

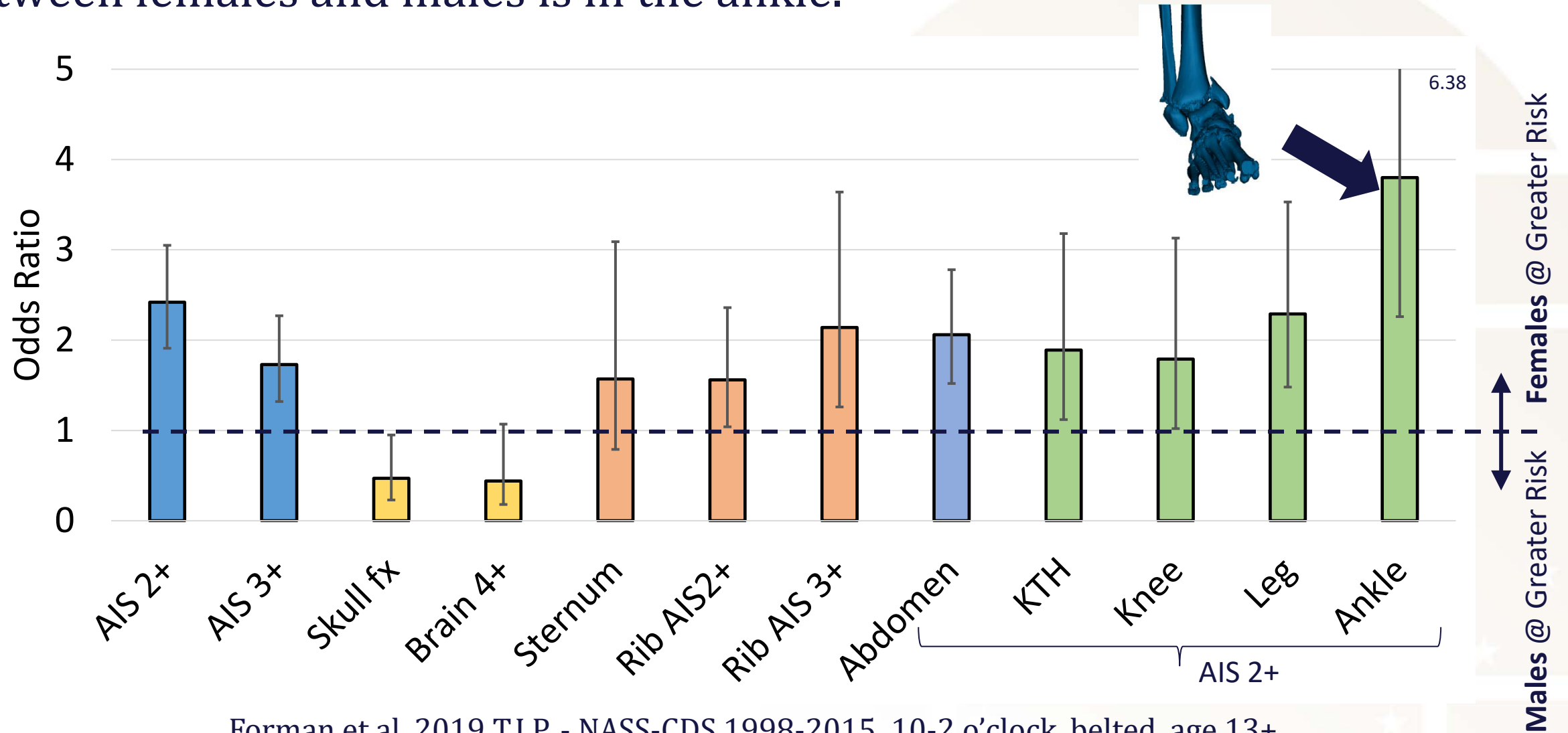
# Observations on Injury Types

Jason Forman

*Associate Professor*

*University of Virginia Dept. of Mechanical and Aerospace  
Engineering*

Ankle fractures remain a common injury type. Much of the difference in risk between females and males is in the ankle.

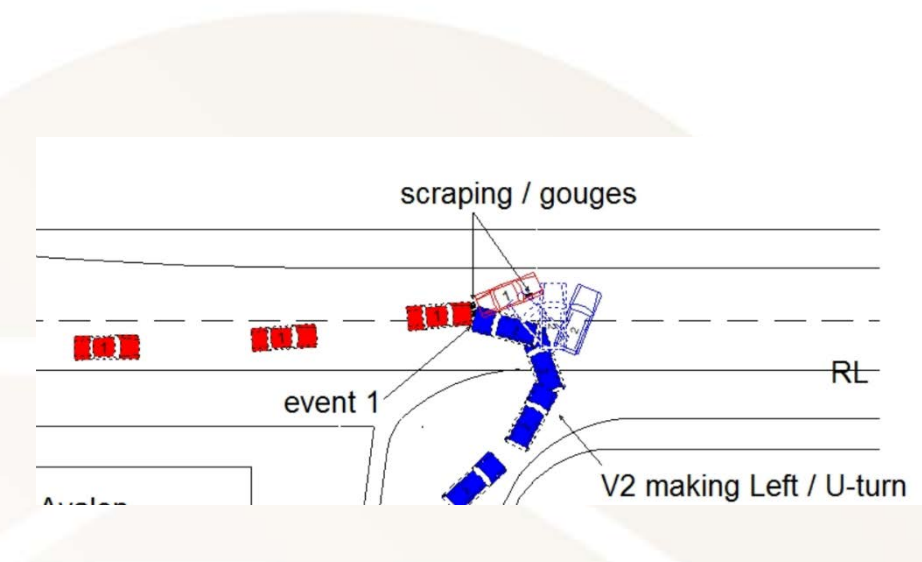
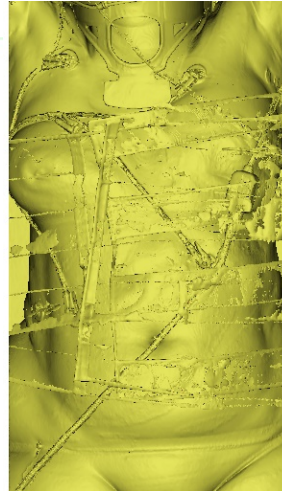
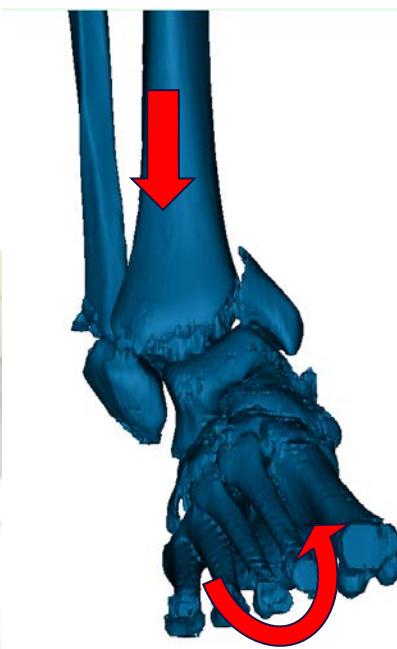


Forman et al. 2019 T.I.P. - NASS-CDS 1998-2015, 10-2 o'clock, belted, age 13+  
Controlling for  $\Delta V$ , Age, Stature, BMI, MY

