State of Knowledge on Upper Extremity Injury Causation and Injury Prediction

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RCCADS Workshop

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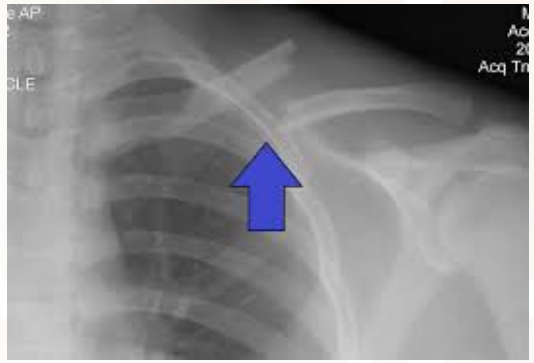
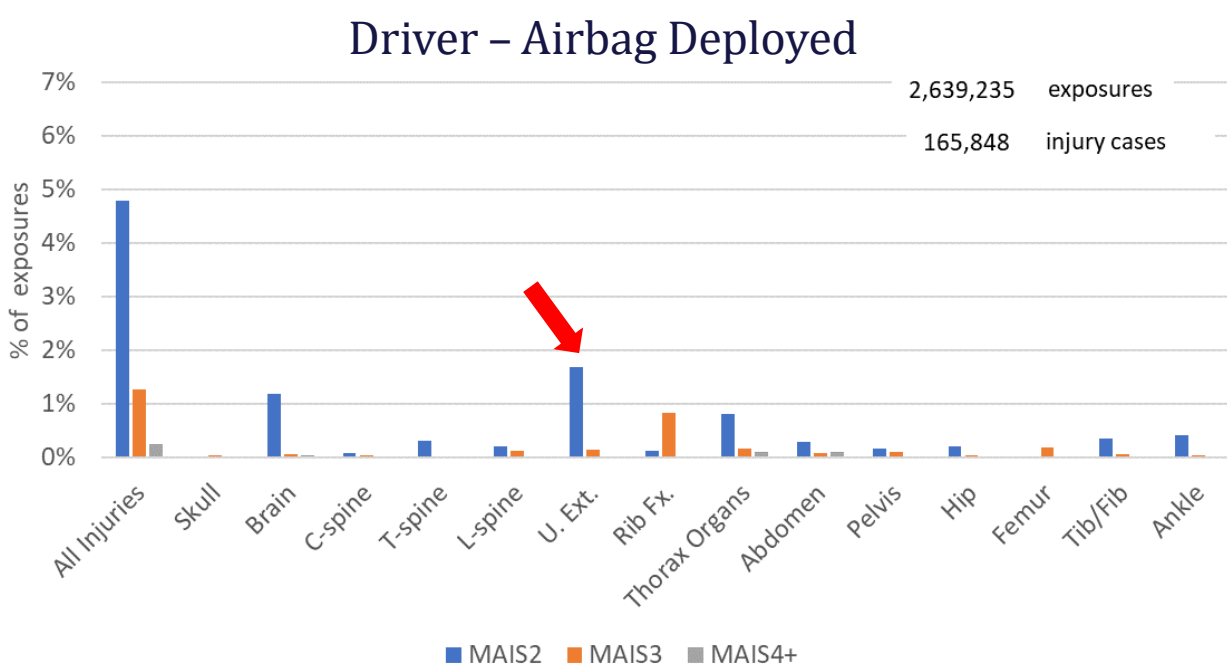
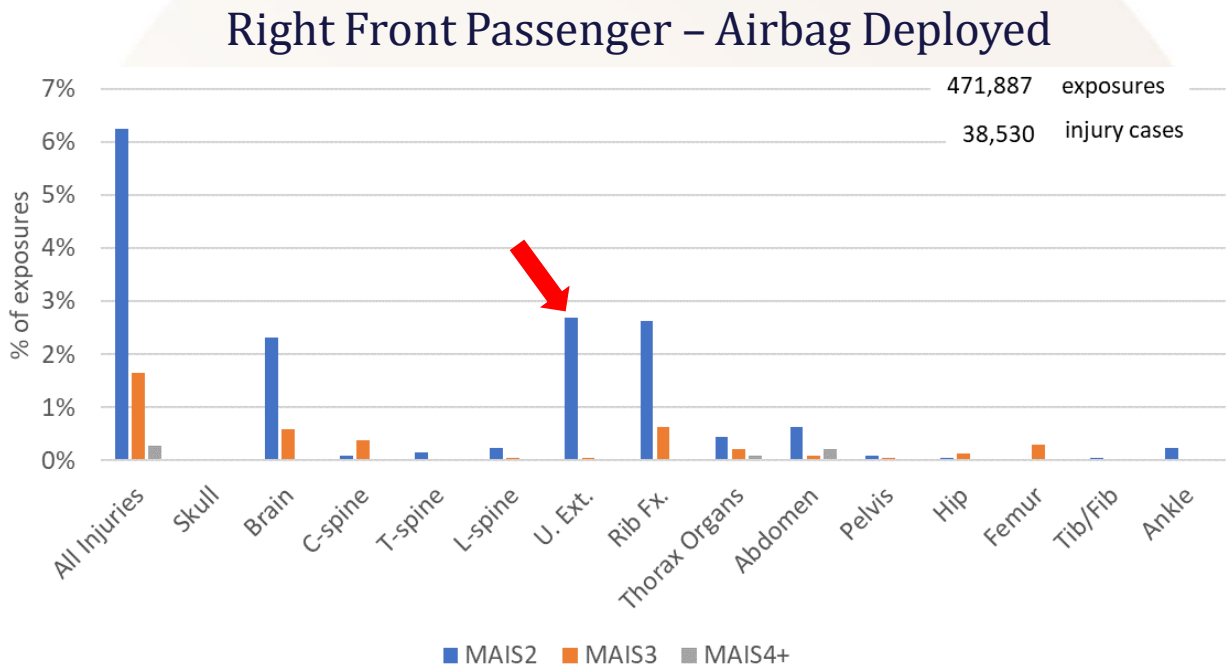
Upper Extremity Injuries

- Among the most common injury types (Forman et al. 2019, Craig et al. 2024)
- Have not decreased in modern vehicles (Forman et al. 2019)
- Most AIS2+ upper extremity injuries are fractures
- Carry substantial risk of long-term disability
  - AIS2: 35% risk of some long-term impairment (Malm et al. 2008)



Upper Extremity Injuries





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

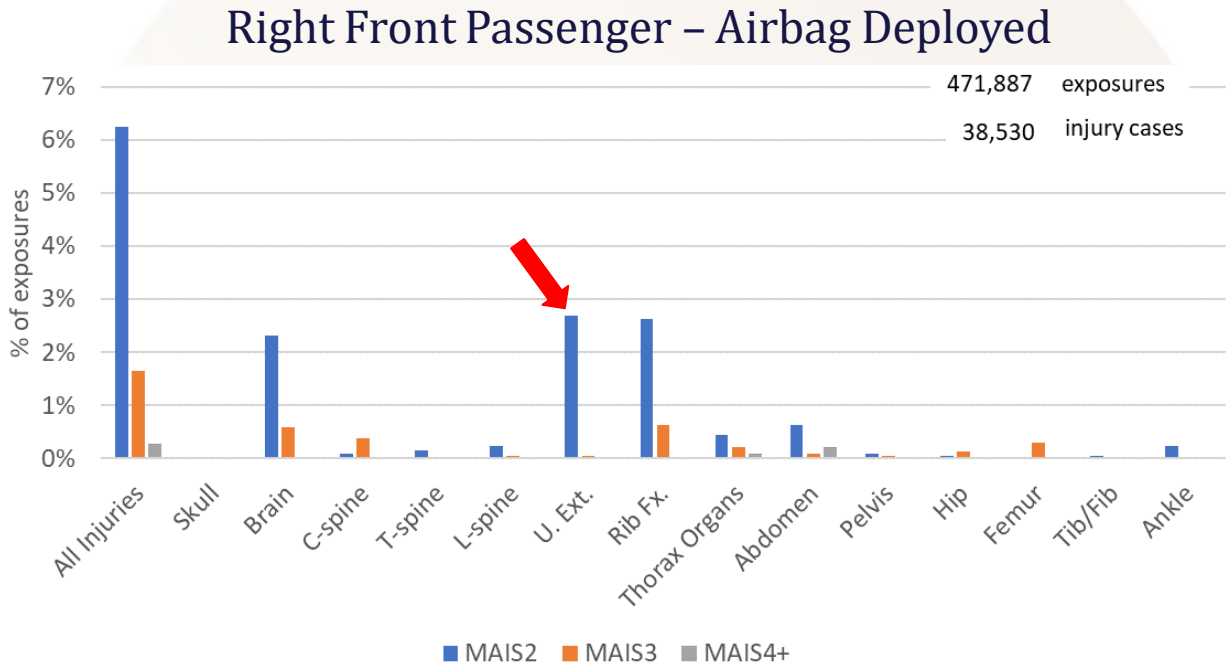
Upper Extremity Injuries are Not Unique to Drivers

Upper Extremity Injuries

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, Airbag Deployed (unweighted)



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

Remaining Questions

- What other upper extremity research is available?
  - Field data studies
  - Biomechanics studies
- What should be targeted for prediction and prevention?
  - Injury types
  - Risk factors
  - Injury mechanisms
  - Causation scenarios
- What are the potential abilities of current tools?
  - ATD and HBM
  - Construction
  - Validation
  - Injury prediction capability

