NHTSA

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Effects of Seatback Recline and Belt Restraint Type on PMHS Injuries in High-speed, Rear-facing Rigid Seat Tests

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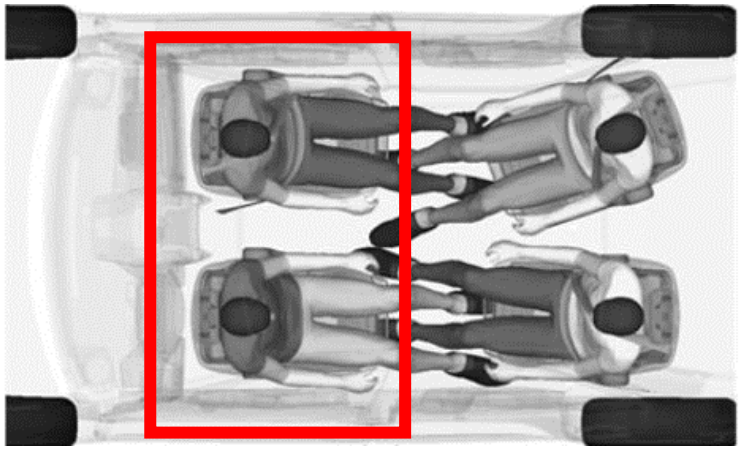
Introduction

- Future vehicle interior cabin designs may incorporate non-standard seating configurations for vehicles with Automated Driving Systems (ADS).
  - One potential configuration is a reclined seat that is rear-facing in a frontal collision
  - Studies using computational models and ATDs [Kitagawa et al., 2017; Jin et al., 2018; Zeller and Manneck, 2019]
    - FE models: validated in low-speeds
    - ATDs: not validated for rear impacts



Kitagawa et al., 2017

Zellmer and Manneck, 2019

Objective

- To investigate biomechanical responses and injuries from Post Mortem Human Subjects (PMHS) in multiple scenarios in a rear-facing seating configuration at high speed frontal impacts
  - Effect of Seat Back Recline (25 deg vs. 45 deg)
  - Effect of Belt Restraint Type (Integrated vs. Fixed D-ring)

Content Warning

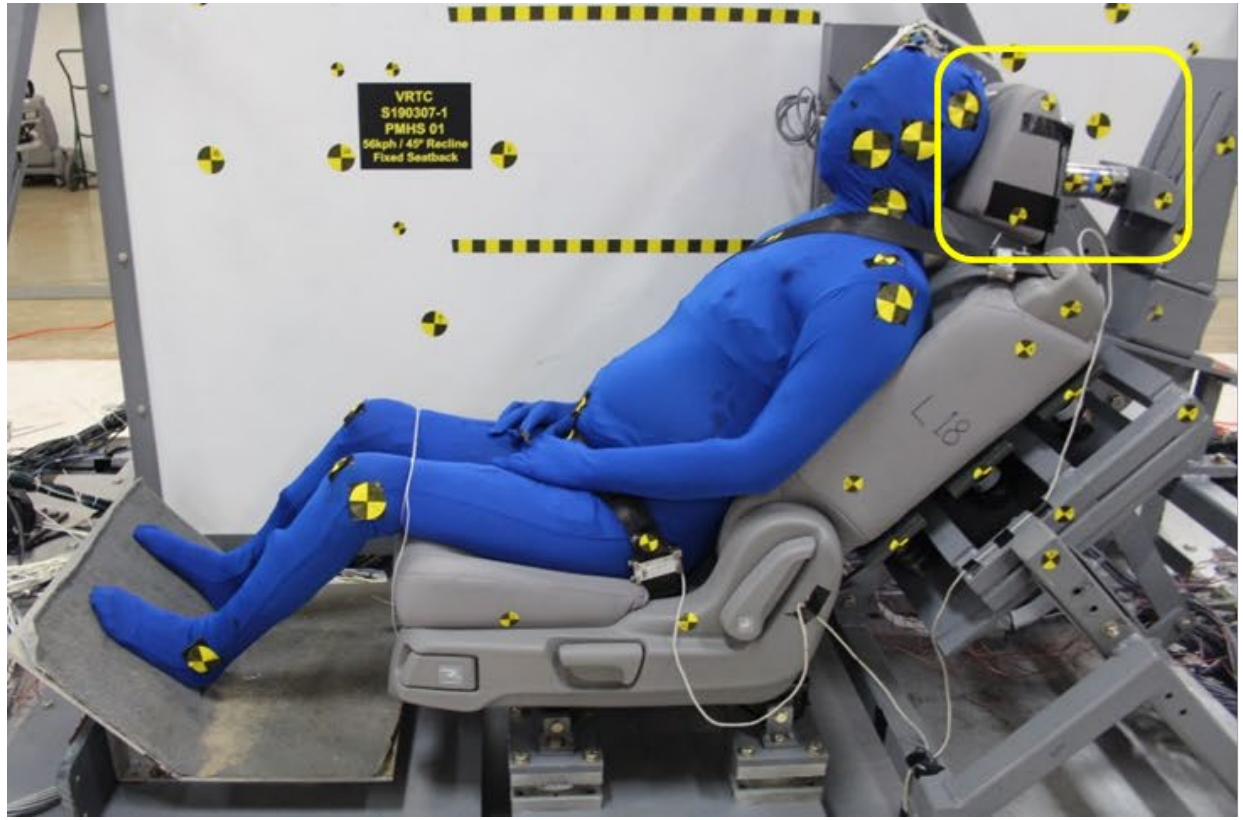
The following slides include cadaveric images that are graphic and may be considered disturbing to some viewers!

Methods

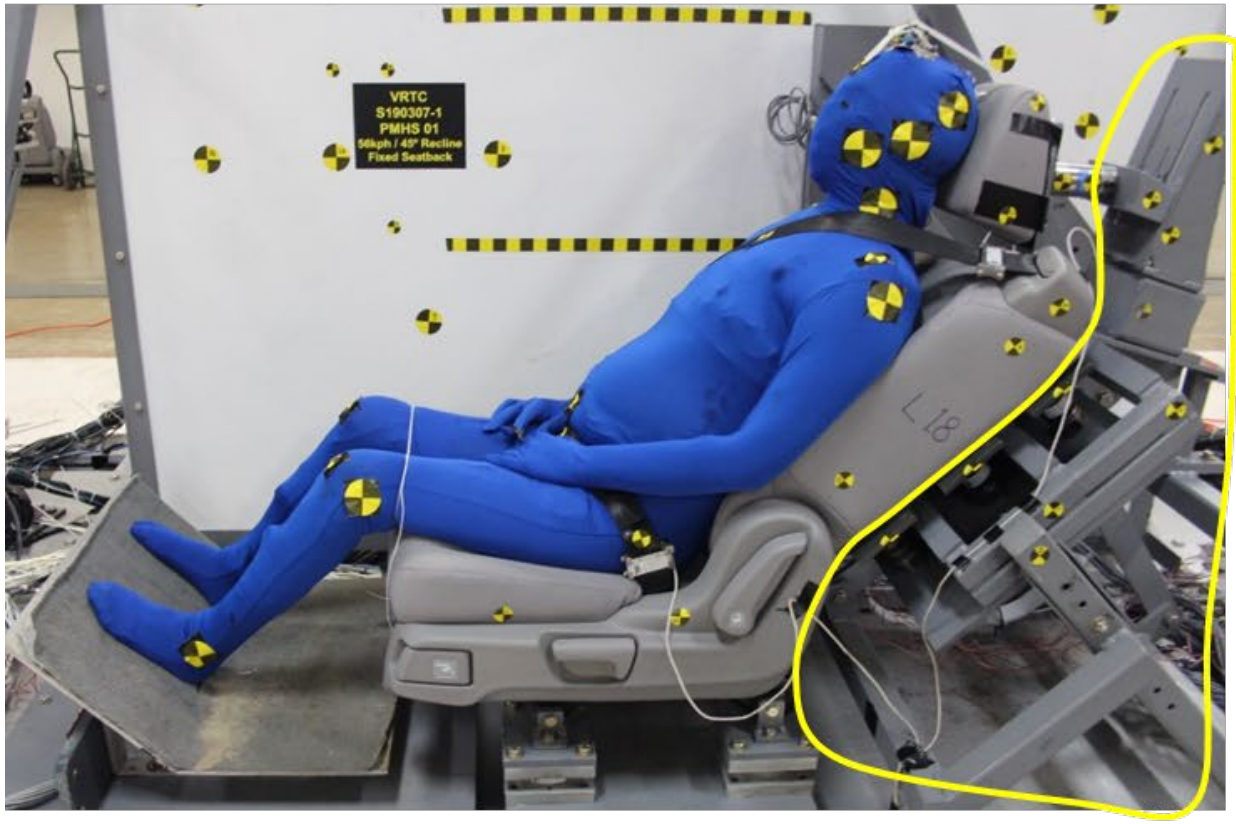
Sled Buck Concept

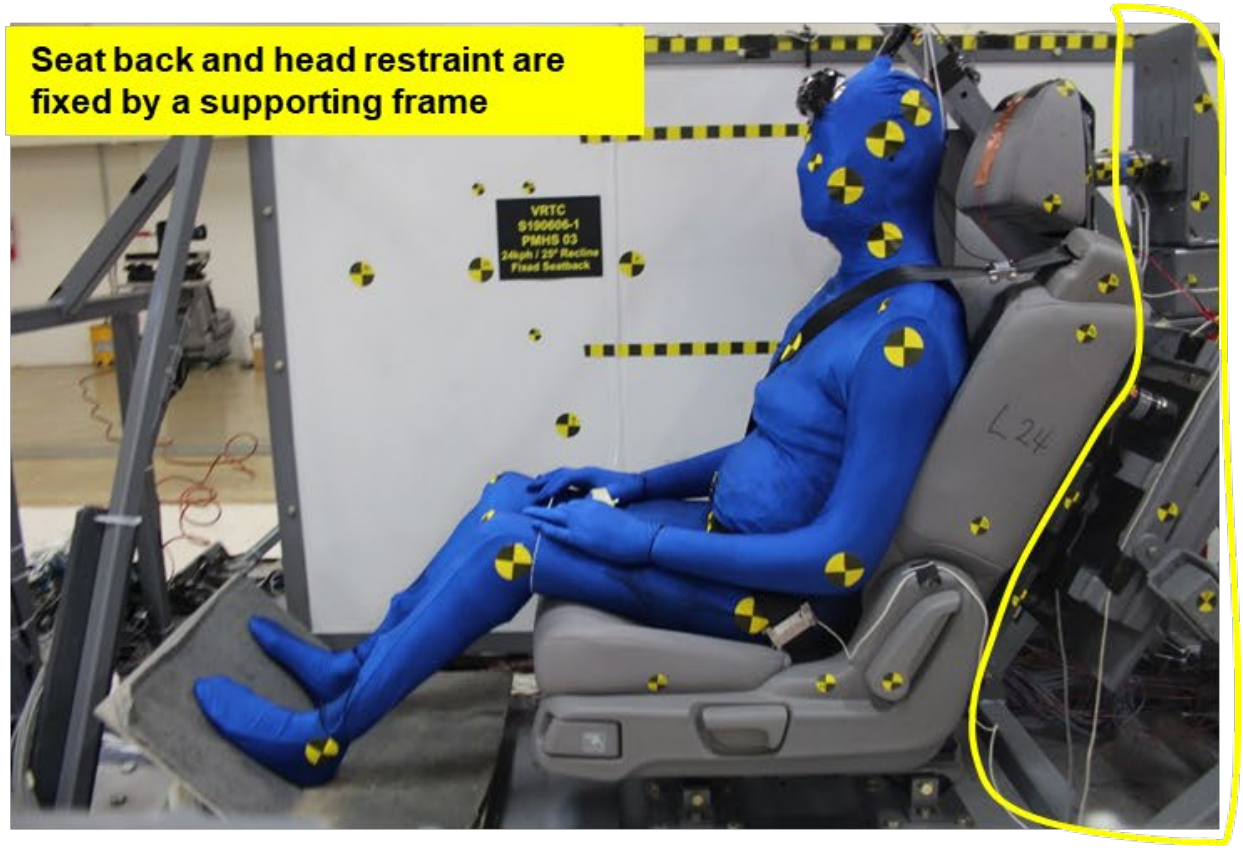
OEM seats: NOT designed for high-speed rear-facing frontal impacts