# 2012 Sedan

63 km/h

54 y.o. female



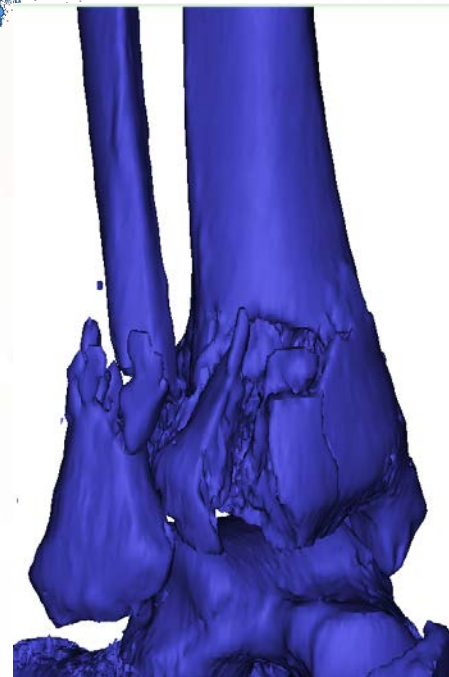
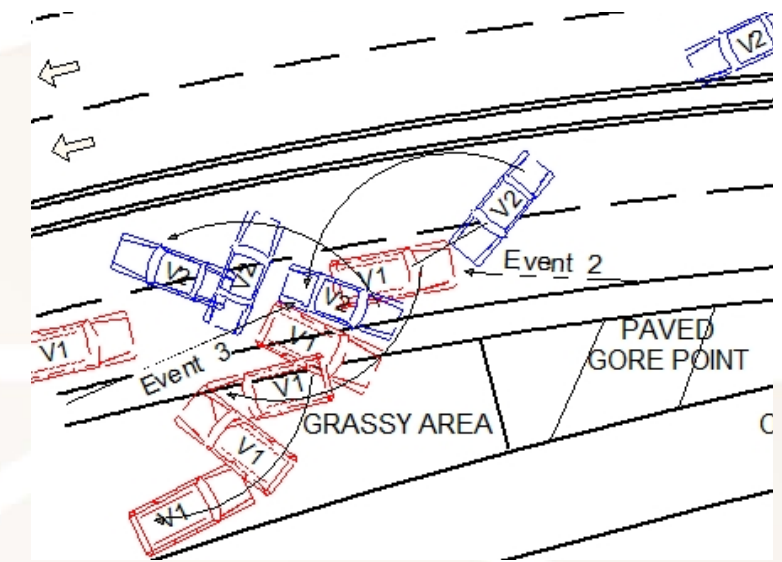
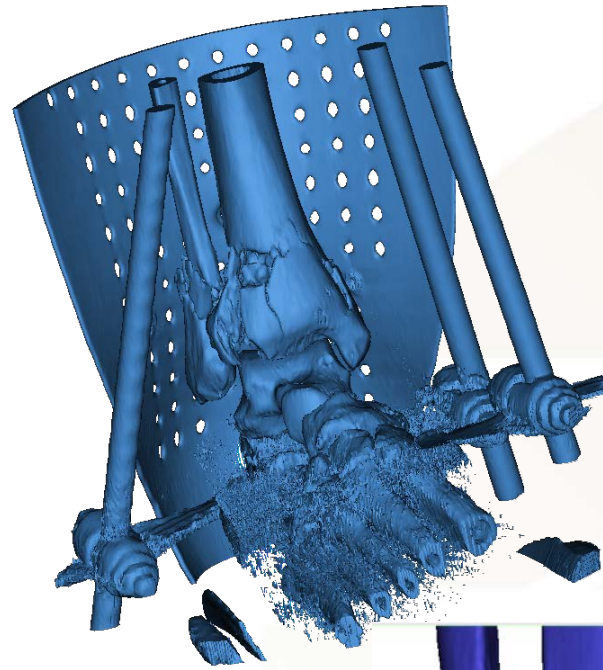
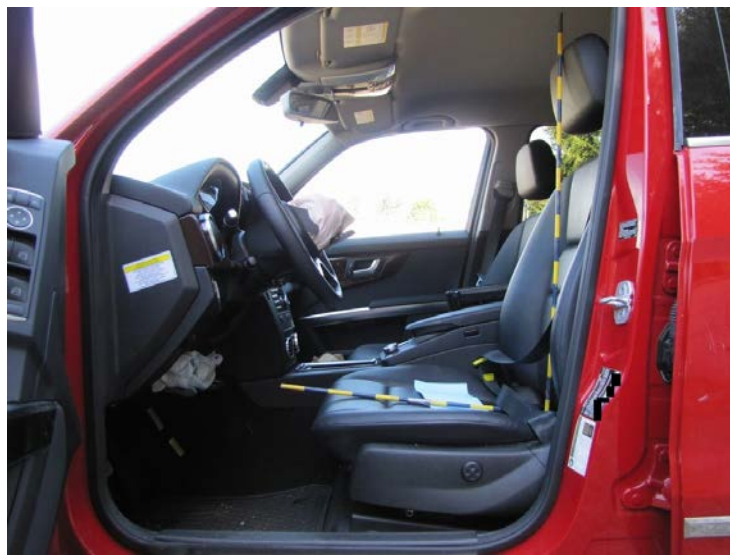
4 cm toepan intrusion  
160 cm 59 kg

Rib & sternum fx.  
Right: medial & lateral malleolus fx, talus fx., ankle dislocation

# 2013 SUV

61 y.o. female  
170 cm 75 kg  
 $\Delta V$  51 km/h  
Driver

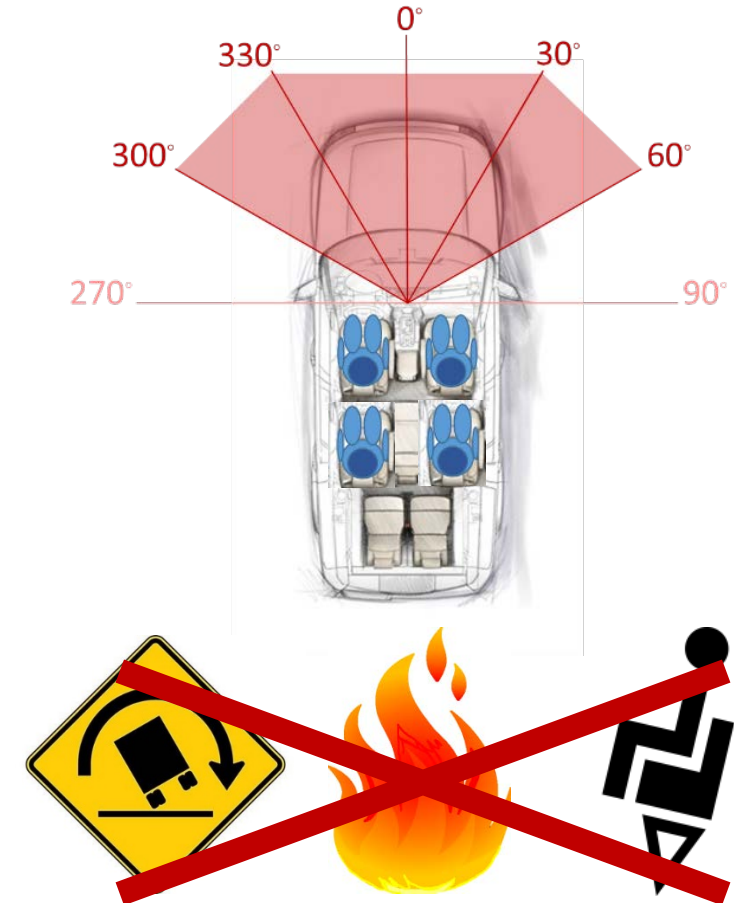
Rib fx., pneumothorax  
Right distal tibia & fibula fx.  
Right talus fx.



