Hybrid-III and THOR-50M Responses in the Rear Seat During Frontal Crash Sled Tests

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Research Objectives

- To help delineate the boundaries of potential issues to be encountered as a result of occupants being seated other than in the front row of ADS-DVs (Automated Driving System-Dedicated Vehicles)
- Investigate the relationships between vehicle design parameters and occupant protection performance
- Evaluate current tools (ATDs) for use in the rear seat environment during frontal crash

Research Rationale

- The risk of injury in frontal collisions is higher for rear seat occupants than for front seat occupants, especially in newer vehicles and for older occupants.

- Rear seat occupancy rates may increase in ADS-DVs, particularly in the rideshare environment.

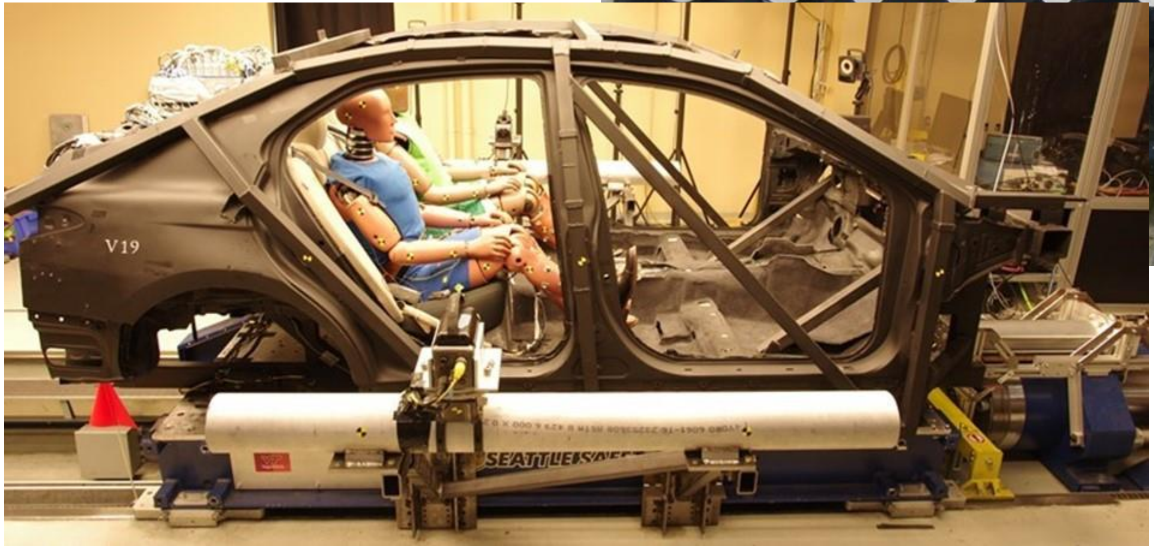
- For many novel seating arrangements, the second or rear row will contain the forward-most front facing seats.

Research Approach Overview

Five primary components of the research approach:

1) REAL-WORLD PROBLEM SCOPING
2) PLATFORM AND ATD MODELING AND VEHICLE SELECTION
3) TEST BUCK PREPARATION
4) ATD SLED TESTING
5) ANALYSES AND OBSERVATIONS

Test Buck Preparation



ATD Sled Testing

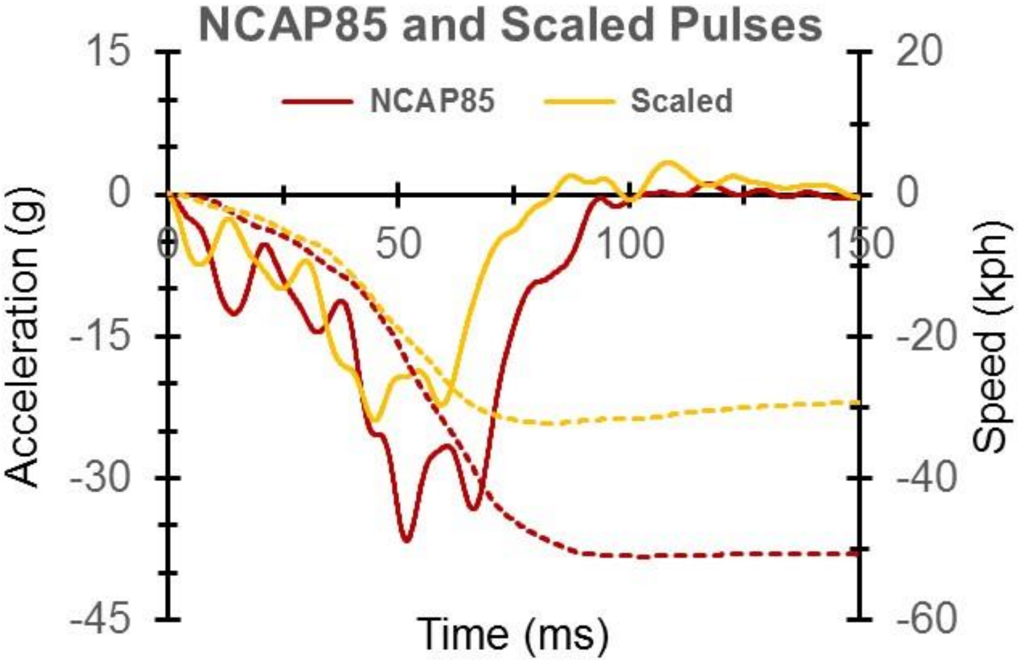
Paired ATD Sled Tests using Vehicle Bucks

- Evaluation of the Effect of the Standard THOR-50M Abdomen compared to a prototype abdomen containing pressure sensors (ABISUP abdomen)
- Comparison between Hybrid-III and THOR-50M for a vehicle with perceived good rear seat occupant protection
- Comparison between Hybrid-III and THOR-50M for a vehicle with perceived poor rear seat occupant protection (severe submarining)
- Evaluation Metrics:
  - Submarining assessment
  - Motion data
  - Head, neck, and chest injury metrics and injury risk calculation
  - Peak lumbar/T12 force and moment comparison

