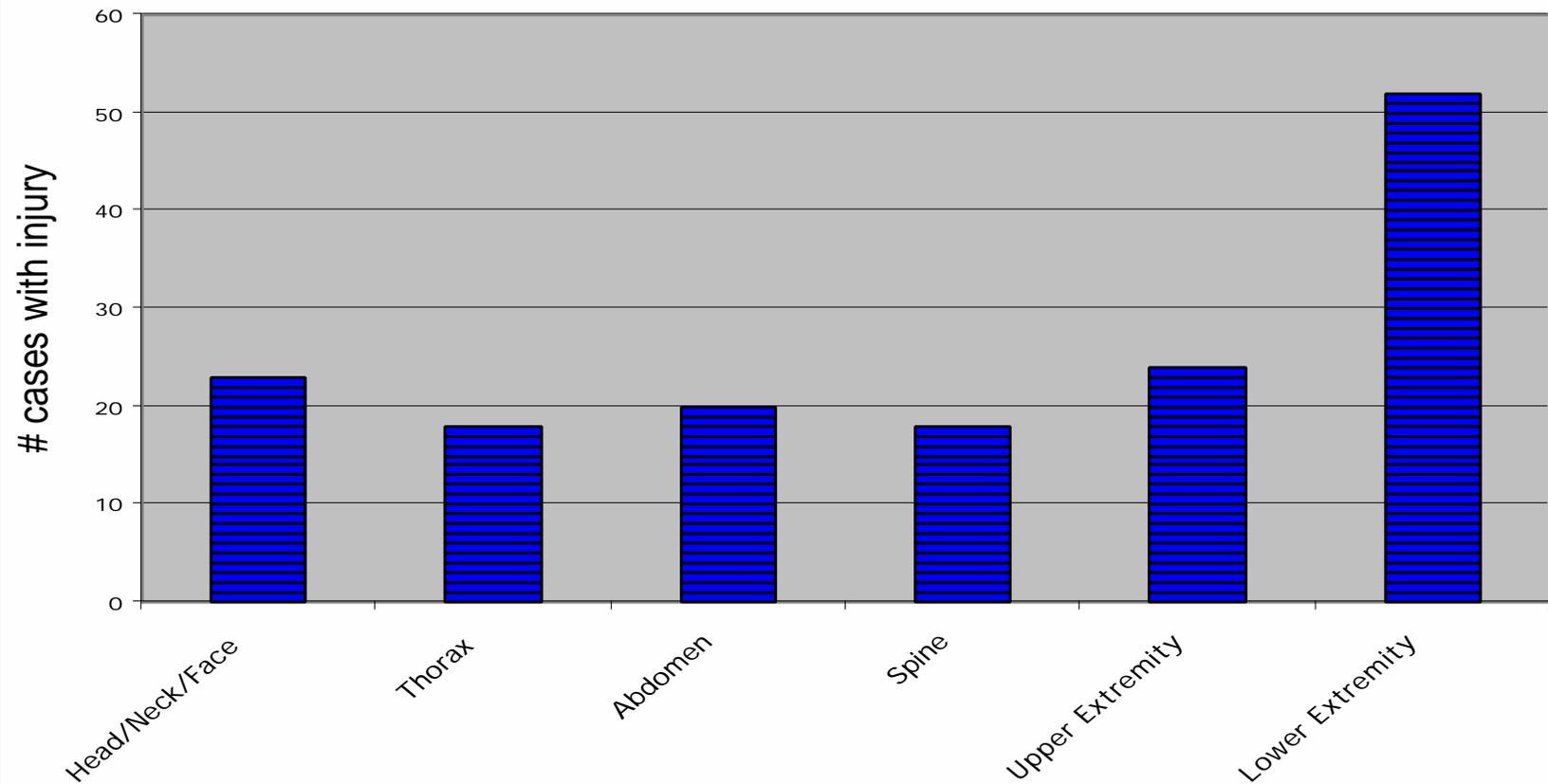


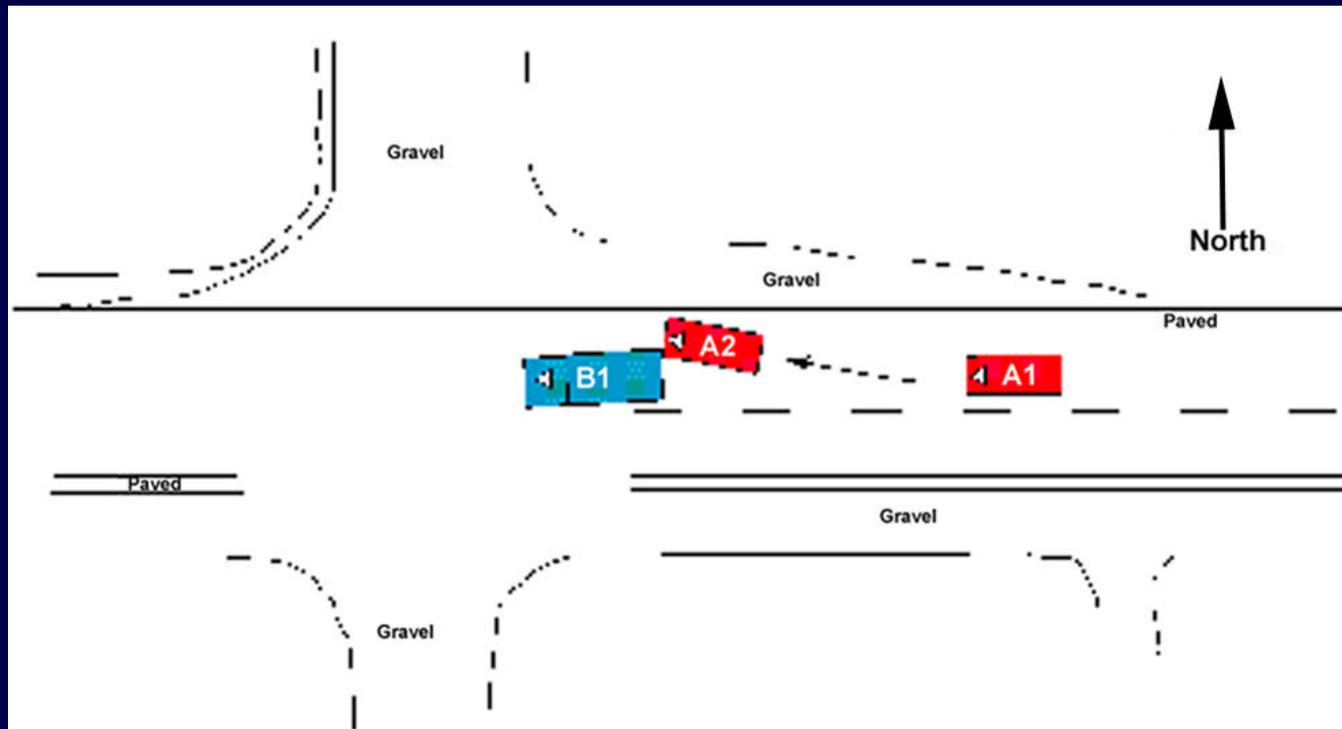
Injured Body Regions in Offset Frontal Cases Michigan CIREN



Offset Frontal Case - A

Case Vehicle:	1999 Ford Explorer, 4X2 SUV
Object Struck:	1991 Ford F-800, straight truck
Impact Type:	Offset frontal (29% VOL)
Conditions:	Day, clear, dry asphalt
Case Occupant:	Driver
Age/Gender:	42-year-old male
Stature/Mass:	183 cm (6'), 104 kg (230 lb)
Restraint:	None

Offset Frontal Case - A



- 1999 Ford Explorer into rear-end of propane truck
- Offset frontal. 29% VOL. Day, clear, dry asphalt
- 42 y/o driver, 6 foot tall, 230 lb. Unbelted, airbag did not deploy.
- 30-minute extrication: Trapped left lower leg with bleeding open fracture. Absent sensation to left foot.









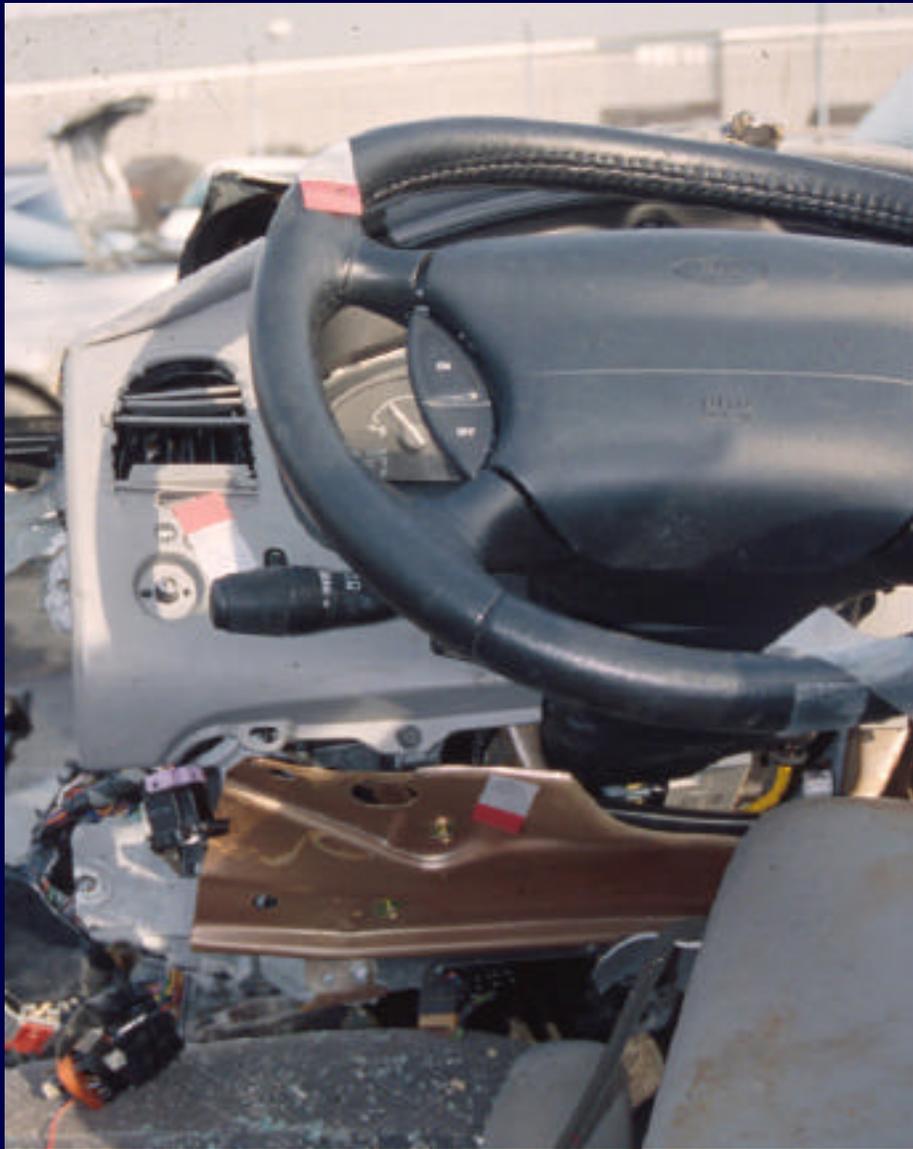
Offset Frontal Case - A

Vehicle Damage

Direct Damage Length:	47 cm <i>est</i>
Maximum Crush:	134 cm <i>est</i>
PDOF:	350
CDC:	12-FLME-5
Impact Severity (mph):	n/a 20 <i>est</i>
Relevant Intrusions:	Instrument Panel – 66 cm rear Steering assembly – 44 cm rear Toe pan – 65 cm rear Brake pedal – 60 cm rear

