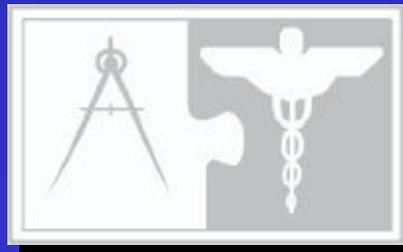


# Gender Differences Related to Offset MVCs

UAB CIREN Center

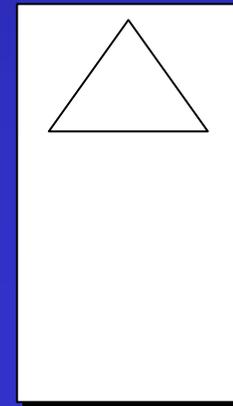
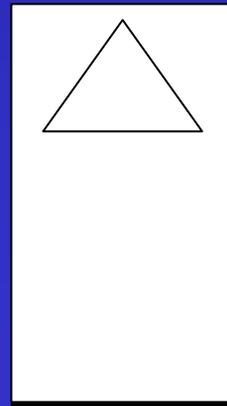
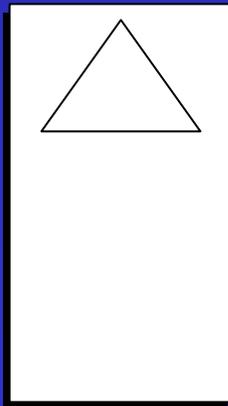
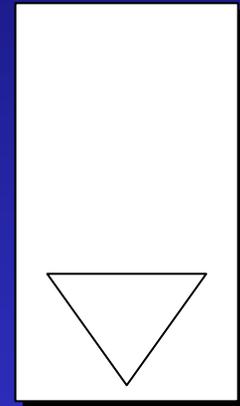
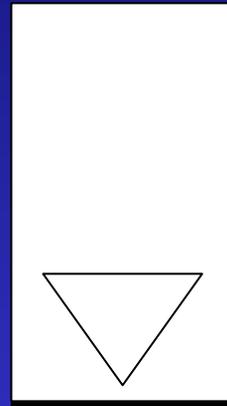
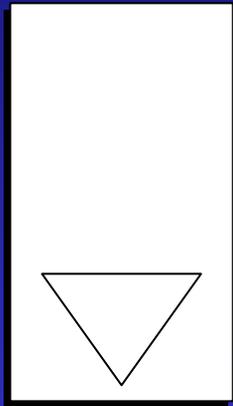