# DATA INCLUDED IN ANALYSIS



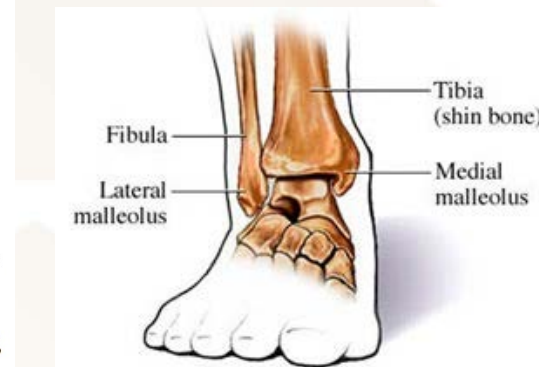
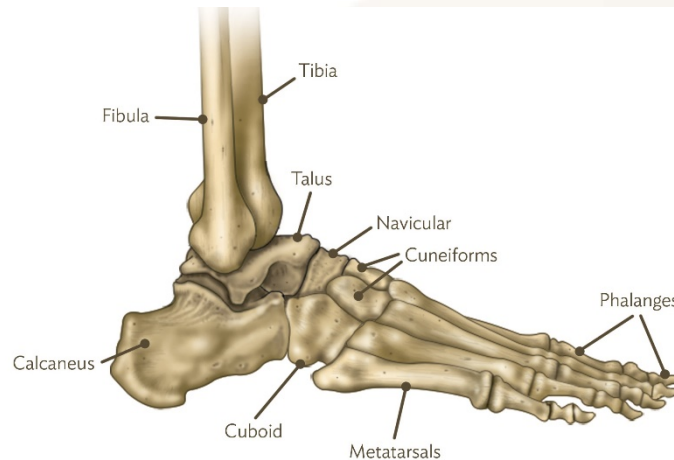
- Belted occupants ages 13+
- PDOF 300°-60°, GAD=F or L/R (if horizontal location Front)
- NASS-CDS ~2010-2015\*, passenger vehicles less than 10 years old
  - ~7,776 cases
- CISS 2017-2019\*
  - ~2,635 cases
- Rollovers, fires, and ejections were excluded
- Include pregnant occupants
  - Separated into 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> trimester in distributions



\*Combined per NHTSA guidance (Zhang et al. 2019)

# Ankle Injury Cases (AIS2+, unweighted)

	Female	Male
All Exposed	5493	4918
AIS 2+ Injury	791	642
AIS 2+ Ankle Injury	126	70
↳ % of Exposures	2.3%	1.4%
↳ % of Injury Cases	15.9%	10.9%

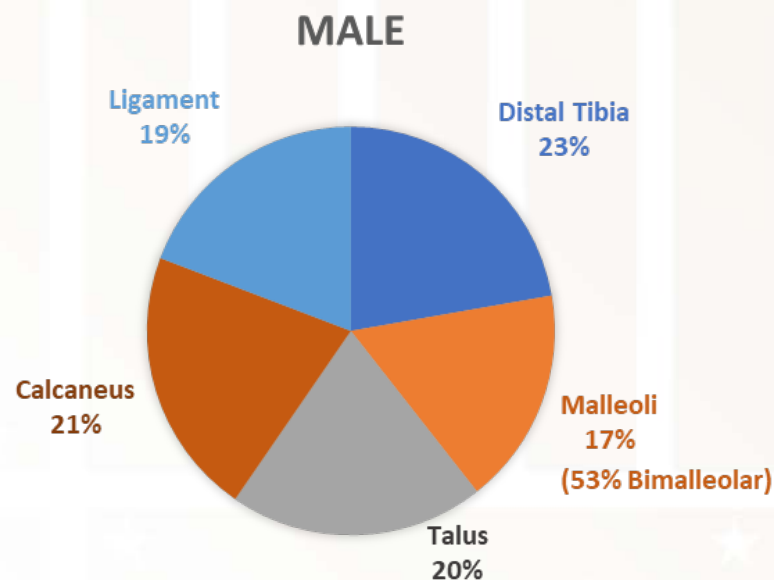
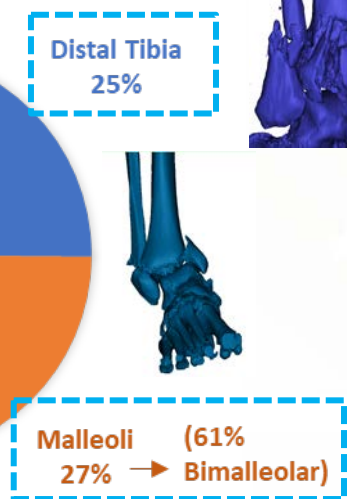
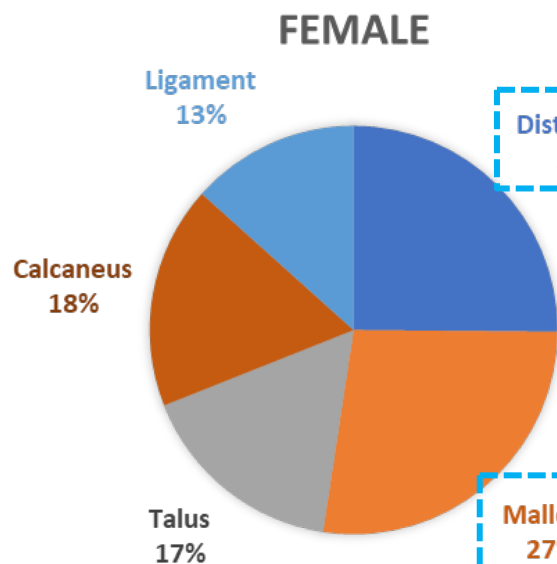


