NHTSA

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Initial Biofidelity Comparison Between THOR-05F and Hybrid-III 5th Percentile Female ATDs

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Motivation

- NHTSA developed the THOR-05F ATD to better evaluate injury risk of small female adult occupants
  - Alternative to Hybrid-III 5th in frontal crash tests
  - Improved biofidelity and measurement capability
  - More thoroughly evaluate & improve advanced restraint systems

THOR-05F

HIII 5th

Test Setup

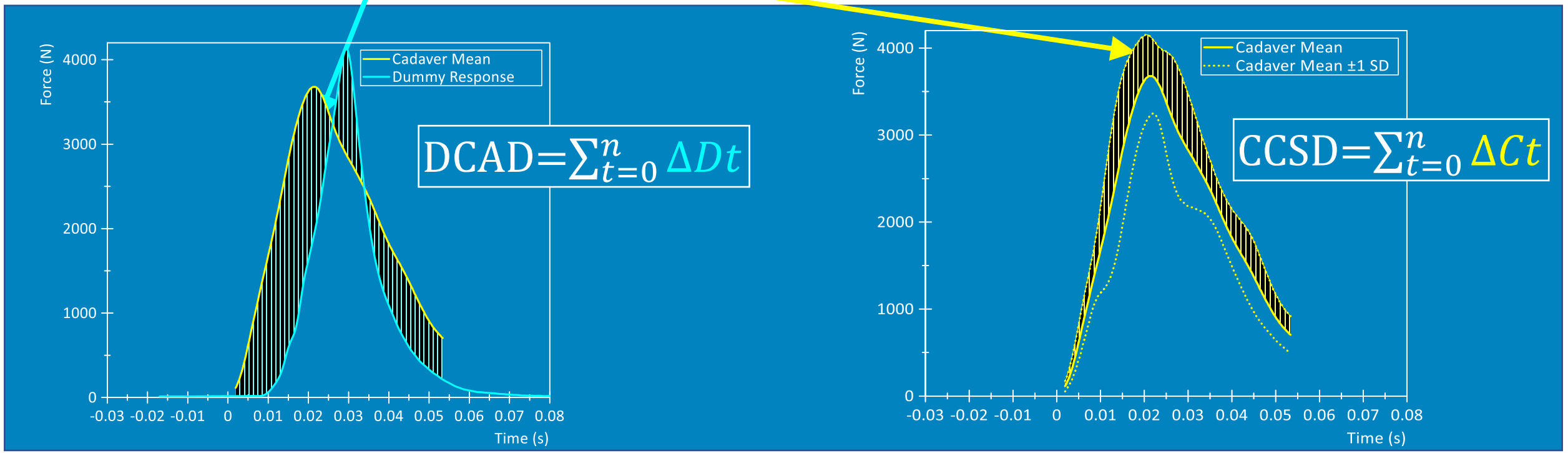
- Objective: Assess differences in biofidelic response between the THOR-05F and HIII 5th ATDs
- Tested in similar conditions for 9 test modes[1]
  - Head Impact
  - Face Rigid Bar Impact
  - Face Rigid Disk Impact
  - Neck Flexion Mini-Sled
  - Shoulder Range of Motion
  - Upper Thorax Impact
  - Upper Abdomen Impact
  - Lower Abdomen Impact
  - Knee Slider Impact
  - Dorsiflexion Dynamic
  - Dynamic Inversion
  - Dynamic Eversion
- Multiple trials (n = 3+) for each ATD in each mode
- BioRanked using the latest method[2]

1. Lee, E. L., et al. ”Biomechanical Response Manual: THOR 5th Percentile Female NHTSA Advanced Frontal Dummy, Revision 2.” No. DOT HS 812 811. United States. Department of Transportation. National Highway Traffic Safety Administration (2020).
2. Hagedorn A., et al. "Biofidelity Evaluation of THOR-50M in Rear-Facing Seating Configurations using an Updated Biorank System." *SAE International Journal of Transportation Safety* Special Issue on Occupant Protection & Crashworthiness for ADS-Equipped Vehicles (2022).

BioRanking

- Phase differences were removed and then the Biofidelity Ranking System score (BRS score) was calculated for each response measurement:

$$BRS\ Score = \frac{DCAD}{CCSD} = \frac{Dummy\ Cumulative\ Absolute\ Difference}{Cadaver\ Cumulative\ Standard\ Deviation}$$



BioRanking

- For each test condition, the average BRS score from the response measurements was calculated. The average of each test condition in a specific body region was calculated. The average of each body region was averaged for a total ATD BRS score.

- The BRS score represents multiples of standard deviation away from the target response (BRS score < 2 is desirable)

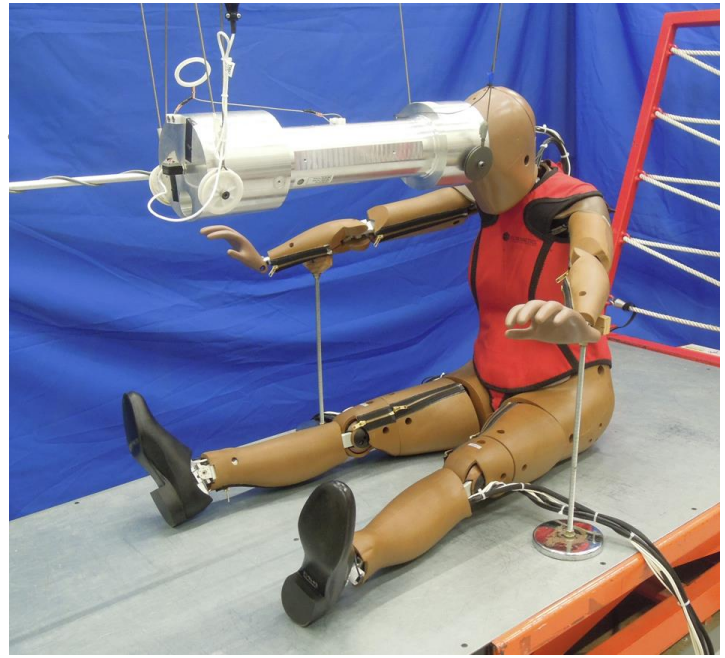
The smaller the BRS score, the more biofidelic the response

Head/Face Biofidelity

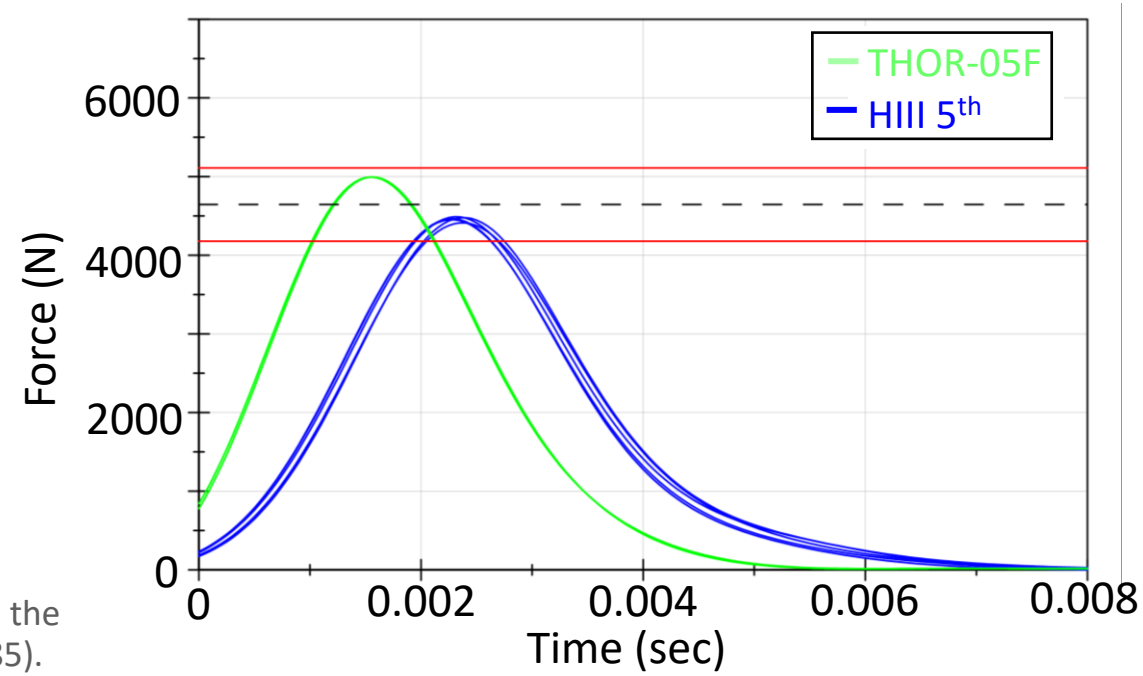
- Whole-body Head Impact
- Face Rigid Bar Impact
- Face Rigid Disk Impact