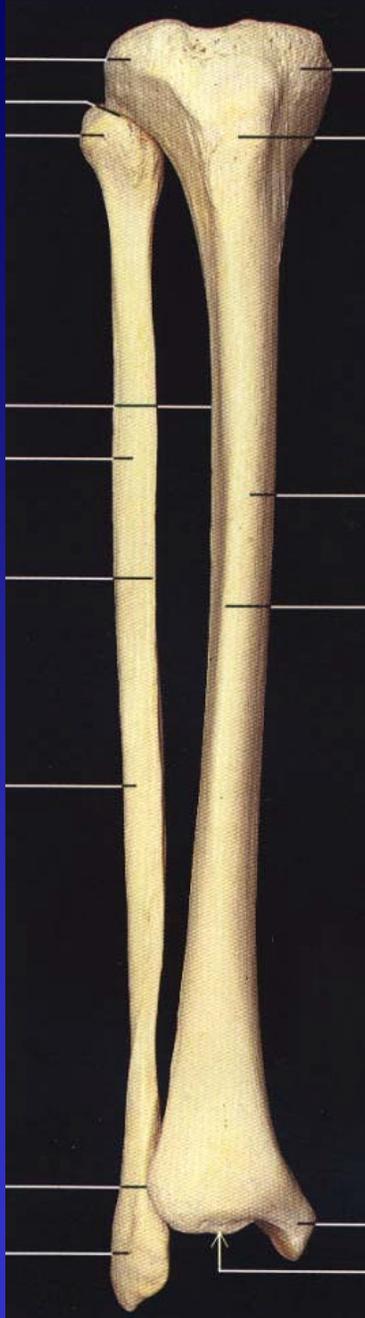
# Definitions

**Left Offset**

**Full Frontal**

**Right Offset**





Condylar

Plateau

Mid-Shaft

Malleolus

# Definitions

## *Tibia/Fibula Fracture*

NASS Definition of Tib/Fib Fx

- Tibia

Condyles

Med/Post Malleolus

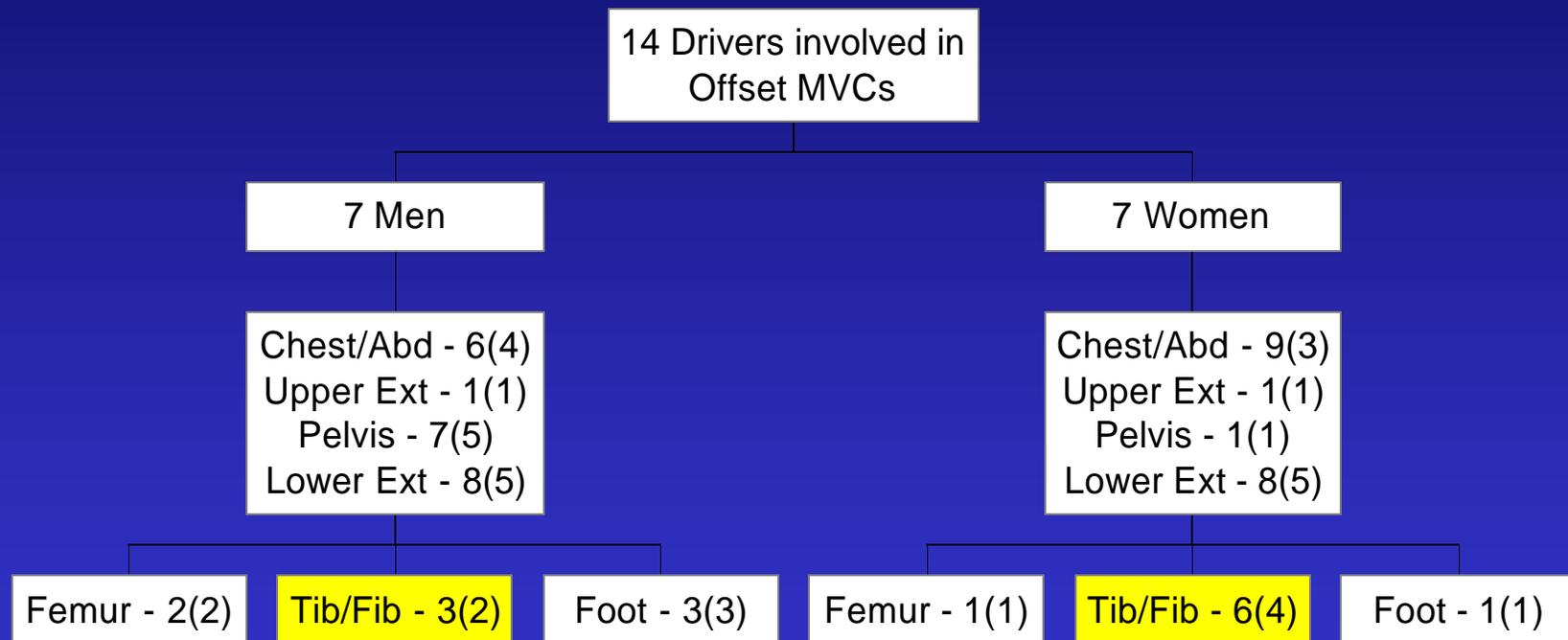
Shaft

-Fibula

Head/Neck/Shaft

Lateral Malleolus

# CIREN Cohort



# Patient Demographics

## *Male Patients*

	<b>Age (yrs)</b>	<b>Mass (kg)</b>	<b>Height (cm)</b>	<b>Seat Position</b>	<b>Belt/Air Bag</b>	<b>Tib/Fib Fracture</b>
<b>#1</b>	<b>51</b>	<b>82</b>	<b>173</b>	<b>Forward</b>	<b>-/-</b>	<b>-</b>
<b>#2</b>	<b>24</b>	<b>82</b>	<b>165</b>	<b>Middle</b>	<b>+/N/A</b>	<b>-</b>
<b>#3</b>	<b>40</b>	<b>100</b>	<b>182</b>	<b>Rear</b>	<b>-/+</b>	<b>-</b>
<b>#4</b>	<b>48</b>	<b>89</b>	<b>180</b>	<b>Middle</b>	<b>-/+</b>	<b>-</b>
<b>#5</b>	<b>78</b>	<b>76</b>	<b>165</b>	<b>Middle</b>	<b>+/N/A</b>	<b>-</b>
<b>#6</b>	<b>35</b>	<b>115</b>	<b>185</b>	<b>Rear</b>	<b>-/+</b>	<b>+</b>
<b>#7</b>	<b>37</b>	<b>118</b>	<b>175</b>	<b>Rear</b>	<b>+/N/A</b>	<b>+</b>

# Patient Demographics

## *Female Patients*

	<b>Age (yrs)</b>	<b>Mass (kg)</b>	<b>Height (cm)</b>	<b>Seat Position</b>	<b>Belt/Air Bag</b>	<b>Tib/Fib Fracture</b>
<b>#1</b>	<b>26</b>	<b>58</b>	<b>158</b>	<b>Middle</b>	<b>+/+</b>	<b>-</b>
<b>#2</b>	<b>16</b>	<b>80</b>	<b>160</b>	<b>Middle</b>	<b>+/N/A</b>	<b>-</b>
<b>#3</b>	<b>24</b>	<b>76</b>	<b>170</b>	<b>Forward</b>	<b>-/+</b>	<b>-</b>
<b>#4</b>	<b>39</b>	<b>91</b>	<b>168</b>	<b>Forward</b>	<b>+/+</b>	<b>+</b>
<b>#5</b>	<b>34</b>	<b>52</b>	<b>152</b>	<b>Forward</b>	<b>+/+</b>	<b>+</b>
<b>#6</b>	<b>20</b>	<b>57</b>	<b>168</b>	<b>Forward</b>	<b>-/+</b>	<b>+</b>
<b>#7</b>	<b>54</b>	<b>86</b>	<b>142</b>	<b>Forward</b>	<b>+/+</b>	<b>+</b>

