Lower Extremity Injuries in Small Overlap Crashes

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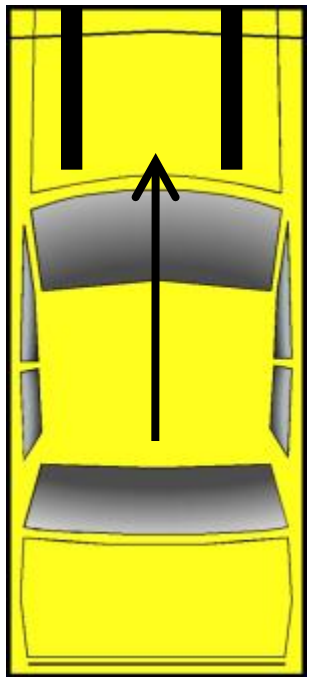
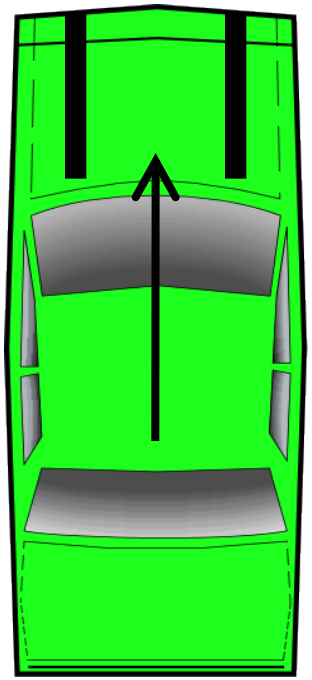
MEDICAL COLLEGE OF WISCONSIN

Introduction

- Crashworthiness improvements



Longitudinal members



NHTSA
www.nhtsa.gov

safercar.gov
U.S. Department of Transportation

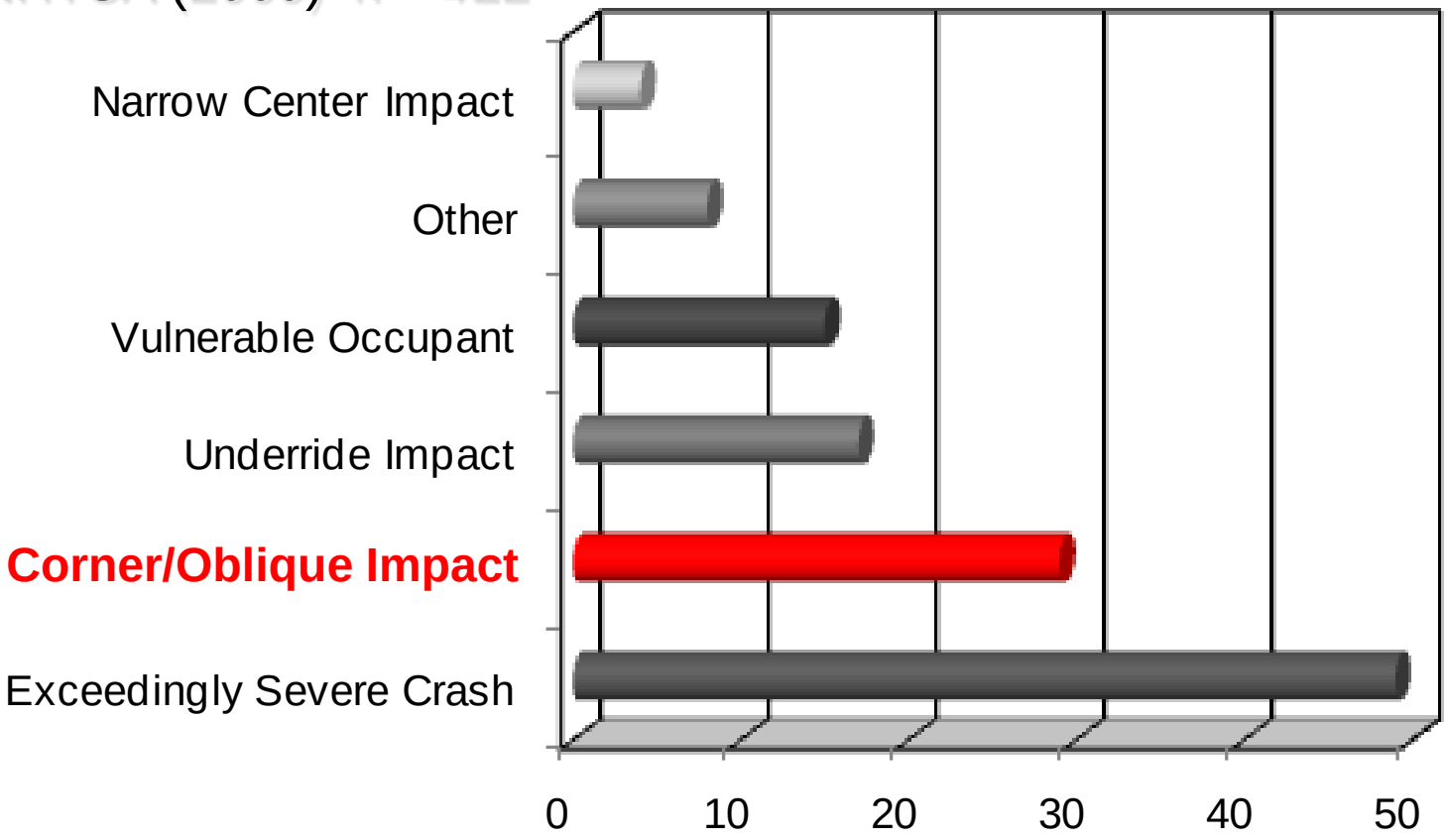
INSURANCE INSTITUTE FOR HIGHWAY SAFETY

FOR SAFER CARS
EURO NCAP
www.euroncap.com

ANCAP
Crash testing for safety

Introduction

- Continued frontal impact fatalities
  - NHTSA (2009) n = 122



What do we know from Crash Tests?

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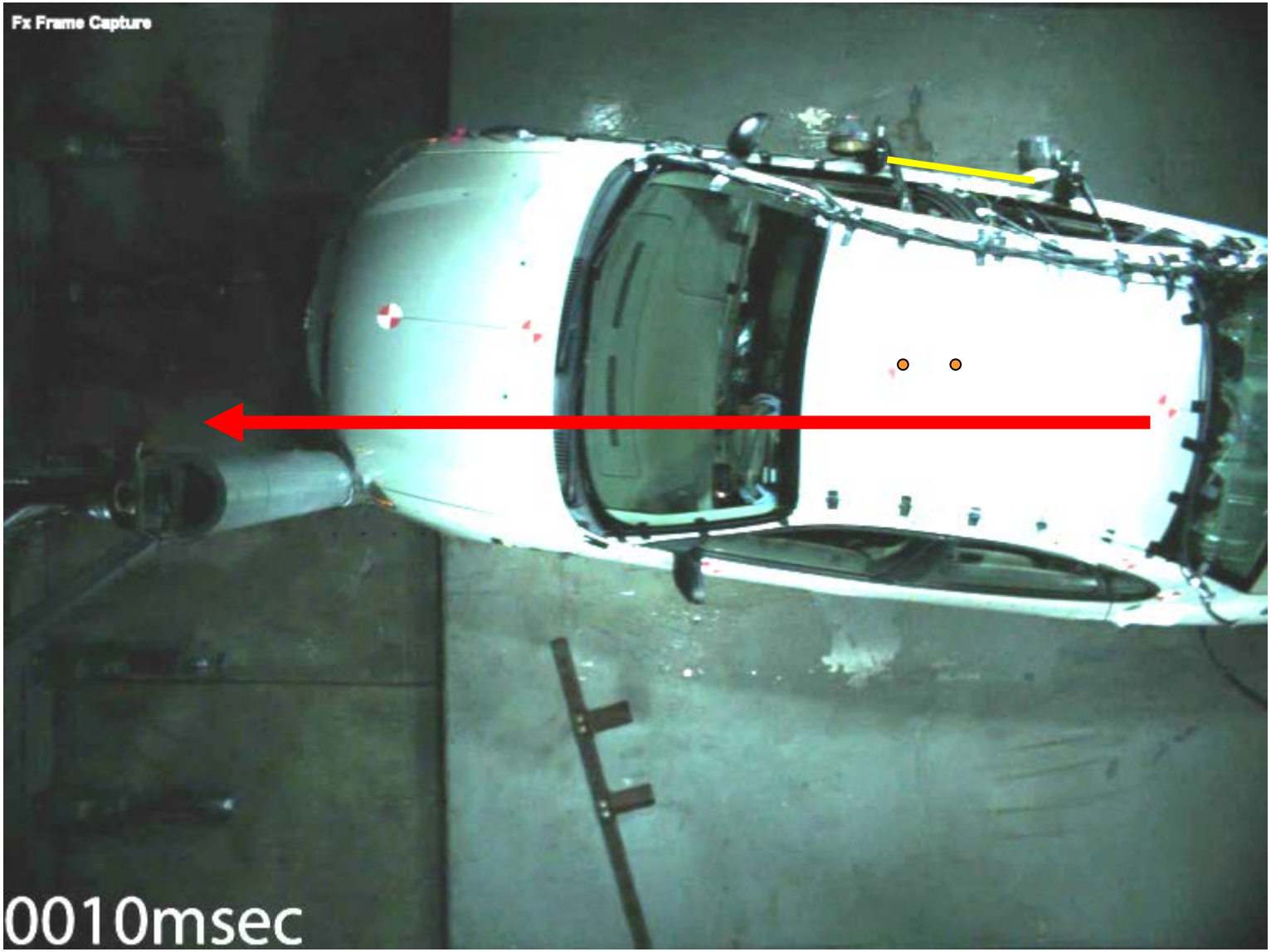
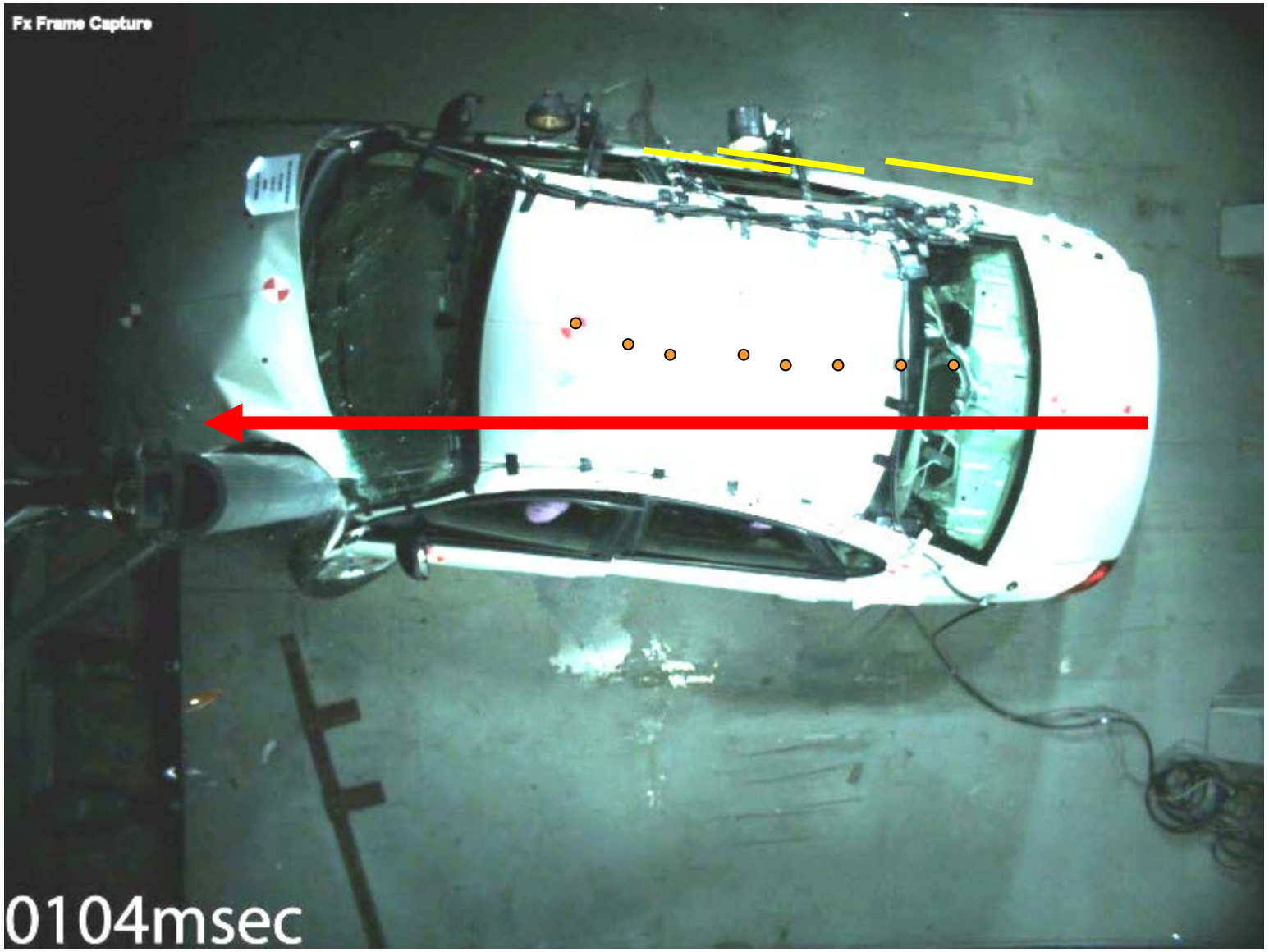
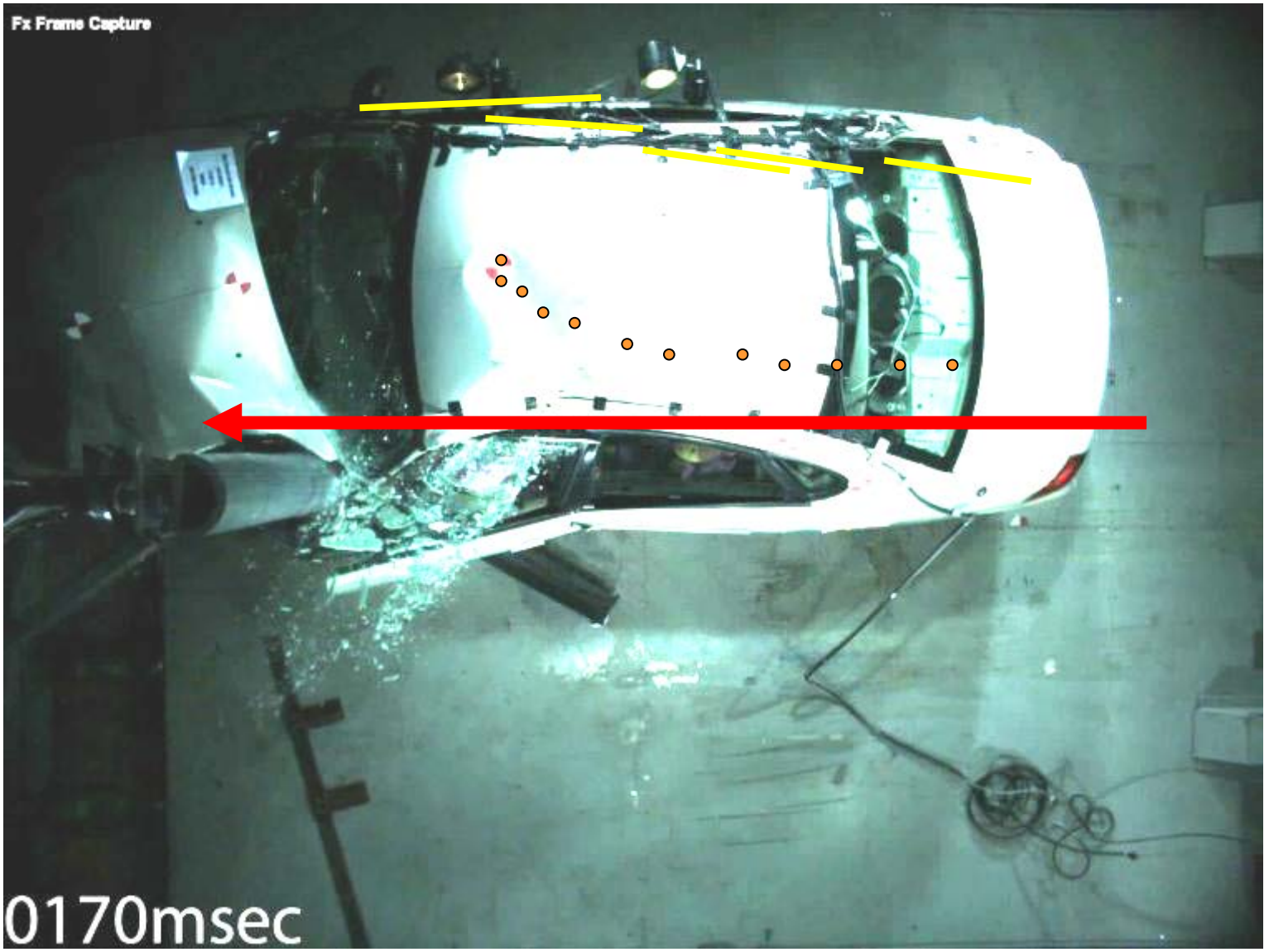
SOI Crash – Midsize Car