Head Biofidelity

- Target Corridor: Melvin et al. 1988 (Scaled PMHS)[3]
- Impactor speed: 2.0 ±0.05 m/s
- Impactor mass: 19.20 kg
- Single-point BioRank at maximum force

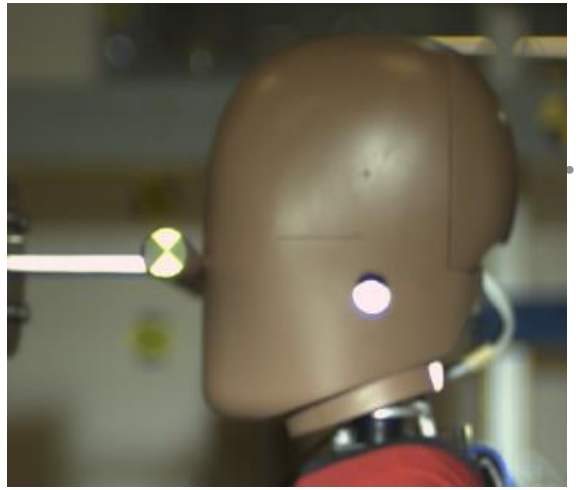


	THOR-05F	HIII 5th
Whole-body Head Impact		
Impact Force	0.75	0.40



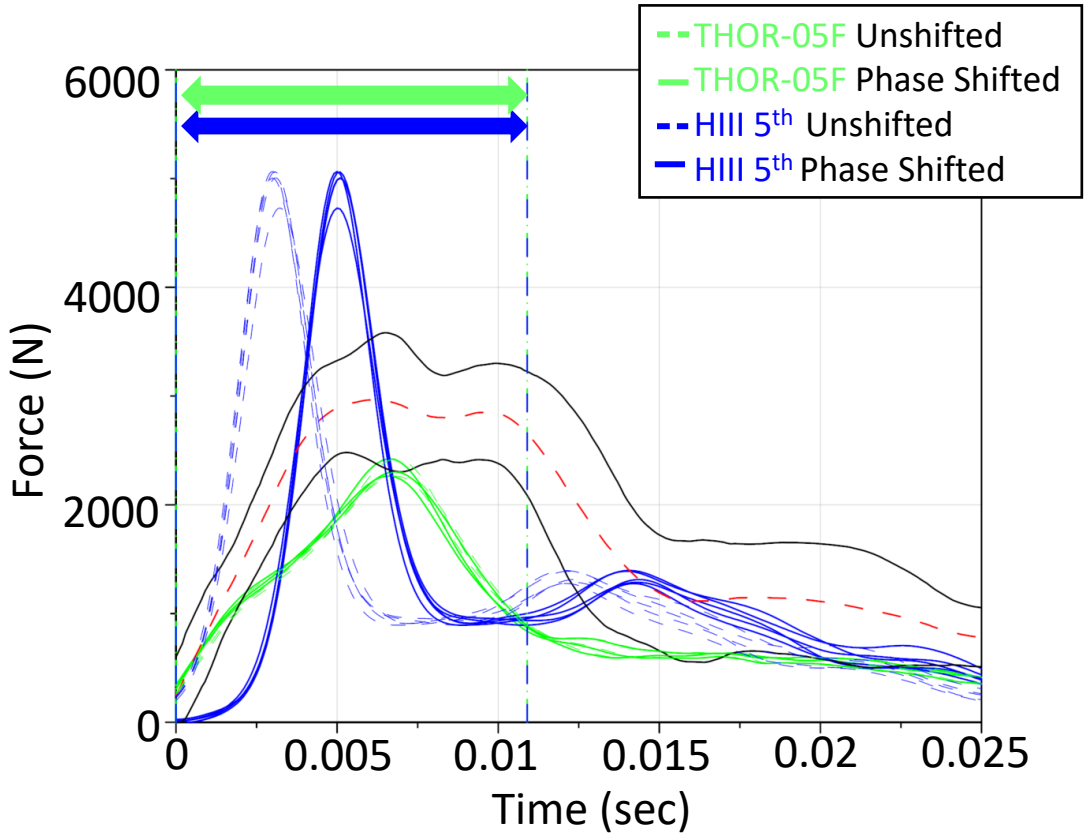
3. Melvin, J. W., and K. Weber. "Review of biomechanical impact response and injury in the automotive environment." *Task B Final Report, NHTSA Contract DTNH22-83-C-07005* (1985).

Face Bar Biofidelity



- New face insert design (not Confor)
- Target Corridor: Nyquist, 1986 (Scaled PMHS)[4]
- Impactor speed: 3.6 ±0.05 m/s
- Impactor mass: 26.2 kg

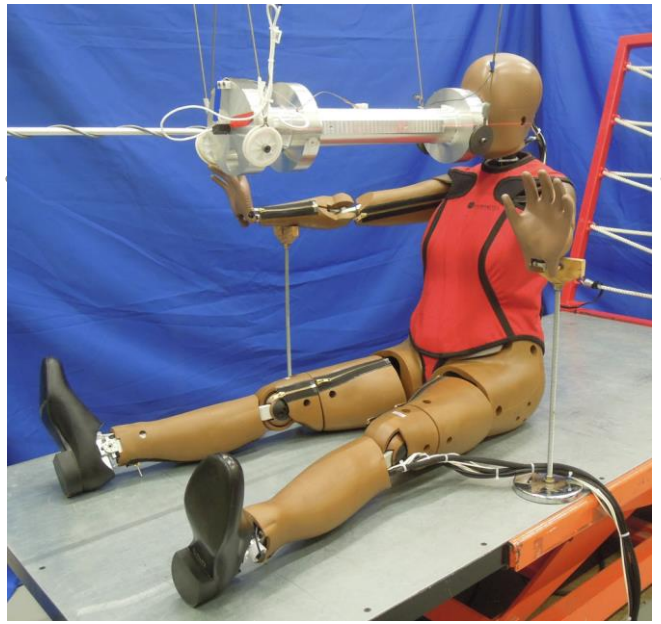
	THOR-05F	HIII 5th
Face Rigid Bar Impact		
Impact Force	1.87	2.82



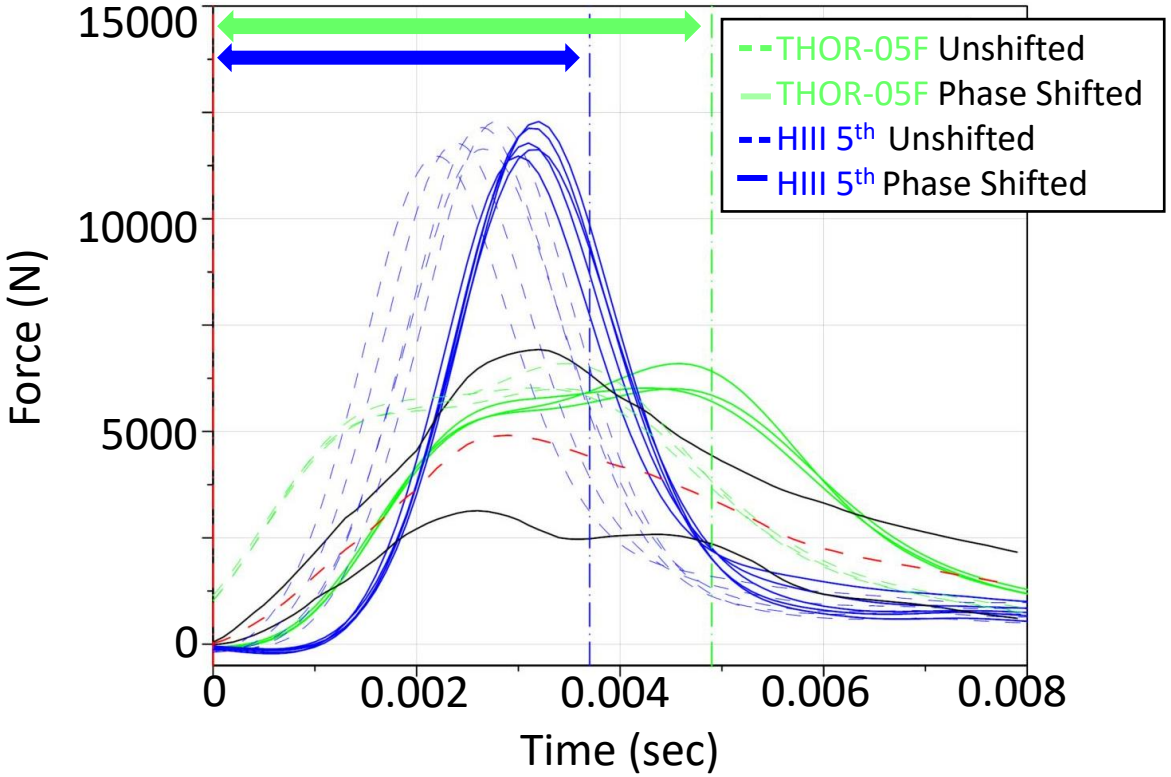
4. Nyquist, G. W., et al. "Impact tolerance and response of the face." Proceedings of the Advances in Bioengineering Conference. Anaheim, CA, 1986.