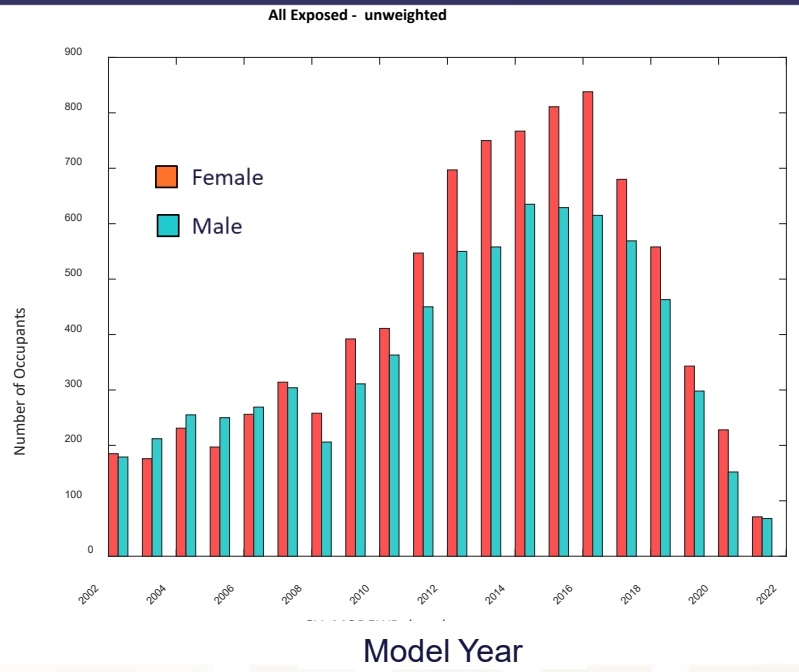
Literature Review

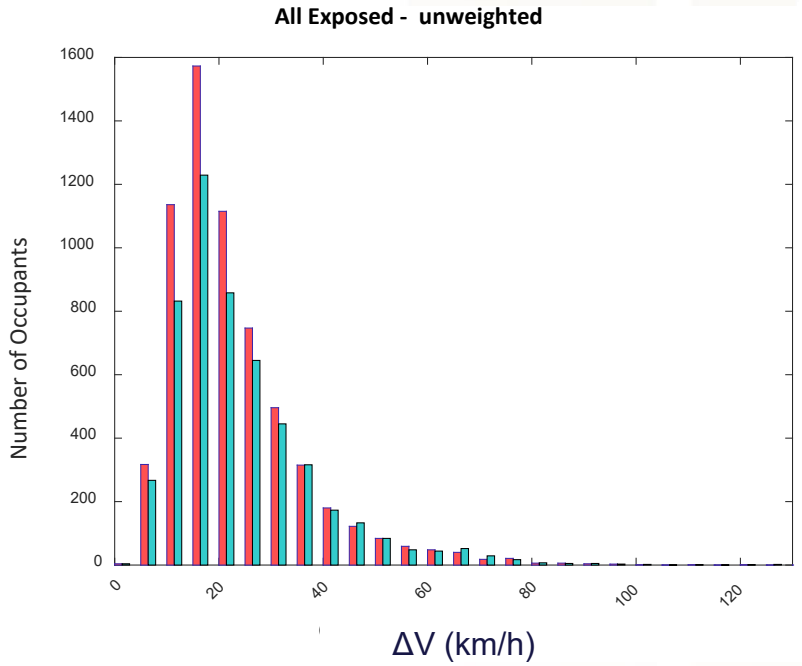
Field Data Analysis and Case Review

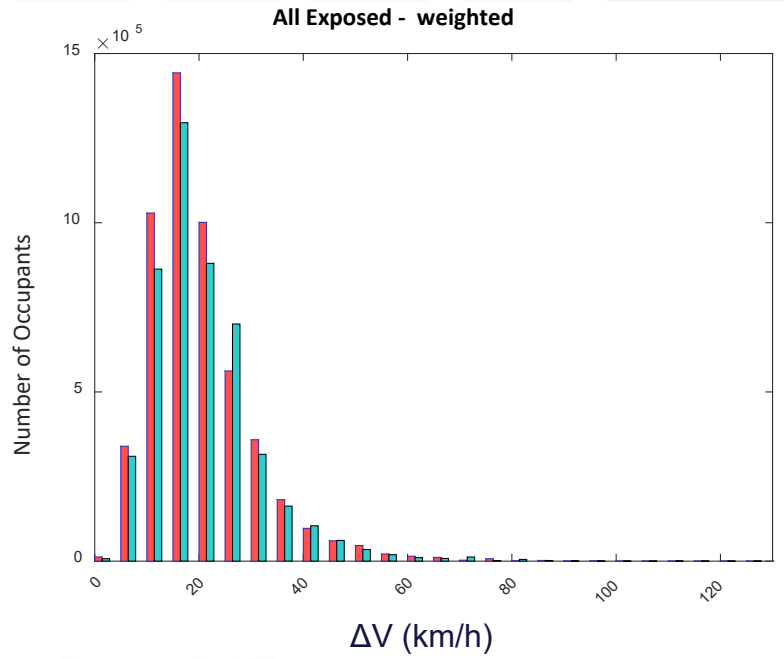
Review of Current Tools

CISS 2017-2022

- 34,873 total occupants
  - Exclude:
    - Age<13 (-2,585)
    - Rollover (-3,258)
    - Fire (-4,278)
    - Ejected (208)
    - No 3 point belt (-6,902)
  - Remain: 17,642 occupants
    - Represents 16 million
    - 77% Drivers
    - 54% Female





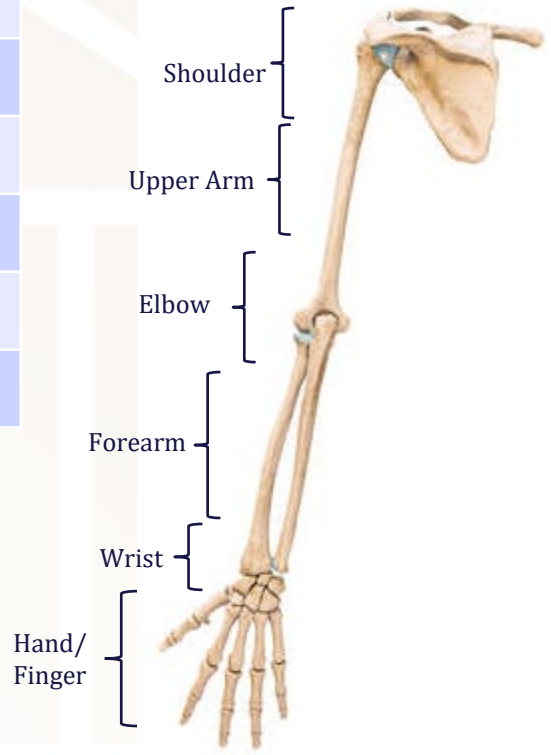


CISS 2017-2022

- Focus on single-event crashes
  - 9,814 occupants
    - 894 with AIS2+ Injury
      - 9.1% of Exposures (3.5% weighted)
      - 303 AIS3+
    - 265 with AIS2+ UX Injury
      - 30% of AIS2+ Inj. Cases
      - 2.7% of Exposures (0.9% weighted)

% of UX Injury Cases	
Shoulder	26.8%
Upper Arm	6.8%
Elbow	7.9%
Forearm	21.9%
Wrist	38.5%
Hand/Finger	15.5%
UX Other	3.8%

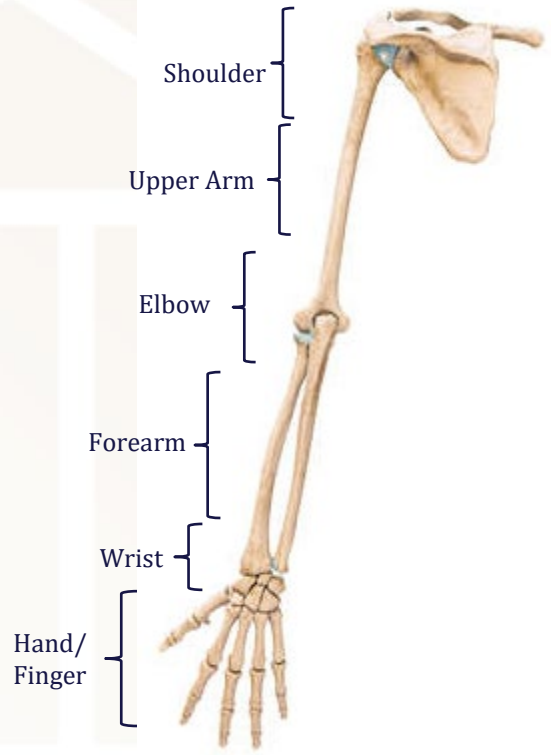
67% Clavicle



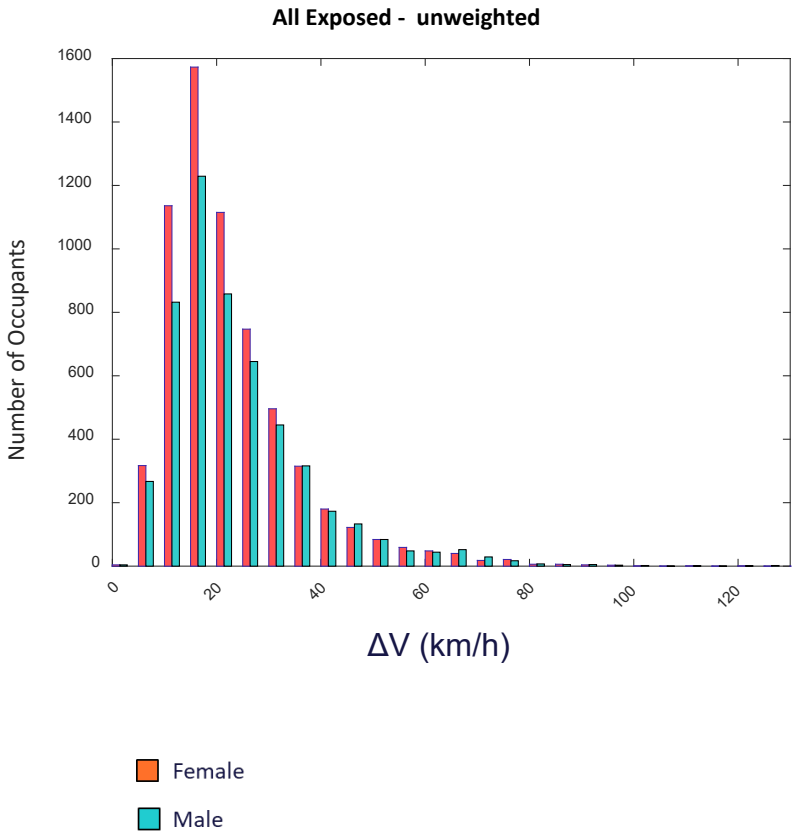
Driver vs. Passenger (Single Event)

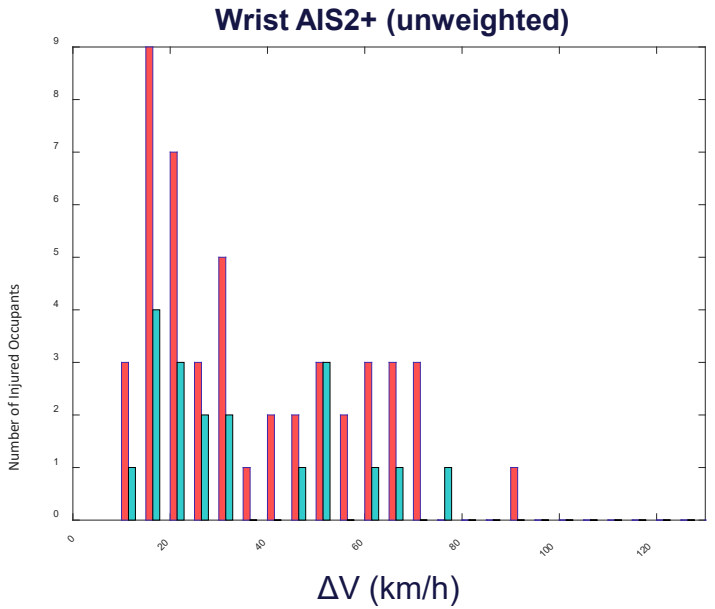
- Driver
  - 7,563 Occupants
    - 713 AIS2+ (9.4%)
    - 218 UX AIS2+ (2.9%)
      - 85% Frontal Airbag Deployment (compared to 72% for all AIS2+)
- Right Front Passenger
  - 1,760 Occupants
    - 155 AIS2+ (8.8%)
    - 41 UX AIS2+ (2.3%)
      - 88% Frontal Airbag Deployment (compared to 68% for all AIS2+)