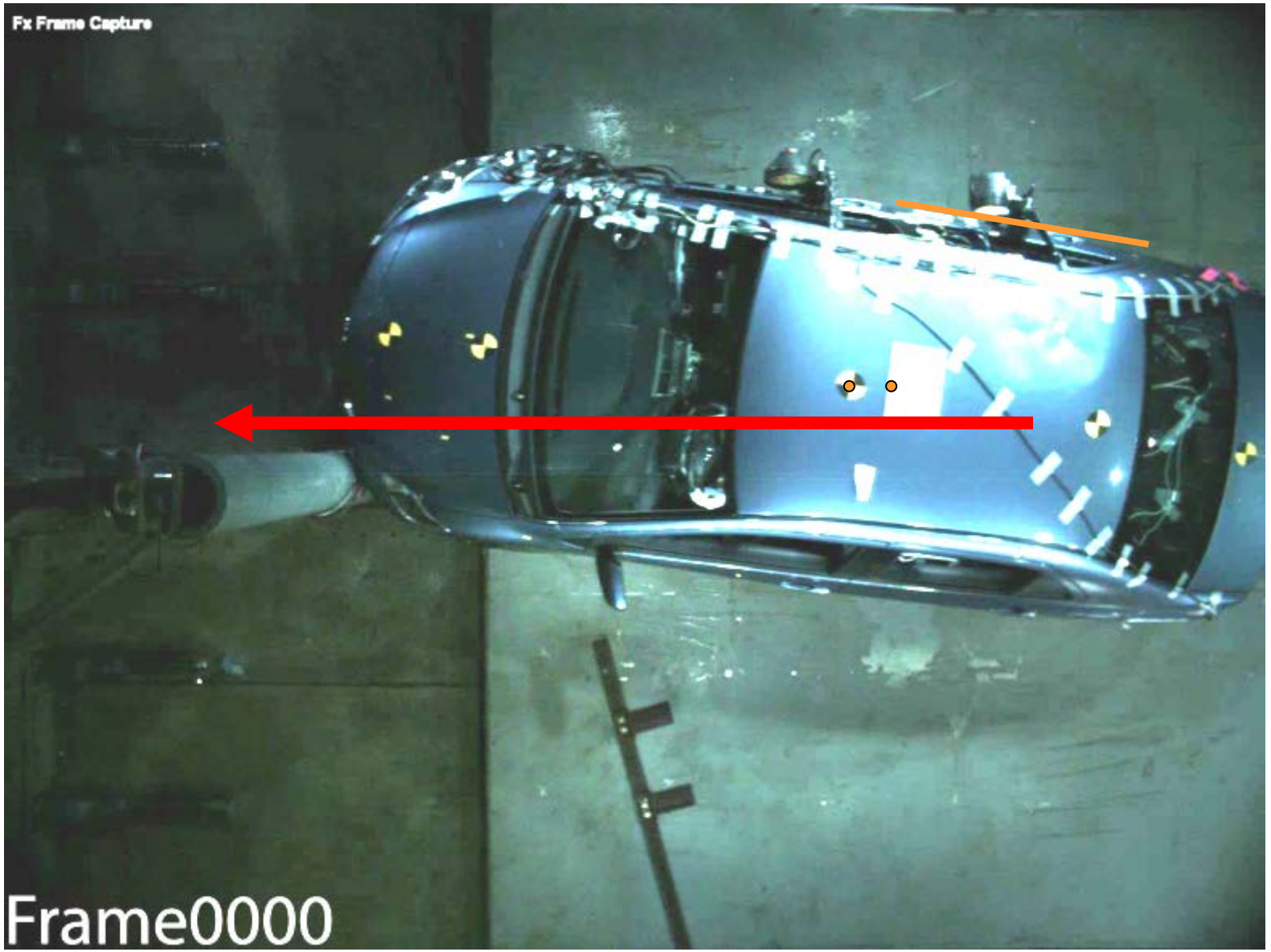
SOI Crash – Midsize Car



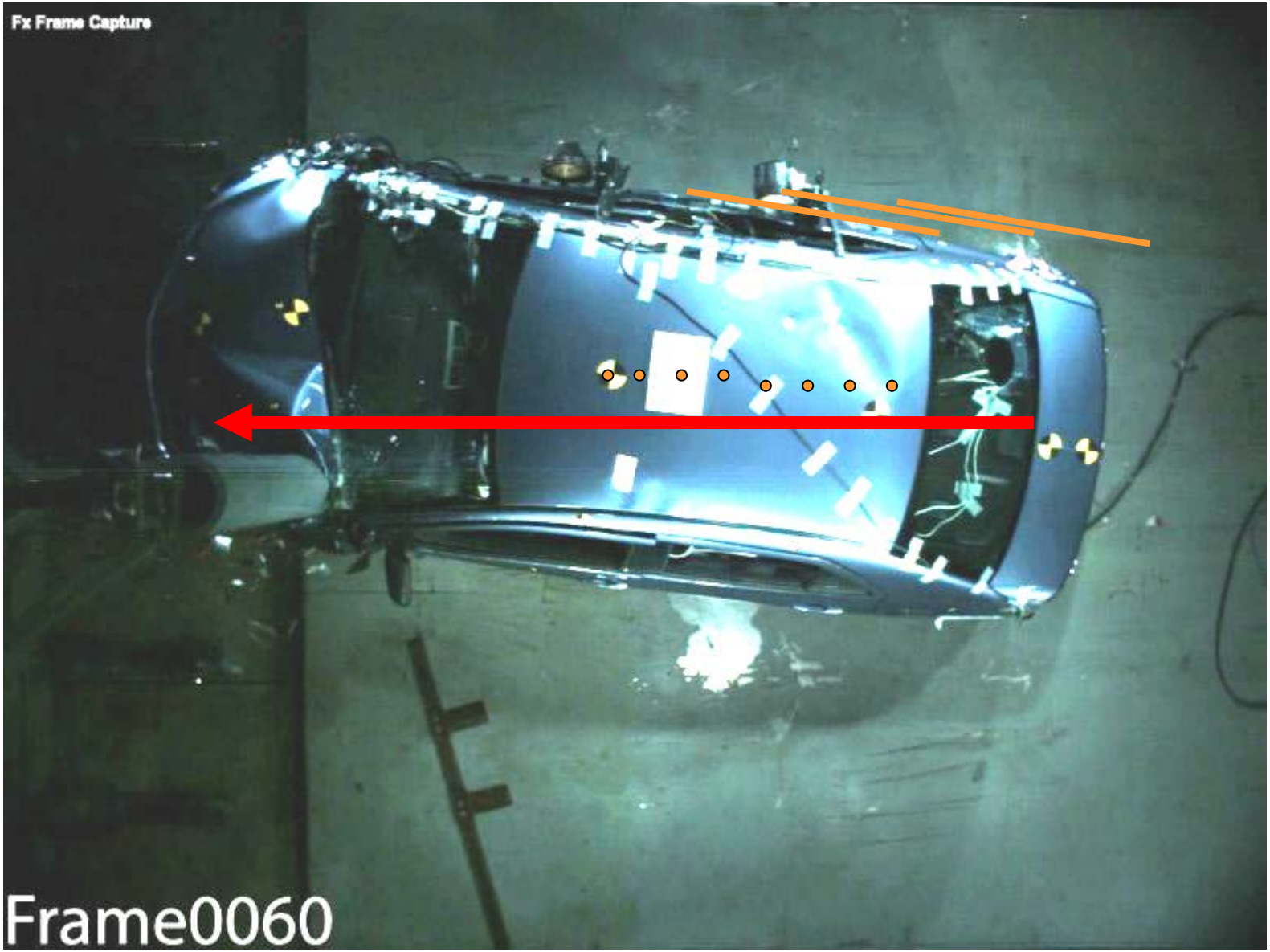
SOI Crash – Midsize Car



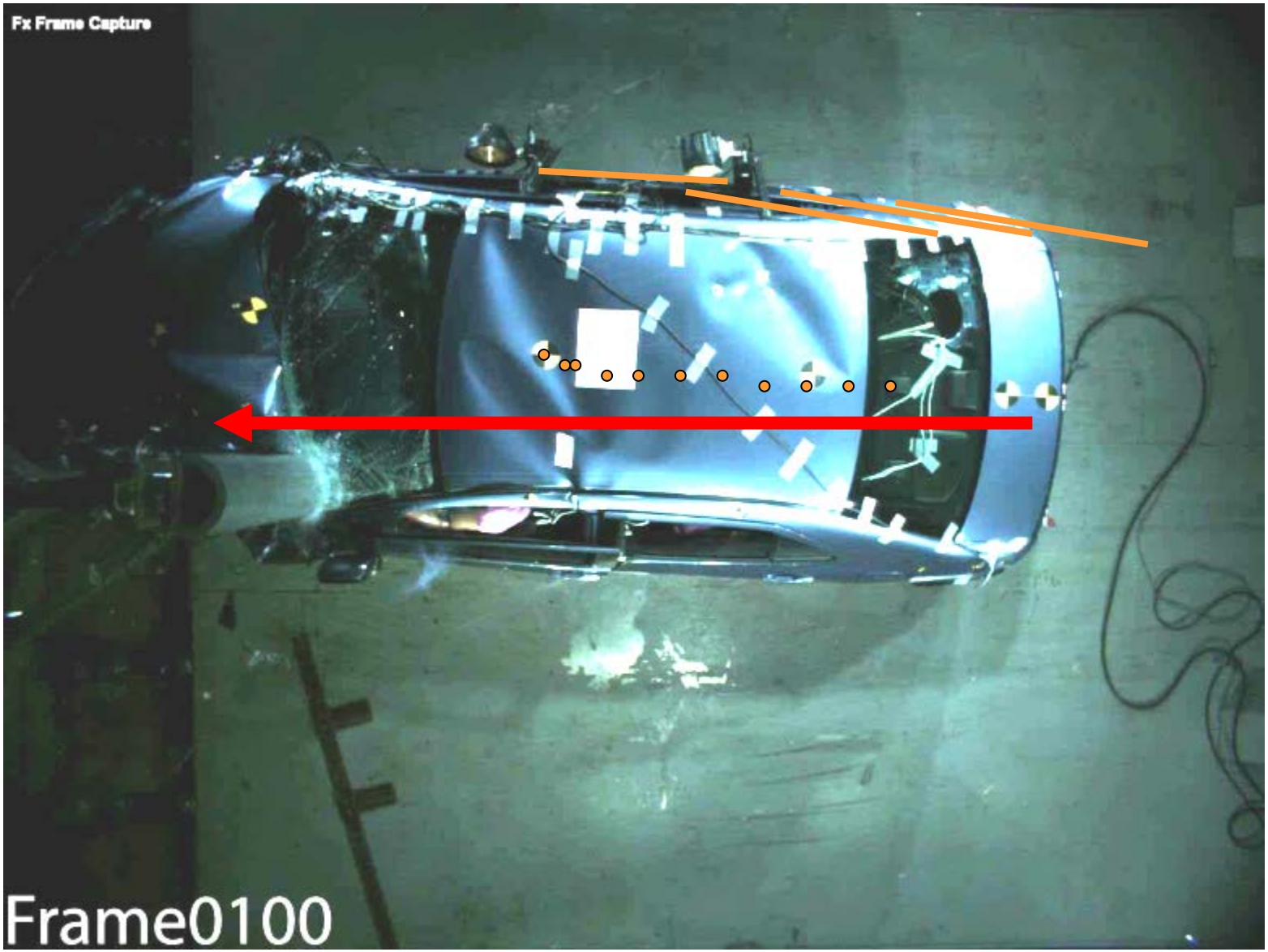
SOI Crash – Small Car



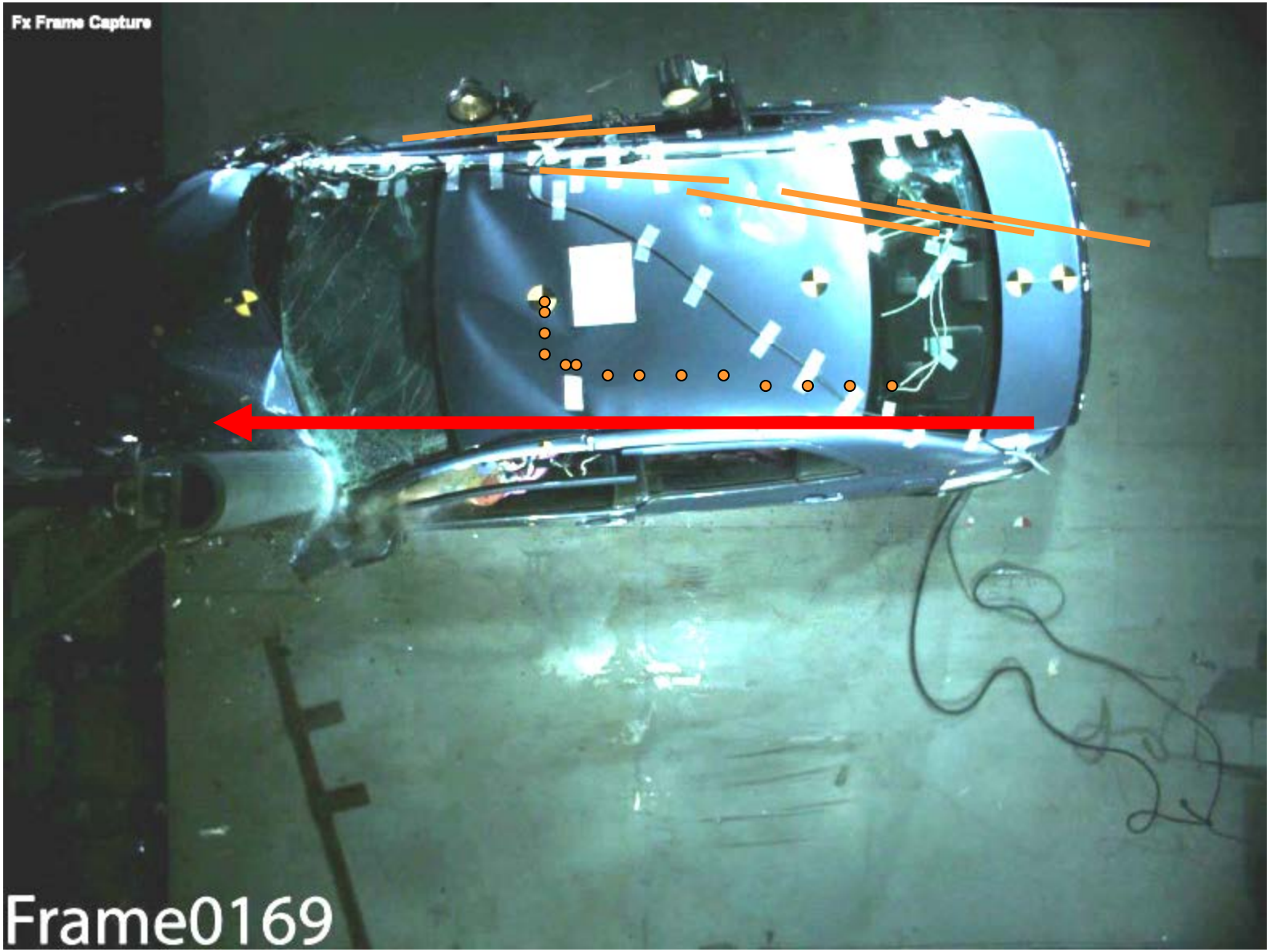
SOI Crash – Small Car



SOI Crash – Small Car

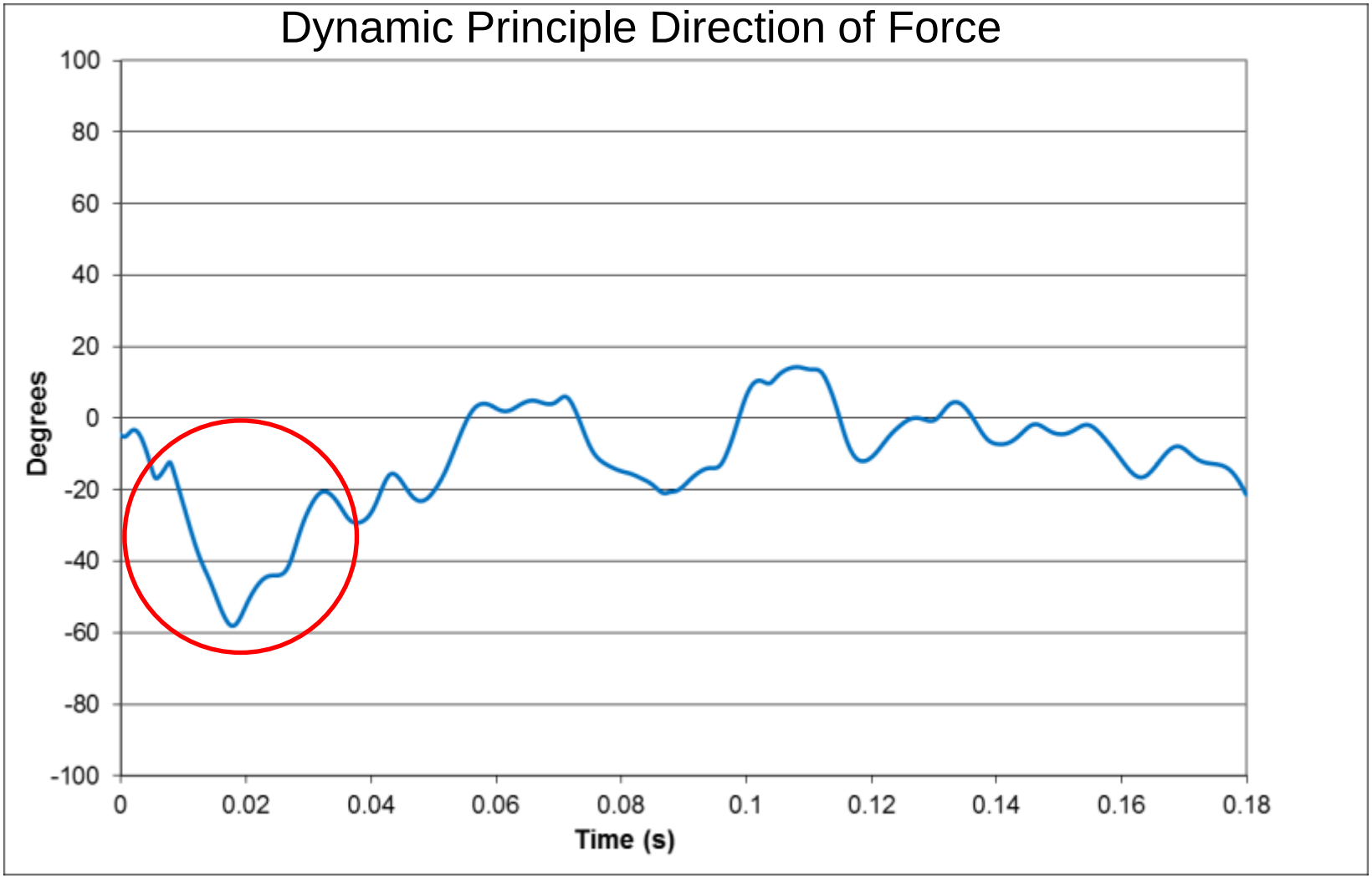


SOI Crash – Small Car



Occupant Kinematics – SOI Crash

PDOF from Small Overlap Crash



SOI Occupant Kinematics

