



# Government/Industry Meeting

January 17-19, 2023

Washington, DC

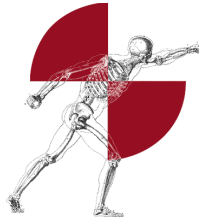
[sae.org/gim](https://sae.org/gim)



## Preliminary Comparison of Female to Male Post Mortem Human Subjects in Rear-Facing Seat Configurations in High-speed Frontal Impacts

Yun-Seok Kang<sup>1</sup>, Vikram Pradhan<sup>1</sup>, Jason Stammen<sup>2</sup>, Alex Bendig<sup>1</sup>, Gretchen Baker<sup>1</sup>, Alena Hagedorn<sup>3</sup>, Amanda Agnew<sup>1</sup>, Kevin Moorhouse<sup>2</sup>, John H. Bolte IV<sup>1</sup>

<sup>1</sup>Injury Biomechanics Research Center, The Ohio State University, <sup>2</sup>NHTSA/VRTC, <sup>3</sup>Transportation Research Center, Inc.



## Content Warning

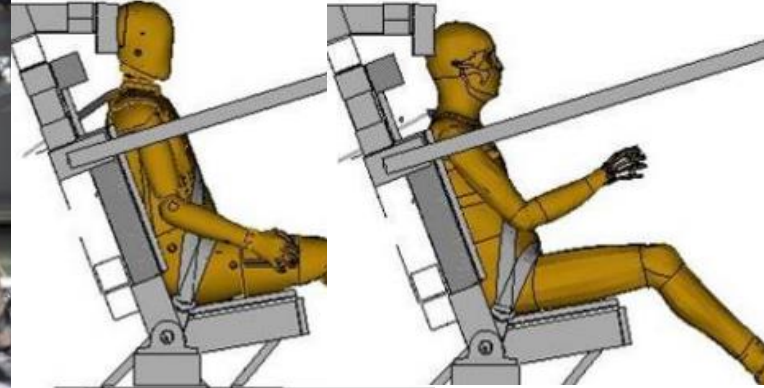
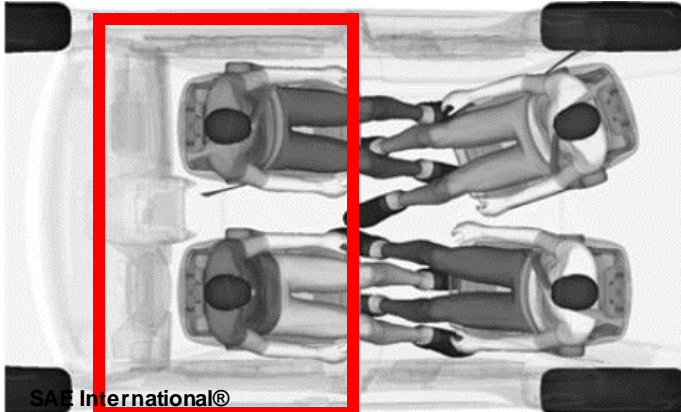
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**The following slides include cadaveric images that are graphic and may be considered disturbing to some viewers!**

# 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 [Jorlov et al., 2017; Koppel et al., 2019; Ostling and Larsson, 2019]
  - 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



Insert SAE event name here

Kitagawa et al., 2017

Zellmer and Manneck, 2019; Soni et al., 2020

# Background and Motivation

- Recent rear-facing studies [Kang et al., 2020 & 2022]
  - **Male PMHS** responses and injuries at  $\Delta V$  of 56km/h
  - Two recline conditions (25deg & 45deg)
  - Original equipment manufacturer (OEM) seats with rigid reinforcement
    - ABTS [Kang et al., 2020]
    - FDR [Kang et al., 2022]
  - PMHS injuries
    - Cervical spine laxity
    - Upper & lower extremity injuries
    - Abdomen injuries
    - **Rib fractures**
    - **Pelvis fractures**
- Females may be at greater risk of injuries than males in MVCs

[Bose et al., 2011; Parenteau et al., 2013; Forman et al., 2019]



ABTS



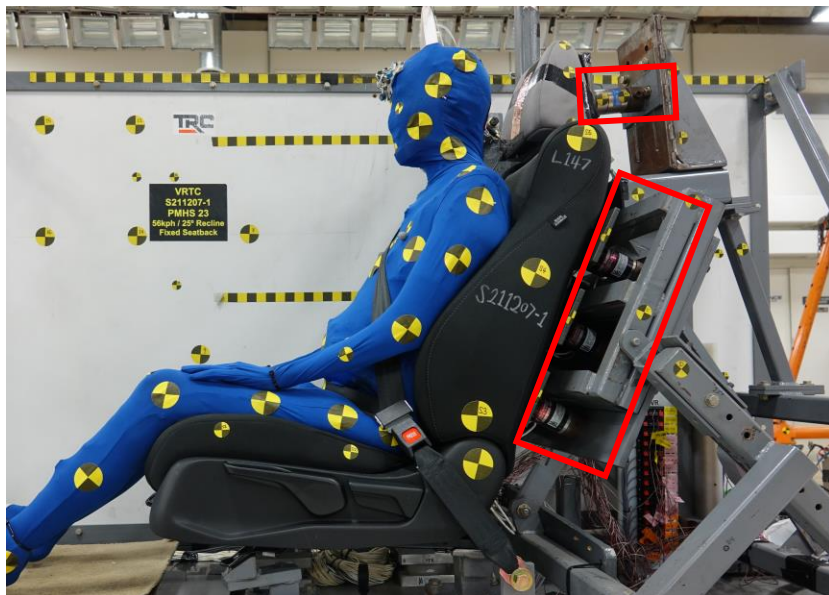
FDR

To compare **female PMHS** biomechanical responses and injuries to **male PMHS**  
**Preliminary results (injury outcomes and rib fracture mechanisms)**

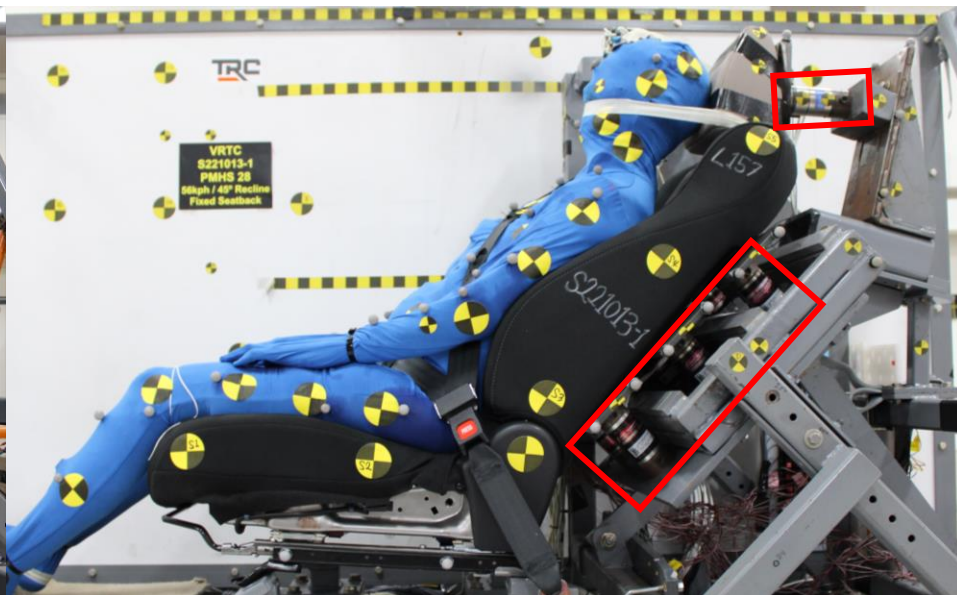
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# Methods

# Sled Buck Description



PMHS23F



PMHS28F

## Female PMHS Characteristics – 56 km/h

N=1

N=6	Speed	Seat	Recline	Age	Height (cm)	Weight (kg)	Seated Height (cm)	Head Mass (kg)	Chest Depth (cm)
PMHS25F	56	ABTS	25	69	167.2	44.2	89.9	2.90	17.2
PMHS26F	56	ABTS	45	48	159.5	51.7	89.3	3.04	17.1
PMHS23F	56	FDR	25	45	162.5	56.0	86.5	3.32	18.1
PMHS24F	56	FDR	45	80	157.5	57.2	79.0	3.05	18.7
PMHS28F	56	FDR	45	73	160.3	57.2	88.7	3.02	17.1
PMHS30F	56	FDR	45	36	171.2	53.1	93.8	3.26	17.1
Mean (SD)	N/A	N/A	N/A	59 (18)	163.0 (5.2)	53.2 (5.0)	87.9 (5.0)	3.1 (0.2)	17.6 (0.7)