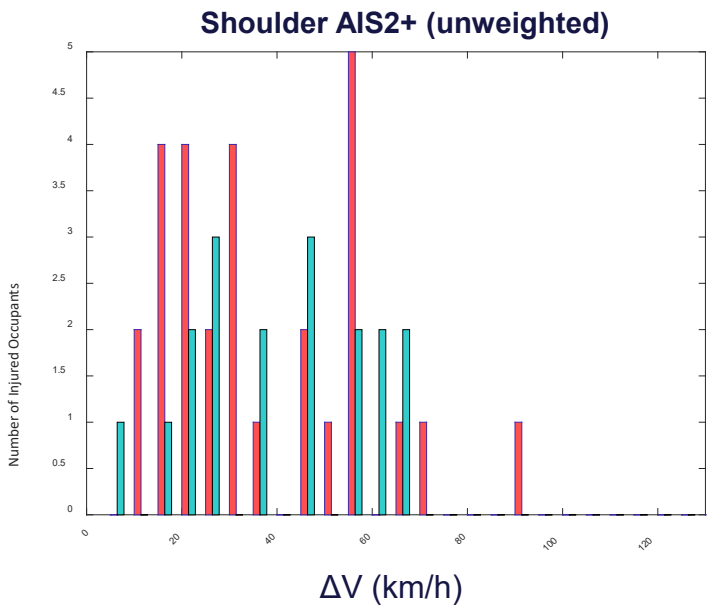
	Driver	Passenger
Shoulder	27.1%	24.4%
Upper Arm	6.0%	9.8%
Elbow	7.3%	12.2%
Forearm	22.5%	19.5%
Wrist	38.5%	39.0%
Hand/Finger	16.1%	12.2%
UX Other	3.2%	7.3%

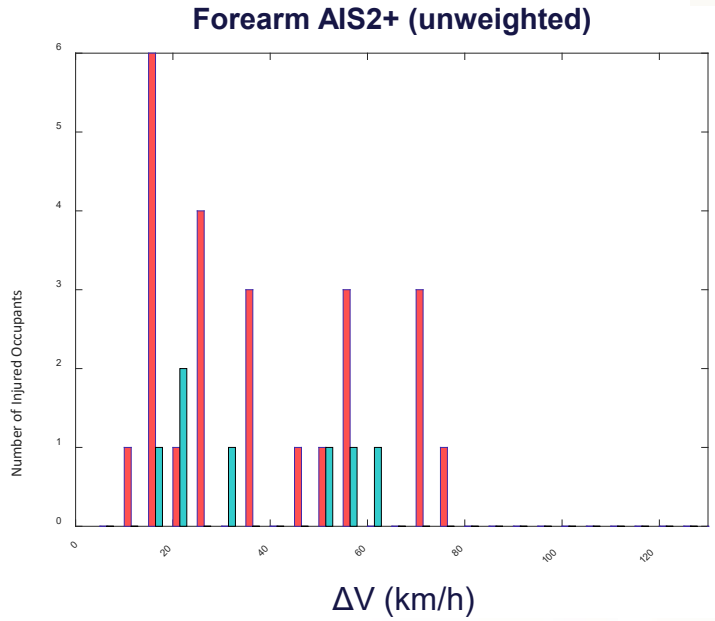


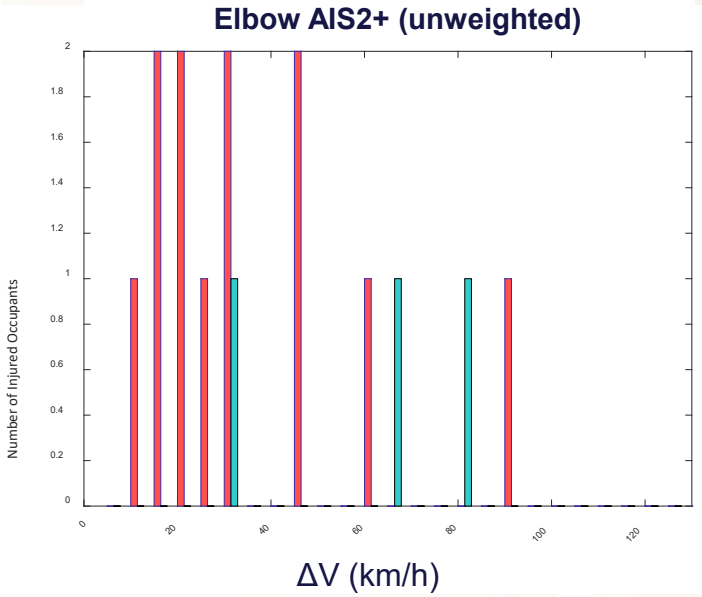
ΔV (Single Event)



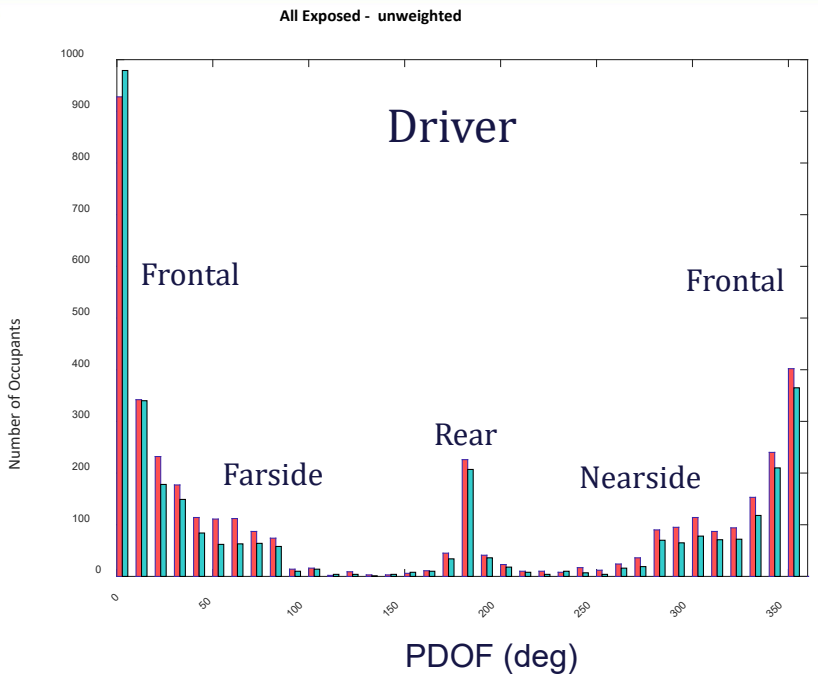


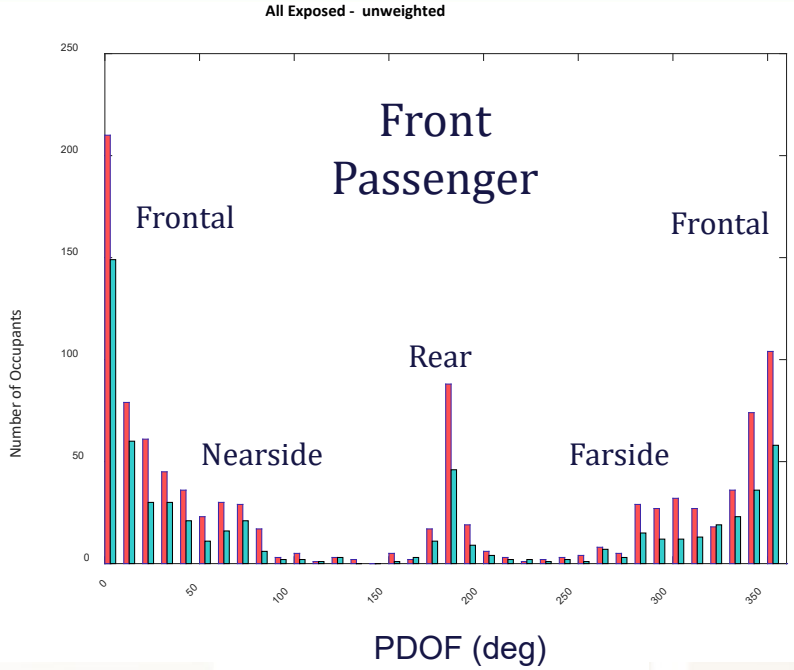


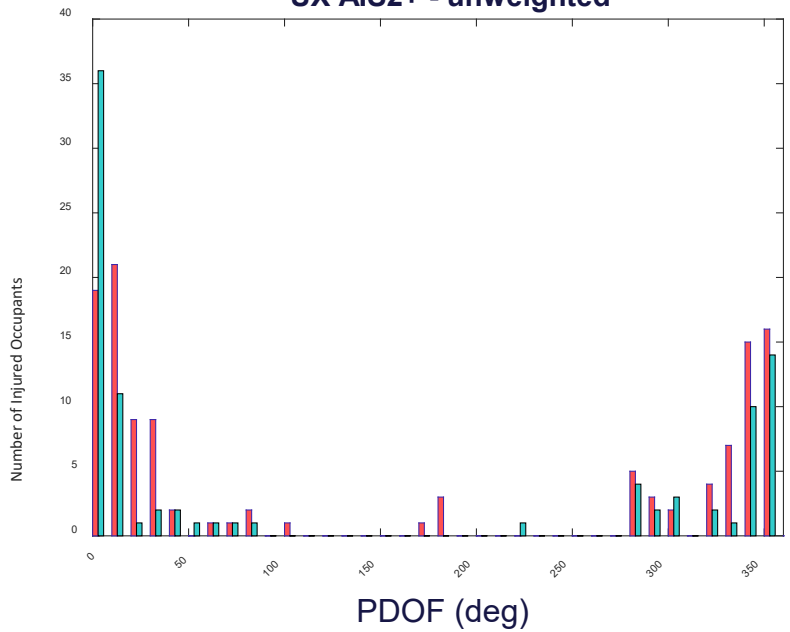


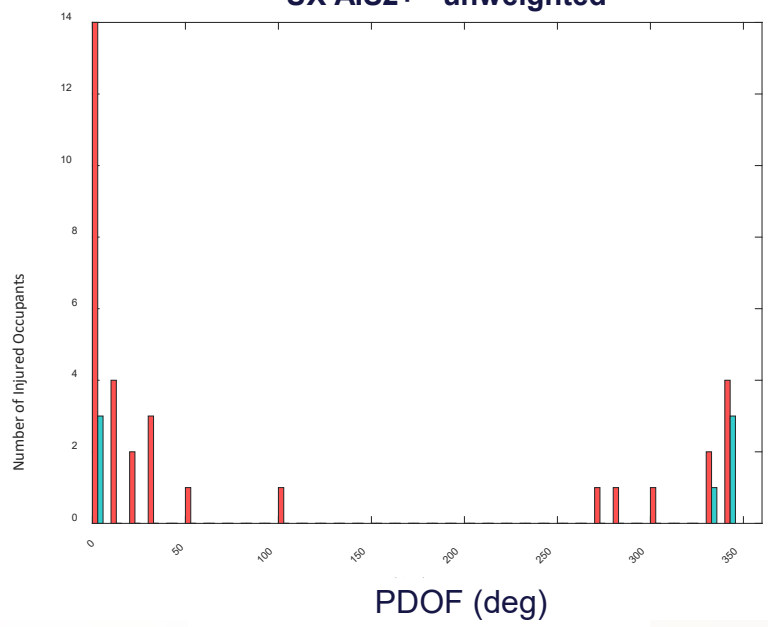


PDOF (Single Event)