Distributions of AIS2+ ankle injuries

Noss et al. 2024  
SAE WCX



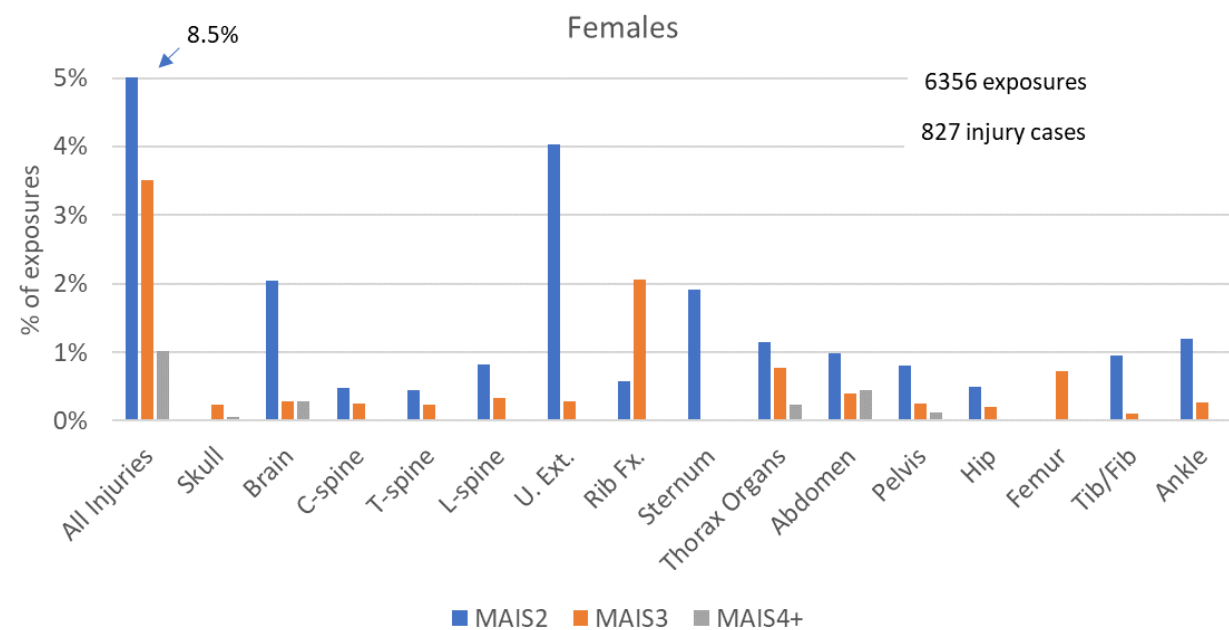
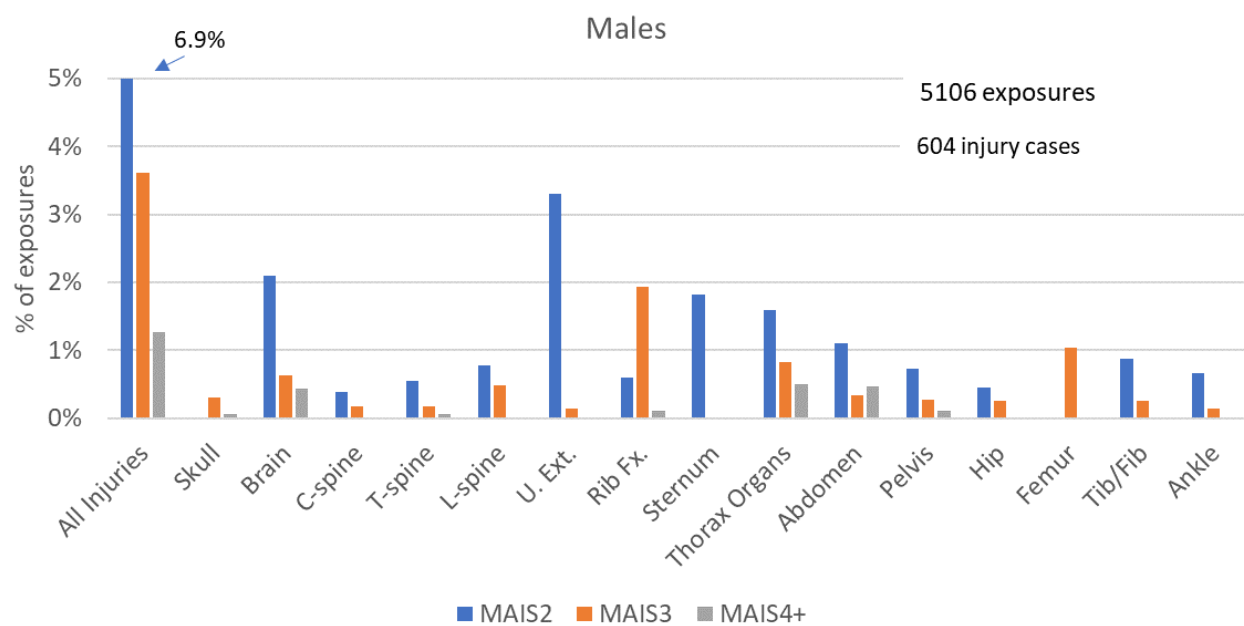
Collaborative Safety Research Center  
TOYOTA



# More recent whole body analysis - CISS

- ▶ CISS collection years 2017-2022
- ▶ MY 2009+
- ▶ Occupant age  $\geq 13$  years
- ▶ No rollover events
- ▶ No fires (major or minor)
- ▶ No ejection
- ▶ Must be restrained with a 3-point belt
- ▶ Frontal impacts, defined by either:
  - - PDOF1 or PDOF2 between 300 to 359, or 0 to 60
  - - Or (GAD1 or GAD2=F)
  - - Or (GAD1=L/R and SHL1=F) or (GAD2=L/R and SHL2=F)

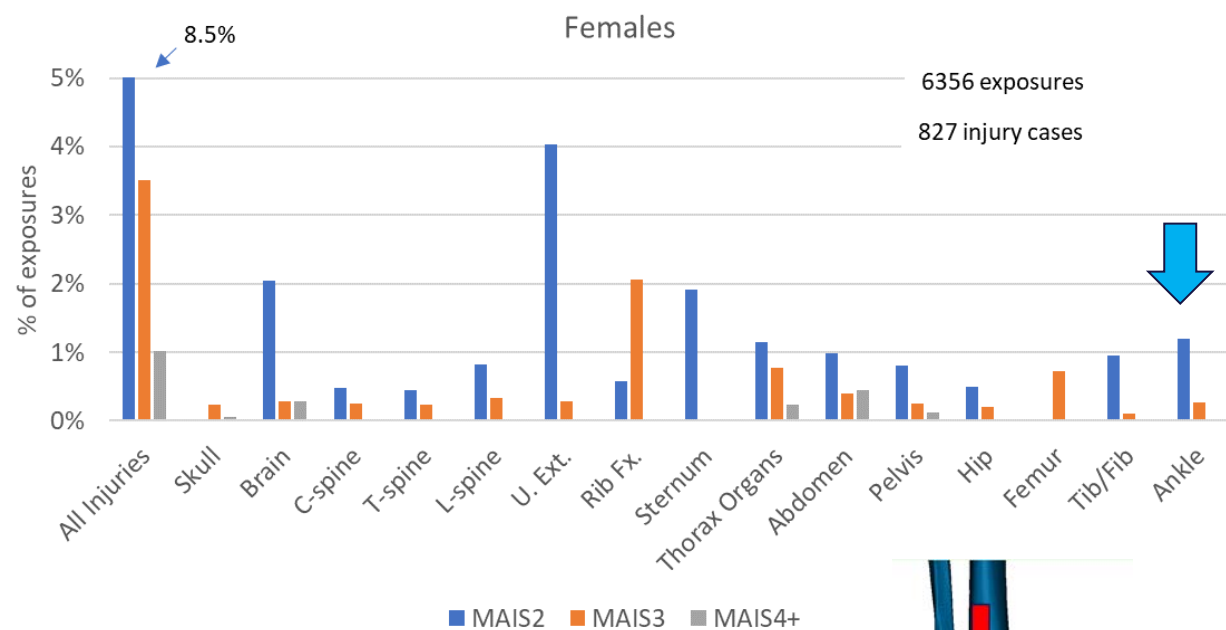
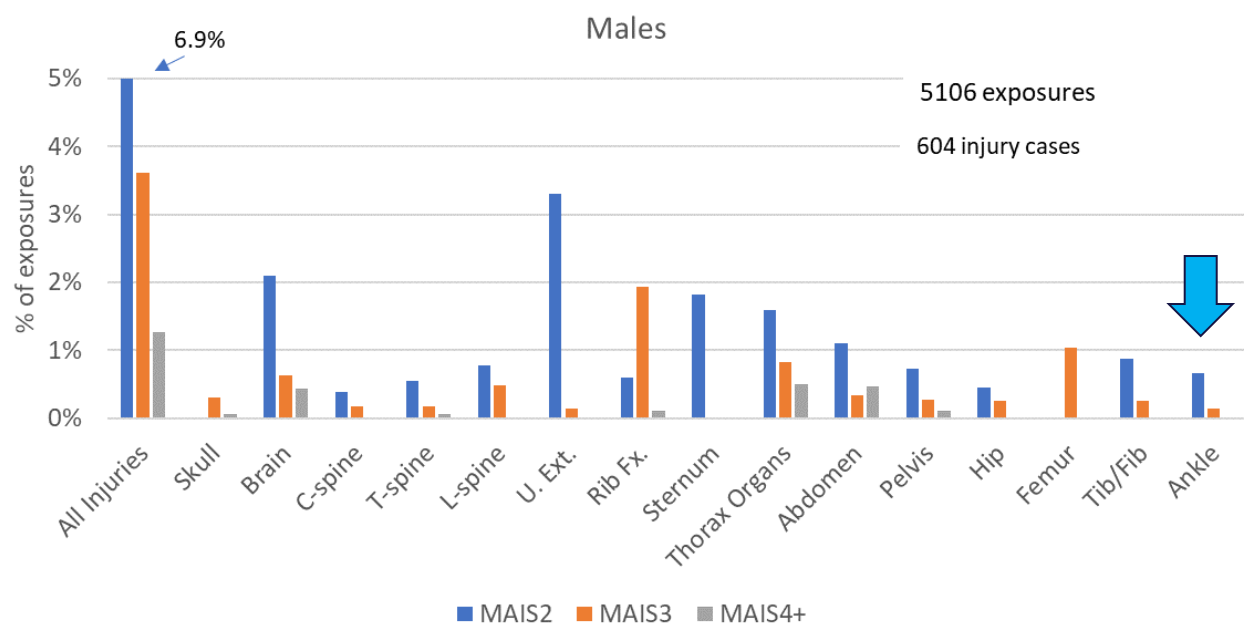
# Injury Distributions (by AIS level) - Unweighted