ATD Sled Testing Matrix

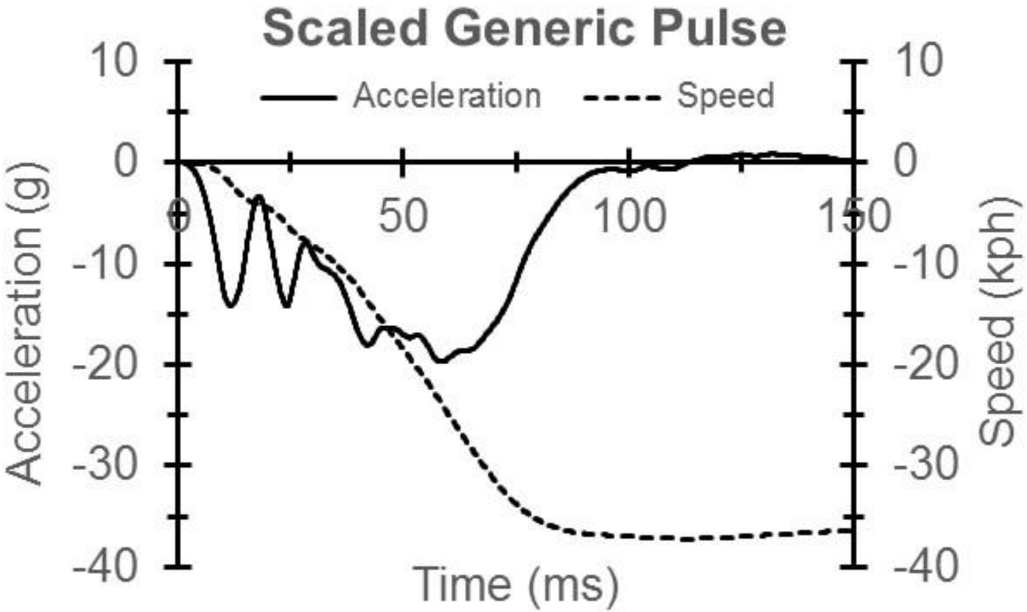
Vehicle Type	Vehicle	Pretensioner/ Load Limiter	Test #	Test Sequence	Pulse	Abdomen	Note
Compact CUV	V1	Y/Y	1	6	Generic	ABISUP	
			2	7	Scaled	ABISUP	
Sub-compact CUV	V13	N/N	1	12	Scaled	ABISUP	
			2	13	NCAP85	ABISUP	
Compact CUV	V14	Y/Y	1	4	Generic	ABISUP	
			2	5	Scaled	ABISUP	
			3	14	NCAP85	ABISUP	DAS failure (THOR side)
			4	15	NCAP85	ABISUP	FRS-V14-3 repeat
Mid-sized Sedan	V15	N/N	1	1	Generic	Standard	
			2	2	Generic	ABISUP	
			3	3	Scaled	ABISUP	
			4	16	NCAP85	ABISUP	Reused FRS-V15-3 fabric
Mid-sized Sedan	V19	Y/Y	1	8	Generic	ABISUP	
			2	9	Scaled	ABISUP	
			3	10	NCAP85	ABISUP	THOR integrity issues
			4	11	NCAP85	ABISUP	FRS-V19-3 repeat

Vehicle Pulses



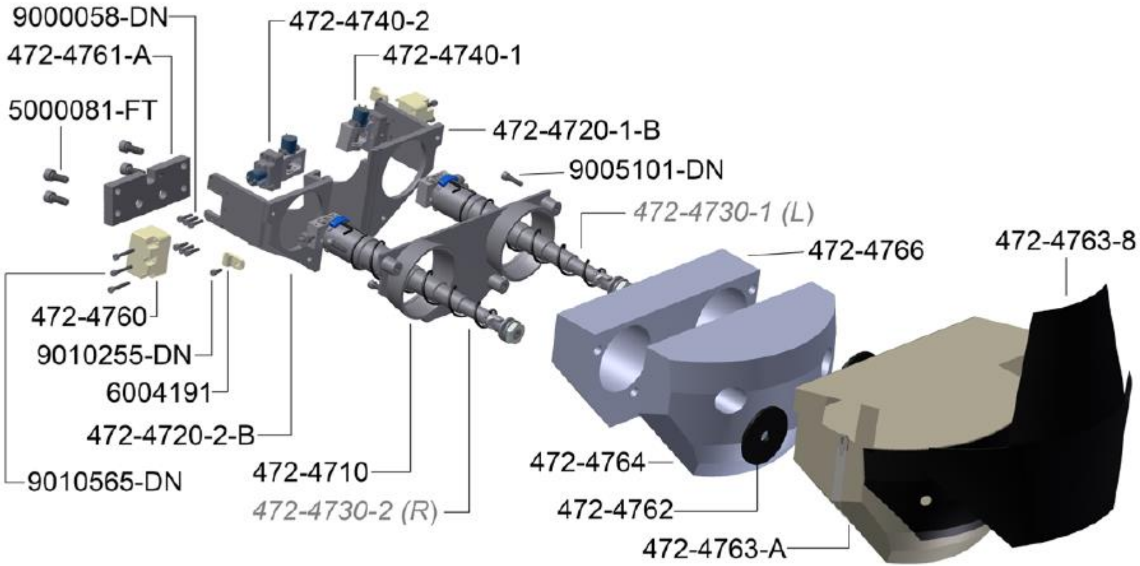
- The NCAP pulses were reduced to 85% to provide sled ΔV closer to 56 kph (NCAP85).
- The scaled-down vehicle-specific sled pulses (ΔV = 32 kph) were generated by applying a scaling factor (32/56 = 0.57) to the NCAP pulses to test in a more-common real-world range.

Vehicle Pulses



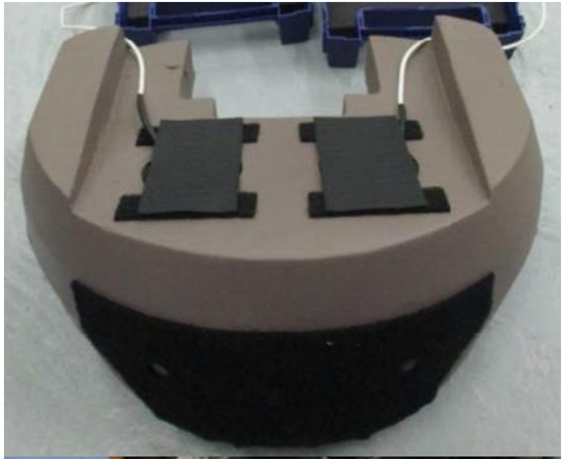
- The scaled-down generic sled pulse was generated by averaging the scaled-down vehicle-specific sled pulses for each of the selected vehicles (n = 7) at each point in time.