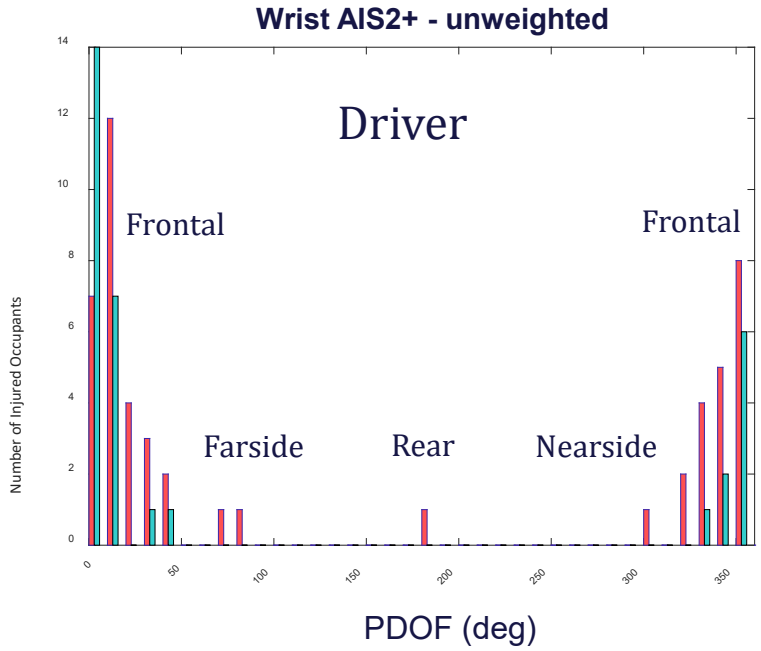


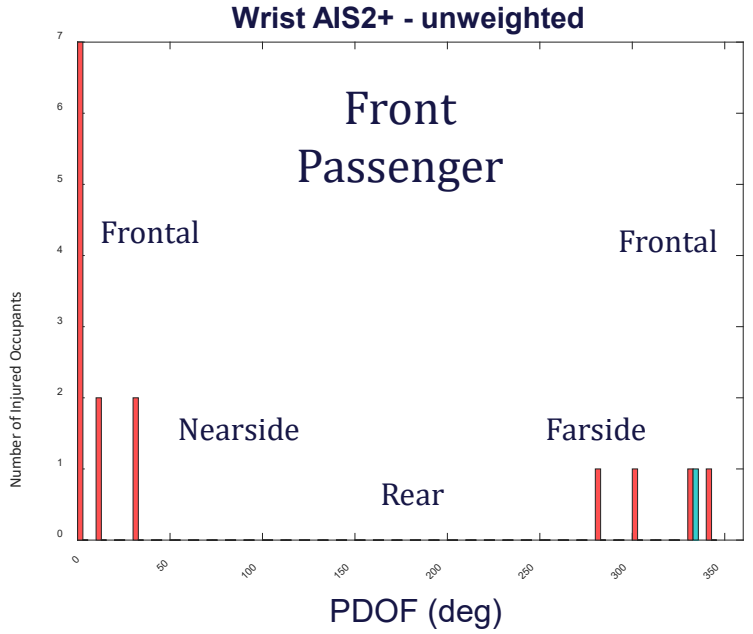


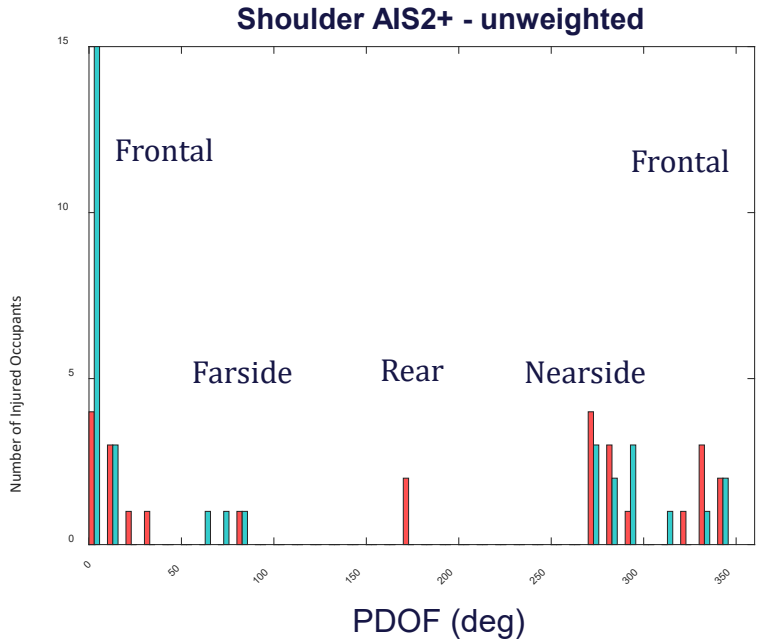
Female

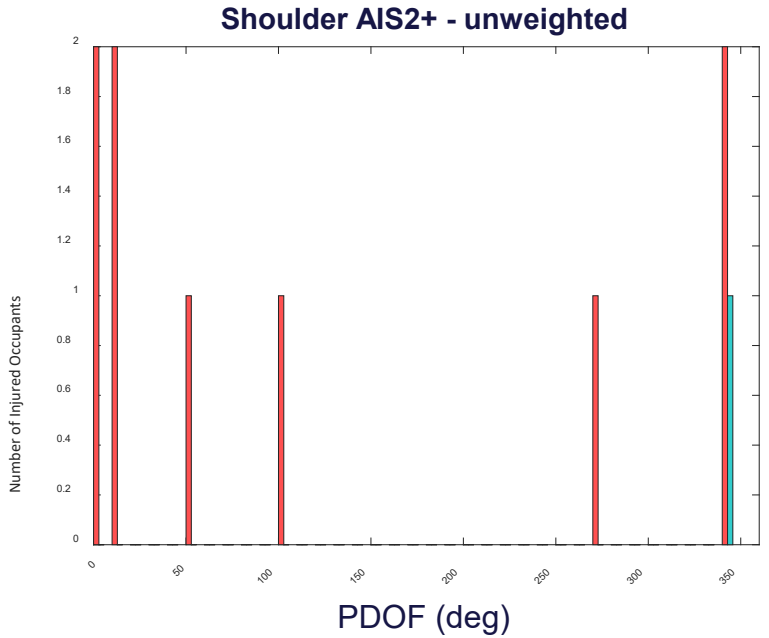
Male

PDOF (Single Event)









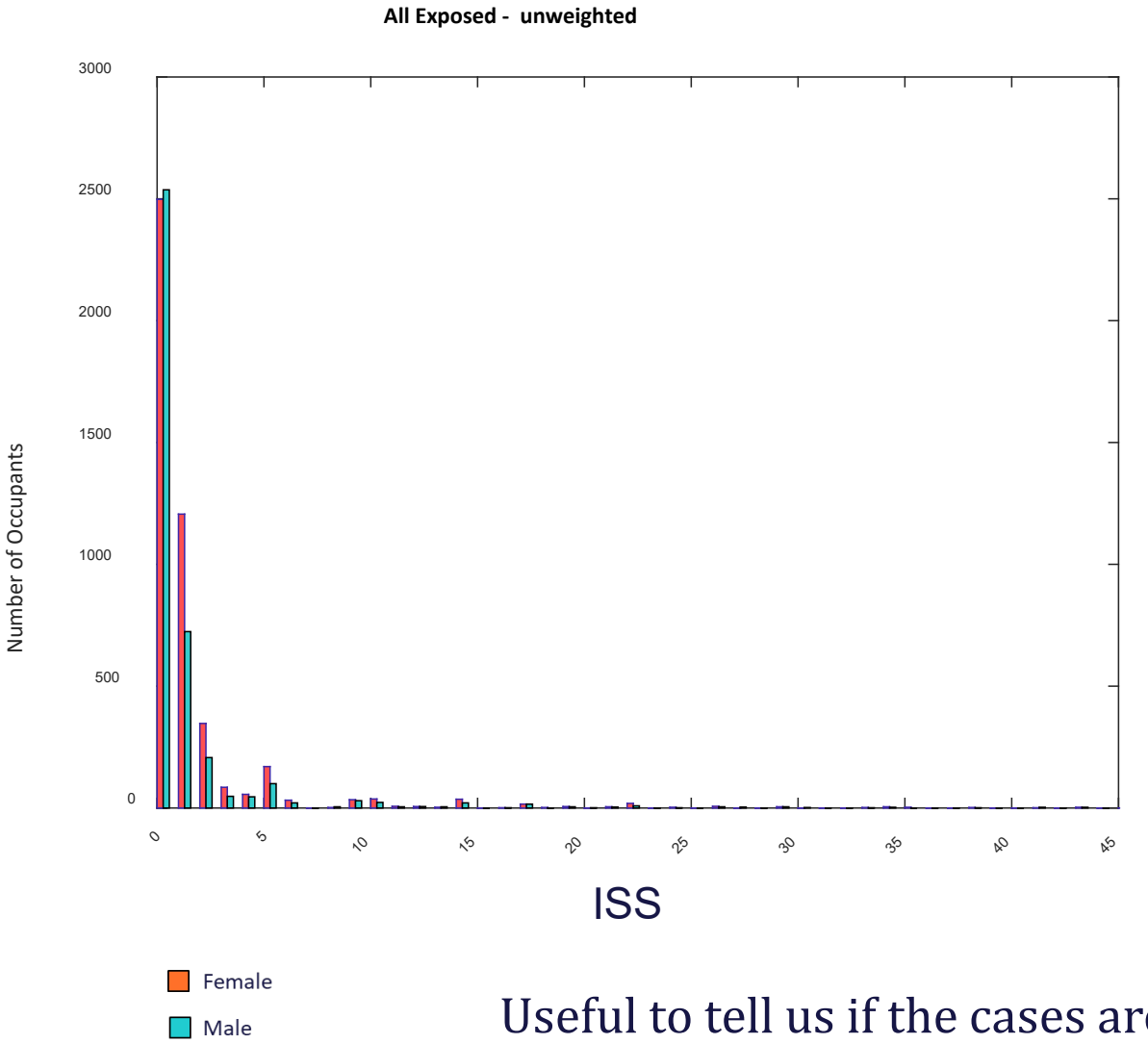
Female

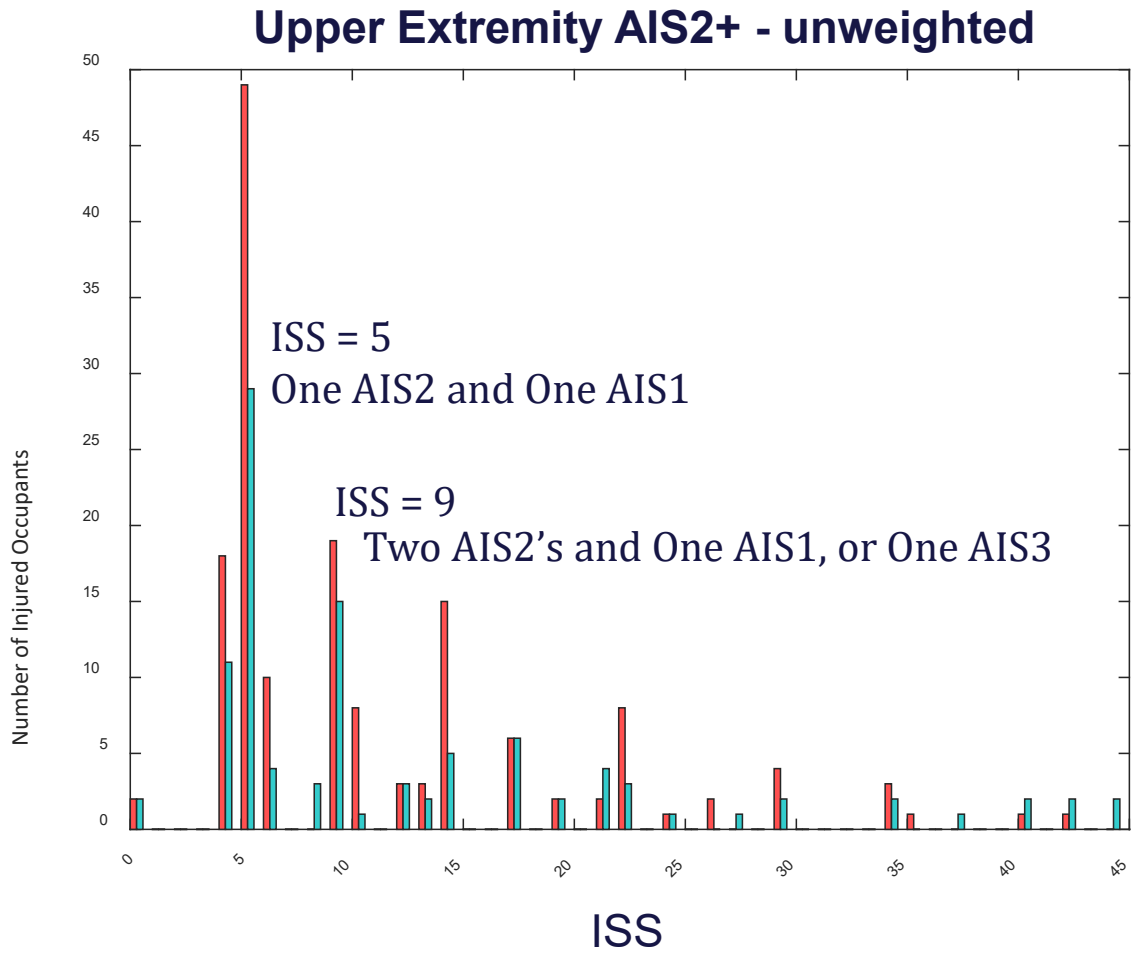
Male

ISS (Single Event)