8 % of exposure cases that have at least one injury in that body region (by AIS level)

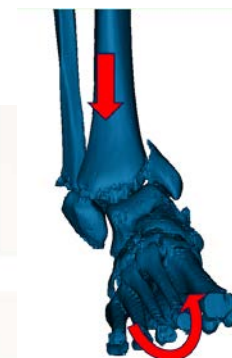


# Injury Distributions (by AIS level) - Unweighted



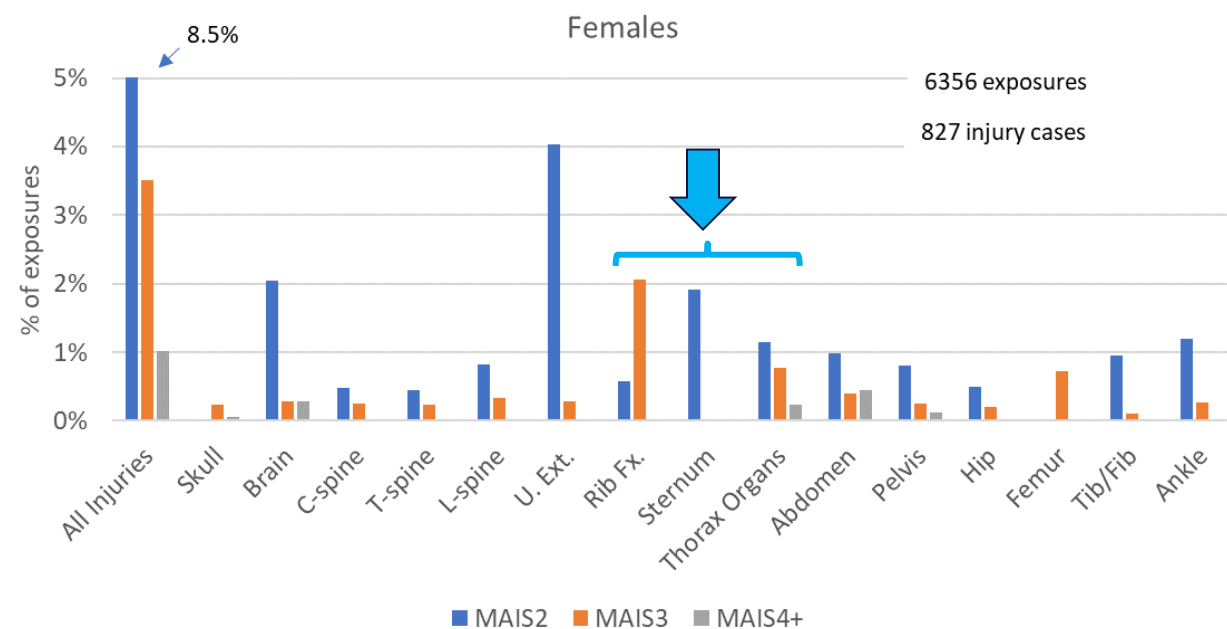
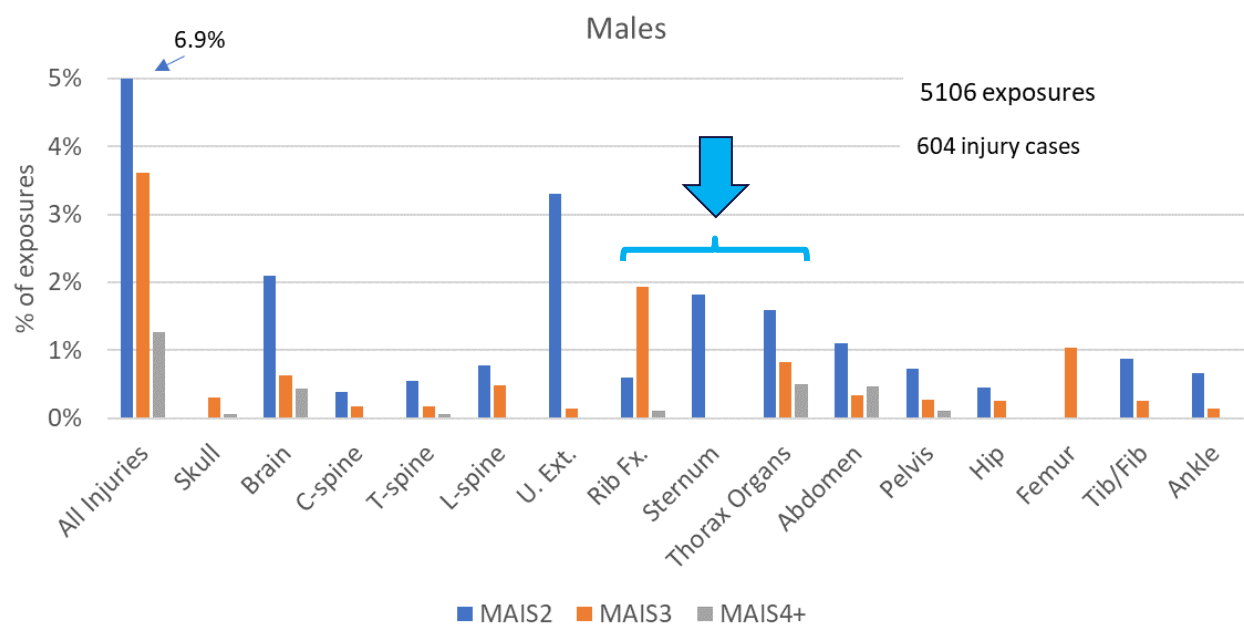
**Autoliv**

Females: higher risk of ankle injury  
(consistent with other studies)



% of exposure cases that have at least one injury in that body region (by AIS level)