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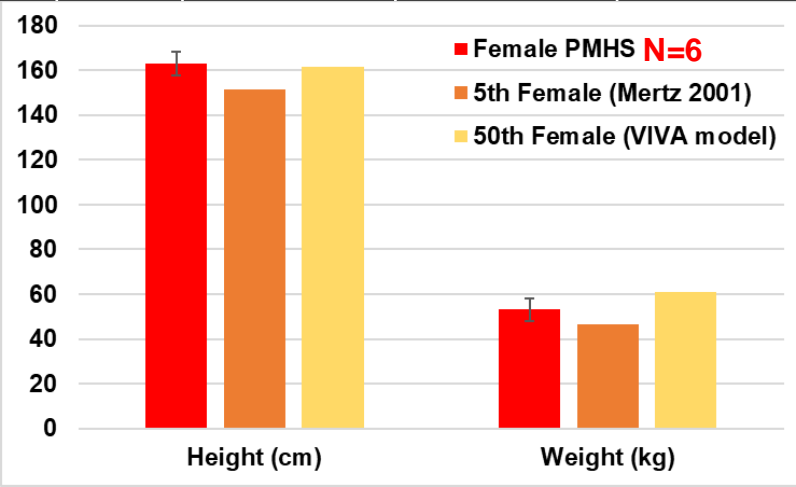
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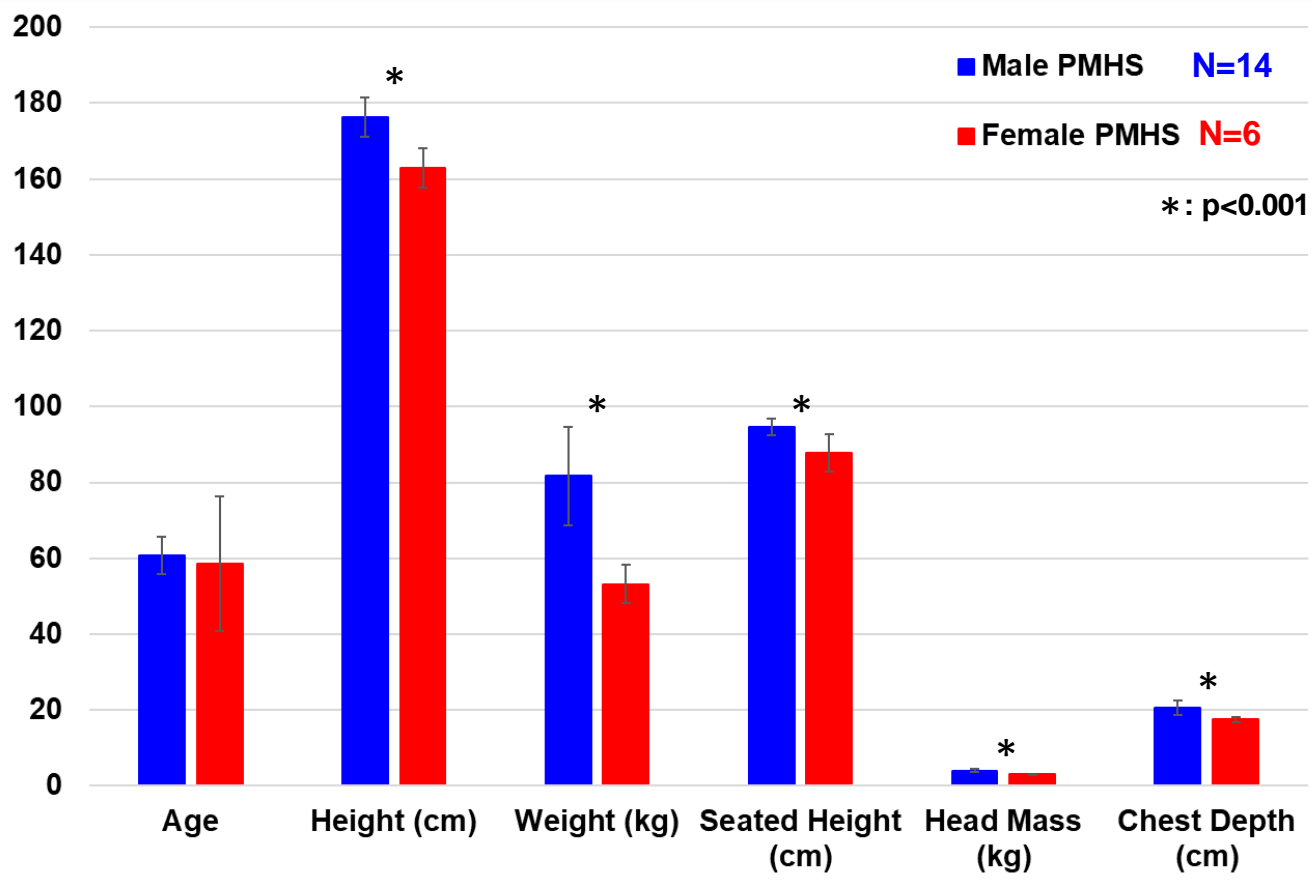
N=3

# Female PMHS Characteristics – 56 km/h

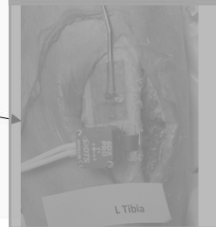
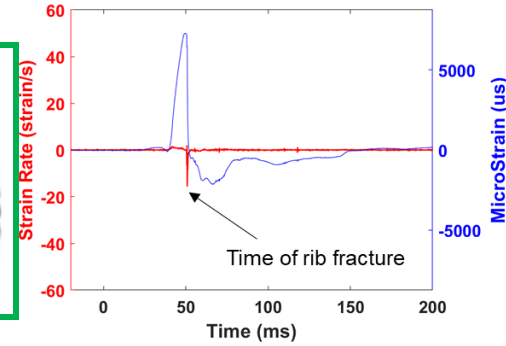
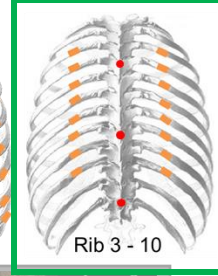
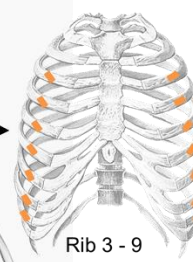
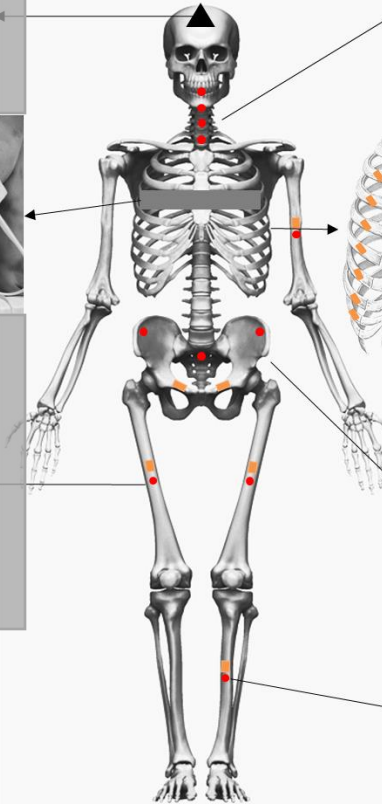
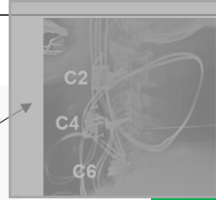
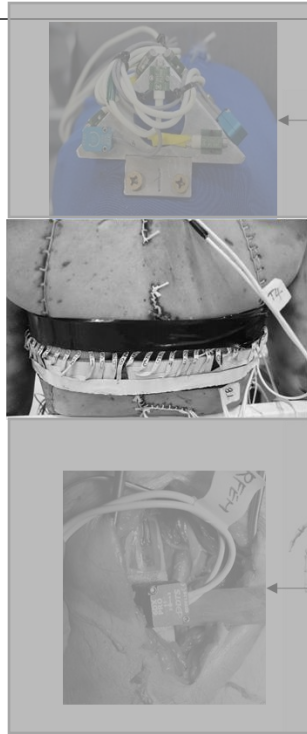
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# PMHS Characteristics – 56 km/h



# PMHS Instrumentation

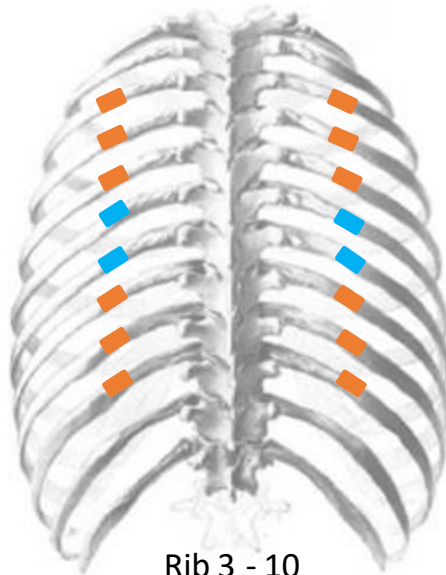
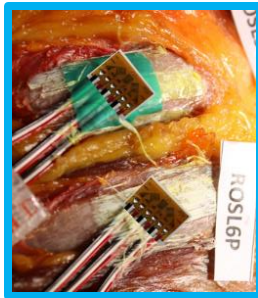


- ▲ 6a $\omega$
- Strain gage
- 3a $\omega$

■ Chestband

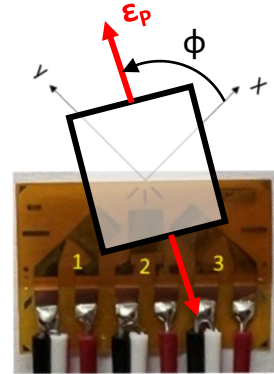
# PMHS Instrumentation – Strain Gage/Rosette

- : Uniaxial strain gage
- : Strain Rosette



Rib 3 - 10  
Posterior

Rosette at 6<sup>th</sup> and 7<sup>th</sup> levels



$$\epsilon_{P,Q} = \frac{\epsilon_1 + \epsilon_3}{2} \pm \frac{1}{\sqrt{2}} \sqrt{(\epsilon_1 - \epsilon_2)^2 + (\epsilon_2 - \epsilon_3)^2}$$

$$\phi_{P,Q} = -\theta = \frac{1}{2} \tan^{-1} \left( \frac{2\epsilon_2 - \epsilon_1 - \epsilon_3}{\epsilon_1 - \epsilon_3} \right)$$

