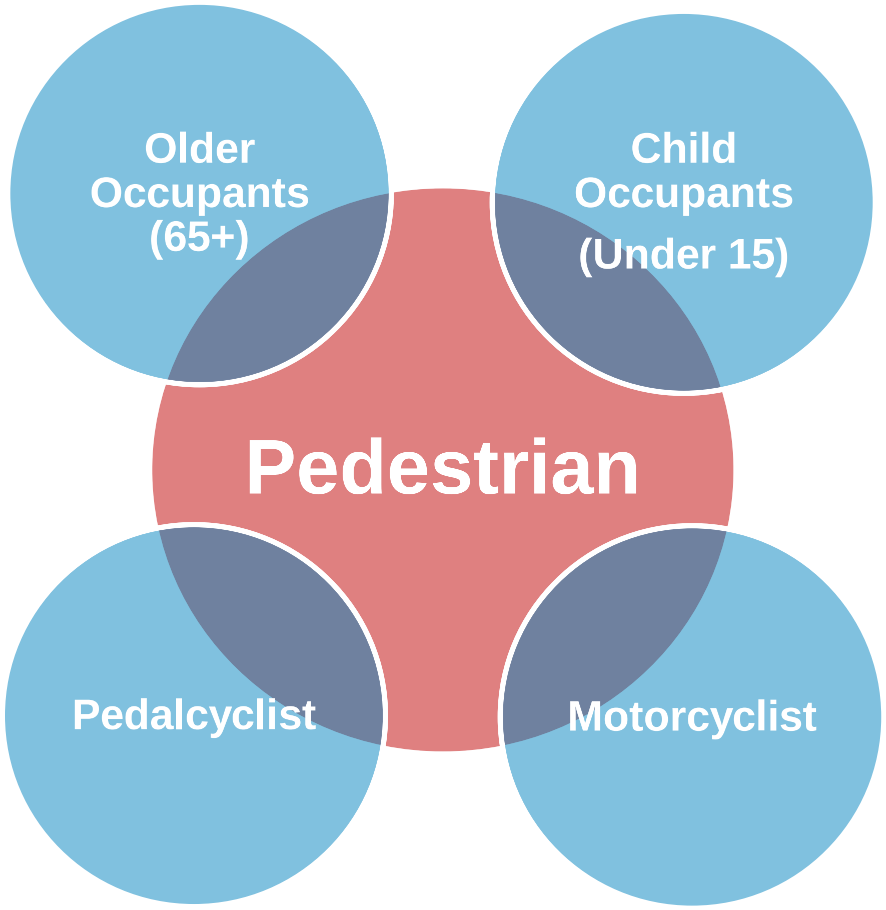
NHTSA

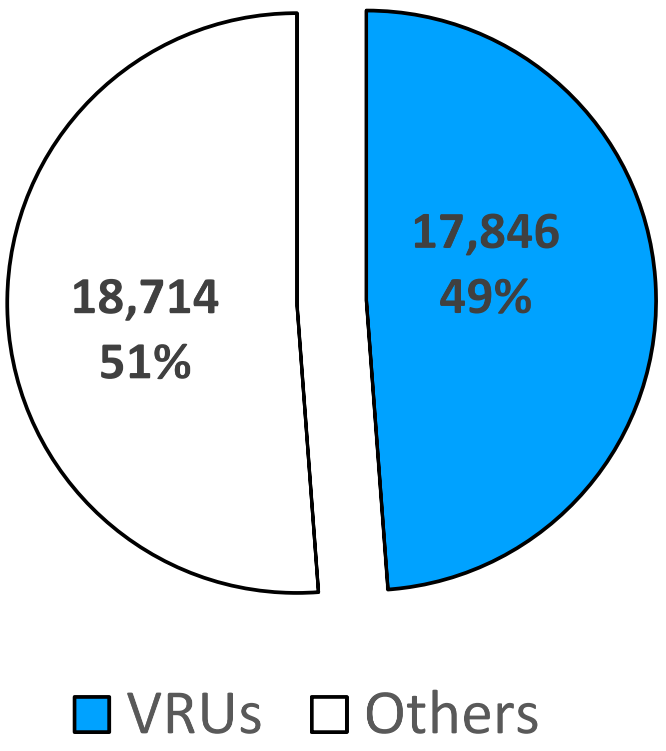
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

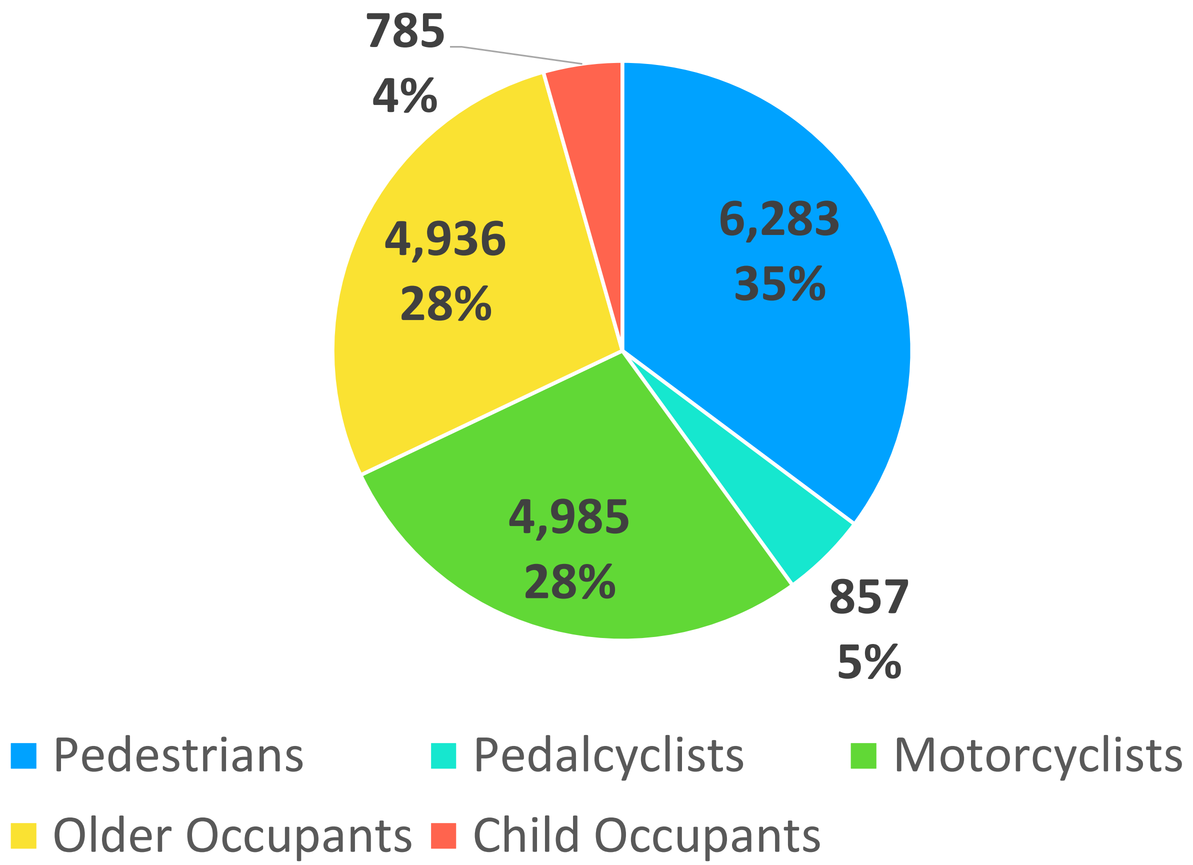
Vulnerable and Other Road Users

Vulnerable Road User (VRU)



Composition of Motor Vehicle Traffic Fatalities, 2018





Changes in VRU Fatalities, 2014-2018

VRU Category	2014		2018		2014-2018 % Change
	Fatalities	% of Total	Fatalities	% of Total	
Pedestrian	4,910	15.0%	6,283	17.2%	+28%
Pedal-cyclist	729	2.2%	857	2.3%	+17.6%
Motorcyclist	4,594	14.0%	4,985	13.6%	+8.5%
Older Occupant	4,218	12.9%	4,936	13.5%	+17%
Child Occupant	761	2.3%	785	2.2%	+3%
Others	17,532	53.5%	18,714	51.2%	+6.7%
Total	32,744	100%	36,560	100%	+11.7%