Sled Buck Description



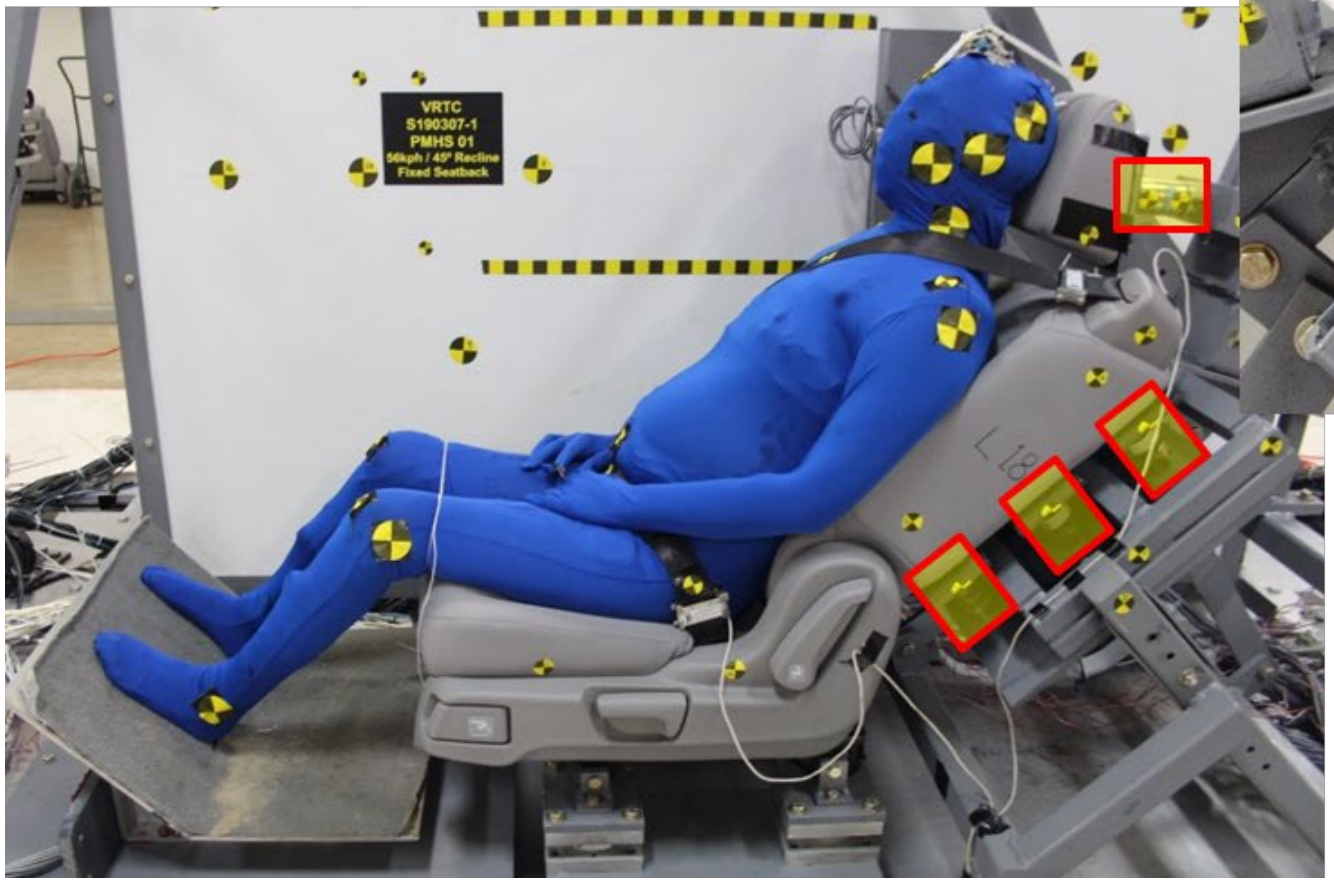
Sled Buck Description

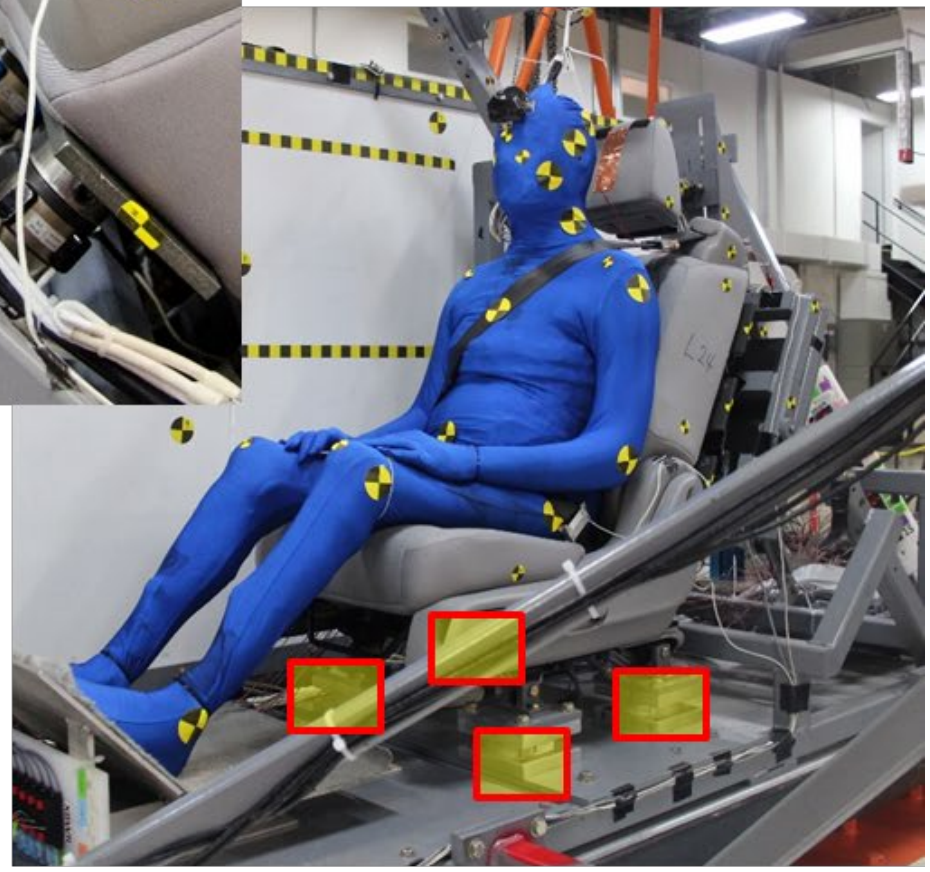




Sled Buck Description

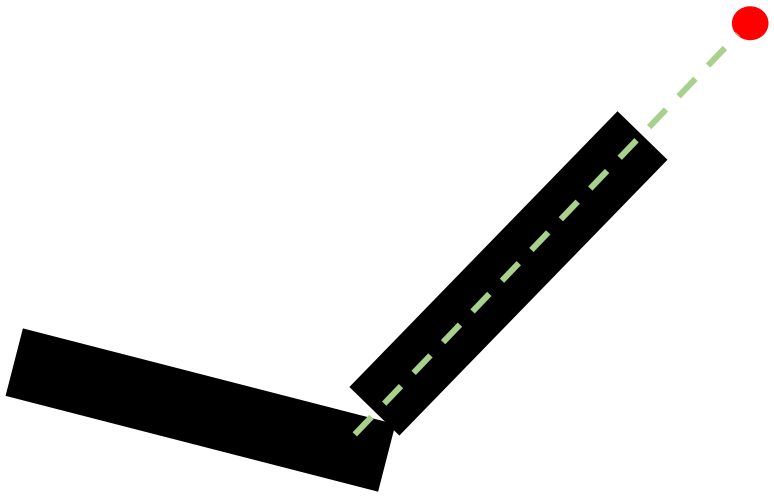
Load cells at head restraint (1), seat back (6), and seat anchors (4) to measure reaction loads

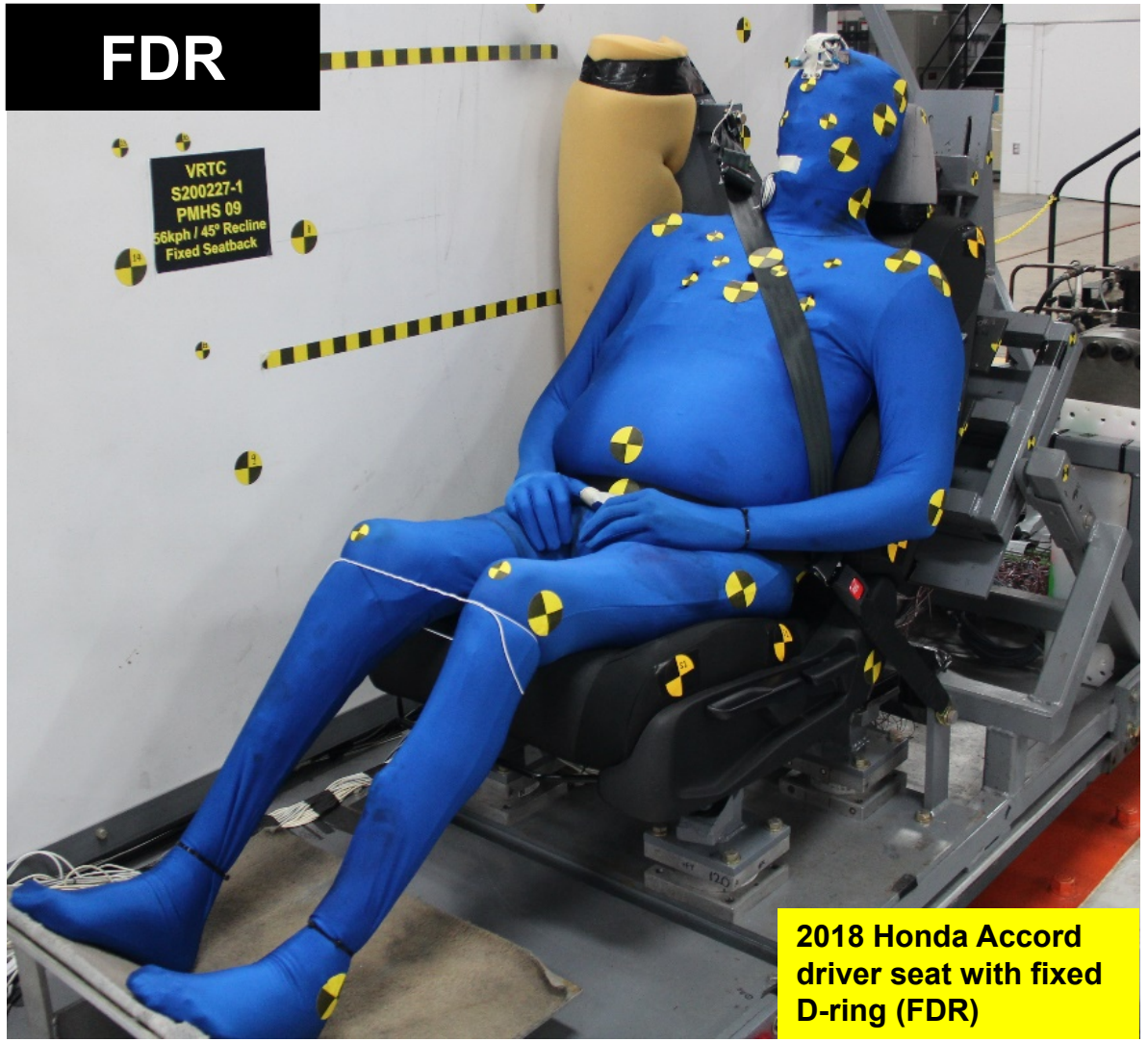




Sled Buck Description

D ring location
45 deg

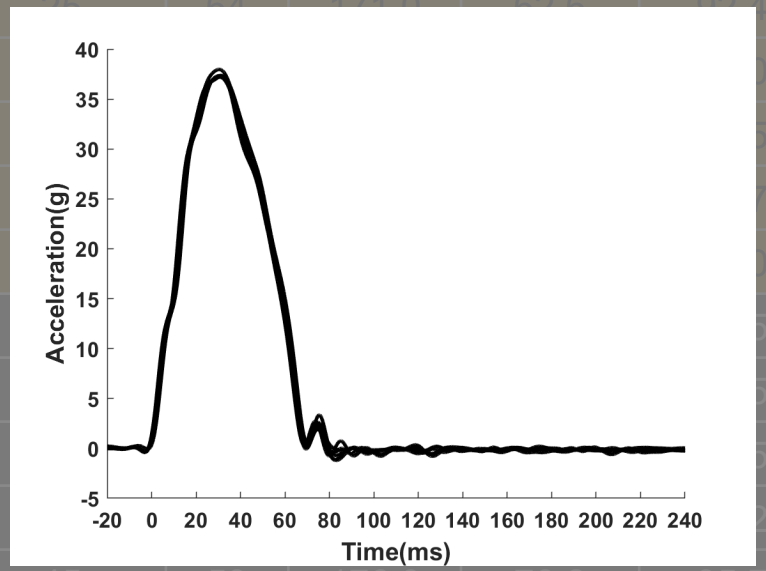


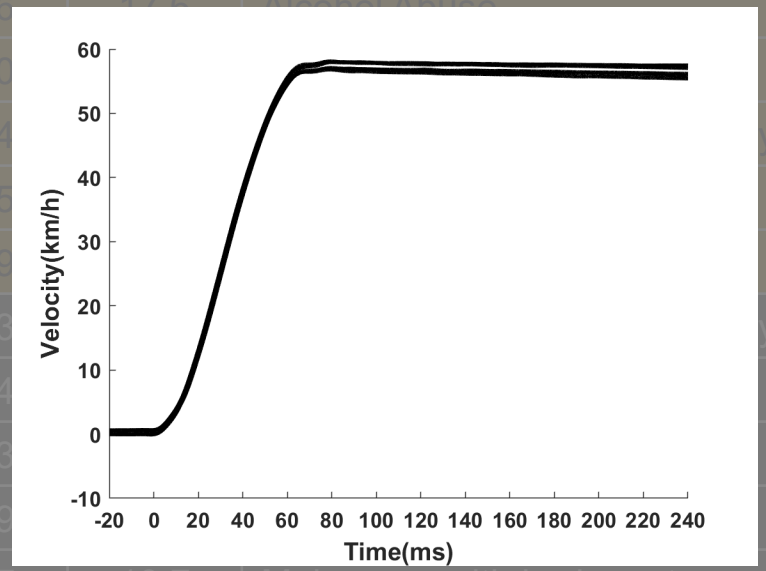


2018 Honda Accord driver seat with fixed D-ring (FDR)

PMHS Characteristics

N=12	Speed	Seat	Recline	Age	Height (cm)	Weight (kg)	Seated Height (cm)	Head Mass (kg)	Chest Depth (cm)	Cause of Death
PMHS01	56	ABTS	45	57	167.0	62.6	90.0	3.8	20.6	Chronic Obstructive Pulmonary Disease
PMHS02	56	ABTS						3.6		
PMHS03	56	ABTS						5.0		
PMHS04	56	ABTS						4.4		y Disease
PMHS05	56	ABTS						3.5		
PMHS06	56	ABTS						3.9		
PMHS09	56	FDR						4.3		y Disease
PMHS10	56	FDR						4.4		
PMHS11	56	FDR						4.3		
PMHS12	56	FDR						3.9		
PMHS13	56	FDR	45	53	176.3	76.2	95.7	3.7	19.7	Melanoma with brain mets
PMHS14	56	FDR	45	63	172.3	85.3	93.0	3.8	23.4	Heart failure
Mean (SD)	N/A	N/A	N/A	61 (5)	176.3 (5.1)	81.7 (13.0)	94.7 (2.1)	4.1 (0.4)	20.9 (1.4)	N/A
50th Male	N/A	N/A	N/A	N/A	45	175	78.2	90.7	4.5	22.9

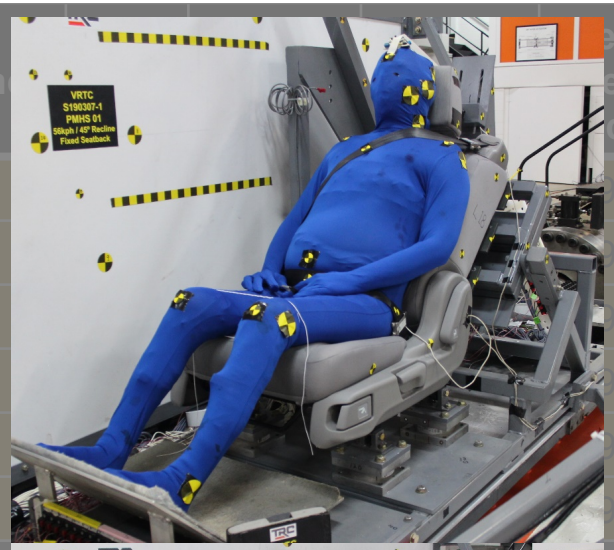


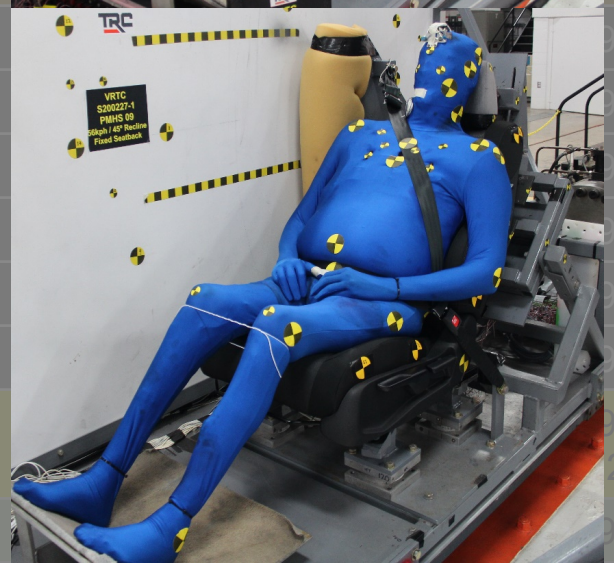


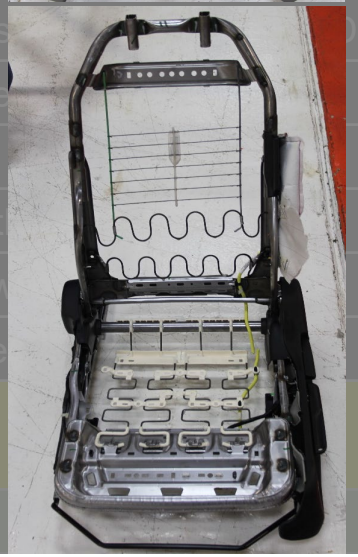
Mertz et al., 2010

PMHS Characteristics

N=12	Speed	Seat
PMHS01	56	ABTS
PMHS02	56	ABTS
PMHS03	56	ABTS
PMHS04	56	ABTS
PMHS05	56	ABTS
PMHS06	56	ABTS
PMHS09	56	FDR
PMHS10	56	FDR
PMHS11	56	FDR
PMHS12	56	FDR
PMHS13	56	FDR
PMHS14	56	FDR
Mean (SD)	N/A	N/A
50th Male	N/A	N/A