# Patient Demographics

## *Comparison of Patients with Tibia/Fibula Fractures*

<b>Gender</b>	<b>Age (yrs)</b>	<b>Mass (kg)</b>	<b>Height (cm)</b>	<b>Seat Position</b>	<b>Belt/Air Bag</b>	<b>Tib/Fib Fracture</b>
<b>M</b>	<b>35</b>	<b>115</b>	<b>185</b>	<b>Rear</b>	<b>-/+</b>	<b>+</b>
<b>M</b>	<b>37</b>	<b>118</b>	<b>175</b>	<b>Rear</b>	<b>+/N/A</b>	<b>+</b>
<b>F</b>	<b>39</b>	<b>91</b>	<b>168</b>	<b>Forward</b>	<b>+/+</b>	<b>+</b>
<b>F</b>	<b>34</b>	<b>52</b>	<b>152</b>	<b>Forward</b>	<b>+/+</b>	<b>+</b>
<b>F</b>	<b>20</b>	<b>57</b>	<b>168</b>	<b>Forward</b>	<b>-/+</b>	<b>+</b>
<b>F</b>	<b>54</b>	<b>86</b>	<b>142</b>	<b>Forward</b>	<b>+/+</b>	<b>+</b>

# Crash Characteristics

## *Male Patients*

	<b>Collision</b>	<b>Delta-V</b>	<b>Seat Position</b>	<b>Toe/pan Intrusion</b>	<b>Tib/Fib Fracture</b>
<b>#1</b>	<b>Left Offset</b>	<b>54 kph</b>	<b>Middle</b>	<b>18 cm</b>	<b>-</b>
<b>#2</b>	<b>Right Offset</b>	<b>115 kph</b>	<b>Middle</b>	<b>55 cm</b>	<b>-</b>
<b>#3</b>	<b>Right Offset</b>	<b>60 kph</b>	<b>Rear</b>	<b>34 cm</b>	<b>-</b>
<b>#4</b>	<b>Right Offset</b>	<b>94 kph</b>	<b>Middle</b>	<b>0 cm</b>	<b>-</b>
<b>#5</b>	<b>Left Offset</b>	<b>27 kph</b>	<b>Middle</b>	<b>31 cm</b>	<b>-</b>
<b>#6</b>	<b>Right Offset</b>	<b>48 kph</b>	<b>Rear</b>	<b>7 cm</b>	<b>+</b>
<b>#7</b>	<b>Left Offset</b>	<b>30 kph</b>	<b>Rear</b>	<b>23 cm</b>	<b>+</b>

# Crash Characteristics

## *Female Patients*

	<b>Collision</b>	<b>Delta-V</b>	<b>Seat Position</b>	<b>Toe/pan Intrusion</b>	<b>Tib/Fib Fracture</b>
<b>#1</b>	<b>Right Offset</b>	<b>73 kph</b>	<b>Middle</b>	<b>19 cm</b>	<b>-</b>
<b>#2</b>	<b>Right Offset</b>	<b>28 kph</b>	<b>Middle</b>	<b>11 cm</b>	<b>-</b>
<b>#3</b>	<b>Left Offset</b>	<b>48 kph</b>	<b>Forward</b>	<b>15 cm</b>	<b>-</b>
<b>#4</b>	<b>Left Offset</b>	<b>19 kph</b>	<b>Forward</b>	<b>5 cm</b>	<b>+</b>
<b>#5</b>	<b>Left Offset</b>	<b>55 kph</b>	<b>Forward</b>	<b>52 cm</b>	<b>+</b>
<b>#6</b>	<b>Left Offset</b>	<b>56 kph</b>	<b>Forward</b>	<b>13 cm</b>	<b>+</b>
<b>#7</b>	<b>Left Offset</b>	<b>29 kph</b>	<b>Forward</b>	<b>0 cm</b>	<b>+</b>

# Crash Characteristics

## *Comparison of Patients with Tibia/Fibula Fractures*

<b>Gender</b>	<b>Collision</b>	<b>Delta-V</b>	<b>Seat Position</b>	<b>Toepan Intrusion</b>
<b>M</b>	<b>Right Offset</b>	<b>48 kph</b>	<b>Rear</b>	<b>7 cm</b>
<b>M</b>	<b>Left Offset</b>	<b>30 kph</b>	<b>Rear</b>	<b>23 cm</b>
<b>F</b>	<b>Left Offset</b>	<b>55 kph</b>	<b>Forward</b>	<b>52 cm</b>
<b>F</b>	<b>Left Offset</b>	<b>56 kph</b>	<b>Forward</b>	<b>13 cm</b>
<b>F</b>	<b>Left Offset</b>	<b>19 kph</b>	<b>Forward</b>	<b>5 cm</b>
<b>F</b>	<b>Left Offset</b>	<b>29 kph</b>	<b>Forward</b>	<b>0 cm</b>

# Crash Characteristics

## *Comparison of Patients with Tibia/Fibula Fractures*

<b>Gender</b>	<b>Collision</b>	<b>Delta-V</b>	<b>Seat Position</b>	<b>Toe pan Intrusion</b>
<b>M</b>	<b>Right Offset</b>	<b>48 kph</b>	<b>Rear</b>	<b>7 cm</b>
<b>M</b>	<b>Left Offset</b>	<b>30 kph</b>	<b>Rear</b>	<b>23 cm</b>
<b>F</b>	<b>Left Offset</b>	<b>55 kph</b>	<b>Forward</b>	<b>52 cm</b>
<b>F</b>	<b>Left Offset</b>	<b>56 kph</b>	<b>Forward</b>	<b>13 cm</b>
<b>F</b>	<b>Left Offset</b>	<b>19 kph</b>	<b>Forward</b>	<b>5 cm</b>
<b>F</b>	<b>Left Offset</b>	<b>29 kph</b>	<b>Forward</b>	<b>0 cm</b>