# Injury Distributions (by AIS level) - Unweighted

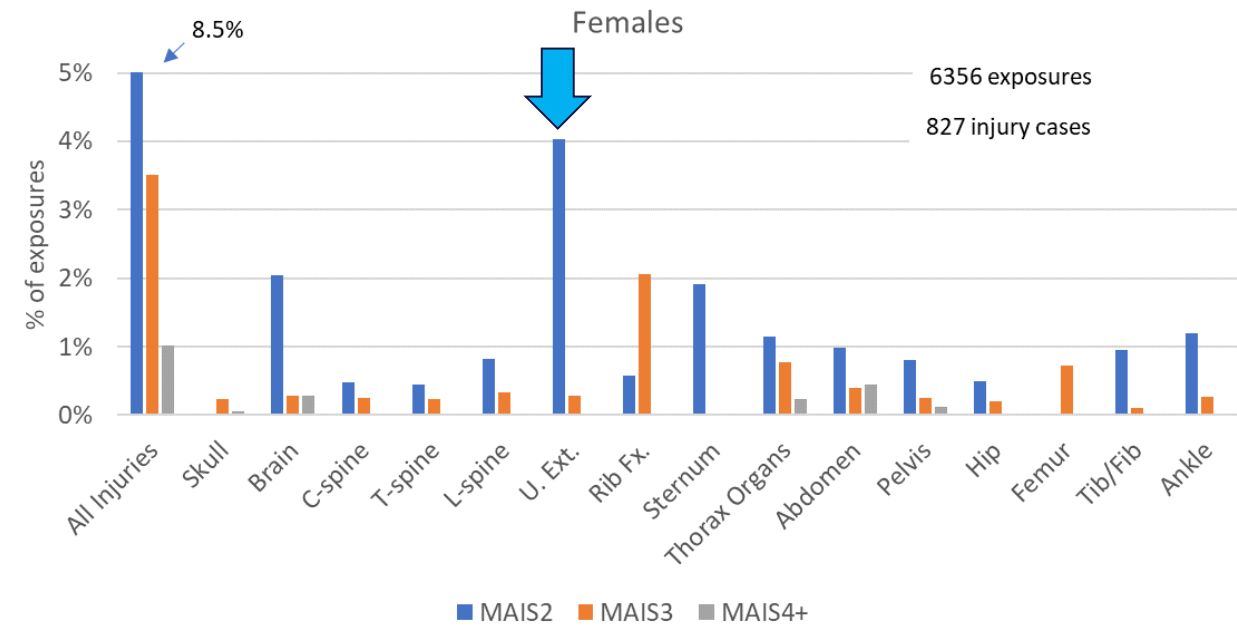
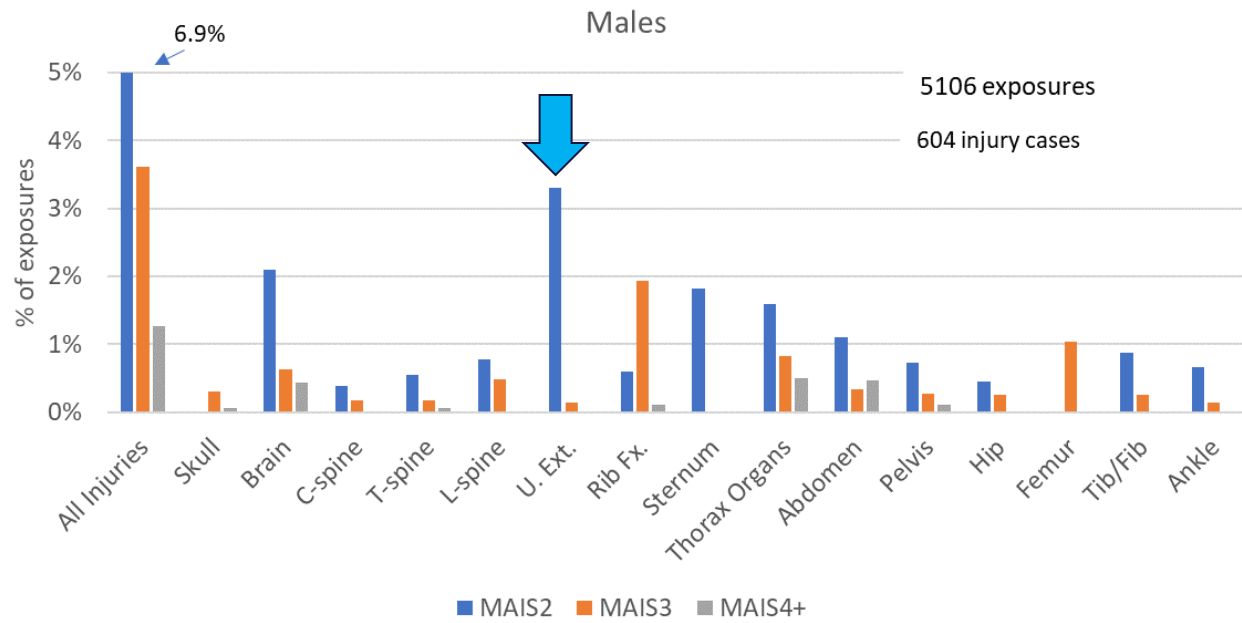


High prevalence of rib, sternum, thoracic organ injury for both males and females.



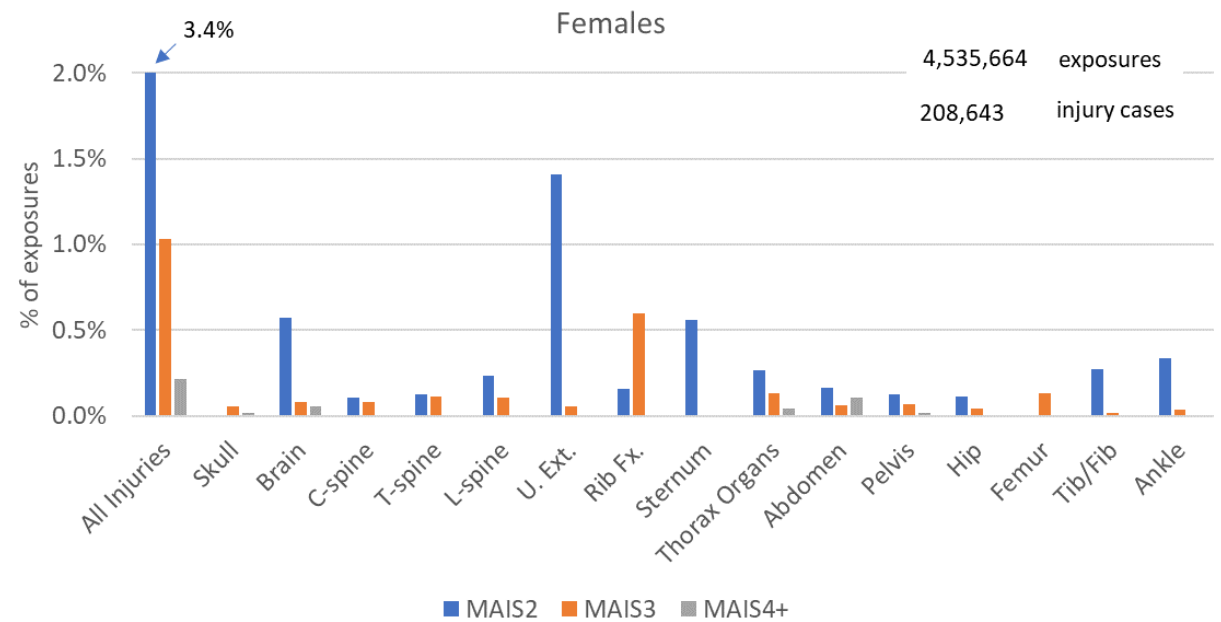
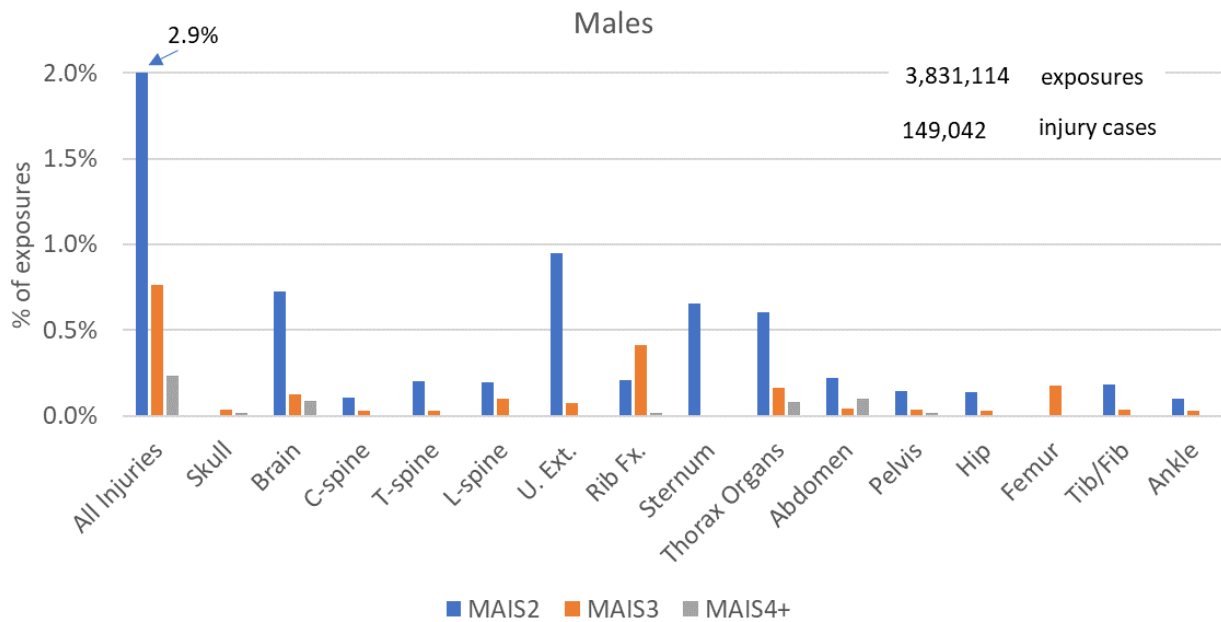
Note: These injuries do not always happen concurrently. Should consider all thorax injuries to achieve accurate injury case counts.