$$ISS = (MAIS_1)^2 + (MAIS_2)^2 + (MAIS_3)^2$$

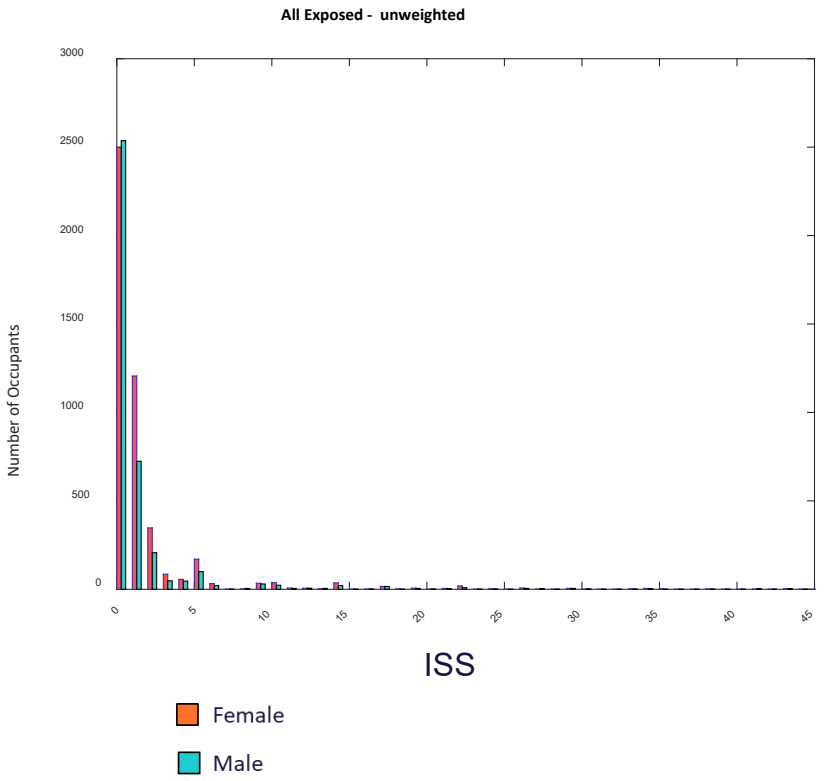
$MAIS_i$ = Max AIS Score in Each of 3 Body Regions

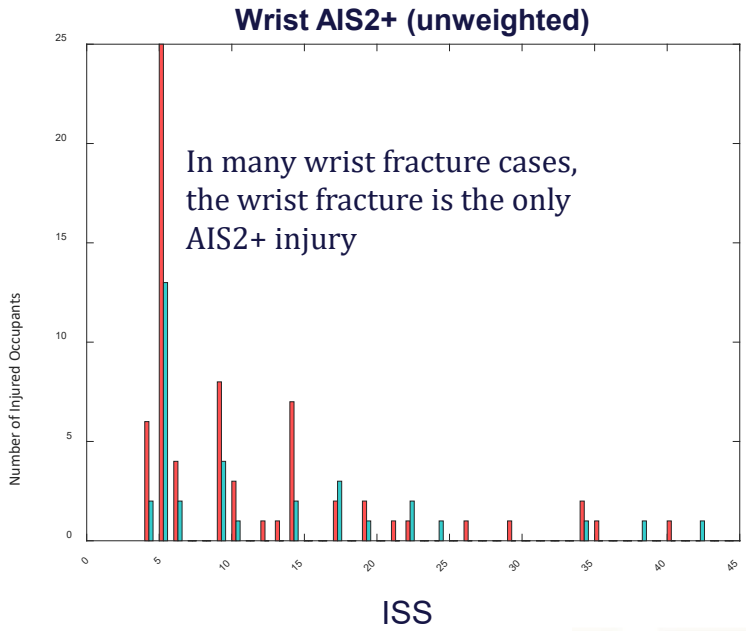




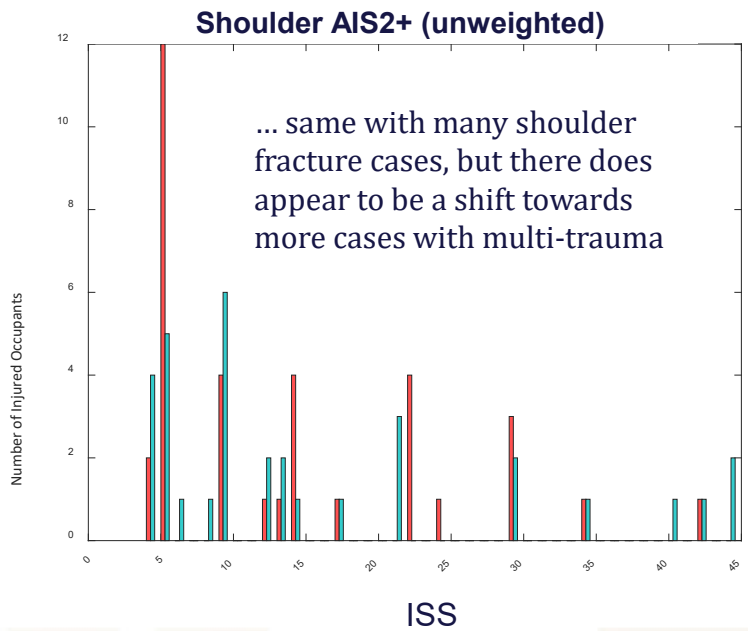
Useful to tell us if the cases are multi-trauma, or singular injuries

ISS (Single Event)

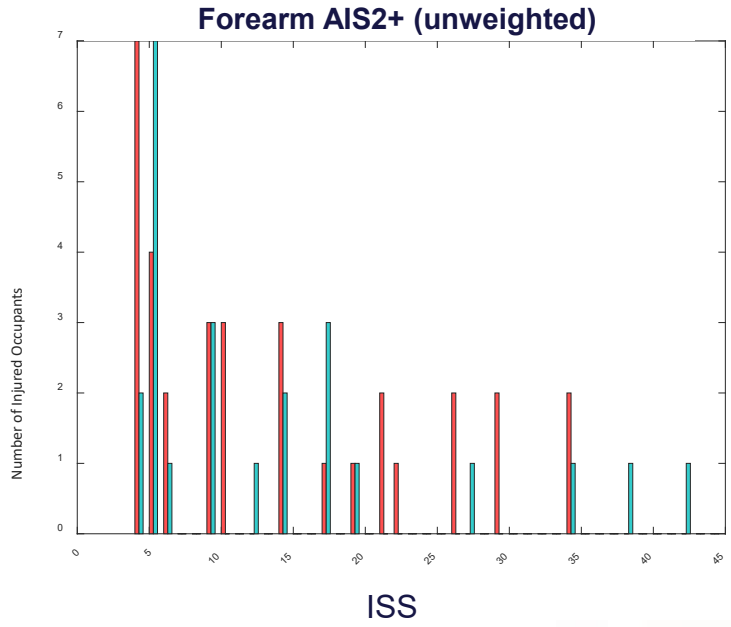


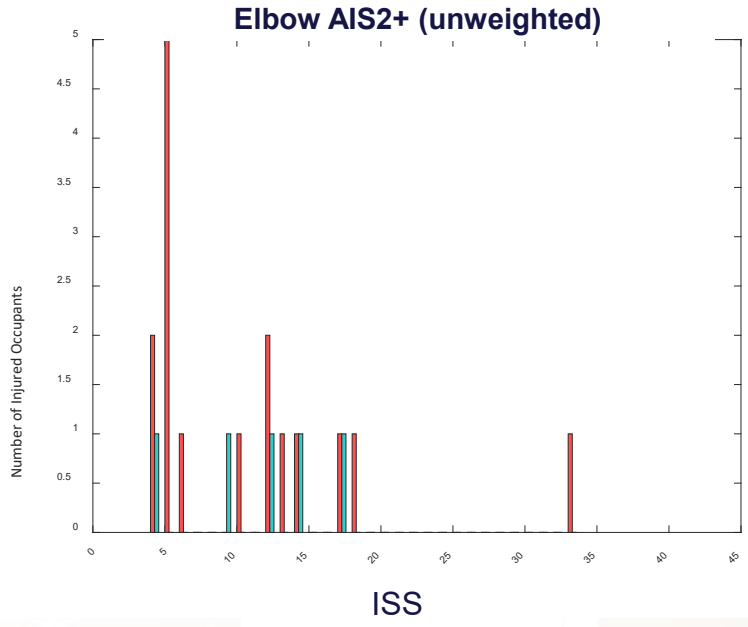


In many wrist fracture cases, the wrist fracture is the only AIS2+ injury



… same with many shoulder fracture cases, but there does appear to be a shift towards more cases with multi-trauma





Lessons learned (so far)*

- Upper extremity injuries are present in 30% of AIS2+ injury cases
  - Similar rate compared to AIS 2+ ribcase fx., lower extremity injury, brain injury
  - Most common: Wrist (39%), Shoulder (27%), Forearm (22%), Hand/Finger (16%)
- Similar upper extremity injury risks, injury distributions for drivers and right front passengers
  - Most in frontal impacts
  - Most with frontal airbag deployment (85-88%; compared to 68-72% for all AIS2+ inj. cases)
- Upper extremity injury cases tend to follow collision and occupant exposures, with some apparent shifts:
  - Wrist – higher BMI, shorter females, many cases as sole AIS2 injury
  - Shoulder – advanced age, nearside (though many still frontal), shift towards multi-trauma
  - Forearm – higher BMI, mid-sized stature
  - Elbow – relatively rare, and most cases that do occur are frontals

* All of the above are stats for single event crashes, unweighted

2016 Sedan (Full Size)

59 y.o. female
Right Front Passenger
173 cm 101 kg
33.7 BMI, ISS = 6
MAIS Rating: 2
EDR ΔV = N/A
ΔV = 28 kmph, 340° PDOF

L. Distal radius fracture-> partial articular; Colles
L. Superior Teeth facial fx.
Hematoma – L. wrist, L. chest, L. face