Mertz et al., 2010

PMHS Characteristics

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PMHS02	56	ABTS	25	64	171				17	
PMHS03	56	ABTS	25	54	174				20	
PMHS04	56	ABTS	45	59	178				23	ry Disease
PMHS05	56	ABTS	45	62	176				21	
PMHS06	56	ABTS	25	61	176				20	
PMHS09	56	FDR	45	71	187				17	ry Disease
PMHS10	56	FDR	25	62	177				20	
PMHS11	56	FDR	25	65	181				21	
PMHS12	56	FDR	25	58	177				21	
PMHS13	56	FDR	45	53	176				19	
PMHS14	56	FDR	45	63	172				23	
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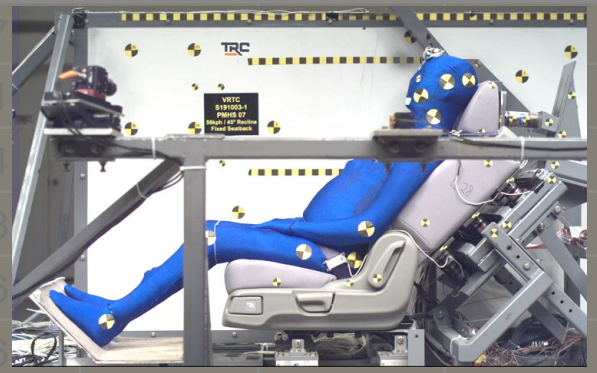
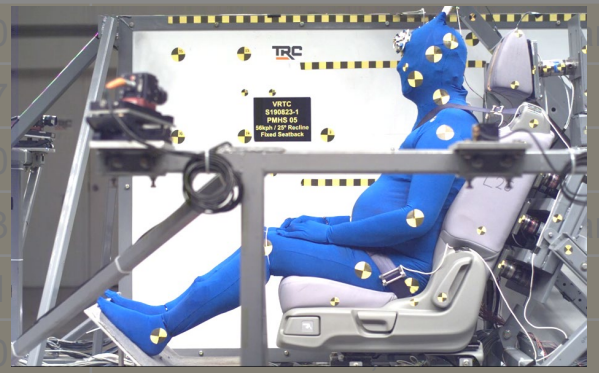
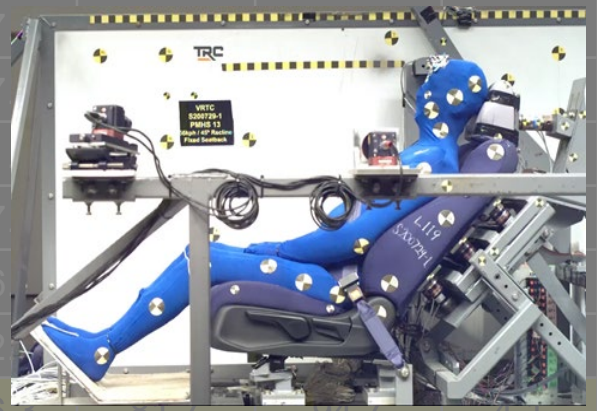
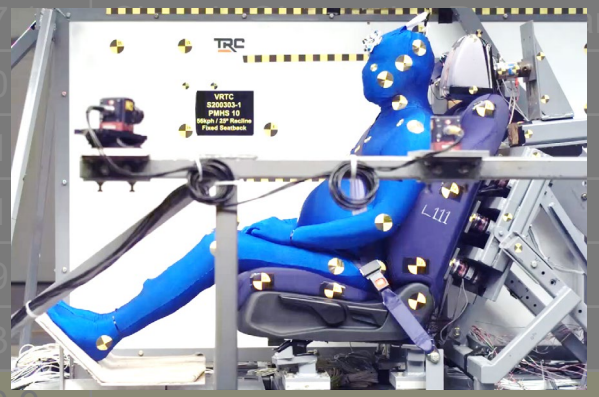


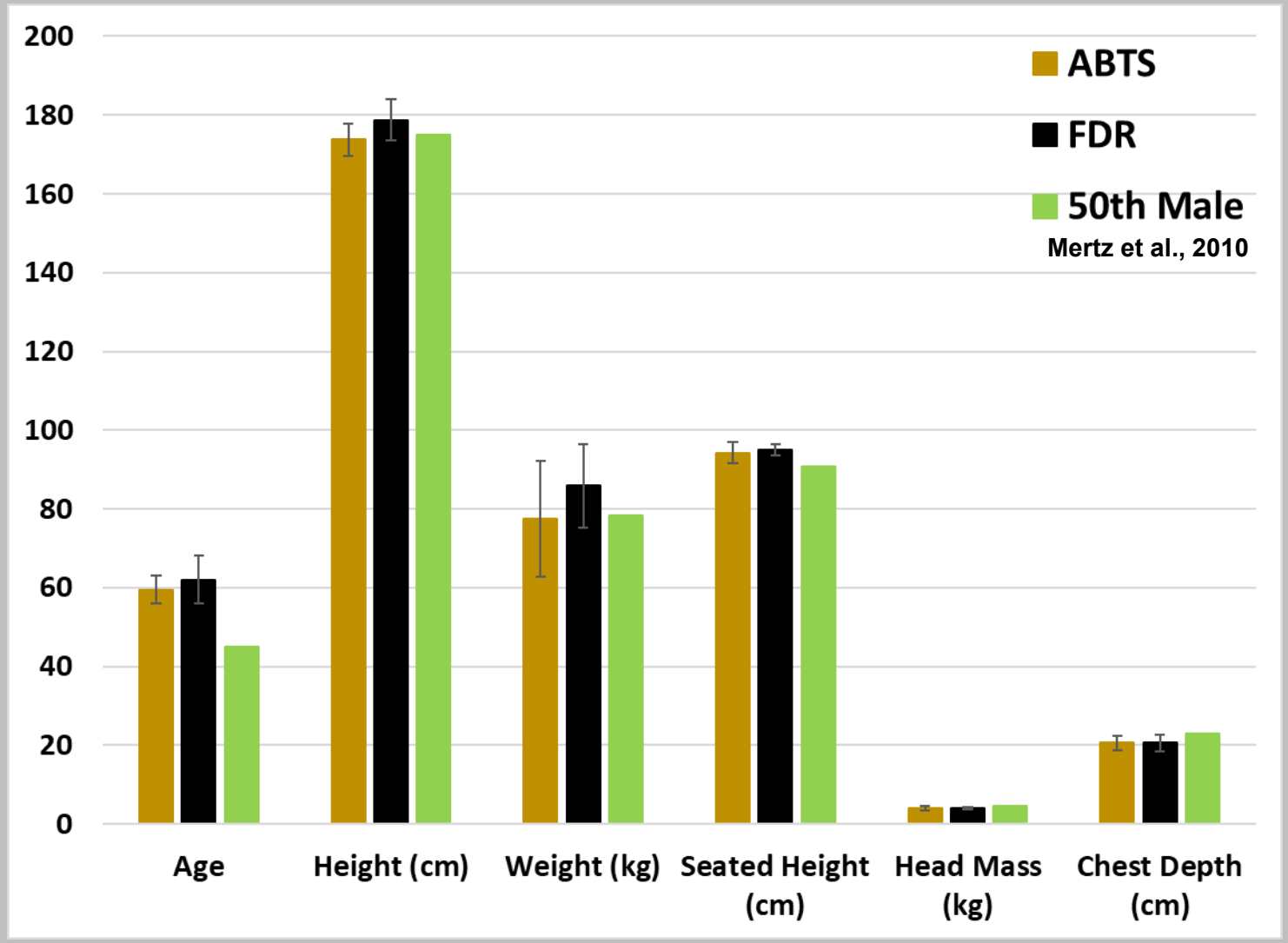






Mertz et al., 2010

PMHS Characteristics



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PMHS02	56	ABTS	25	64	171.0	62.6	92.4	3.6	17.6	Alcohol Abuse
PMHS03	56	ABTS	25	54	174.0	93.9	97.0	5.0	20.6	Choking and asphyxiation
PMHS04	56	ABTS	45	59	178.0	96.2	96.5	4.4	23.2	Chronic Obstructive Pulmonary Disease
PMHS05	56	ABTS	45	62	176.0	77.1	95.7	3.5	21.2	Pancreatic CA
PMHS06	56	ABTS	25	61	176.5	72.6	94.0	3.9	20.2	Ischemic stroke, heart failure
PMHS09	56	FDR	45	71	187.5	89.4	96.5	4.3	17.1	Chronic Obstructive Pulmonary Disease
PMHS10	56	FDR	25	62	177.8	100.7	94.5	4.4	20.1	Cardiac Arrest
PMHS11	56	FDR	25	65	181.0	92.1	96.5	4.3	21.7	Stroke
PMHS12	56	FDR	25	58	177.8	71.7	94.2	3.9	21.1	Lung CA with mets
PMHS13	56	FDR	45	53	176.3	76.2	95.7	3.7	19.7	Melanoma with brain mets
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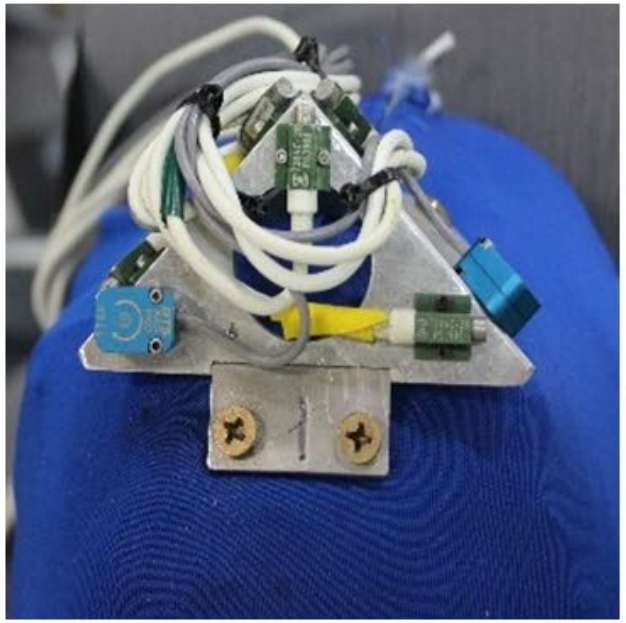
Mertz et al., 2010

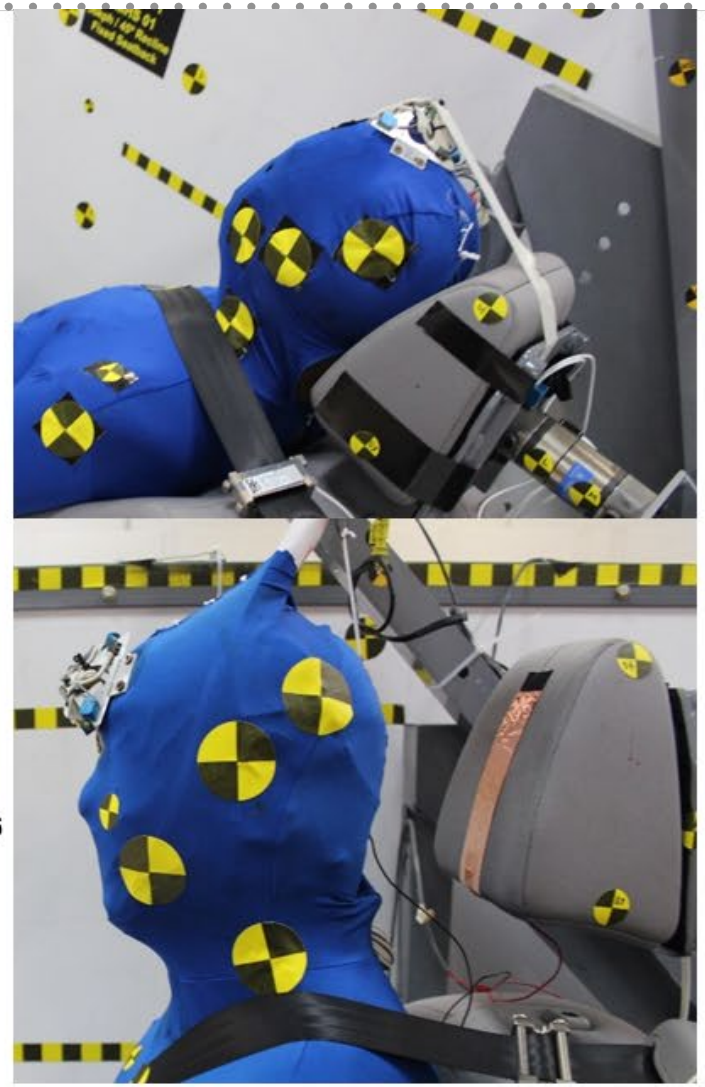
Instrumentation

6aω

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



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



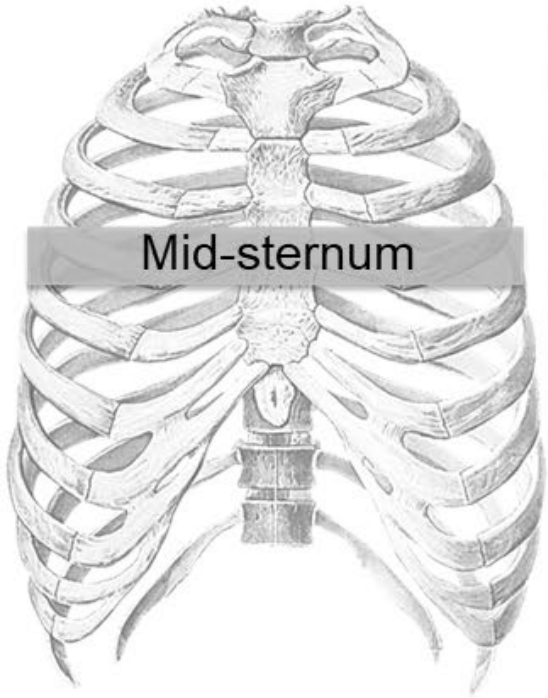
Instrumentation

6aω

Chestband

Strain Gauges

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



Instrumentation

6aω

Chestband

Strain Gauges

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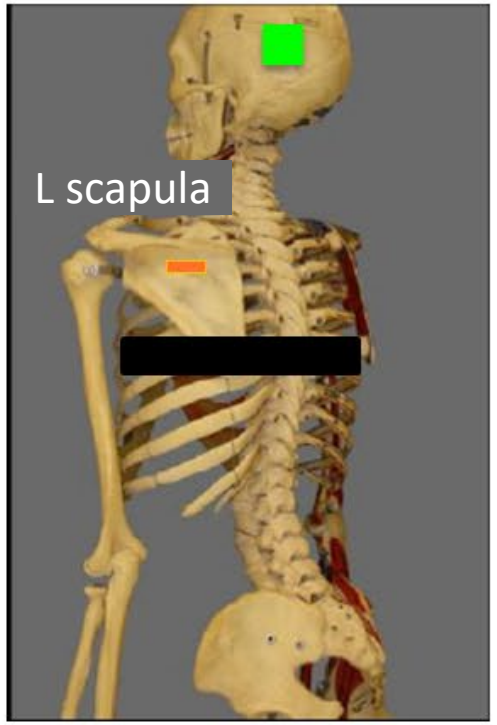
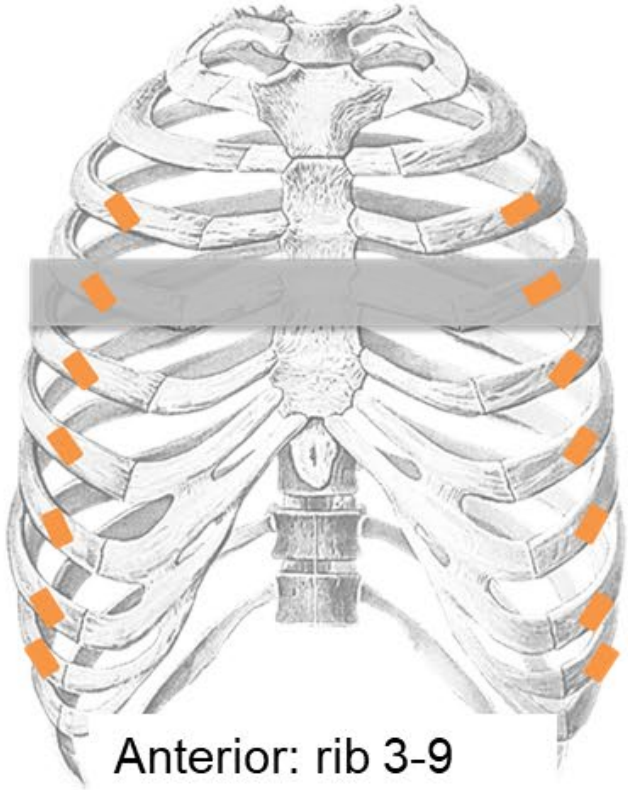
T12	
S1	
Pelvis	
Femur	
Tibia	