# Case Photographs



# Crash Characteristics

## *Comparison of Patients with Tibia/Fibula Fractures*

Gender	Collision	Delta-V	Seat Position	Toepan Intrusion
M	Right Offset	48 kph	Rear	7 cm
<b>M</b>	<b>Left Offset</b>	<b>30 kph</b>	<b>Rear</b>	<b>23 cm</b>
F	Left Offset	55 kph	Forward	52 cm
F	Left Offset	56 kph	Forward	13 cm
F	Left Offset	19 kph	Forward	5 cm
F	Left Offset	29 kph	Forward	0 cm

# Case Photographs



# Crash Characteristics

## *Comparison of Patients with Tibia/Fibula Fractures*

<b>Gender</b>	<b>Collision</b>	<b>Delta-V</b>	<b>Seat Position</b>	<b>Toepan Intrusion</b>
M	Right Offset	48 kph	Rear	7 cm
M	Left Offset	30 kph	Rear	23 cm
<b>F</b>	<b>Left Offset</b>	<b>55 kph</b>	<b>Forward</b>	<b>52 cm</b>
F	Left Offset	56 kph	Forward	13 cm
F	Left Offset	19 kph	Forward	5 cm
F	Left Offset	29 kph	Forward	0 cm

# Case Photographs



# Crash Characteristics

## *Comparison of Patients with Tibia/Fibula Fractures*

Gender	Collision	Delta-V	Seat Position	Toe pan Intrusion
M	Right Offset	48 kph	Rear	7 cm
M	Left Offset	30 kph	Rear	23 cm
F	Left Offset	55 kph	Forward	52 cm
<b>F</b>	<b>Left Offset</b>	<b>56 kph</b>	<b>Forward</b>	<b>13 cm</b>
F	Left Offset	19 kph	Forward	5 cm
F	Left Offset	29 kph	Forward	0 cm

# Case Photographs

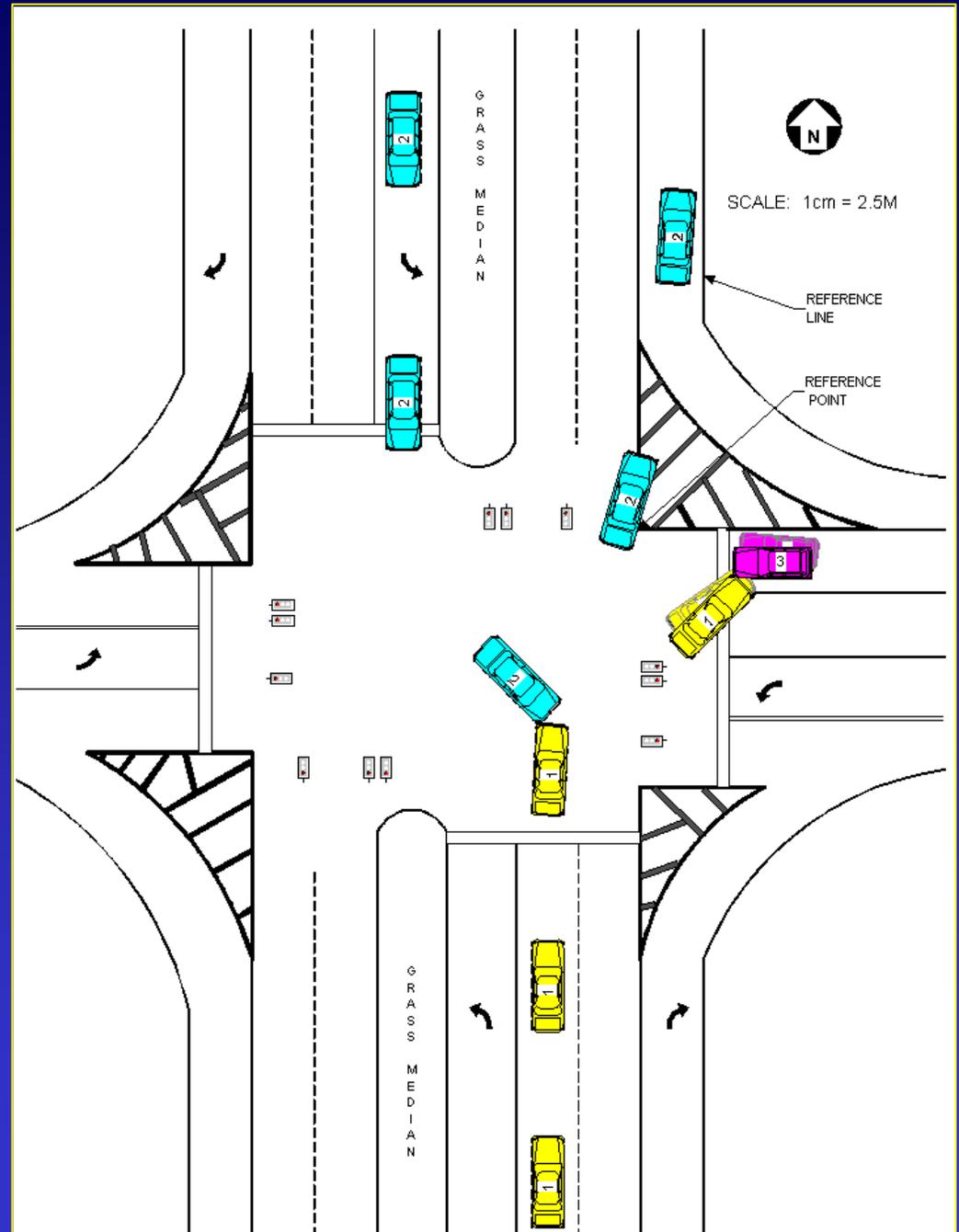


# Crash Characteristics

## *Comparison of Patients with Tibia/Fibula Fractures*

<b>Gender</b>	<b>Collision</b>	<b>Delta-V</b>	<b>Seat Position</b>	<b>Toepan Intrusion</b>
M	Right Offset	48 kph	Rear	7 cm
M	Left Offset	30 kph	Rear	23 cm
F	Left Offset	55 kph	Forward	52 cm
F	Left Offset	56 kph	Forward	13 cm
<b>F</b>	<b>Left Offset</b>	<b>19 kph</b>	<b>Forward</b>	<b>5 cm</b>
F	Left Offset	29 kph	Forward	0 cm