THOR-50M Standard Abdomen



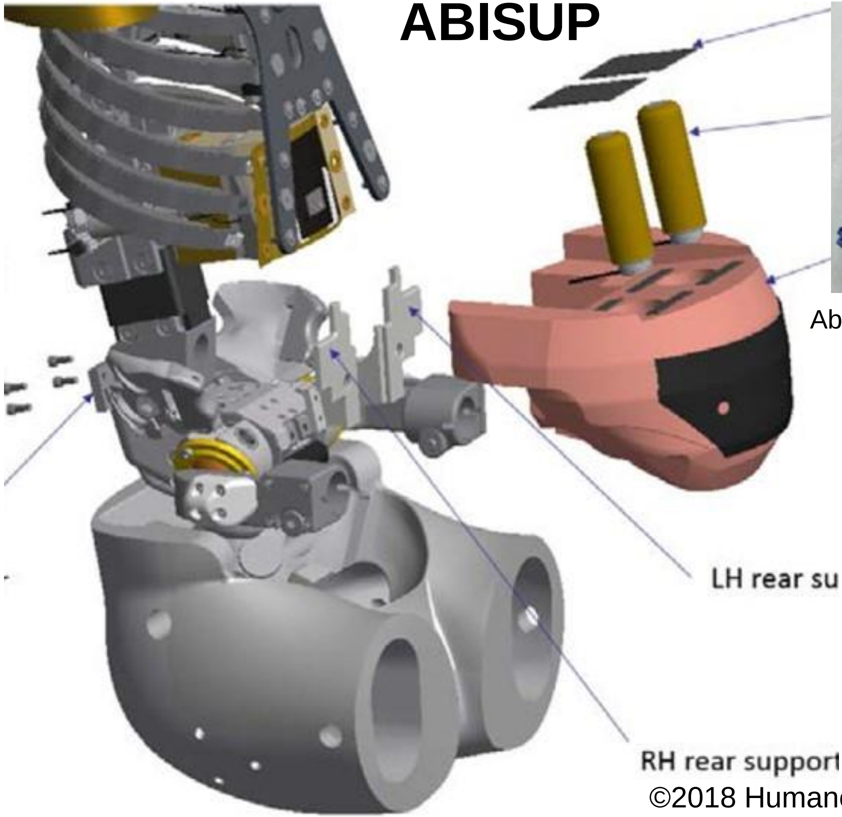
THOR-M Parts Catalog
Courtesy of Humanetics