Anterior: rib 3-9

Posterior: rib 3-10

Instrumentation

6aω
Chestband
Strain Gauges
3aω

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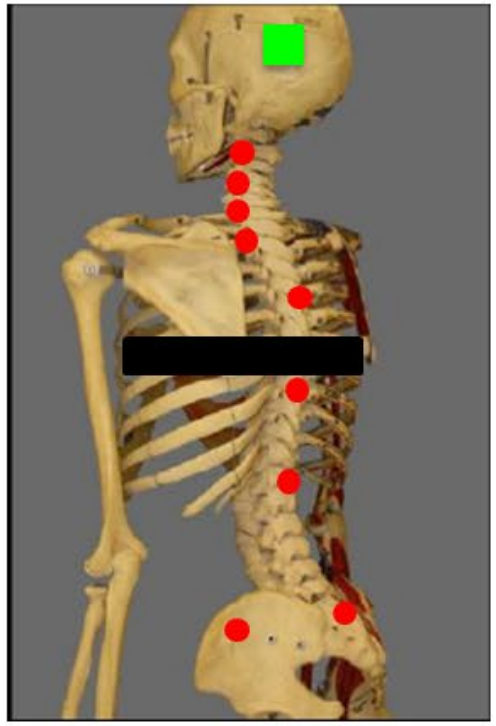
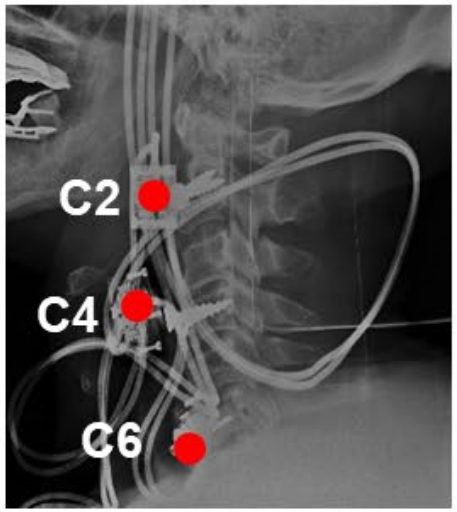
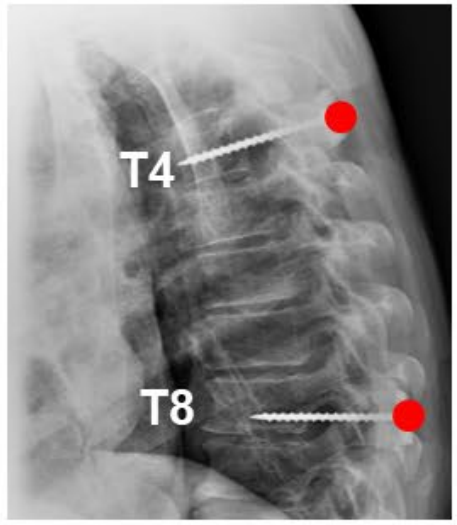
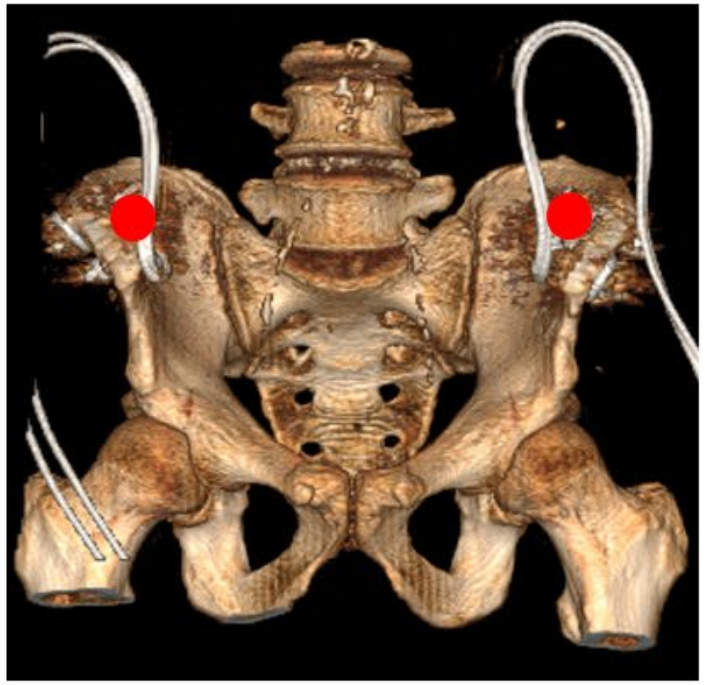
Pelvis	
Femur	
Tibia	









Instrumentation

6aω
Chestband
Strain Gauges
3aω

	PMHS
Head	
Chest	
C2/4/6	
T1	
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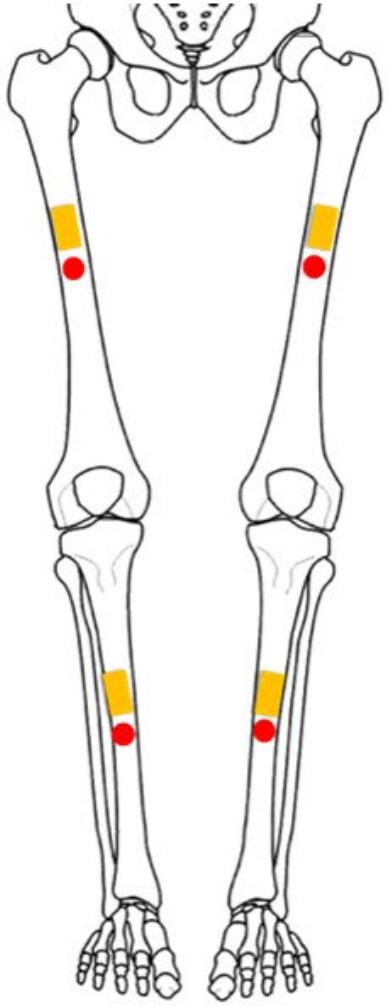
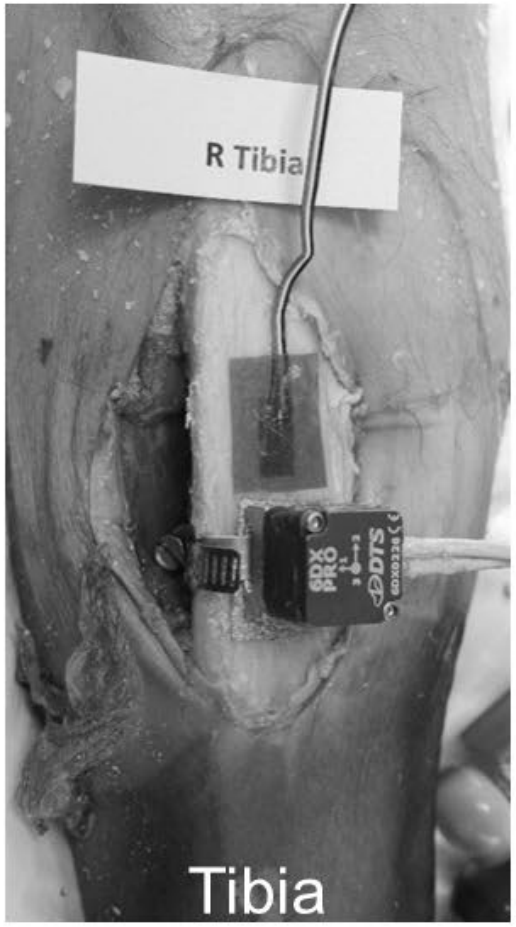
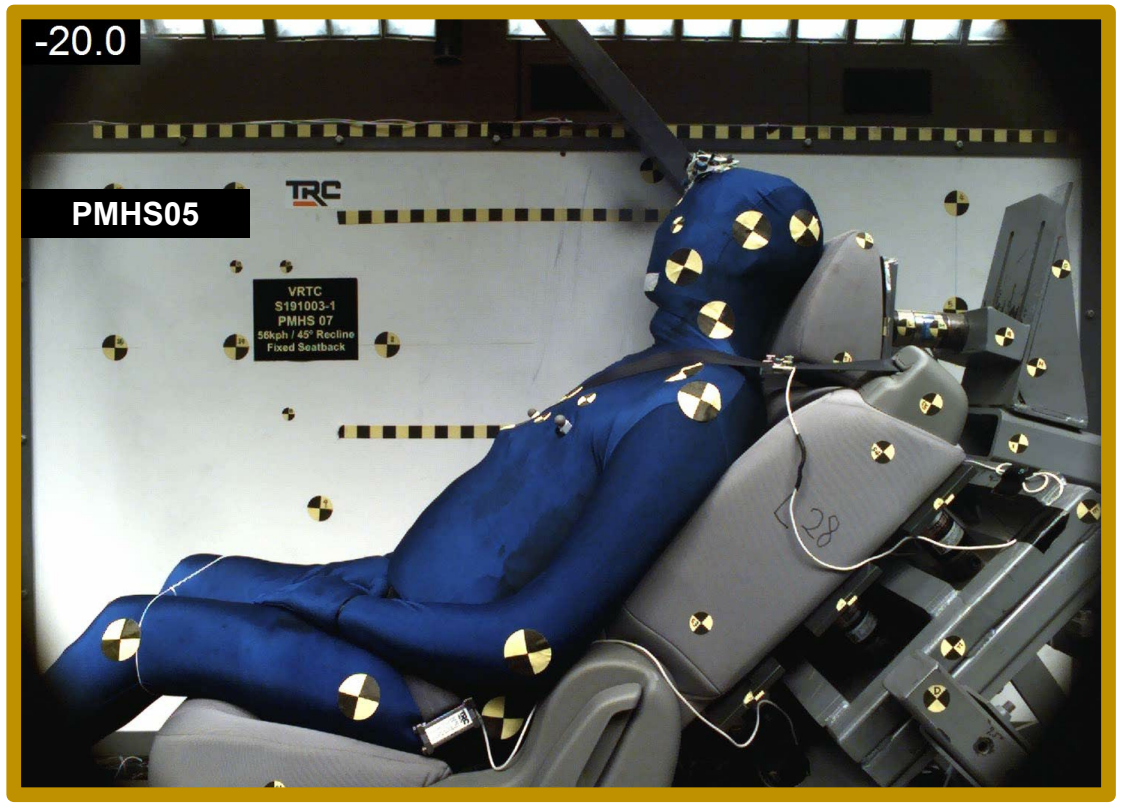


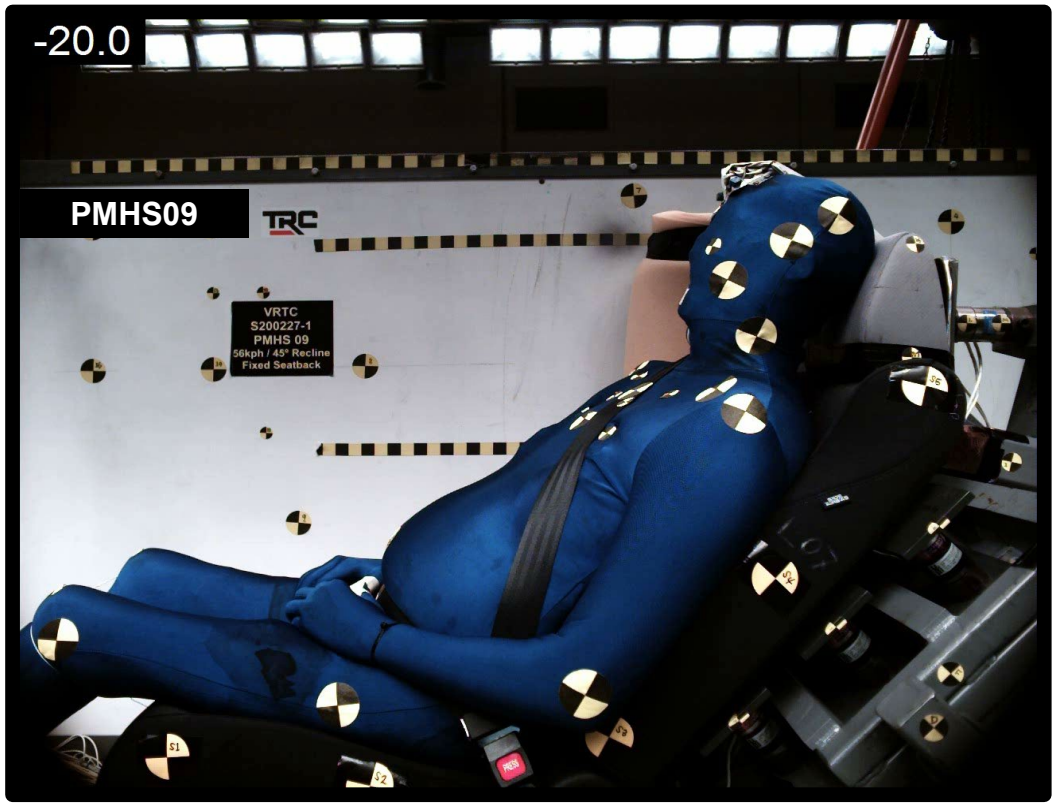


Results
(Preliminary Results)