Overview

- NHTSA conducts research to improve the safety of people in and around vehicles that are particularly vulnerable to injury and/or have special considerations
  - Children
  - Pedestrians and pedalcyclists
  - Motorcyclists
  - Older occupants
  - Obese occupants
  - Disabled road users
- Cross-cutting vehicle/equipment and behavioral-based research
  - Crash avoidance
  - Crashworthiness
  - Biomechanics
  - Enforcement
  - Education/Awareness

Overview – Research Programs

- Child Safety
  - Child restraint systems (front & side impact, LATCH ease-of-use)
  - Unattended child reminder systems
  - Large omni-directional child (LODC) ATD development
  - Awareness and availability of child passenger safety resources
  - Factors affecting correct child restraint system installation
- Pedestrian and Bicyclist Safety
  - Pedestrian impact protection (head, upper/lower leg)
  - Pedestrian impact avoidance (PAEB)
  - Integrated crash avoidance and crashworthiness pedestrian testing
  - Pedestrian crash data collection (CIREN)
  - Pedestrian distraction
  - High Visibility Enforcement and compliance with safe bicycle passing laws
  - Use of speed-related programs to improve pedestrian and bicyclist safety
  - Evaluation of “Safety in Numbers” concept

Overview – Research Programs

- Motorcycle Safety
  - Evaluation of motorcycle helmet test procedures
  - Motorcycle helmet safety (rotational injury)
  - Motorcycle conspicuity to light vehicle ADAS capabilities
  - Survey of driver attitudes toward motorcycling
  - Motorcyclists’ attitudes on using high-visibility gear to improve conspicuity
  - Estimating motorcycle travel from State annual safety inspection data
- Older Occupant Safety
  - Injury criteria development - subdural hematoma, thorax
  - Older drivers’ use of rearview video systems
  - Visual scanning training for older drivers
  - Exploring older drivers’ self-regulation and exposure
- Obese Occupant Safety
  - Restraint design for obese occupants
- Disabled Road Users Safety
  - Vulnerable and disabled road users: considerations inside and outside the vehicle
  - Automated restraints systems for wheelchair occupants

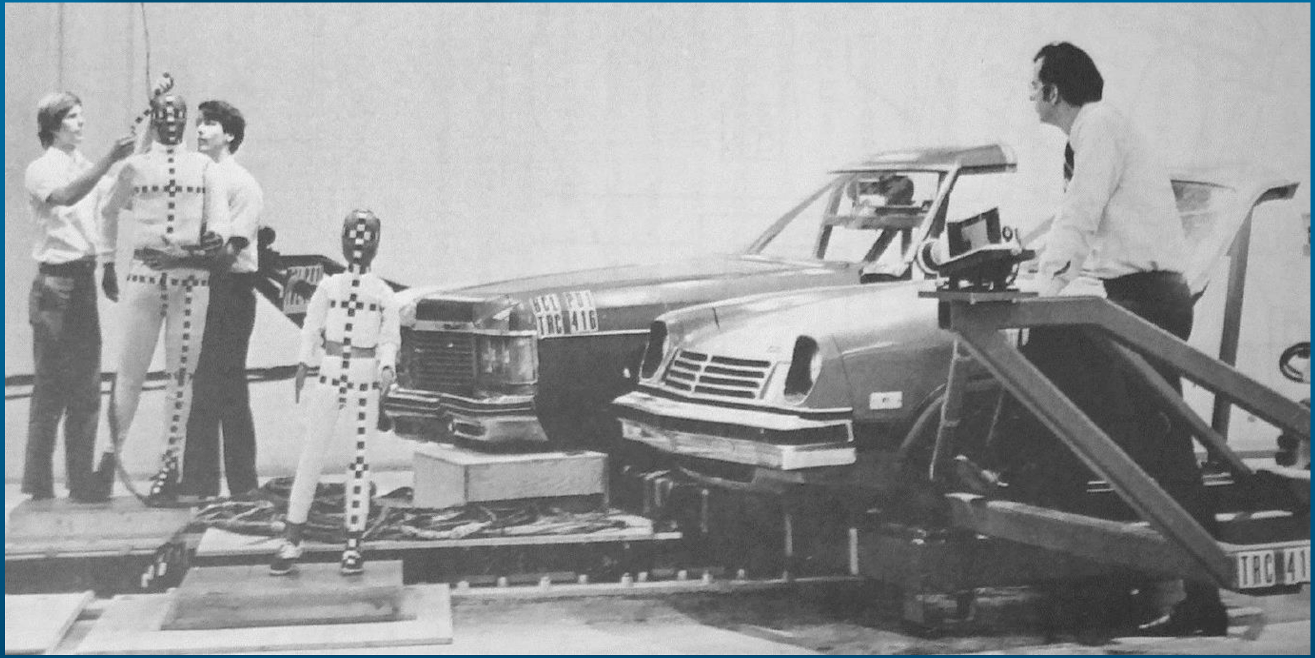
1. Pedestrian Protection – Crashworthiness
2. CIREN Pedestrian Pilot Study
3. Pedestrian Distraction
4. Effect of High Visibility Enforcement (HVE) on Driver Compliance with Bicycle Safe Passing Laws
5. Motorcyclists' Attitudes on Using High-Visibility Gear
6. Motorcycle Conspicuity to Light Vehicle ADAS Capabilities

Pedestrian Protection – Crashworthiness

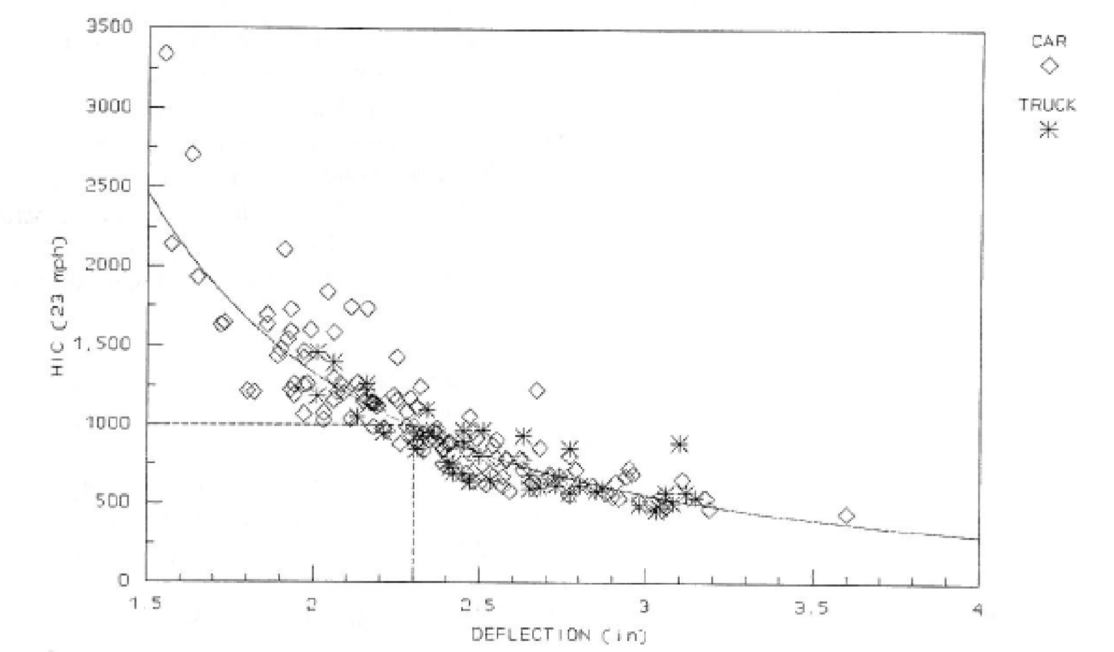
Jason Stammen, Ph.D.

Background and History

1970s-80s: Seminal research to understand how pedestrian kinematics are affected by vehicle geometry and how head injury risk is affected by underhood clearance



Pritz H. "Vehicle Design for Pedestrian Protection" DOT HS 805 199 (1979).



MacLaughlin T, Kessler J. "Test Procedure – Pedestrian Head Impact Against Central Hood" SAE 902315, Stapp Conference (1990).