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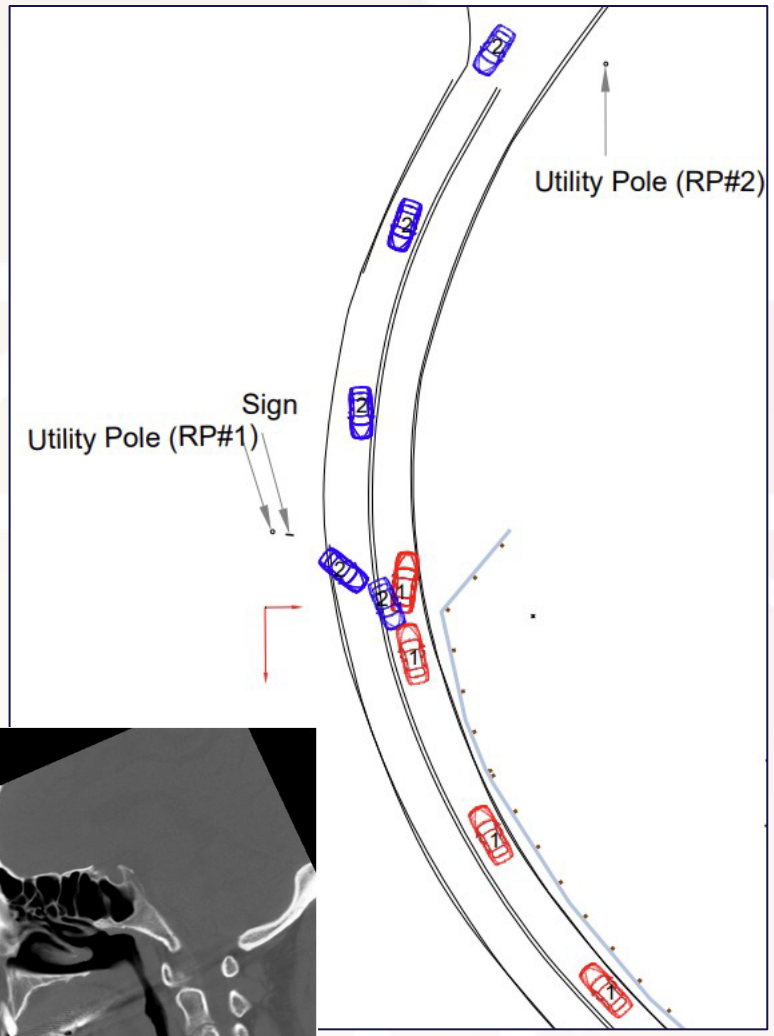

Exemplar Frontal-Oblique Crash Test (NHTSA Research Test)

Remaining Questions

- What other upper extremity research is available?
  - Field data studies
  - Biomechanics studies
- What should be targeted for prediction and prevention?
  - Injury types
  - Risk factors
  - Injury mechanisms
  - Causation scenarios
- What are the potential abilities of current tools?
  - ATD and HBM
  - Construction
  - Validation
  - Injury prediction capability

Literature Review

Field Data Analysis and Case Review

Review of Current Tools

State of Knowledge on Upper Extremity Injury Causation and Injury Prediction

Thank You RCCADS!

Questions?

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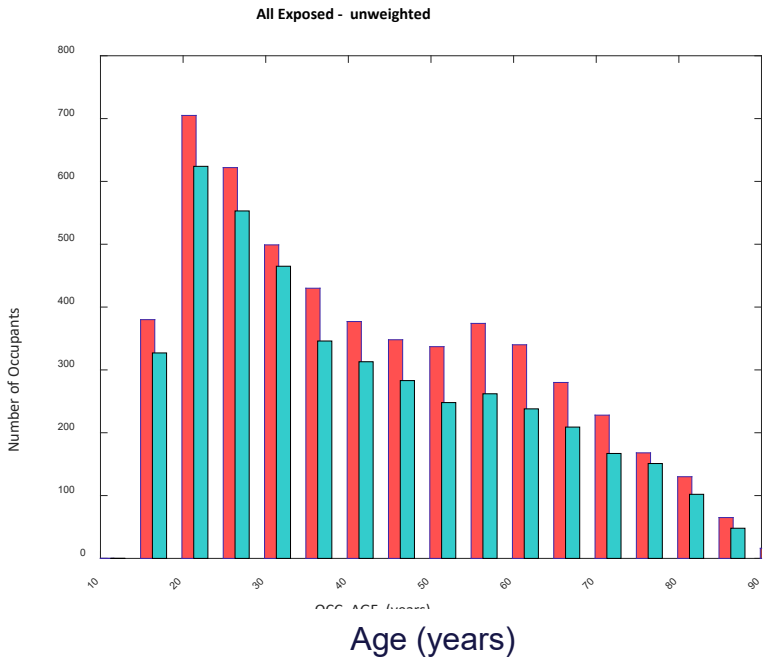
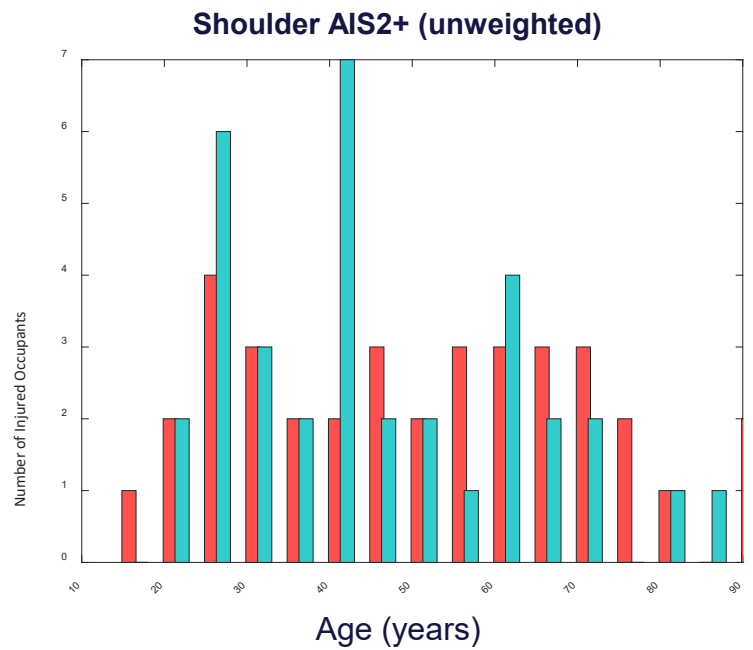
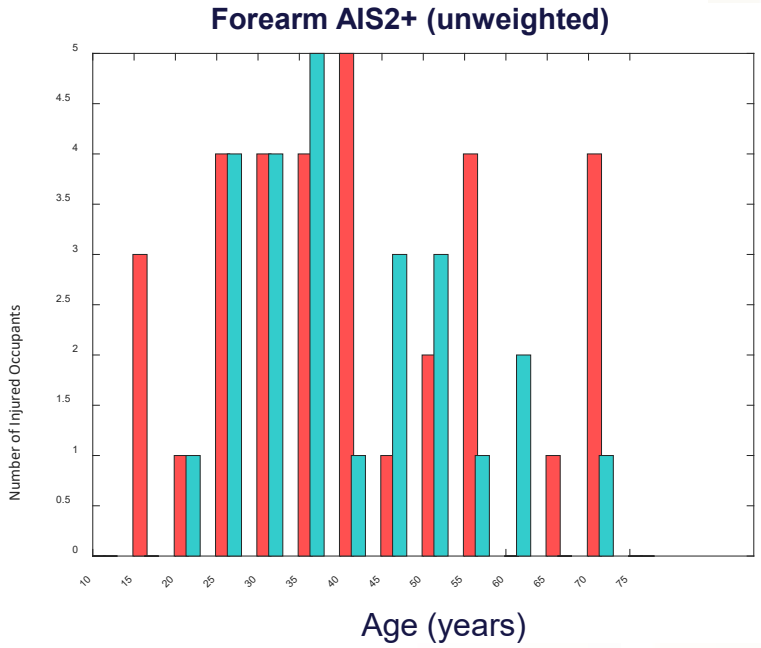
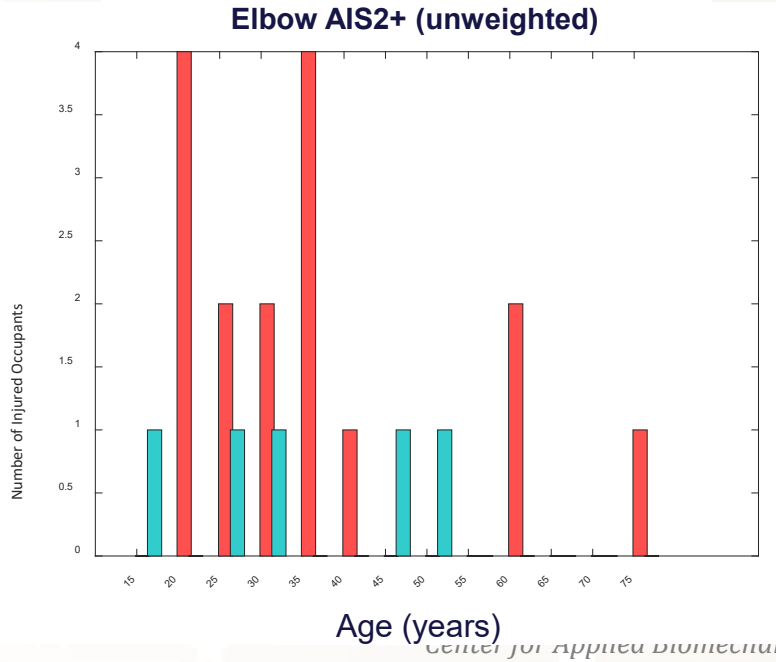
Age (Single Event)