ABdominal Injury and SUbmarining Prediction



Ifsttar-Transpolis

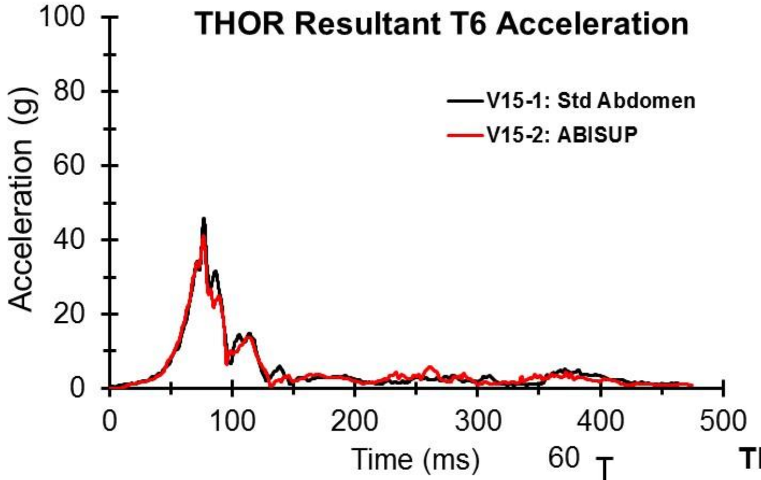
ABISUP

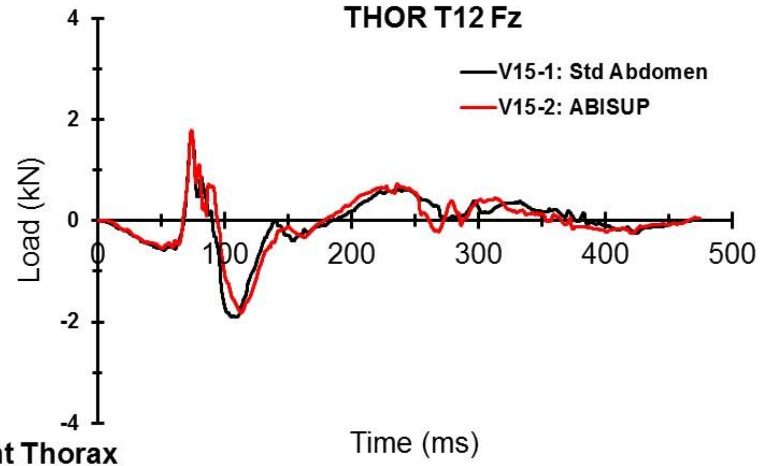


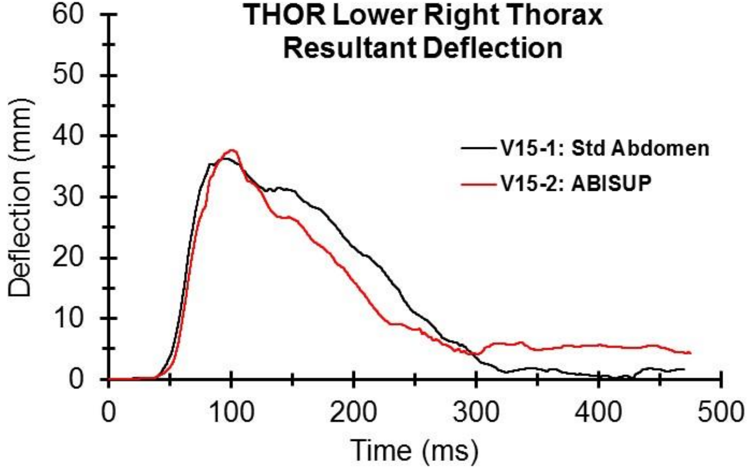
Abdominal Twin Pressure Sensors

ABISUP Fitting Instructions [Rev. 1]
Courtesy of Humanetics

THOR-50M Abdomen vs. ABISUP







Hybrid-III/THOR-50M Positions

ATD Motion

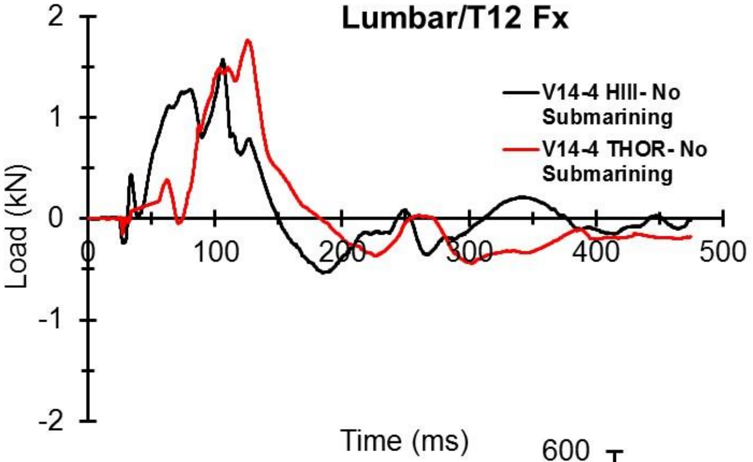
FRS-V13-2

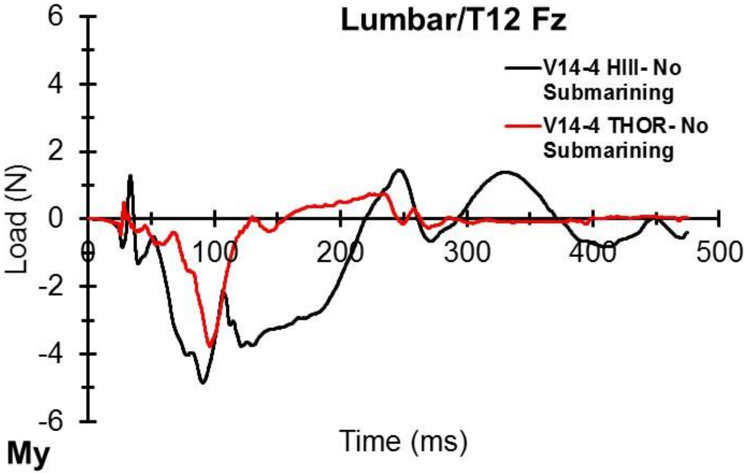
Poor Protection

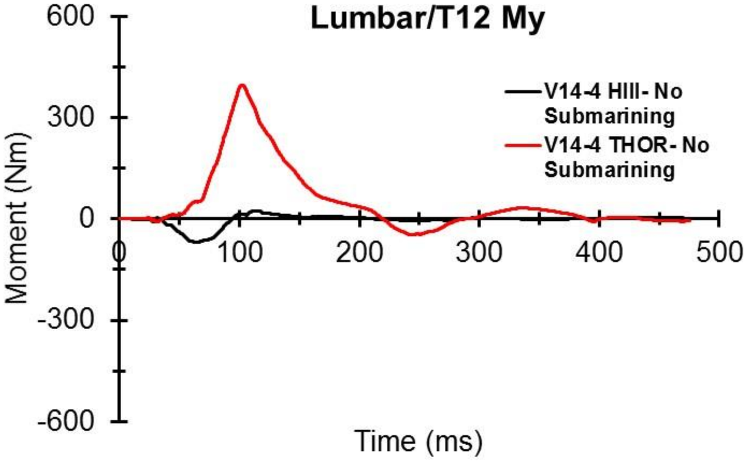
FRS-V14-3

Good Protection

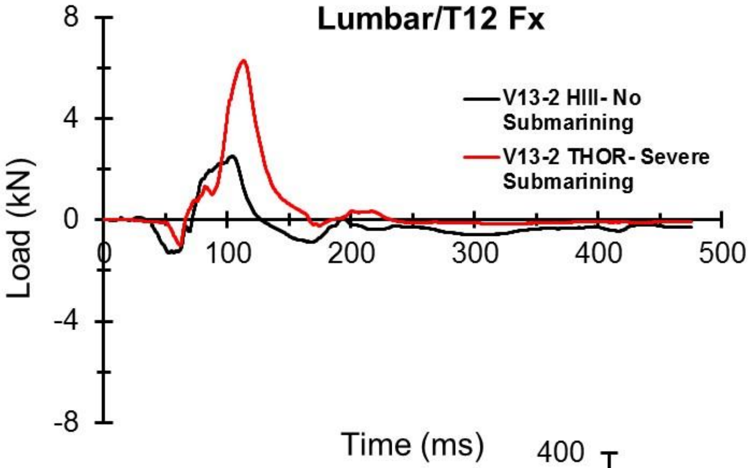
Hybrid-III/THOR-50M: Good Protection

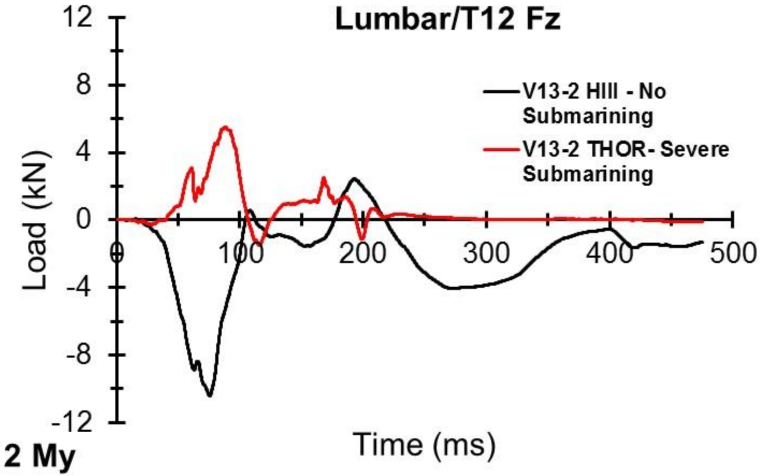


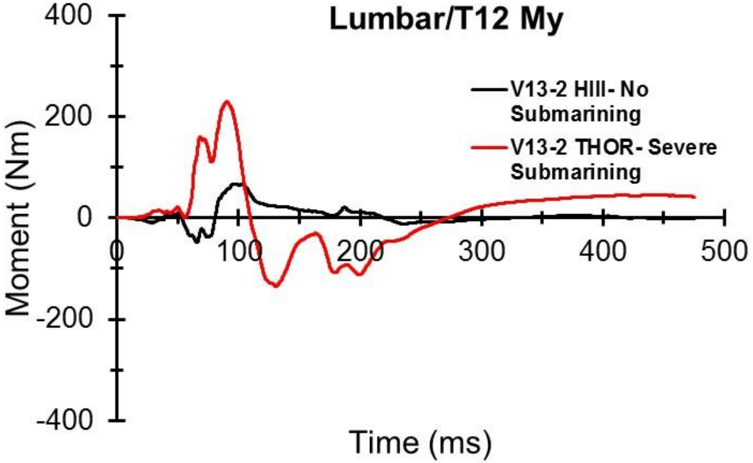




Hybrid-III/THOR-50M: Poor Protection







Submarining: THOR-50M

Vehicle	Test	Pulse	Degree	Side
V1	1	L		
	2	L		
V13	1	L	Moderate	Bilateral
	2	H	Severe	Bilateral
V14	1	L		
	2	L		
	3	H		
	4	H		
V15	1	L	Minor	Right
	2	L	Minor	Right
	3	L	Minor	Right
	4	H	Moderate	Bilateral
V19	1	L	Minor	Right
	2	L	Minor	Bilateral
	3	H	Moderate	Bilateral
	4	H	Moderate	Bilateral

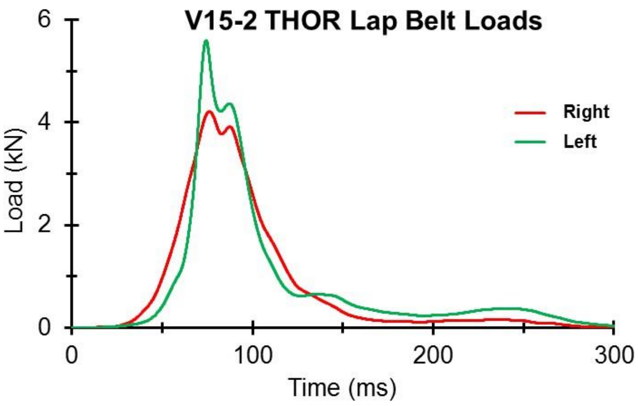
High-speed video, post-test observation, seatbelt loads, ABISUP pressure, and ASIS X-direction loads and moments about Y axis