1970s-80s: Seminal research to understand how pedestrian kinematics are affected by vehicle geometry and how head injury risk is affected by underhood clearance

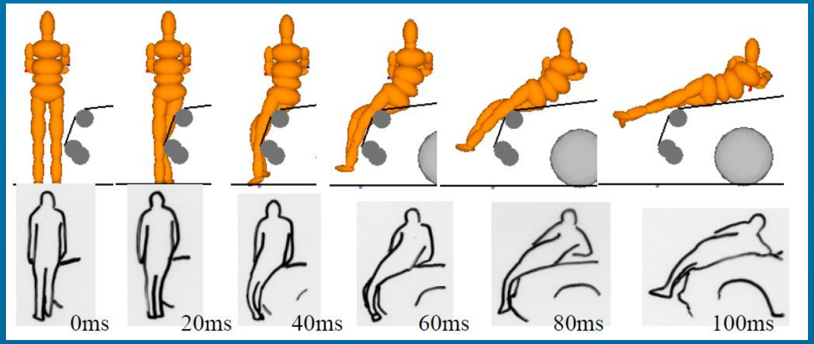
1990s: International collaboration to examine the relationship between vehicle contact sources and injuries to various body regions; develop harmonized test procedures to measure head/leg injury risk

(For AIS 2-6)

Injury Location	US	Europe	Japan	Global	
Head	32.7%	29.8%	28.6%	30.9%	
Face	3.7%	5.3%	2.4%	4.3%	
Neck	0.0%	1.8%	4.5%	1.4%	
Chest	9.5%	11.6%	8.5%	10.3%	
Abdomen	7.7%	3.8%	4.8%	5.6%	
Pelvis	5.3%	7.9%	4.5%	6.4%	
Arms	7.9%	8.1%	9.0%	8.1%	
Overall Legs	7.9%	0.7%	2.1%	3.9%	
Femur	3.2%	4.0%	9.3%	4.3%	30.3%
Knee	3.0%	3.4%	4.2%	3.3%	
Lower Leg	18.1%	19.8%	17.2%	18.8%	
Foot	1.1%	3.4%	2.9%	2.4%	
Unknown	0.0%	0.5%	2.1%	0.5%	
Others	0.0%	0.0%	0.0%	0.0%	

Table 2 Global Pedestrian Accident Dataset

Region	Cases	Injuries
Europe	772	4,191
Japan	240	901
United States	518	4,107
Total	1,530	9,199



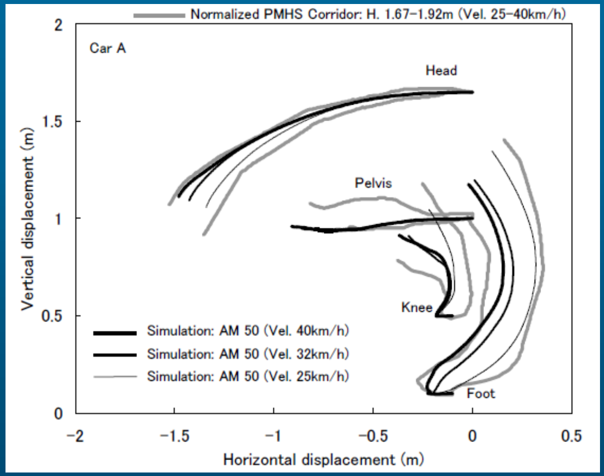
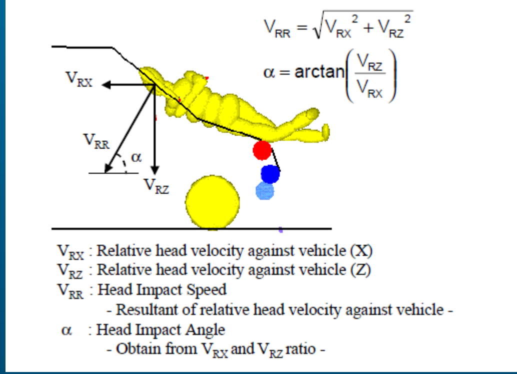


Figure 17 Definition of Head Impact Velocity and Head Impact Angle



Mizuno Y. "Summary Of IHRA Pedestrian Safety WG Activities – Proposed Test Methods To Evaluate Pedestrian Protection Afforded By Passenger Cars" ESV (2001).

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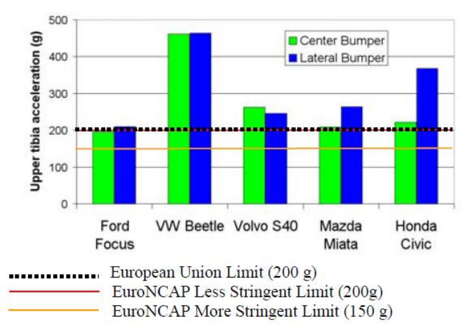
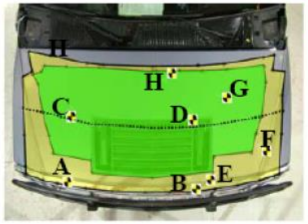
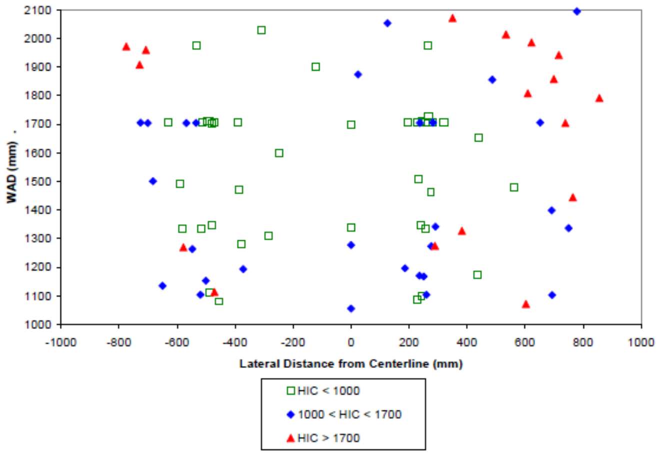


Mallory et al. “Component Leg Testing of Vehicle Front Structures” ESV (2005).



	HIC
A	4252
B	4594
C	1220
D	909
E	6773
F	2307
G	1220
H	1493



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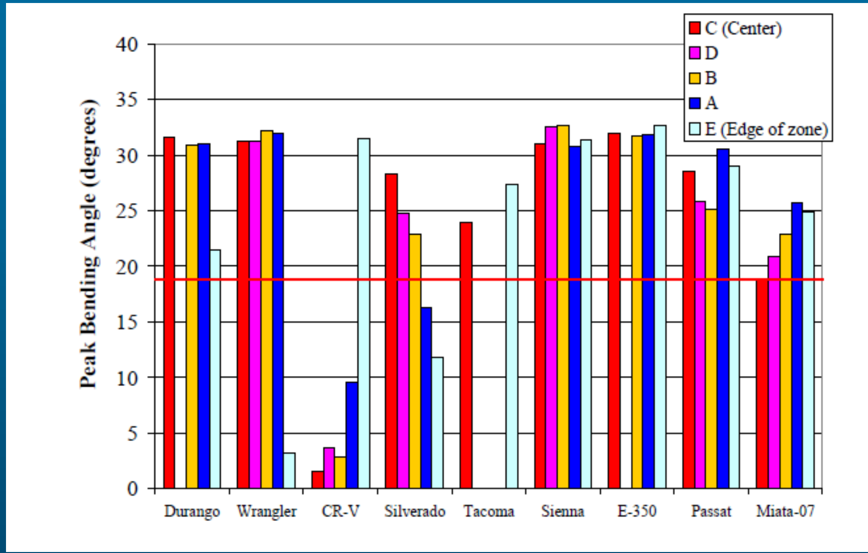

Mallory et al. “Performance of Vehicle Bumper Systems with the EEVC/TRL Pedestrian Lower Legform” ESV (2009).

