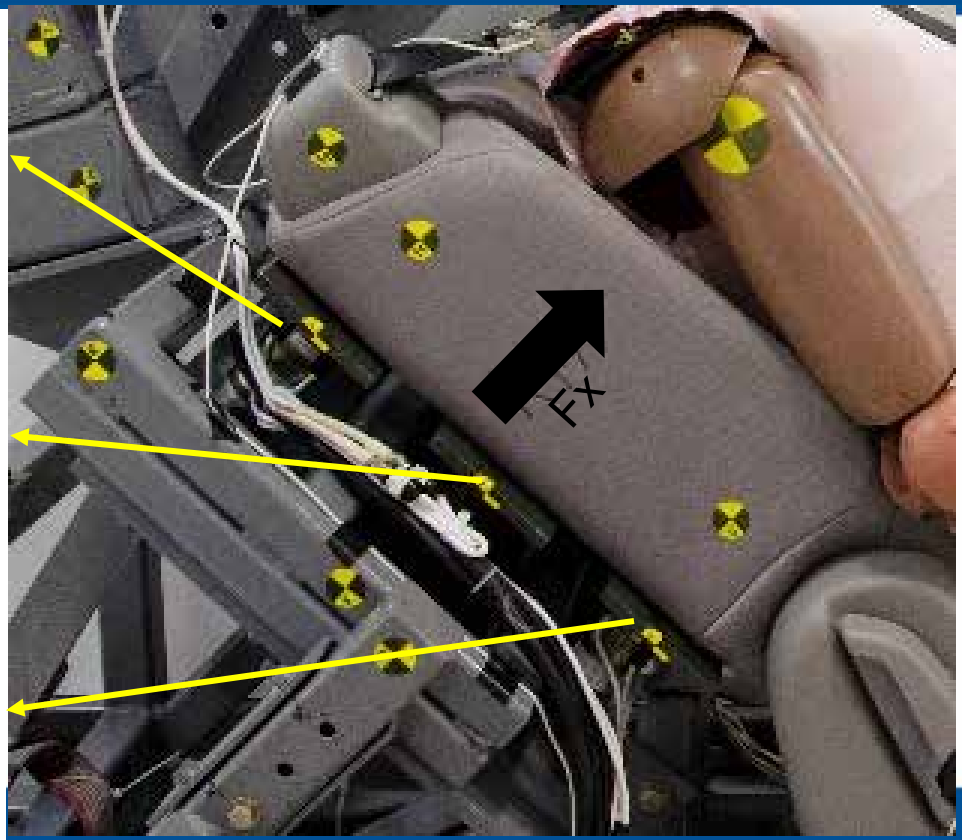
- Left side – comminuted, medial border and superior angle

Ribs (≥3 rib fx; 450203.3)

- R3: fracture through cutaneous cortex only
- L3: fracture through both cortices
- L6: fracture at CCJ, through cutaneous cortex only
- L7: fracture at CCJ, through cutaneous cortex only