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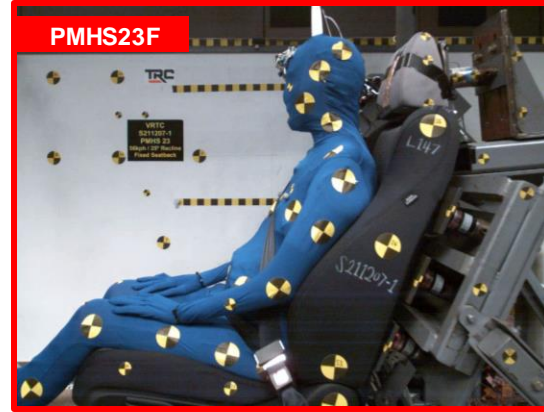
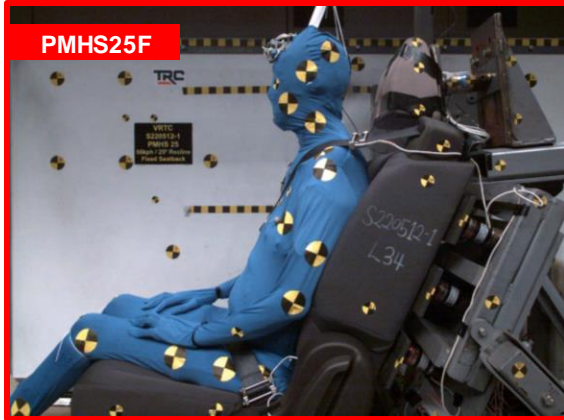
# Preliminary Results

# High Speed Videos – 25deg

ABTS

FDR

Female



Male



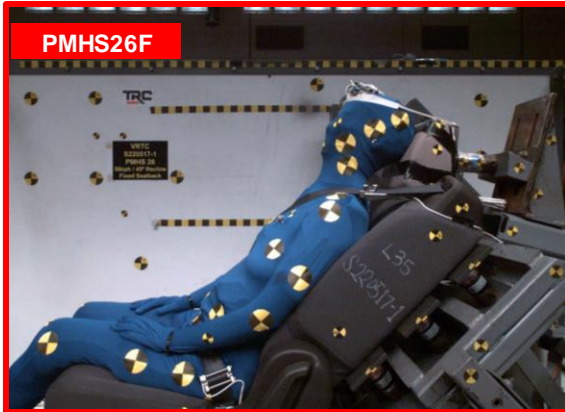


# High Speed Videos

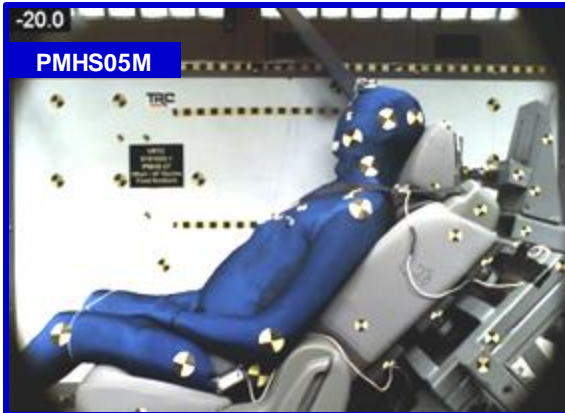
ABTS

FDR

Female



Male



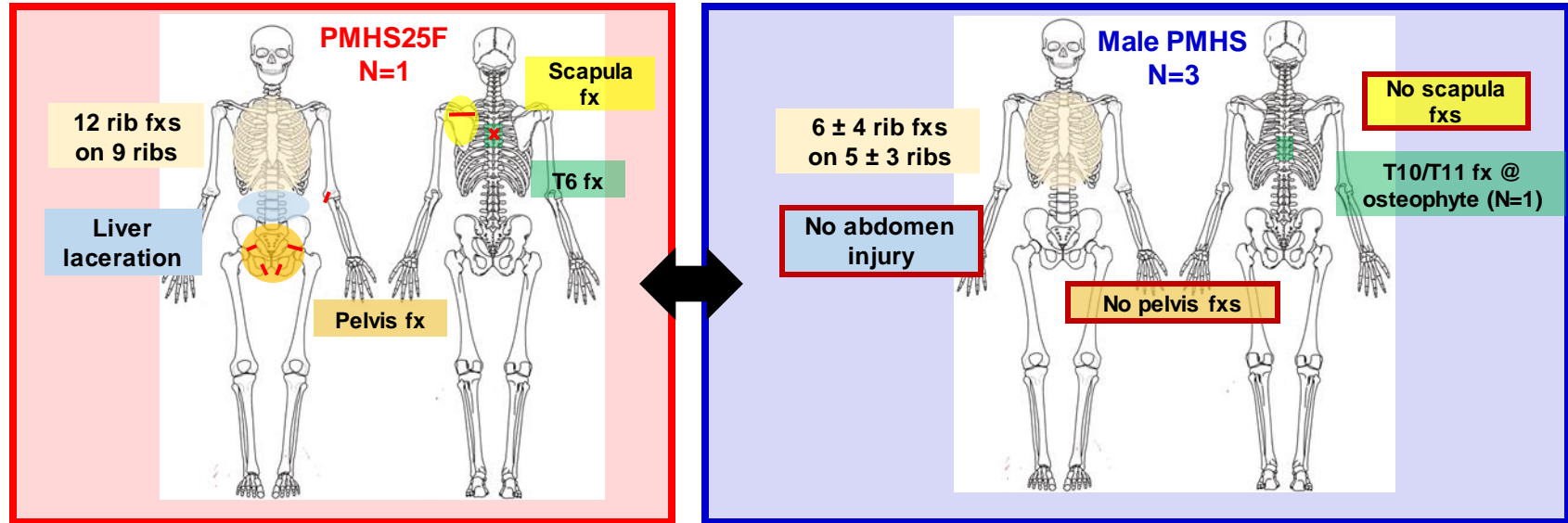
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# Injury Comparison

	# of Female PMHS	# of Male PMHS
ABTS25	N=1	N=3
ATBS45	N=1	N=3
FDR25	N=1	N=4
FDR45	N=3	N=4

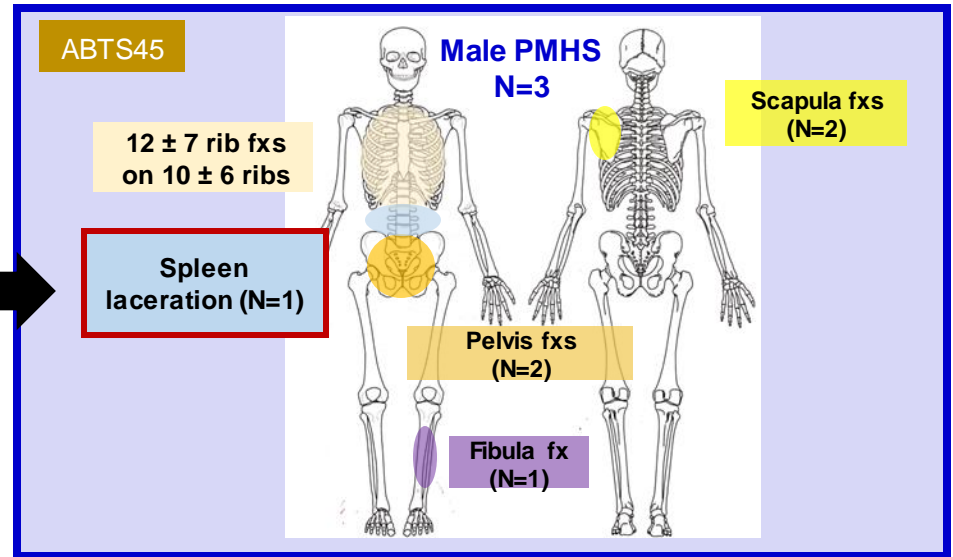
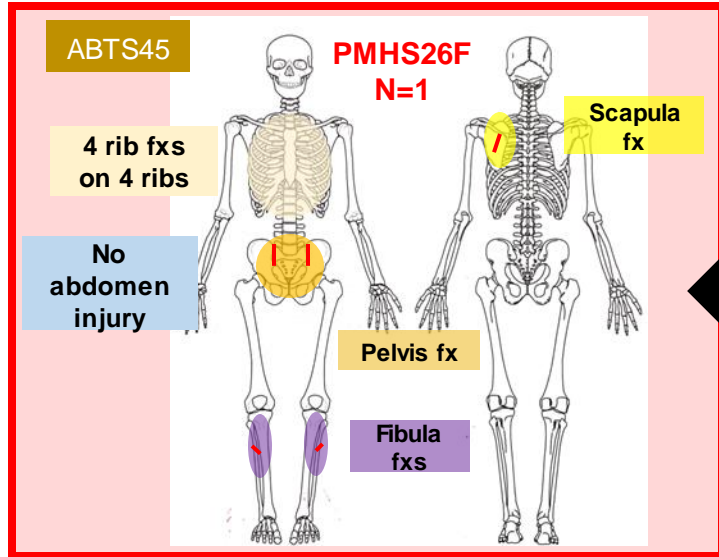
# Injury Female vs. Male (Odyssey 25deg)

ABTS25



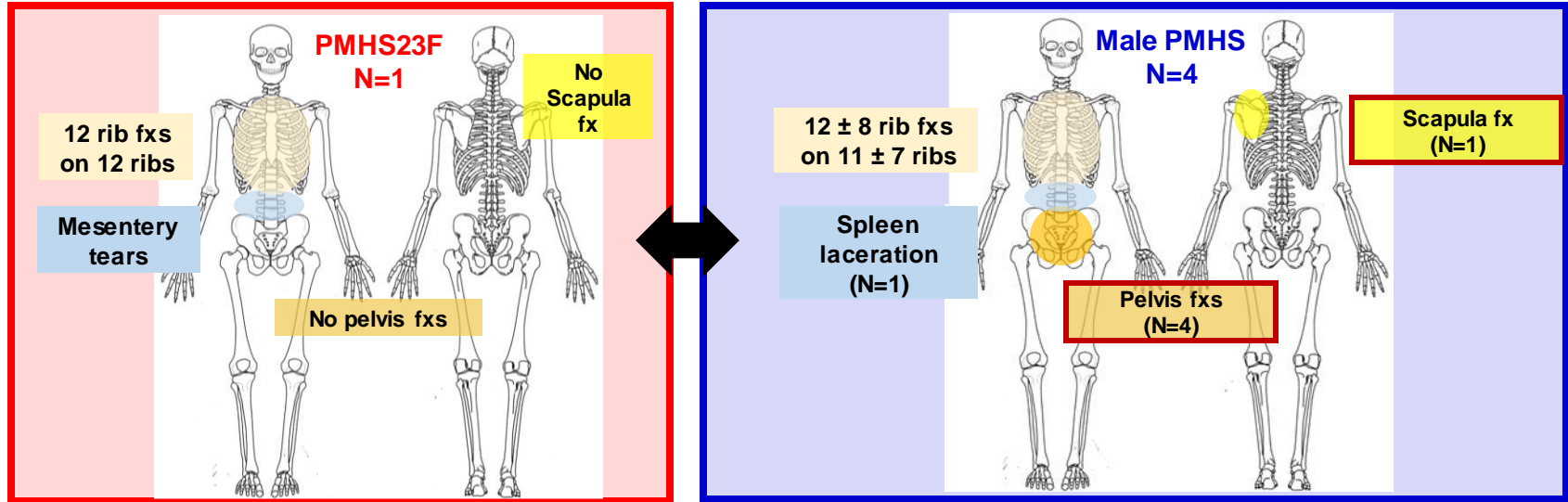
# Injury Female vs. Male (Odyssey 45deg)