High Speed Videos – ABTS vs. FDR

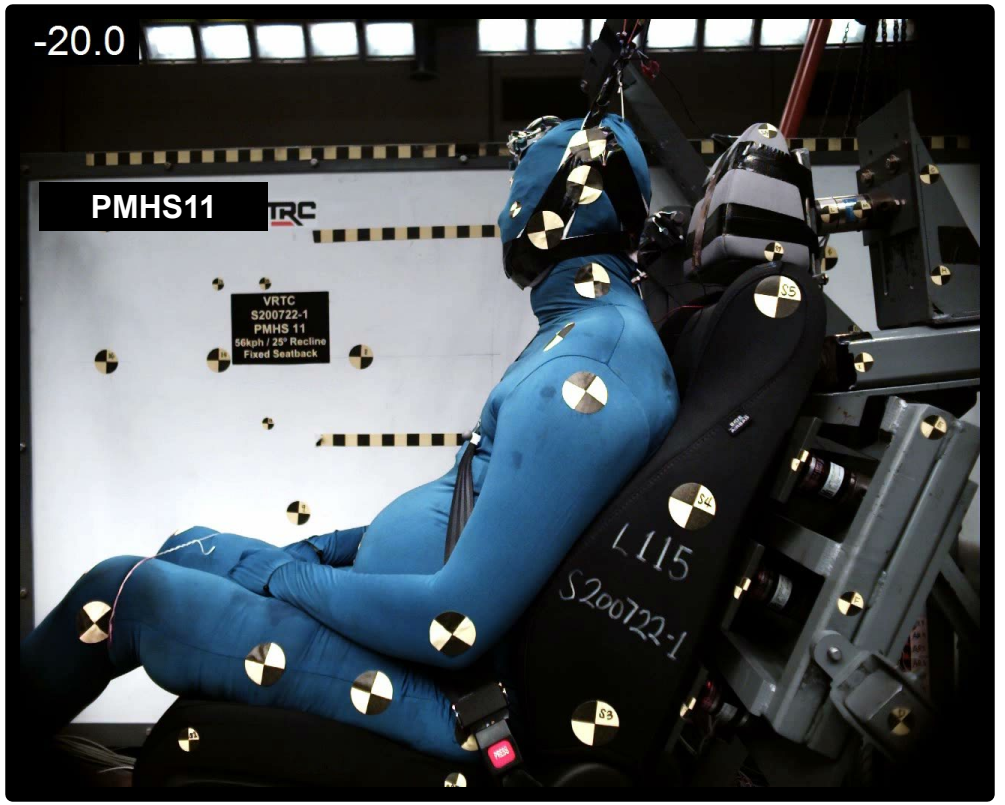
45 degree recline





High Speed Videos – ABTS vs. FDR

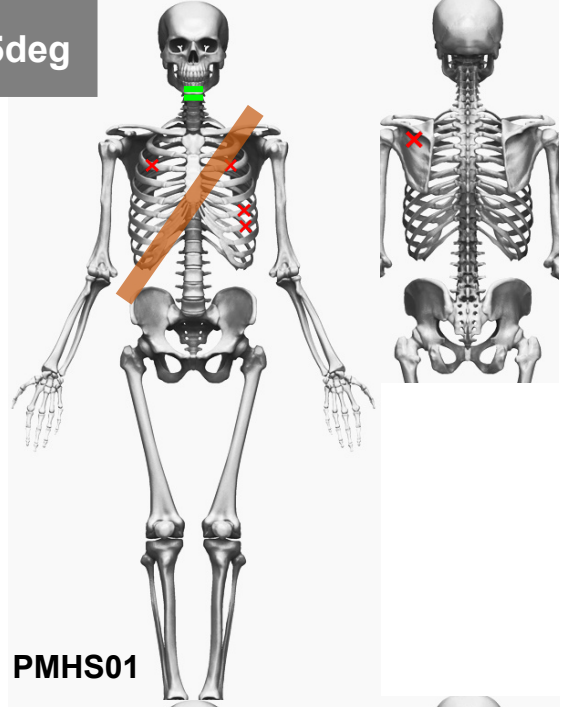
25 degree recline



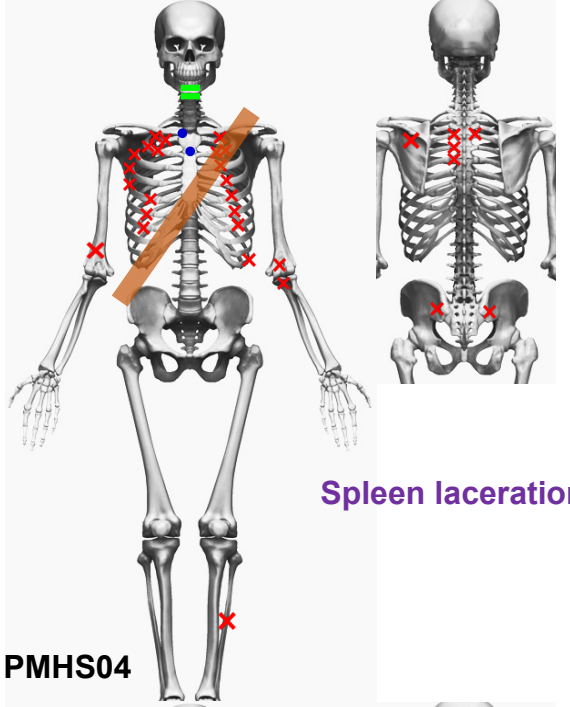
ABTS

FDR

45deg

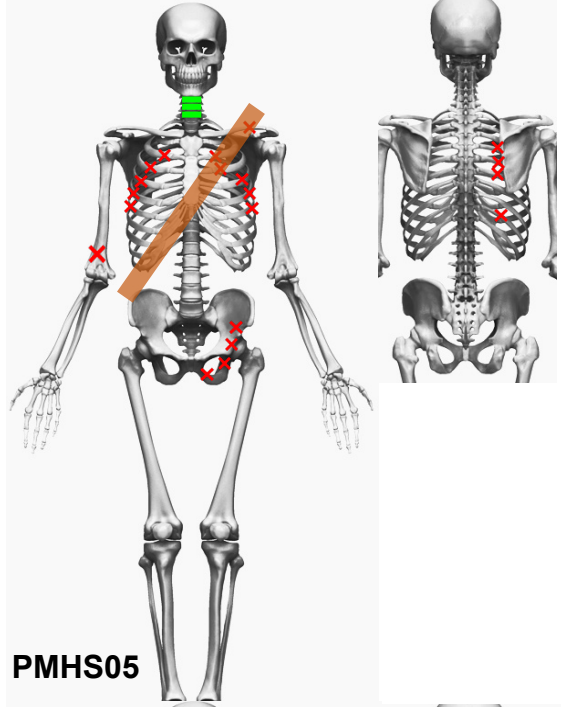


PMHS01



Spleen laceration

PMHS04

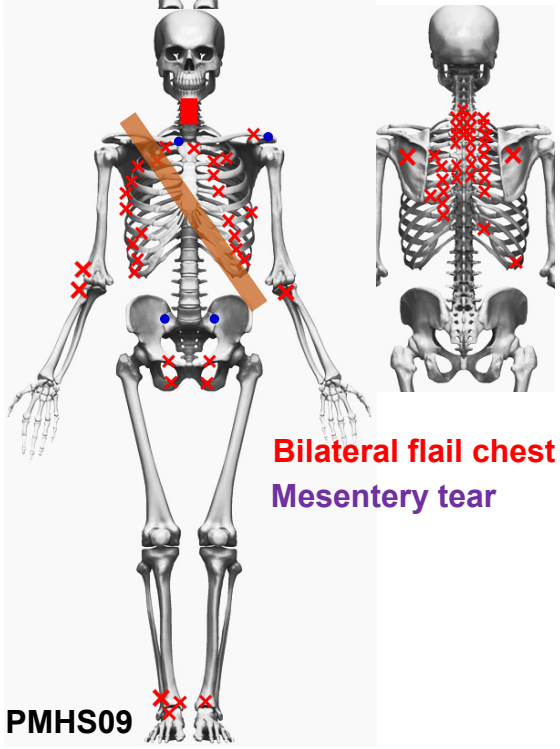


PMHS05

laxity

Fracture

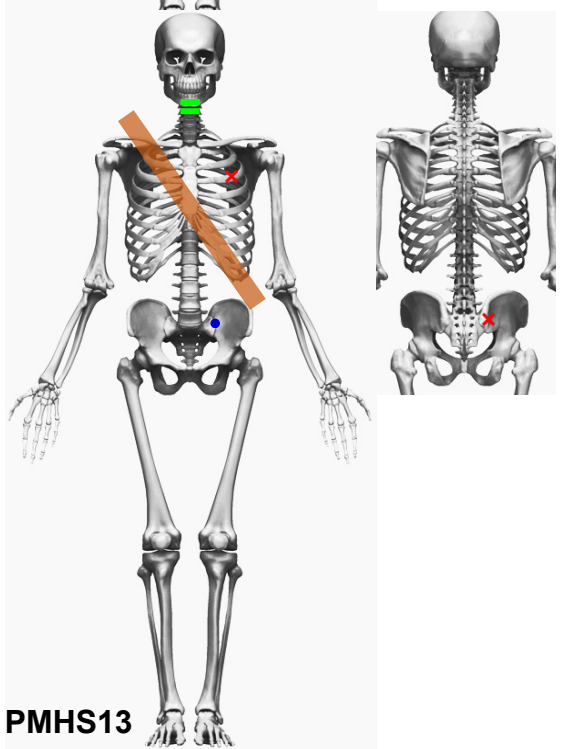
Joint damage



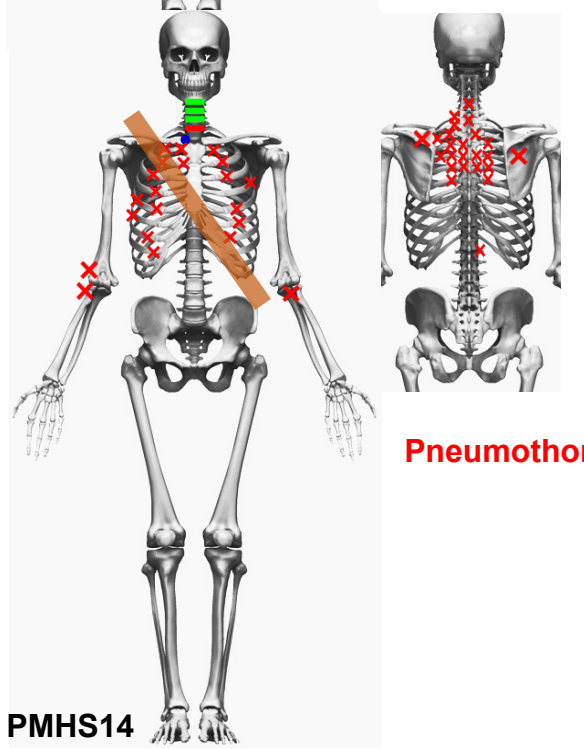
Bilateral flail chest

Mesentery tear

PMHS09



PMHS13



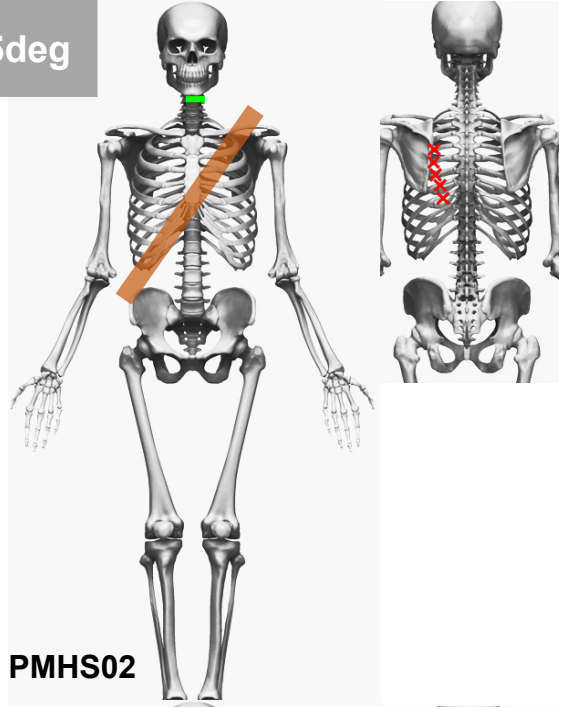
Pneumothorax

PMHS14

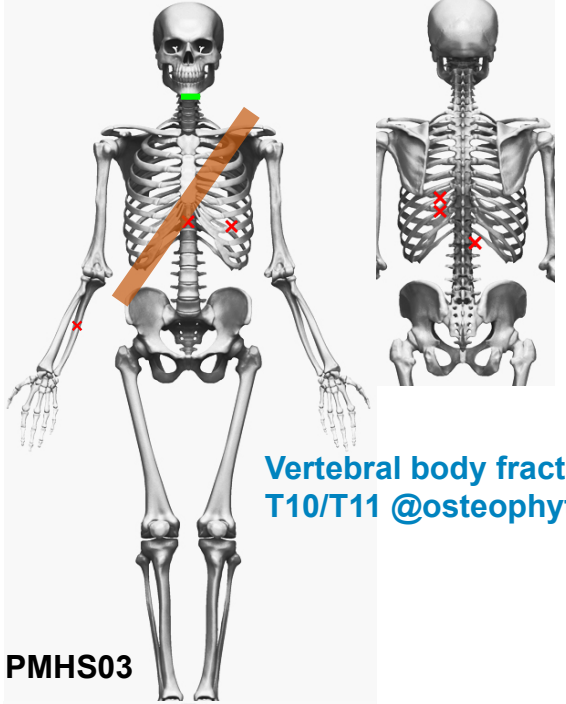
ABTS

FDR

25deg

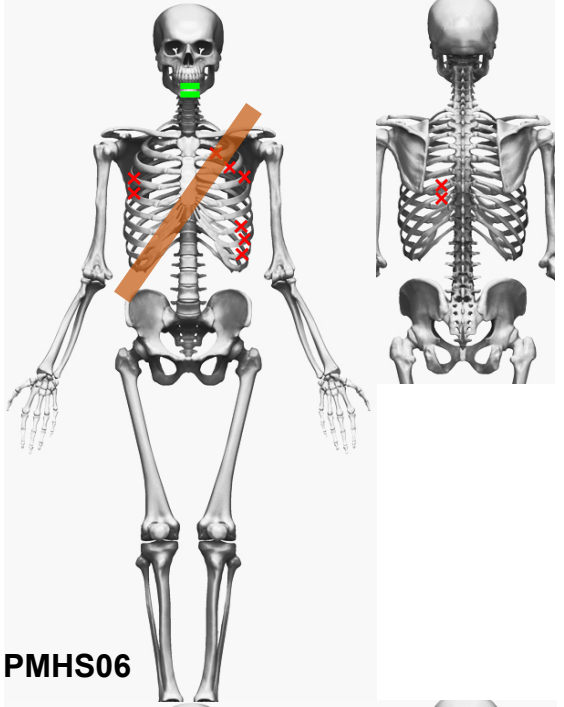


PMHS02



Vertebral body fracture at T10/T11 @osteophyte

PMHS03