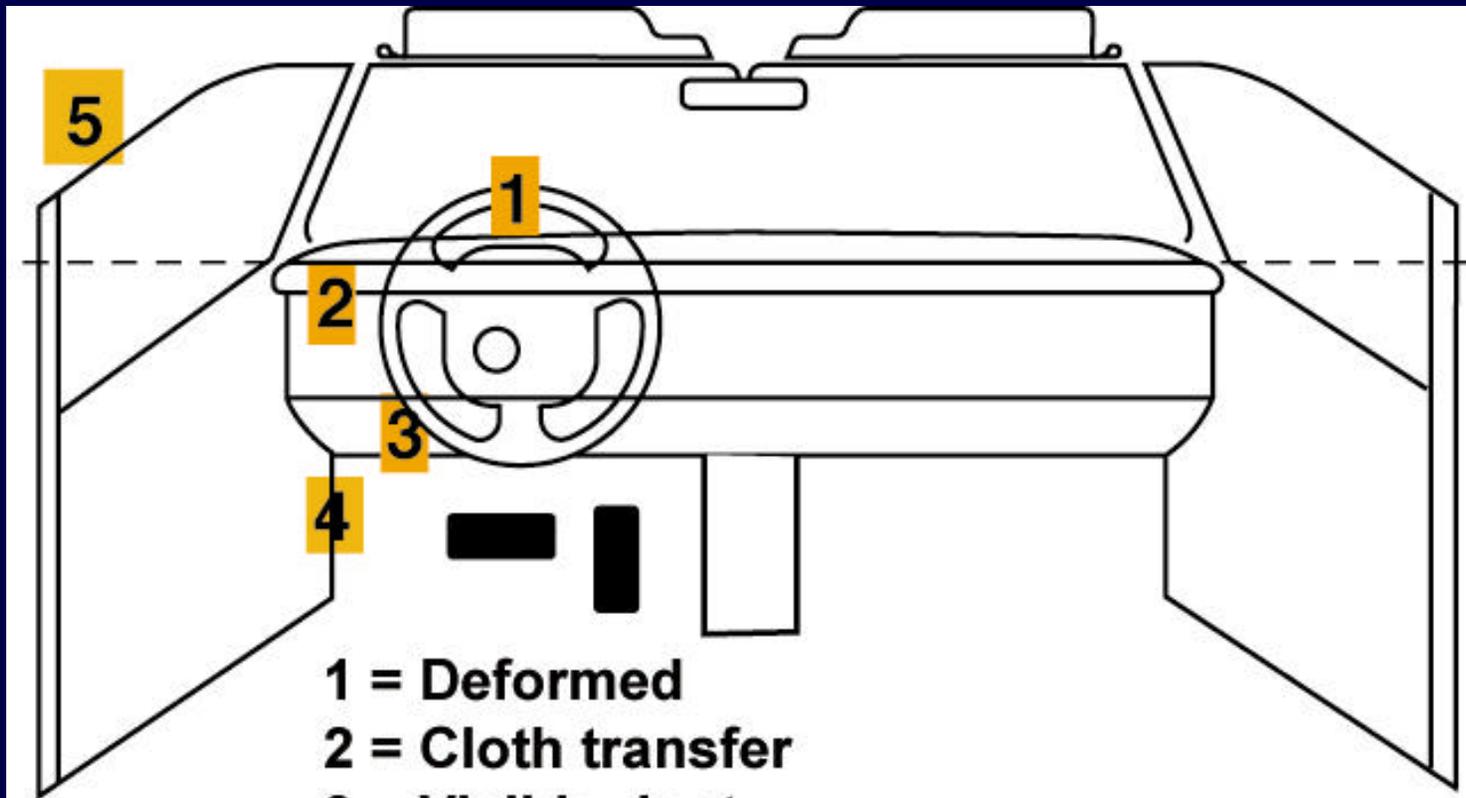












1 = Deformed

2 = Cloth transfer

3 = Visible dent

4 = Flesh/blood

5 = Scuff mark on roof rail

Note: Steering column off of shear capsules

Offset Frontal Case - A

Injuries

- **Mesenteric hematoma at the terminal ileum**
- **Left acetabular fracture, comminuted with posterior displacement of left femoral head**
- **Left sacroiliac joint widening**
- **Left iliac crest fracture**
- **Left anterior tibial artery occlusion**
- **Left tibia fracture, open with widening of lateral knee joint and anterior subluxation at tibiotalar joint**
- **Peroneal nerve avulsion at level of fibula head**

Offset Frontal Case - A

Lower Extremity Injuries

LEFT acetabular fx, comminuted, w/ posterior displacement of left femoral head	Knee bolster	Compression Axial load (femur)
LEFT proximal tibia fx, comminuted, open, impacted, w/ widening of lateral knee joint, involves tibial plateau	Knee bolster	Compressive loading
Left distal tibia fx, comminuted, with anterior subluxation at the tibiotalar joint	Kick panel	Bending

Offset Frontal Case - B

1996 Oldsmobile Delta 88
(vs. 1999 Ford Explorer)

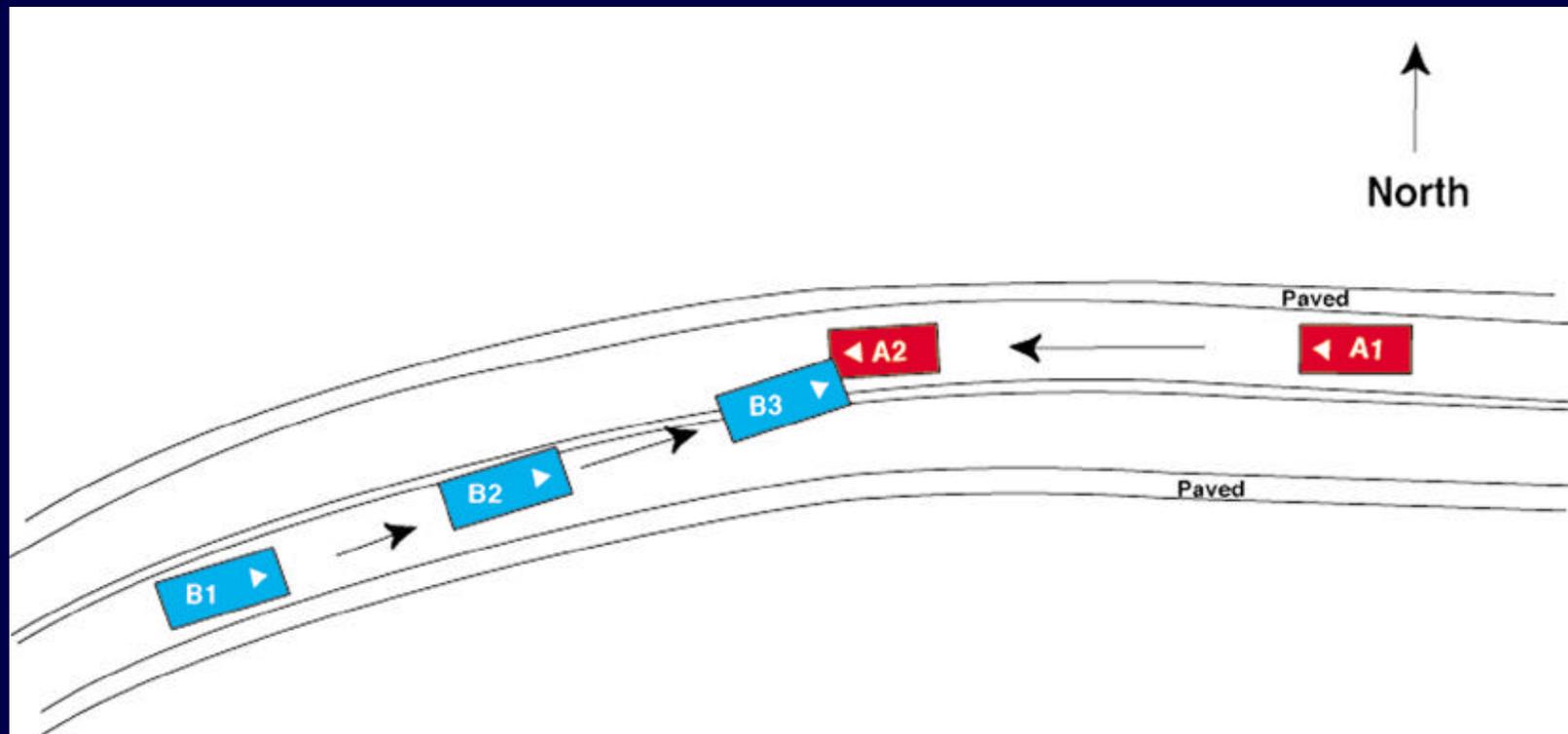
Impact: Offset frontal (36% VOL)

Conditions: Night, clear, dry asphalt

54-year-old female, Driver

163 cm (5' 4"), 110 kg (220 lb)