ABTS45



# Injury Female vs. Male (Accord 25deg)

FDR25

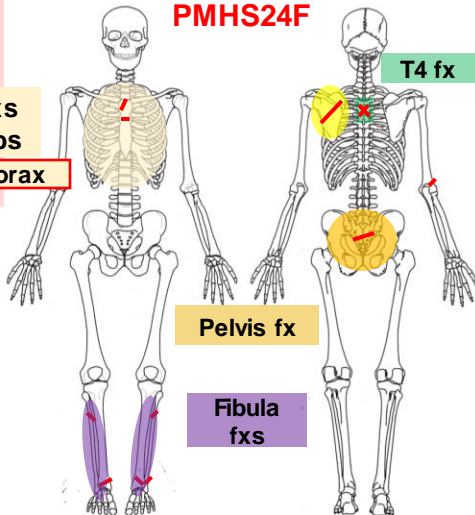


FDR45

PMHS24F

27 rib fxs  
on 19 ribs

Pneumothorax



Pelvis fx

Fibula  
fxs

T4 fx

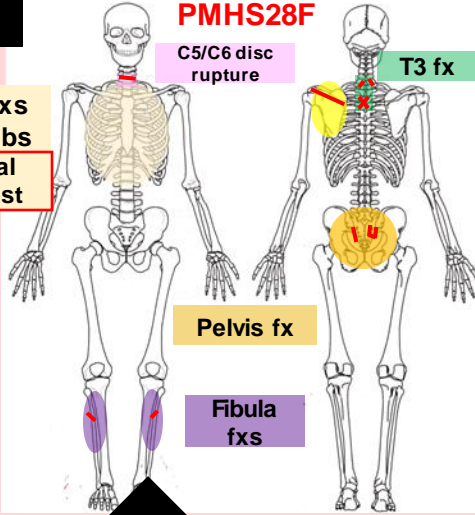
FDR45

PMHS28F

19 rib fxs  
on 10 ribs  
Bilateral  
flail chest

C5/C6 disc  
rupture

T3 fx



Pelvis fx

Fibula  
fxs

FDR45

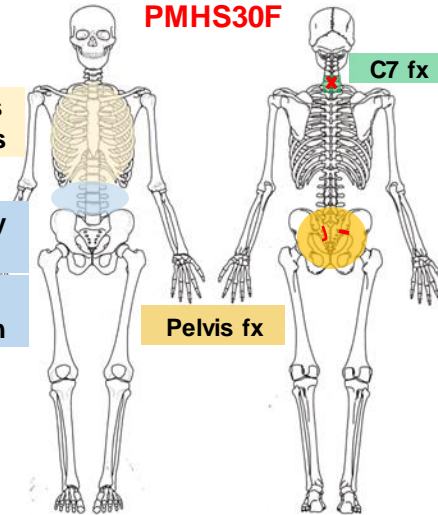
PMHS30F

13 rib fxs  
on 12 ribs

Mesentery  
tears  
Spleen  
laceration

Pelvis fx

C7 fx



FDR45

Male PMHS

N=4

No vertebral  
body fxs

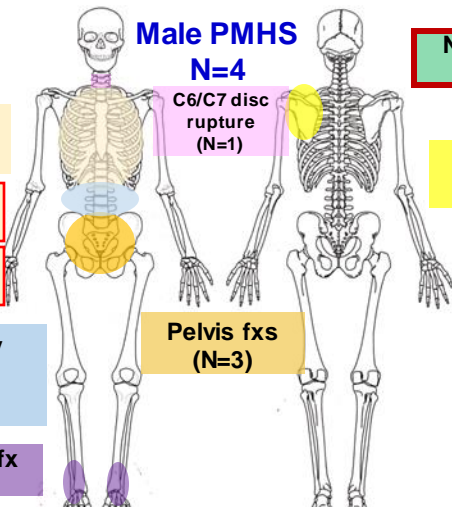
25 ± 18 rib fxs  
on 13 ± 8 ribs

Bilateral flail  
chest (N=1)

Pneumothorax  
(N=1)

Mesentery  
tears  
(N=1)

Tibia/Fibula fx  
(N=1)



C6/C7 disc  
rupture  
(N=1)

Scapula fx  
(N=2)

Pelvis fxs  
(N=3)

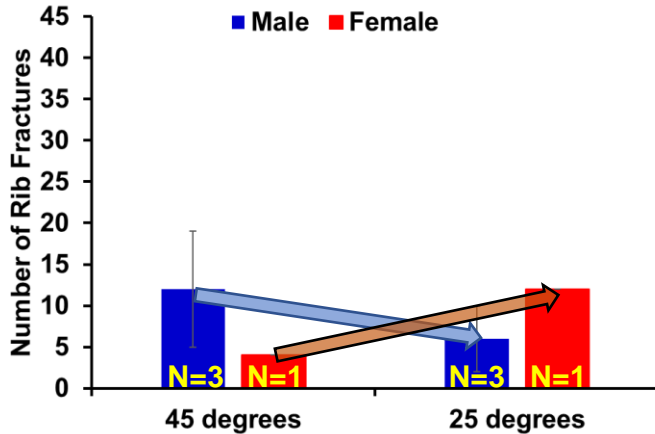
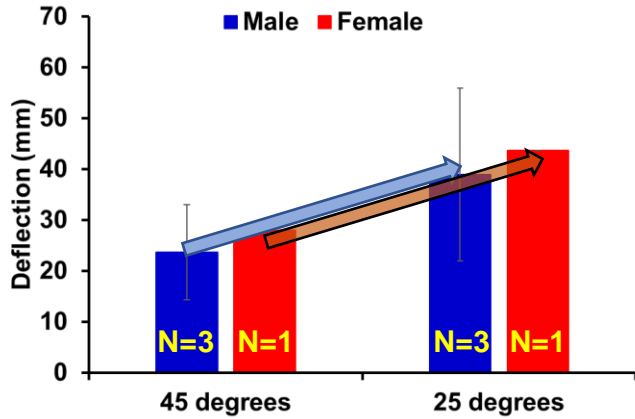
- No major differences in injury types and frequencies between female and male PMHS

- One exception: C- and T-spine vertebral body fractures in Female PMHS (FDR45)

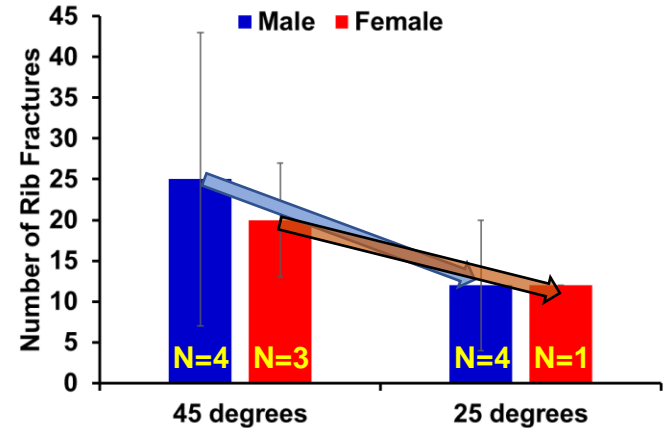
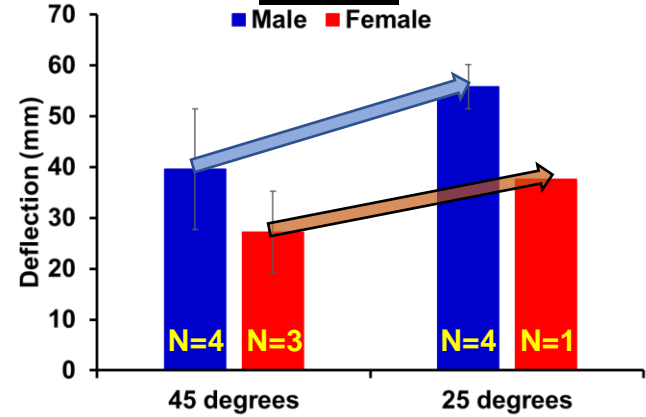
- Rib** and **pelvis fractures**: still major injuries