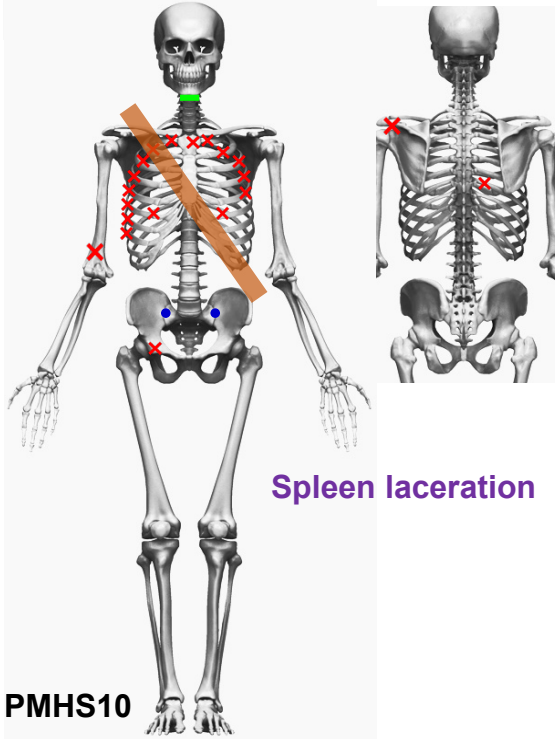


PMHS06

laxity

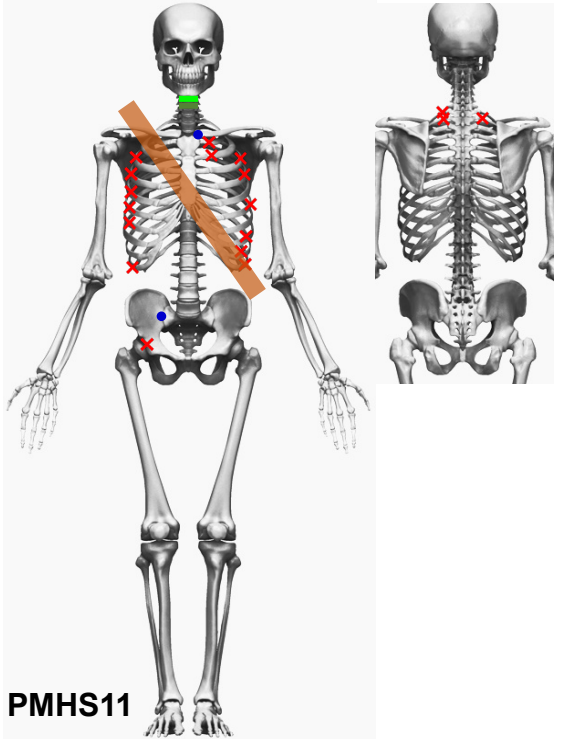
Fracture

Joint damage

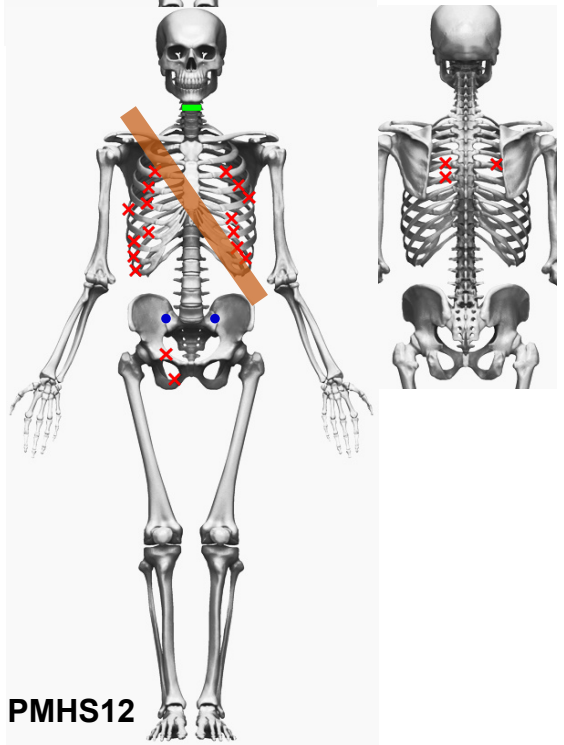


Spleen laceration

PMHS10



PMHS11



Pneumothorax

PMHS12

Ramping Behavior
→ Hyperextension in FDR

ABTS 45 Deg

ABTS 25 Deg

FDR 45 Deg

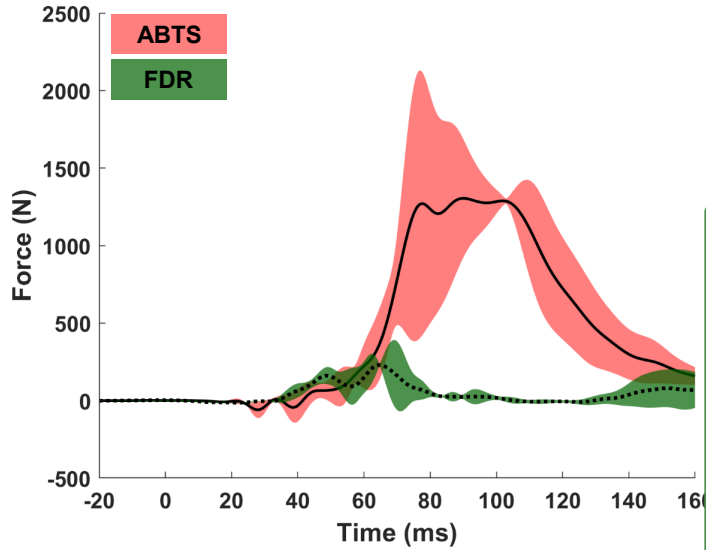
FDR 25 Deg

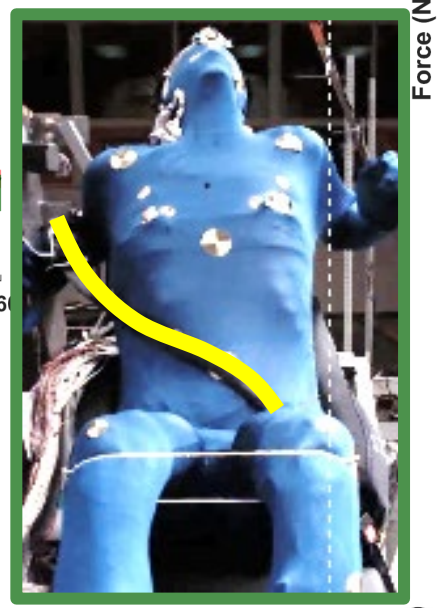
Seat Belt Loads

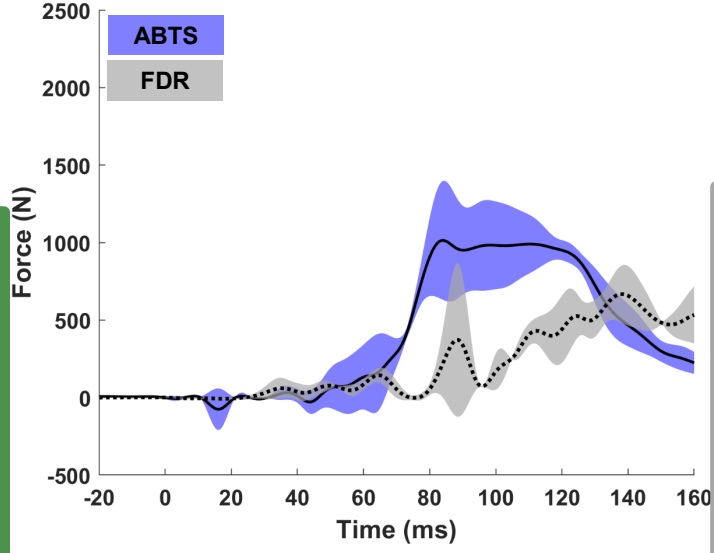
45 deg

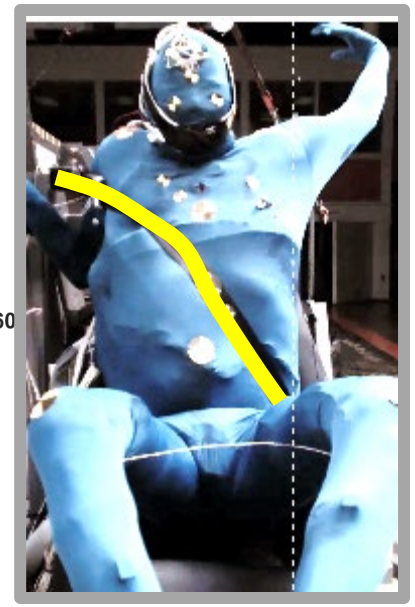
25 deg

Shoulder Belt

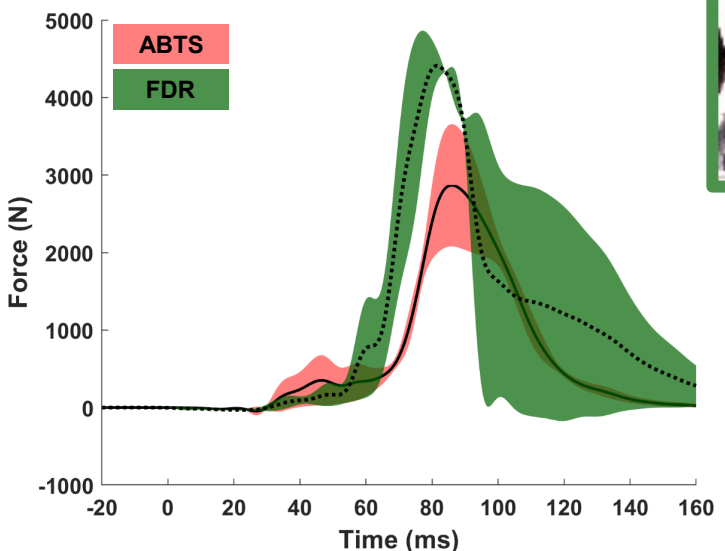


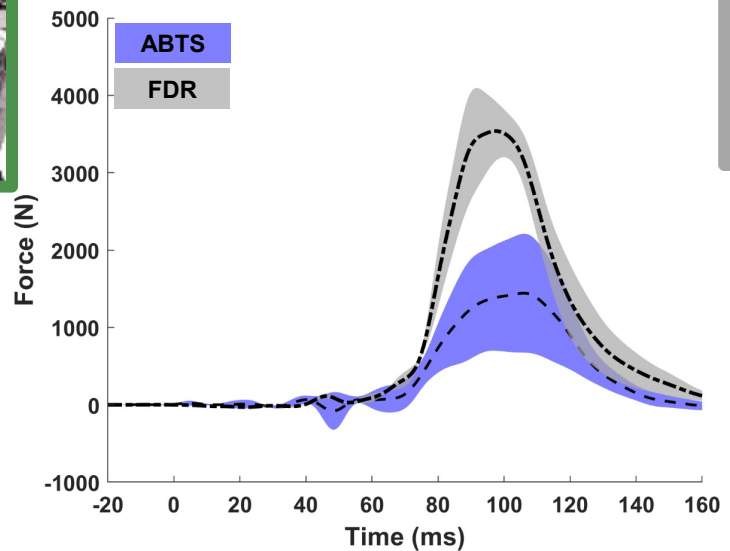






Lap Belt

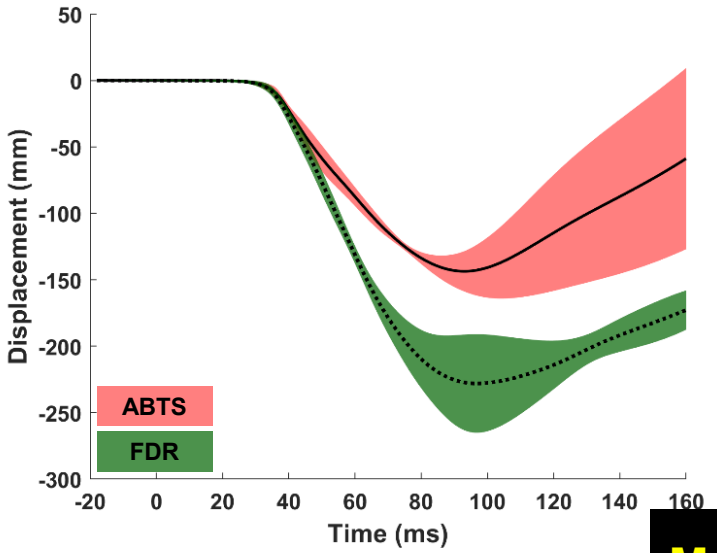




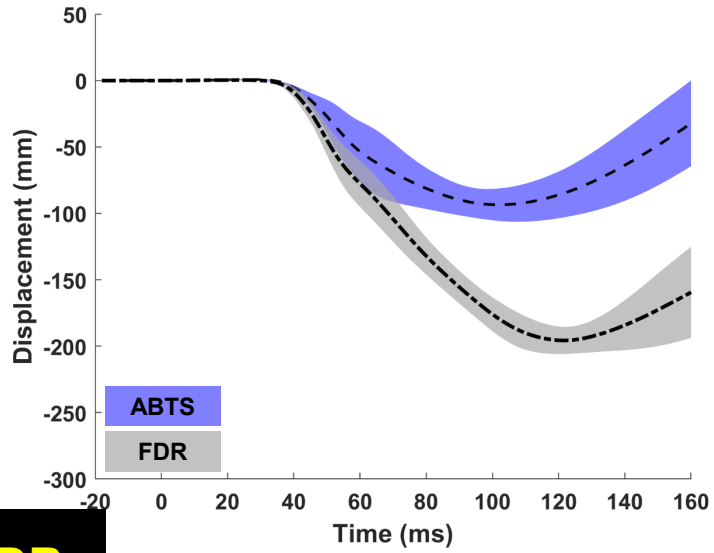
Head/Pelvis Z-Displacement

Head

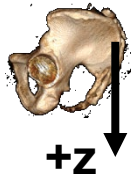
45 deg



