

# Update on Modification of THOR for Reclined Postures: Testing to Evaluate Prototype Pelvis Modifications

*RCCADS-Funded Project*

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*Public Workshop – Thursday, June 6, 2024*



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- ▶ **Disclaimer:** The opinions expressed herein are those of the authors and not necessarily those of the RCCADS members or of NHTSA.

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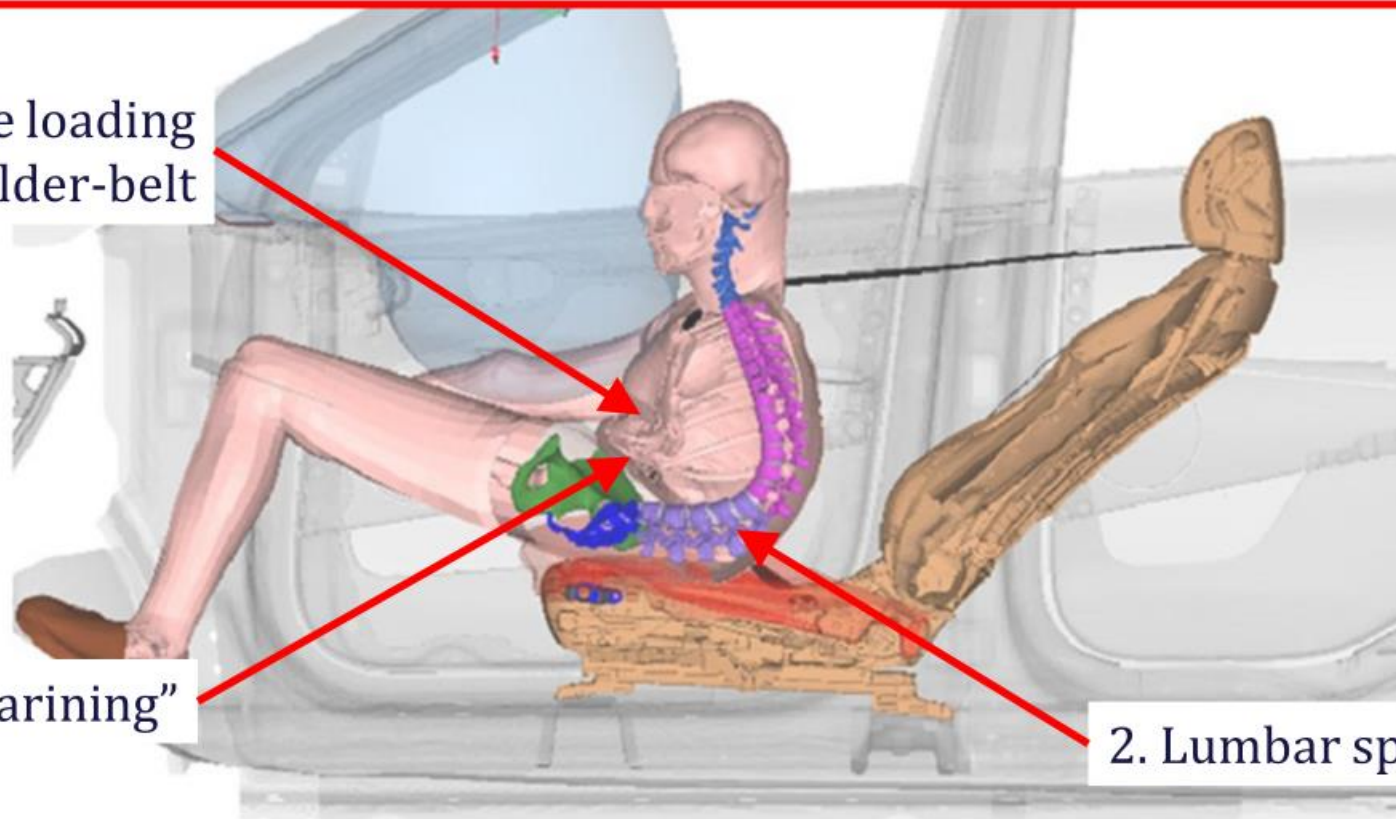
- ▶ **Warning:** This presentation includes photographs of human cadaver tissue.

Restraint challenges are expected for reclined occupants

## Need tools to assess risks of reclined occupants

3. Inferior ribcage loading  
by shoulder-belt

1. Lap-belt “submarining”



2. Lumbar spine compression/flexion

*Rawska et al., 2020*

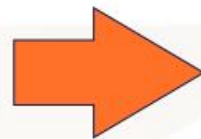
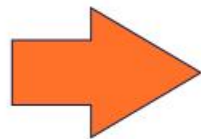


# Series goal: Design modifications to make a dummy reclinable

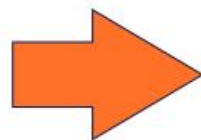
2019-2023: Modifications to THOR-50M Dummy

Current Study: most recent iteration

2019: Dummy Static Positioning  
*Prasad et al. 2019*



2019: PMHS Dynamic Sled Tests  
*Richardson et al. 2019, 2020abc*



2021, 2022, 2023: Physical & Computational Assessment



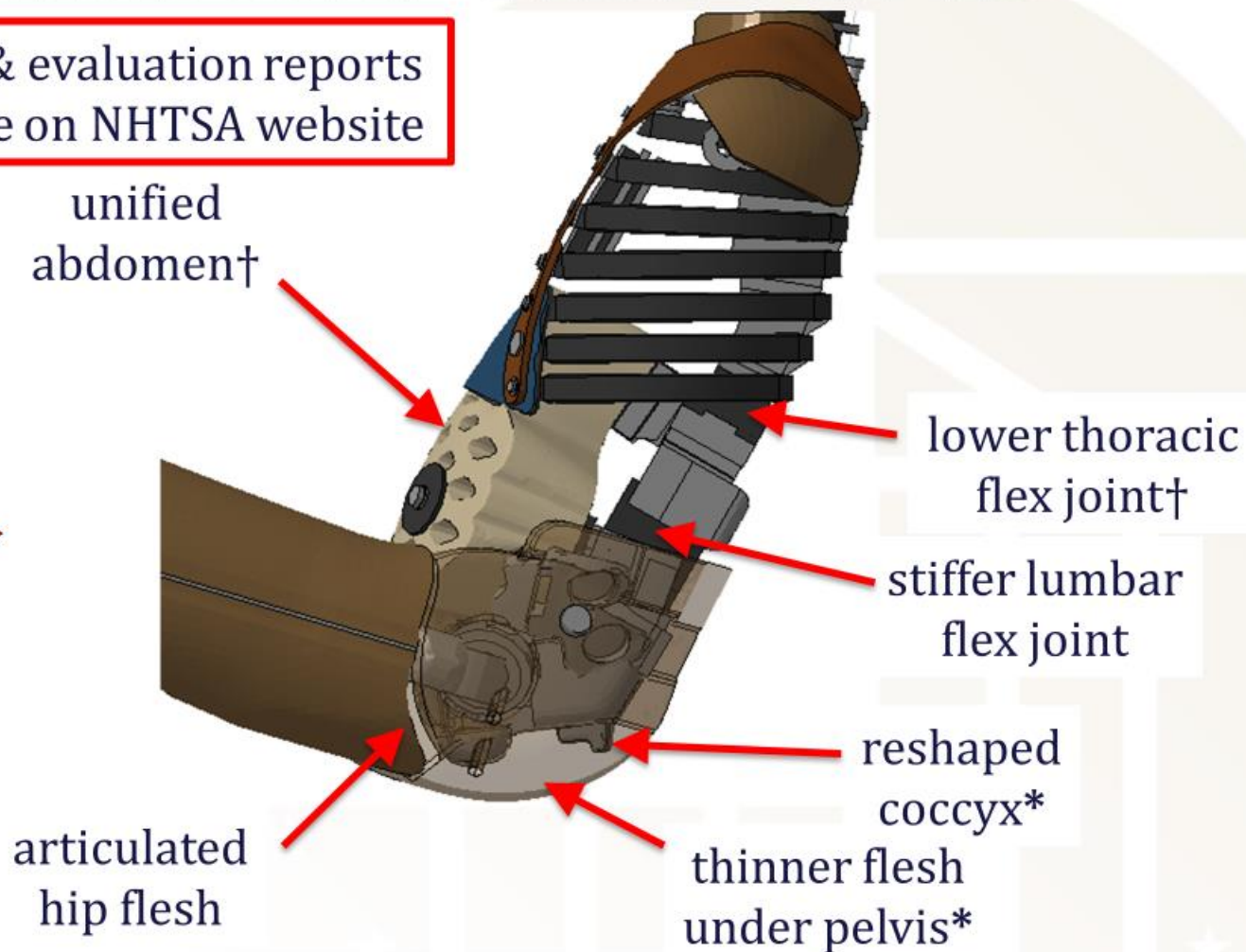
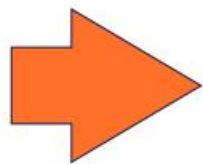
Iterative Design