# A-P Chest Deflection (Chestband)

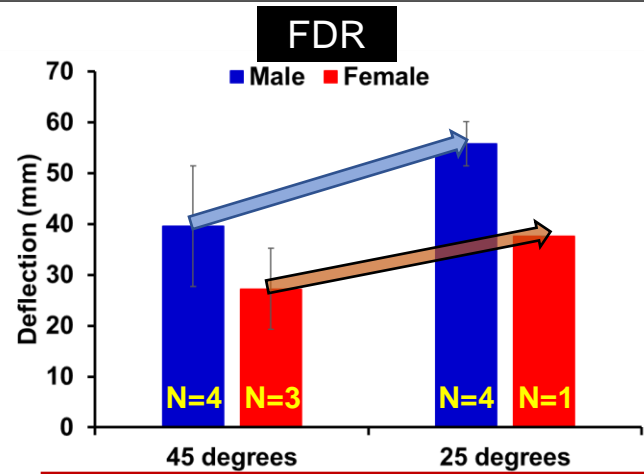
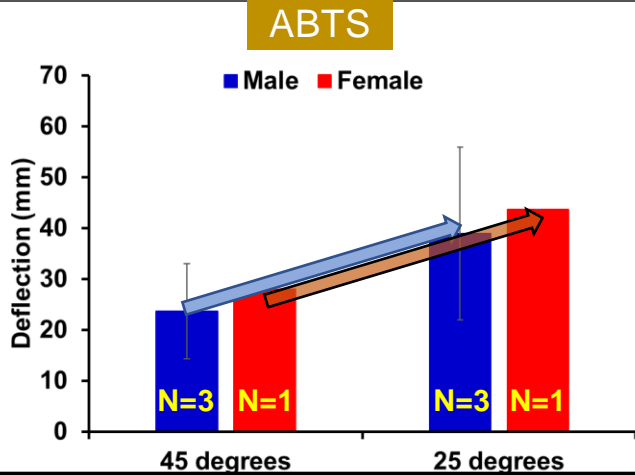
ABTS



FDR



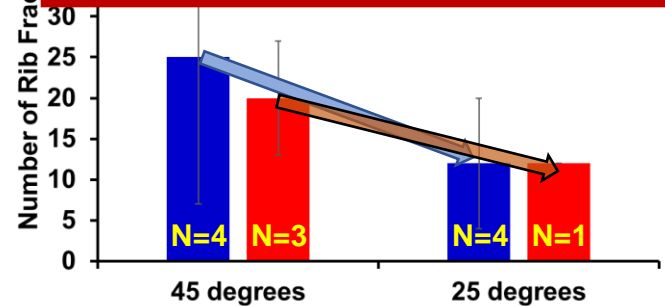
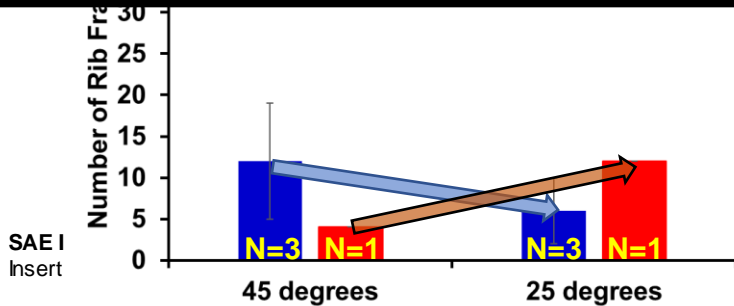
# A-P Chest Deflection (Chestband)



Larger A-P deflection at 25 deg than 45deg  
 More NRF at 45deg than 25deg (except female ABTS)



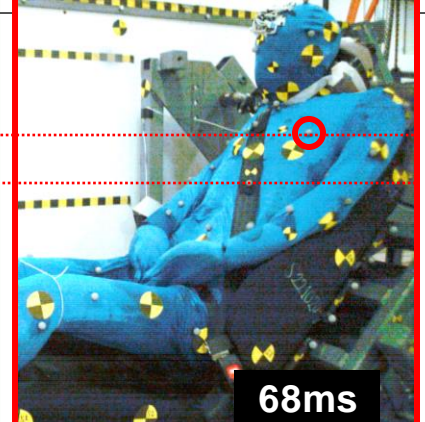
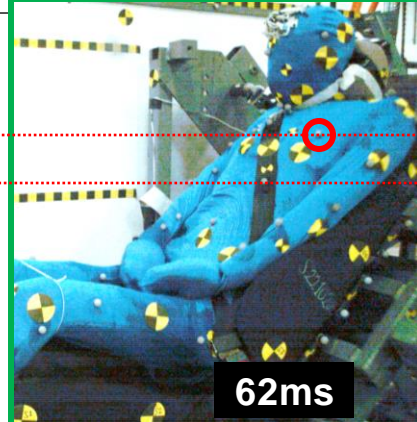
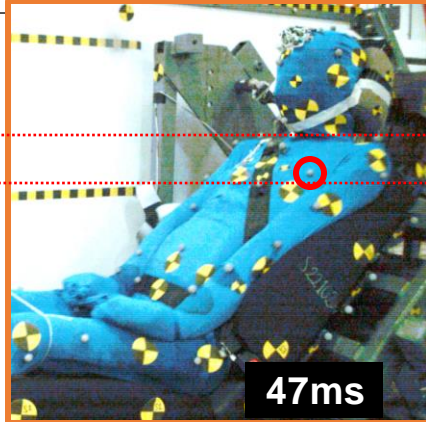
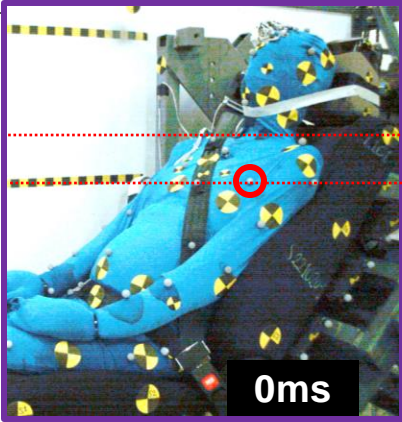
A-P deflection alone may not explain number of rib fractures





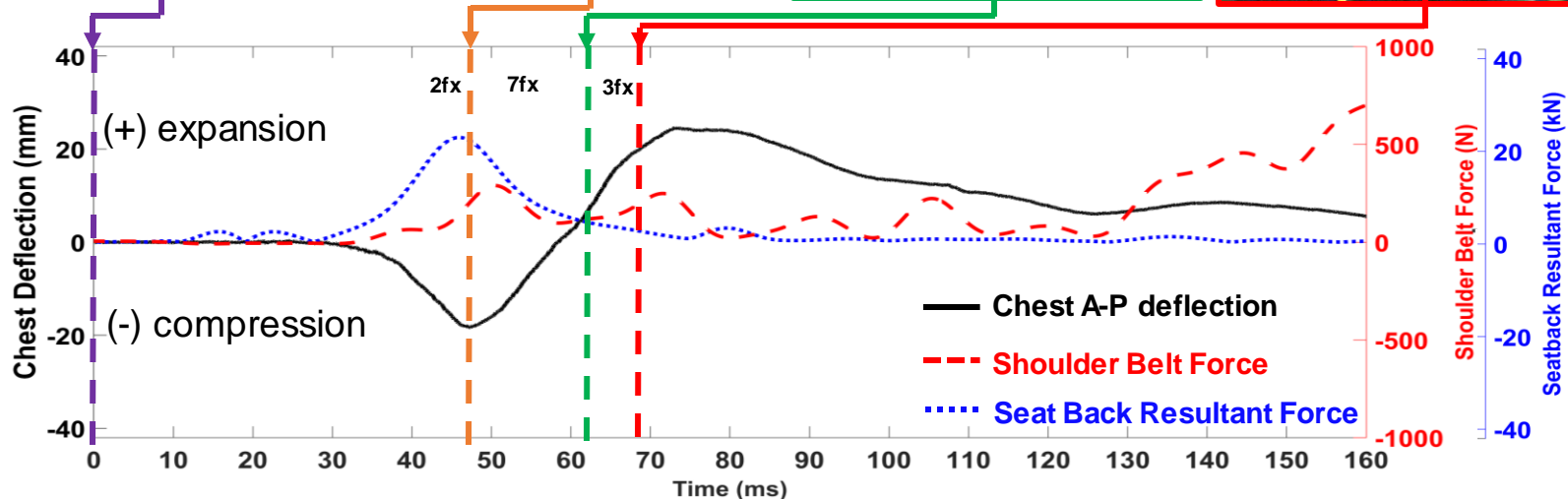
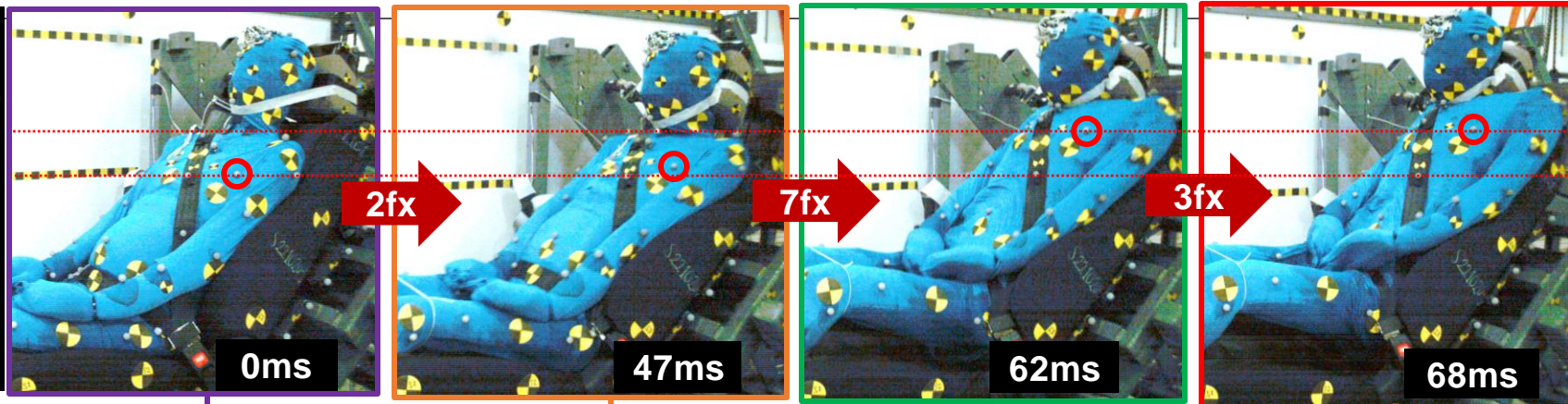
# PMHS30F