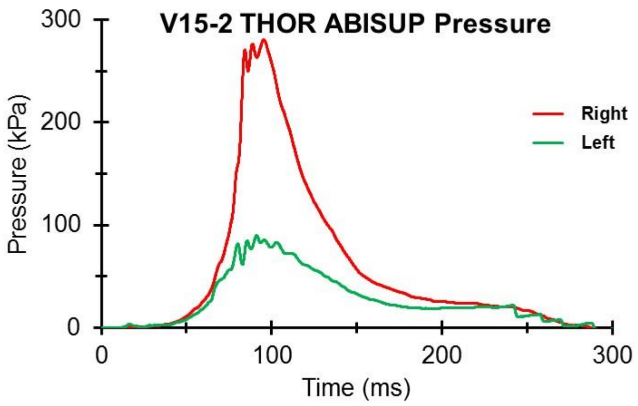
- Minor submarining: Belt encroaching upon the abdomen on one side
- Moderate submarining: Bilateral encroachment of the lap belt upon the abdomen, without substantial penetration as indicated by the ABISUP pressure sensors
- Severe submarining: Considerable penetration of the belt into the abdomen, very large ABISUP pressures, and substantial departure of the dummy pelvis from the seat

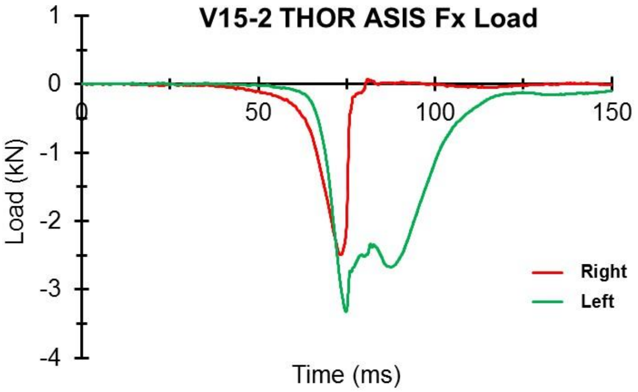
Submarining: THOR-50M

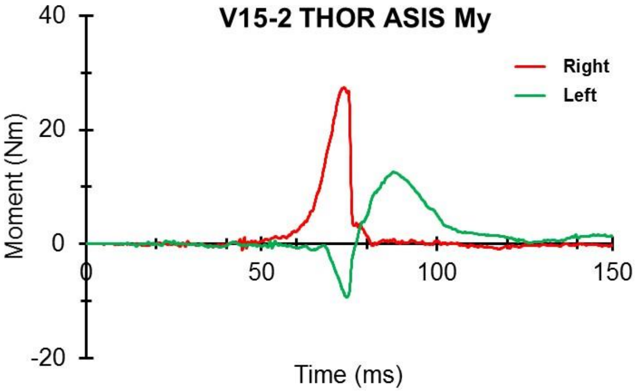
- Ten out of sixteen tests resulted in some degree of submarining in the THOR dummy.
- The Hybrid III dummy did not submarine during any test.
- Vehicles V1 and V14 had pretensioners and load limiters, and demonstrated no submarining.
- Vehicle V13 had simple retractors and a relatively flat surface under the seat, and was associated with the most pronounced submarining.
- Vehicle V15 had basic retractors, but had pronounced anti-submarining ramps under the seat bottom cushion.
- Vehicle V19 also had pretensioners and load limiters, but did not eliminate submarining in the THOR.