Lap & shoulder belt + airbag



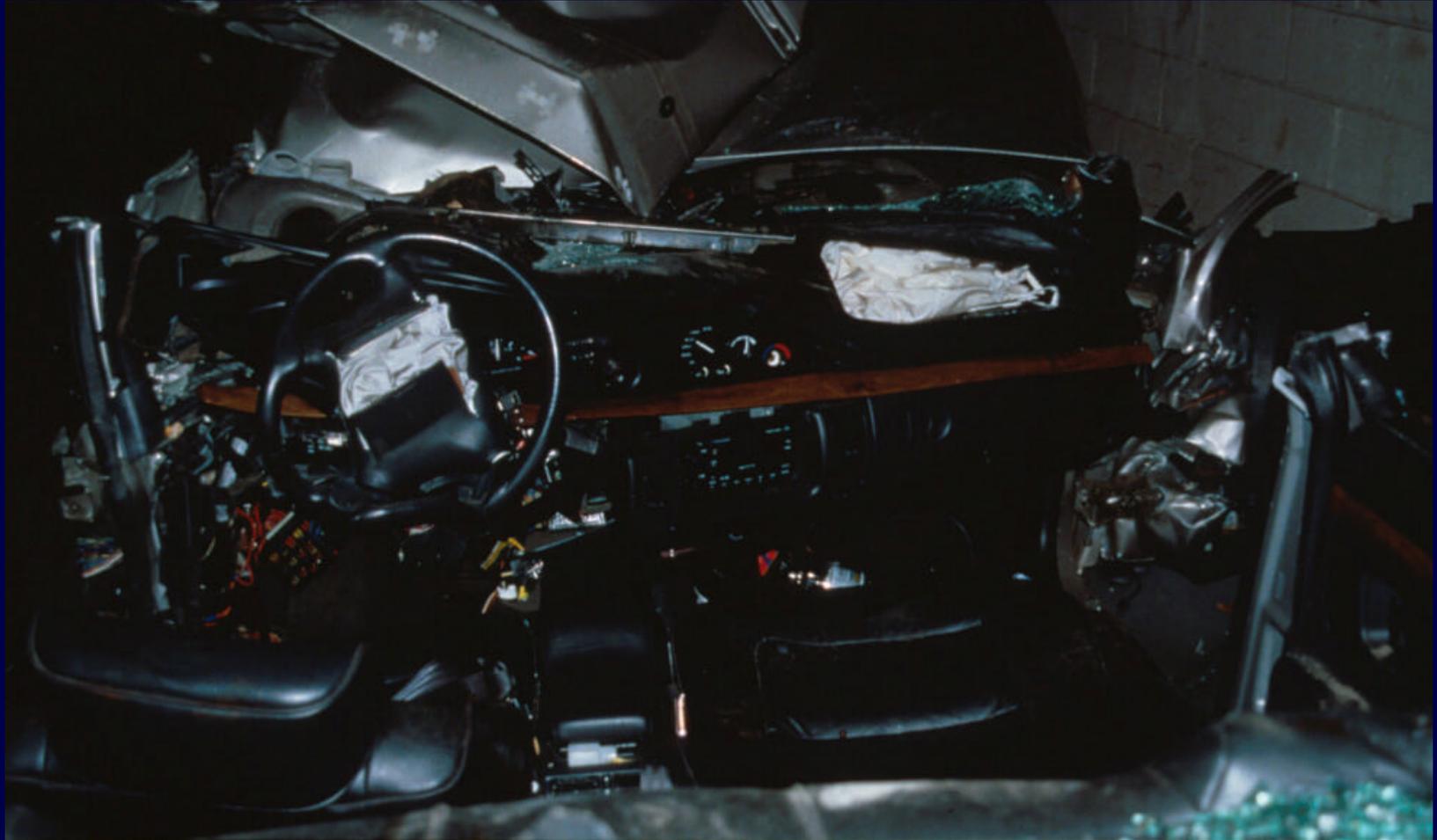
•Extrication took 60 minutes (UEX took 25 minutes and LEX 35 minutes)



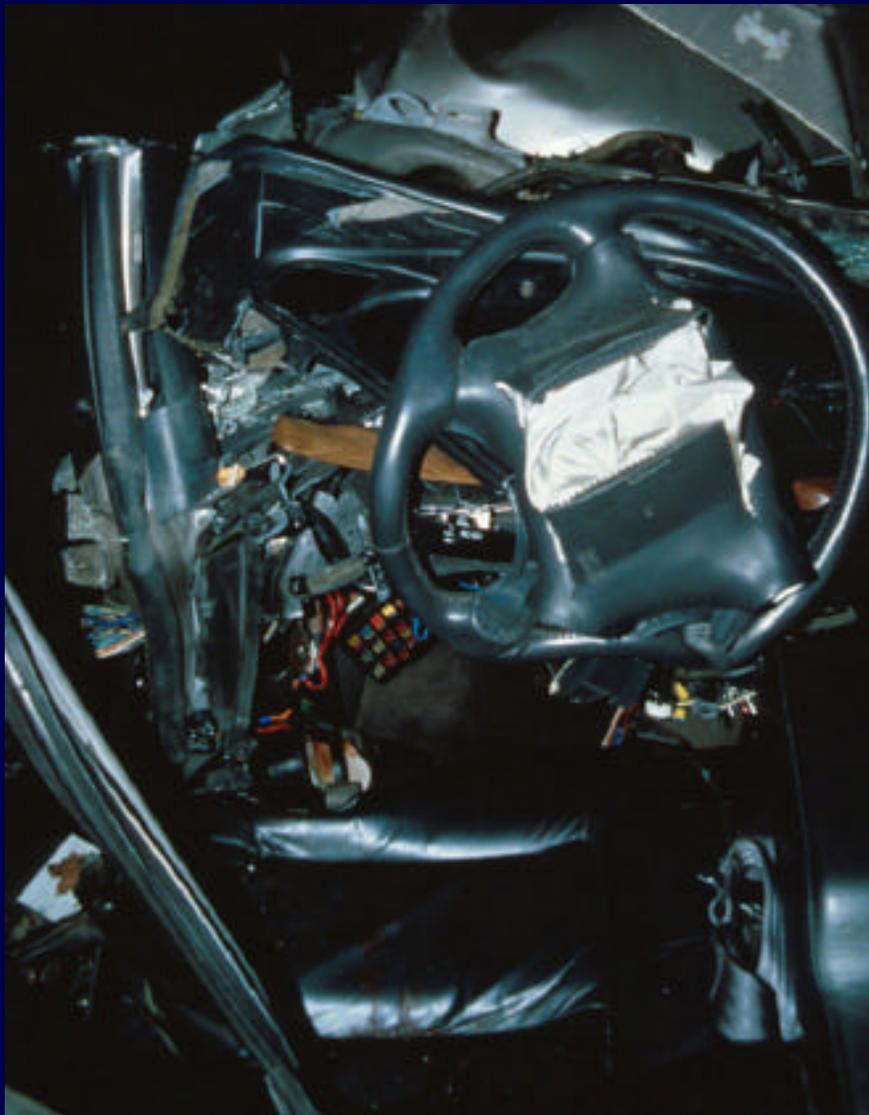
Offset Frontal Case - B

Vehicle Damage

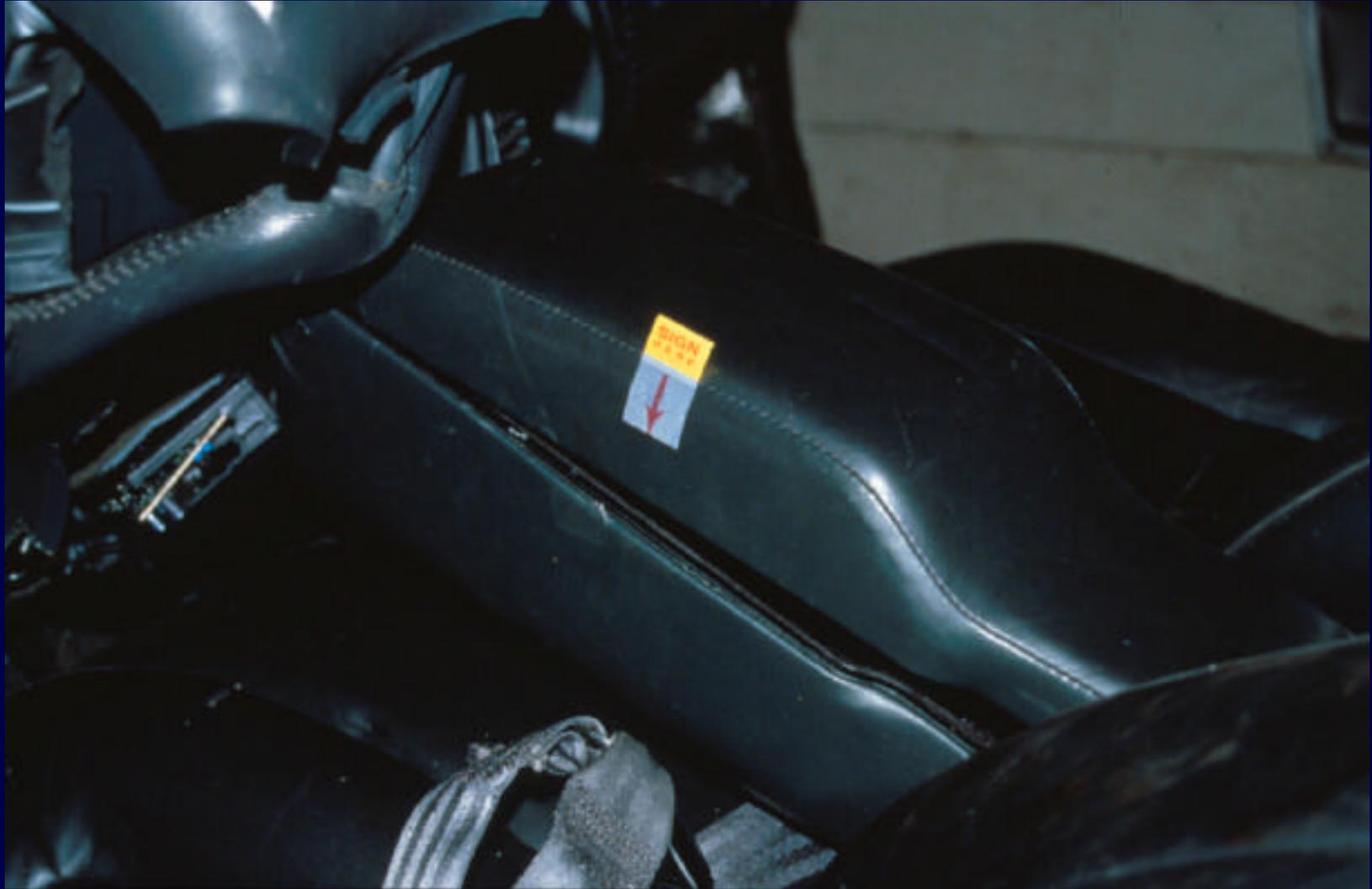
Direct Damage Length:	54 cm
Maximum Crush:	93 cm
PDOF:	350
CDC:	12-FYEW-4
Impact Severity (mph):	41 ΔV
Relevant Intrusions:	Instrument Panel – 58 cm rear Steering wheel hub – 40 cm rear Left toepan – 52 cm rear Right toepan – 45 cm rear