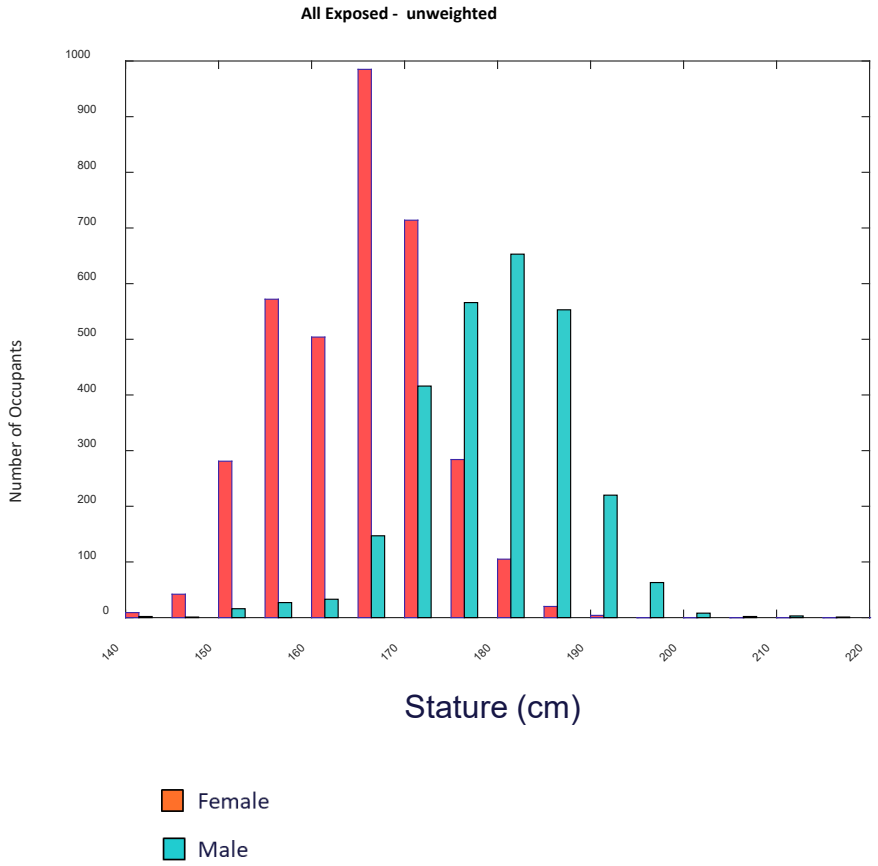


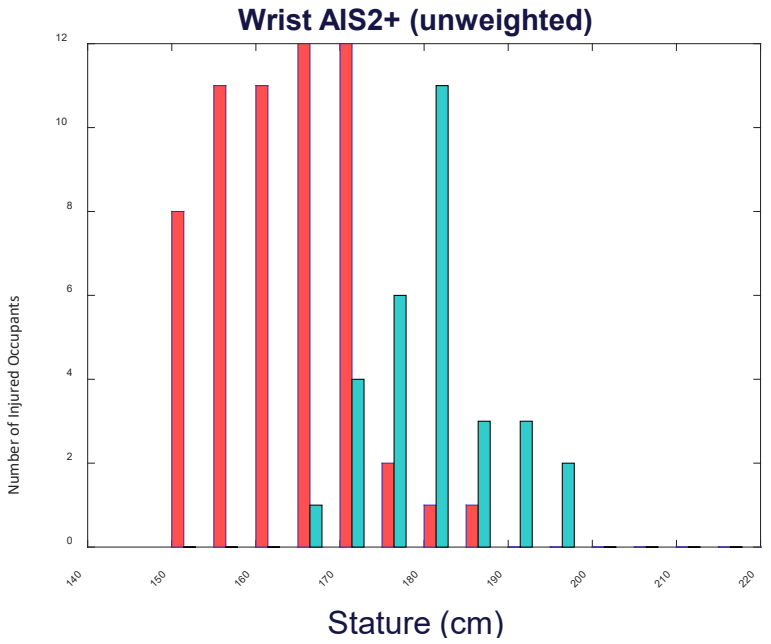


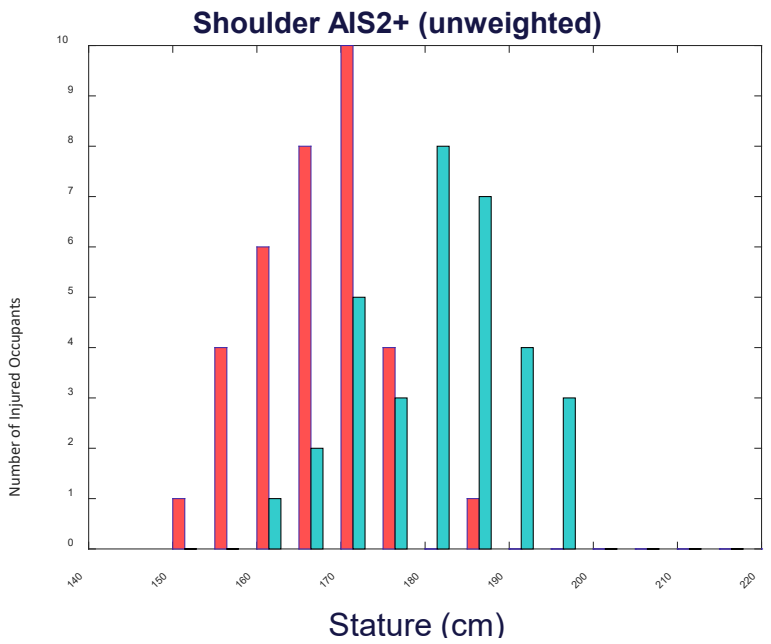


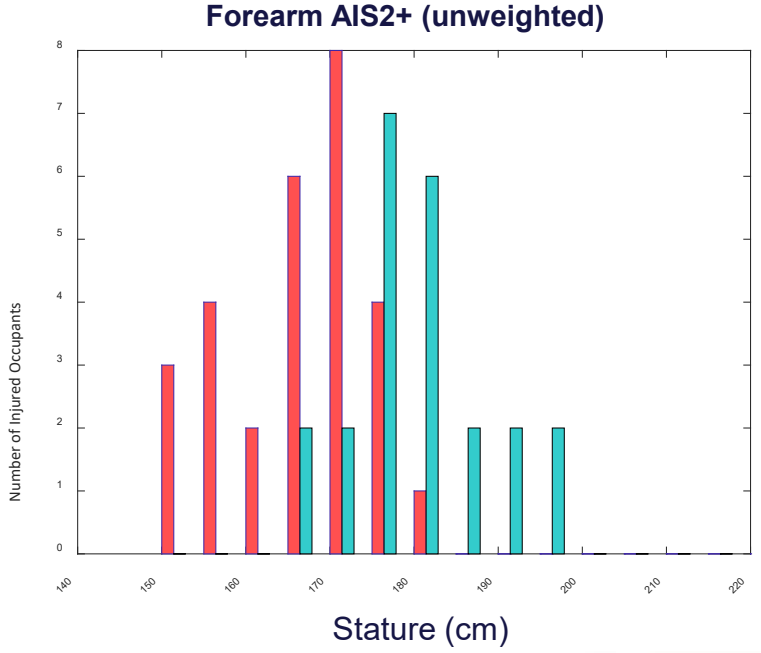


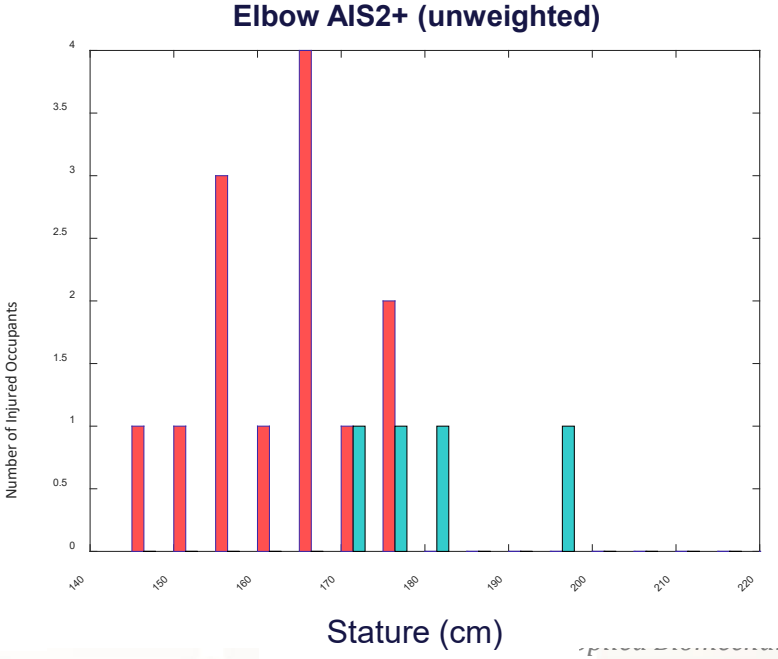
Stature (Single Event)