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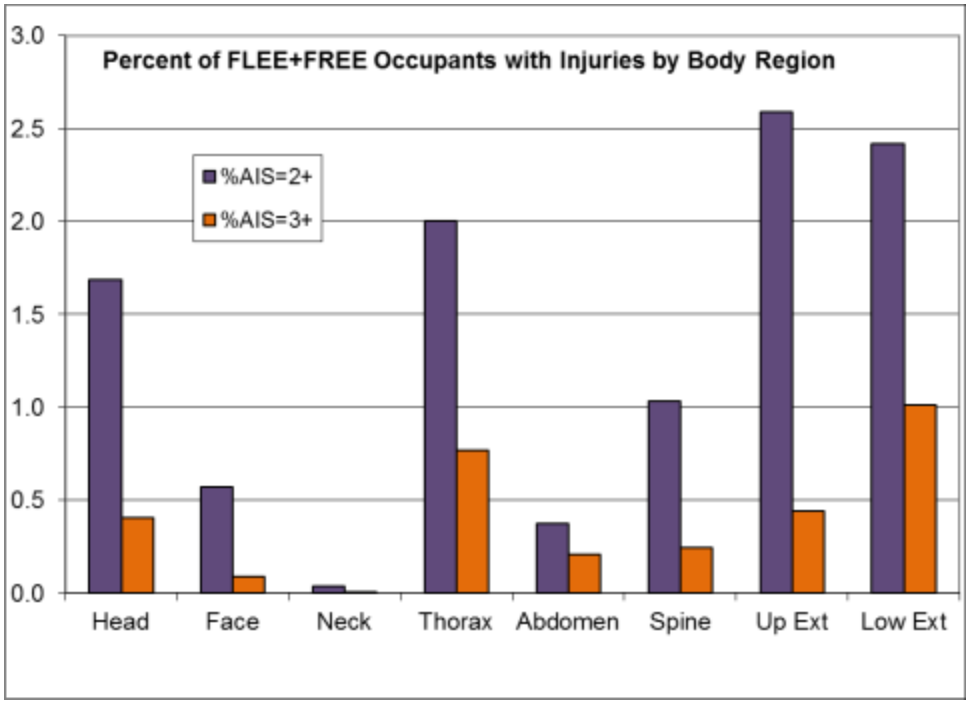
- Occupant moves initially forward in response to frontal crash vector
- Occupant moves laterally due to vehicle sideways translation
- Vehicle rotation occurs late and usually does not influence occupant motion until late in event
- Suspect lower extremity moves laterally either before dash impact or dash impact with body lateral movement induces bending moment