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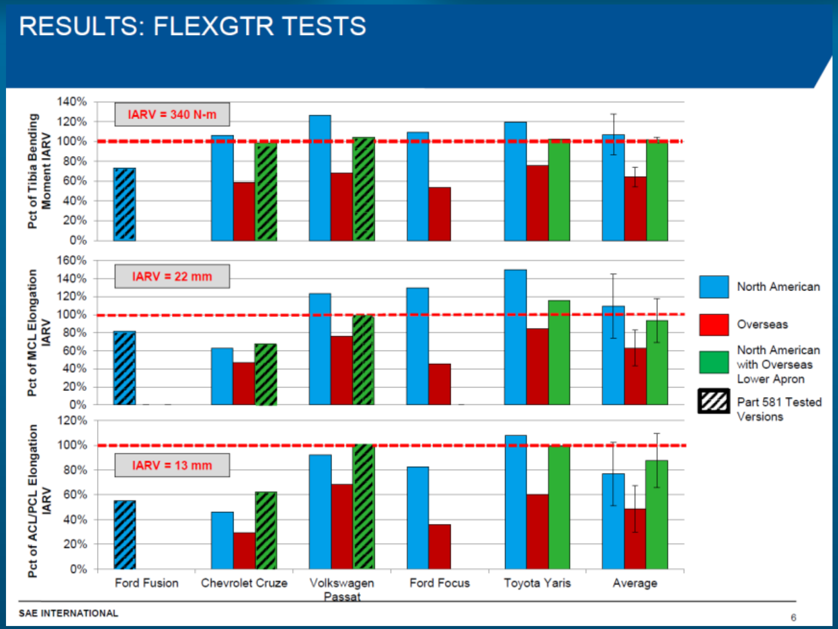

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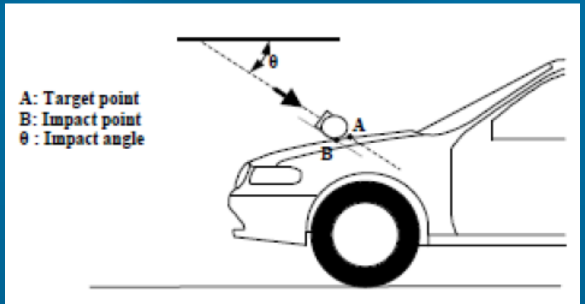
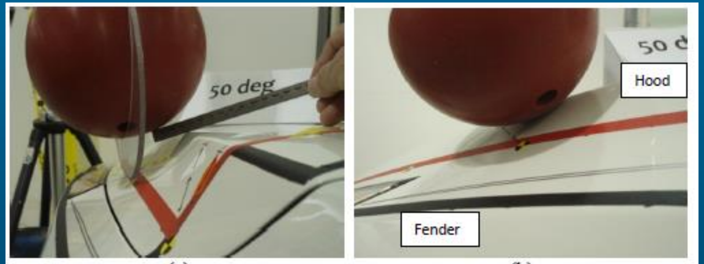


Table 1. Difference between actual launch area for 3D point of first contact (3D POFC) and aiming point (AP) protocols

Vehicle	% Change in Impacted Area
Buick LaCrosse, 2010	-8.2
Kia Forte, 2010	-6.6
Acura MDX, 2010	-1.7
Hyundai Tucson, 2010	-9.2
Honda Odyssey, 2011	-5.2
Jeep Grand Cherokee, 2011	-3.2
Average	-5.7



(a) (b)

Suntay B, Stammen J. "Vehicle Hood Testing to Evaluate Pedestrian Headform Reproducibility, GTR No. 9 Test Procedural Issues, and U.S. Fleet Performance"

NHTSA Docket No. NHTSA-2008-0145-0014

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2010-2015: Testing to assess industry-proposed amendments to test procedures

2015 – Present: Research and testing to evaluate, finalize, and document tools and test procedures for US vehicles

EVALUATION OF TEST TOOLS & PROCEDURES

US FLEET ASSESSMENT

INJURY DATA STUDIES

Evaluation of Test Tools & Procedures

Headforms

- Technical evaluation found that the headforms are durable, repeatable & reproducible, sensitive to vehicle design[1]
- Observed HIC improvements in newer vs. older MY vehicles; trying to see if this is consistent with real world U.S. data
- Safety benefit provided by active hoods varies by vehicle in laboratory; unclear from real world data[2]
- Very good lab-to-lab consistency in global platform vehicles tested at VRTC and EuroNCAP[3]

[1]Suntay & Stammen "Vehicle Hood Testing to Evaluate Pedestrian Headform Reproducibility, GTR No. 9 Test Procedural Issues, and U.S. Fleet Performance" NHTSA Docket No. NHTSA-2008-0145-0014.
[2]Suntay & Stammen "Assessment of Hood Designs for Pedestrian Head Protection: Active Hood Systems" DOT HS 812 762. (will be posted to research docket soon)
[3]Suntay, Stammen, Martin "Pedestrian Protection: U.S. Vehicle Fleet Assessment" DOT HS 812 723. https://rosap.ntl.bts.gov/view/dot/41841

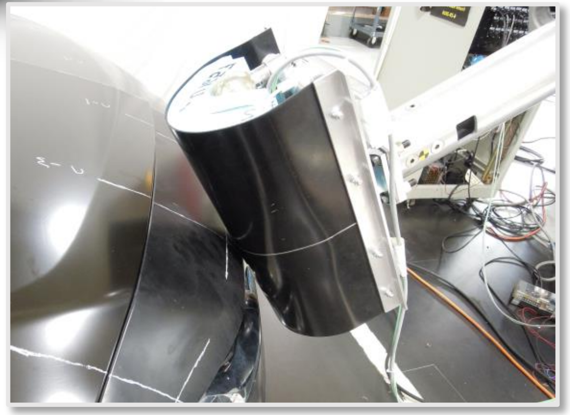
Flex-PLI Lower Legform

- Technical evaluation found that the Flex-PLI is durable, repeatable & reproducible, sensitive to vehicle design[1]
- Observed improvements in newer vs. older MY vehicles; trying to see if this is consistent with real world U.S. data
- Found that front end designs can be both pedestrian-friendly and limit cosmetic damage in low speed bumper impacts[2]
- Determined that global platform vehicles tend to do better than US-only vehicles[3]

[1]Suntay B, Stammen J. "Technical Evaluation of the Flexible Pedestrian Leg Impactor (Flex-PLI)" NHTSA Docket No. NHTSA-2008-0145-0014.
[2]Suntay & Stammen "Vehicle Bumper Performance in Part 581 vs. Pedestrian Leg Protection" DOT HS 812 ###. (will be posted to research docket soon)
[3]Suntay, Stammen, Martin "Pedestrian Protection: U.S. Vehicle Fleet Assessment" DOT HS 812 723. https://rosap.ntl.bts.gov/view/dot/41841

Upper Legform

- Technical evaluation found that the upper legform is durable, repeatable & reproducible, sensitive to vehicle design[1]
- Smaller vehicles performed better than larger vehicles, reflecting real world trend
- Even though lab-specific measurements & environmental conditions were found to influence test results, VRTC results matched EuroNCAP scores[2]



[1]Suntay & Stammen "Technical Evaluation Of the TRL Pedestrian Upper Legform" DOT HS 812 659. https://rosap.ntl.bts.gov/view/dot/41916
[2]Suntay, Stammen, Martin "Pedestrian Protection: U.S. Vehicle Fleet Assessment" DOT HS 812 723. https://rosap.ntl.bts.gov/view/dot/41841

US Vehicle Fleet Assessment

US Fleet Tests

- EuroNCAP test procedures
  - Head, Flex-PLI, upper leg
- Nine vehicles (MY 2015-2017)
- Impact location distribution simulates EuroNCP distribution

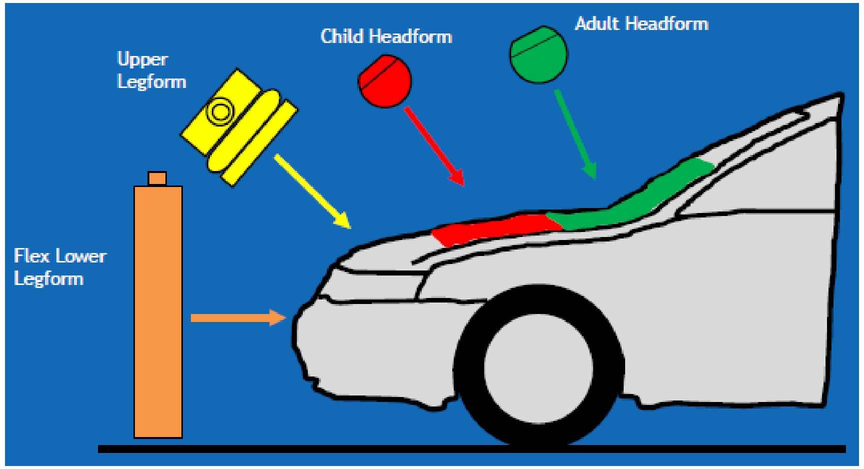


Table 1. List and description of U.S. vehicles tested by NHTSA. Rows colored gray have European variants that have been tested by Euro NCAP.