# Modifications to the THOR-50M: "THOR-50M-RS"

Test Device for  
**Human**  
**Occupant**  
**Restraint,**  
**50<sup>th</sup>-percentile**  
**Male,**  
**Reclined**  
**Seating**



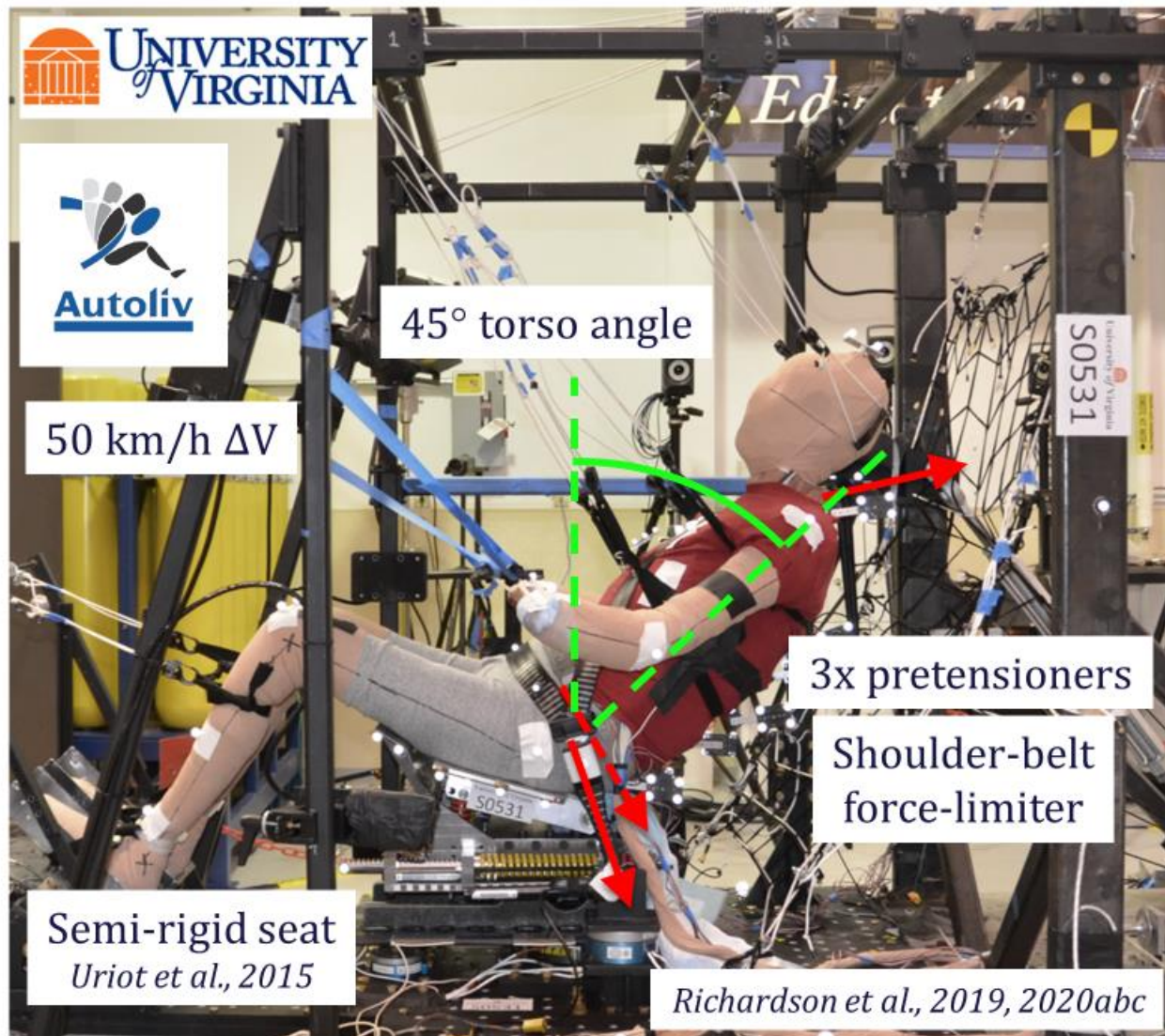
Design & evaluation reports  
 available on NHTSA website



\* new in current study  
 † revised in current study

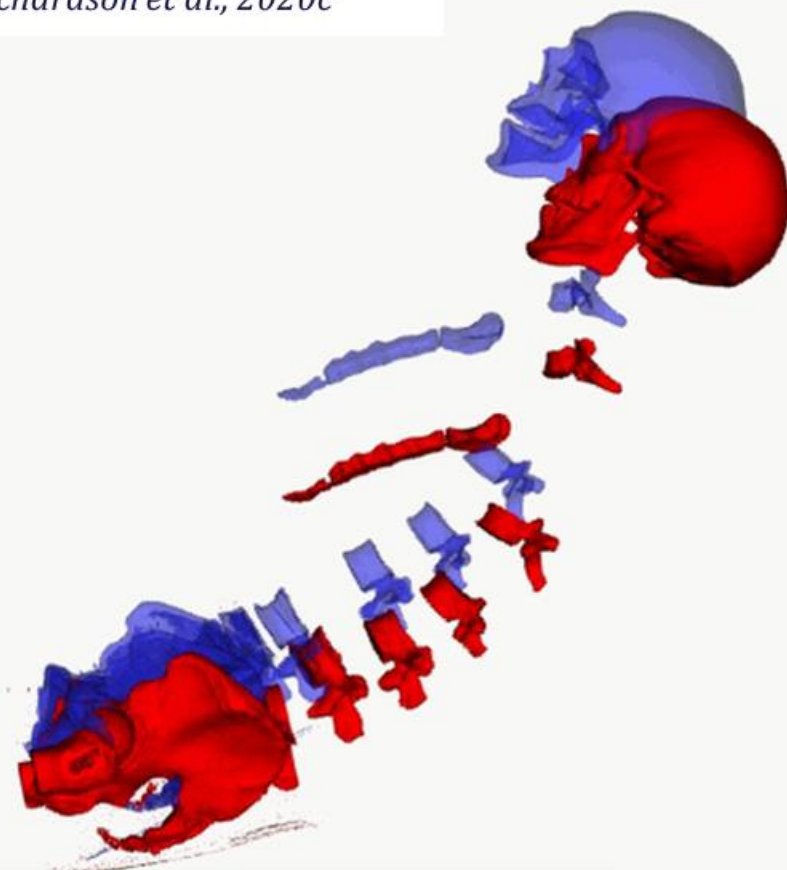
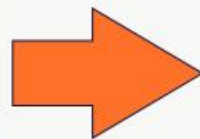


# Cadaver sled tests to inform modifications



Biomechanical response targets ("corridors")