Seat Reactions: Seat Back Fx





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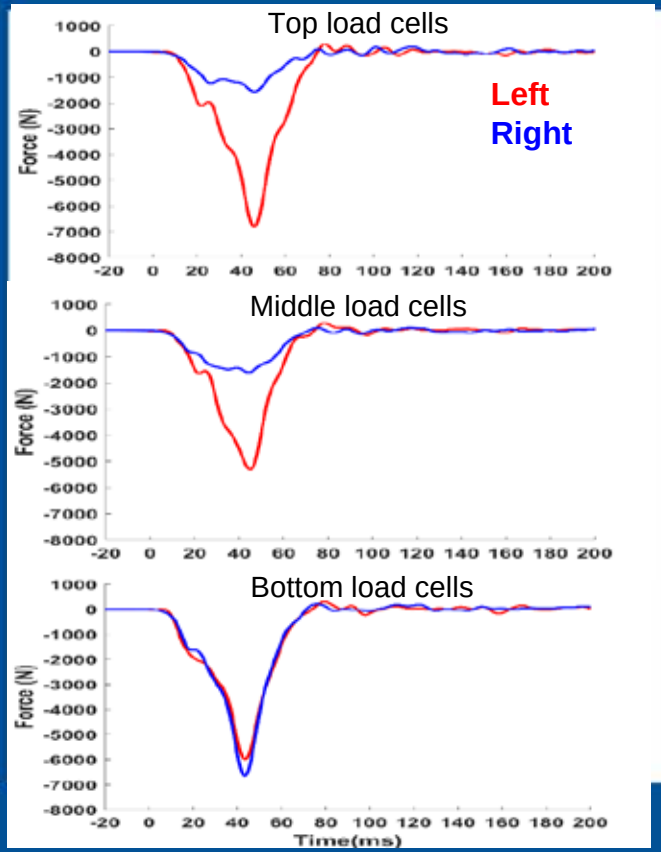