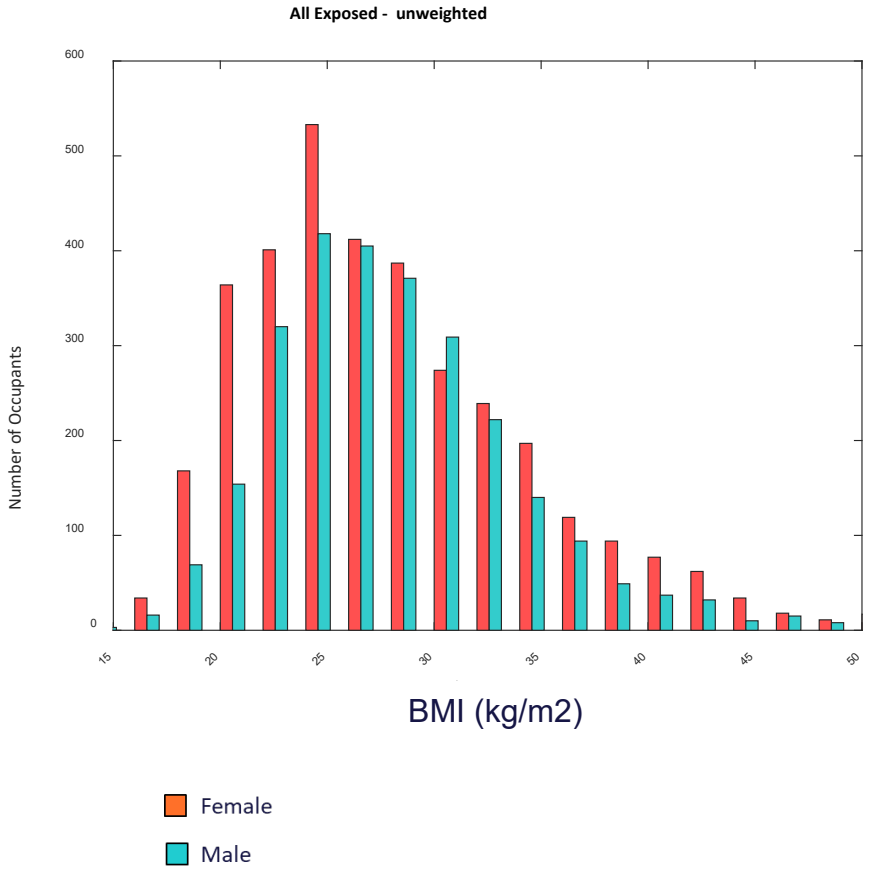


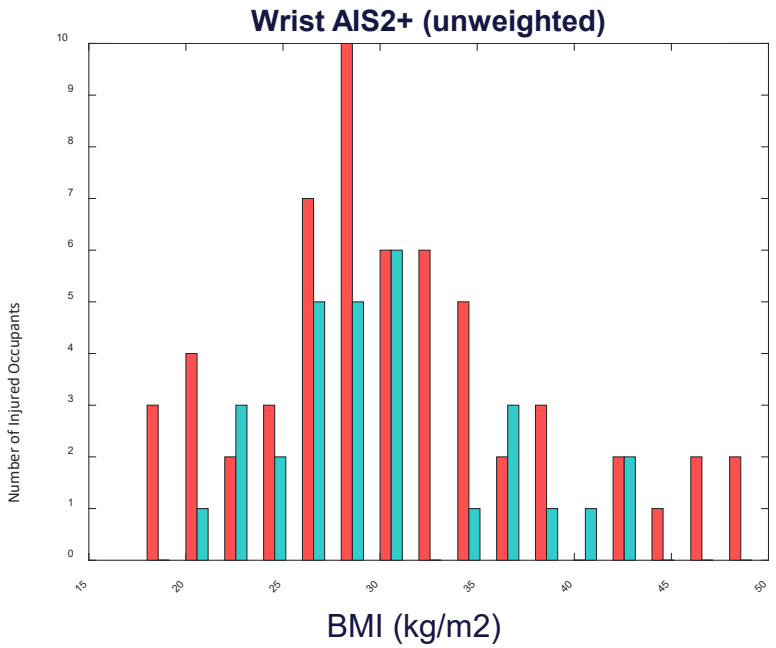


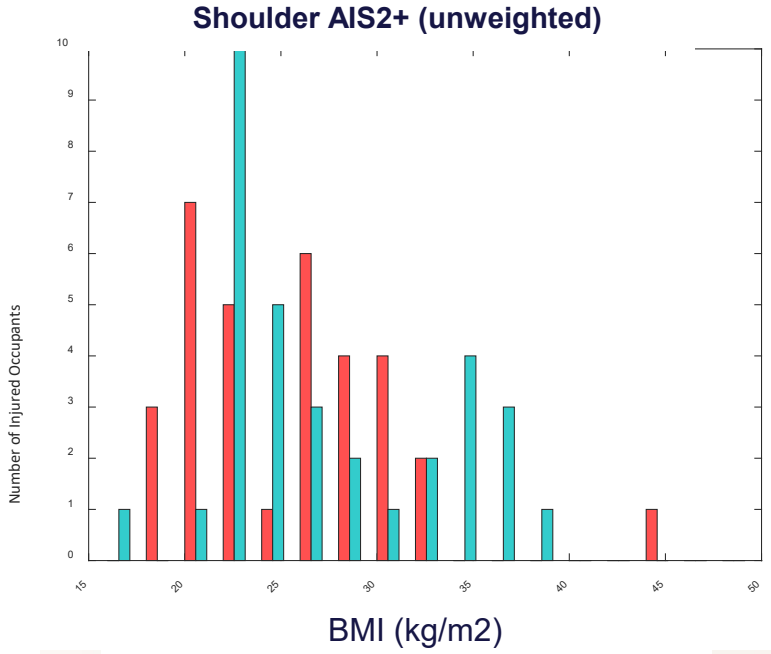


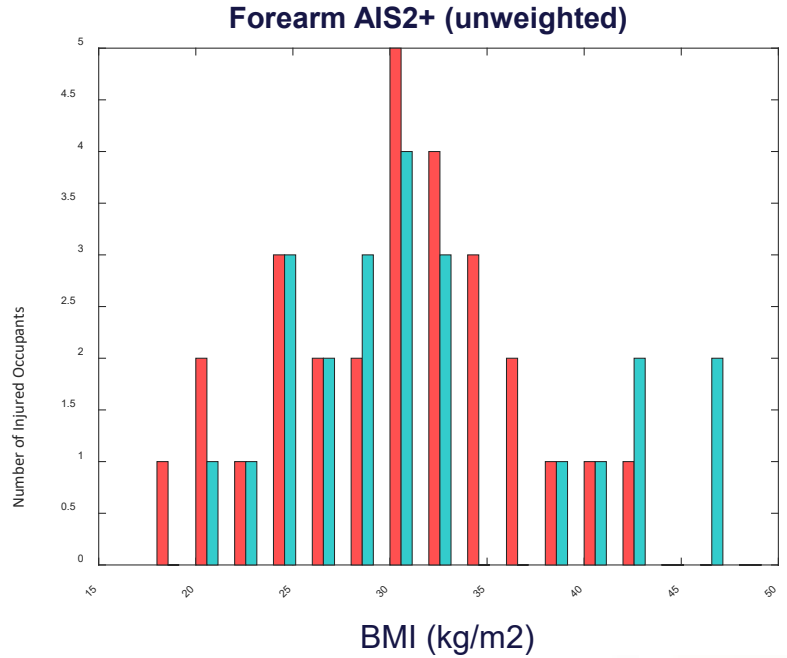


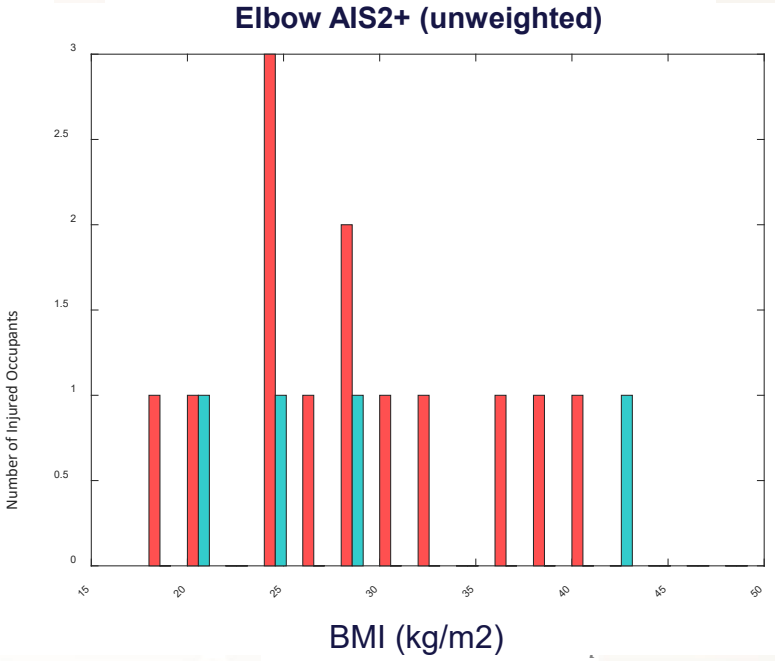
BMI (Single Event)



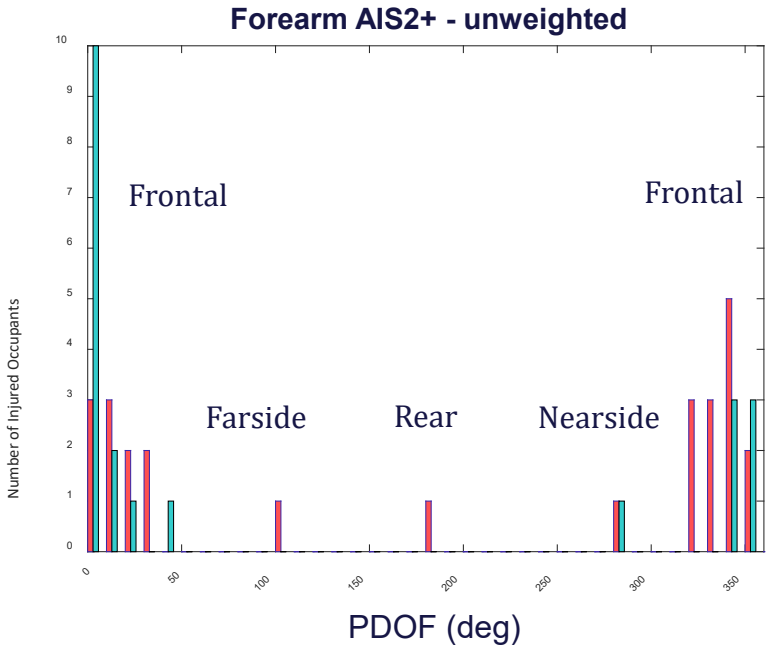


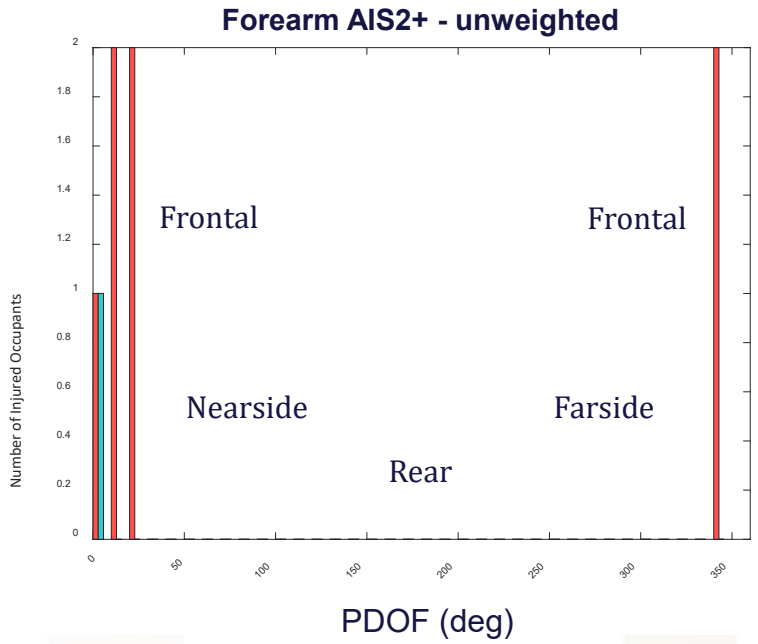


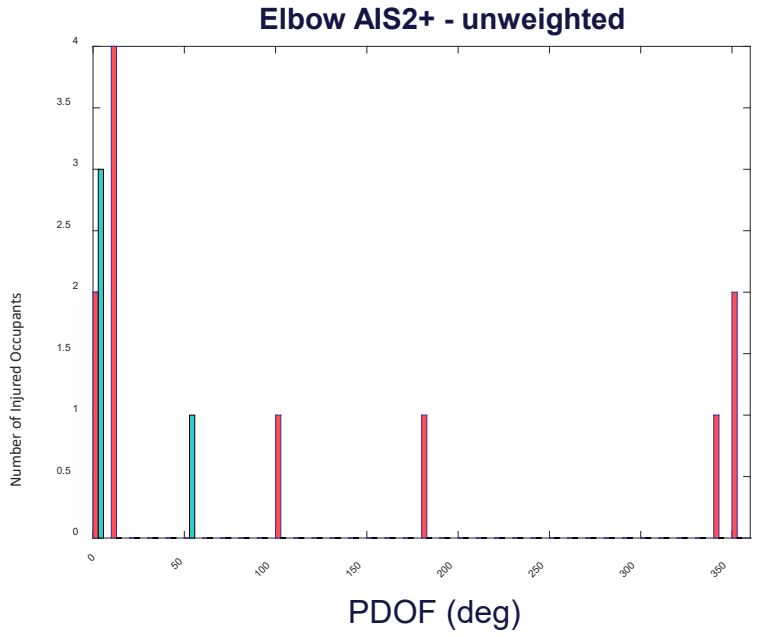


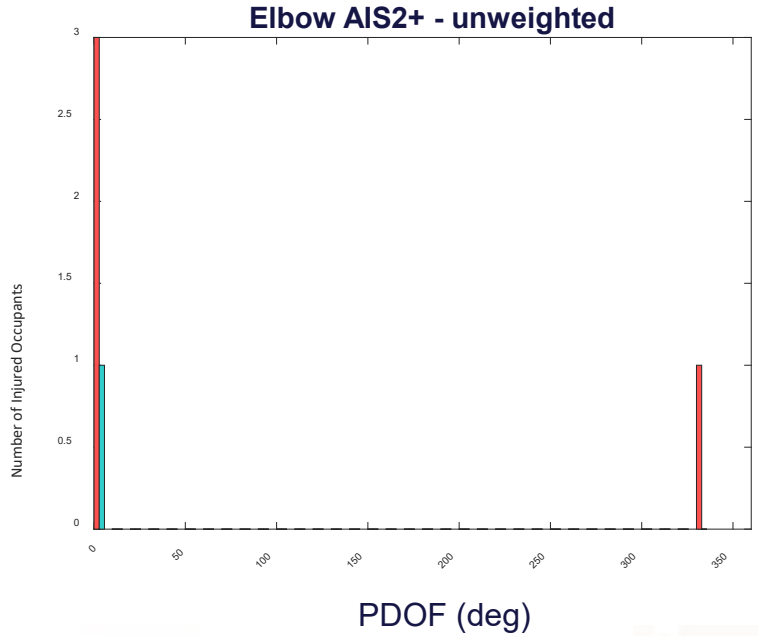


PDOF (Single Event)









Female

Male