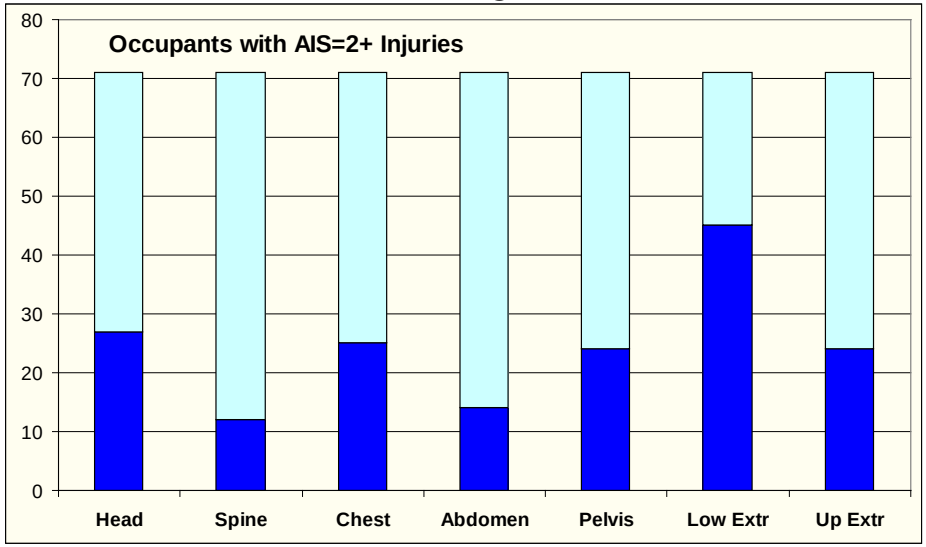
Literature: Injuries

- US Data: NASS and CIREN
  - "FLEE" and "FREE" designations (CDC)

NASS



CIREN



Pintar et al. (2008)

Aims: Lower Extremity Injuries

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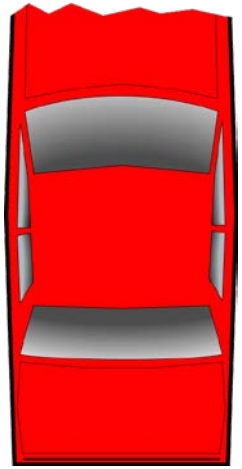
- Small Overlap Crashes – Occupant Kinematics
- NASS study – SOI vs Frontal-208
- CIREN Injury examination
- Laboratory Crash Tests

NASS Query (2005 – 2009)

Any Lower Extremity Injury
Only Belted Drivers

Both rails engaged
12-o'clock impacts
FDEW and DVD=0



No rail engaged
Frontal plane impacts
SOI filter defined

Demographic Results

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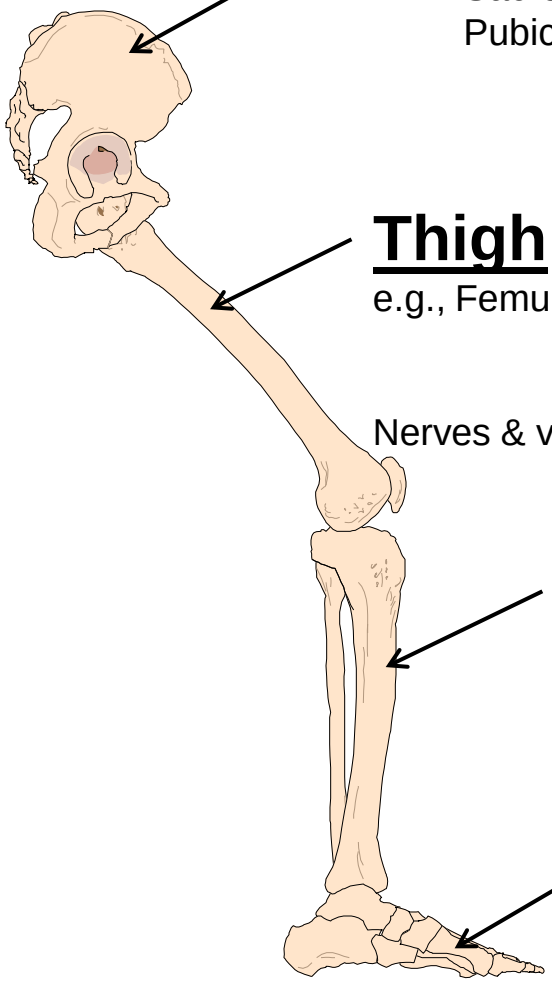
	Small Overlap	Frontal
Occupants (raw)	536	243
Occupants (weighted)	125,055	49,842
Mean age	41.6	40.0
Age range	16-92	15-91
Lo. Ex. Injuries (raw counts)	1111	666

Statistical Analysis

- SAS 9.2
- Logistic regression
  - Considered crash type only (SOI vs. Frontal)
- Computed odds ratio (OR) for lower extremity anatomic regions
  - Pelvis
  - Hip
  - Thigh
  - Knee
  - Shank
  - Ankle
  - Forefoot

Anatomic Regions (BioTab Style)

MEDICAL COLLEGE OF WISCONSIN



Pelvis

e.g., Open/closed fx
Sacroilium fx
Pubic fx

Hip/Proximal Femur

e.g., Sprain
Dislocation
Femoral head, neck, trochanters

Thigh

e.g., Femur: shaft fx
subtrochanteric fx
supercondylar fx
Nerves & vasculature

Knee

e.g., Tibial platea fx
Femoral condyle fx
Meniscii
ligaments

Leg

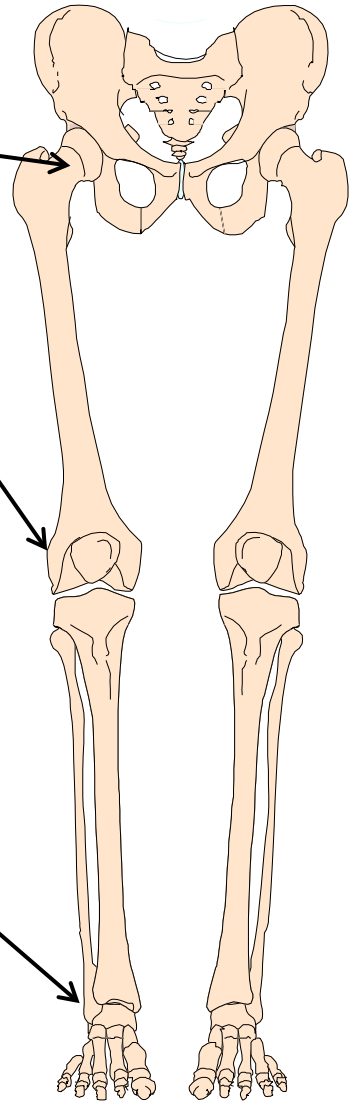
e.g., Tibial shaft
Fibula shaft
Vasculature

Ankle

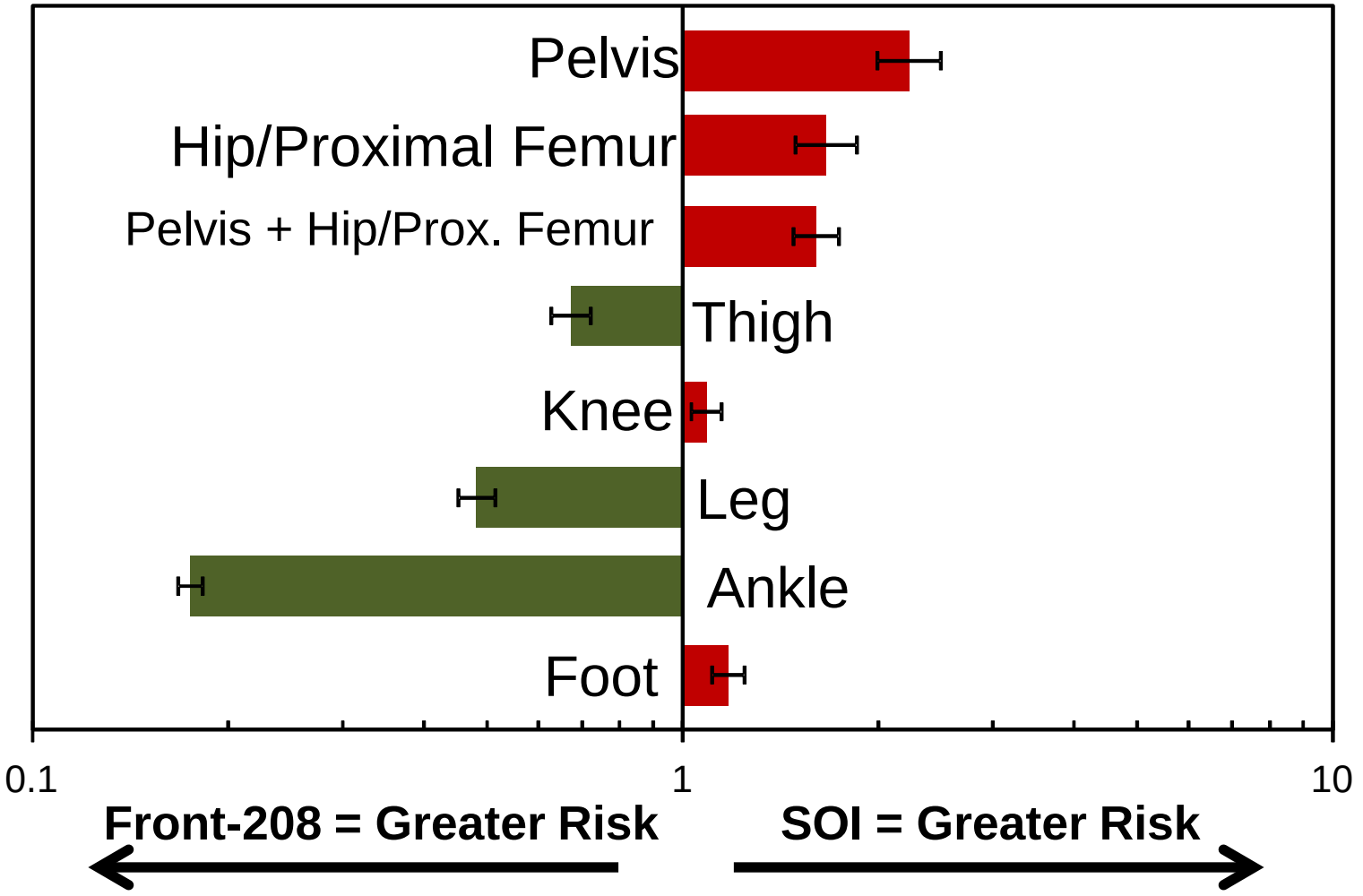
e.g., Joint
Ligaments
Malleoli
Talus

Foot

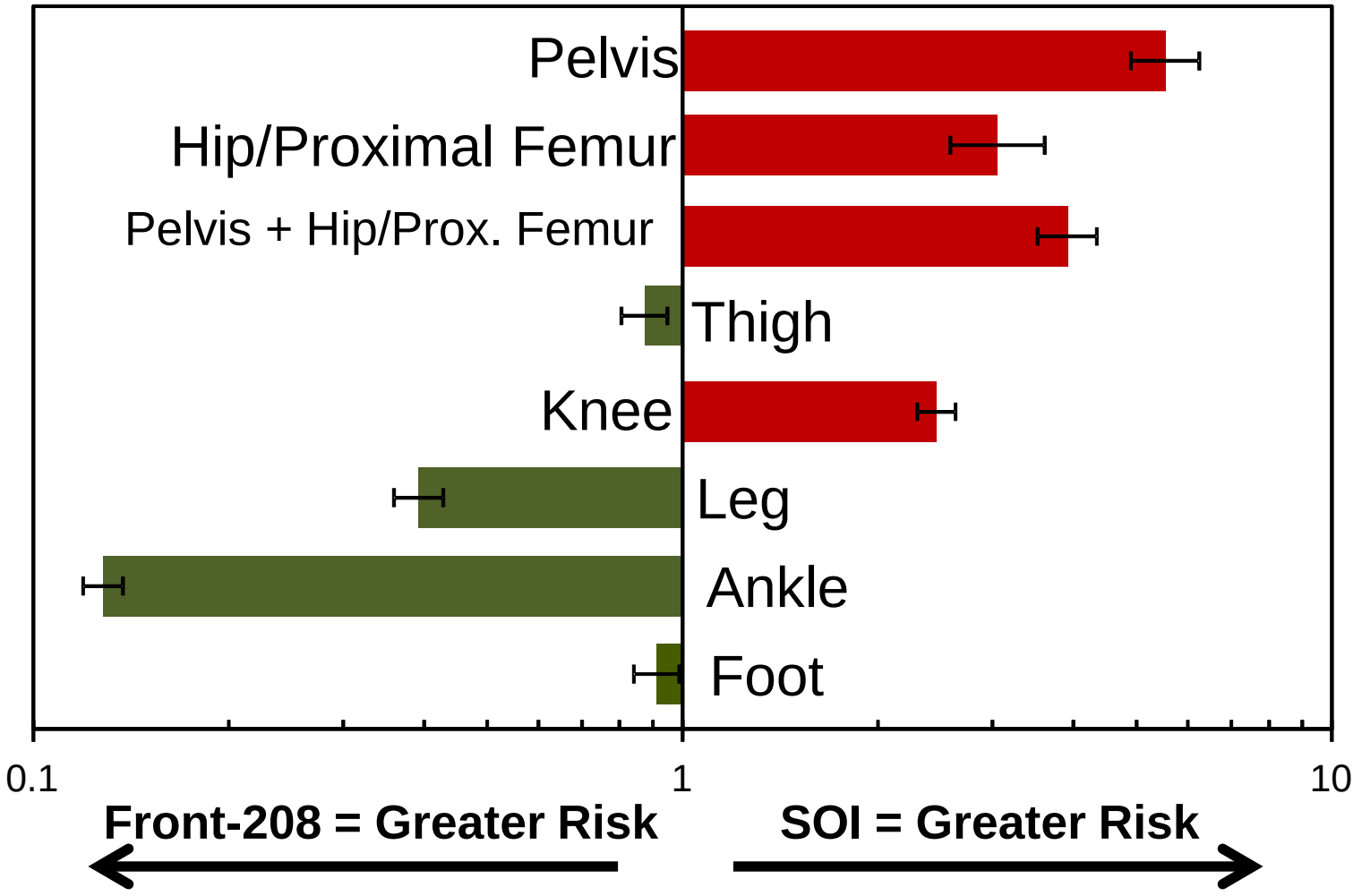
e.g., Toe
Metatarsals
Foot
Calcaneus



Odds Ratio: AIS 1+ Occupants



Odds Ratio: AIS 2+ Occupants



Pelvis + Hip/Femur

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Top 5 injury codes (by occupant counts)