- V1 1995 Chevrolet Monte Carlo
- V2 1998 Cadillac DeVille
- V3 1995 Eagle Summit
- 72 kmph / 45 mph
- Lap & Shoulder Belt
- Airbag Deployed



PDOF =  $-30^\circ$  CDC = 11FYEW2  $\Delta V = 19 \text{ kmph} / 12 \text{ mph}$



VOL = 36% Left

Curb weight = 1500 kg / 3307 lb

Toe pan intrusion =  
5 cm / 2 in  
Longitudinal







# Right Tibia/Fibula Fracture



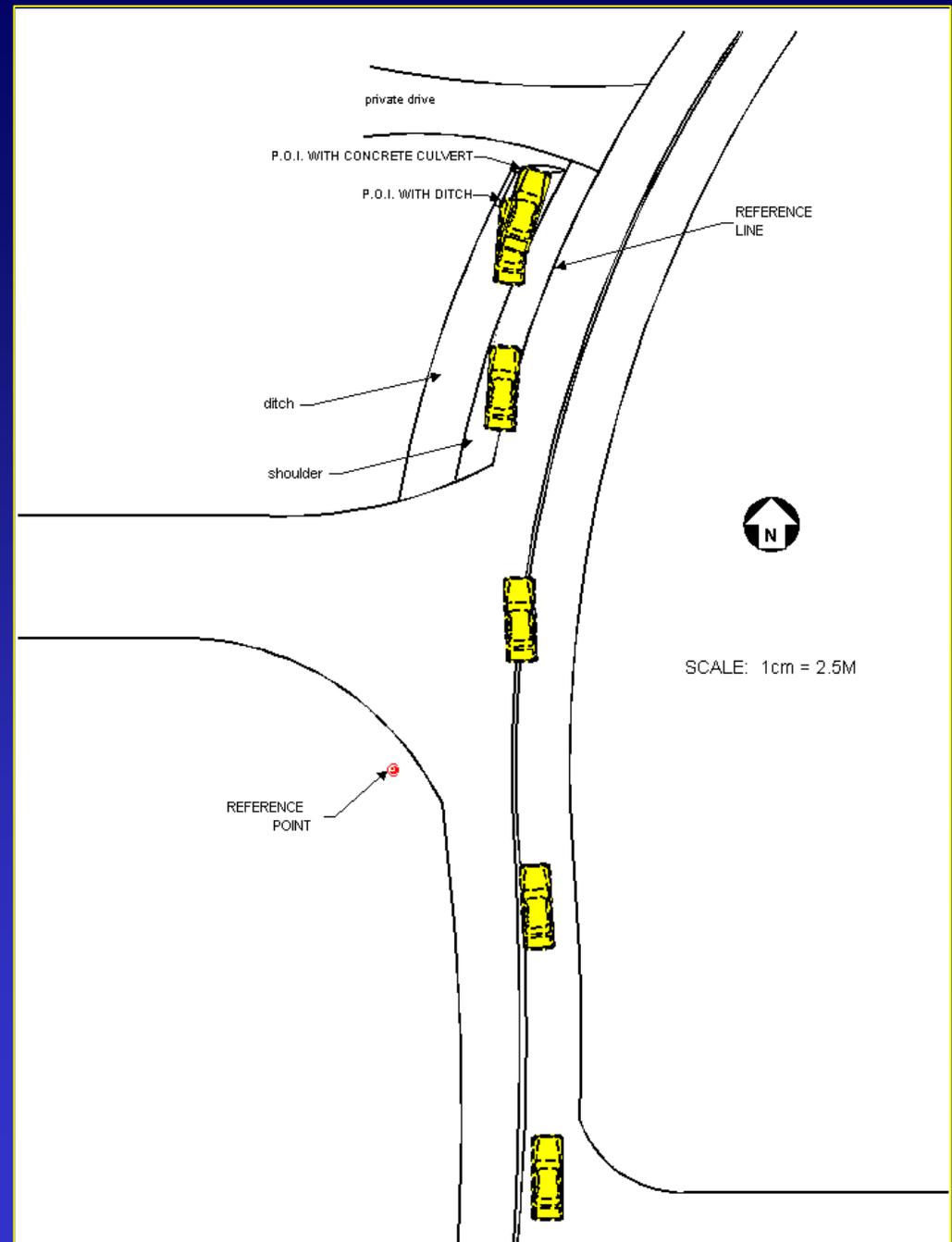


# Crash Characteristics

## *Comparison of Patients with Tibia/Fibula Fractures*

<b>Gender</b>	<b>Collision</b>	<b>Delta-V</b>	<b>Seat Position</b>	<b>Toepan Intrusion</b>
M	Right Offset	48 kph	Rear	7 cm
M	Left Offset	30 kph	Rear	23 cm
F	Left Offset	55 kph	Forward	52 cm
F	Left Offset	56 kph	Forward	13 cm
F	Left Offset	19 kph	Forward	5 cm
<b>F</b>	<b>Left Offset</b>	<b>29 kph</b>	<b>Forward</b>	<b>0 cm</b>