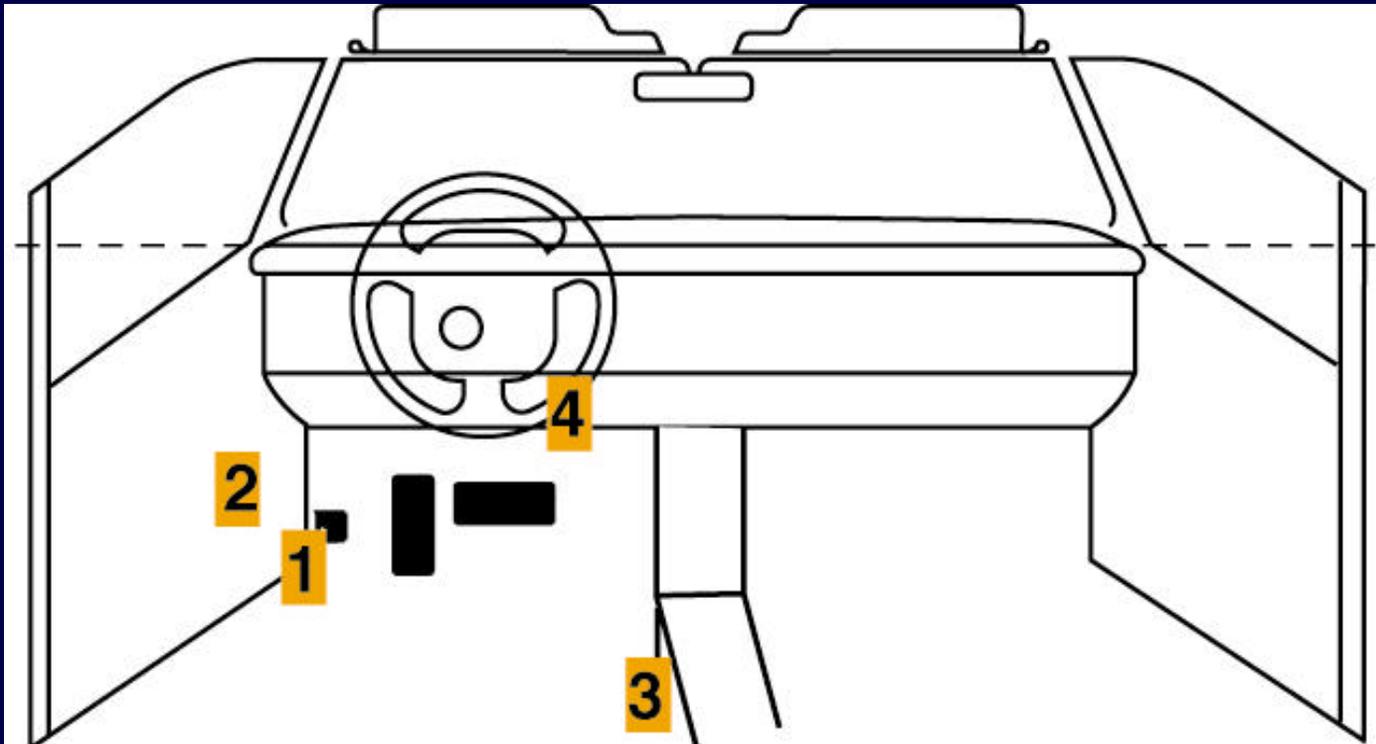












- 1 = Shoe pinned between parking brake and seat bottom
- 2 = Scuff marks on fragments of interior door panel
- 3 = Scuff mark
- 4 = Deformed

Offset Frontal Case - B

Injuries

- **Right anterior-lateral #2-7, left #6-7 rib fractures**
- **Liver contusion**
- **Spleen laceration**
- **Right T1 transverse process fracture**
- **Left open supracondylar/intracondylar humerus fracture**
- **Right distal radius and ulna fractures**
- **Bilateral proximal ulna fractures**

Offset Frontal Case - B

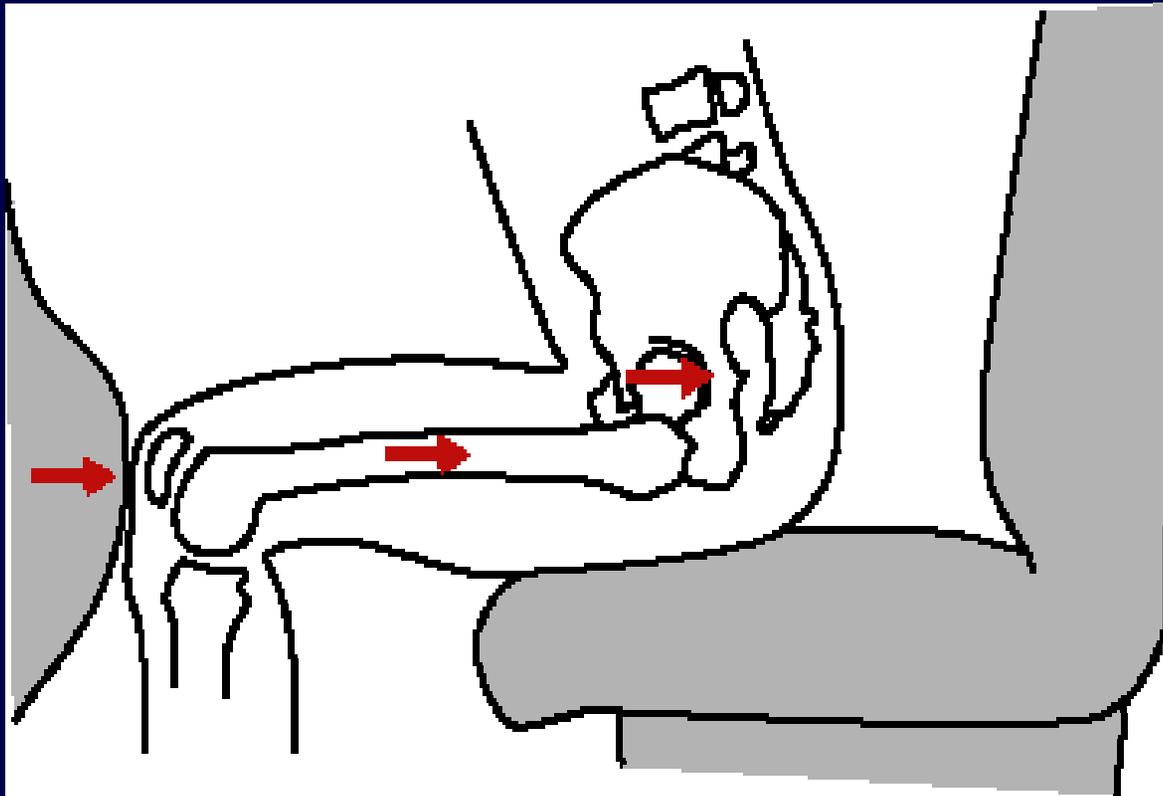
LEX Injuries

- **Right calcaneus fracture**
- **Right proximal fibula fracture**
- **Left distal femur fracture**
- **Left navicular fracture**
- **Left medial, middle, and lateral cuneiform fractures**
- **Left #2-4 metatarsal base fractures**
- **Bilateral patella fractures**
- **Left acetabular fracture**
- **Right superior and inferior pubic ramus fractures**
- **Bilateral sacral iliac joint diastasis, right sacrococcygeal fracture**
- **Pubic symphysis diastasis**
- **Right tibial plateau fracture**