Submarining: THOR-50M



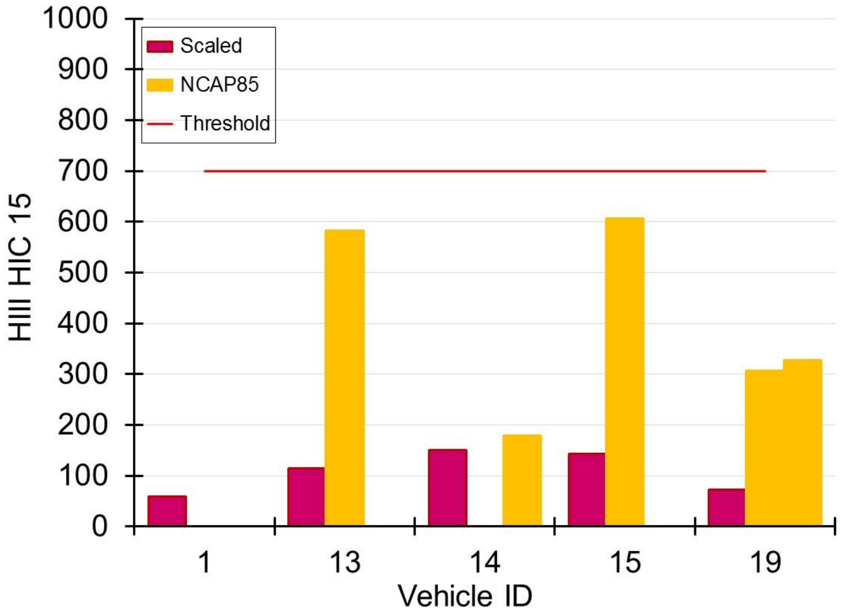




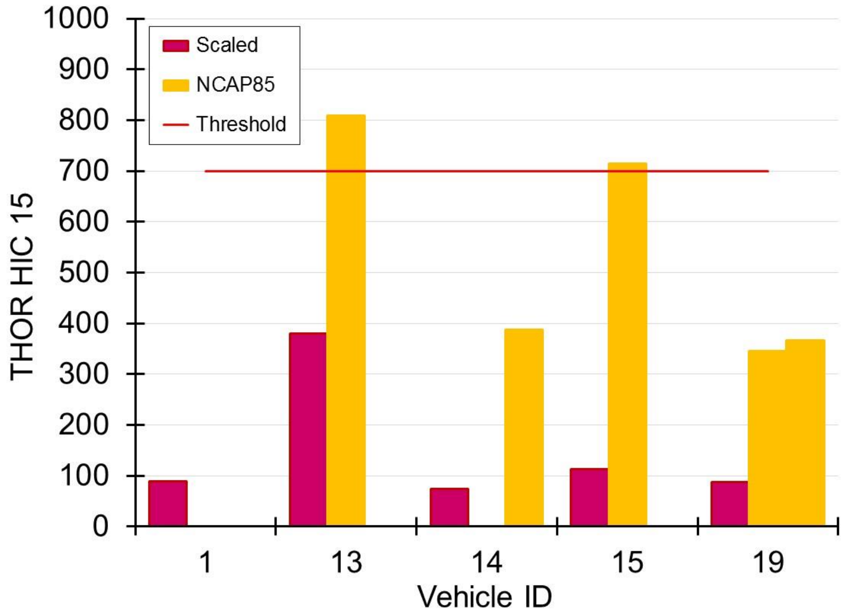


HIC15

HIII



THOR-50M



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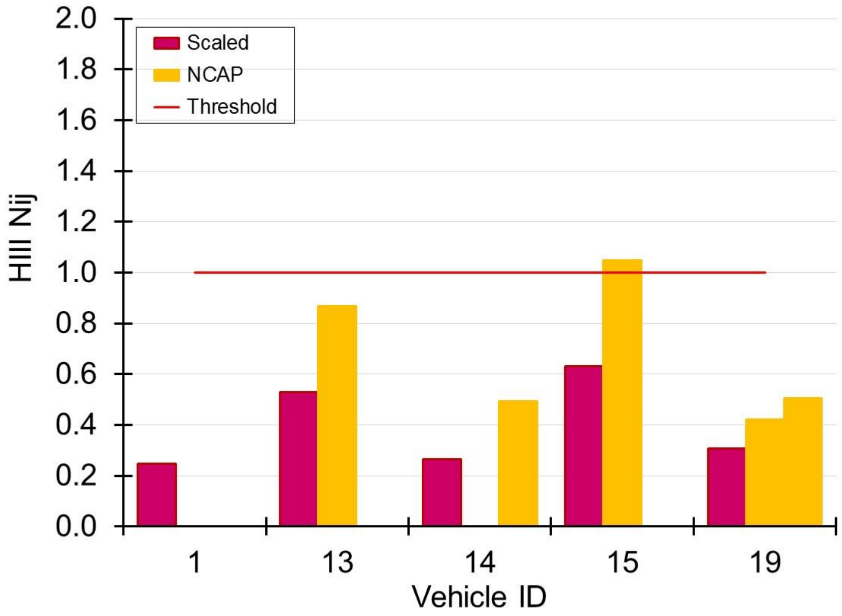
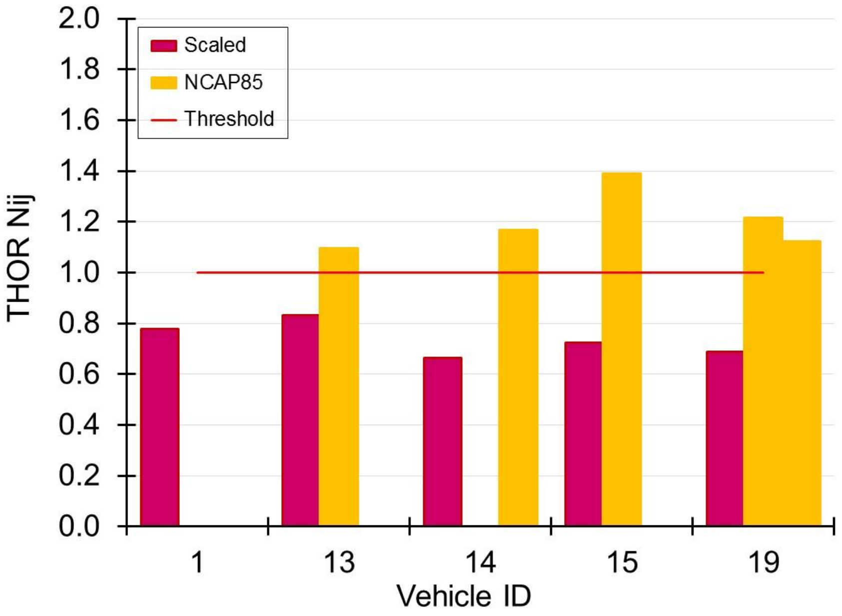
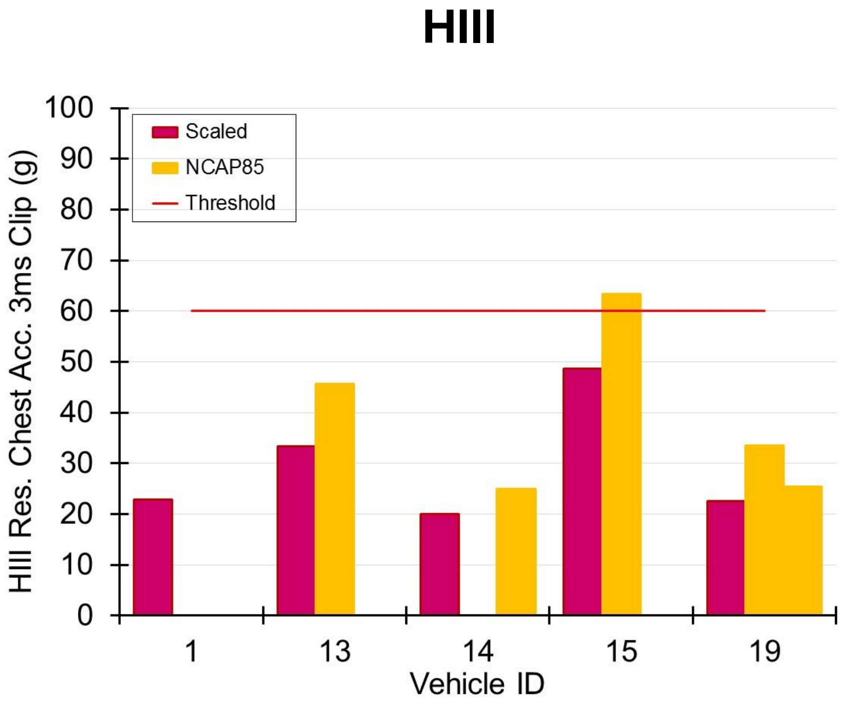
HIII