Face Disk Biofidelity

- New face insert design (not Confor)
- Target Corridor: Melvin et al. 1989 (Scaled PMHS)[5]
- Impactor speed: 6.7 ±0.05 m/s
- Impactor mass: 10.7 kg



	THOR-05F	HIII 5th
Face Disk Impact		
Impact Force	0.84	2.51



5. Melvin, J. and T. Shee. “Facial injury assessment techniques.” (1989).

Head/Face Summary

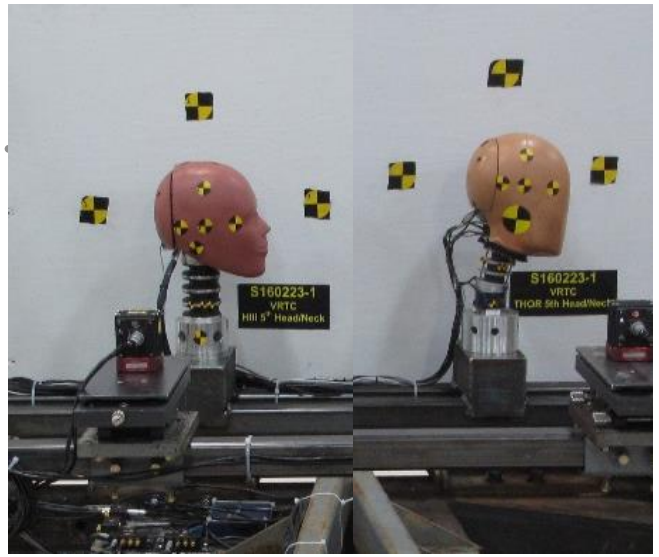
	THOR-05F	HIII 5th
Whole-body Head Impact		
Impact Force	0.75	0.40
Face Rigid Bar Impact		
Impact Force	1.87	2.82
Face Disk Impact		
Impact Force	0.84	2.51
HEAD/FACE AVERAGE	**1.16**	**1.91**

Neck Biofidelity

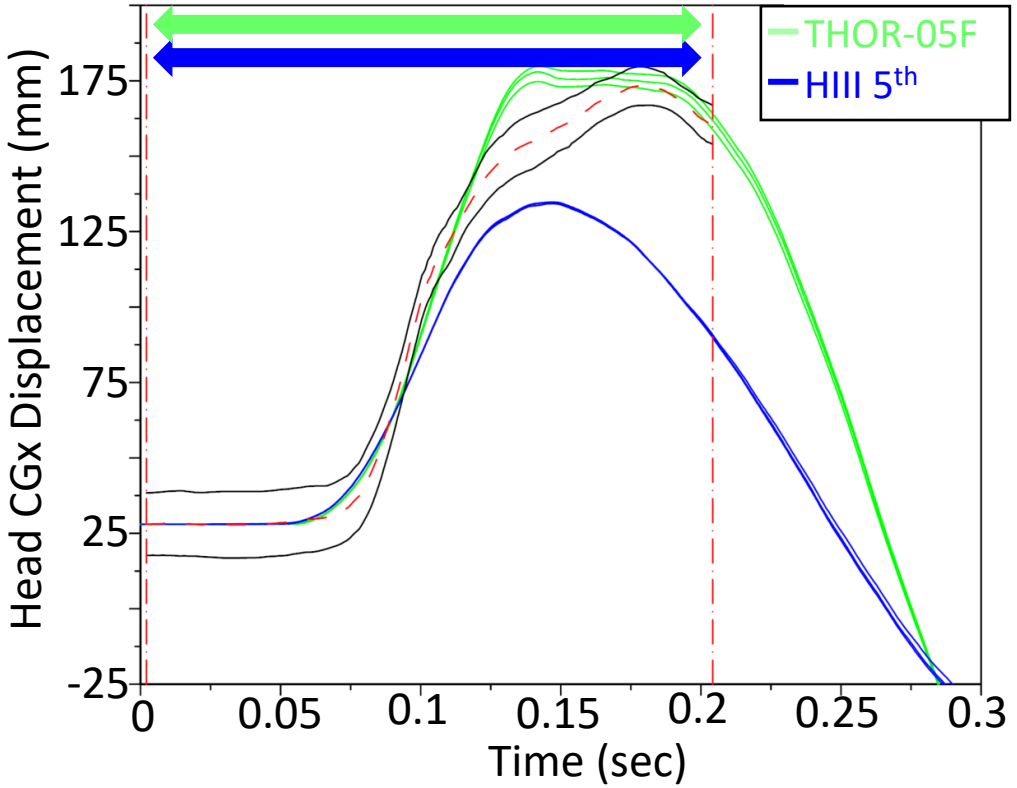
- Frontal Flexion Mini-Sled

Summary

- Target Corridor: Thunnissen et al, 1995 (Scaled NBDL Volunteer)[6]
- Frontal flexion sled series - 15 G_x pulse



	THOR-05F	HIII 5th
Neck Frontal Flexion Mini-Sled		
Head Resultant Acceleration	1.96	1.81
Head CGx Displacement	0.64	2.24
Head CGz Displacement	0.96	1.33
Head Angle	1.01	0.59
Neck Angle	0.97	4.43
NECK AVERAGE	**1.11**	**2.08**



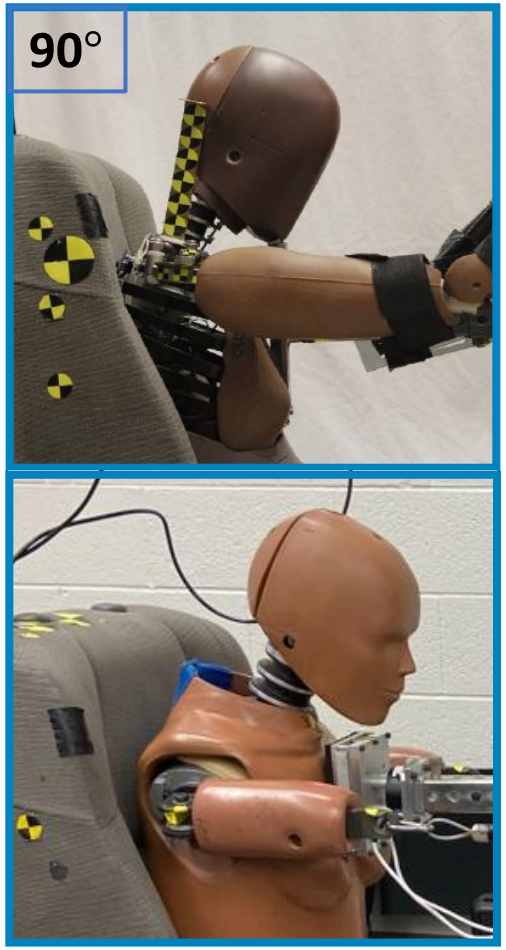
6. Thunnissen, J. G. M., et al. "Human volunteer head-neck response in frontal flexion: a new analysis." *SAE transactions* (1995): 3065-3086.