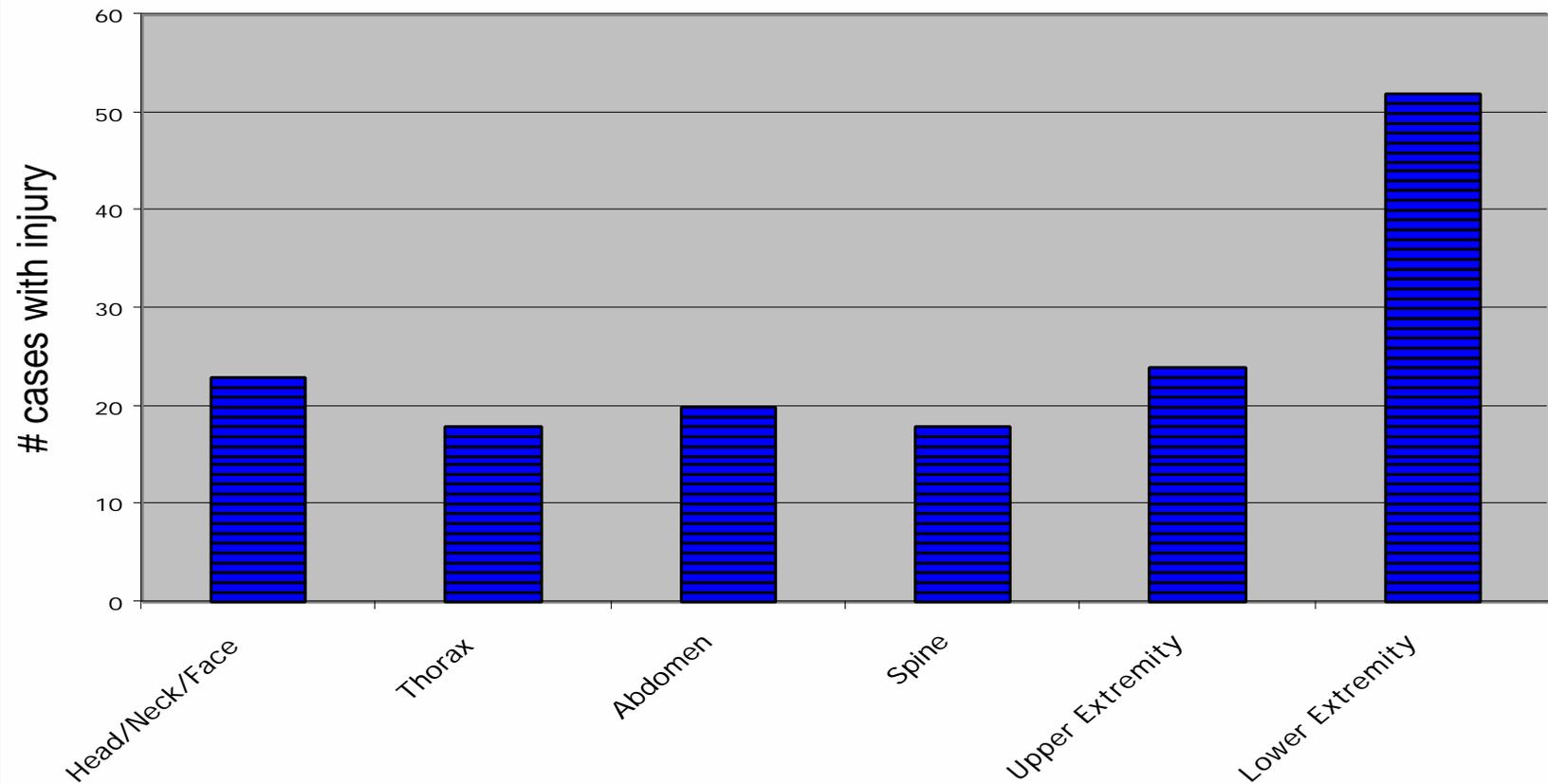
LEX Injury Mechanisms

Bilateral sacral iliac joint diastasis, right sacrococcygeal fx Pubic symphysis diastasis Right superior and inferior pubic rami fx	Steering wheel and lap belt Steering wheel rim	Direct A/P compression & direct
LEFT acetabular fx, comminuted LEFT distal femur fx, open LEFT patella fx, comminuted RIGHT patella fx, comminuted	Knee bolster	Axial Direct
Right calcaneus fx, comminuted Right proximal fibula fx, comminuted Right tibial plateau fx	Toe pan Toe pan/pedals	Direct Axial
L lateral cuneiform fx L middle cuneiform fx L medial cuneiform fx L navicular fx, comminuted Left metatarsal base fx, #2 comminuted L metatarsal base fx #3 comminuted L metatarsal base fx #4 comminuted	Parking brake	Direct

Postulated mechanism of KTH injuries for Cases A & B

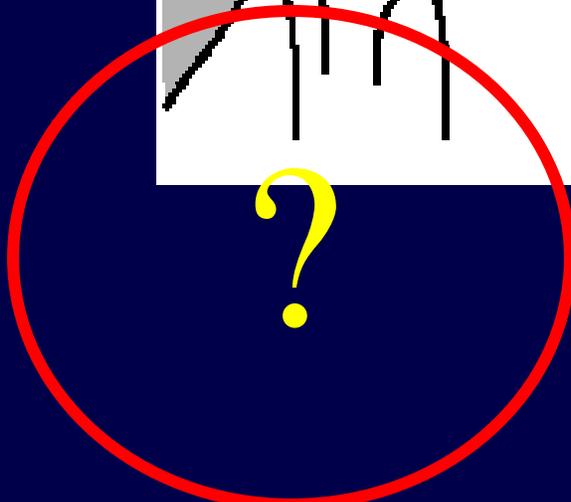
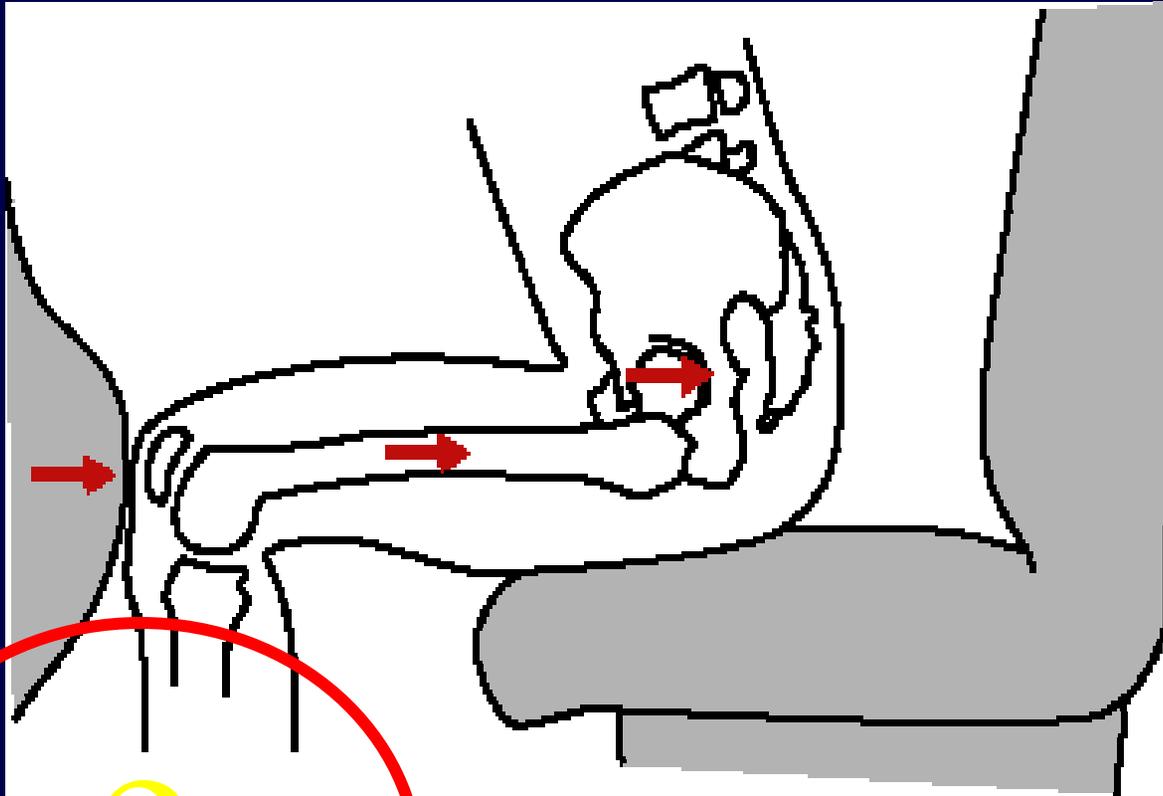


Injured Body Regions in Offset Frontal Cases



Injury Mechanism Analysis

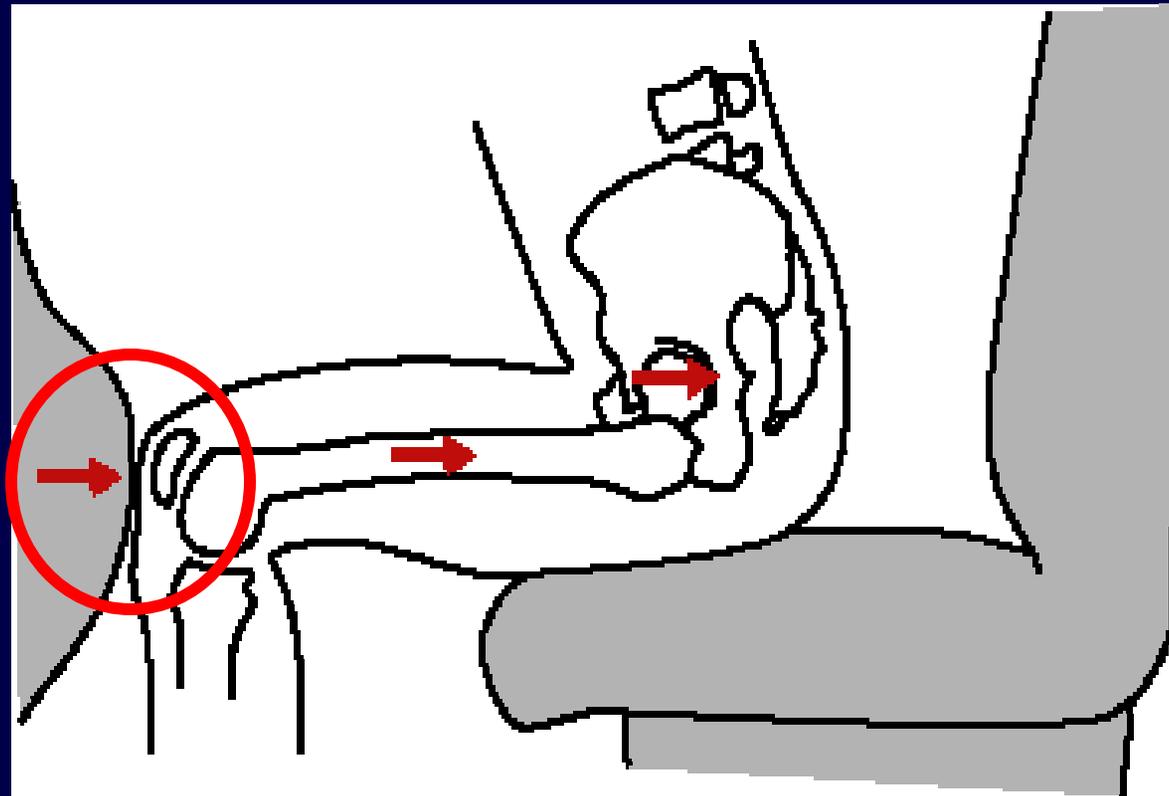
Lower leg & Foot



Position, Pedals, Joint angles
Muscle activity, Footwear

Injury Mechanism Analysis

Knee Thigh Hip (KTH)