*Richardson et al., 2020c*

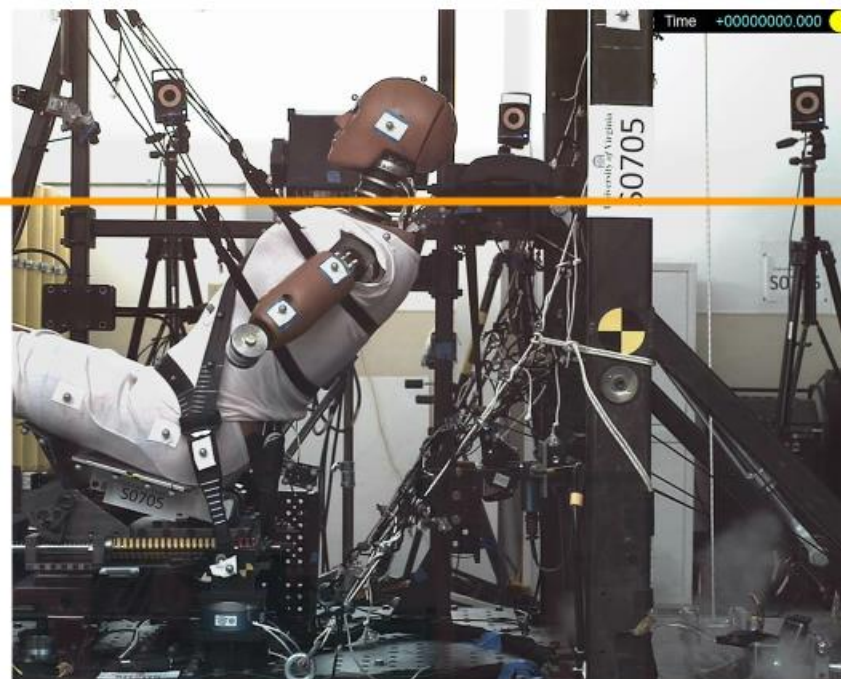
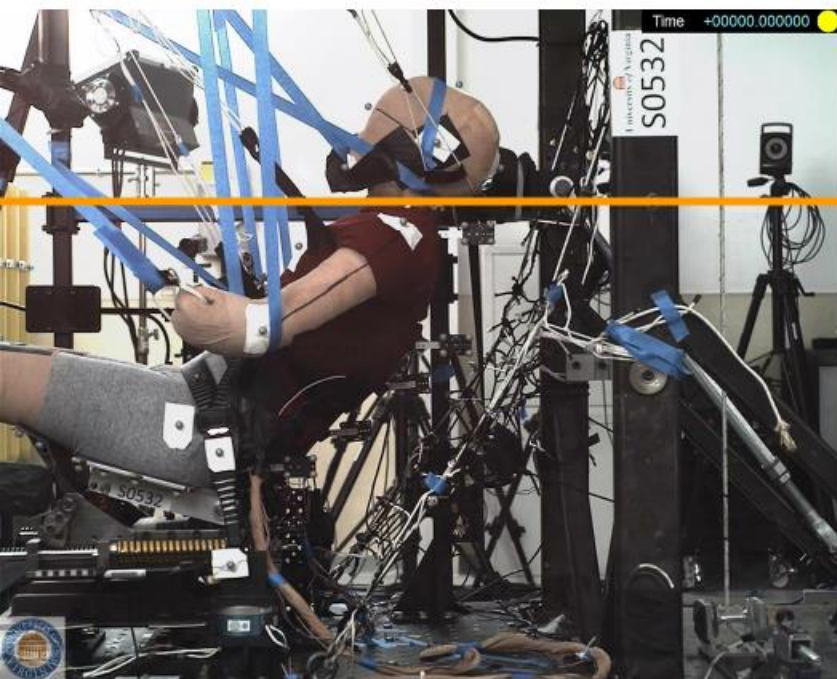


Motion of cadaver bones from test

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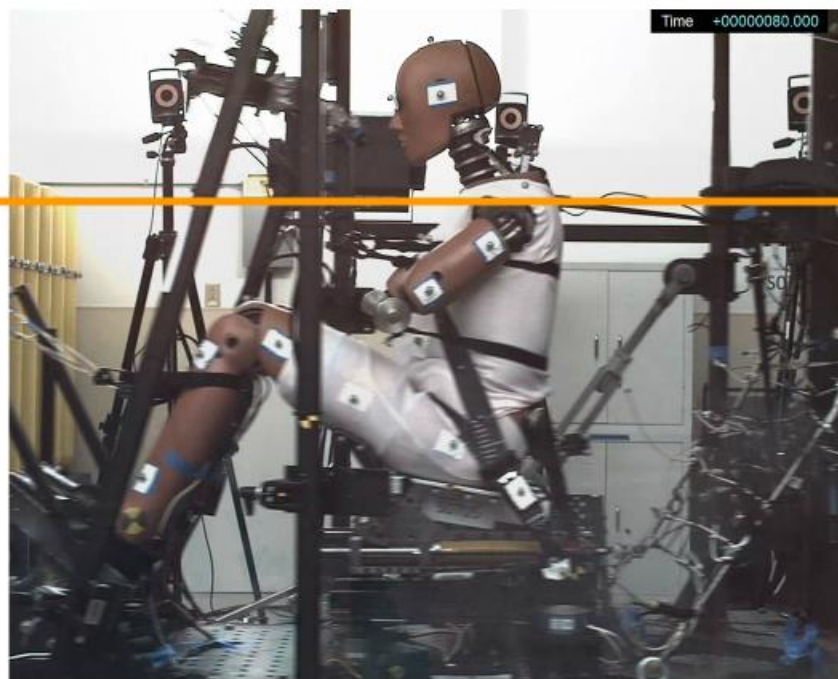
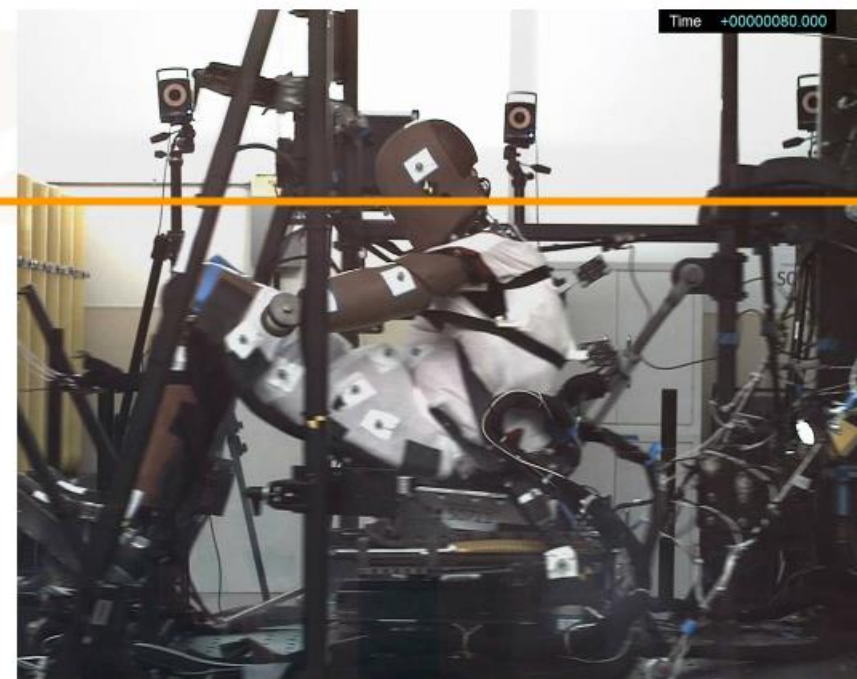