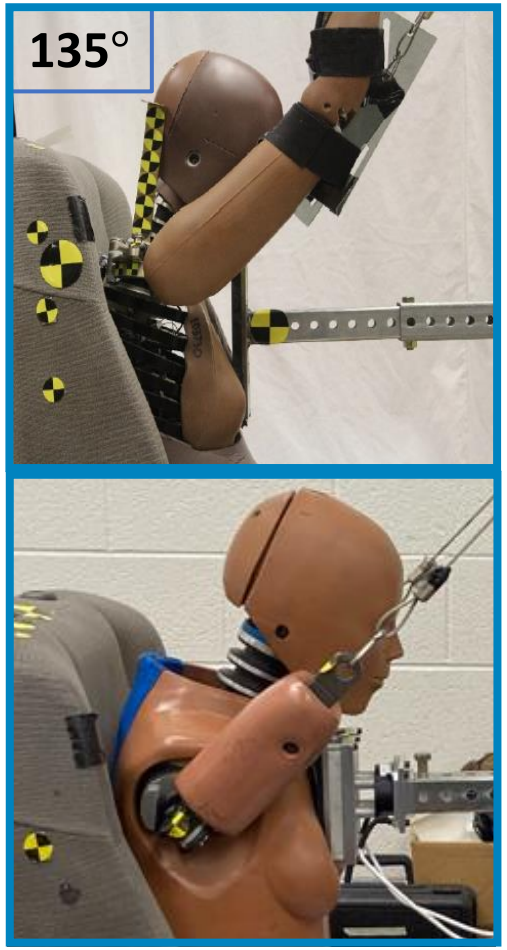
Shoulder Biofidelity

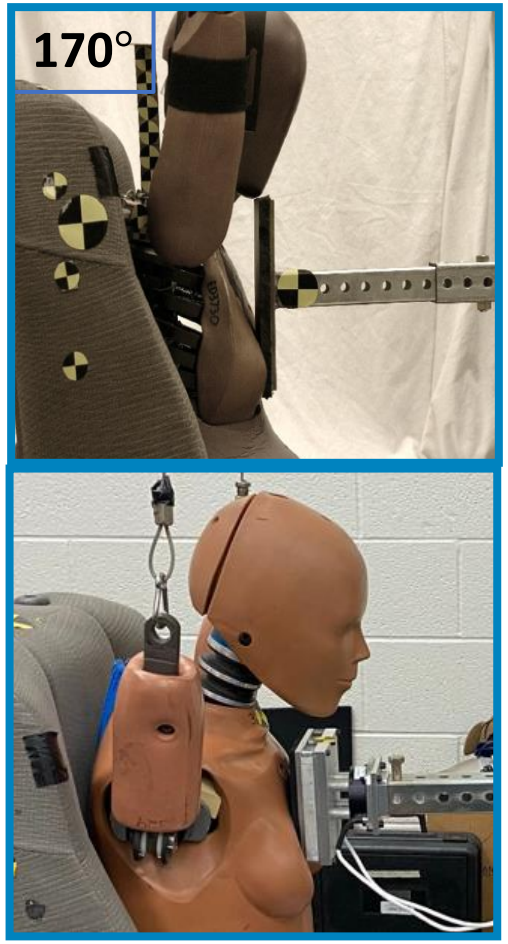
- 90° Arm Position
- 135° Arm Position
- 170° Arm Position

Shoulder Biofidelity

- Target Corridor: Tornvall et al. 2005 (Volunteer)[7]
- Range of motion: 200N load at 90°, 135°, 170°