Code	Description	Small Overlap	Frontal
852604.3	Pelvis fracture (open, displaced, and/or comminuted)	15	5
852602.2	Pelvis fracture (closed)	14	9
852600.2	Pelvis fracture (NFS)	7	4
850614.2	Hip dislocation (no articular cartilage involvement)	5	2
851810.3	Femur fracture (intertrochanteric)	5	2

CIREN Database Methods

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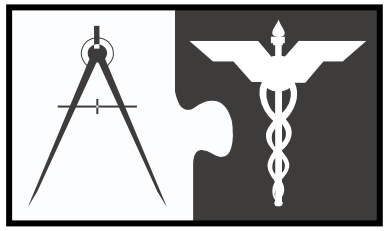
- CIREN Database
  - Occupant data
    - Gender
    - Age
    - Injury severity score (ISS)
    - Seat position
    - Injury patterns
  - Vehicle/crash data
    - Extent zone
    - Collision partner
- Only Small Overlap Impacts



CIREN Results

- CIREN SOI cases = 84

Shotgun beam ***(deformed)***

Suspension tower ***(deformed)***

Longitudinal member ***(undeformed)***

Wheel ***(deformed)***

CIREN Results 84 SOI Cases

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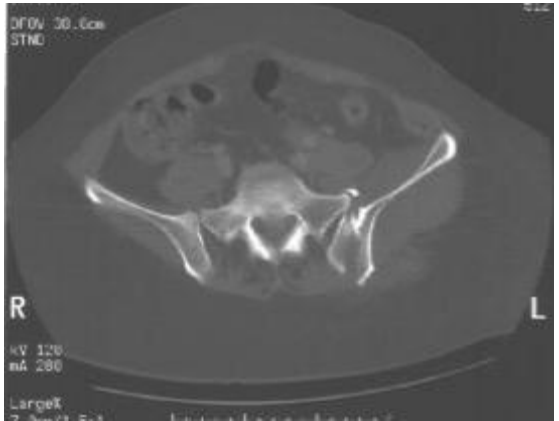
- 70 out of 84 occupants had lower extremity injury
- Of the 70:
  - 26 had Pelvis trauma
  - 17 had Hip trauma
  - 27 had Thigh trauma
  - 15 had Knee trauma
  - 24 had Leg trauma
  - 17 had Ankle trauma
  - 19 had Foot trauma

Pelvis Injuries

- Closed pelvis fx
  - Sacrum or pubis: 5-left, 3-right, 4-bilateral
- Open/displaced/comminuted fx
  - Acetabulum or ilium: 12-left, 2-right, 1-bilateral
  - Sacrum or pubis: 0-left, 6-right, 1-bilateral
- Hip dislocation
  - 5-left, 0-right, 1-bilateral
- Sacroilium fx
  - 5-left, 3-right, 2-bilateral
- Symphysis Pubis
  - Separation – 5



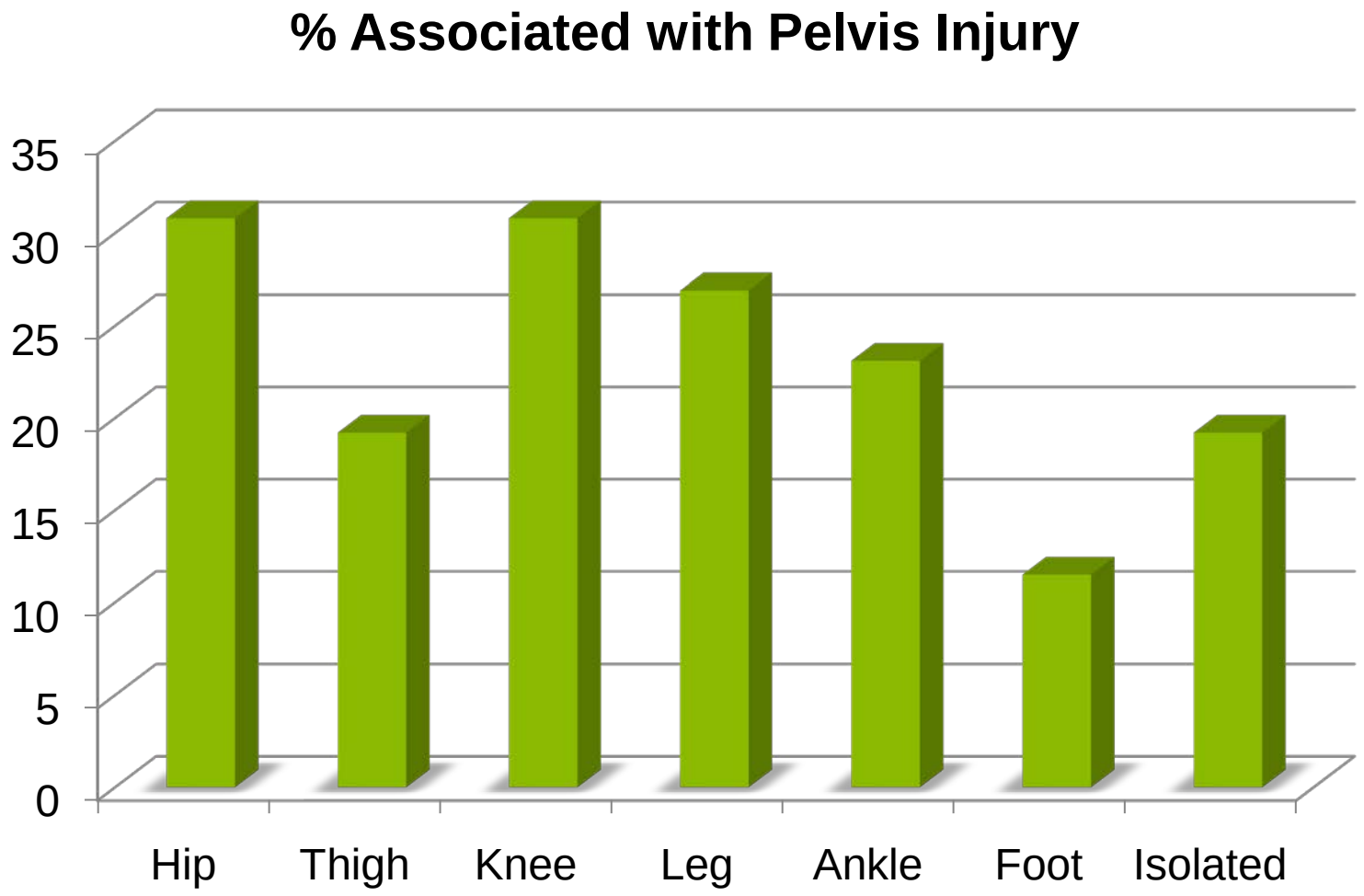
Thigh and Knee Injuries

- Mid Shaft Femur fx
  - 22-left, 2-right
- Head, Neck or subtrochanteric
  - 5-left, 0-right
- Condylar or supracondylar
  - 4-left, 1-right
- Patella or knee condyles
  - 10-left, 5-right

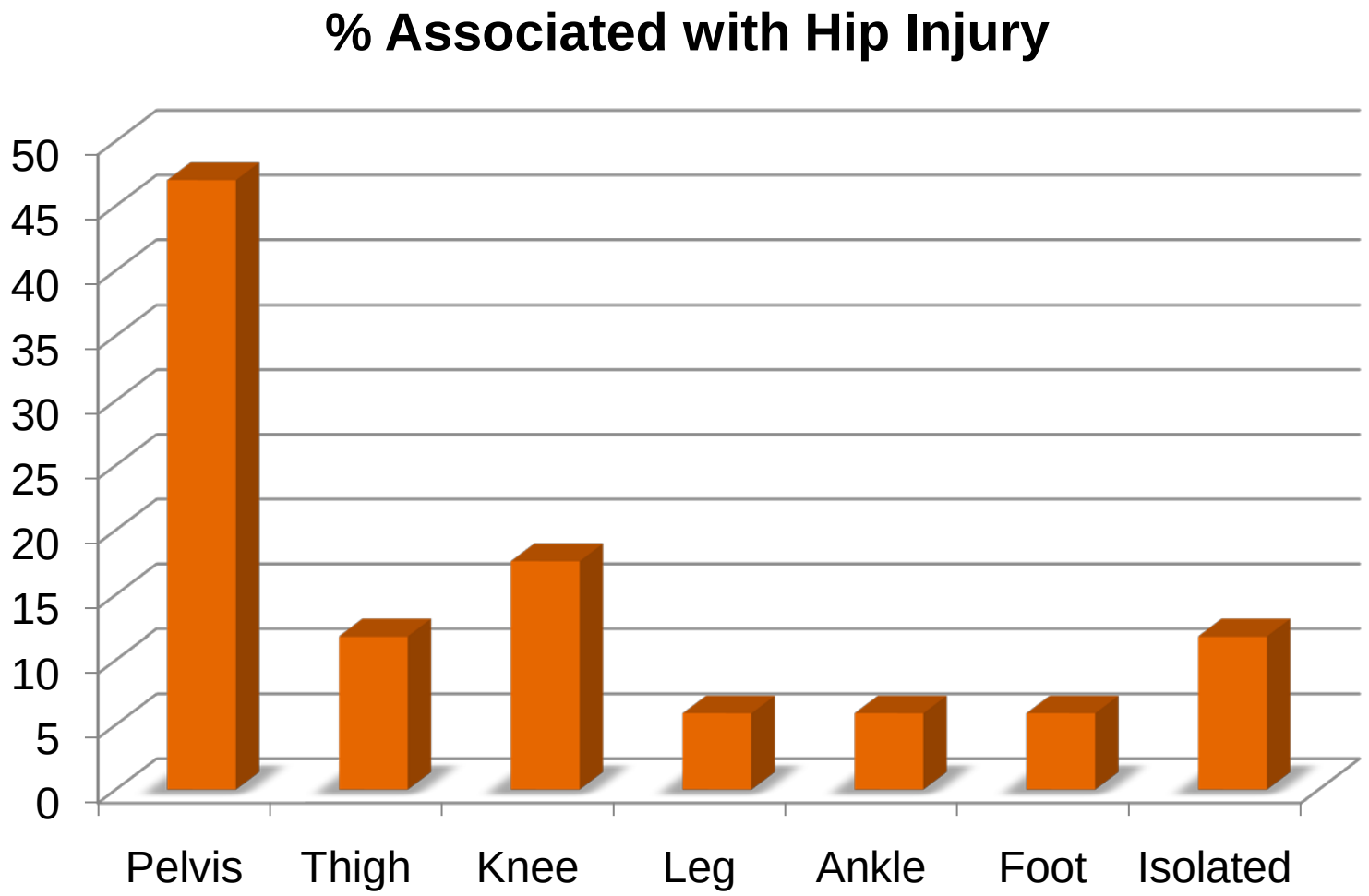
Foot and Ankle Injuries

- Tibial condyle fx
  - 7-left, 4-right
- Tibia – Fibula shaft fx
  - 9-left, 6-right, 2-bilateral
- Ankle single, bi, or tri-malleolar
  - 2-left, 5-right
- Ankle or foot joint dislocation
  - 2-left, 1-right
- Calcaneous or Talus fx
  - 3-left, 4-right
- Tarsal or Metatarsal fx
  - 20-left, 12-right