## Unmodified dummy versus cadaver

**PMHS****Hybrid-III 50<sup>th</sup> Male****THOR-50M**

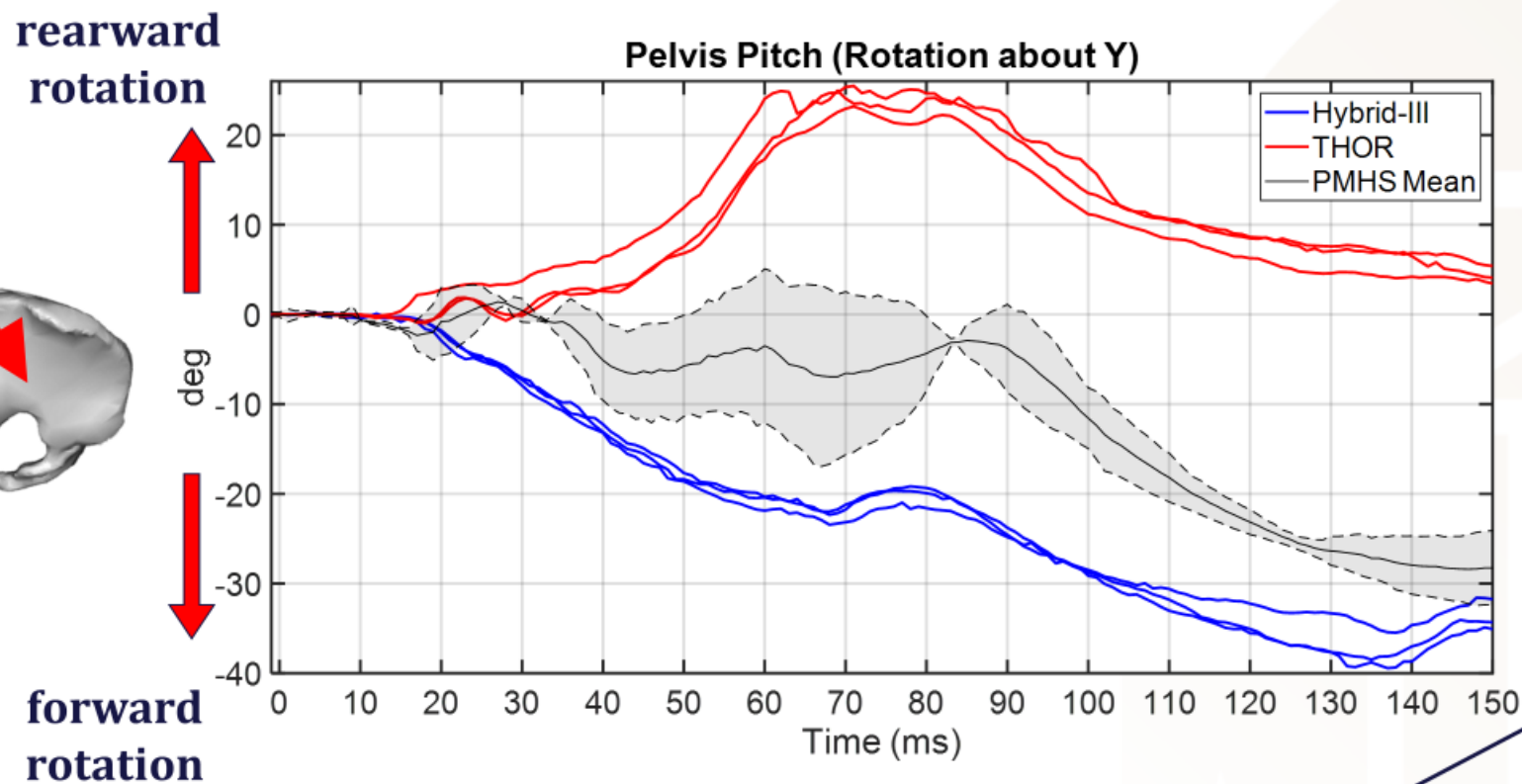


## Unmodified dummy versus cadaver

**PMHS****Hybrid-III 50<sup>th</sup> Male****THOR-50M**



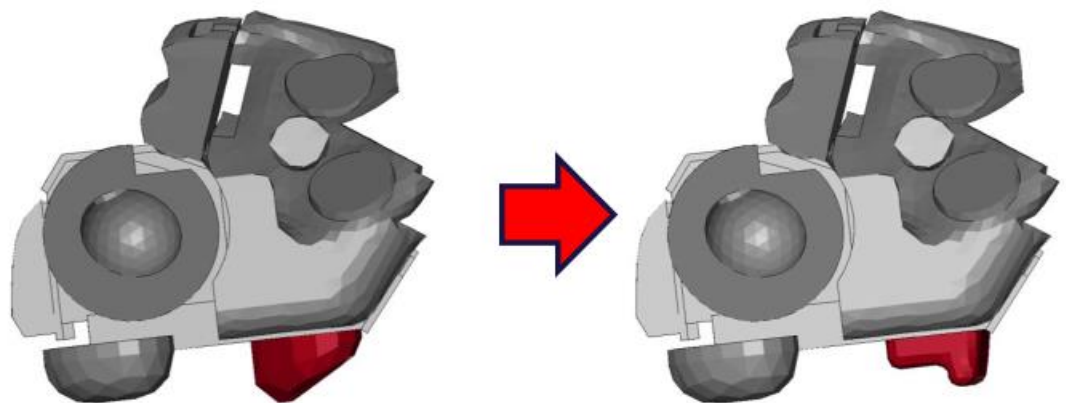
# Dummy pelvis motion not matching cadaver