Vehicles Tested			
Model Year (MY)	Make	Model	Description
2017	Audi	A4*	Midsize Passenger Car
2016	Chevrolet	Malibu	Midsize Passenger Car
2016	Chevrolet	Tahoe	Large SUV
2016	Ford	Edge	Midsize SUV
2015	Ford	F-150	Standard Pickup Truck
2016	Honda	Fit	Small Passenger Car
2016	Nissan	Rogue	Small SUV
2016	Toyota	Prius	Small Passenger Car
2015	Toyota	Sienna	Minivan

*An Audi A4 with an active hood was tested by Euro NCAP. An active hood is standard on European variants of the A4, but is not available on models sold in the U.S.

Suntay & Stammen "Overview of NHTSA Pedestrian Crashworthiness Research" SAE Govt/Industry 2018

Suntay, Stammen, Martin "Pedestrian Protection: U.S. Vehicle Fleet Assessment" DOT HS 812 723.
https://rosap.ntl.bts.gov/view/dot/41841

SUMMARY - HEAD

- **Performance of global vehicles is markedly better**
  - **- Many underpinnings same EU/US**
- **Larger vehicles had test zones encompassing more hard points and thus did worse**
- **NHTSA and EuroNCAP scores were similar**

Vehicle	Head Scores (Max 24 pts)	
	NHTSA	Euro NCAP
2017 Audi A4	17.00	16.58*
2016 Chevrolet Malibu	16.36	--
2016 Chevrolet Tahoe	14.18	--
2016 Ford Edge	17.40	16.04
2015 Ford F-150	9.82	--
2016 Honda Fit	18.67	17.10
2016 Nissan Rogue	18.00	15.44
2016 Toyota Prius	19.80	16.91
2015 Toyota Sienna	16.67	--
Average Score (% of Max)	16.02 (67%)	16.41 (68%)

* Euro NCAP tests performed on an active hood.

Suntay, Stammen, Martin "Pedestrian Protection: U.S. Vehicle Fleet Assessment" DOT HS 812 723. https://rosap.ntl.bts.gov/view/dot/41841

SUMMARY – LOWER LEG

- **Performance of vehicles somewhat dependent on whether Part 581 applies**
- **Higher bumper vehicles did worse due to more wrapping of lower leg under bumper beam**
- **NHTSA and EuroNCAP scores were not as consistent; function of different bumper components**

Vehicle	Is Part 581 Applicable to U.S. Version?	Lower Leg Scores (Max 6 pts)	
		NHTSA	Euro NCAP
2017 Audi A4	Yes	2.24	5.32
2016 Chevrolet Malibu	Yes	1.99	--
2016 Chevrolet Tahoe	No	0.00	--
2016 Ford Edge	No	0.40	6.00
2015 Ford F-150	No	0.00	--
2016 Honda Fit	Yes	0.00	6.00
2016 Nissan Rogue	No	6.00	6.00
2016 Toyota Prius	Yes	4.41	6.00
2015 Toyota Sienna	No	0.00	--
Average Score (% of Max)		1.67 (28%)	5.86 (98%)

Suntay, Stammen, Martin "Pedestrian Protection: U.S. Vehicle Fleet Assessment" DOT HS 812 723. https://rosap.ntl.bts.gov/view/dot/41841

SUMMARY – UPPER LEG

- **Global vehicles did relatively well – small vehicles especially due to lower test energy & hood involvement**

- **Larger vehicles did worse due to higher test energy & bumper impact**

- **NHTSA and EuroNCAP scores were not as consistent; function of different bumper/grille components**

Vehicle	Impact Location*	Is Part 581 Applicable to U.S. Version?	Upper Leg Scores (Max 6 pts)	
			NHTSA	Euro NCAP
2017 Audi A4	BLE	Yes	5.17	5.46
2016 Chevrolet Malibu	BLE	Yes	3.40	--
2016 Chevrolet Tahoe	Grille + Bumper	No	0.80	--
2016 Ford Edge	Grille	No	0.80	3.56
2015 Ford F-150	Grille + Bumper	No	1.20	--
2016 Honda Fit	BLE	Yes	6.00	3.23
2016 Nissan Rogue	Grille	No	6.00	5.40
2016 Toyota Prius	Hood	Yes	5.91	4.82
2015 Toyota Sienna	Grille	No	2.44	--
Average Score (% of Max)			3.52 (59%)	4.49 (75%)

* BLE is the bonnet (or hood) leading edge.

Suntay, Stammen, Martin "Pedestrian Protection: U.S. Vehicle Fleet Assessment" DOT HS 812 723. https://rosap.ntl.bts.gov/view/dot/41841

Injury Data Studies

Injury Data Studies

- Related frequency of real-world injuries from National Trauma Data Bank (NTDB) to component tests
- When normalized for MAIS 3+, headform and lower legform were 3/8 each while upper legform was 1/4

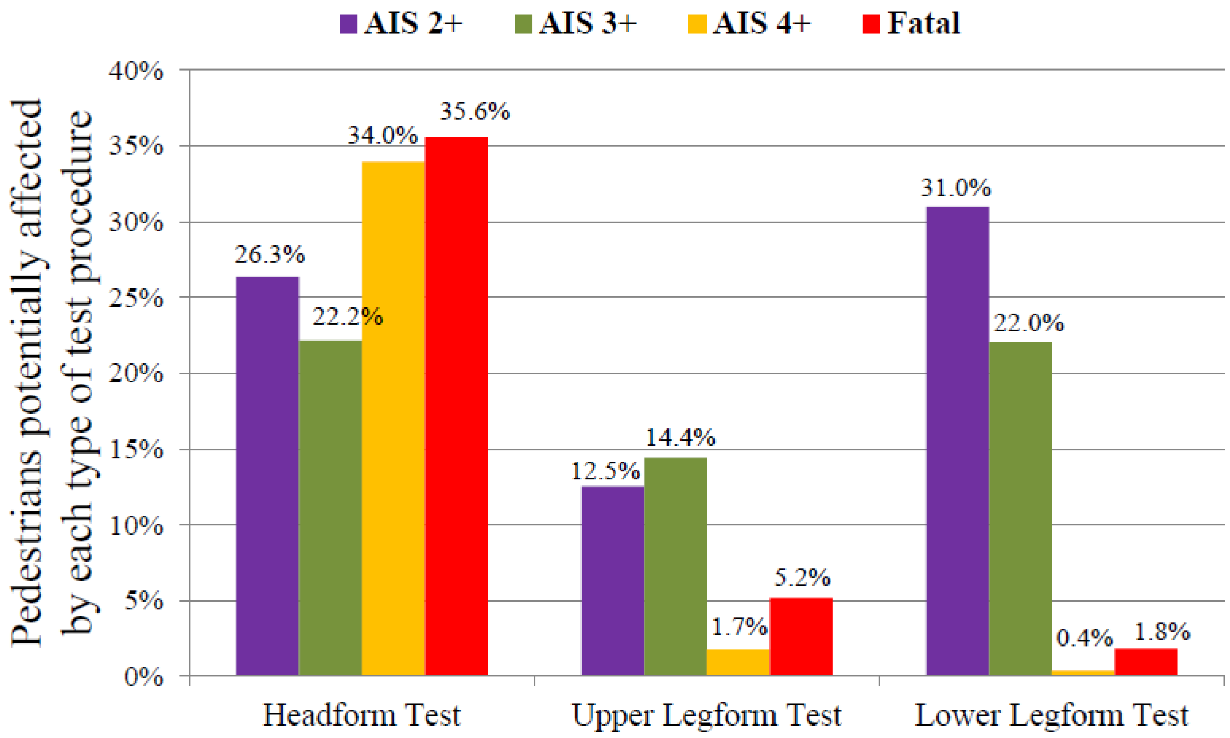


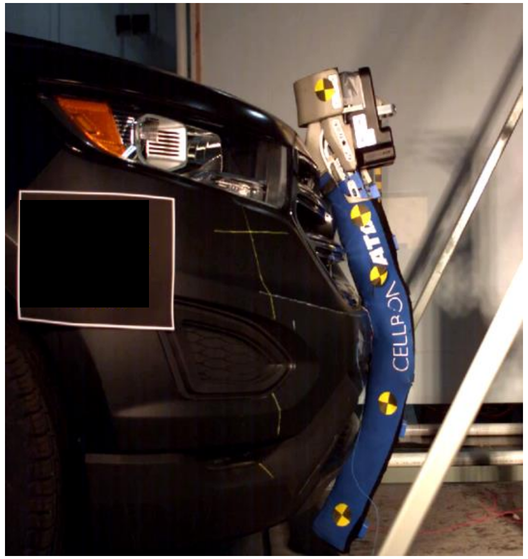
Figure 3. Comparison of pedestrians potentially affected by each type of test procedure