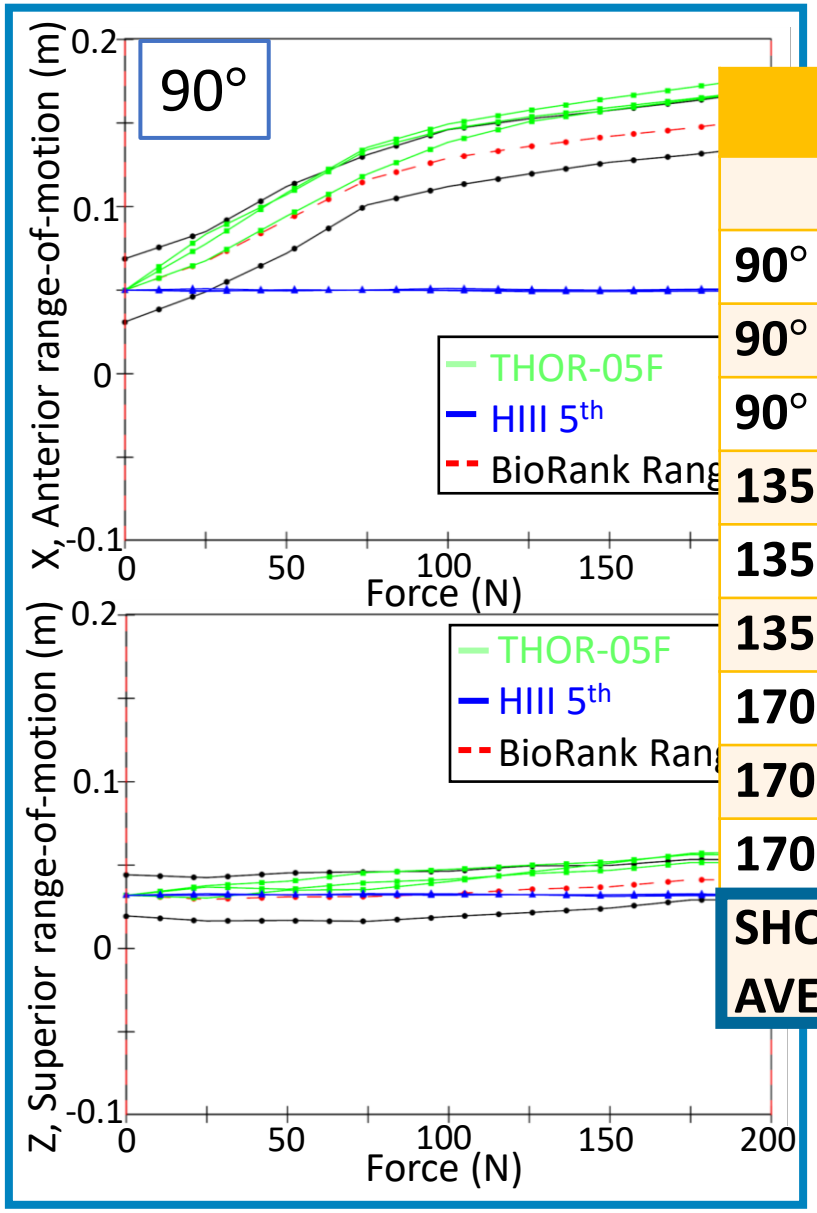


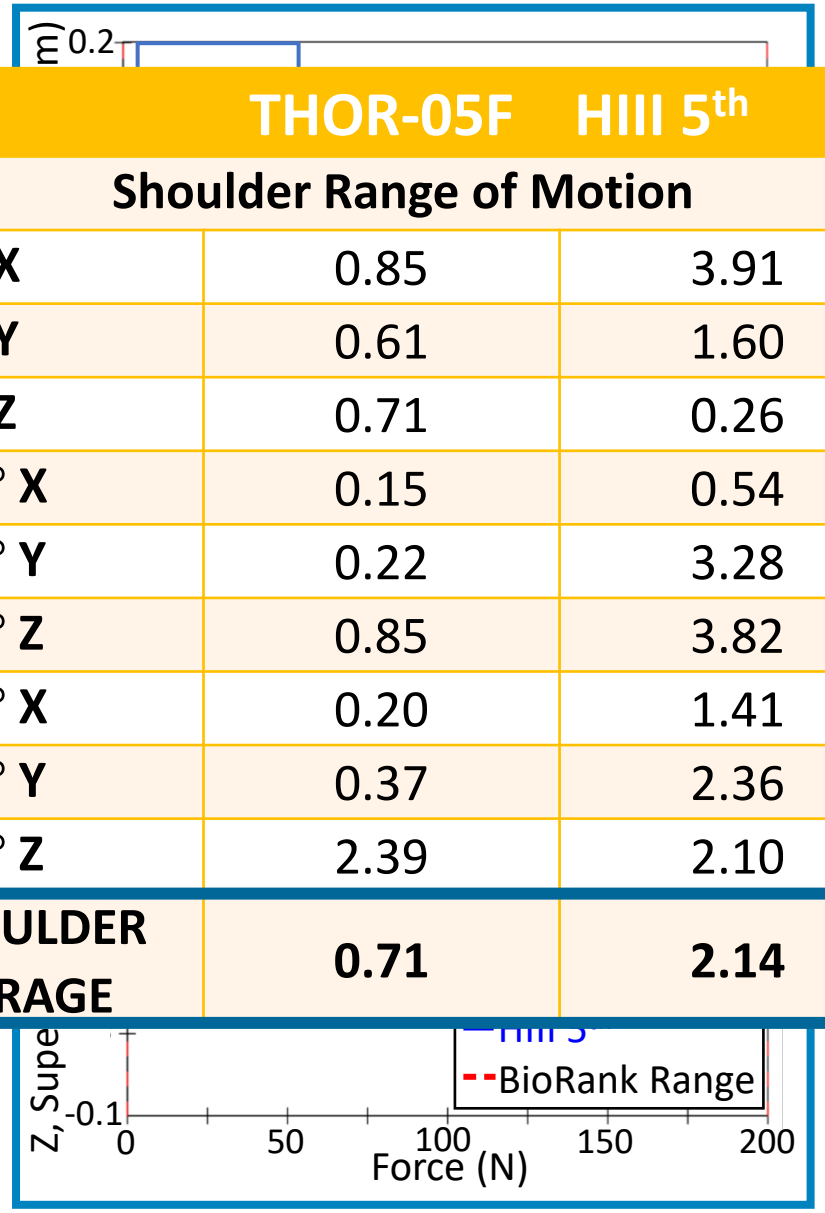


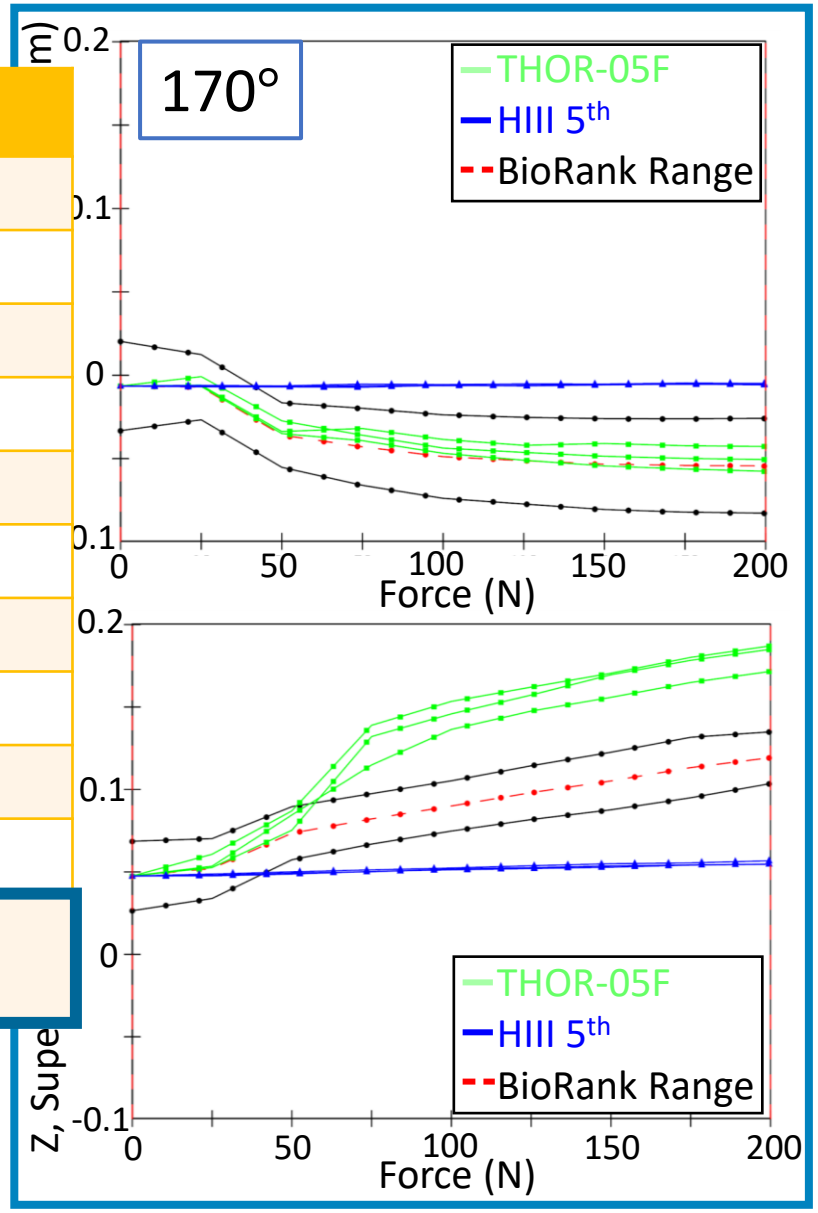


7. Törnvall, F. V., et al. "Comparison of shoulder range-of-motion and stiffness between volunteers, Hybrid III and THOR Alpha in static frontal impact loading." *International Journal of Crashworthiness* 10.2 (2005): 151-160.

Shoulder Biofidelity







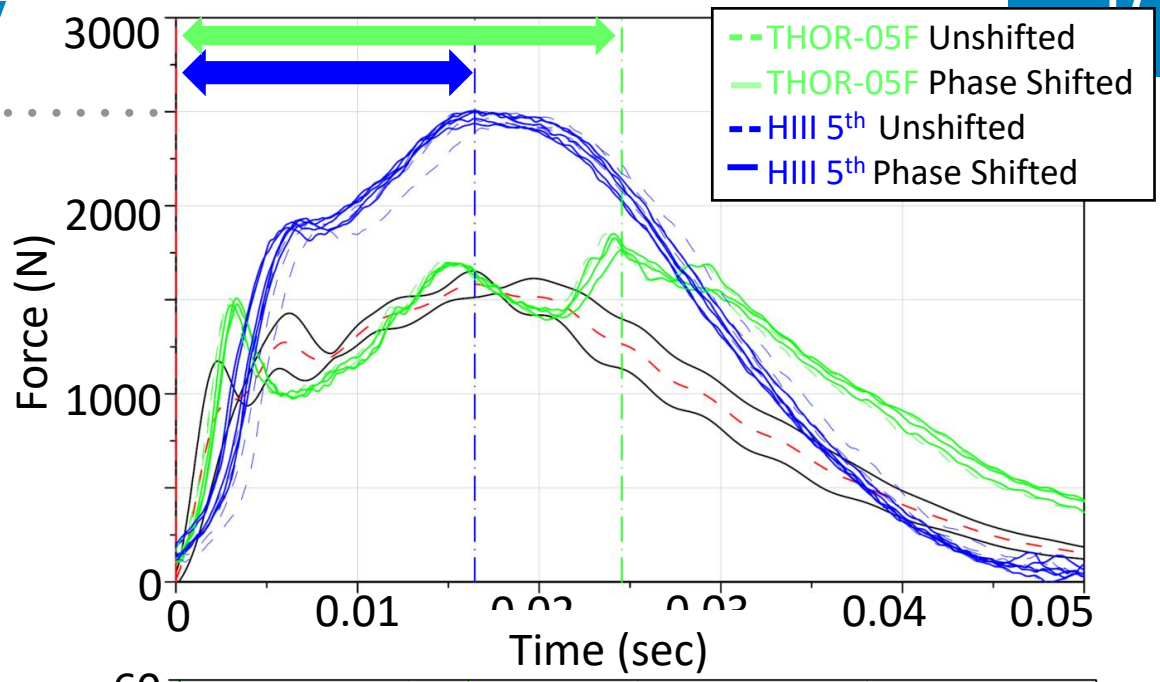
Shoulder Range of Motion	THOR-05F	HIII 5th
90° X	0.85	3.91
90° Y	0.61	1.60
90° Z	0.71	0.26
135° X	0.15	0.54
135° Y	0.22	3.28
135° Z	0.85	3.82
170° X	0.20	1.41
170° Y	0.37	2.36
170° Z	2.39	2.10
SHOULDER AVERAGE	**0.71**	**2.14**