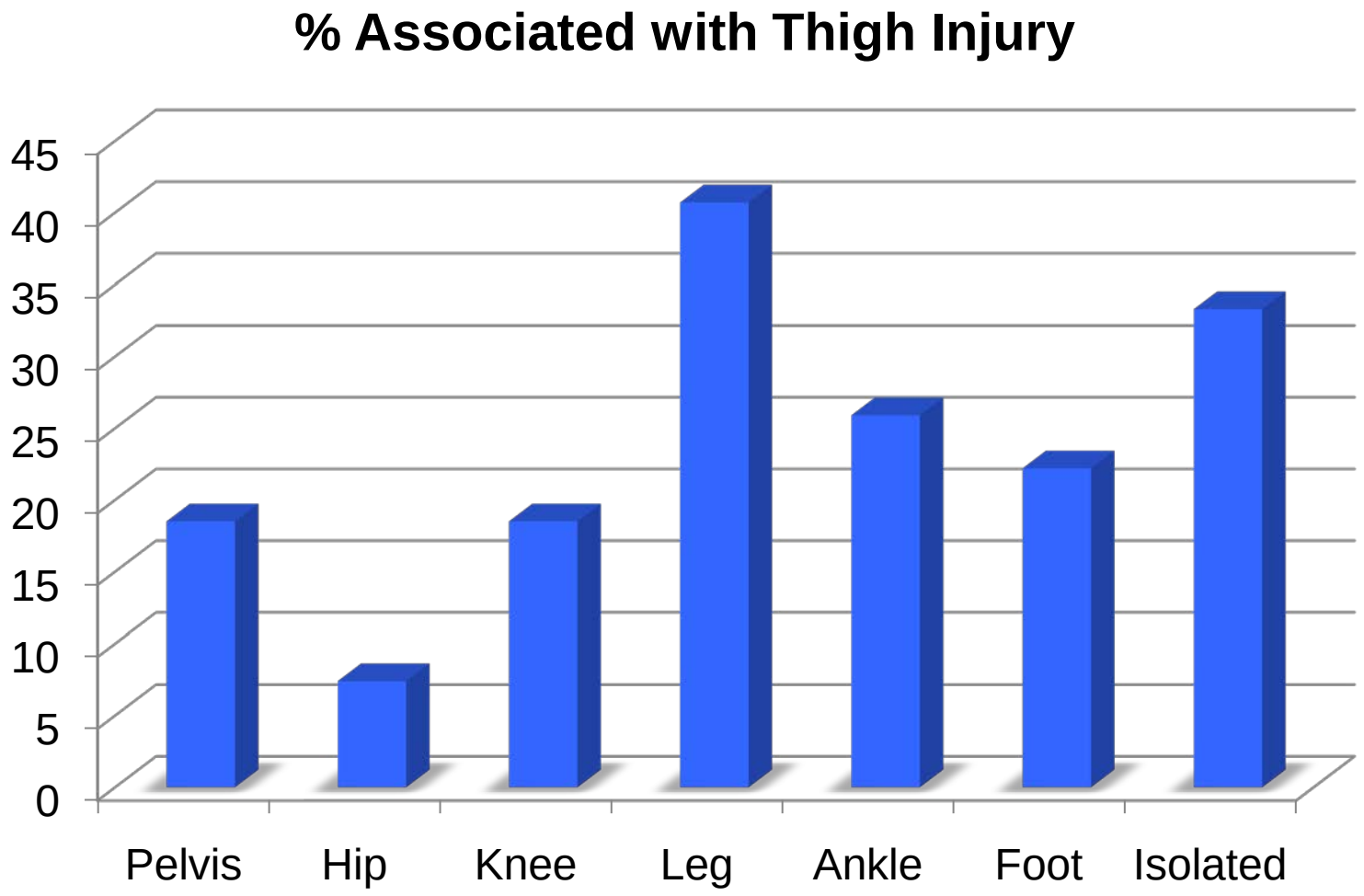
Associated Injuries



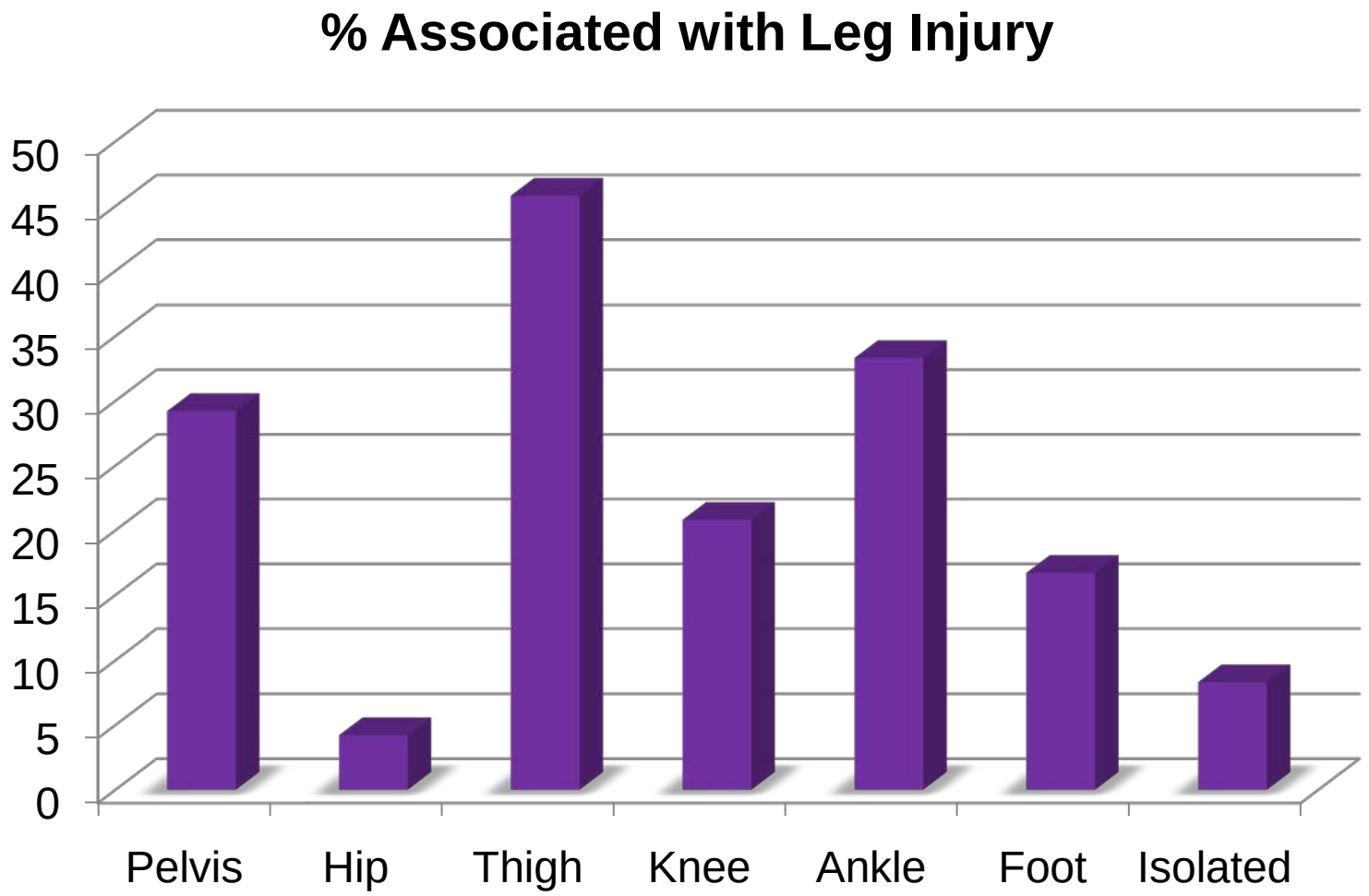
Associated Injuries



Associated Injuries

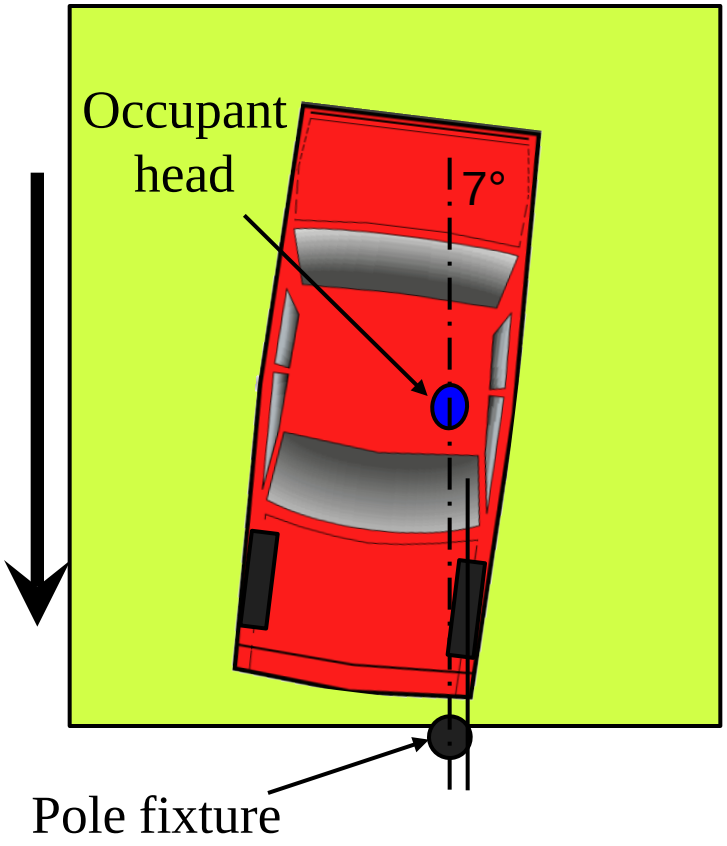


Associated Injuries



Methods: Vehicle Tests

- Four vehicles



Test	Model year	Class	Weight (kg)	Structure
1	2006	Mid-sized	1742.7	Normal
2	2010	Sub-Compact	1268.2	Normal
3	2005	Compact	1445.6	Normal
4	2010	Compact	1446.0	Enhanced*

* As advertised by manufacturer

Methods: Vehicle Tests

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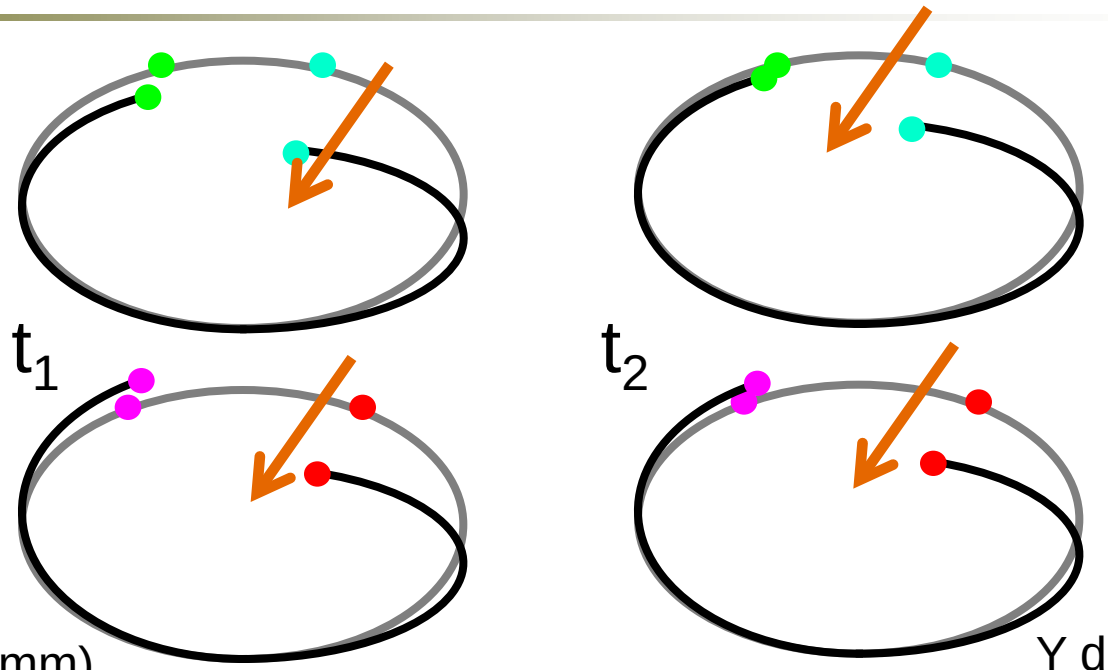
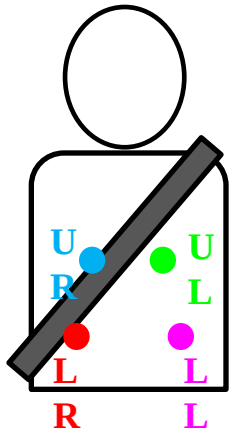
- THOR-NT occupant (driver)
  - 50th percentile