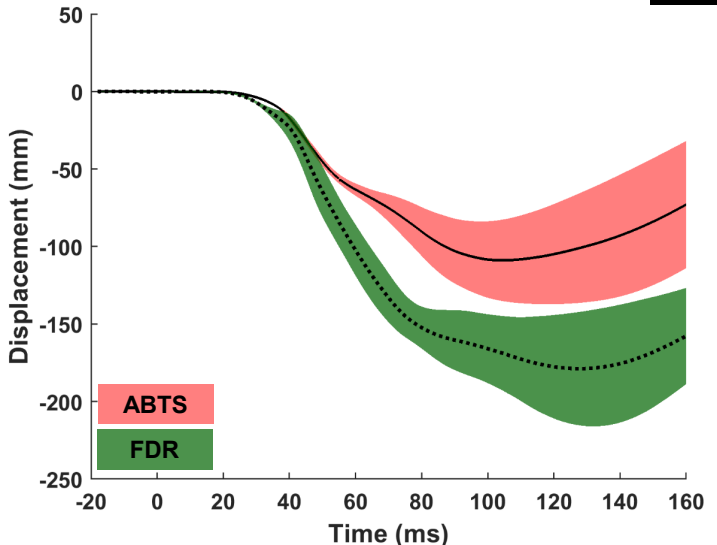
25 deg

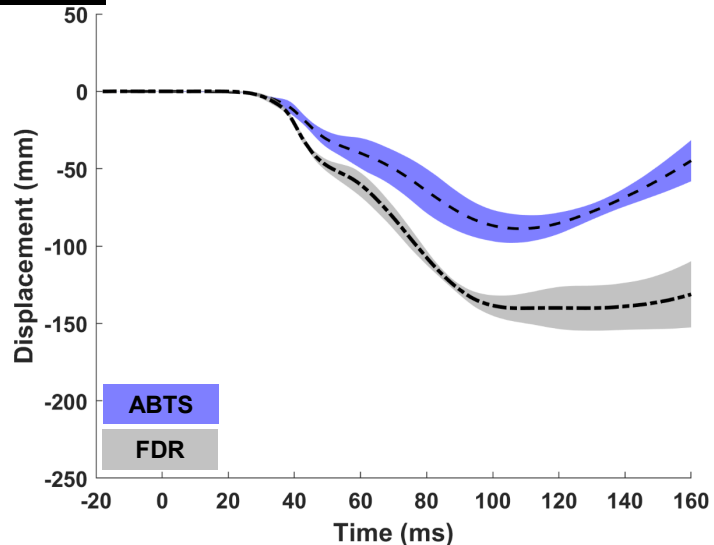


More ramping in FDR



Pelvis





Thorax Responses
→ More Rib Fractures in FDR

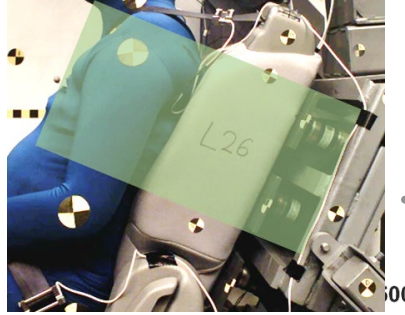
ABTS 45 Deg

FDR 45 Deg

ABTS 25 Deg

FDR 25 Deg

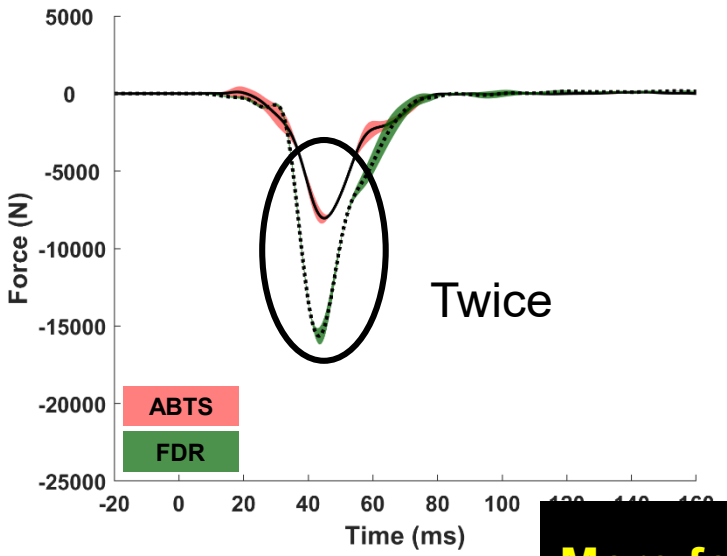
Seat Back Loads

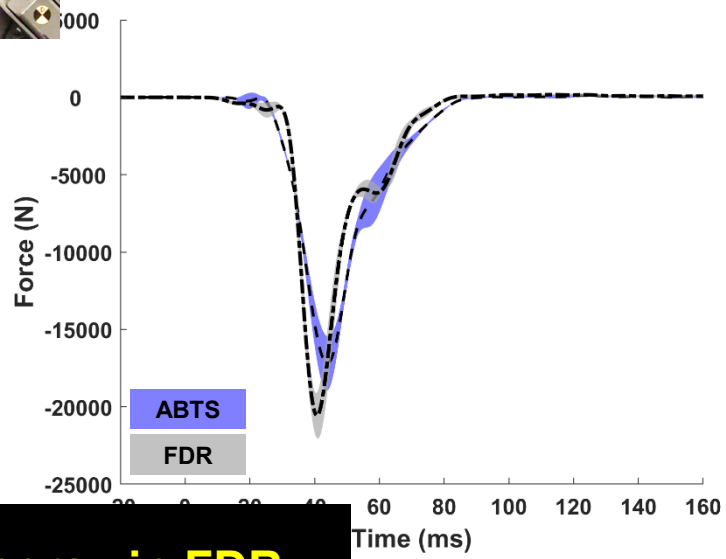


45 deg

25 deg

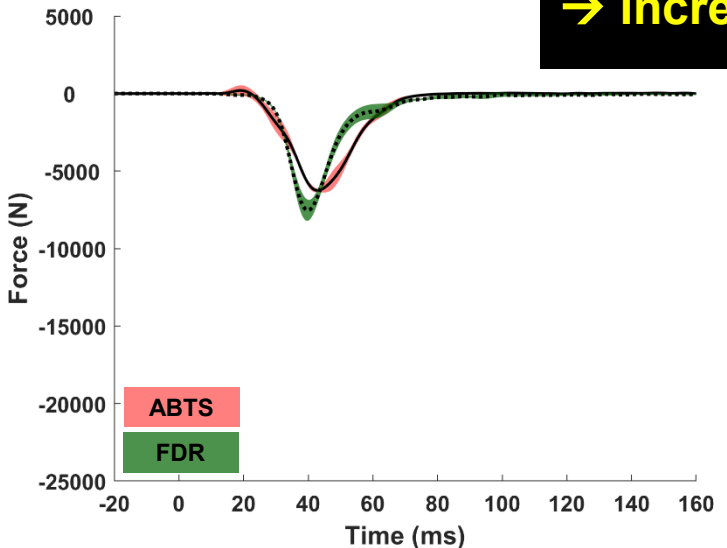
Top Load Cell Sum

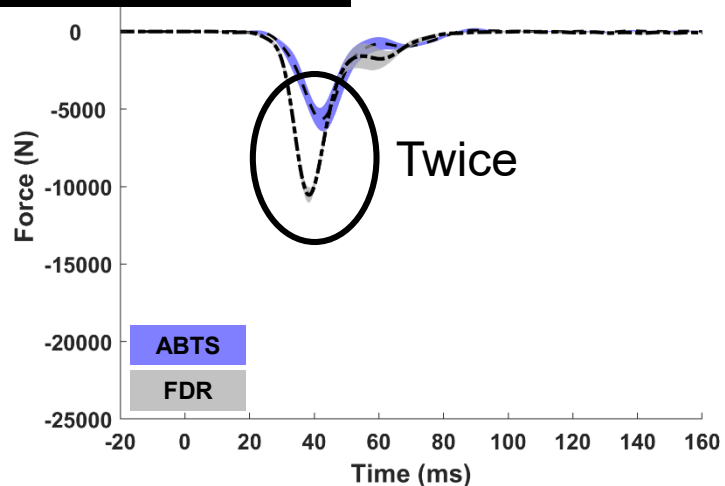




More force applied to thorax in FDR
→ Increase risk of rib fractures

Middle Load Cell Sum

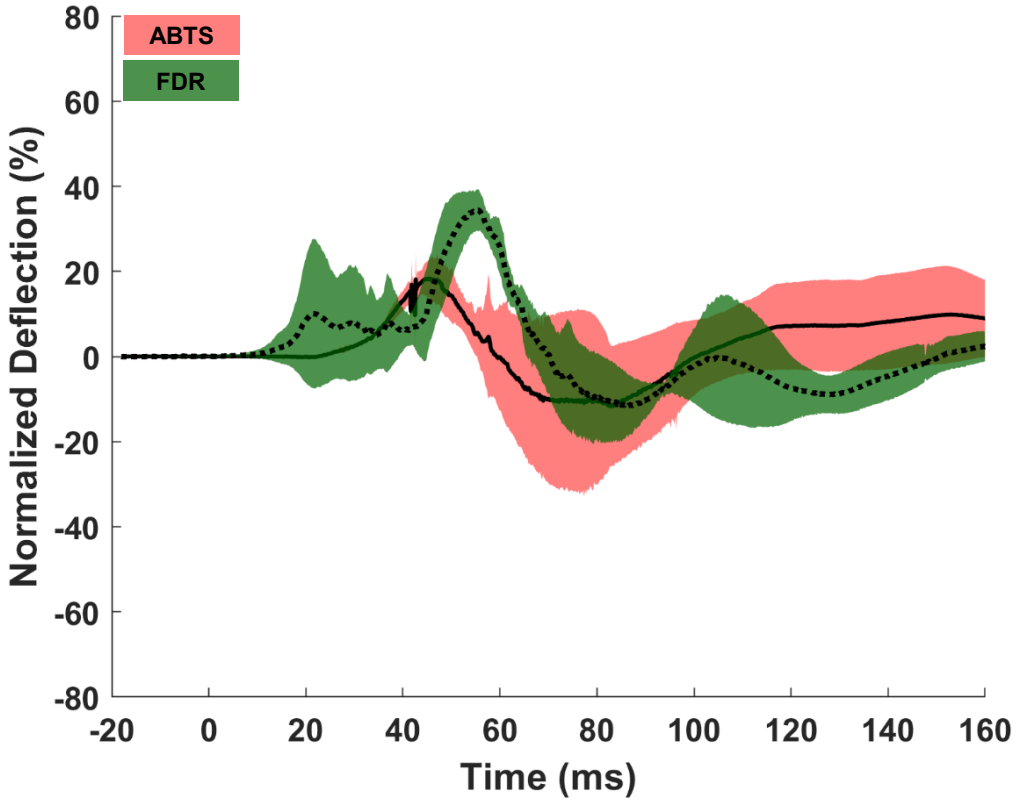




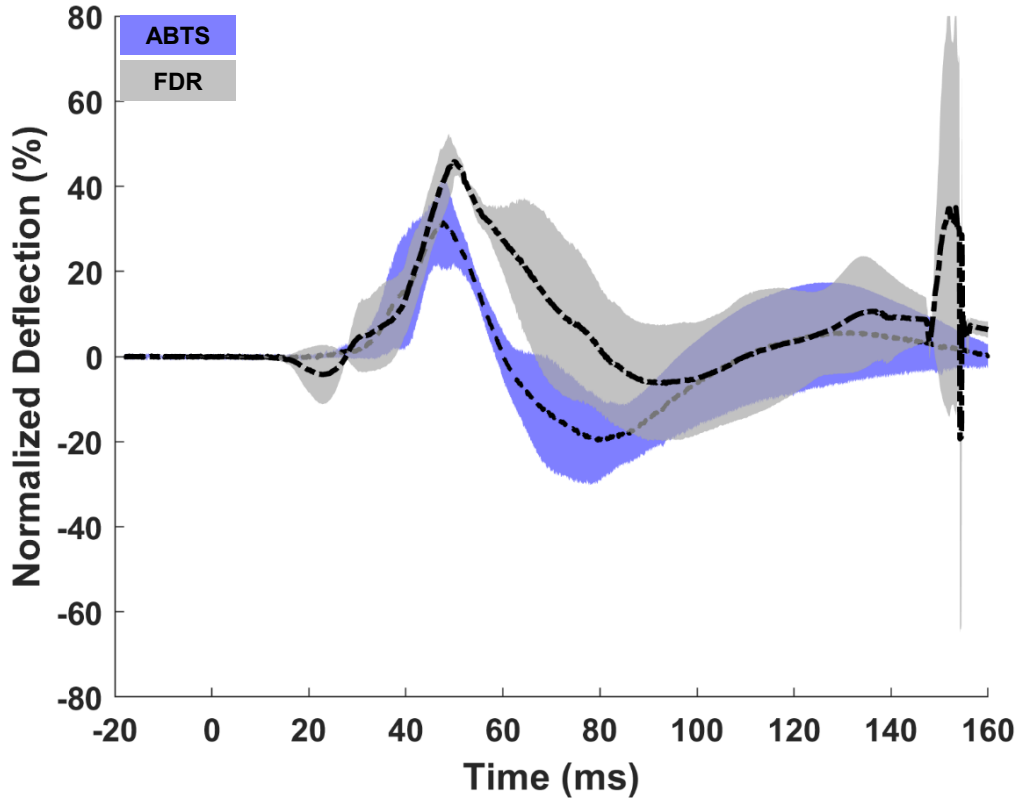
Chestband

Chest % deflection

45 deg



25 deg



More deflection in FDR
→ Increase risk of rib fractures

Pelvis Responses
→Pelvis Fractures in FDR (25 deg)