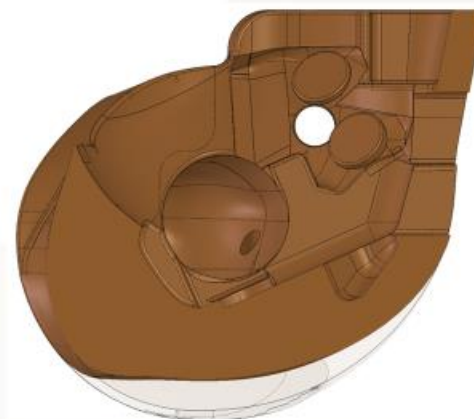
pelvis rotates  
FORWARD

pelvis rotates  
REARWARD

# Goal: Make modifications to correct pelvis rotation

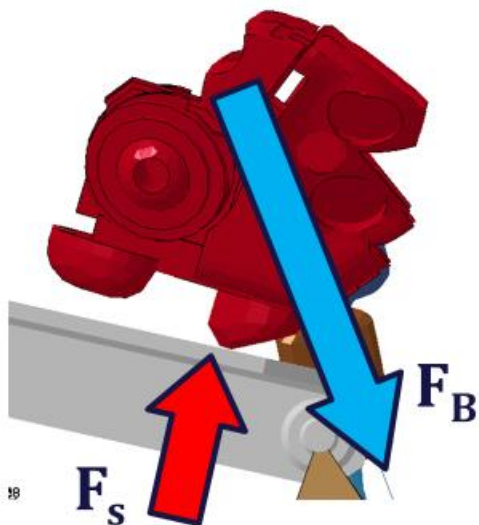


Reshaped sacrum/coccyx bone protrusion



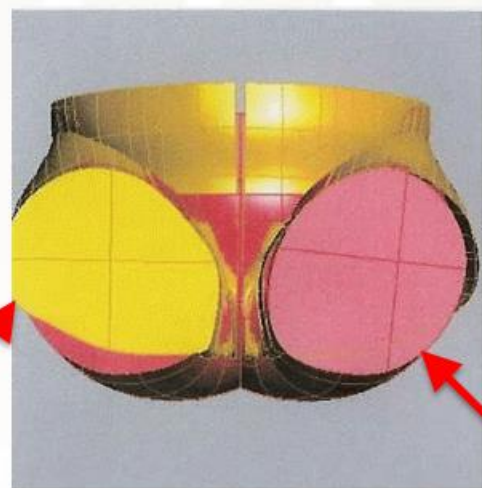
reduced buttock thickness

affects FORWARD position too



2022 Project

AMVO-50 seated buttock

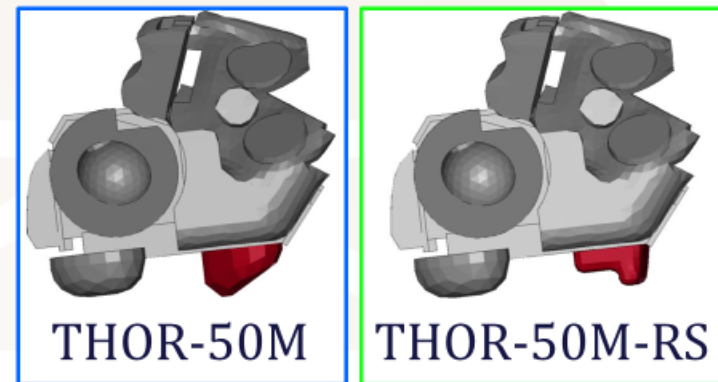
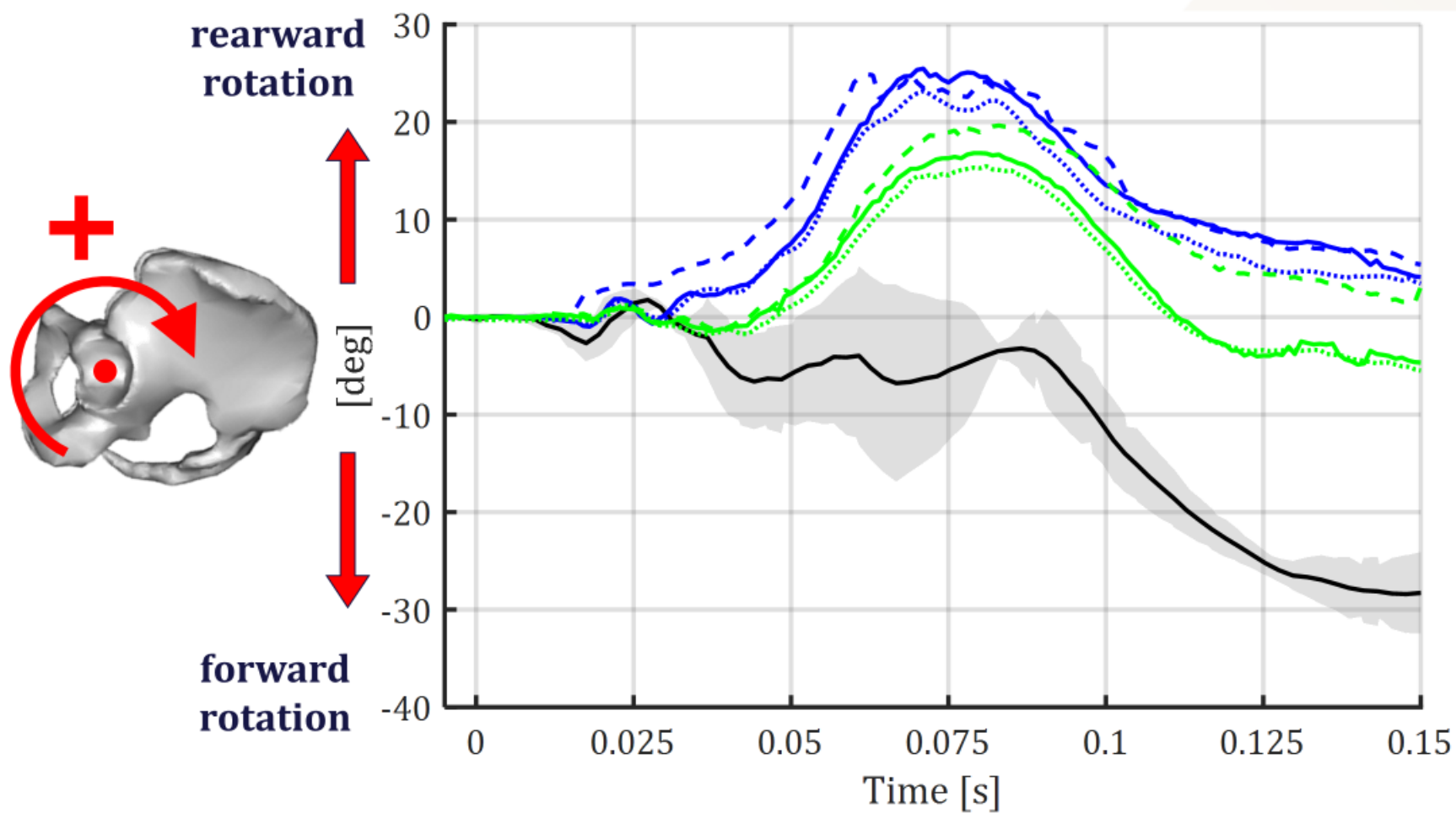


THOR-50M undeformed buttock

Shams et al., 2005



## Sacrum shape affects pelvis rotation - some

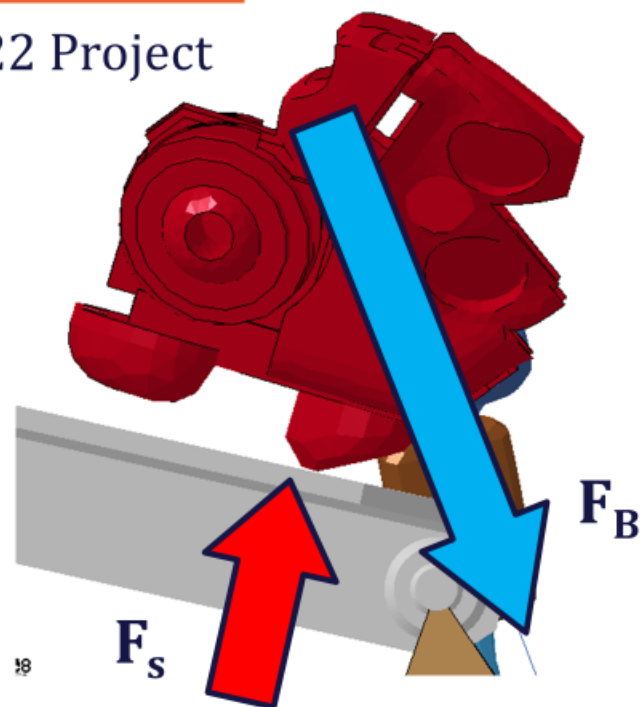


- Cadaver Mean
- Cadaver Corridor
- THOR-50M
- THOR-50M-RS

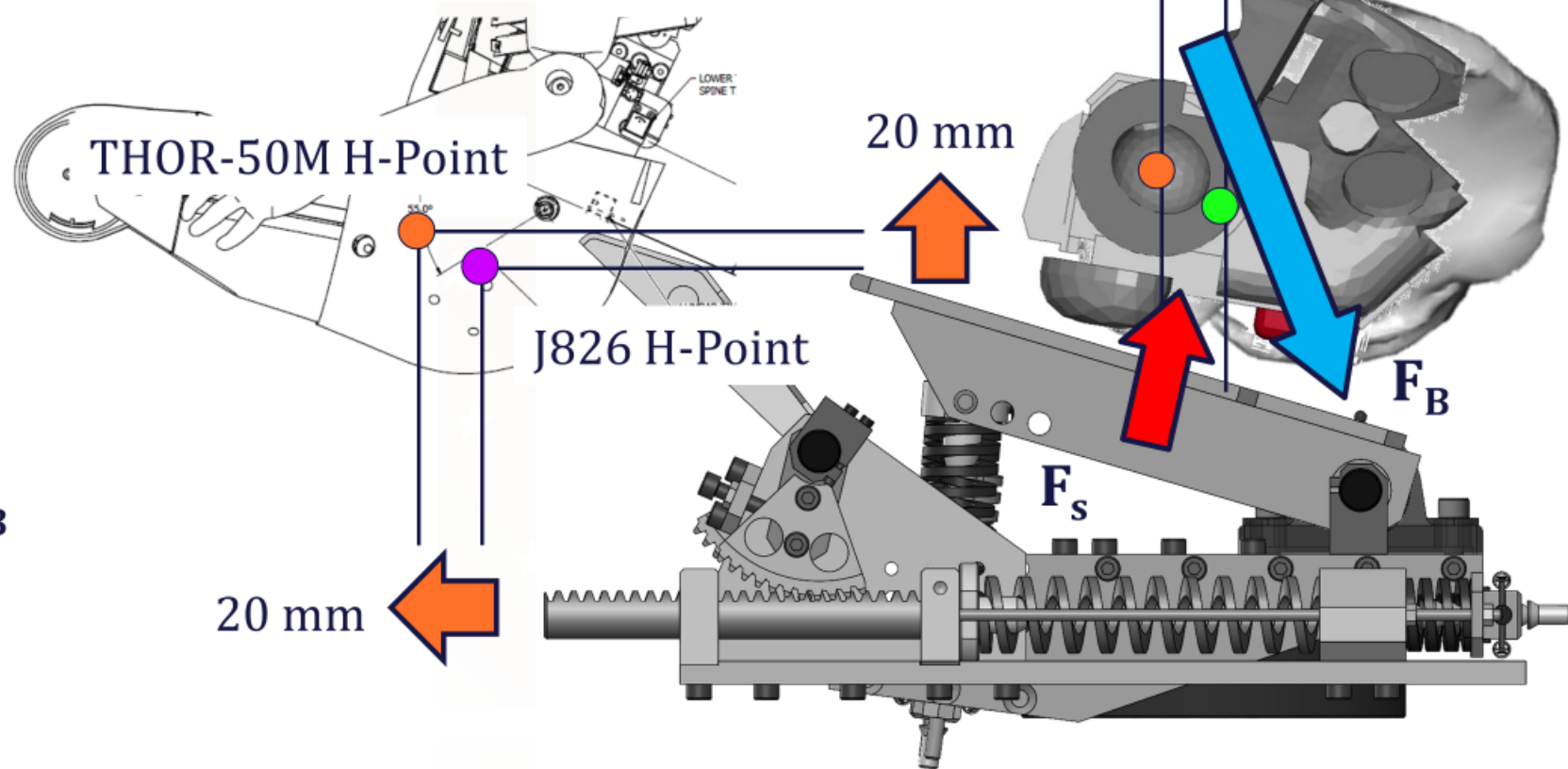
# What else could affect pelvis rotation?