# Injury Distributions (by AIS level) - Unweighted



High prevalence of upper extremity injury.

# Injury Distributions (by AIS level) - Weighted



Trends are generally consistent after applying case weights.  
(Though overall risk magnitude is lower, as should be expected.)

# Distribution of Upper Extremity Injuries (AIS2+)

% of AIS2+ UX injury cases that contain at least one injury in the noted subregion (unweighted)

Subregion	Males (n=177)	Females (n=274)
Shoulder & Clavicle	33%	23%
Upper Arm (Ulna)	10%	11%
Forearm	24%	29%
Wrist	29%	38%
Hand/Finger	15%	17%
Other	6%	3%

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Includes distal  
radius and ulna fx.



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Males seem to have more shoulder & clavicle fractures





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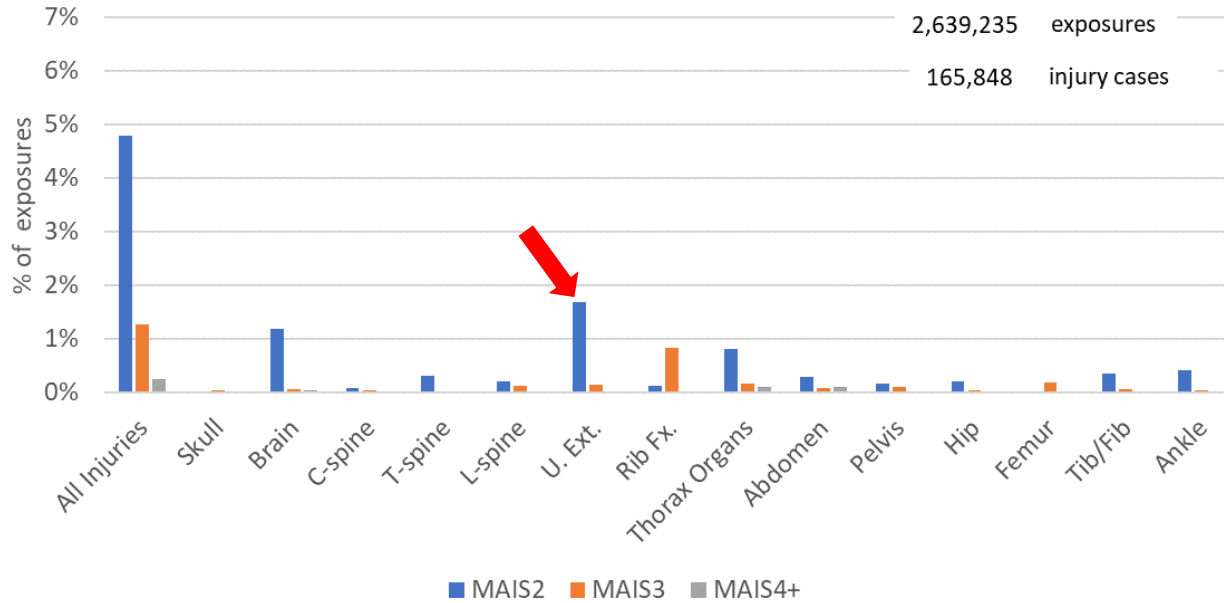
Females seem to have more wrist fractures



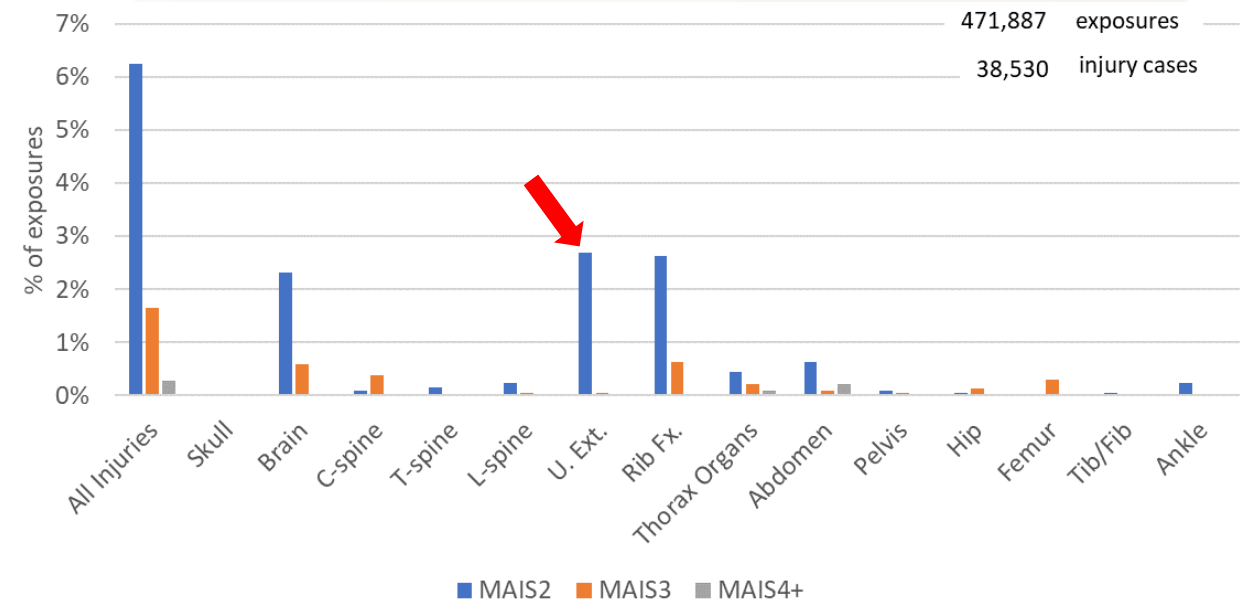
# Upper Extremity Injuries

Are these due to airbag interaction?