FDR 45deg



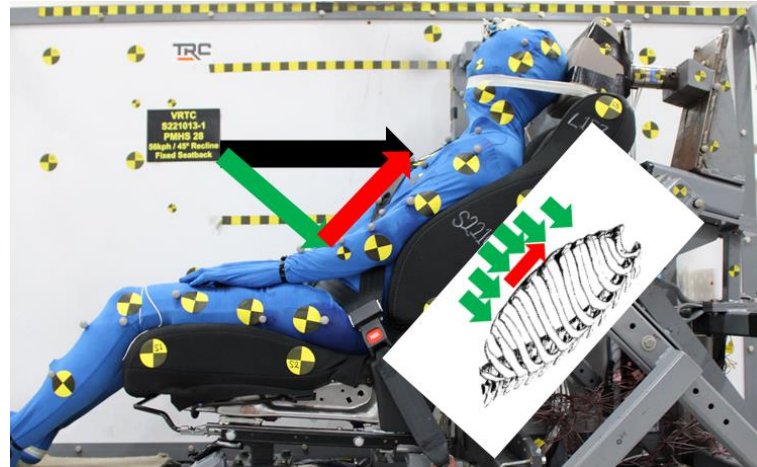
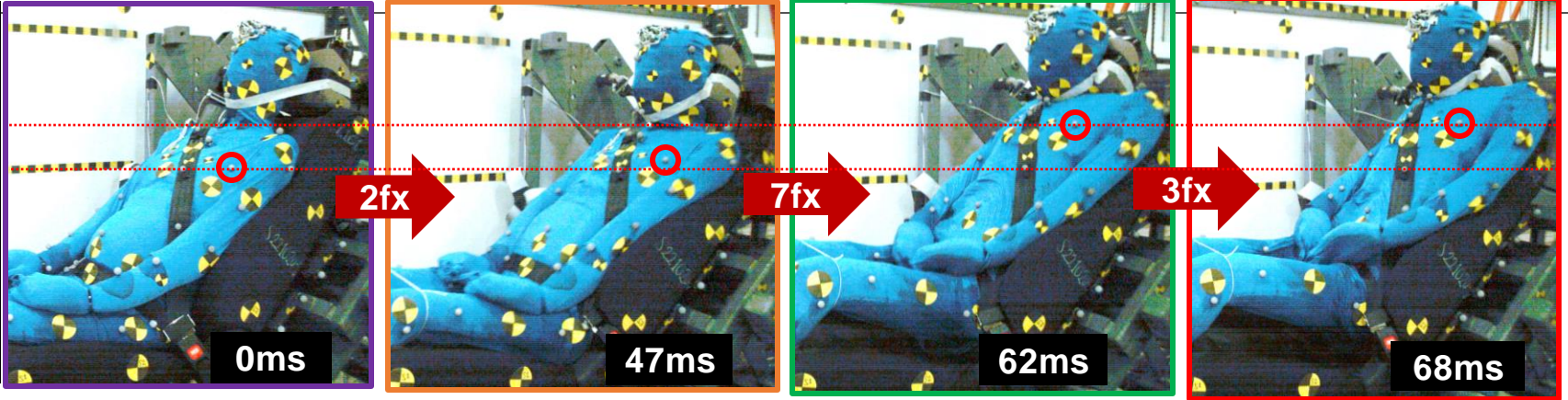
# PMHS30F

FDR 45deg

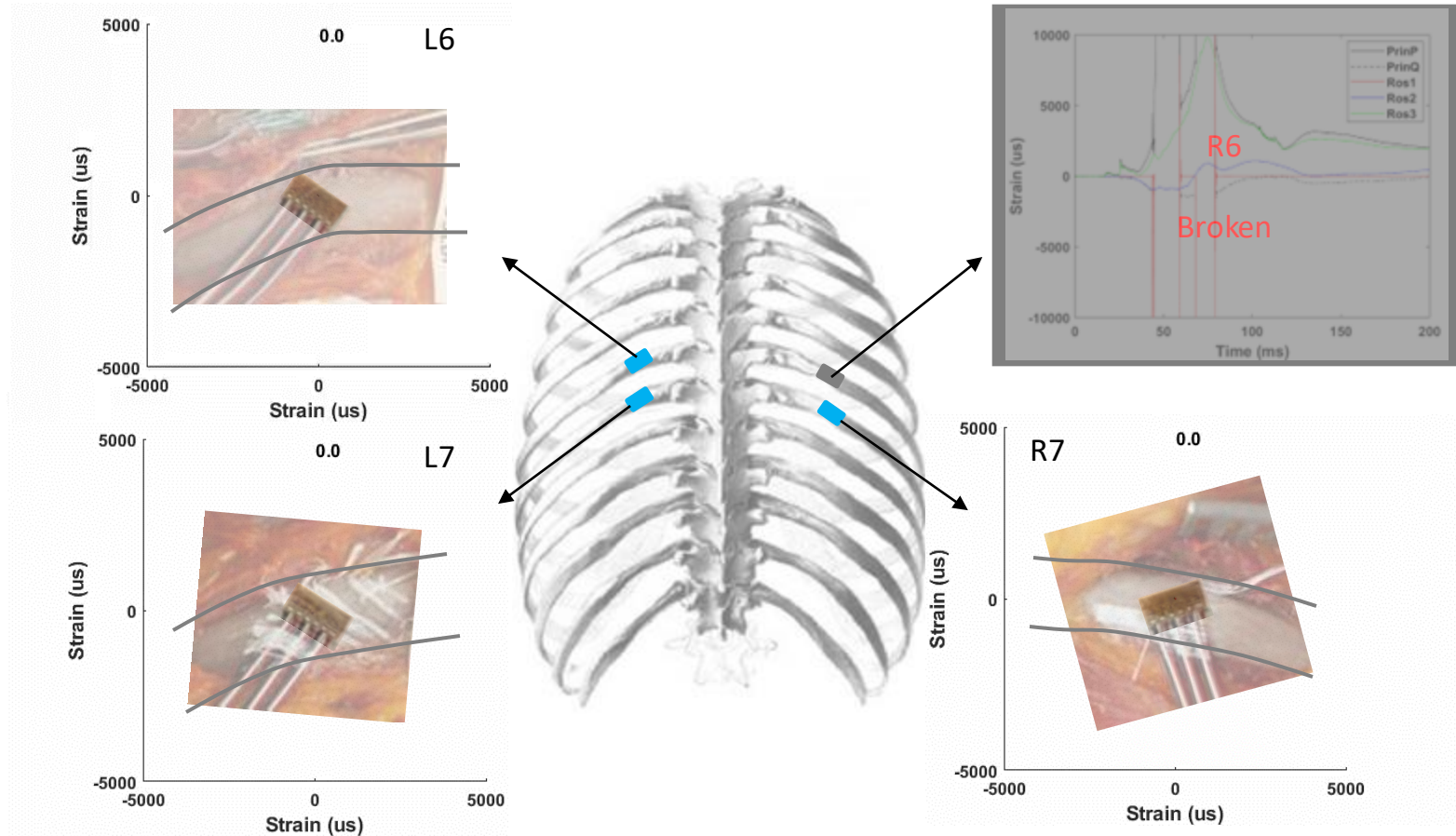


# PMHS30F

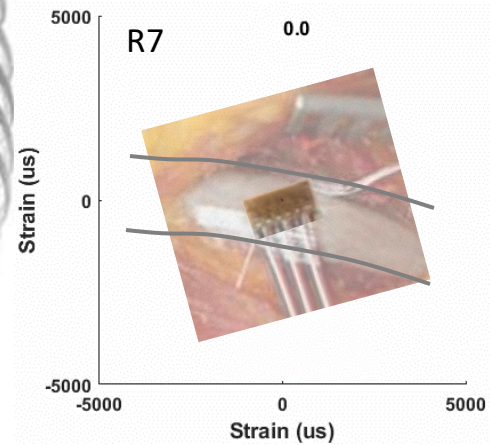
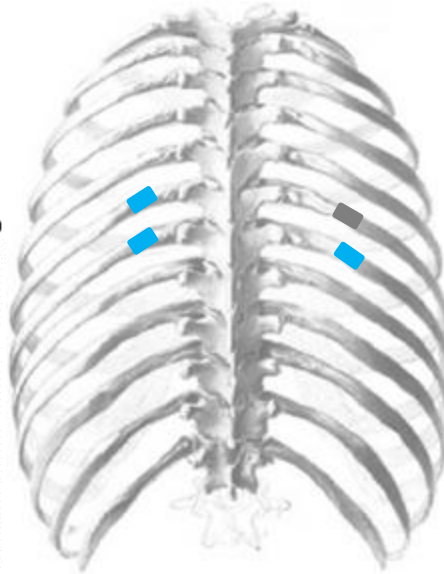
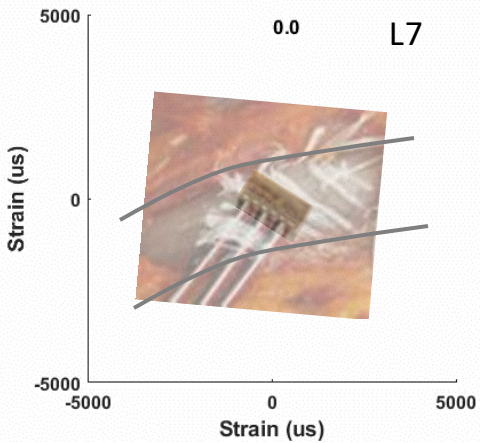
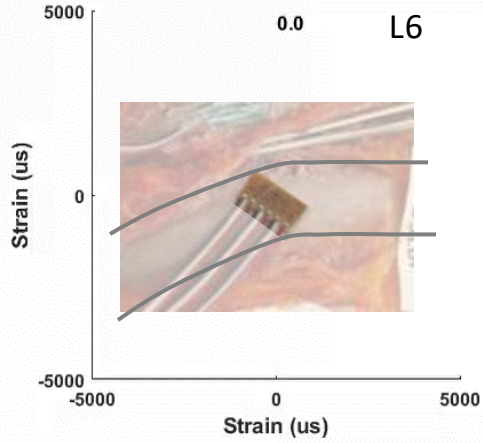
FDR 45deg



