BIOMECHANICS OF PASSENGER VEHICLE UNDERRIDE

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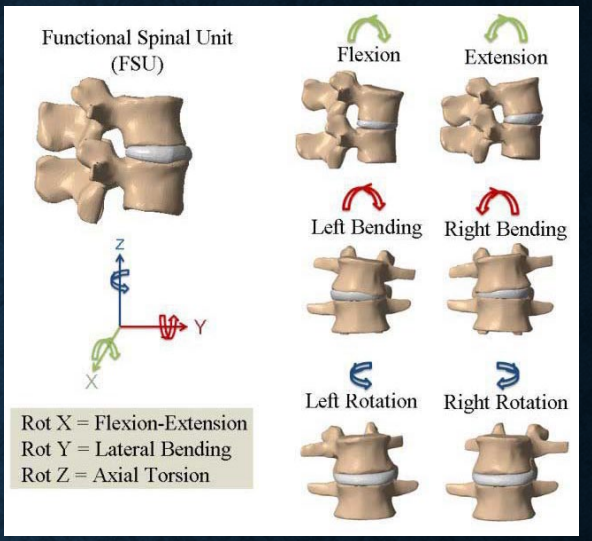
Background:

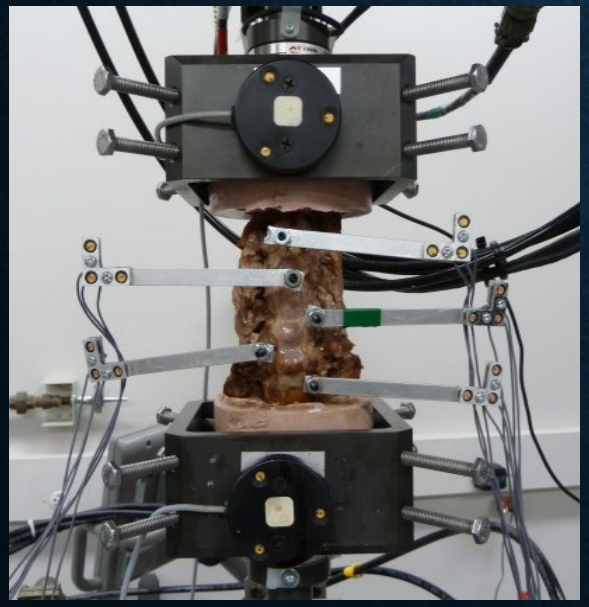
- PhD & Post-Doctoral in Biomedical Engineering (Biomechanics)
- MSc and BSc in Mechanical Engineering
- Professional Mechanical Engineer (PE) in California, Nevada and Colorado

- Accident Reconstructionist and Biomechanical Engineer
- Several peer-reviewed publications and conference presentations
- Several professional affiliations: SAE, ISB, ASME, CA2RS
- 150+ vehicle collision cases per year

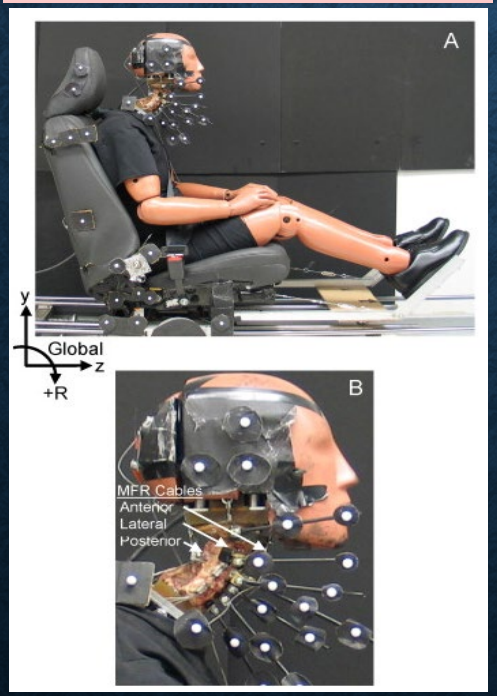
- **Accident Reconstruction (AR):**
  - The study of vehicle motions and forces
  - Delta-V, PDOF, Impact Duration, etc.
- **Injury Biomechanics:** Bio + Mechanics
  - The study of body motions and forces
  - Occupant Kinematics and Dynamics
  - Injury Mechanisms



PMHS (Cadavers)



Crash Dummies (ATDs)