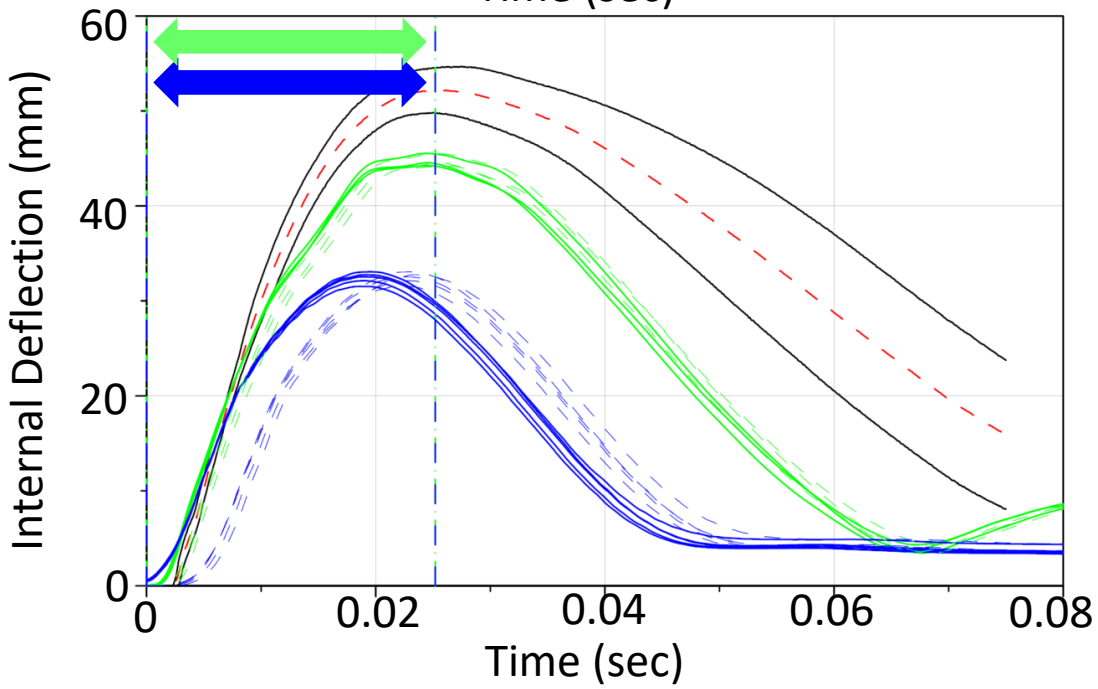
Thorax Biofidelity

- Upper Thorax Impact

Upper Thorax Biofidelity

- Target Corridor: Agnew, Kang et al. (Female PMHS)[8]
- Impactor speed: 4.3 ±0.05 m/s
- Impactor mass: 14 kg





	THOR-05F	HIII 5th
Upper Thorax Impact		
Impact Force	1.48	6.07
Internal Deflection	2.29	5.61
THORAX AVERAGE	**1.89**	**5.84**

8. Data collected by Agnew, Kang, et al. under NHTSA contract in Fall 2021. Publication expected in 2022

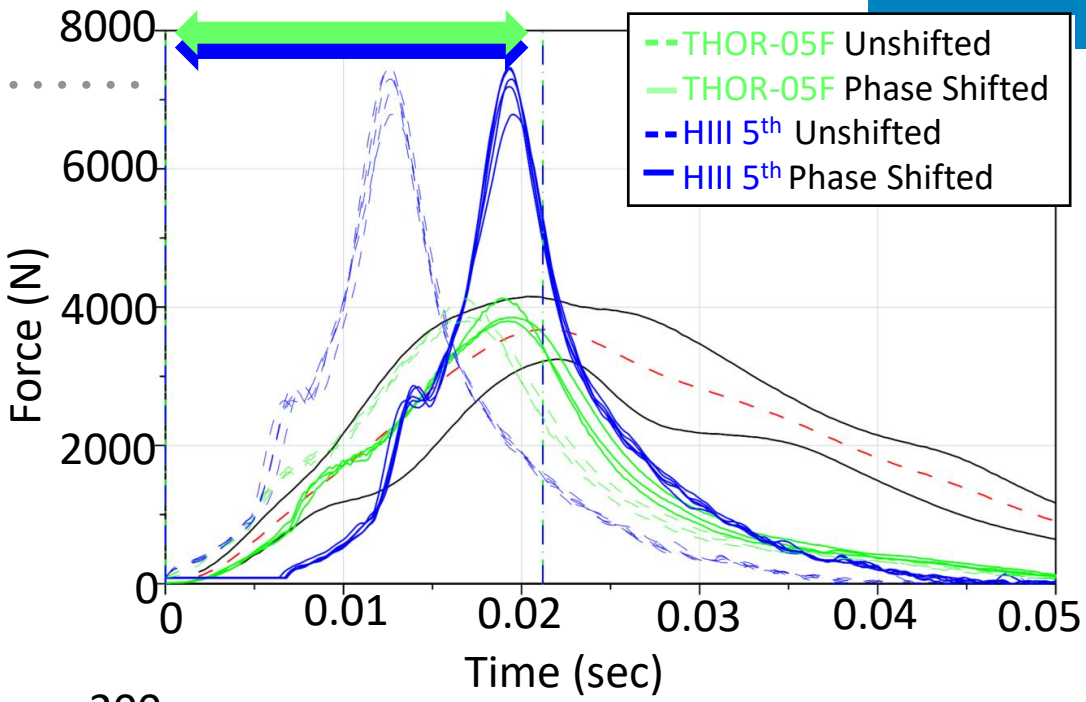
Abdomen Biofidelity

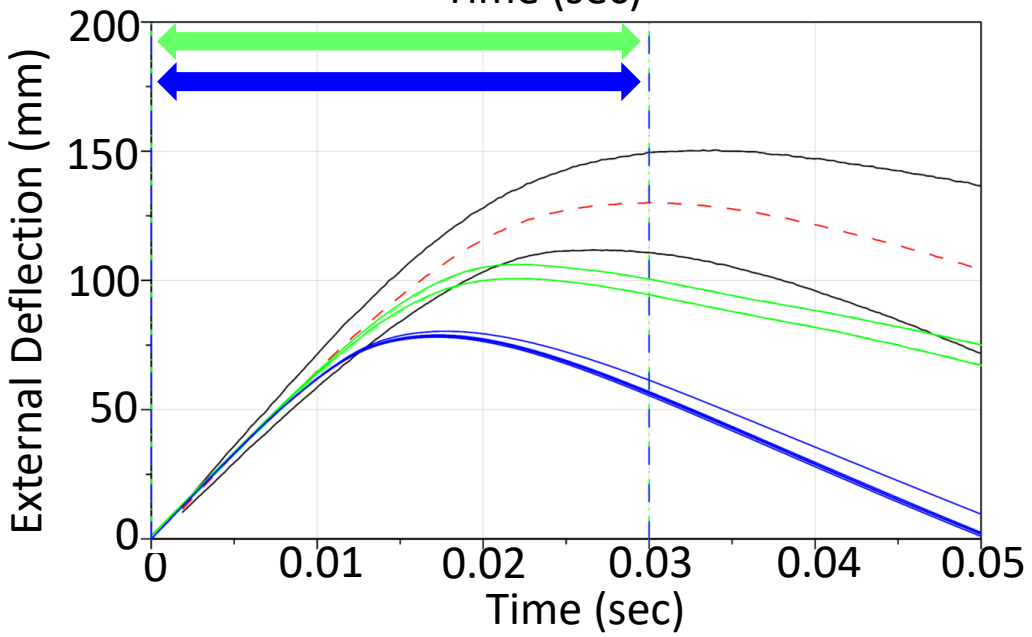
- Upper Abdomen Steering Wheel Impact
- Lower Abdomen Rigid Bar Impact

Upper Abdomen Biofidelity

- Target Corridor: Nusholtz et al. 1994 (Scaled PMHS)[9]
- Impactor speed: 6.7 m/s ±0.05 m/s
- Impactor mass: 9.0 kg

	THOR-05F	HIII 5th
Upper Abdomen Impact		
Impact Force	0.3	2.07
External Deflection	1.06	2.65