- 1997 Pontiac Grand Am
- Struck a ditch / culvert
- 64 kmph / 40 mph
- Lap & Shoulder Belt
- Airbag deployed



PDOF = 0°

CDC = 12FYEW2

$\Delta V = 29 \text{ kmph} / 18 \text{ mph}$



VOL = 47% Left

Curb weight = 1413 kg / 3115 lb

No Intrusion







# Right Tibia/Fibula Fracture



# Right Tibia/Fibula Fracture



# Overall Comparison of Fractures

Gender	Height	Seat Position	Belt/Air Bag	Delta-V	Toe/pan Intrusion
M	185	Rear	-/+	48 kph	7 cm
M	175	Rear	+/N/A	30 kph	23 cm
F	152	Forward	+/+	55 kph	52 cm
F	168	Forward	-/+	56 kph	13 cm
F	168	Forward	+/+	19 kph	5 cm
F	142	Forward	+/+	29 kph	0 cm

# **Collisions**

**Center for Injury Sciences**

**University of Alabama at Birmingham**

# Hypotheses

**Females have higher rates of tibia-fibula fractures in offset frontal collisions.**

**This association can be explained by driver height and/or seating position.**

# Methods – Data Source

National Automotive Sampling System  
(NASS) data, 1995-1999

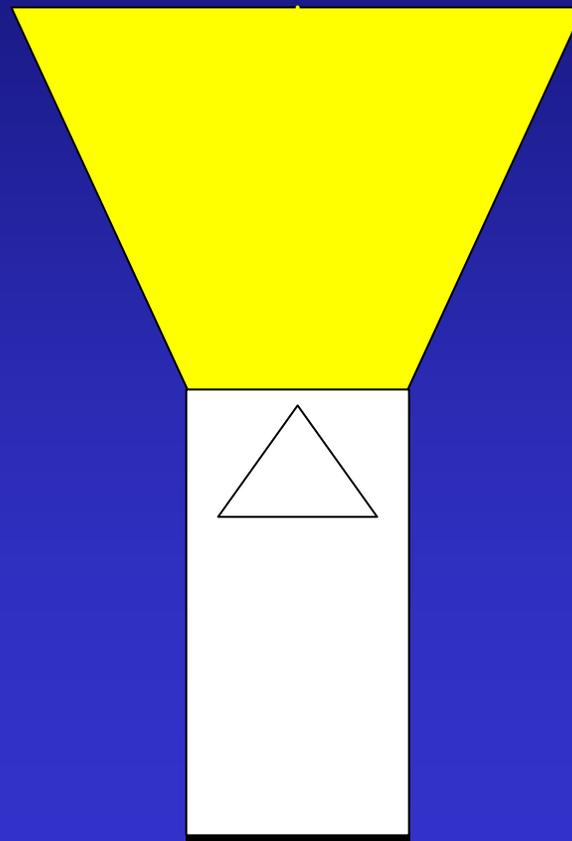
# Methods – Study Population

- Selected cases wherein initial event was frontal collision (o'clock direction of force) and partial/complete inspection of vehicles

# Methods – Study Population

11 o'clock

1 o'clock



# Methods – Study Population

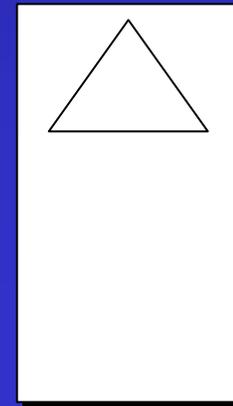
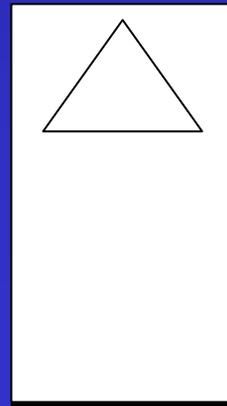
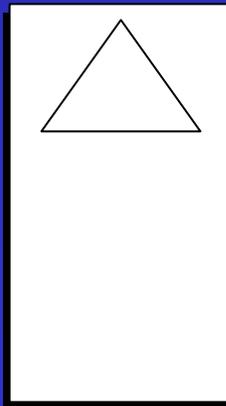
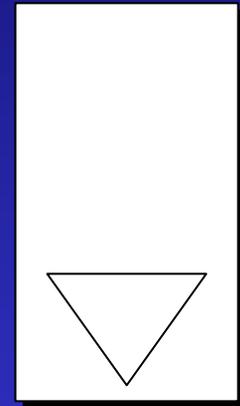
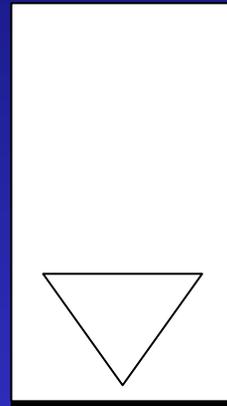
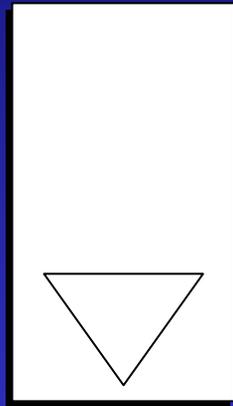
- Selected cases wherein initial event was frontal collision (o'clock direction of force) and partial/complete inspection of vehicles
- Within each case, vehicles were classified as full frontal, left offset frontal, right offset frontal using Specific Horizontal Location information