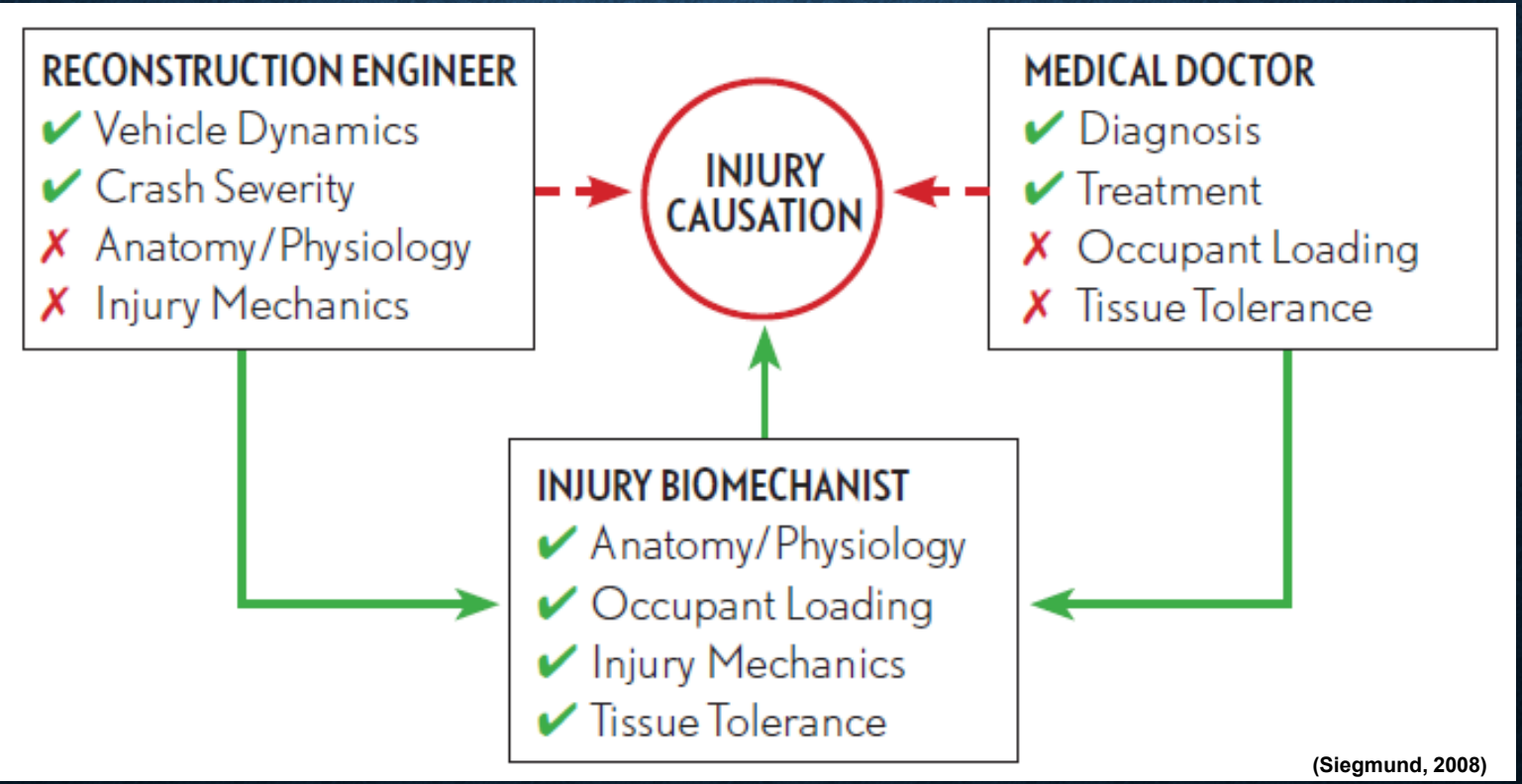
Human Volunteers

Injury Tolerance:

Cadavers < Humans < ATDs

Injury Biomechanist vs. Medical Doctor:

- Two distinct and complementary perspectives on injury:
  - Injuries Biomechanist: Motions, forces, injury tolerance, injury mechanisms
  - Medical Doctor: Diagnosis (physical exams, radiology, etc.) AND Treatment (pain medication, PT, injections, surgery, etc)



(Siegmund, 2008)

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Biomechanics of Passenger Vehicle Underride: An Analysis of IIHS Crash Test Data

Mohammad Atarod Vollmer-Gray Engineering Laboratories

Citation: Atarod, M., "Biomechanics of Passenger Vehicle Underride: An Analysis of IIHS Crash Test Data," SAE Technical Paper 2020-01-0525, 2020, doi:10.4271/2020-01-0525.

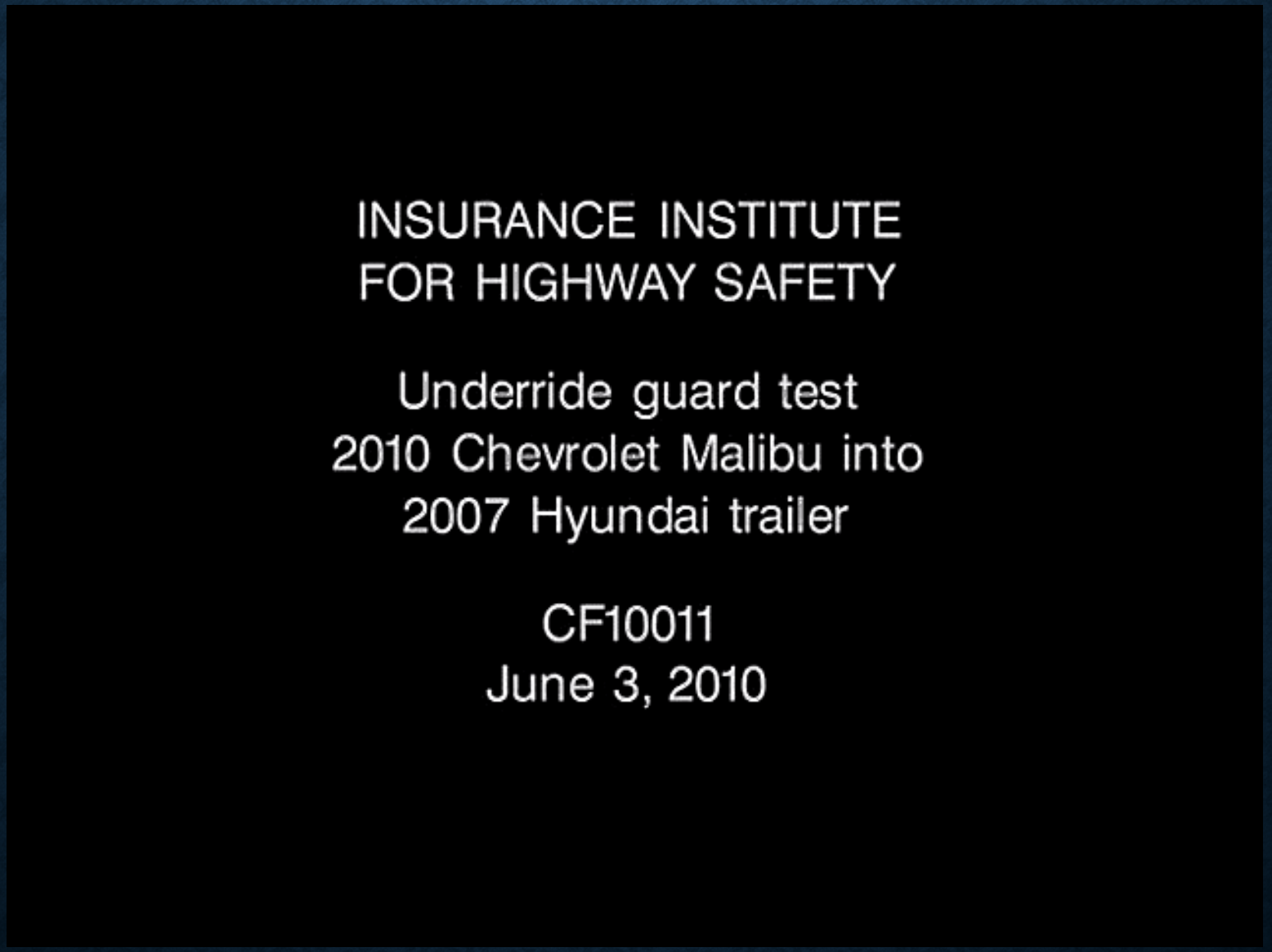
2020-01-5091 Published 14 Oct 2020

Reconstruction of Passenger Vehicle Underride: An Analysis of Insurance Institute for Highway Safety Semitrailer Rear Underride Crash Data

Mohammad Atarod Vollmer-Gray Engineering Laboratories, Inc.