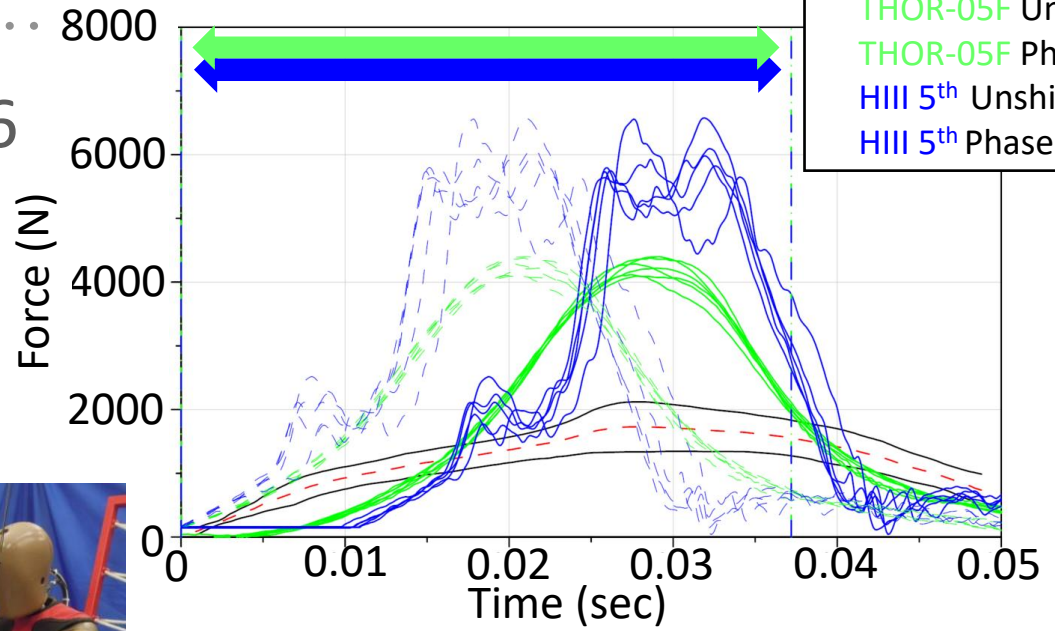




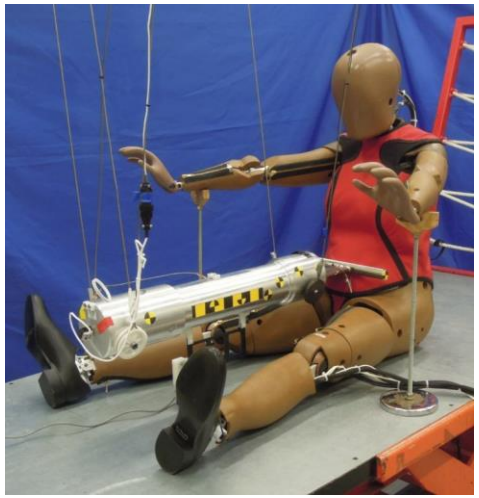
9. Nusholtz, G. S., and P. Kaiker. "Abdominal response to steering wheel loading." *Proceedings: International Technical Conference on the Enhanced Safety of Vehicles*. Vol. 1995. National Highway Traffic Safety Administration (1994).

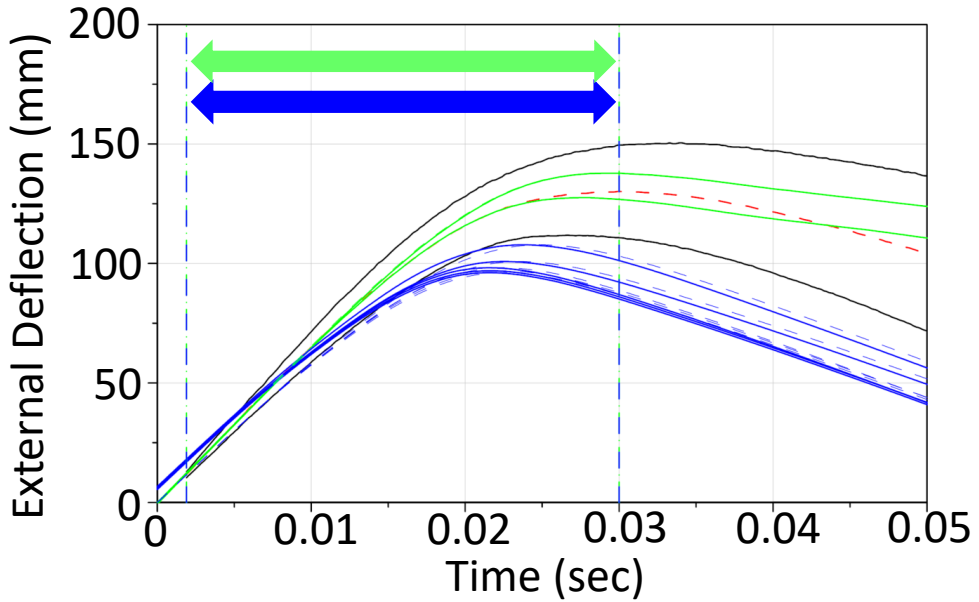
Lower Abdomen Biofidelity

- Target Corridor: Cavanaugh et al. 1986 (Scaled PMHS)[10]
- Impactor speed: 6.1 m/s ±0.05 m/s
- Impactor mass: 16 kg



	THOR-05F	HIII 5th
Lower Abdomen Impact		
Impact Force	4.67	6.53
External Deflection	0.18	1.40





10. Cavanaugh, John M., et al. "Lower abdominal tolerance and response." *SAE transactions* (1986): 611-633.

Abdomen Biofidelity Summary

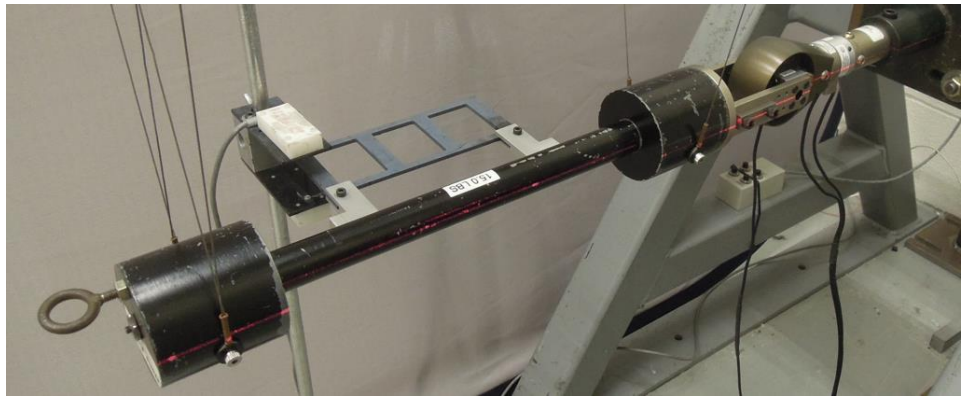
	THOR-05F	HIII 5th
Upper Abdomen Impact		
Average	0.68	2.36
Lower Abdomen Impact		
Average	2.42	3.97
ABDOMEN AVERAGE	**1.55**	**3.16**

Lower Extremity Biofidelity

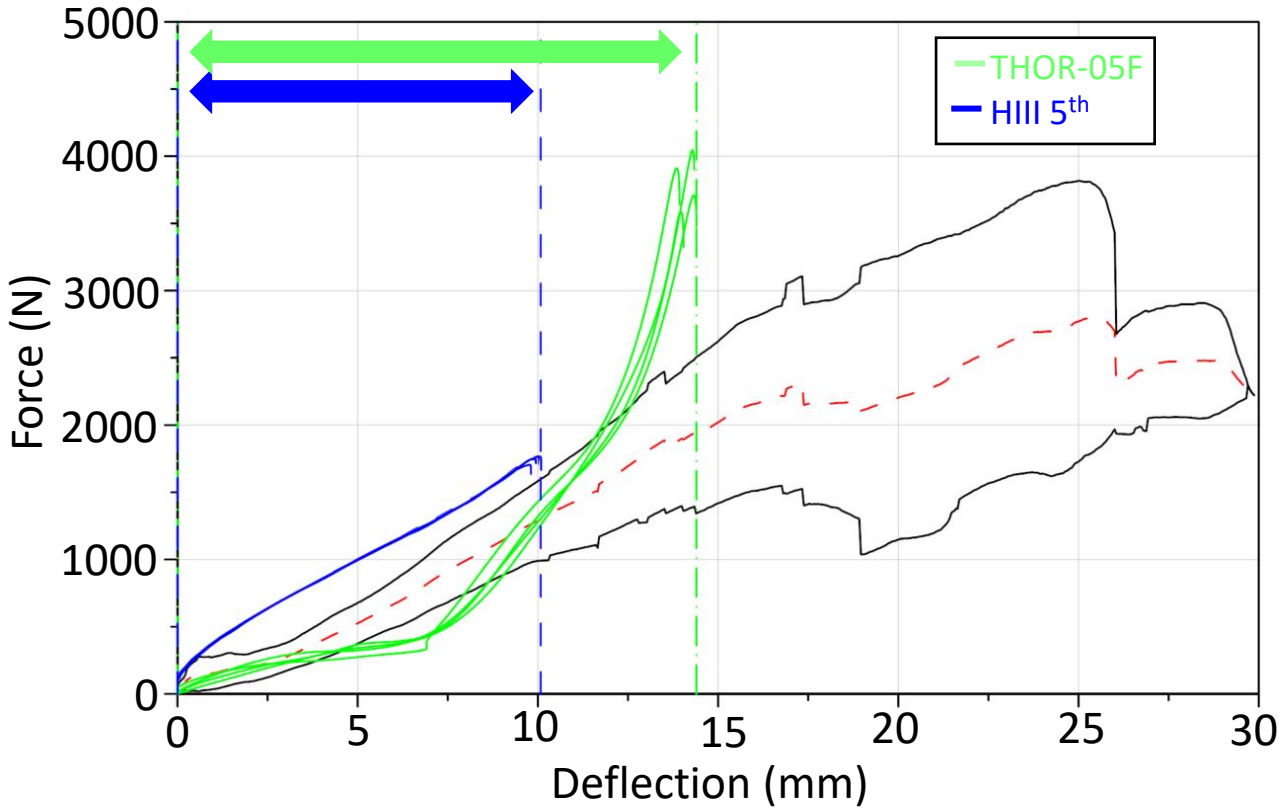
- Knee Slider Impact
- Dorsiflexion Dynamic
- Dynamic Inversion
- Dynamic Eversion