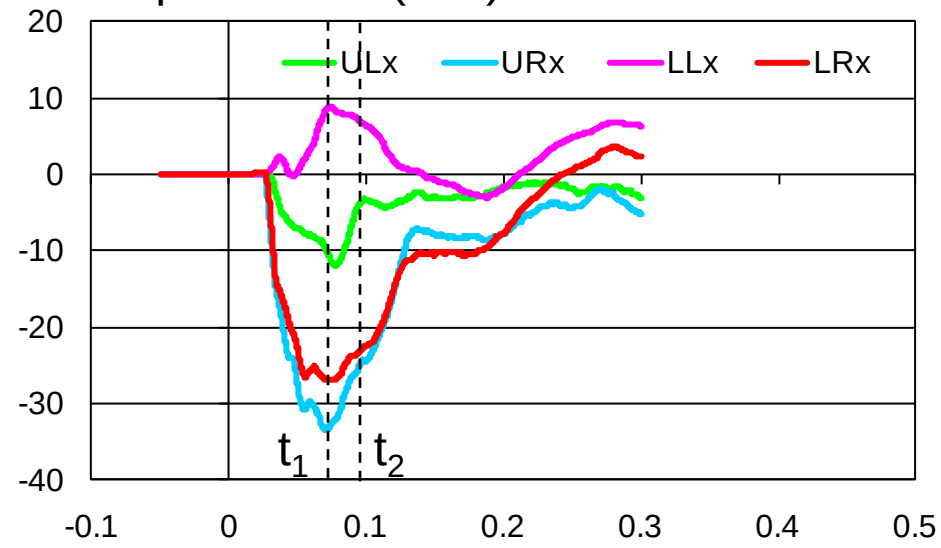
Results: Vehicle deformation

Typical JARI sled test

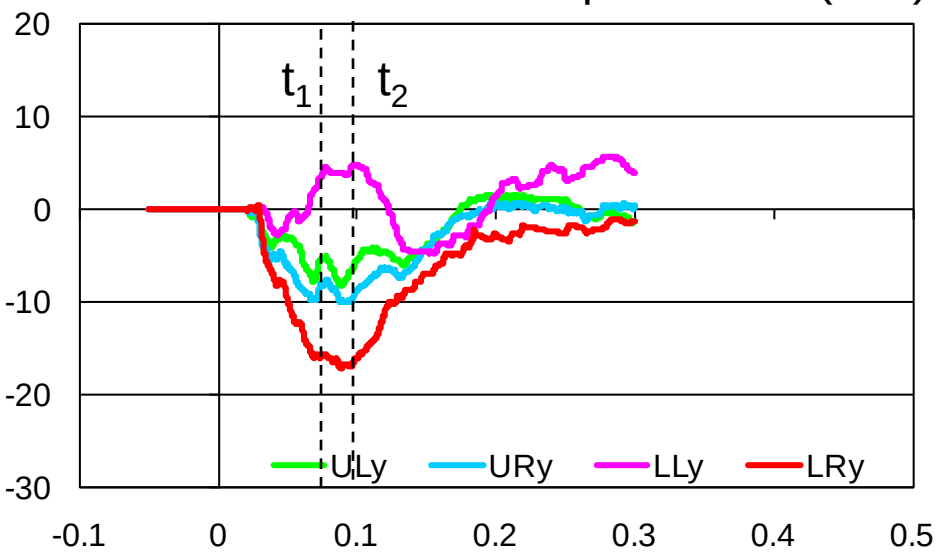




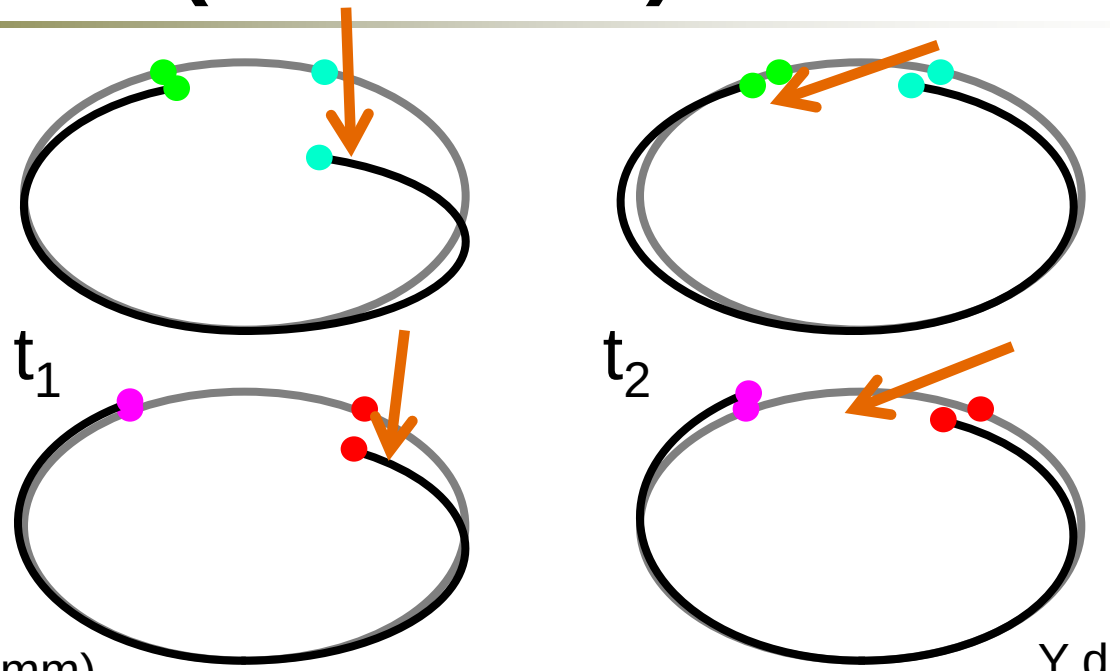
X displacement (mm)



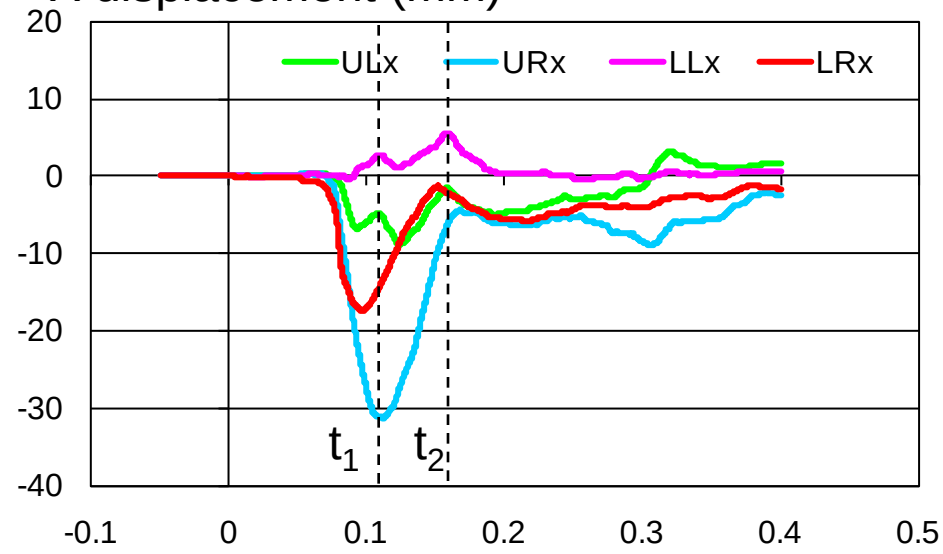
Y displacement (mm)



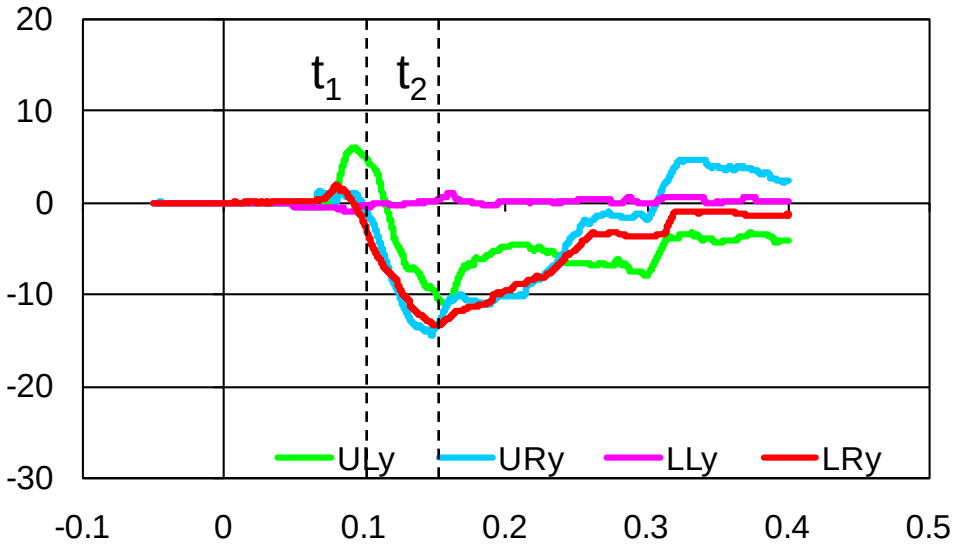
SOI Test 1 (Mid-sized)



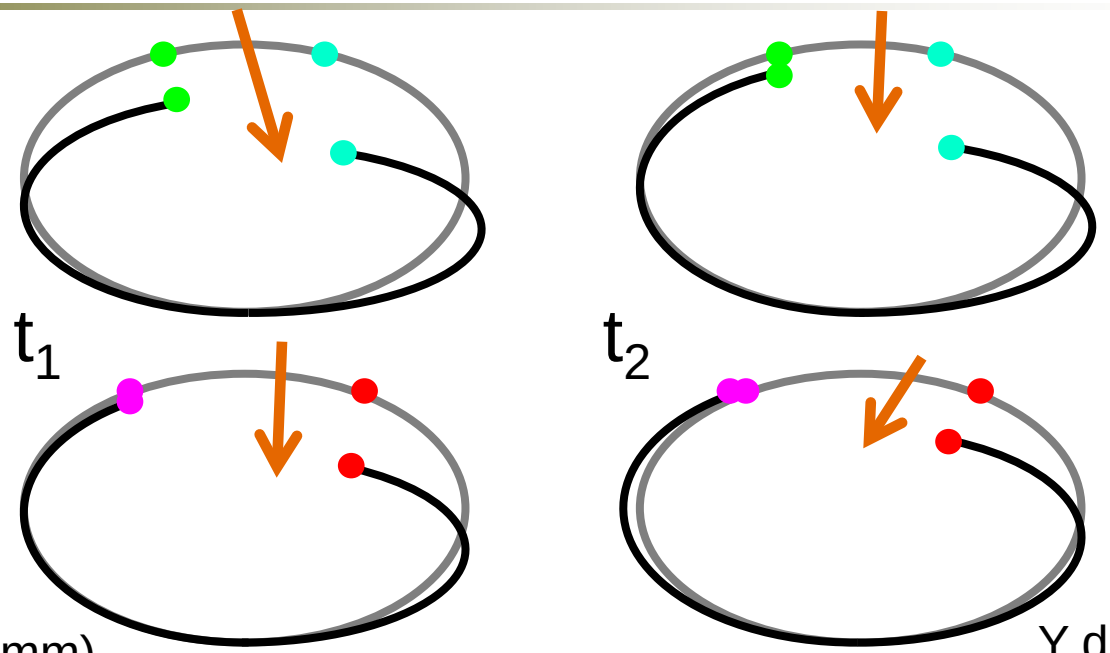
X displacement (mm)



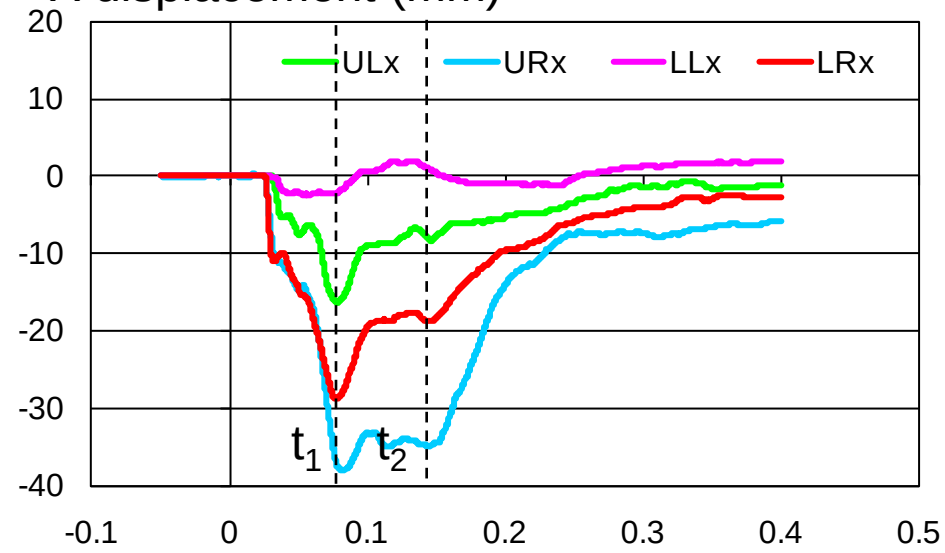
Y displacement (mm)