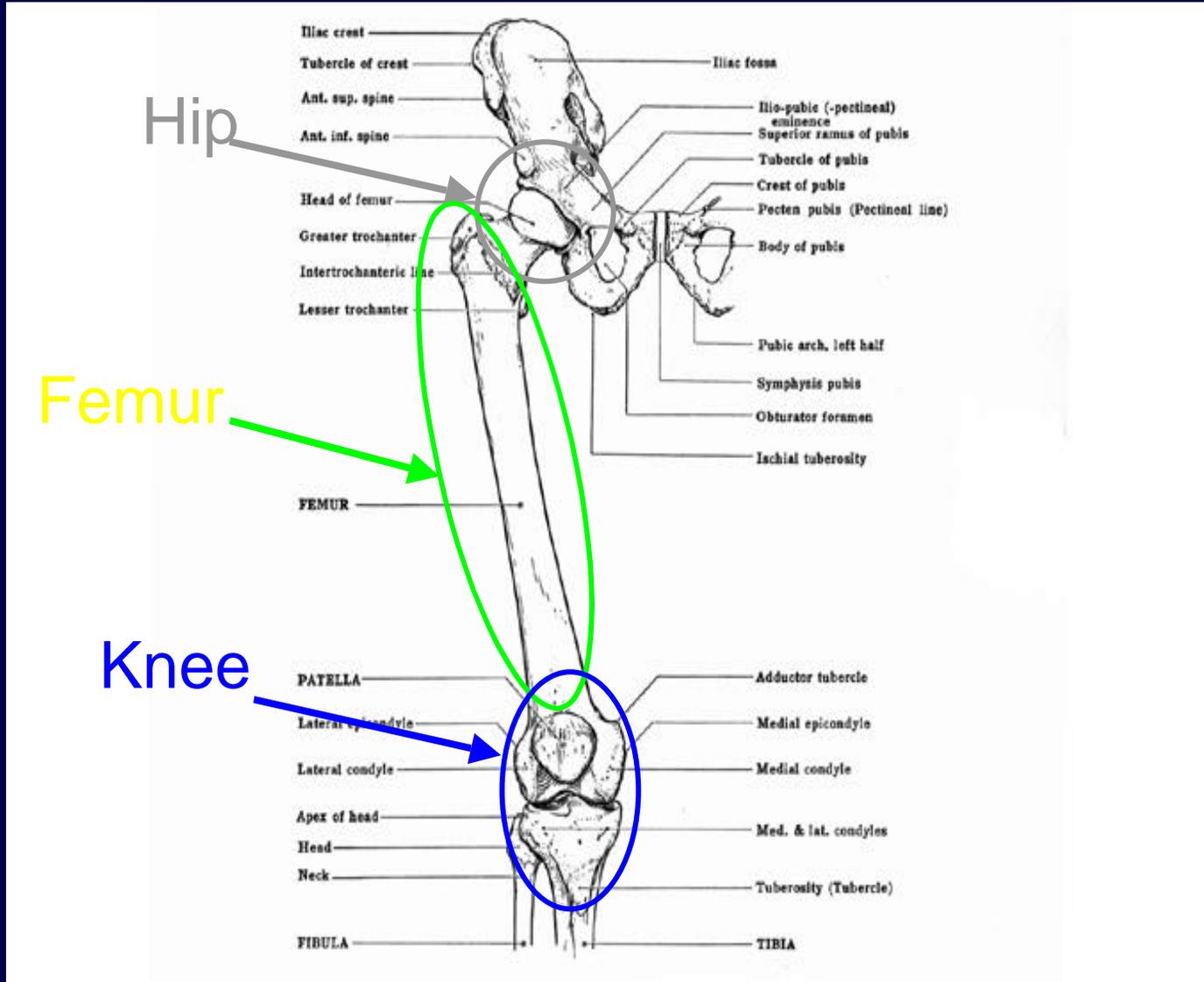




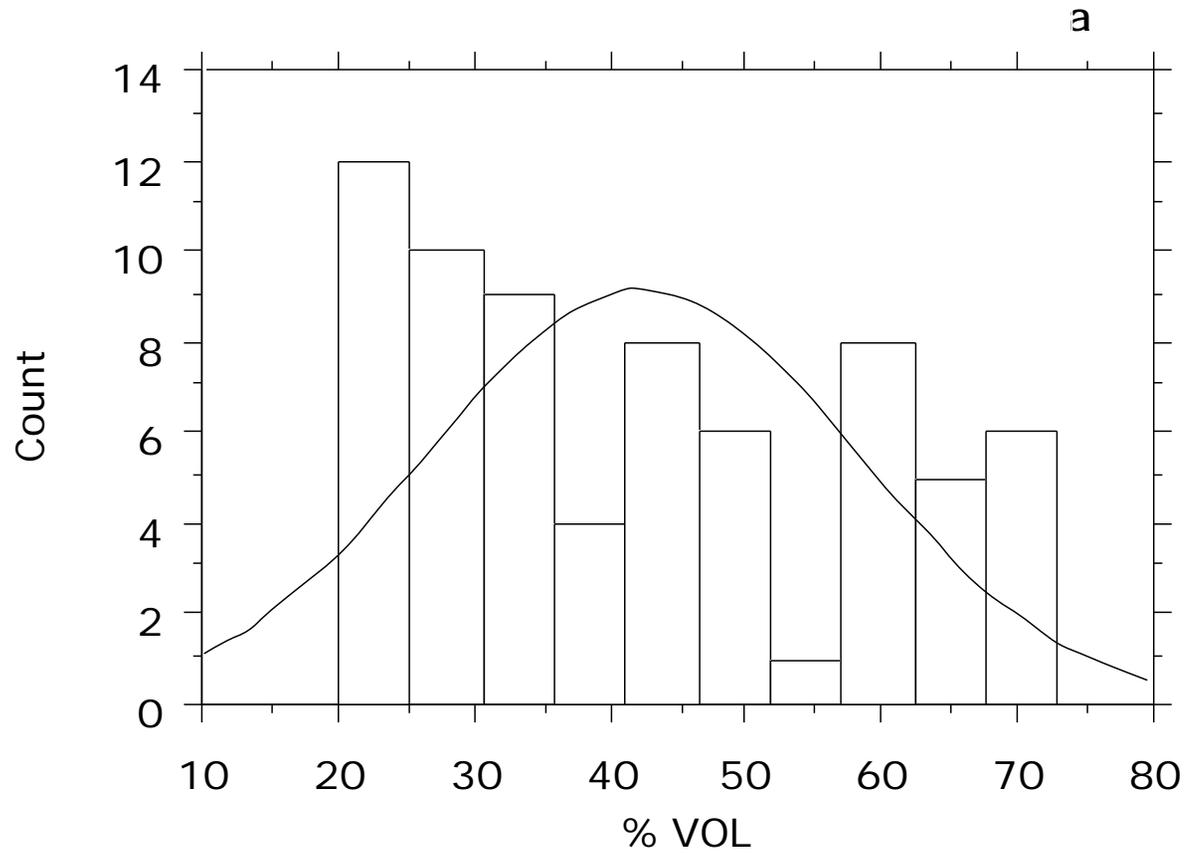
Study Parameters

- **46** offset frontal crash case occupants with KTH injuries. (*Michigan CIREN only - June 2000*)
- **69** Knee-Thigh-Hip injuries with mechanism attributed to knee bolster contact (*also lower IP, steering column, glove box*).
- Factors analyzed:
 - Region of injury (K, T, H), Side of injury, Age, Weight, ISS
 - PDOF, % VOL, CDC, Crash severity, Restraint use.

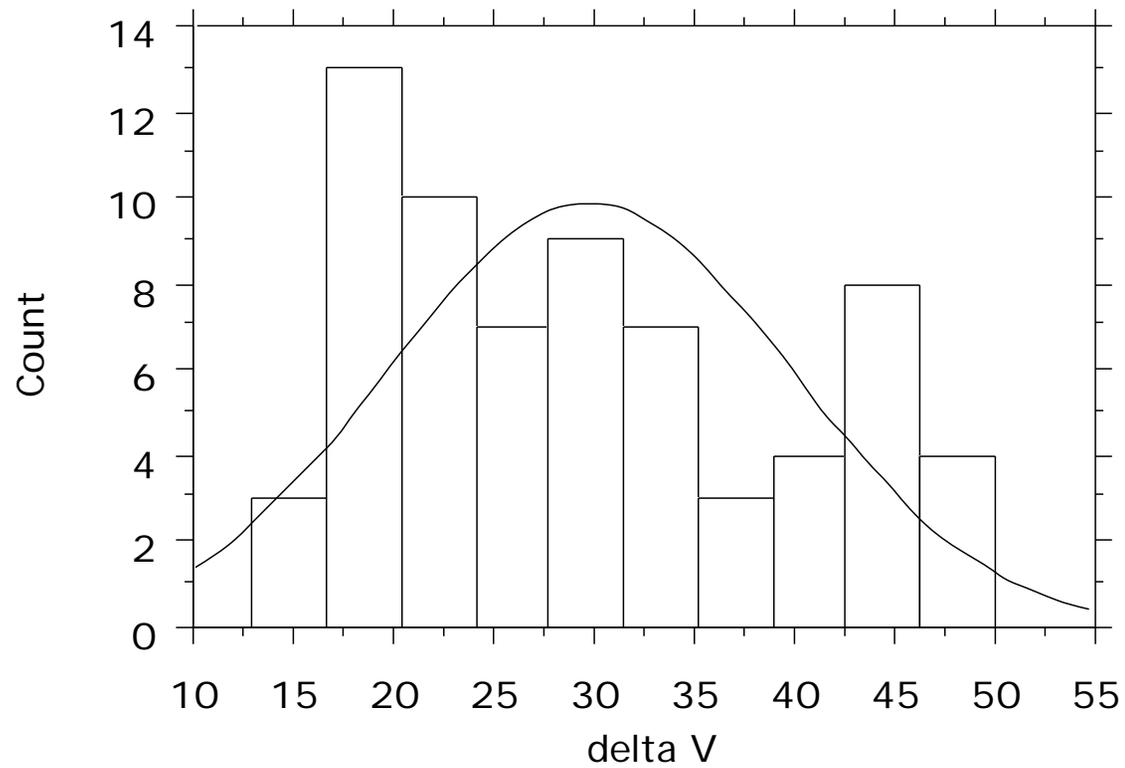
Knee-Thigh-Hip Injuries in Offset Frontal Crashes