Driver – Airbag Deployed



Right Front Passenger – Airbag Deployed

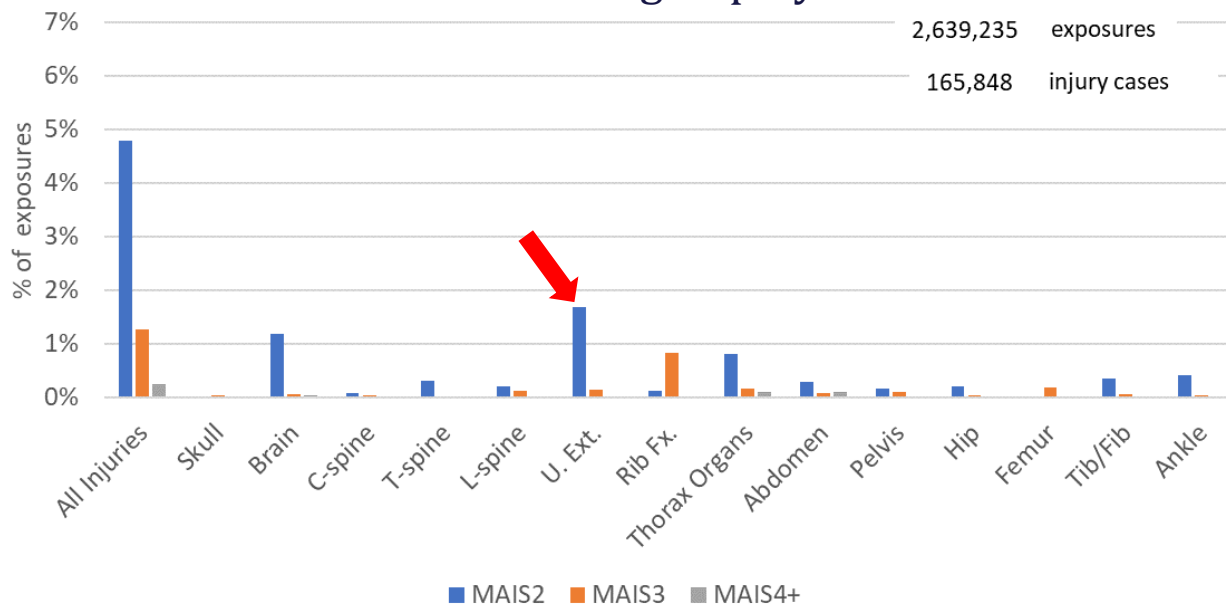


CISS 2017-2022 Belted Frontals, All MY, Single Event (weighted)

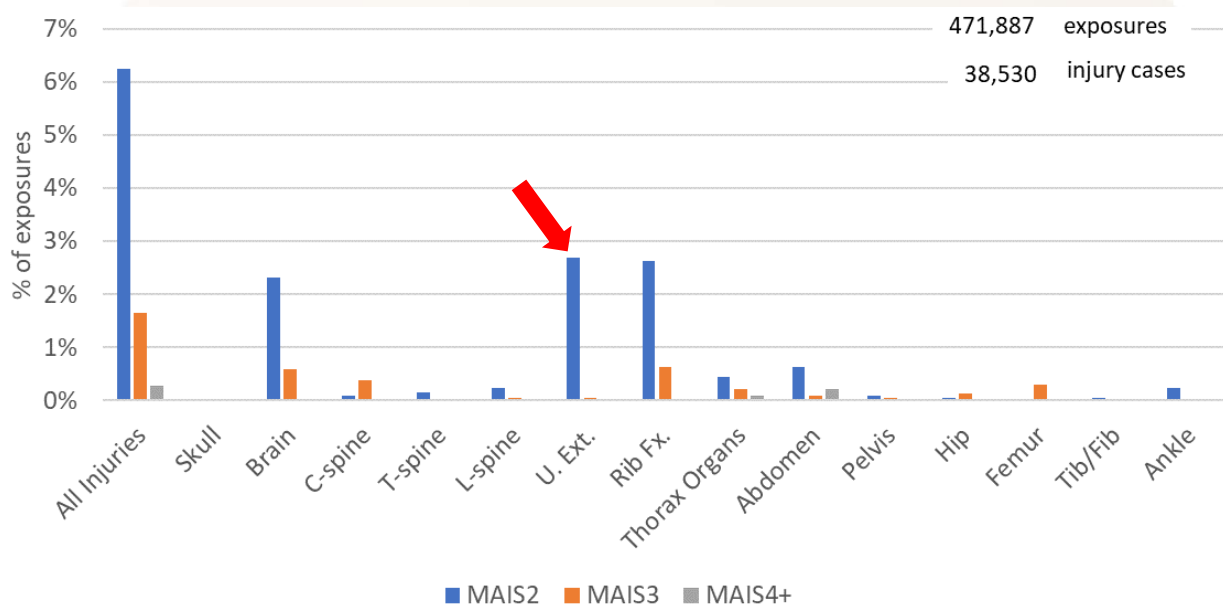
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CISS 2017-2022 Belted Frontals, All MY, Single Event (weighted)

Upper Extremity Injuries are Not Unique to Drivers



# Upper Extremity Injuries

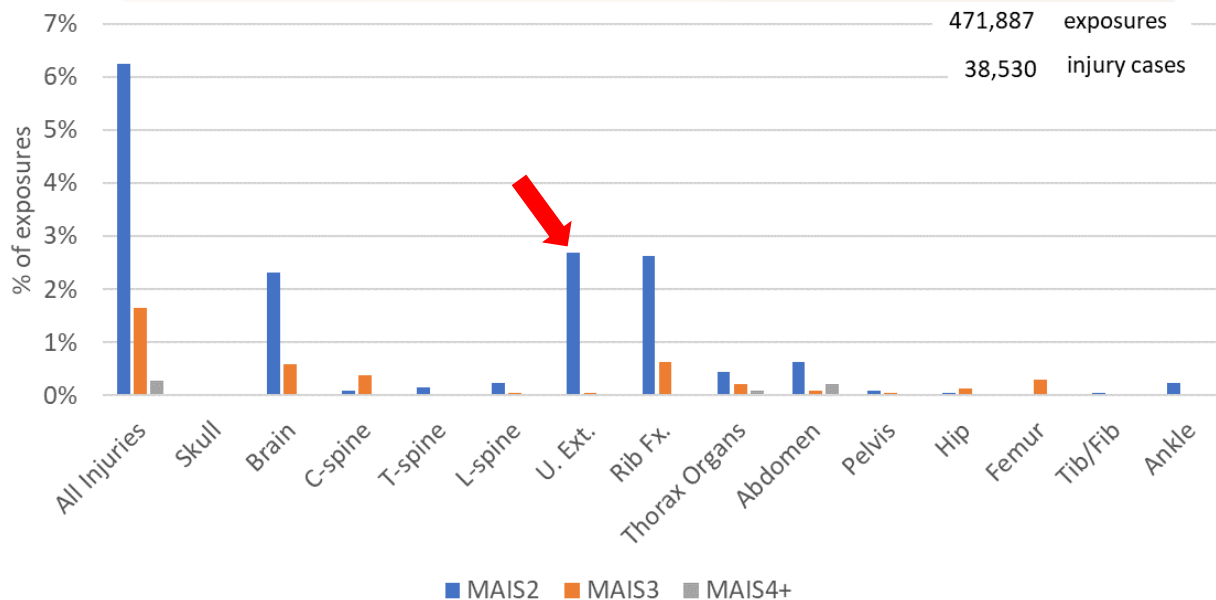
Are these due to airbag interaction?

Distribution of AIS2+ Upper Extremity Injuries

	Driver	RFP
shoulder & clavicle	18.8%	13.9%
upper arm	9.9%	19.4%
forearm	29.3%	30.6%
wrist	43.6%	41.7%
hand & finger	18.2%	13.9%
other	2.2%	5.6%

CISS 2017-2022 Belted Frontals, Single Event,  
All MY, Airbag Deployed (unweighted)

Right Front Passenger – Airbag Deployed



Upper Extremity Injury Types Very Similar between Drivers and Right Front Passengers

# Summary – Upper Extremity Injuries

- ▶ Upper extremity injuries are among the most common types of AIS2+ injury in modern vehicles
- ▶ Males tend more toward clavicle/shoulder, females tend more toward wrist fracture
- ▶ Similar injury risks, patterns between driver and right front passenger
  - Upper extremity injuries are not solely due to steering wheel/driver airbag interaction