# Methods – Study Population

**Left Offset**

**Full Frontal**

**Right Offset**



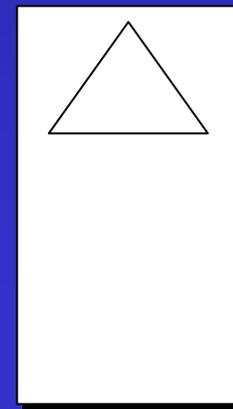
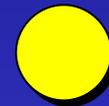
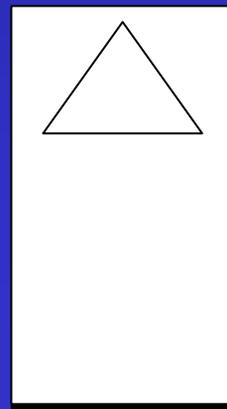
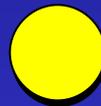
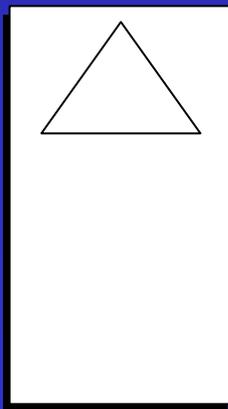
# Methods – Study Population

Left Offset

Full Frontal

Right Offset

---



# Methods – Study Population

- Selected cases wherein initial event was frontal collision (o'clock direction of force) and partial/complete inspection of vehicles
- Within each case, vehicles were classified as full frontal, left offset frontal, right offset frontal using Specific Horizontal Location information
- Only drivers were included in the present analysis

# Methods - Definitions

## *Primary Outcome of Interest Tibia/Fibula (TF) Fracture*

- *Tibia Fracture*

- AIS 90 codes 853404.2 – 853422.3

- *Fibula Fracture*

- AIS 90 codes 851605.2 – 851612.2

# Methods - Definitions

## *Selected Measures of Interest*

- *Occupant Characteristics*
  - Age, gender, height, restraint use, seating position
- *Vehicle Characteristics*
  - Weight, intrusion
- *Collision Characteristics*
  - Change in velocity

# Methods - Analysis

*Analyses conducted using weighted data*

- Calculate and compare TF fracture rates among males and females in offset collisions
- Stratify gender-specific TF rates by occupant, vehicle, and collisions characteristics
- Odds ratios (ORs) and 95% confidence intervals (CIs) calculated using SUDAAN to account for multistage sampling in NASS

# Results

---

	<b>Number</b>	<b>Percent</b>
<b>Left Offset</b>	<b>608,035</b>	<b>32.1</b>
<b>Full Frontal</b>	<b>713,278</b>	<b>37.7</b>
<b>Right Offset</b>	<b>570,439</b>	<b>30.2</b>

---

# Results

## *Lower Extremity Injury Rates ALL Frontal Collisions*

---

	Female	Male	Odds Ratio
	Rate per 100 Occupants		
<b>Pelvic Fracture</b>	<b>0.92</b>	<b>0.96</b>	<b>1.05</b>
<b>Femur Fracture</b>	<b>1.33</b>	<b>1.47</b>	<b>1.10</b>
<b>Tib./Fib. Fracture</b>	<b>2.55</b>	<b>2.05</b>	<b>0.80</b>

---

# Results

## *Gender Odds Ratios Males vs. Females*

---

	Left Offset	Full Frontal	Right Offset
<b>Pelvic</b>	<b>1.96</b>	<b>0.68</b>	<b>0.72</b>
<b>Femur</b>	<b>1.23</b>	<b>0.96</b>	<b>1.62</b>
<b>Tib./Fib.</b>	<b>0.72</b>	<b>1.20</b>	<b>0.37</b>

---

# Results

## *Gender Odds Ratios Males vs. Females*

---

	<b>Left Offset</b>	<b>Full Frontal</b>	<b>Right Offset</b>
Pelvic	1.96	0.68	0.72
Femur	1.23	0.96	1.62
<b>Tib./Fib.</b>	<b>0.72</b>	1.20	<b>0.37</b>

---

# Results

## *Tib./Fib. Fracture Rates Offset Frontal Collisions*

<b>Age</b>	<b>Female</b>	<b>Male</b>	<b>Odds Ratio</b>
	<b>Rate per 100 Occupants</b>		
<b>&lt;30</b>	<b>2.24</b>	<b>1.26</b>	<b>0.56</b>
<b>30-39</b>	<b>2.63</b>	<b>1.27</b>	<b>0.48</b>
<b>40-49</b>	<b>3.21</b>	<b>2.34</b>	<b>0.73</b>
<b>50-59</b>	<b>2.30</b>	<b>0.62</b>	<b>0.27</b>
<b>60-69</b>	<b>4.88</b>	<b>1.25</b>	<b>0.25</b>
<b><sup>3</sup>70</b>	<b>2.57</b>	<b>4.15</b>	<b>1.64</b>

# Results

## *Tib./Fib. Fracture Rates Offset Frontal Collisions*

---

	Female	Male	Odds Ratio
Delta – V	Rate per 100 Occupants		
01-16	0.00	0.00	-
17-23	1.72	0.16	0.09
24-33	1.79	0.60	0.33
<sup>3</sup> 34	16.99	6.29	0.33