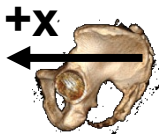
ABTS 45 Deg

FDR 45 Deg

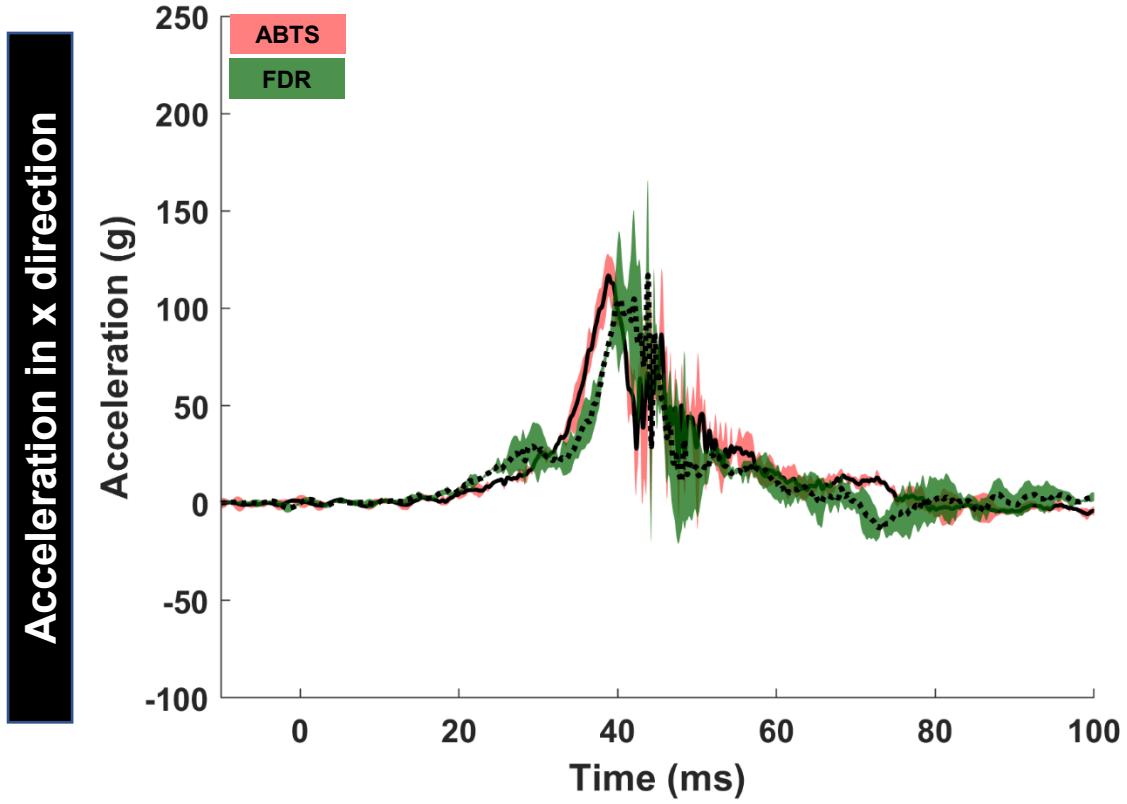
ABTS 25 Deg

FDR 25 Deg

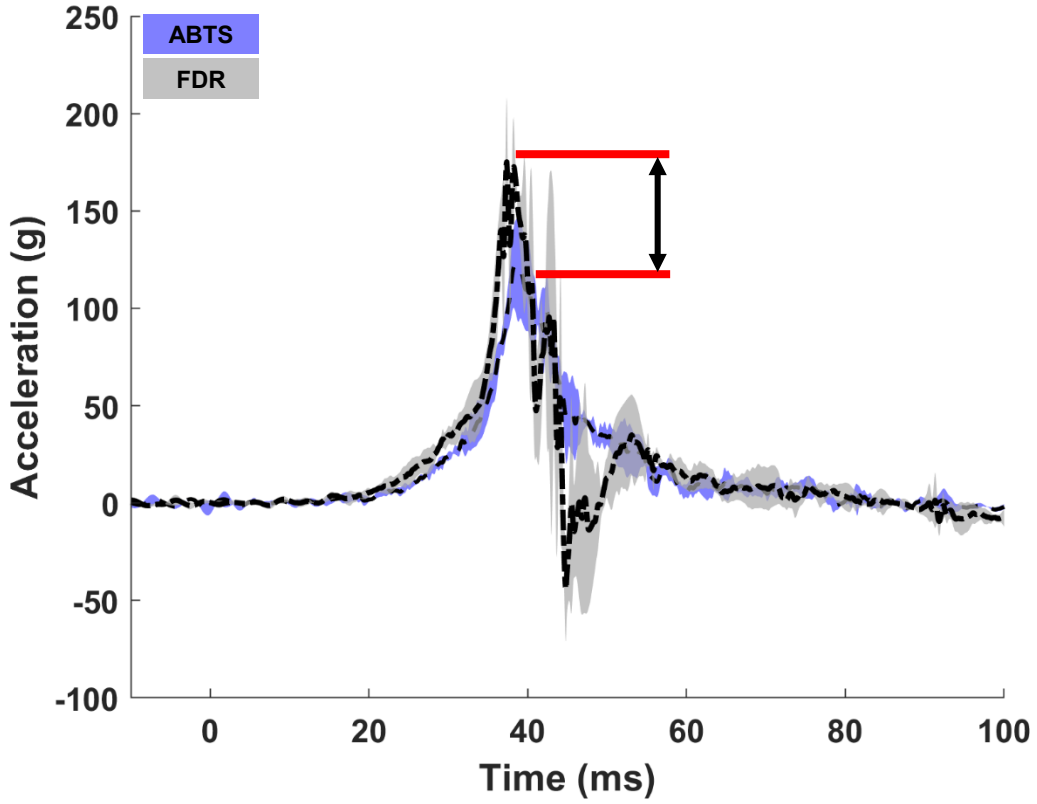
Pelvis Kinematics



45 deg



25 deg

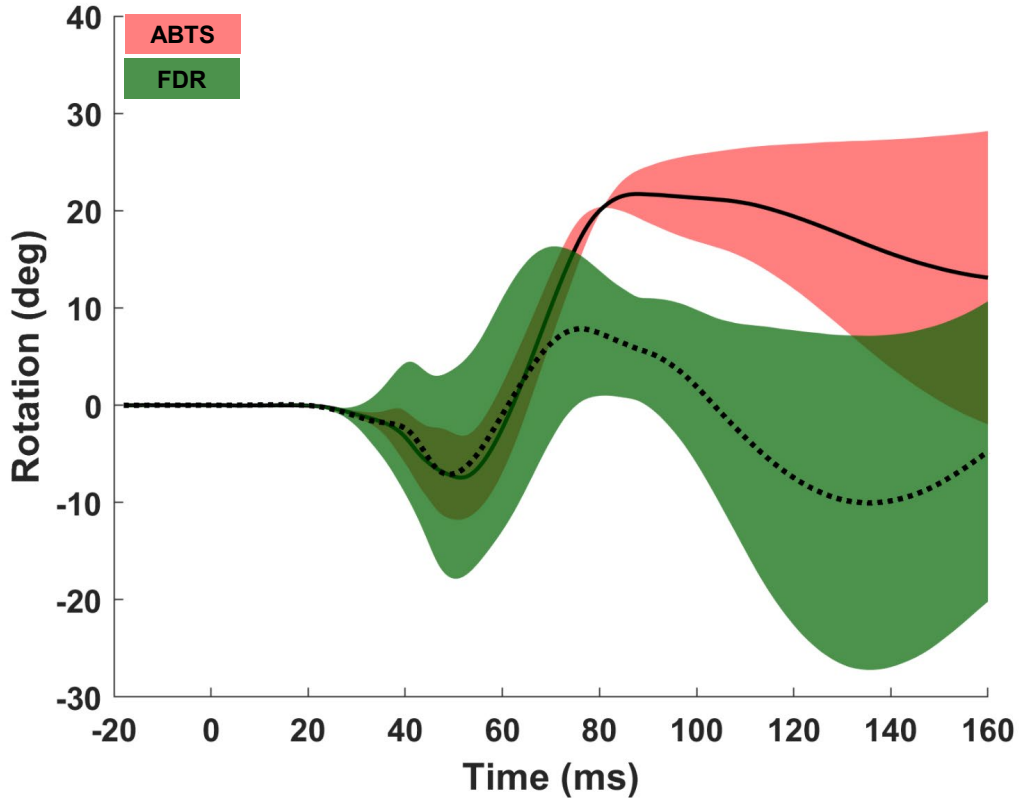


45deg: similar acceleration
25deg: higher acceleration in FDR

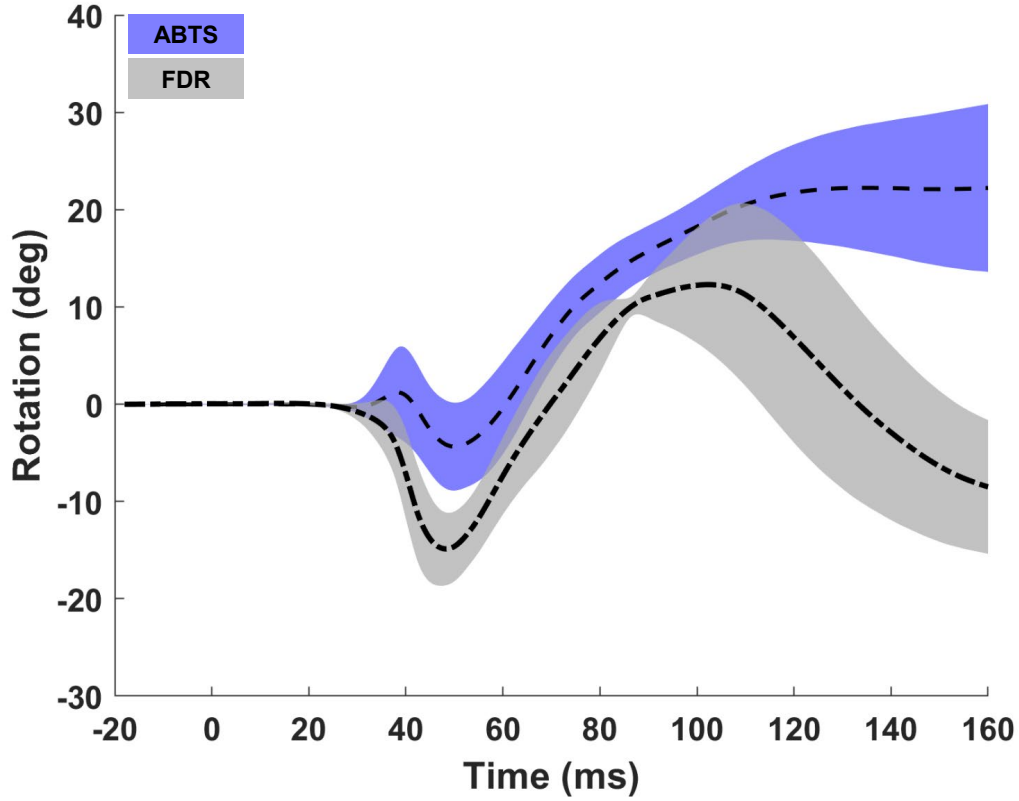
Pelvis Kinematics

Y - Rotation

45 deg



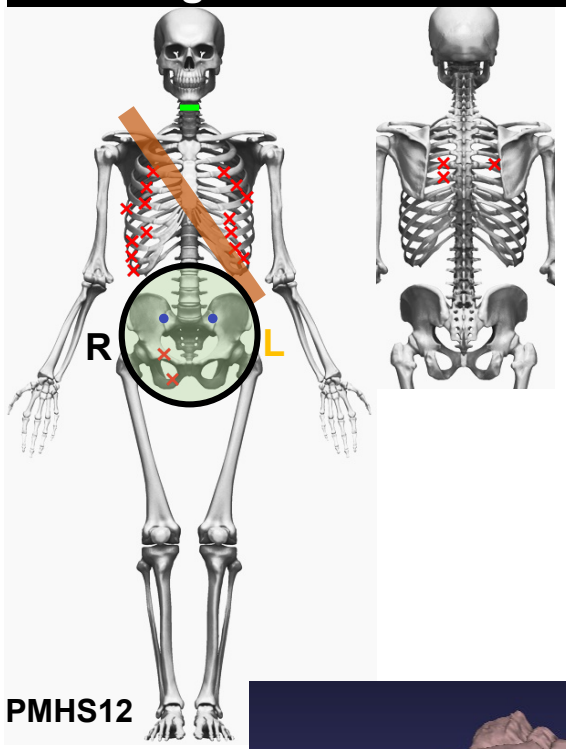
25 deg



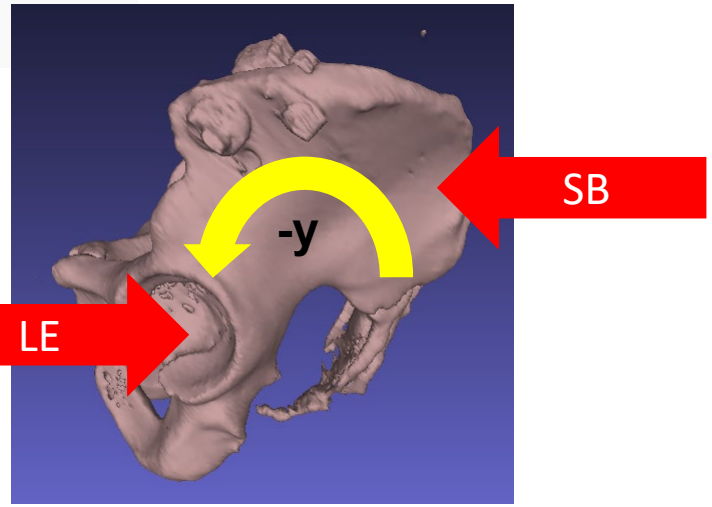
45deg: similar forward rotation but less rearward rotation in FDR
25deg: larger forward rotation but less rearward rotation in FDR

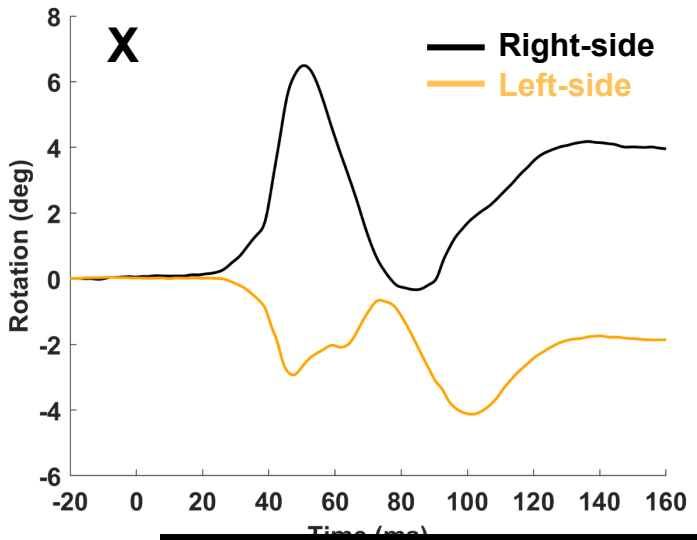
Pelvis Kinematics

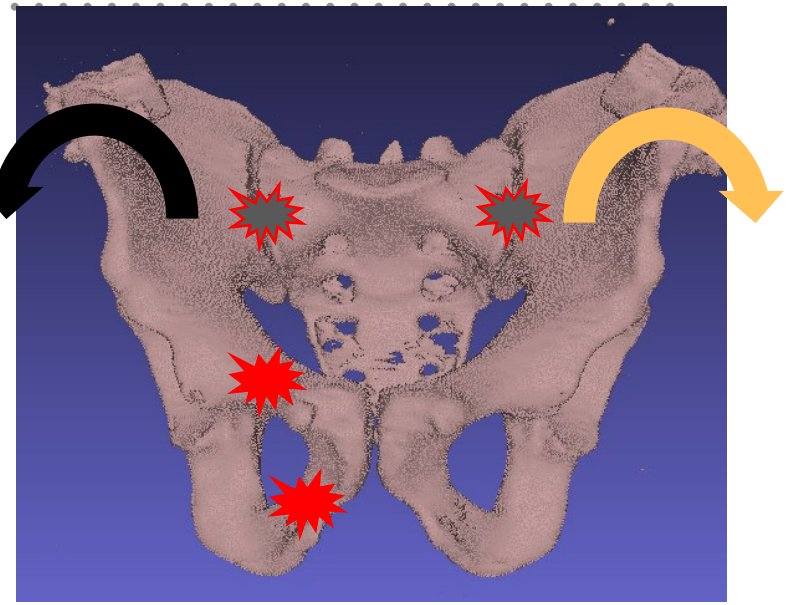
25 deg & 56km/h in FDR



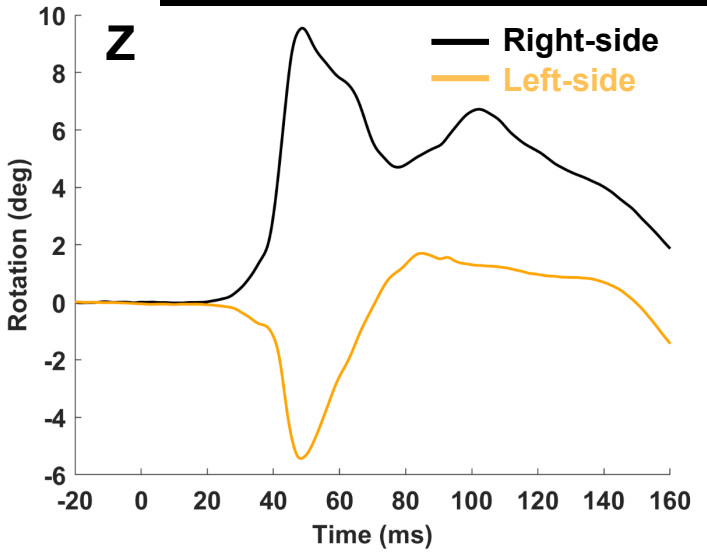
PMHS12

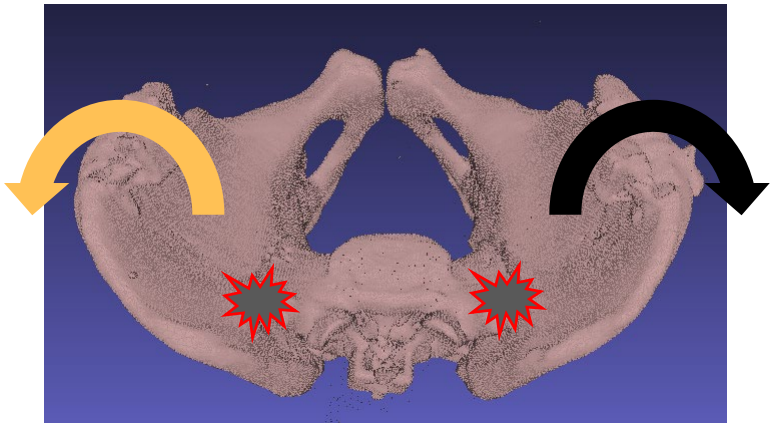






Off-axis rotations may be an indicator of fractures





Summary

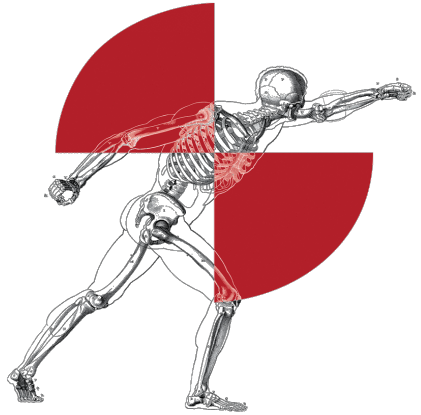
- Rear-facing sled tests using 12 PMHS were conducted at 56 km/h with different conditions
  - More injuries in FDR
  - Higher seat back loads in FDR
  - Higher ramping up motions in FDR

PMHS responses and injuries depend on seatback recline angles, restraint type (ABTS vs. FDR) and seat properties

Acknowledgements

Anatomical Donors of…

THE OHIO STATE UNIVERSITY



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TRC Transportation Research Center Inc.

Jason Jenkins and Duey Thomas

NHTSA

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Effects of seatback recline and belt restraint type on PMHS injuries in high-speed, rear-facing rigid seat tests

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