Mallory et al. "Relative Frequency of U.S. Pedestrian Injuries Associated with Risk Measured in Component-Level Pedestrian Tests" DOT HS 812 658. https://rosap.ntl.bts.gov/view/dot/40784

Current Research

Advanced Legform Evaluation

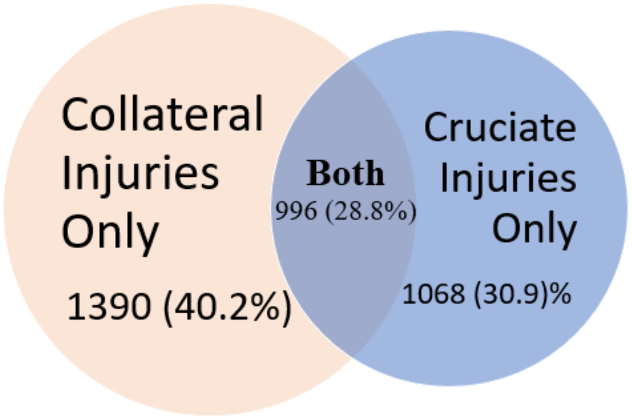
- Addition of upper body mass provides more accurate femur injury measurement
- Evaluating and comparing two candidate legforms (aPLI, Flex-UBM) that do this
- Replace FlexPLI & upper legform tests with just one test to assess overall leg protection



Project status will be presented at SAE G/I 2020

Injury Data Studies

- **Knee cruciate/collateral ligament injury patterns:** is there a need for a cruciate injury metric in the FlexPLI or does a collateral injury metric alone adequately protect the cruciate ligaments?



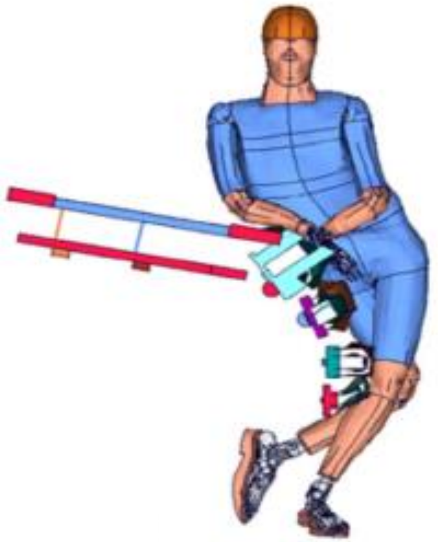
- **Prevalence of pedestrian countermeasures in U.S. vehicles:** are newer model year vehicles less likely to produce serious/fatal injuries than older model year vehicles?[1,2]

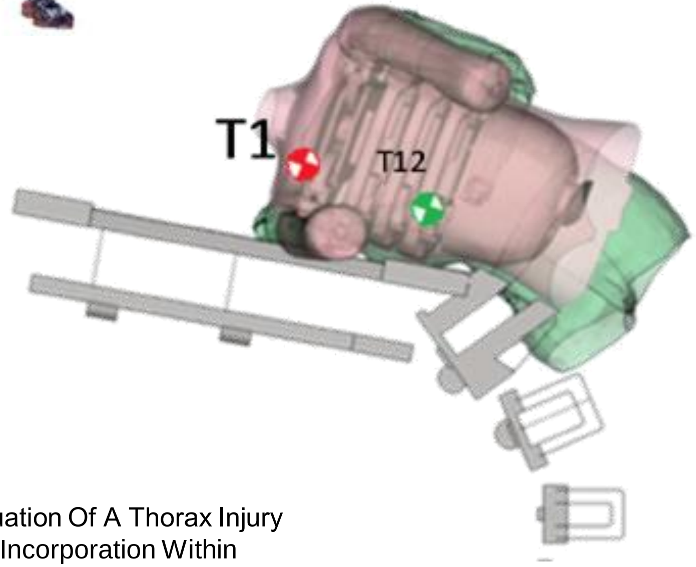
[1] *Martin & Pfeiffer "Real-World Pedestrian Crashes: Injury Trends and Fatality Risks" SAE Govt/Industry 2017.*

[2] *Pfeiffer "Analysis of Pedestrian Injuries by Passenger Vehicle Model Year" DOT HS 812 819.*

Thorax Injury Assessment

- Are vehicle countermeasures that protect the head/leg also reducing thoracic injury risk?
- What are the circumstances of a pedestrian collision that lead to a higher chance of thorax injury?
- Can we come up with an experimental approach to evaluate thorax risk?





From Zander et al. “Development And Evaluation Of A Thorax Injury Prediction Tool (TIPT) And Possibilities For Incorporation Within Improved Test And Assessment Procedures – Results From SENIORS” ESV 2019.

Integrated Crash Avoidance/Crash Worthiness Tests

- How do crash avoidance technologies (pre-crash systems) and crashworthiness countermeasures work together in a given vehicle to reduce injury severity?

- Assess CW countermeasure performance at various levels of CA effectiveness to help with real-world performance projections

Summary

- NHTSA research in the development and use of pedestrian tools and procedures has contributed to how vehicles are constructed today

- Existing test tools & procedures can be effectively applied to U.S. vehicles

- Current research is focusing on improving pedestrian safety even further

- **For more information see Docket ID NHTSA-2019-0112 NHTSA Crashworthiness Research – Pedestrian Protection Documentation**

RESEARCH DOCKET ENTRIES

1. MacLaughlin T, Kessler J. "Test Procedure – Pedestrian Head Impact Against Central Hood" SAE 902315, Stapp Car Crash Conference (1990).
2. Mizuno Y. "Summary of IHRA Pedestrian Safety WG Activities – Proposed Test Methods to Evaluate Pedestrian Protection Afforded by Passenger Cars" ESV (2001).
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5. Stammen et al. "A Demographic Analysis and Reconstruction of Selected Cases from the Pedestrian Crash Data Study" SAE 2002-01-0560 (2002).
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7. Mallory et al. "Component Leg Testing of Vehicle Front Structures" ESV (2005).
8. Mallory & Stammen. "The Relationship Between Pedestrian Component Legform and Full Dummy Testing in Assessing Bumper Performance" SAE Govt/Industry (2006).
9. NHTSA "VRTC Pedestrian Research Activities" GTR No. 9 Informal Working Group Document #WP29-144-03.
10. Mallory et al. "Pedestrian GTR Testing of Current Vehicles" ESV (2007).
11. Mallory et al. "Performance of Vehicle Bumper Systems with the EEVC/TRL Pedestrian Lower Legform" ESV (2009).
12. Mallory et al. "NHTSA Pedestrian Testing with TRL and Flex-GTR Legforms and the Status of the GTR" SAE Govt/Industry (2010).
13. Ott et al. "Assessment of the Simulated Injury Monitor (SIMon) in Analyzing Head Injuries in Pedestrian Crashes" SAE 2012-01-0569 (2012).
14. Mallory et al. "Pedestrian Injuries By Source: Serious and Disabling Injuries in US and European Cases" AAAM (2012).
15. Suntay et al. "NHTSA Evaluation of the Flex-GTR Legform on US Vehicles" SAE Govt/Industry (2012).
16. Stammen J. "Performance of Bumper Systems with Respect to Pedestrian Protection and Bumper Damageability Requirements" SAE Govt/Industry (2014).
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26. Suntay & Stammen "Vehicle Bumper Performance in Part 581 vs. Pedestrian Leg Protection" DOT HS 812 ###. (will be posted to research docket soon)
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CIREN Pedestrian Pilot Study

Rodney Rudd

Crash Injury Research and Engineering Network

- Current program for occupant investigations began in 2017
  - Five enrolling sites and four engineering review centers
  - Emphasis remains on in-depth review of injury causation of motor vehicle occupants

    https://www.nhtsa.gov/research-data/crash-injury-research

    https://crashviewer.nhtsa.dot.gov/

- Pedestrian pilot study began in 2018
  - Awards made to two enrollment sites
    - Emory (enrolling at Grady Memorial Hospital in Atlanta, GA)
    - Wake Forest/Virginia Tech (enrolling at Wake Forest Baptist Medical Center in Winston-Salem, NC)
    - Additional engineering support from Medical College of Wisconsin CIREN center