---

# Results

## *Tib./Fib. Fracture Rates Offset Frontal Collisions*

---

	Female	Male	Odds Ratio
	Rate per 100 Occupants		
<b>Small</b>	<b>2.62</b>	<b>1.98</b>	<b>0.75</b>
<b>Mid-Size</b>	<b>4.69</b>	<b>1.77</b>	<b>0.37</b>
<b>Large</b>	<b>0.90</b>	<b>1.07</b>	<b>1.19</b>

---

# Results

## *Tib./Fib. Fracture Rates Offset Frontal Collisions*

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	Female	Male	Odds Ratio
	Rate per 100 Occupants		
<b>Unrestrained</b>	<b>4.86</b>	<b>2.44</b>	<b>0.49</b>
<b>Restrained</b>	<b>1.54</b>	<b>0.76</b>	<b>0.49</b>

---

# Results

## *Tib./Fib. Fracture Rates Offset Frontal Collisions*

---

	Female	Male	Odds Ratio
	Rate per 100 Occupants		
Height < 5'5"	1.86	0.89	0.48
Height <sup>≥</sup> 5'5"	2.32	1.67	0.71
Unknown	5.43	0.67	0.12

---

# Results

## *Tib./Fib. Fracture Rates Offset Frontal Collisions*

---

	Female	Male	Odds Ratio
	Rate per 100 Occupants		
<b>Seat Forward</b>	<b>2.63</b>	<b>0.59</b>	<b>0.22</b>
<b>Seat Middle/Back</b>	<b>2.35</b>	<b>1.54</b>	<b>0.65</b>

---

# Results

## *Tib./Fib. Fracture Rates Offset Frontal Collisions*

	Female	Male	Odds Ratio
Intrusion*	Rate per 100 Occupants		
Lateral <8 cm.	2.26	1.27	0.56
Lateral ≥8 cm.	12.67	7.16	0.53
Frontal <8 cm.	1.48	0.38	0.26
Frontal ≥8 cm.	16.82	10.34	0.57

\* Driver's seating position.

# Results

## *Intrusion Characteristics Among Occupants with Tib./Fib. Fractures*

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	<b>Female</b>	<b>Male</b>
<b>Intrusion*</b>	<b>Percent</b>	<b>Percent</b>
<b>Lateral &lt;8 cm.</b>	<b>90.6</b>	<b>86.3</b>
<b>Lateral ≥8 cm.</b>	<b>9.4</b>	<b>13.7</b>
<b>Frontal &lt;8 cm.</b>	<b>56.3</b>	<b>24.0</b>
<b>Frontal ≥8 cm.</b>	<b>43.7</b>	<b>76.0</b>

---

\* Driver's seating position.

# Results

## *Aspect of Tib./Fib. Fractures*

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<b>Aspect</b>	<b>Left Offset</b>		<b>Right Offset</b>	
	<b>Female</b>	<b>Male</b>	<b>Female</b>	<b>Male</b>
	<b>Percent</b>	<b>Percent</b>	<b>Percent</b>	<b>Percent</b>
<b>Left</b>	<b>44.1</b>	<b>31.7</b>	<b>38.6</b>	<b>21.3</b>
<b>Right</b>	<b>53.0</b>	<b>54.2</b>	<b>59.9</b>	<b>69.4</b>
<b>Bilateral</b>	<b>2.9</b>	<b>14.1</b>	<b>1.5</b>	<b>9.3</b>

---

# Results

## *Impact Characteristics Among Occupants with Tib./Fib. Fractures*

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	<b>Female</b>	<b>Male</b>
<b>Injury Source</b>	<b>Percent</b>	<b>Percent</b>
<b>Knee Bolster</b>	<b>5.3</b>	<b>10.8</b>
<b>Instrument Panel</b>	<b>16.3</b>	<b>35.2</b>
<b>Floor/Toe Pan</b>	<b>43.6</b>	<b>41.9</b>
<b>Pedals</b>	<b>35.9</b>	<b>19.3</b>

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# Summary

- Females drivers have higher rates of tib./fib. fracture in offset frontal collisions
- Observed higher rates not explained by occupant, vehicle, collision characteristics
- Tib./fib. fractures in females occur at lower  $\Delta V$  and are more associated with pedal contacts

# Literature Survey

Surveyed publications from the past ten years related to improving safety standards and test on lower extremity injuries in frontal crashes

Objective: Understand outstanding issues and

# Notable Findings

- Importance of the issue is clearly agreed upon:
  - 
  - 
  -
- Lower limb injuries are second only to head injuries in frequency among motor vehicle occupants
- Lower limb injuries are a frequent cause of permanent disability and impairment; costs to society are exorbitant

# Notable Findings

- Load transfer mechanism of below knee injuries from frontal crashes are not well understood
  - Intrusion vs. deceleration
  - Role of contact with pedals
  - Effectiveness of restraints
- Possible injury mechanisms have been described and compared to laboratory tests and computer modeling

# Notable Findings

- Case studies indicate that there must be a lateral load component contributing to malleolar fractures
- Intrusion and lower extremity injuries increase as overlap decreases
- Tarsal intrusion is not a prerequisite for tib /fib injury

# Notable Findings

- Below-knee injuries are occurring at delta-Vs less than 30 mph (48 kmph)
- Higher injury rate to driver's right lower extremities in offset crashes
- Other contributing factors postulated: leg position, foot size, contribution of knee contacts, muscle tension, maximum angle of ankle motion

# Notable Findings

- Other researchers have pointed out apparent gender differences -- however, exact reasons have not been discerned
  - Size? Seat Position? Other physiological? Behavioral? External conditions such as footwear? Car attributes?
- Frontal offset crash tests indicate that lower limb dummy than the 50<sup>th</sup> percentile male