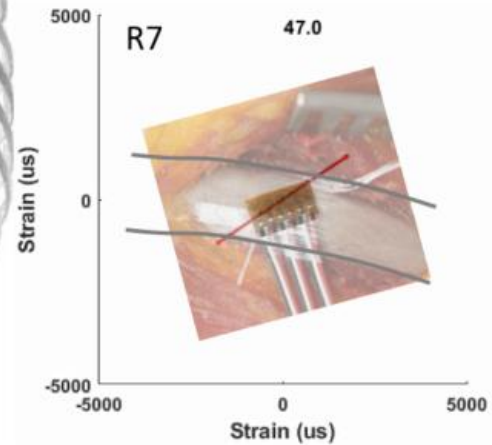
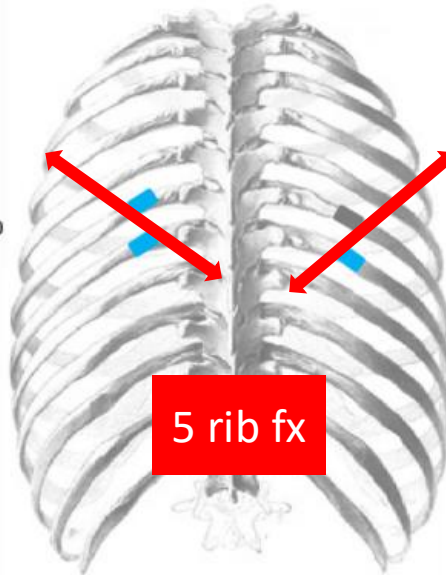
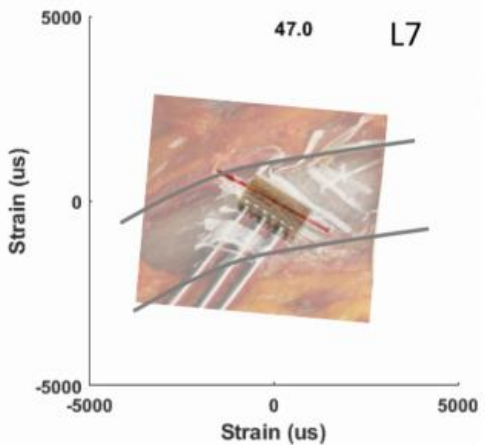
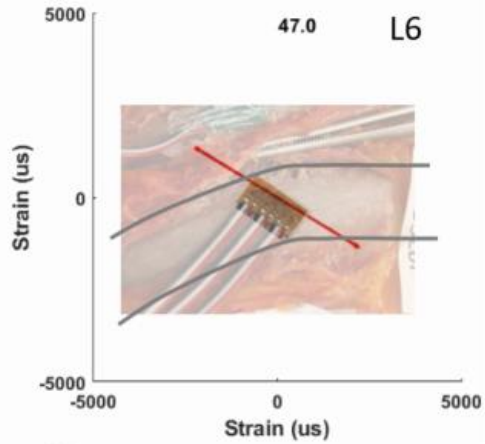
# Strain Rosette – PMHS28F FDR 45 deg



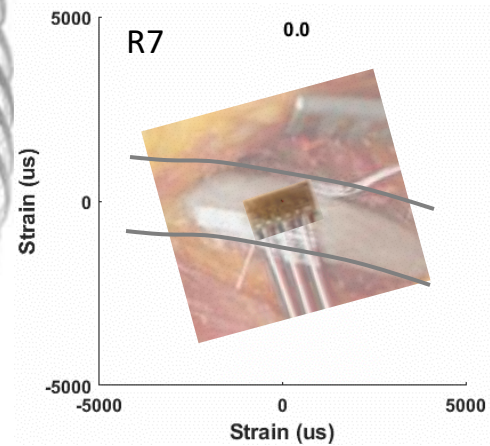
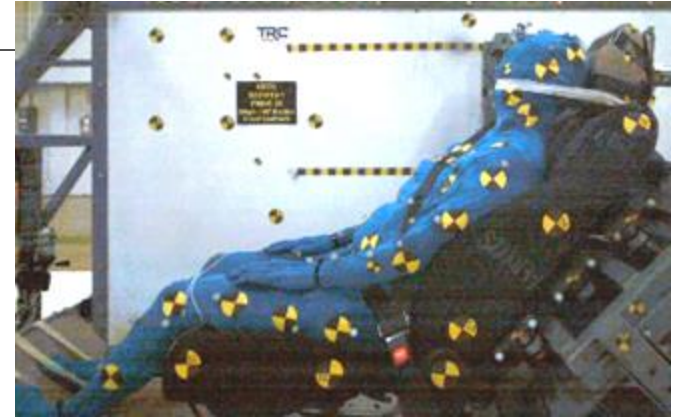
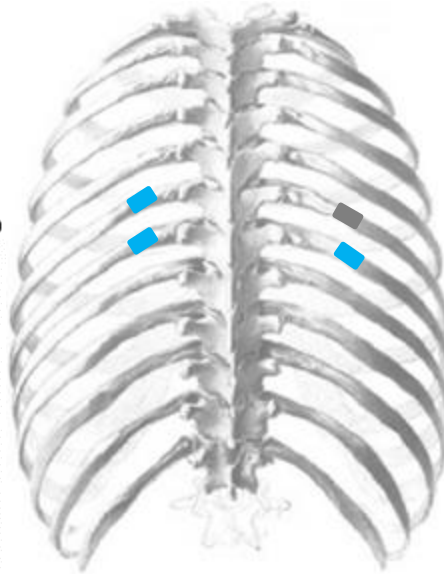
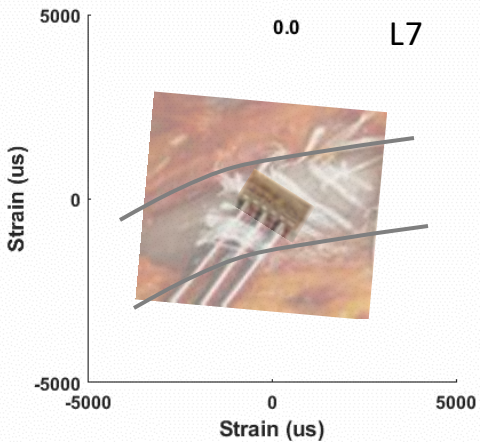
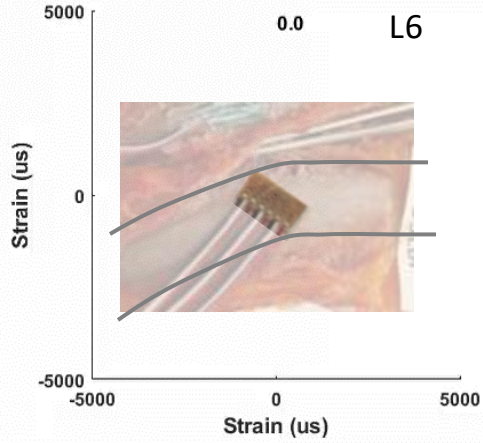
# Strain Rosette – **PMHS28F** FDR 45 deg



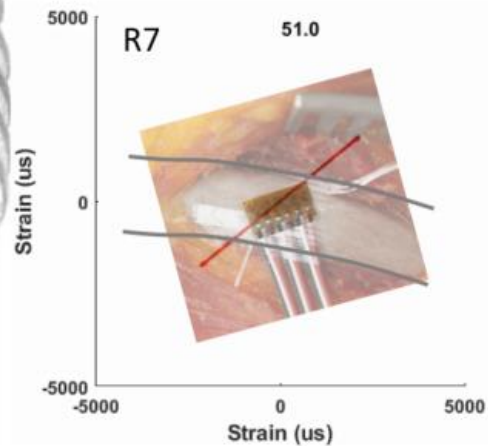
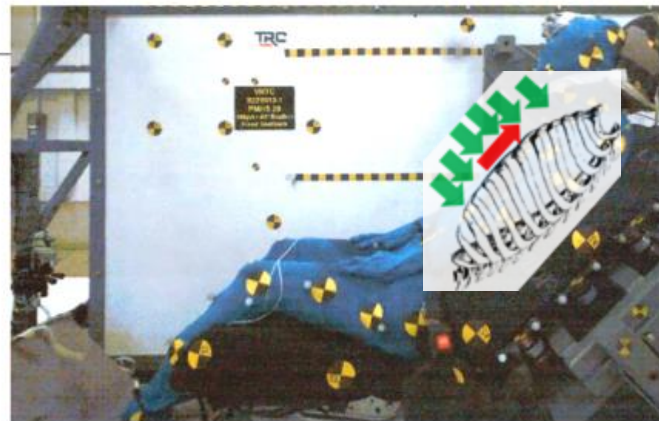
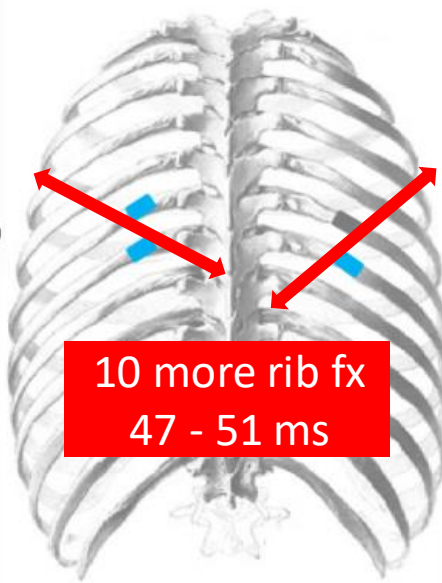
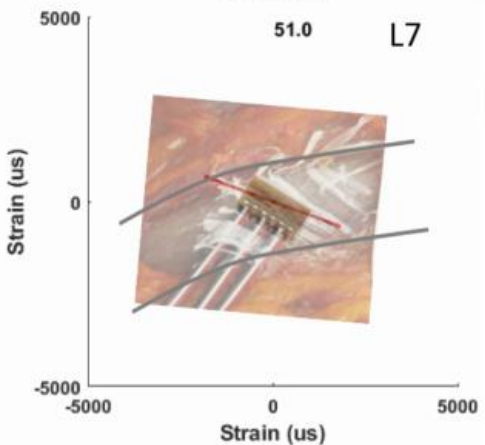
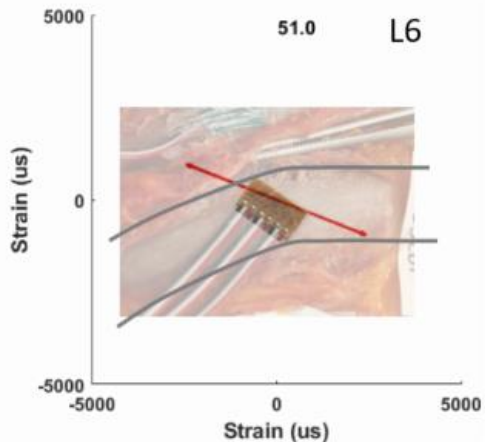
# Strain Rosette – PMHS28F FDR 45 deg