Citation: Atarod, M., "Reconstruction of Passenger Vehicle Underride: An Analysis of Insurance Institute for Highway Safety Semitrailer Rear Underride Crash Data," SAE Technical Paper 2020-01-5091, 2020, doi:10.4271/2020-01-5091.

Passenger Vehicle Rear Underride



Passenger Vehicle Underride

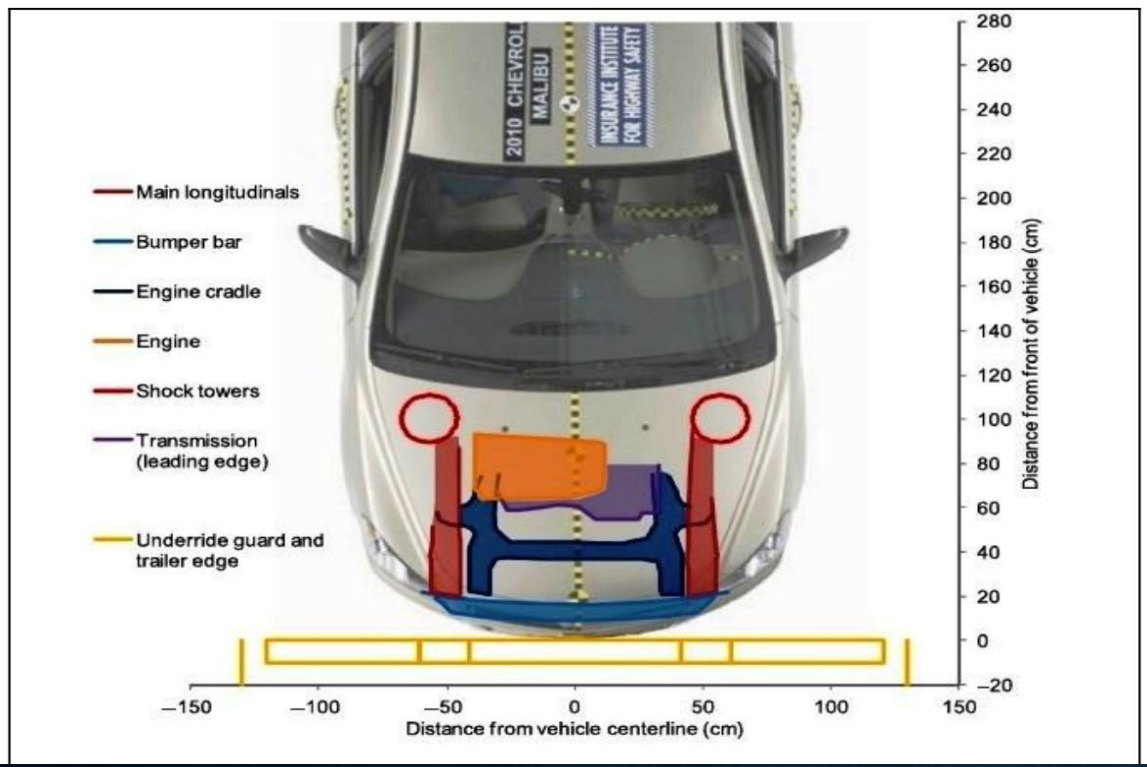
- A total of N=35 IIHS crash tests were evaluated
- Full-width (n = 9), 50% overlap (n = 11), and 30% overlap (n = 15)
- 2010 Chevrolet Malibu vs. rear underride guard of a stationary trailer
- Impact speed of 35 mph

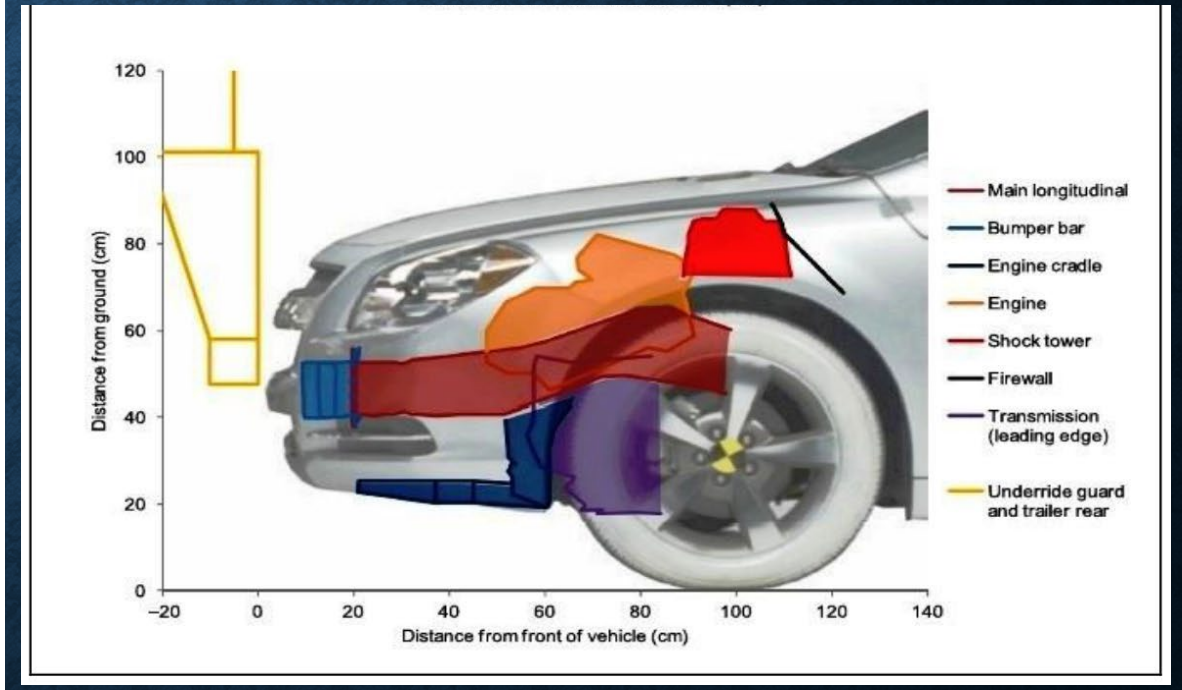
- Vehicle: Accelerations, Delta-Vs, Occupant Compartment Intrusions
- Occupant: head, neck, chest, femurs, knee, tibia, foot