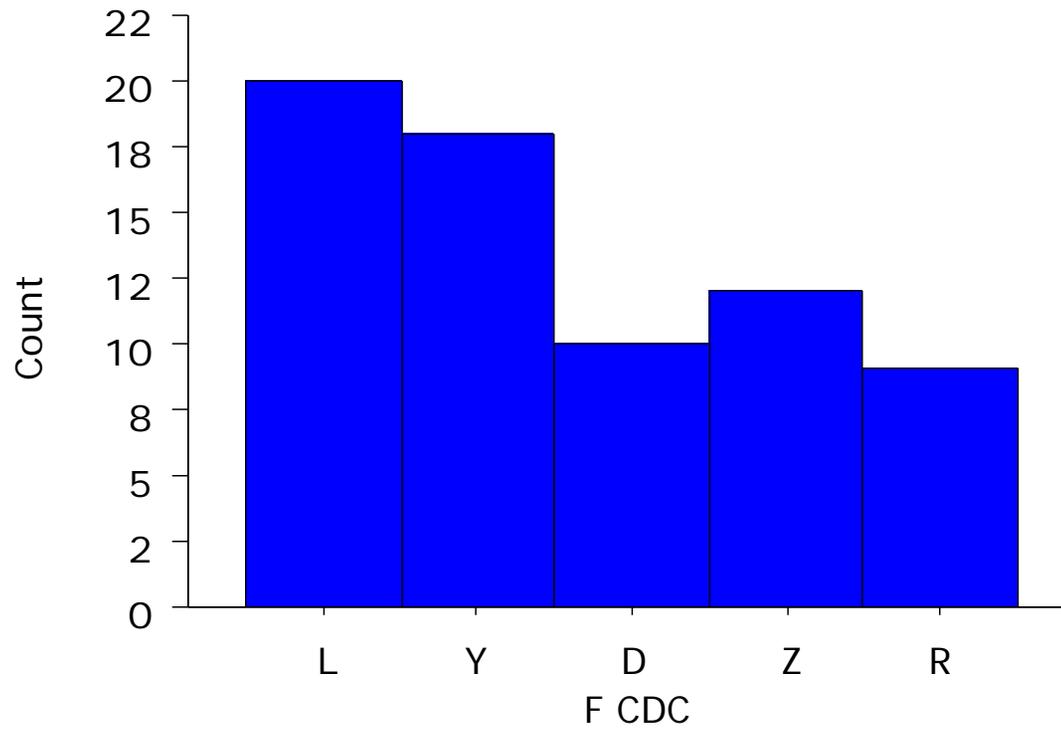
% Vehicle Overlap



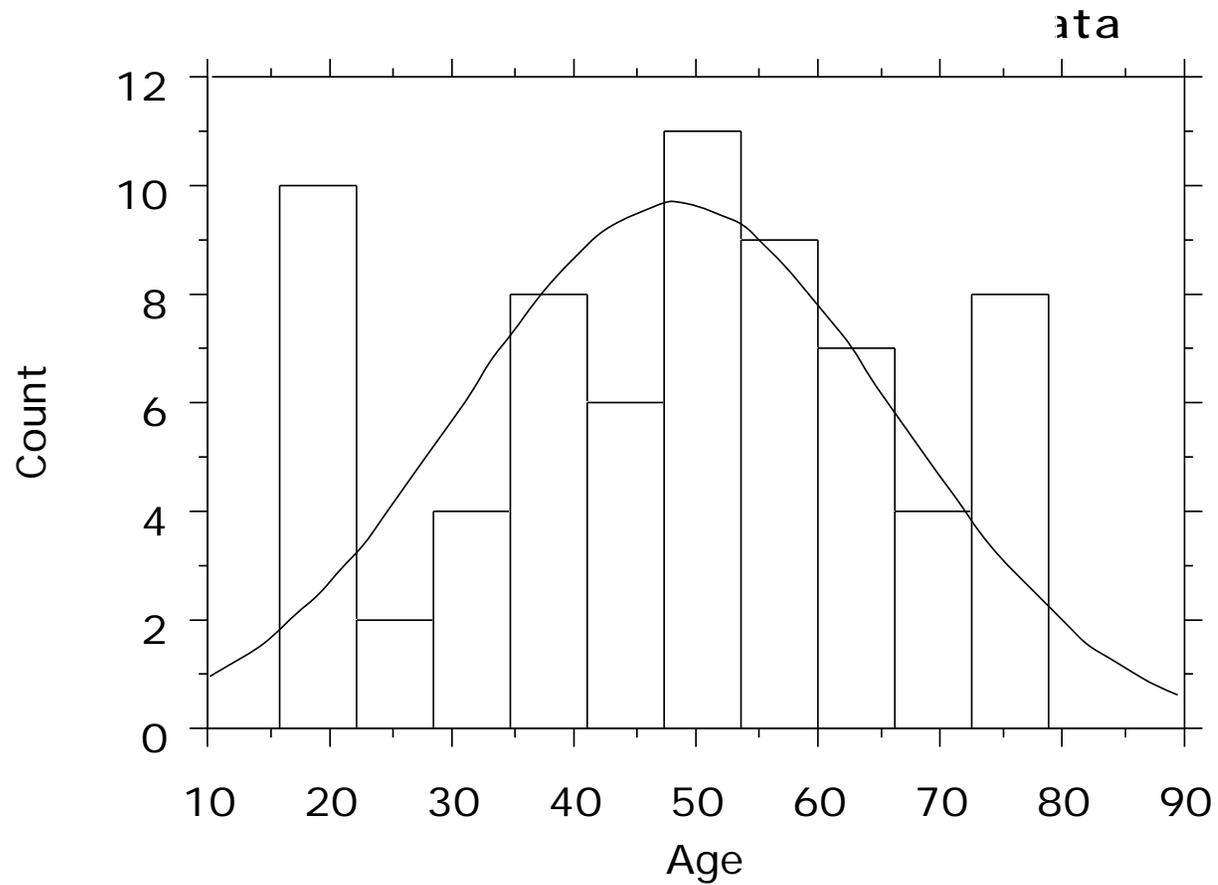
Crash Severity



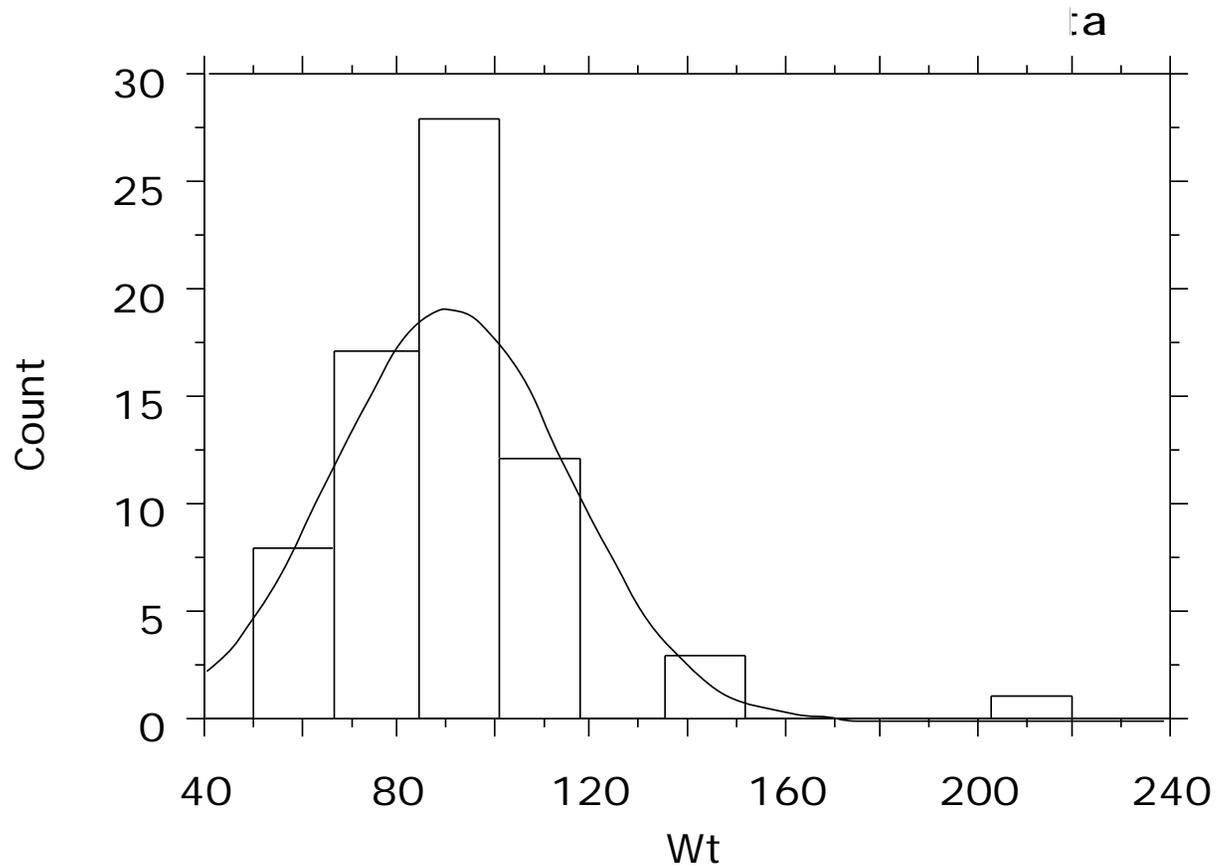
Offset Frontal Crashes by CDC