EMORY UNIVERSITY SCHOOL OF MEDICINE

MEDICAL COLLEGE OF WISCONSIN

Wake Forest School of Medicine

CIB

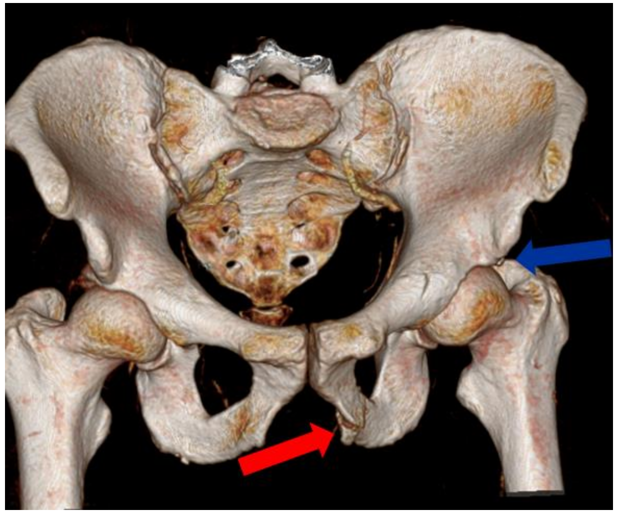
Virginia Tech Wake Forest University

School of Biomedical Engineering and Sciences

CIREN Pedestrian Pilot Study

Objective and Goals

- Revisit prior investigation protocol (PCDS and Honda Inova CIREN) and update for current and future research needs
  - Injury causation and crashworthiness
  - Crash avoidance and behavioral
- Test new scene and vehicle documentation techniques
- Assess feasibility of fast-response case capture and compare results to follow-on investigation approach
- Adapt injury causation coding (BioTab) for pedestrian crashes
- Develop data collection tools and database
- Acquire data for nine (9) pilot cases total



Lockerby et al. (2018) "Identifying Field Crash Data Collection Needs for a Pedestrian Crash Avoidance and Crashworthiness Study."

On-scene evidence collection

- Early observations highlight the importance of strong cooperation with law enforcement for on-scene evidence

Scene and vehicle documentation

- 3D photogrammetry produces point cloud to more comprehensively capture details
- Rapid data collection via drone

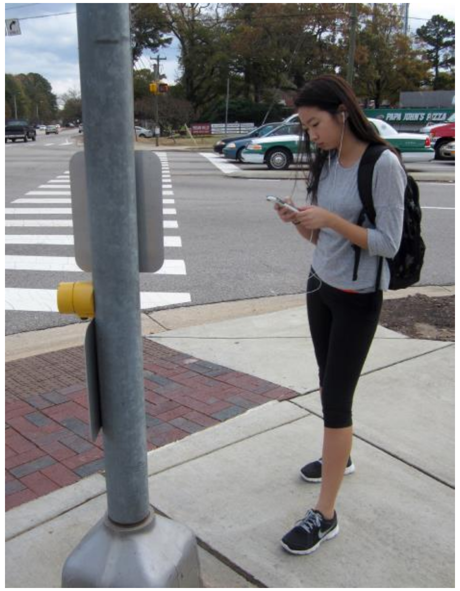
Overhead view for scene diagram

Driver or pedestrian perspective view

Pedestrian Distraction

Kristie Johnson, Ph.D.

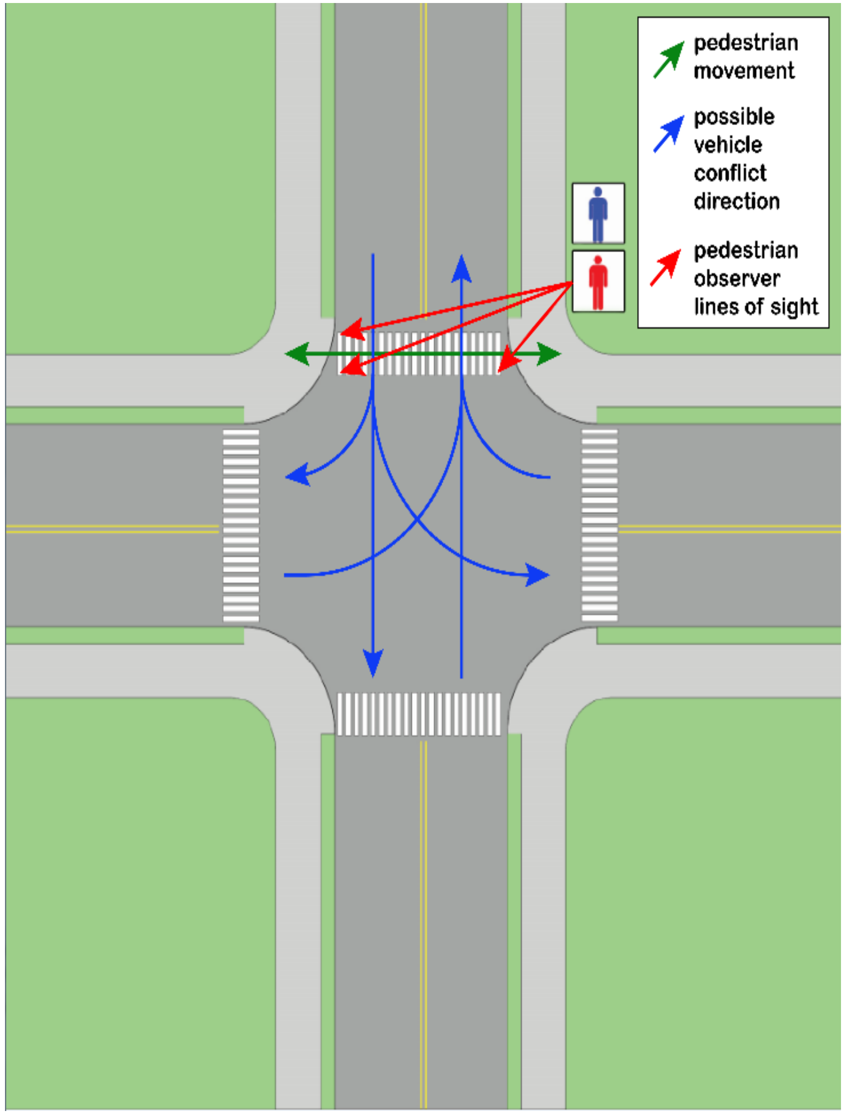
Pedestrian Distraction



- **Study Components**
  - Literature review (DOT HS 812 256)
  - Crash report analysis
  - Naturalistic observations
- **Our List of Observed Distractors**
  - Electronic distractors - cell phone, audio device, tablet, GPS, other electronic
  - Non-electronic distractors – other people, reading, eating/drinking, other

Pedestrian Distraction

- Pedestrian Crossing Observations – Observed at curb & during crossing
    - Demographics, distraction(s) before & during, conflict presence & severity, position in group, glances L & R, latency & total time, path keeping
- Driver Observations (paired with pedestrian) – Observed driver/vehicle closest
    - Demographics, distraction(s), conflict presence & severity



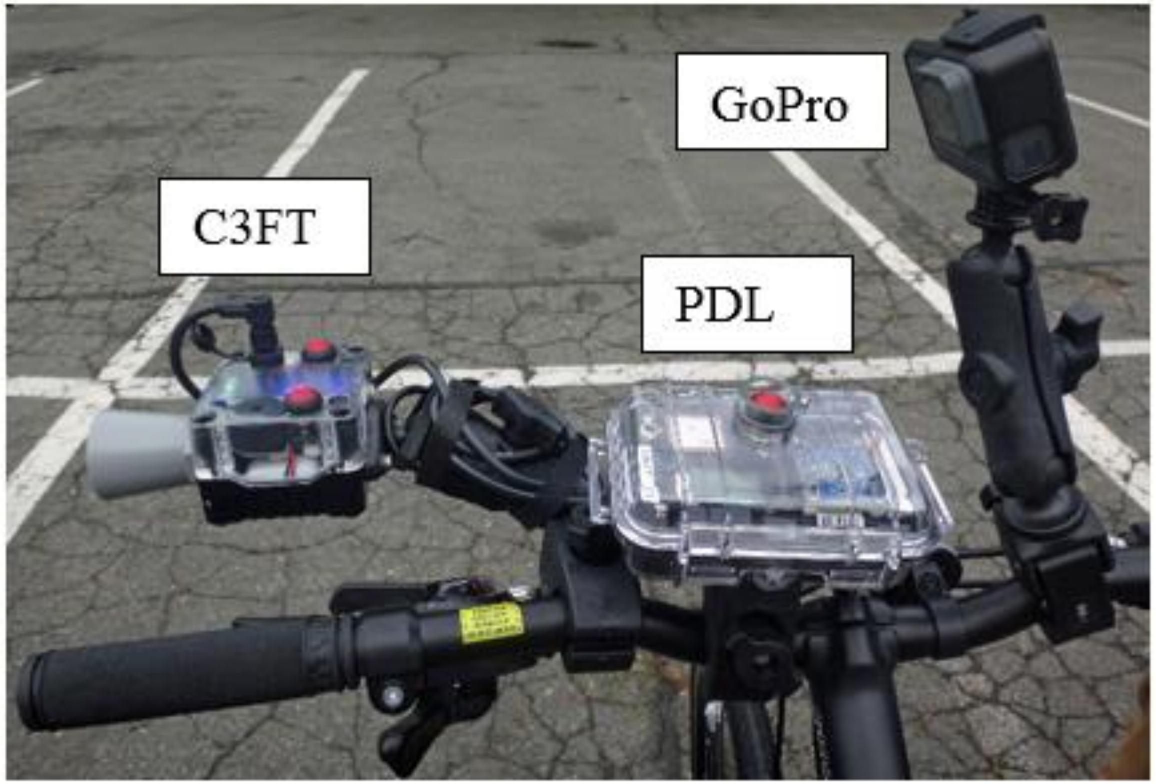
Effect of High Visibility Enforcement (HVE) on Driver Compliance with Bicycle Safe Passing Laws