(IIHS test CF10009, 50% overlap)

Passenger Vehicle Underride

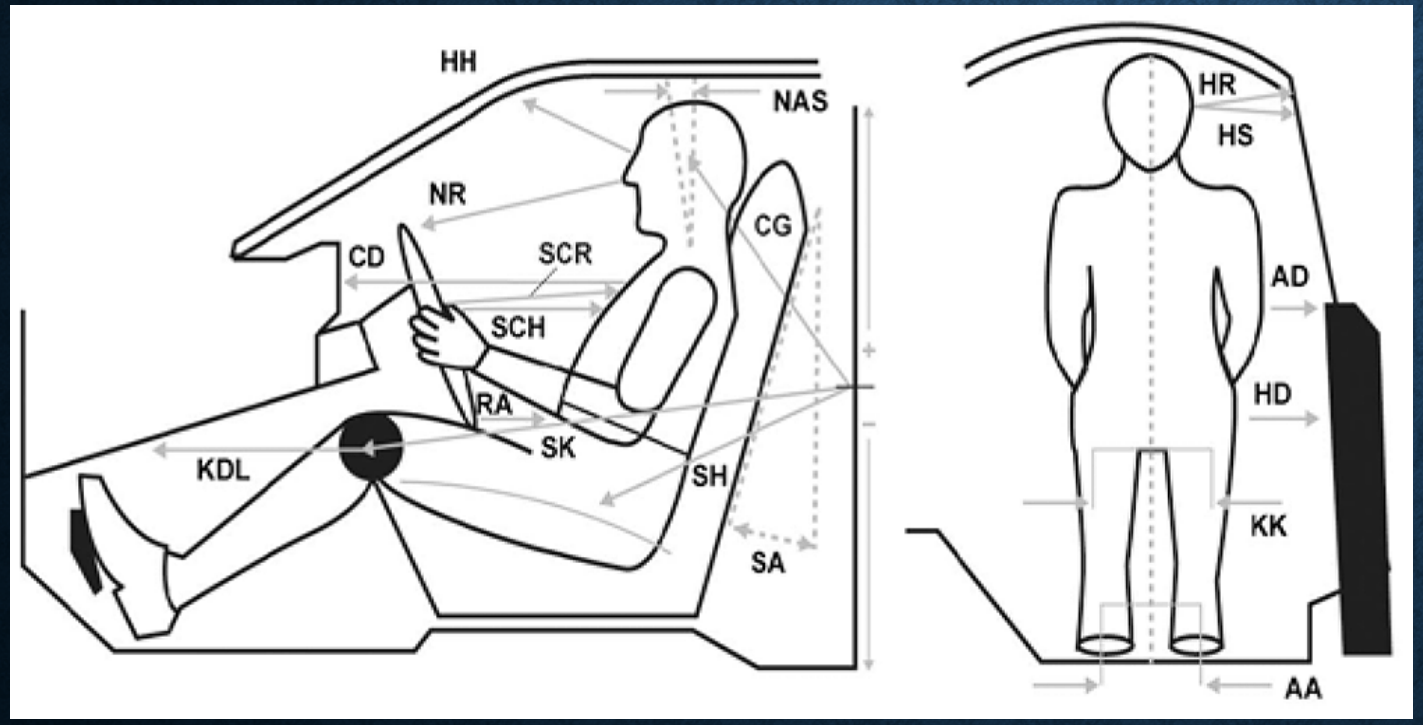
- Pre-crash measurements of the Malibu front structure and the rear underride guard

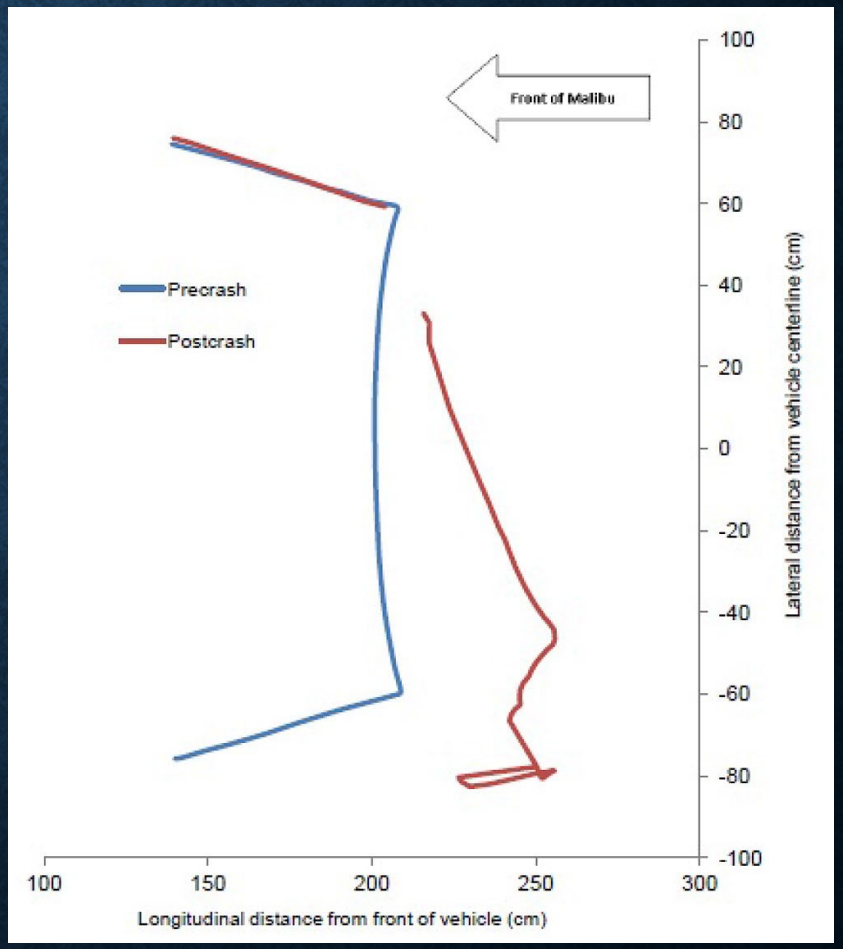




Passenger Vehicle Underride

- Intrusion of the Driver and Passenger A-Pillars and Roof Headers:





(IIHS test CF13003, 30% overlap)

Passenger Vehicle Underride: Injury Criteria

TABLE 1 Upper Body Injury Criteria and IARVs

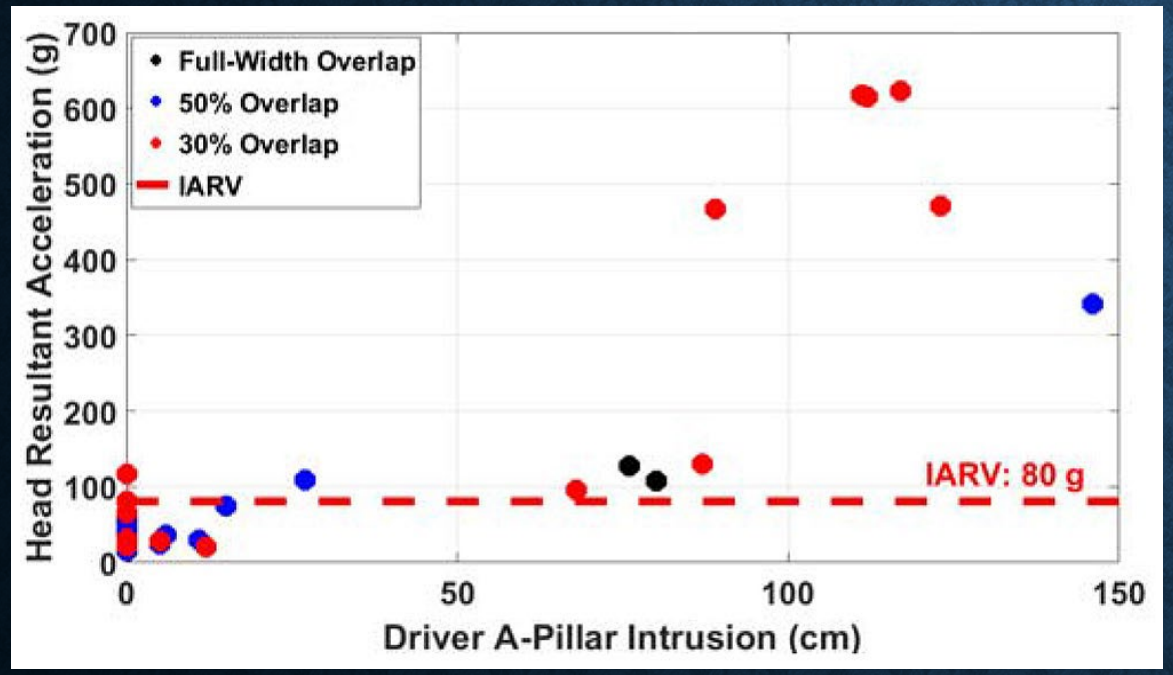
Body Part	Injury Criterion	Reference Value
Head	Resultant acceleration (g)	80
	Resultant acceleration (3ms clip, g)	80
	HIC	1000
	HIC15	700
Neck	A-P shear force (kN)	±3.1
	Lateral force (kN)	
	Axial compression (kN)	4.0
	Axial tension (kN)	3.3
	Flexion moment (Nm)	
	Extension moment (Nm)	
	Nij - Tension-Extension*	1.0
	Nij - Tension-Flexion	1.0
	Nij - Compression-Extension	1.0
	Nij - Compression-Flexion	1.0
Chest	Resultant acceleration (3ms clip, g)	60
	X displacement (mm)	-50
	V*C (m/s)	1.0
	Sternum deflection rate (m/s)	-8.2

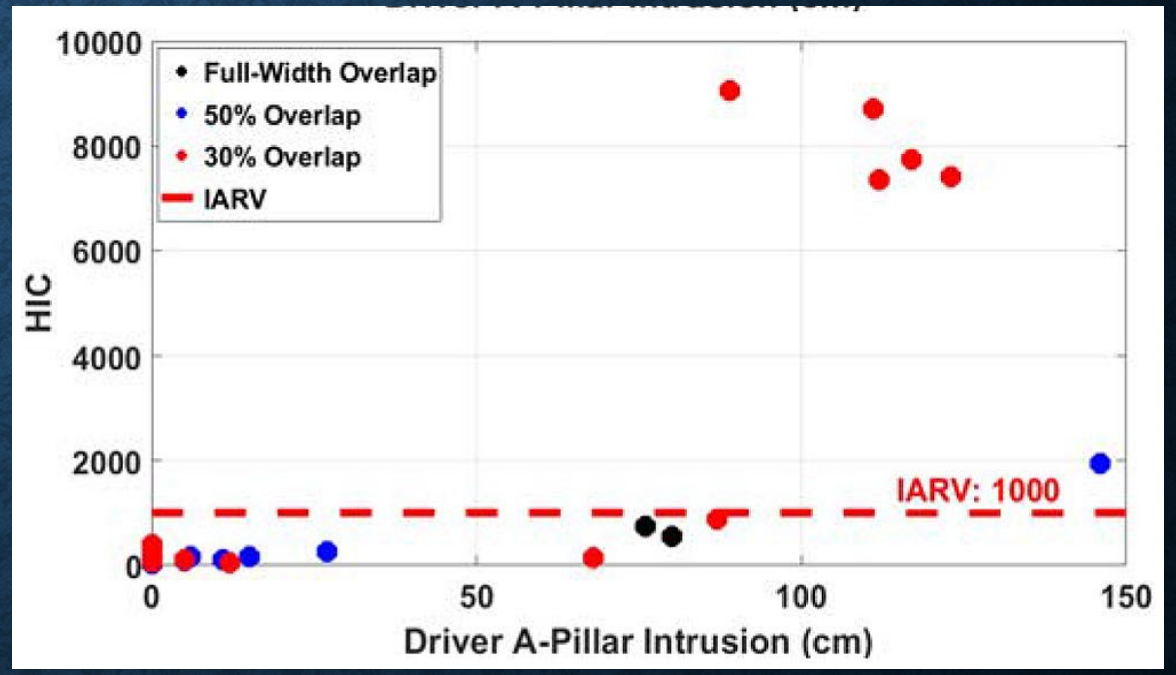
TABLE 2 Lower Body Injury Criteria and IARVs