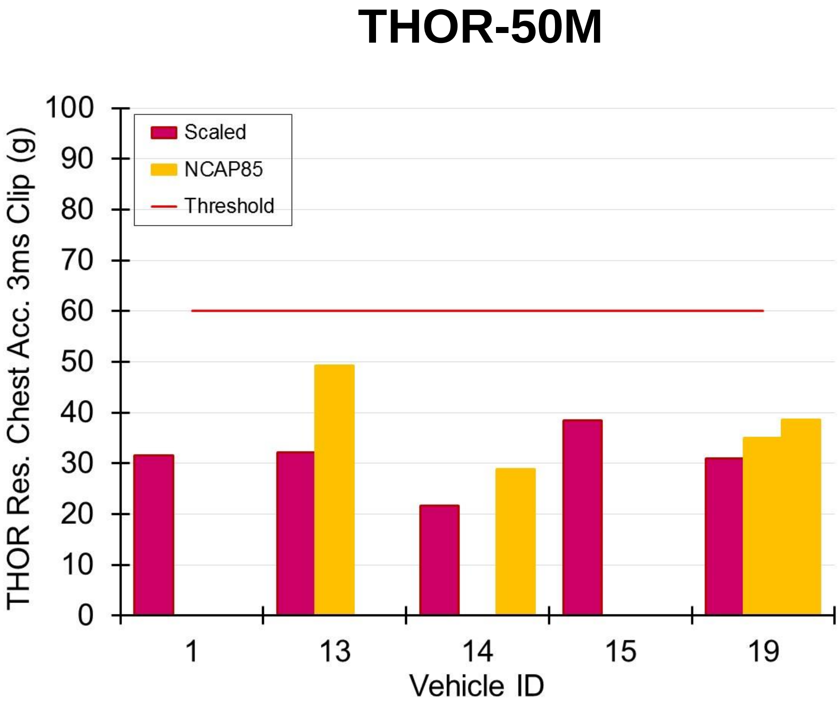


THOR-50M



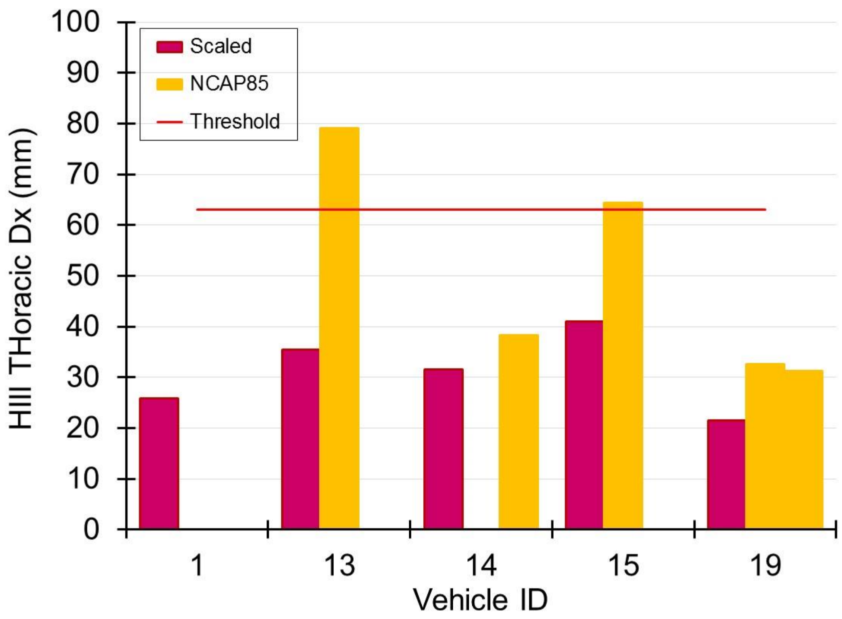
3-ms Clip Chest Acceleration



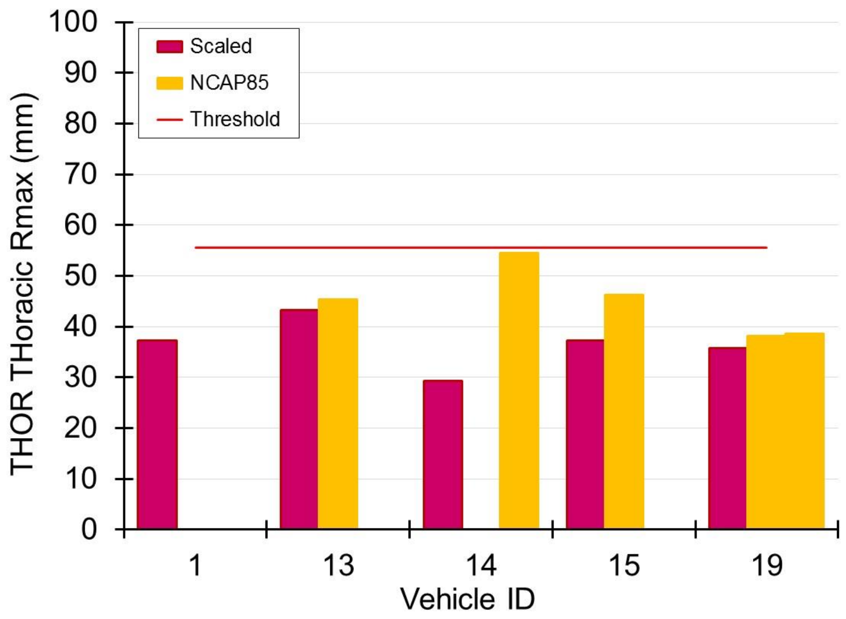


Chest Deflection

HIII



THOR-50M

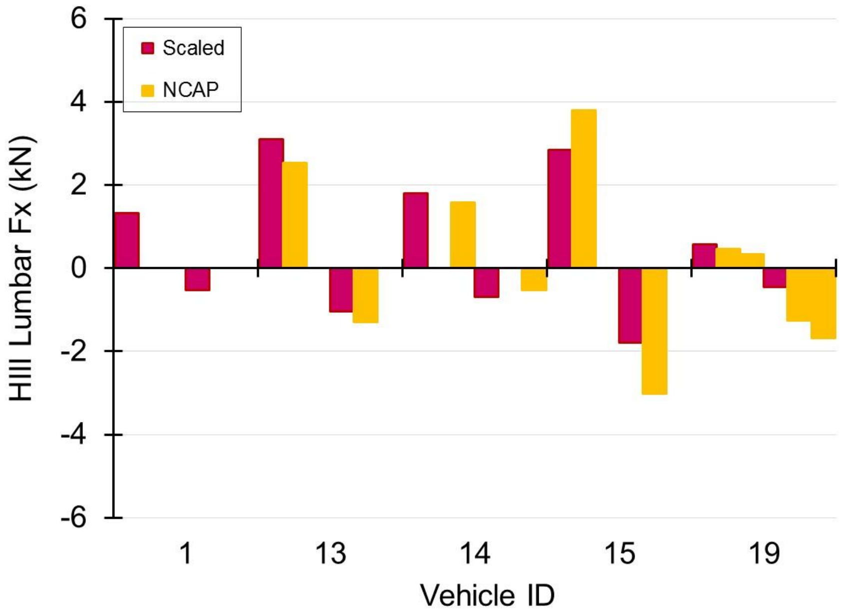


$$R_{max} = \max(UL_{max}, UR_{max}, LL_{max}, LR_{max})$$

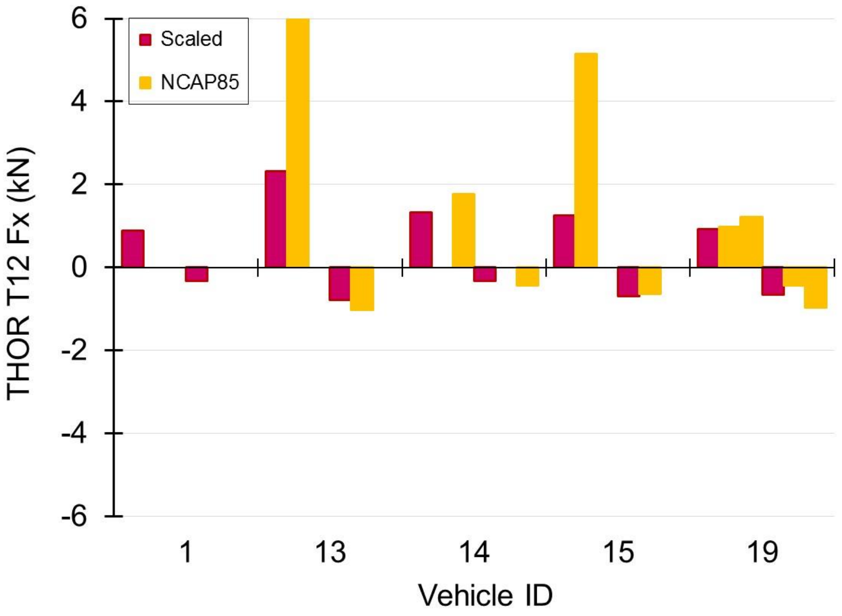
$$\{U/L|R/L\}_{max} = max\left(\sqrt{[L/R]X^2_{[U/L]S} + [L/R]Y^2_{[U/L]S} + [L/R]Z^2_{[U/L]S}}\right)$$