2022 Project

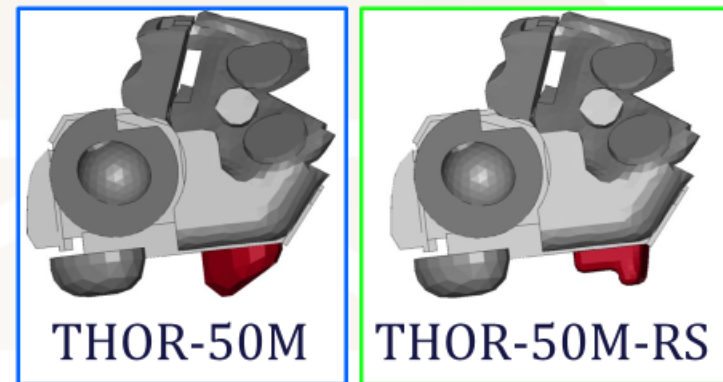
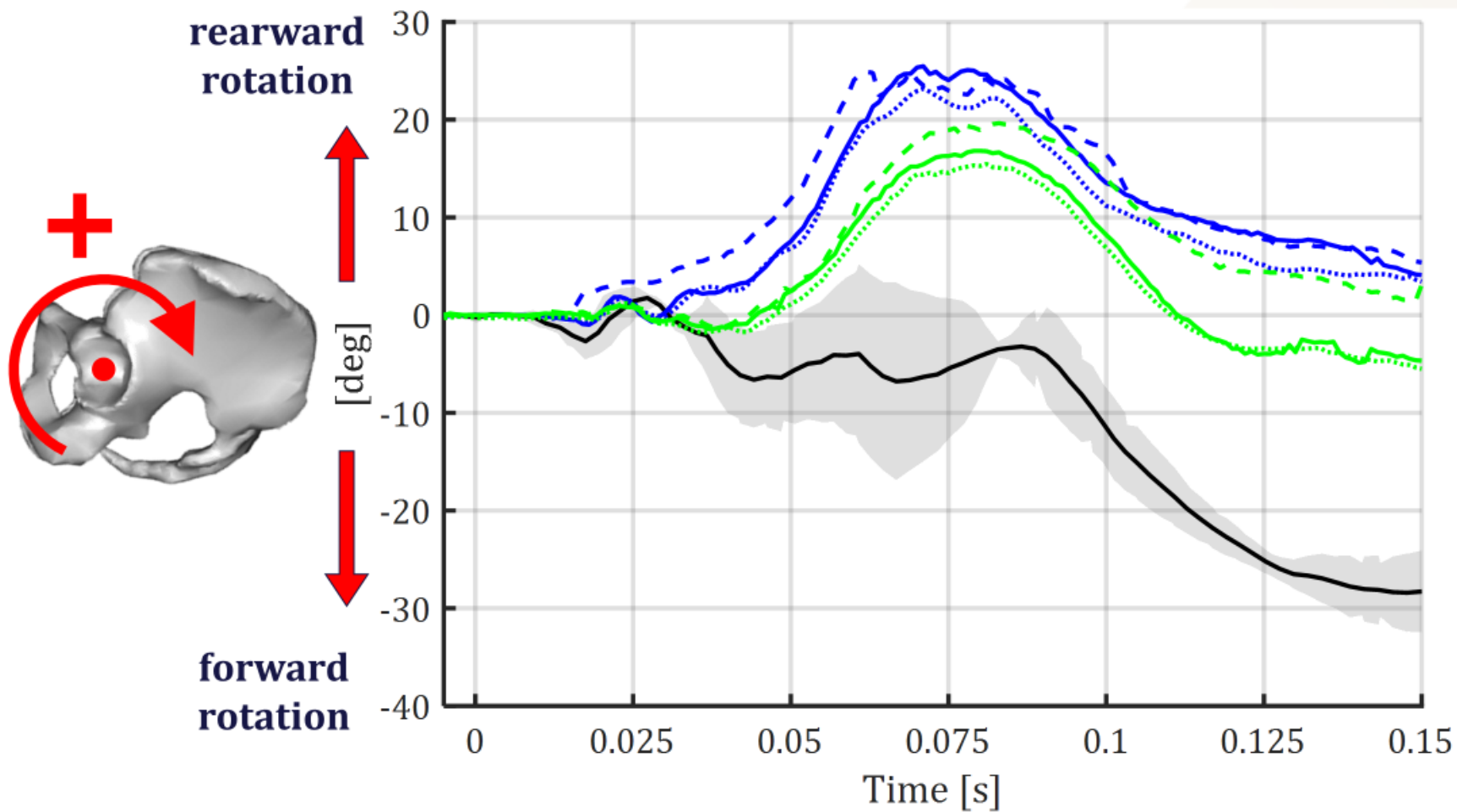