# Strain Rosette – **PMHS28F** FDR 45 deg

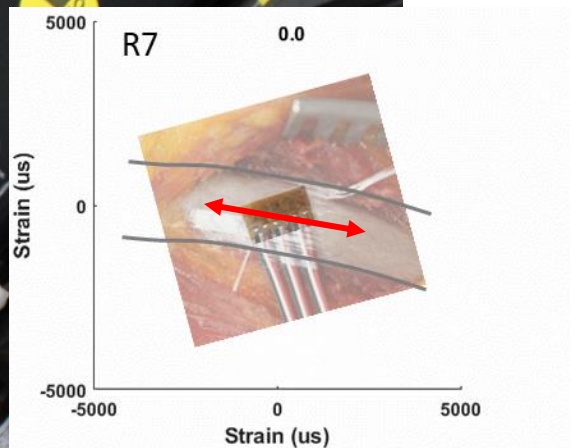
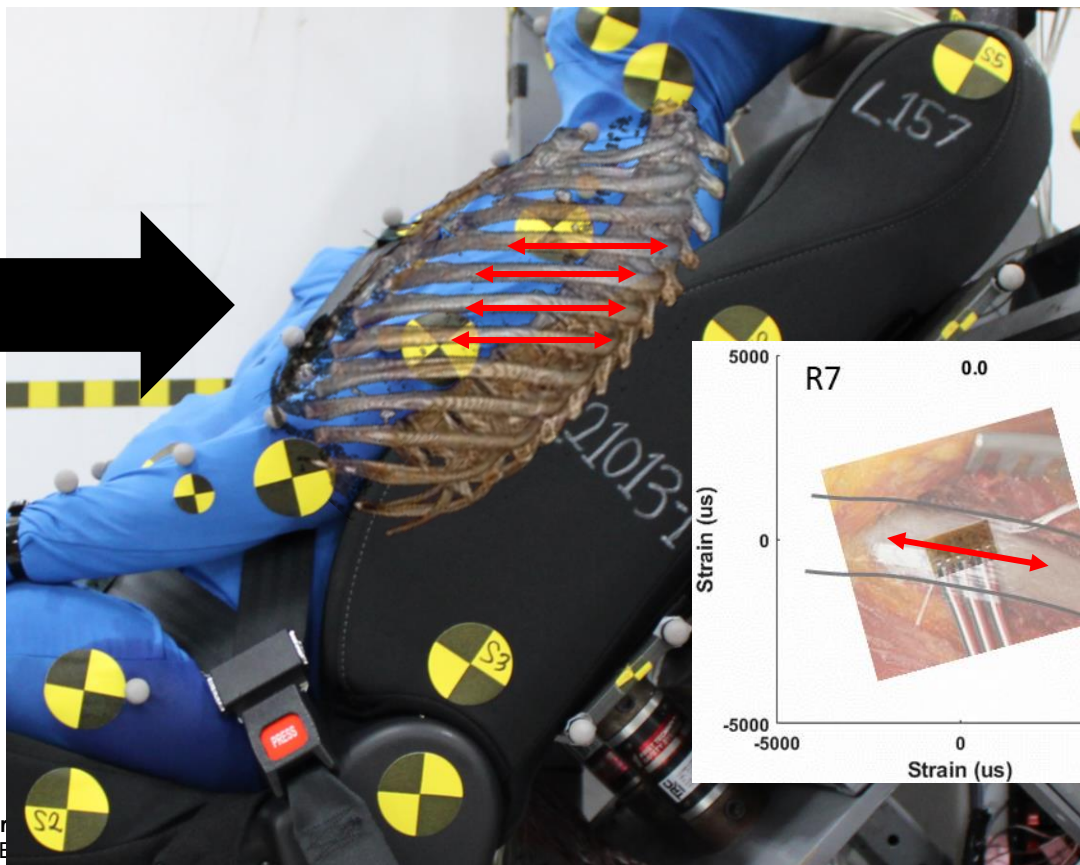


# Strain Rosette – **PMHS28F** FDR 45 deg

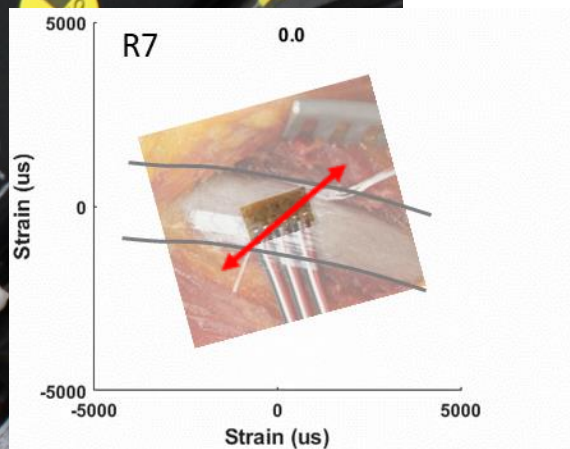
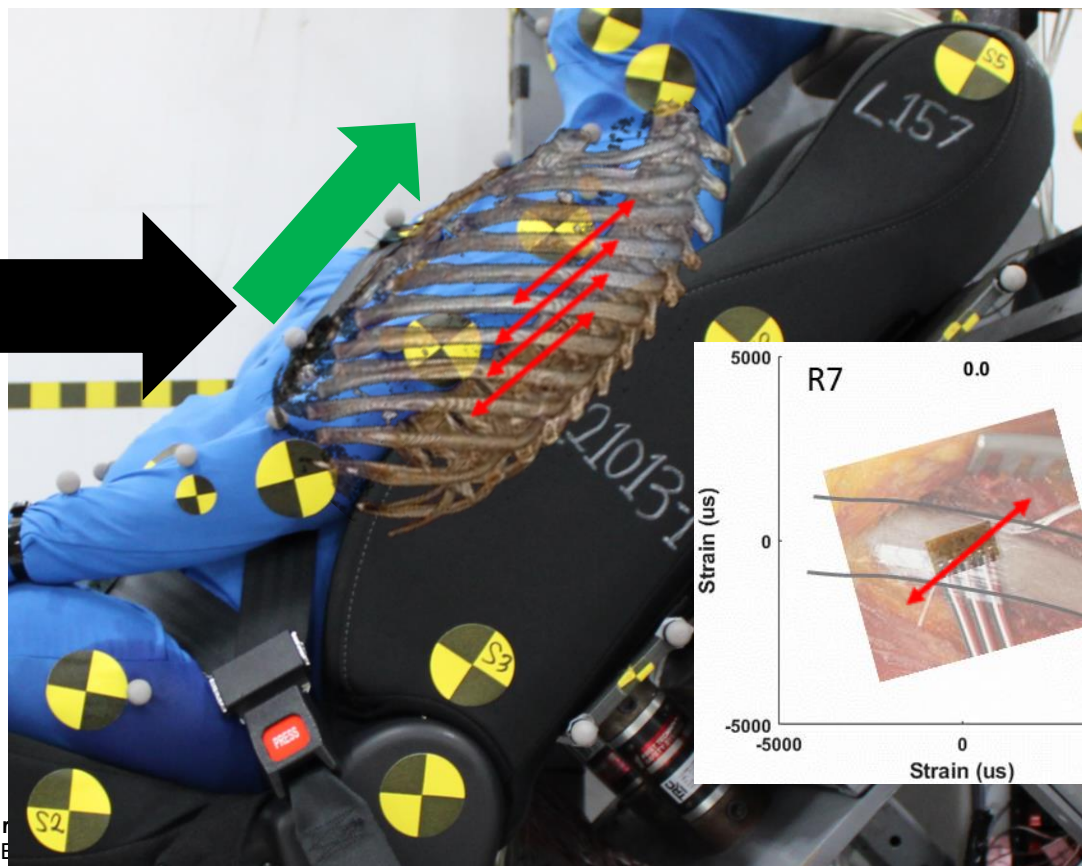




# Strain Rosette – **PMHS28F** FDR 45 deg



# Strain Rosette – **PMHS28F** FDR 45 deg



# Summary

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- No major differences in PMHS injury between female and male (FDR45)
  - Exception: vertebral body fractures in female PMHS
    - C7, T3, T4
  - Limited sample size
  - Rib and pelvis fractures: still major injury
- Female thorax also experienced both A-P and upward deflection
  - Larger A-P deflection in 25-degree condition than 45-degree condition
  - More NRF in 45-degree condition than 25-degree condition
- Strain rosette
  - Maximum principal strain
    - Considered both magnitude and orientation
  - Evidence of thoracic upward deflection

# Acknowledgements

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Anatomical Donors of...



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UNIVERSITY



The opinions expressed within are solely those of the authors and do not represent the views of any sponsors or collaborators



Students and staff of the Injury Biomechanics Research Center

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# Government/Industry Meeting

January 17-19, 2023

Washington, DC

[sae.org/gim](https://sae.org/gim)



## Preliminary Comparison of Female to Male Post Mortem Human Subjects in Rear-Facing Seat Configurations in High-speed Frontal Impacts

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