Kristie Johnson, Ph.D.

Effect of HVE on Driver Compliance with Bicycle Safe Passing Laws

- Study Components
  - Literature/program scan
  - Naturalistic observations
    - Staged and random rides
  - HVE Program
    - Grand Rapids, MI and Knoxville, TN

EQUIPMENT CONFIGURATION



Effect of HVE on Driver Compliance with Bicycle Safe Passing Laws

- Determine the impact of combined law enforcement and education on bicycle/driver interactions

www.knoxvilletn.gov

Motorcyclists’ Attitudes About Using High-Visibility Gear to Improve Conspicuity

Kathryn Wochinger

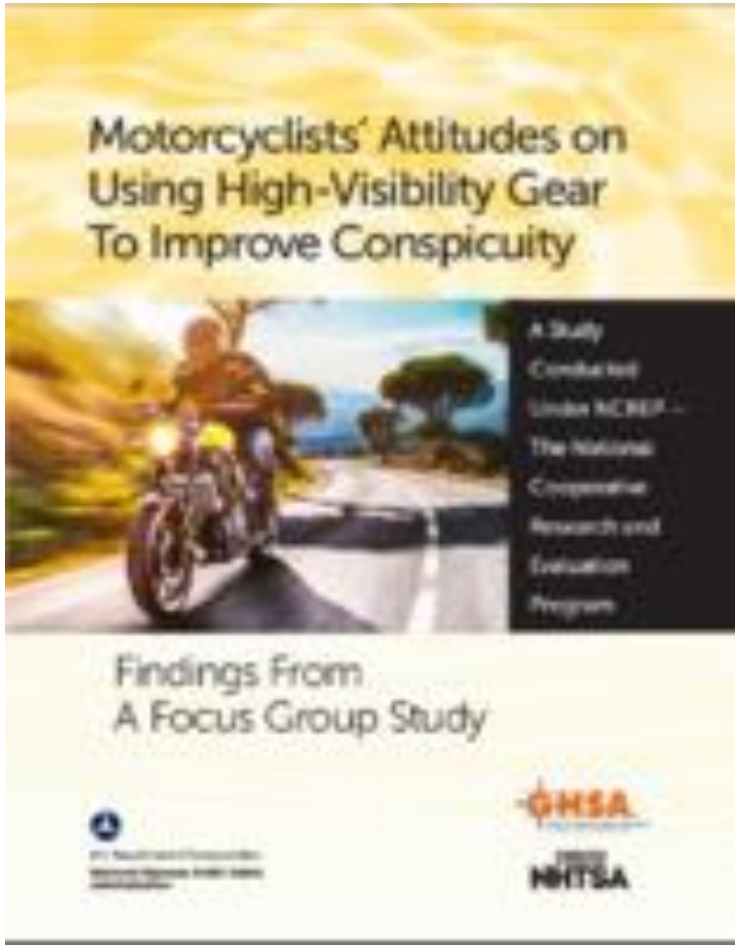
Presented by Amy Berning

Background and Objective

- NHTSA wants to increase the visibility of motorcyclists
  - Increase use of high-visibility apparel and gear
- Many motorcyclists do not use high-visibility gear
- Understand why riders do not choose high-visibility gear
- Examined attitudes/opinions about gear and conspicuity

Approach and Results

- Focus groups in California, Maryland, Michigan, and Texas
- Most riders do not use Hi-Viz gear; dislike appearance and do not believe Hi-Viz would improve safety
- Expressed belief that driver distraction is the primary safety problem/risk faced by motorcyclists
- More confident riders believe they do not need Hi-Viz as their skill keeps them safe, but Hi-Viz could help novice riders
- Would be more willing to use Hi-Viz if more convinced of safety benefits

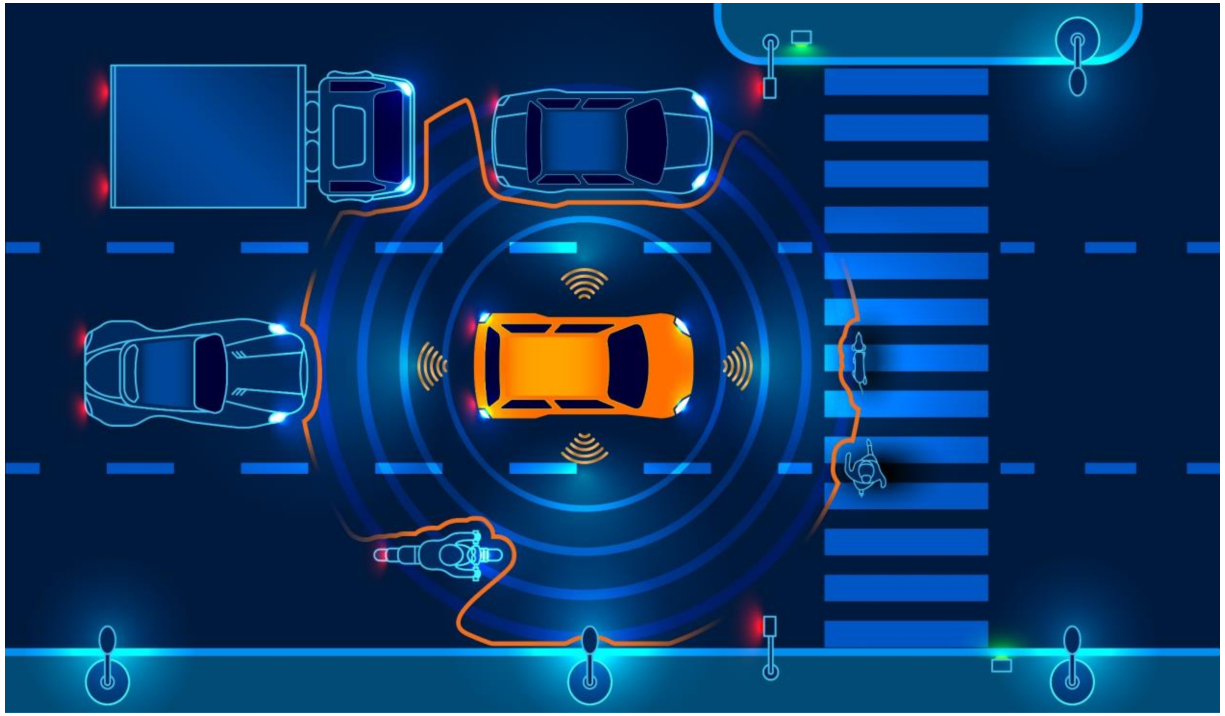


Motorcycle Conspicuity to Light Vehicle ADAS Capabilities

Rob Heilman

Motorcycle Conspicuity to Vehicle ADAS

- Motivation
  - ADAS technology is expected produce a safer environment for all road users



- Research Question
  - Can light vehicle ADAS applications detect and appropriately react to motorcycles?

Motorcycle Conspicuity to Vehicle ADAS

- Develop test metrics & procedures
  - Evaluate ability of light vehicle ADAS technologies to detect, perceive and react to motorcycles
- Assess motorcycle target requirements
- Comparative assessment with corresponding Euro NCAP test procedures
- Comparative tests of ADAS performance against motorcycles and light vehicles
- Emphasize scenarios/conditions that challenge ADAS capabilities in responding to motorcycles