THOR-50M Seated  
Positioning Procedure  
*Louden et al., 2019*



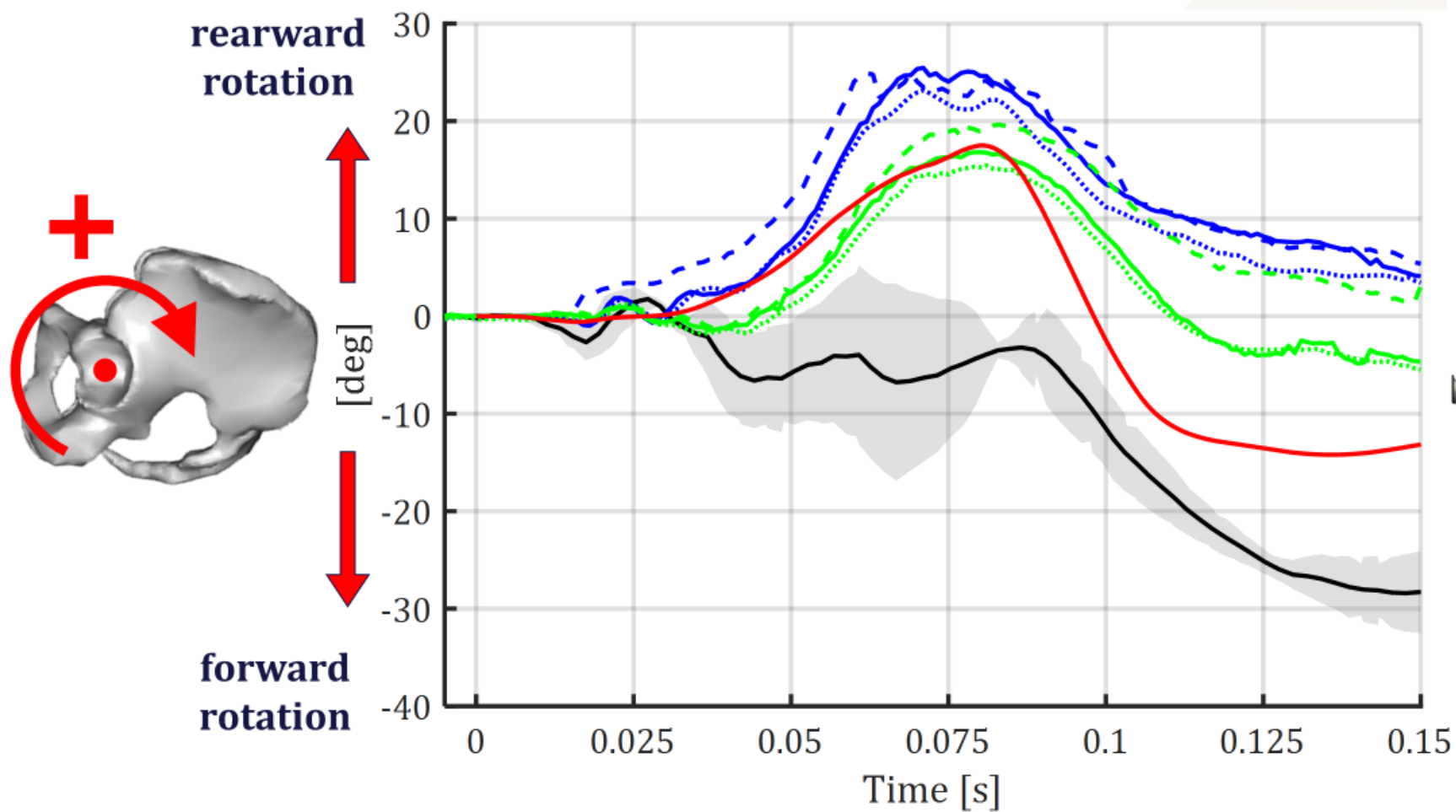


# Sacrum shape affects pelvis rotation - some

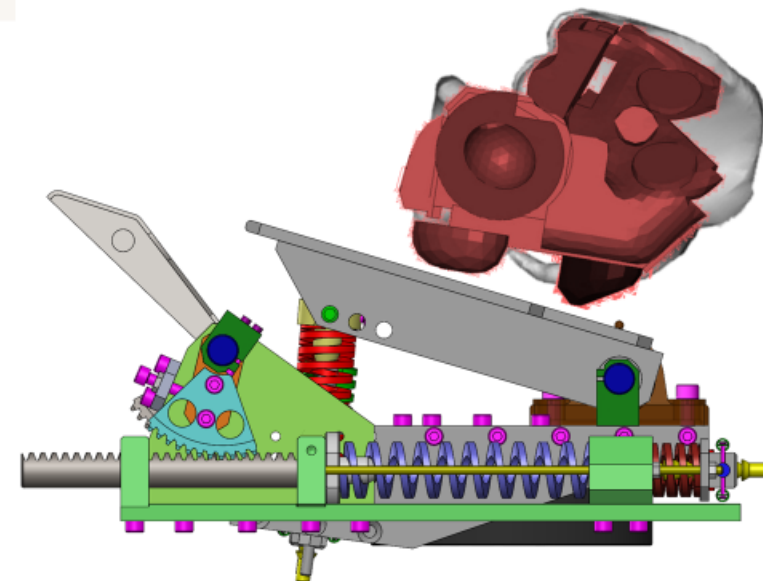


- Cadaver Mean
- Cadaver Corridor
- THOR-50M (forward)
- THOR-50M-RS (forward)

## Initial pelvis position affects pelvis rotation – some



THOR-50M rearward



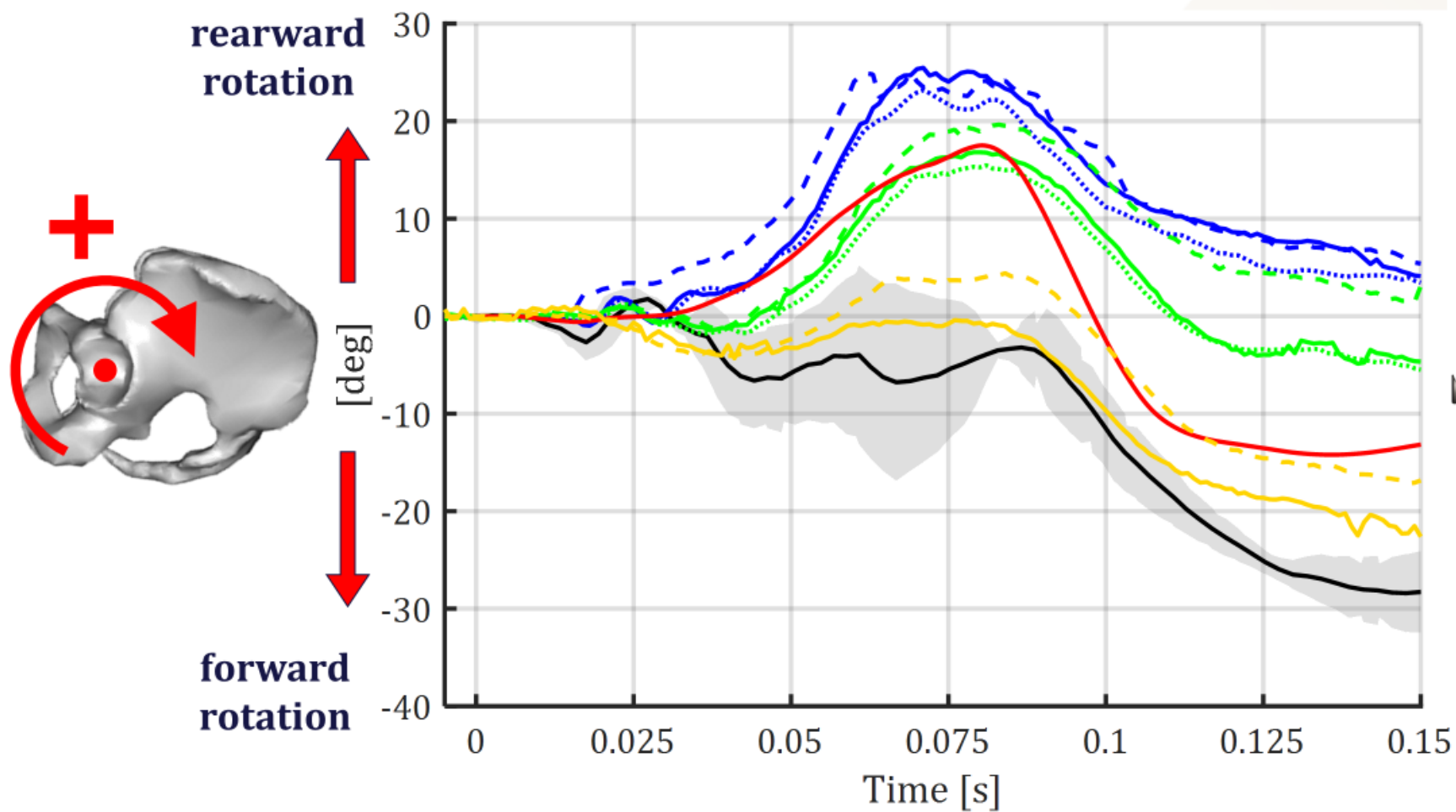
- Cadaver Mean
- █ Cadaver Corridor
- THOR-50M (forward)
- THOR-50M\* (rearward)
- THOR-50M-RS (forward)