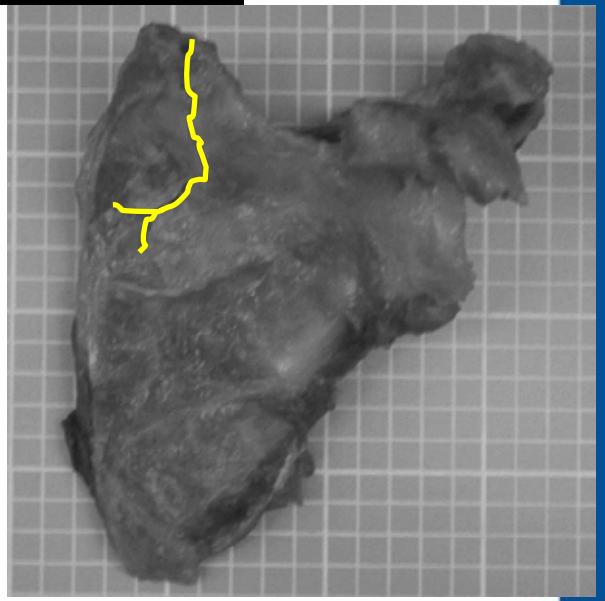
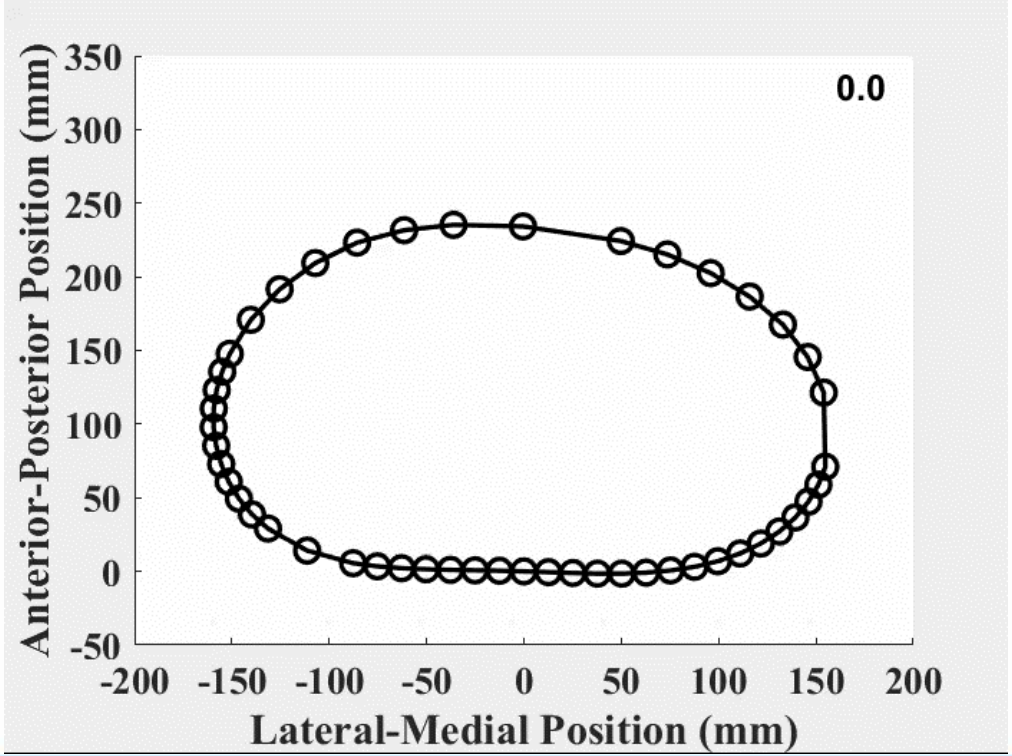
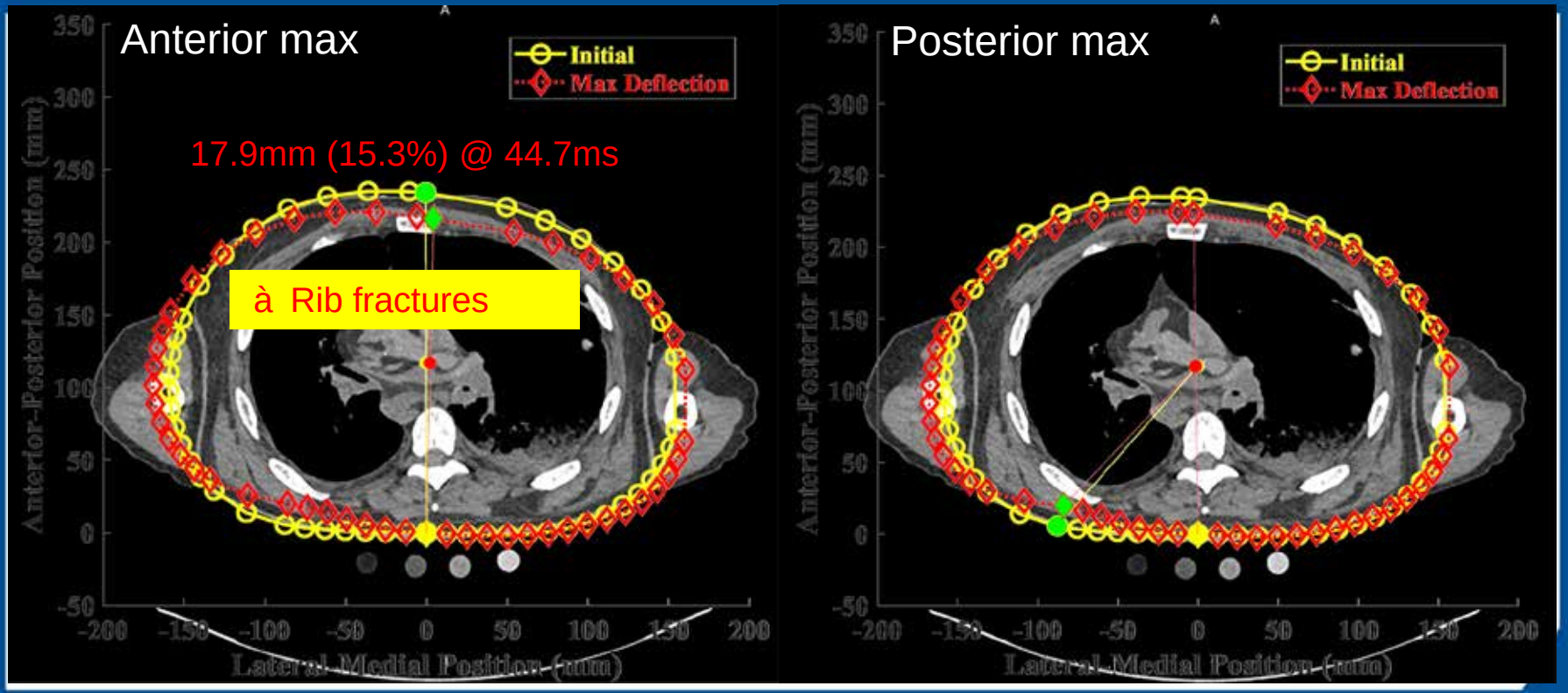