Knee Slider Biofidelity

- Target Corridor: Balasubramanian et al. 2004 (Scaled PMHS)[11]
- Impactor speed: 2.15 ±0.05 m/s
- Impactor mass: 7.26 kg
- BioRanking performed up to the maximum ATD deflection



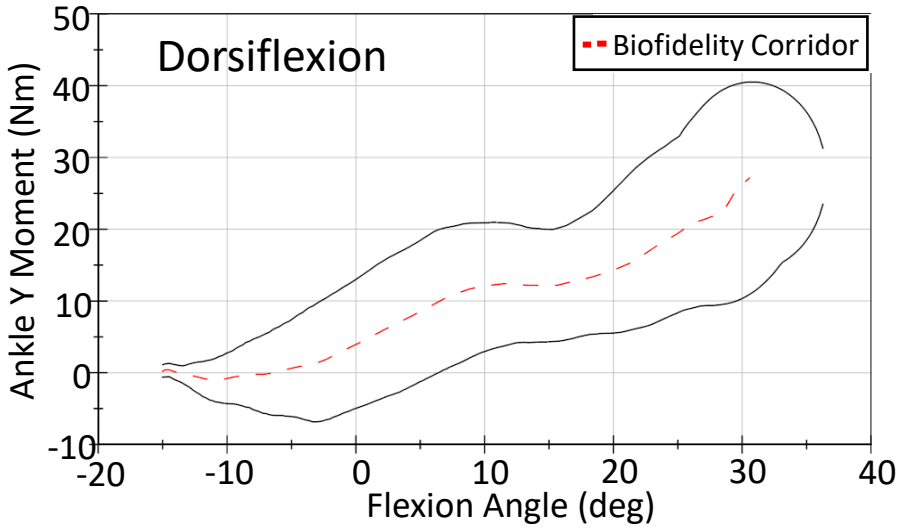
	THOR-05F	HIII 5th
Knee Slider Impact		
Femur Force	1.22	2.35

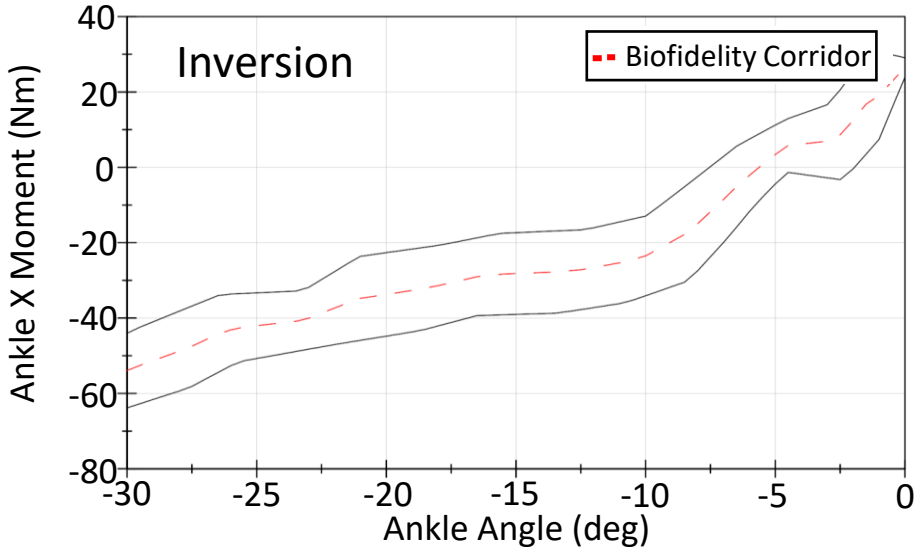


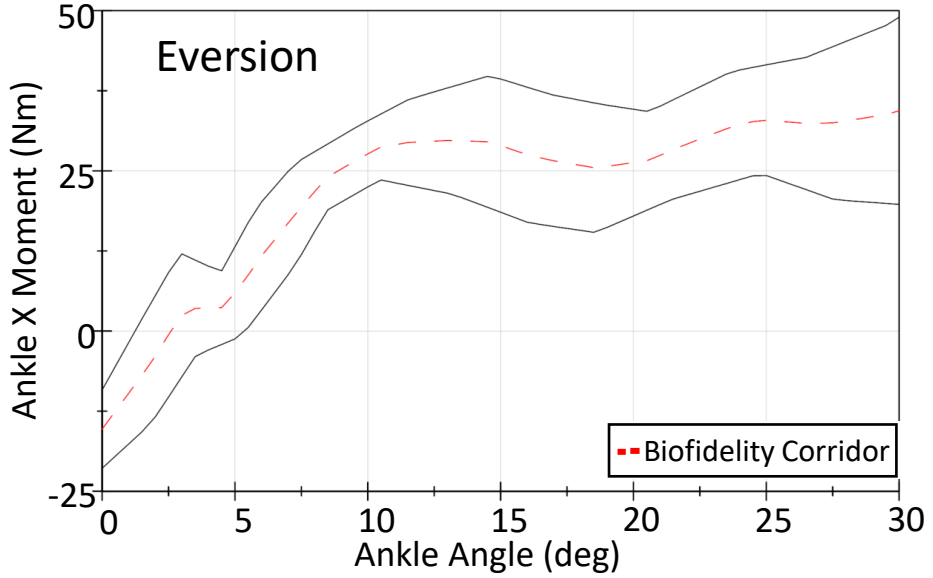
11. Balasubramanian, S., et al. "Below knee impact responses using cadaveric specimens." *Stapp Car Crash Journal* 48 (2004): 71.

Dorsiflexion/Inversion/Eversion Biofidelity

- Target Corridors: UVA/NHTSA Contracts[12,13]
- Normalized by leg length, shod corridors







12. Forman, J. L., J. Crandall, and C. Roberts. *Lower Leg Biofidelity Corridors for Heel Impact*. No. DOT HS 812 641. United States. Department of Transportation. National Highway Traffic Safety Administration, (2019).

13. Roberts, C., J. Forman, and J. Kerrigan. "Injury risk functions for 5th percentile females: ankle inversion and eversion." *Proceedings of the 2018 International IRCOBI Conference*. (2018).

THOR-05F & HIII 5th Summary

THOR-05F & HIII 5th BioRanking Summary

- THOR-05F is showing a biofidelity improvement over the HIII 5th

	THOR-05F	HIII 5th
Head		
Average	1.16	1.91
Neck		
Average	1.11	2.08
Shoulder		
Average	0.71	2.14
Thorax		
Average	1.89	5.84
Abdomen		
Average	1.55	3.16
Lower Extremity		
Average	1.22	2.35
Average BRS Score	1.27	2.91

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NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Initial Biofidelity Comparison Between THOR-05F and Hybrid-III 5th Percentile Female ATDs

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Questions?