\*Predicted with FE model

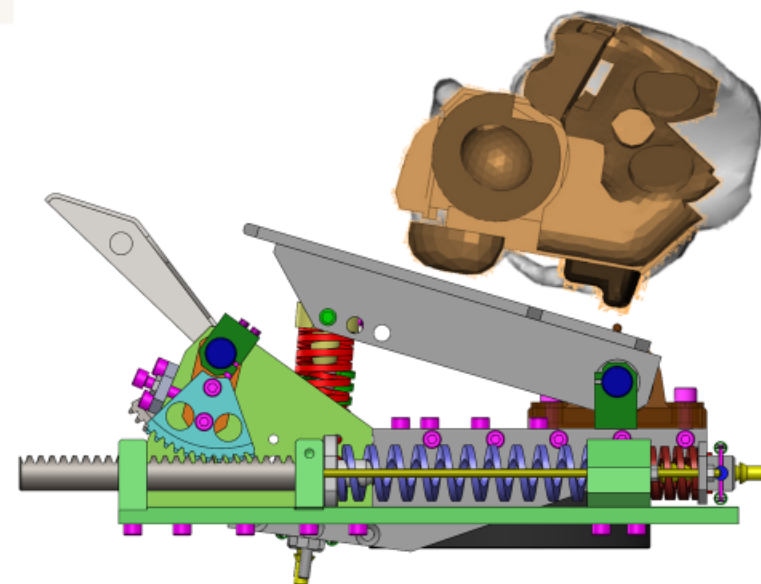
Center for Applied Biomechanics



# Sacrum shape & pelvis position affect pelvis rotation



THOR-50M-RS rearward



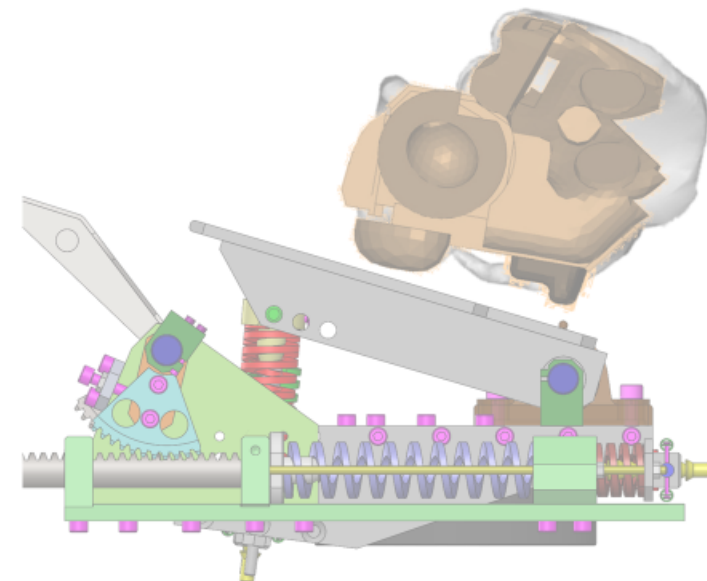
- Cadaver Mean
- Cadaver Corridor
- THOR-50M (forward)
- THOR-50M\* (rearward)
- THOR-50M-RS (forward)
- THOR-50M-RS (rearward)

\*Predicted with FE model

# Sacrum shape & pelvis position affect pelvis rotation



THOR-50M-RS rearward



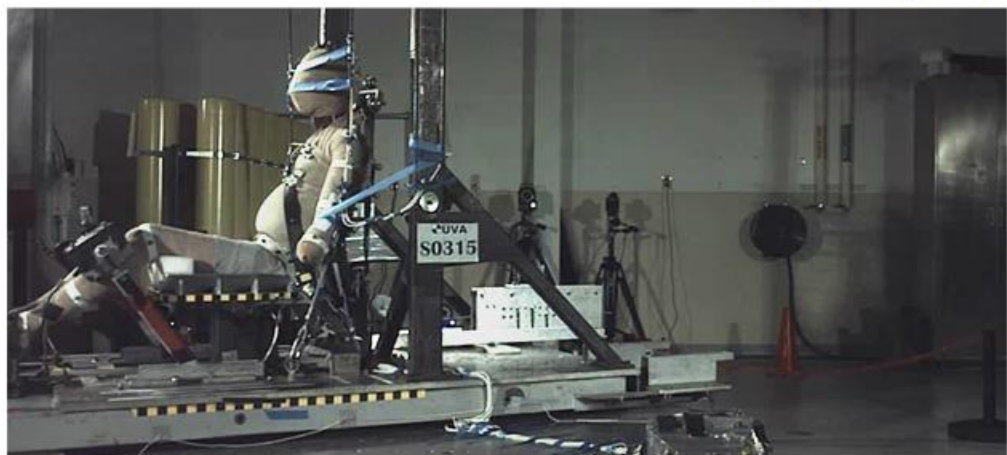
- Cadaver Mean
- Cadaver Corridor
- THOR-50M (forward)
- THOR-50M\* (rearward)
- THOR-50M-RS (forward)
- THOR-50M-RS (rearward)

\*Predicted with FE model



# Moving forward

- ▶ Concluded four-year series of projects to modify a dummy to be reclinable
- ▶ Achieved goal to refine dummy modifications to correct pelvis rotation
  - Whole-body dummy responses publication planned
- ▶ *Reclinable, not reclined*: ongoing NHTSA-funded project, UVA to assess THOR-50M-RS in standard (upright) conditions & other reclined conditions



“Gold Standard”

*Shaw et al., 2009, 2014,  
Montesinos-Acosta et al., 2016*



“Silver Standard”

*Donlon et al., 2020*

*Center for Applied Biomechanics*

Thank you!

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# References & More Data

## ▶ THOR-50M-RS Development:

- Assessment of THOR-50M in reclined seats: <https://www.nhtsa.gov/research-data/research-testing-databases#/biomechanics/12990>
  - Including UVA's positioning procedure for THOR-50M in reclined postures
- Assessment of THOR-50M in reclined impact (Shin et al., 2022): <https://www.ircobi.org/wordpress/downloads/irc22/pdf-files/2248.pdf>
- Assessment of THOR-50M-RS in reclined seats: <https://www.nhtsa.gov/research-data/research-testing-databases#/biomechanics/13255>

## ▶ PMHS Biofidelity Source:

- Richardson et al., 2019: <https://www-esv.nhtsa.dot.gov/Proceedings/26/26ESV-000243.pdf>
- Richardson et al., 2020a: <https://www.ircobi.org/wordpress/downloads/irc20/pdf-files/60.pdf>
- Richardson et al., 2020b: <https://doi.org/10.1080/15389588.2020.1837365>
- Richardson et al., 2020c: <https://doi.org/10.4271/2020-22-0004>

## ▶ Additional Citations in this Presentation:

- Donlon et al., 2020: <https://doi.org/10.1080/15389588.2020.1745787>
- Loudon et al., 2019: [https://downloads.regulations.gov/NHTSA-2019-0106-0006/attachment\\_1.pdf](https://downloads.regulations.gov/NHTSA-2019-0106-0006/attachment_1.pdf)
- Montesinos-Acosta et al., 2016: <https://www.ircobi.org/wordpress/downloads/irc16/pdf-files/94.pdf>
- Prasad et al., 2019: [https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/atd\\_seating\\_in\\_highly\\_reclined\\_seats.pdf](https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/atd_seating_in_highly_reclined_seats.pdf)
- Rawska et al., 2020: <https://doi.org/10.1080/15389588.2020.1791324>
- Shams et al., 2005: <https://www-nrd.nhtsa.dot.gov/pdf/ESV/esv19/Other/Print%2019.pdf>
- Shaw et al., 2009: <https://doi.org/10.4271/2009-22-0001>
- Shaw et al., 2014: [http://dx.doi.org/10.20485/jsaeijae.5.1\\_39](http://dx.doi.org/10.20485/jsaeijae.5.1_39)
- Shin et al., 2022: <https://www.ircobi.org/wordpress/downloads/irc22/pdf-files/2248.pdf>