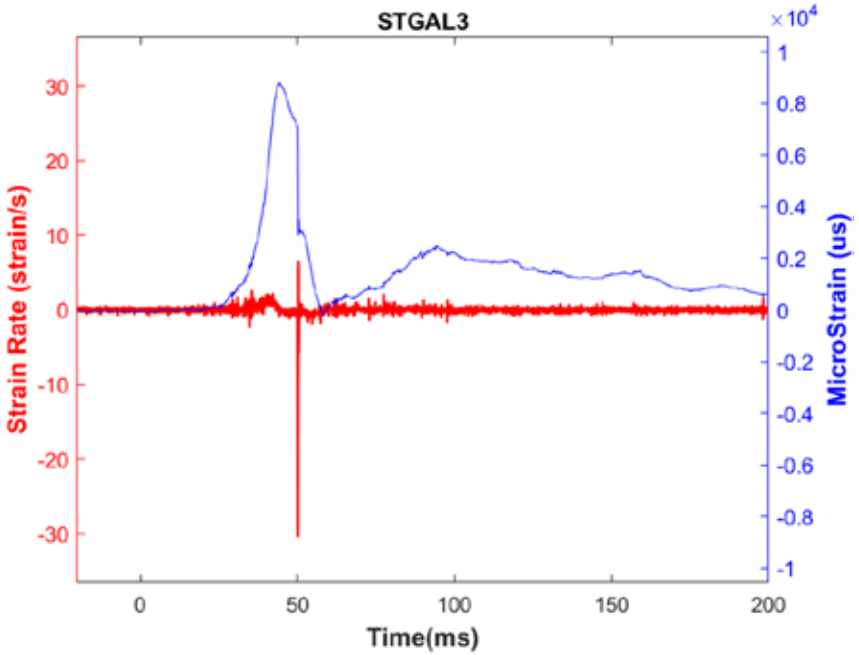
Chest Deformation vs. Time

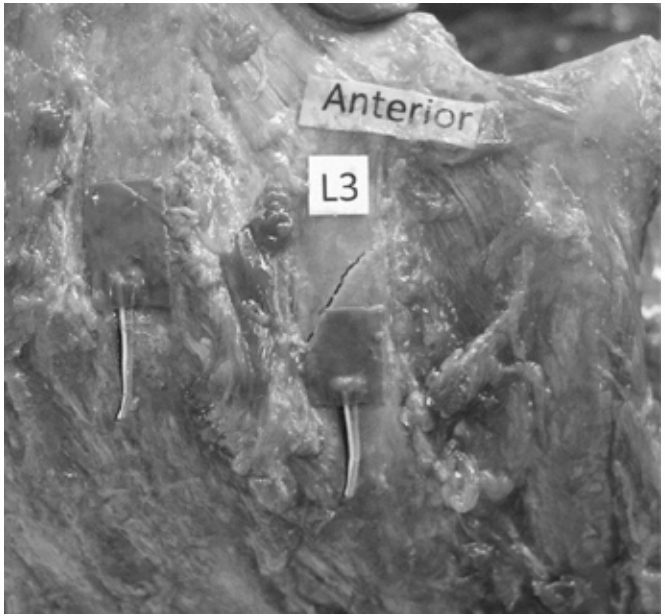


Chest Deflection



Rib (L3) Fracture





Summary

- **Designed and built a repeatable, realistic as possible, adjustable setup that measures seat reaction loads**
- **Able to match PMHS to UMTRI positioning target**
- **Conducted one PMHS test**
  - Scapula and rib fractures were found (minor C spine injury)
  - Integrated belt system prevented PMHS ejection but may affect injury response in high speed rear impacts
- **Future Work: More PMHS tests (25/45 deg reclined, 24/56 kph)**
  - Develop response targets
  - Matched pair ATD tests to evaluate biofidelity
  - Create injury risk functions

Acknowledgements

- **IBRC at The Ohio State University**
  - Amanda Agnew and Rakshit Ramachandra
  - Julie Mansfield and Arri Willis
  - Angela Tesny and Akshara Sreedhar

- **TRC**
  - Colton Thomas and Brian Suntay
  - Hyun Jung Kwon and Duey Thomas

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New HR Attachment

Seat Reactions: Head Restraint Fx