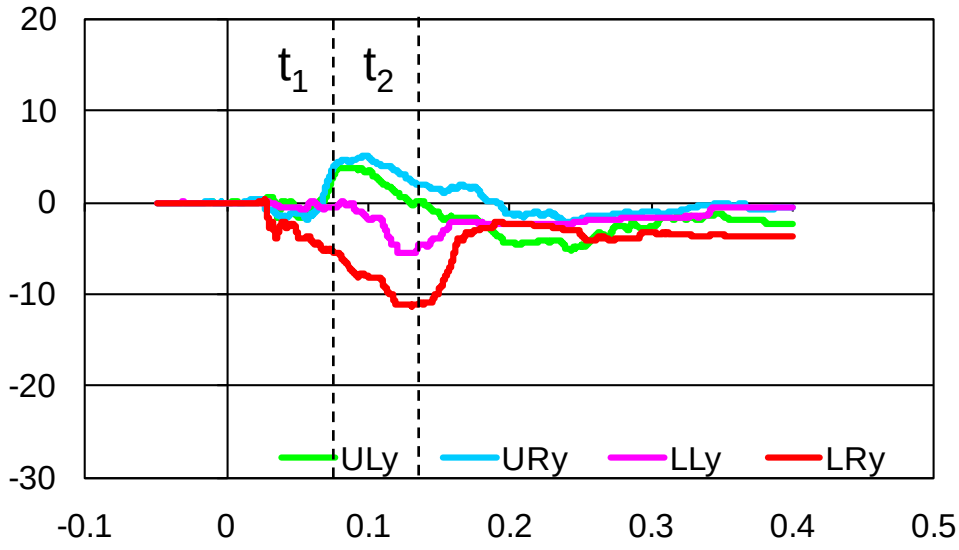
Test 3 (Compact)



X displacement (mm)



Y displacement (mm)



THOR-NT Lower Extremity Results

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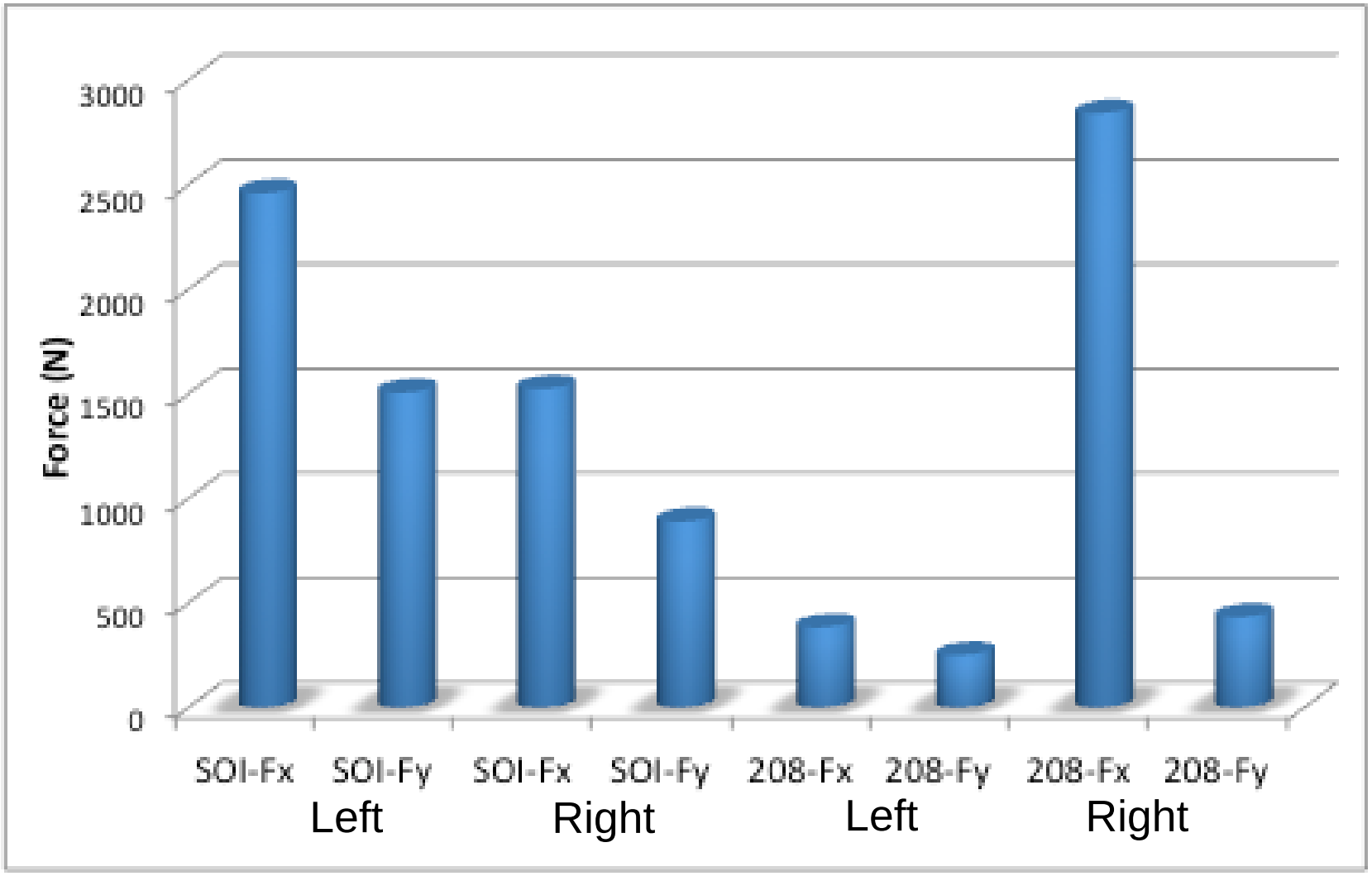
Acetabulum Forces N=4



THOR-NT Lower Extremity Results

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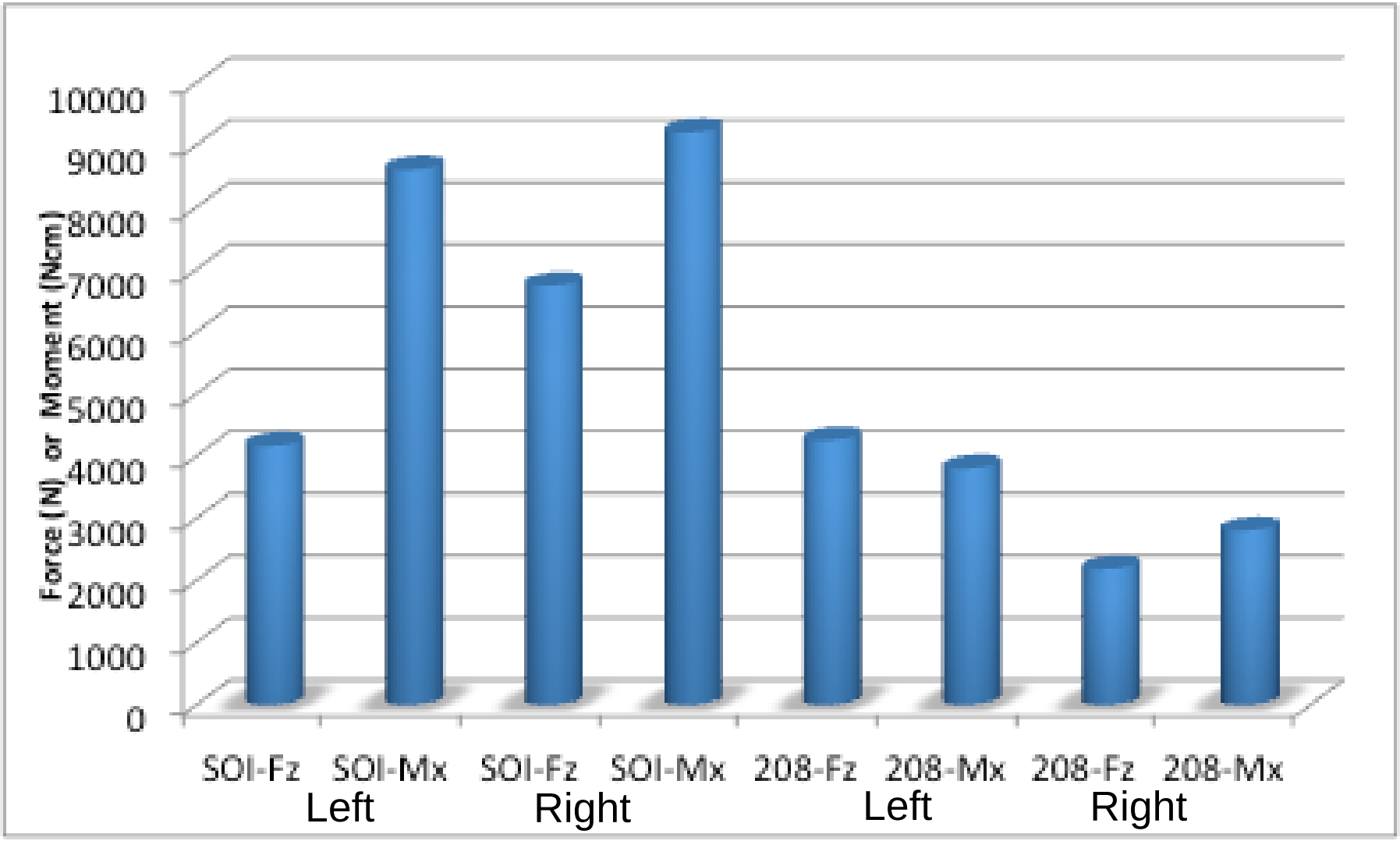
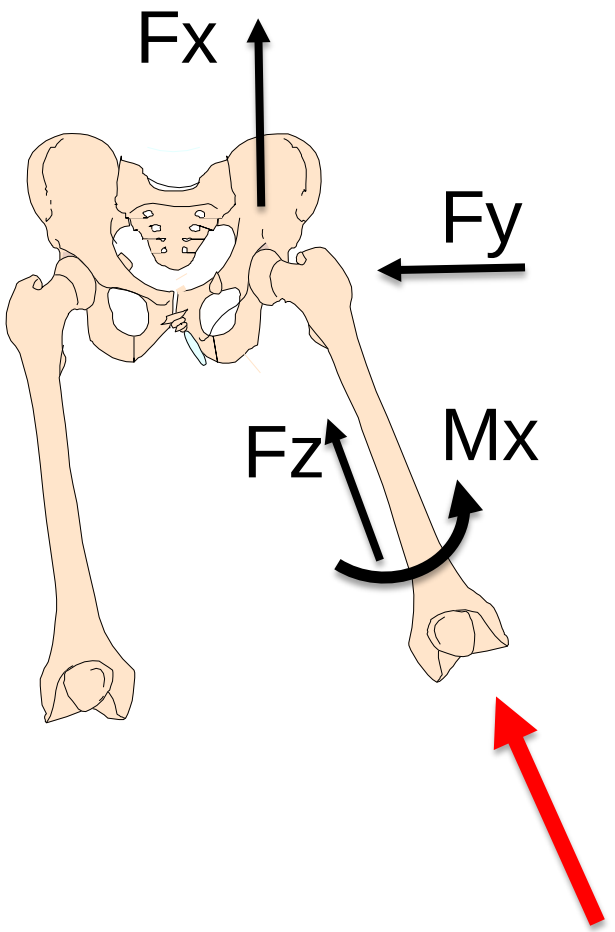
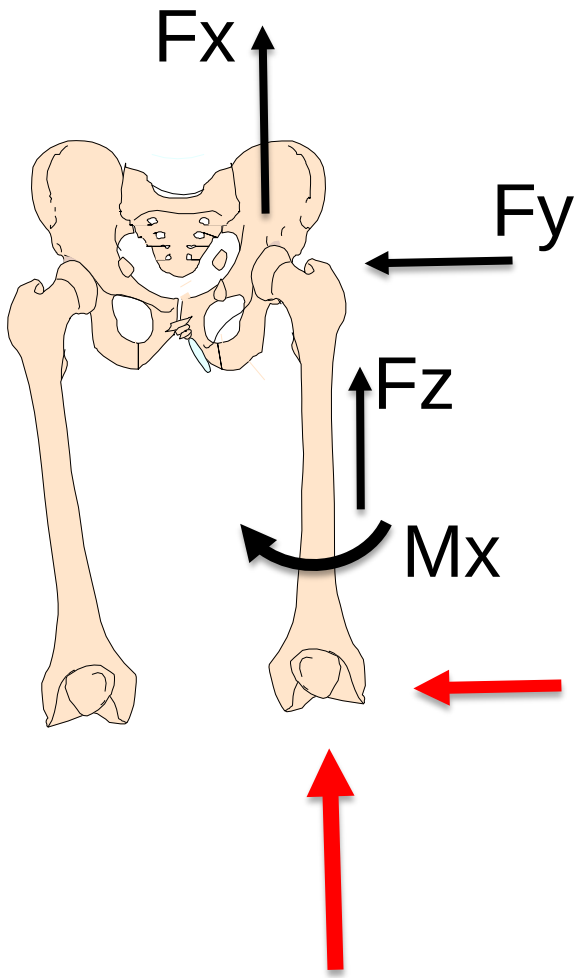
Femur Loads N=4



Mechanisms of Lower Extremity Injury





Conclusions

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- NASS analysis
  - Lower Extremity injuries substantial problem
  - SOI higher odd ration for Pelvis, Hip, Proximal Femur, and Knee
- CIREN analysis
  - Pelvis injuries more severe and more left side
  - Proximal femur fractures more prevalent and associated with pelvis fractures
  - Mid-shaft femur fractures more severe
- Vehicle crash tests
  - Occupant kinematics altered toward side
  - THOR dummy indicates higher off-axis loads
    - Shear in acetabulum; bending moment in femur

Acknowledgments

- US Department of Transportation
  - DTNH22-10-H00292
- VA Medical Research
  - MCW Neuroscience Laboratories Staff