Body Part	Injury Criterion	Reference Value
Left Leg	Left femur maximum force (kN)	-9.1
	Left femur impulse (Ns)	
	Left knee displacement (mm)	-15
	Left upper tibia L-M moment (Nm)	±225
	Left upper tibia A-P moment (Nm)	±225
	Left upper tibia resultant moment (Nm)	225
	Left upper tibia index	1.00
	Left lower tibia L-M moment (Nm)	±225
	Left lower tibia A-P moment (Nm)	±225
	Left lower tibia resultant moment (Nm)	225
	Left lower tibia axial force (kN)	-8.0
	Left lower tibia index	1.00
	Left foot A-P acceleration (g)	
	Left foot I-S acceleration (g)	
	Left foot resultant acceleration (g)	150

Passenger Vehicle Underride

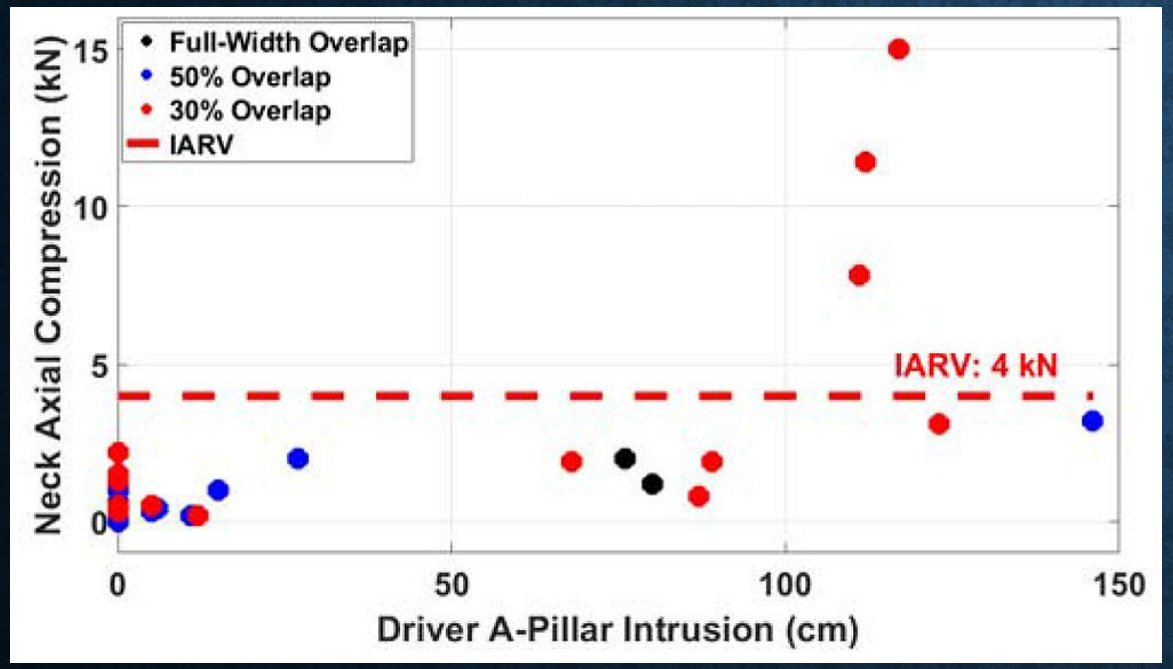
- Head Injury Biomechanics:

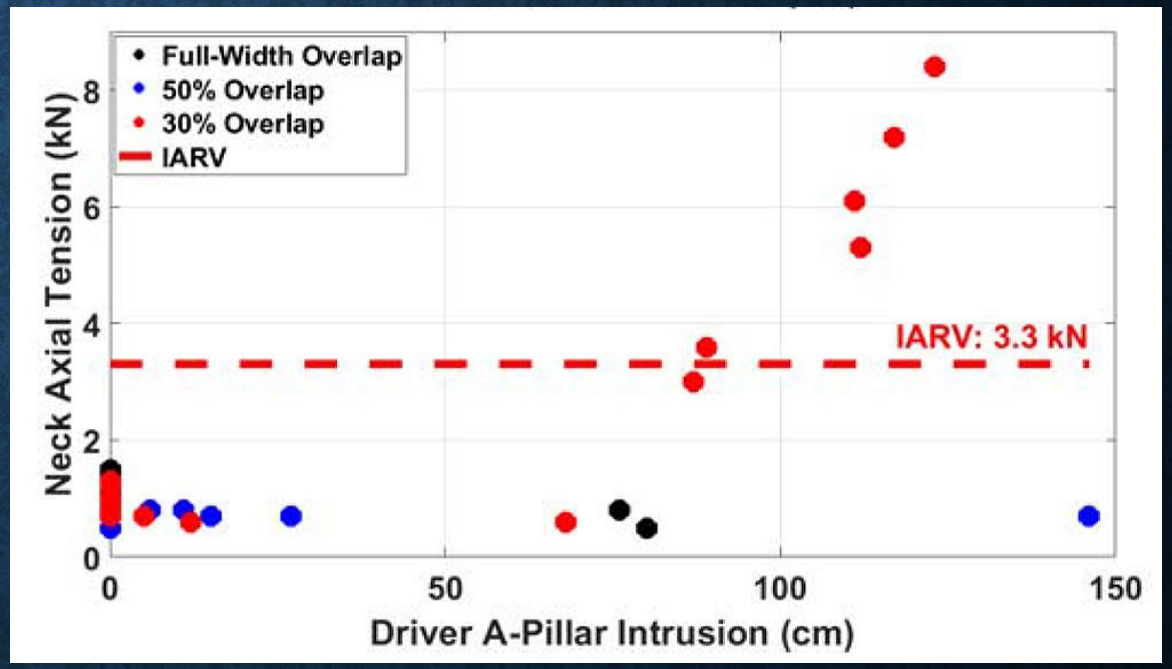




Passenger Vehicle Underride

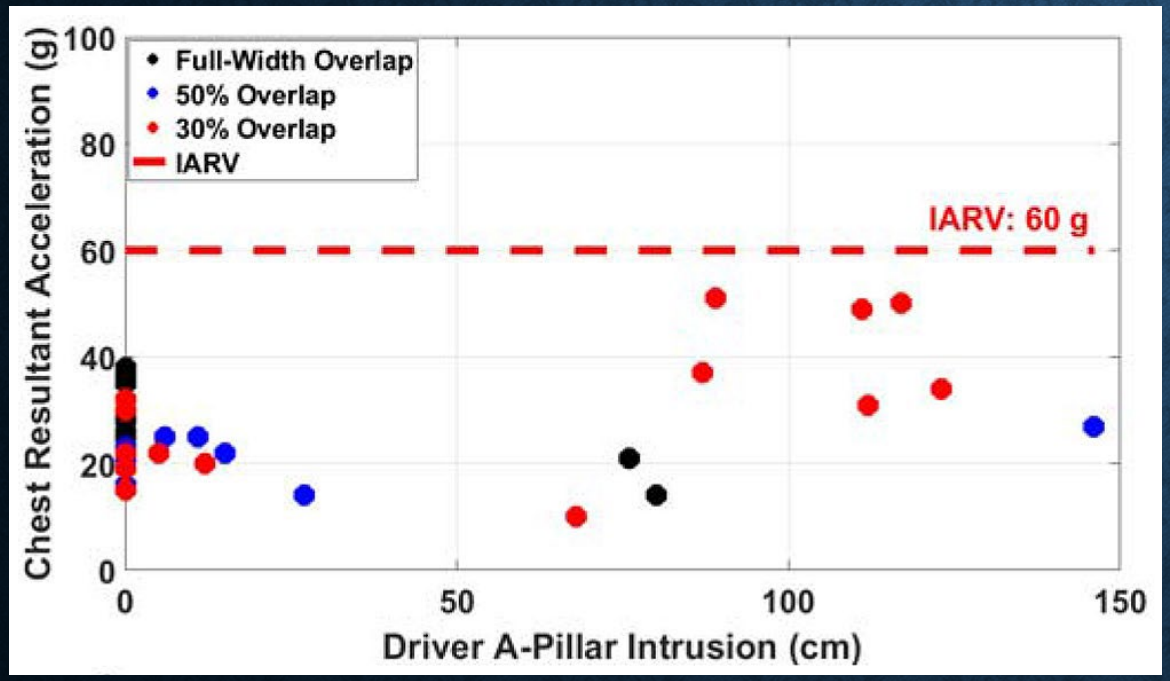
- Neck Injury Biomechanics:

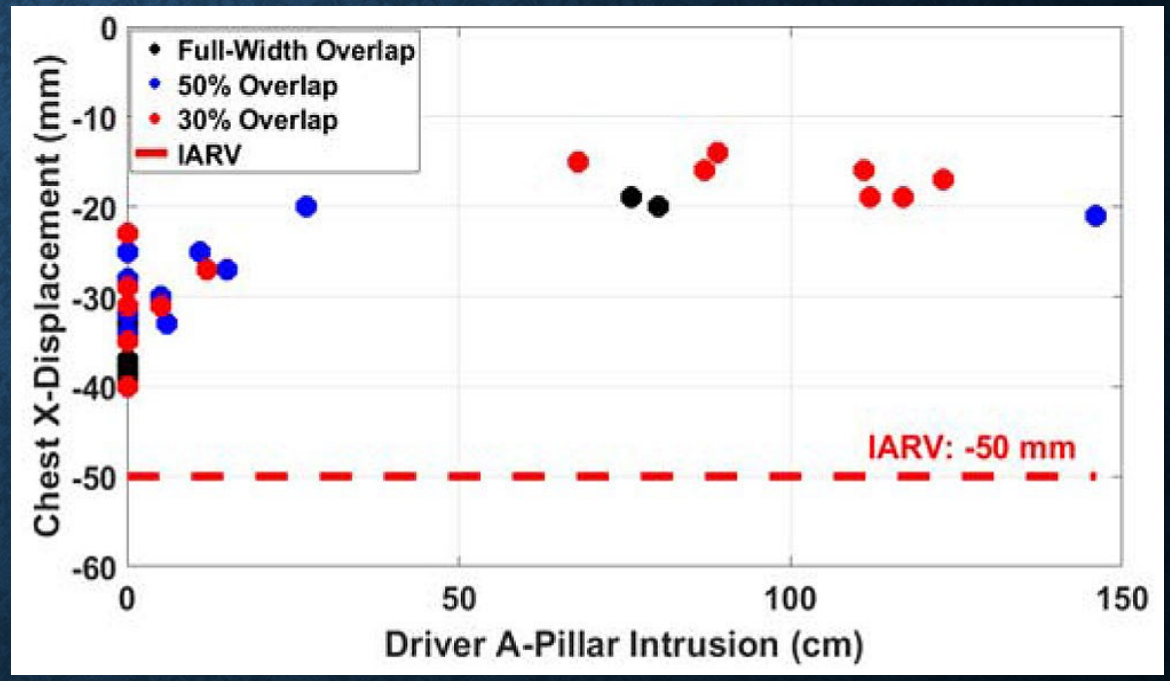




Passenger Vehicle Underride

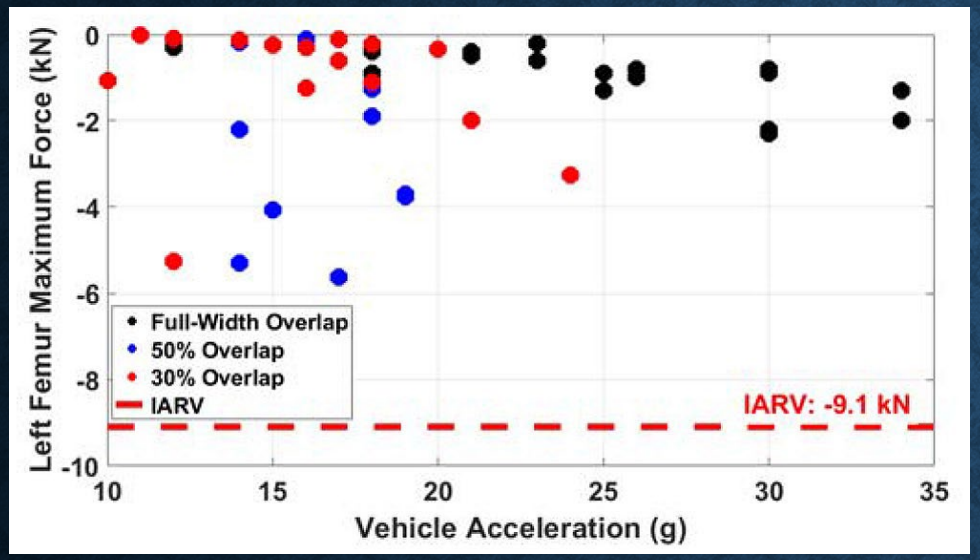
- Chest Injury Biomechanics:

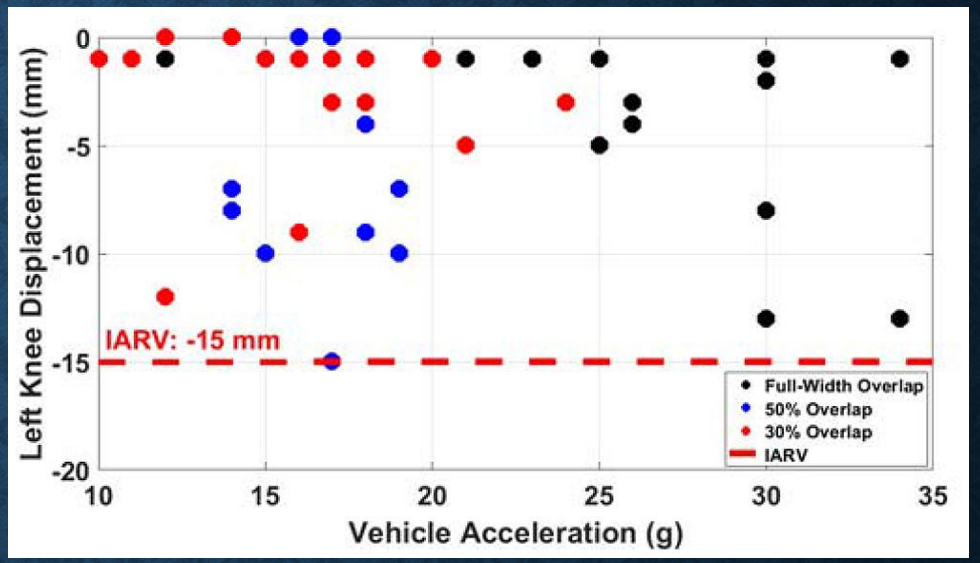


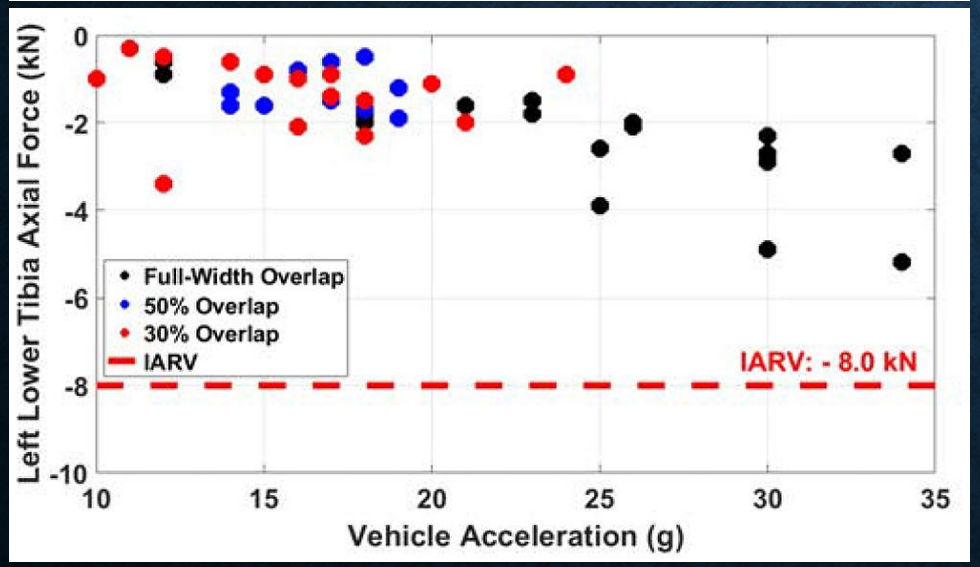


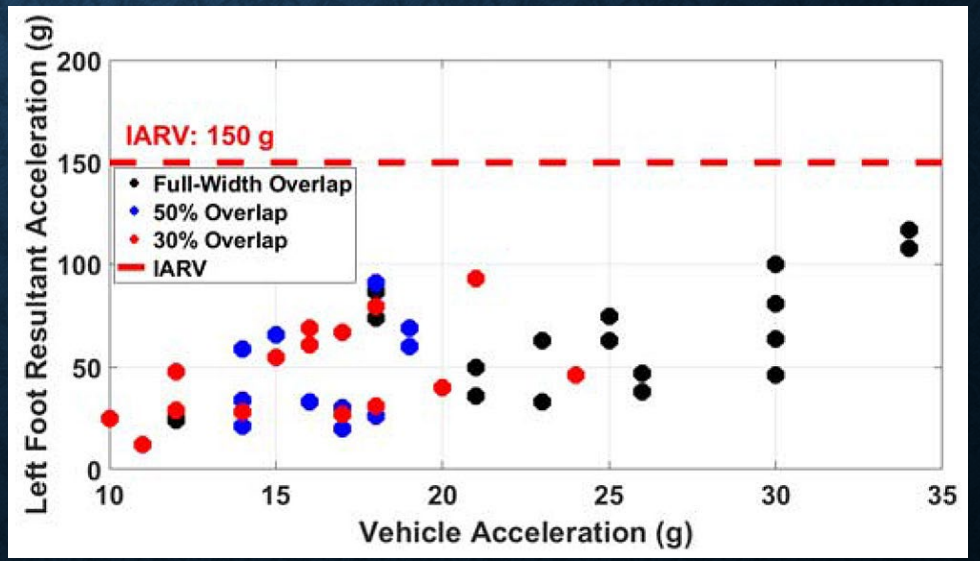
Passenger Vehicle Underride

- Lower Extremity Injury Biomechanics:









Passenger Vehicle Underride

Conclusions:

- Percent overlap, guard deformation, vehicle excursion and occupant compartment intrusion should also be taken into consideration in underride crashes.

- The 30% overlap crashes showed significantly higher intrusion and head and neck injury values than the 50% and full-width crashes.

- Head and neck injury parameters were positively correlated with driver A-pillar rearward intrusion.

- In underride crashes there is a higher chance of head/neck injuries than other body regions.

Passenger Vehicle Side Underride

Questions