Lumbar/T12 Load: Fx

HIII



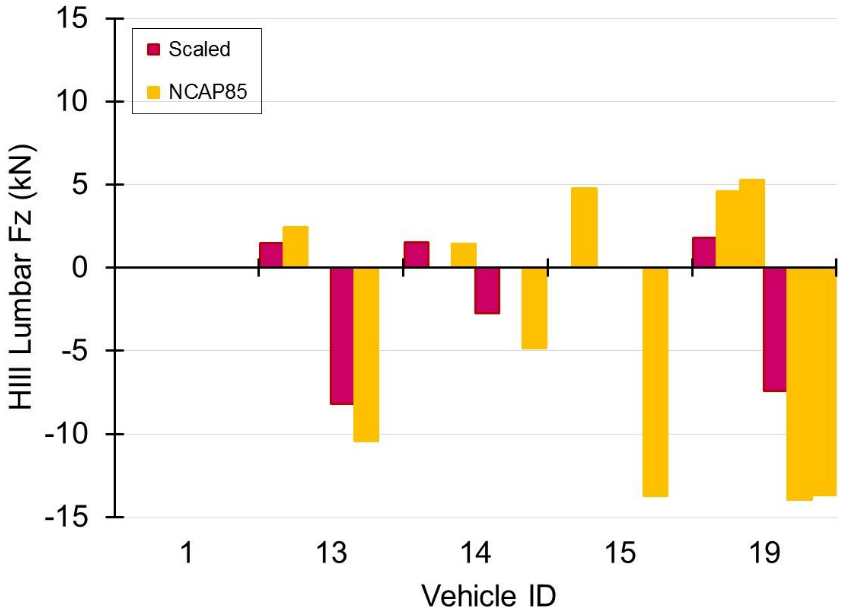
THOR-50M



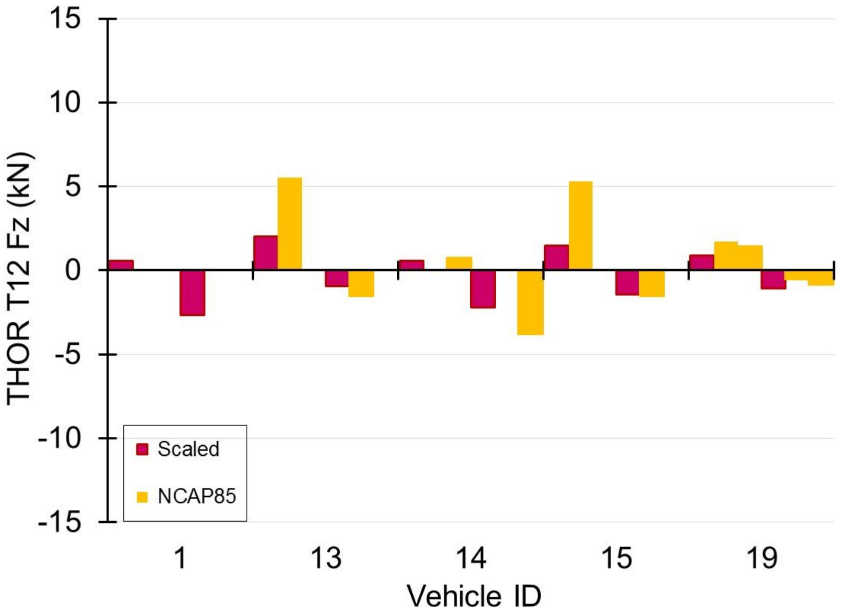
Sundararajan (2005): Average shear failure force of lumbar spine functional spinal units ranges from 1850 N to 2616 N

Lumbar/T12 Load: Fz

HIII



THOR-50M



Average axial compression failure load for lower thoracic/lumbar vertebral bodies ranges approximately from 3264 N to 8691 N (Hansson *et al.*, 1979; Hutton, W, et al., 1979; Kazarian and Graves, 1977; Messerer, 1880; Pintar, 1986; Sonoda, 1962)

Average axial compression failure load for lumbar spine functional spinal units ranges from 5204 N to 12411 N (Brown et al., 1957; Perry, 1957; Yoganandan et al., 1989; Duma et al., 2006)

Summary Remarks

- The matched generic scaled tests with the Standard THOR-50M Abdomen (V15-1) and ABISUP abdomen (V15-2) showed that the ABISUP abdomen did not have a considerable effect on the response of the THOR-50M, and that both the THOR-50M and testing procedures were extremely repeatable

Summary Remarks

- Hybrid-III and THOR-50M comparison for good occupant protection:

  The shape, polarity, and phasing of the data were similar between the two ATDs for the majority of measurements

- Hybrid-III and THOR-50M comparison for poor occupant protection (THOR-50M submarining):

  The shape of the curves differed between ATDs for a number of variables and the polarity of the lower neck forces and lumbar T12 axial force differed between the ATDs

Summary Remarks

- Different combinations of vehicle structure and restraint system characteristics resulted in different ATD responses and injury prediction outcomes
- The span of ATD responses observed in these rear seat (second row) frontal impact tests suggests that a wide range of safety performance could exist in the vehicle fleet
- These tests indicate that there are tradeoffs between vehicle design parameters that need to be examined more closely
- The ATD sled testing results can be used to examine the relationships between vehicle design and vehicle performance

Summary Remarks

- PMHS testing can be used to corroborate the ATD results, and to determine the efficacy of the ATDs for assessing this type of crash scenario/occupant position within a vehicle
- When completed, this study will help to better understand current safety-related issues for the second row of passenger vehicles

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Thank you!

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Lumbar Response Observations

- The Hybrid-III lumbar and THOR-50M T12 load cells registered considerably different peak fore/aft force, peak tension/compression force, and peak flexion/extension moment responses
- Moderate to severe submarining observed for two THOR-50M tests resulted in shear forces that were larger than the average shear failure force of lumbar spine functional spinal units
- High compressive loads measured by the Hybrid-III for both the scaled and NCAP85 pulses exceeded or nearly exceeded the average compressive failure force for isolated lumbar vertebral bodies and lumbar spine functional spinal units


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