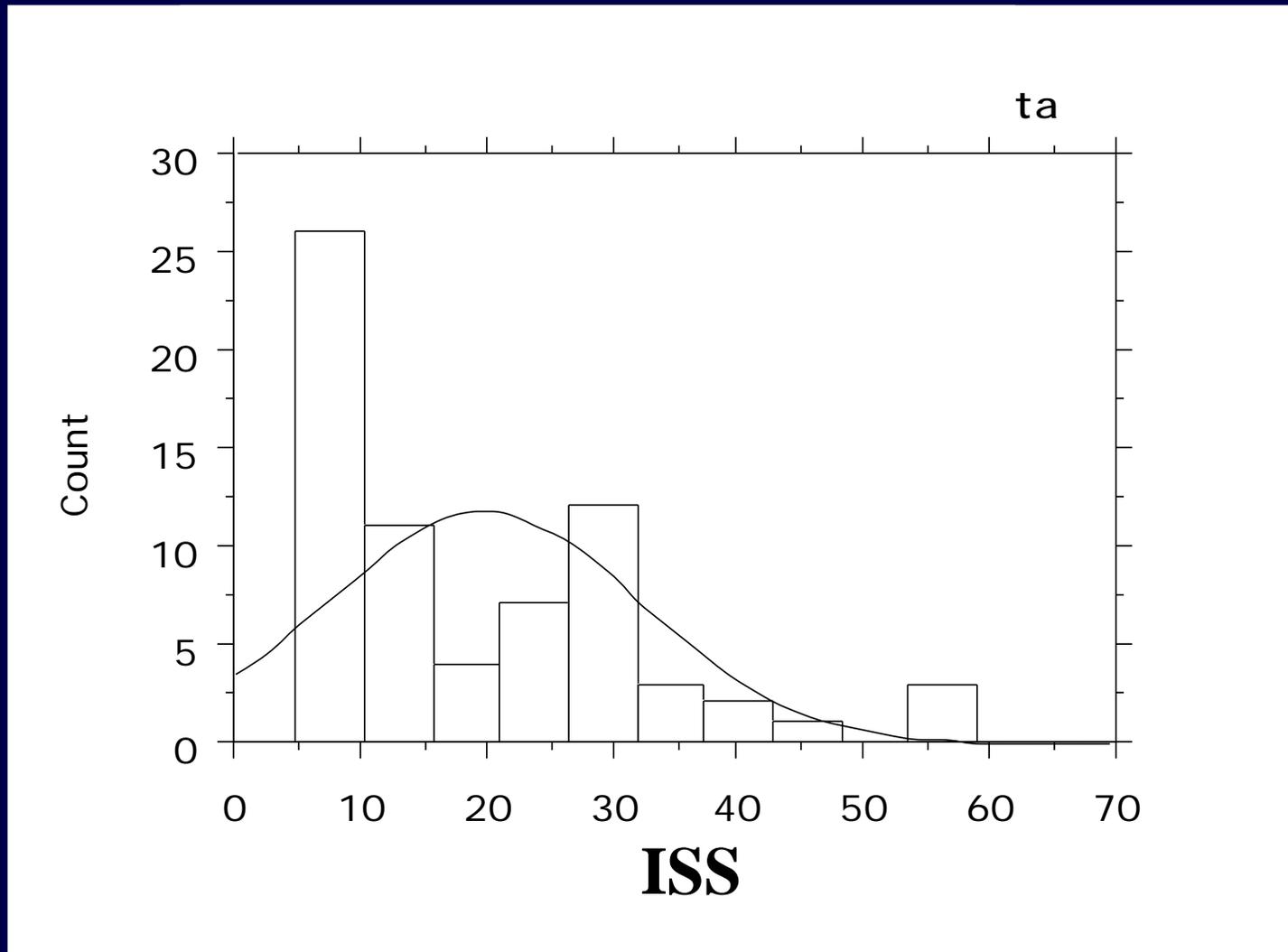
Occupant Age



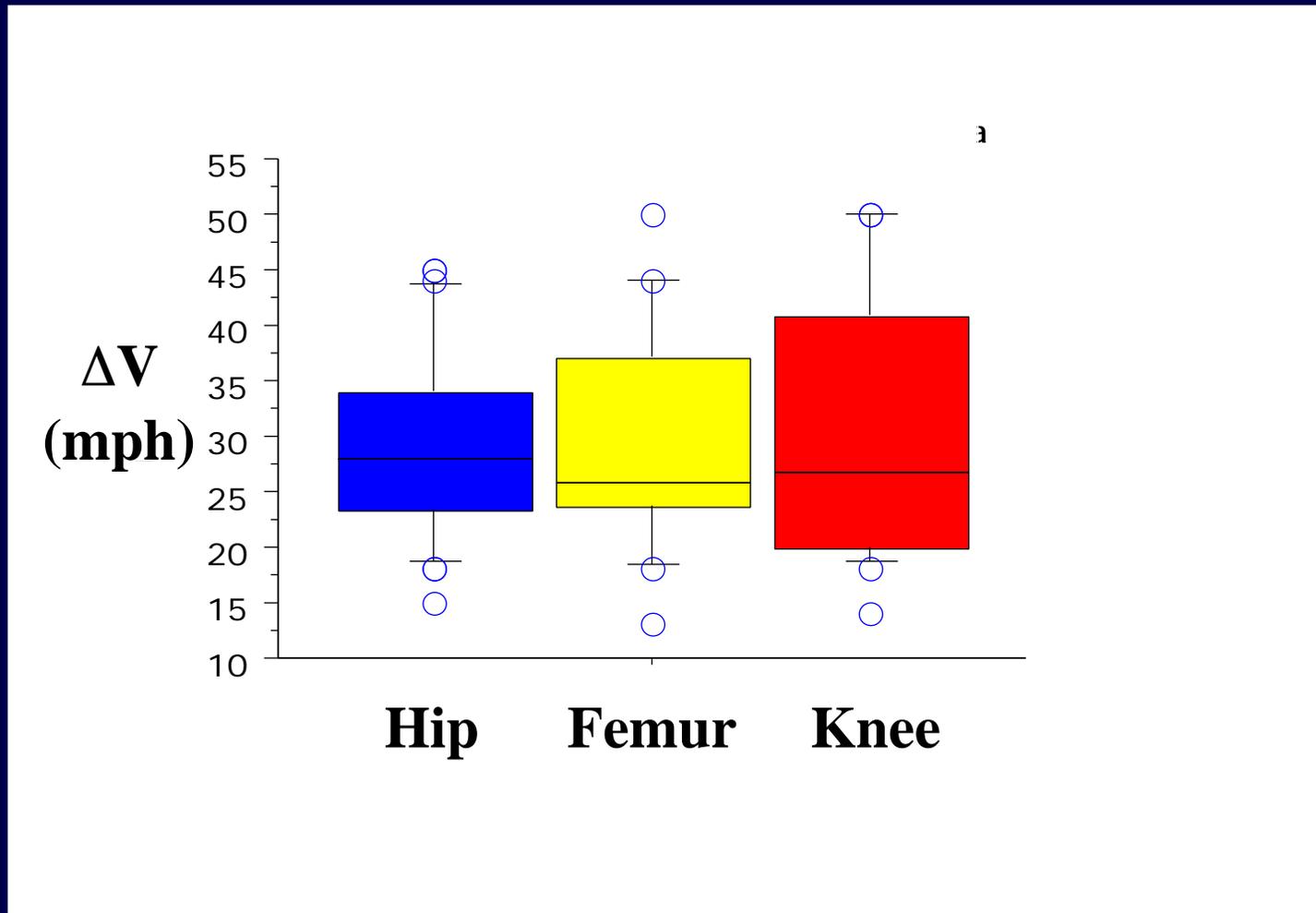
Occupant Weight



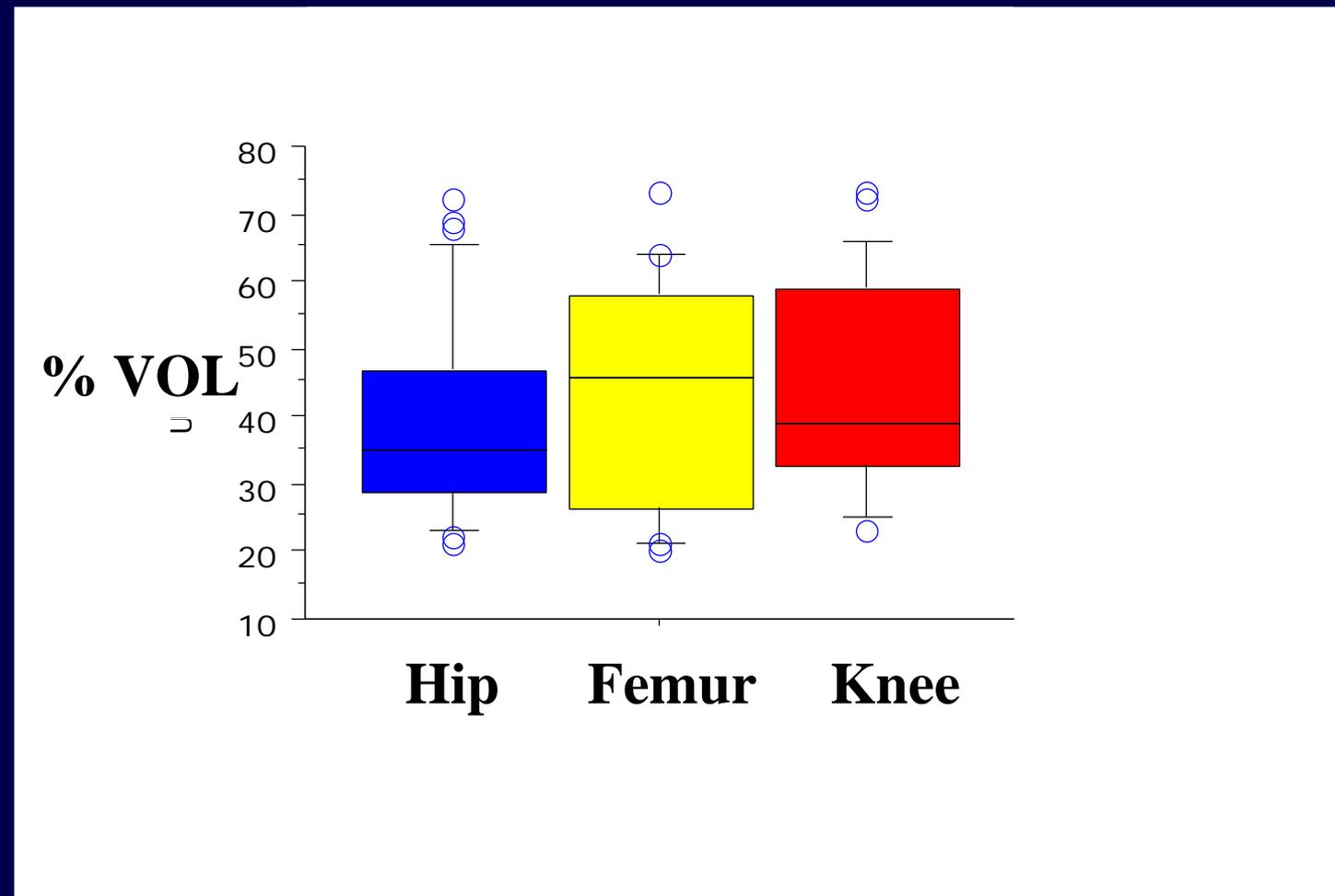
Injury Severity (ISS)



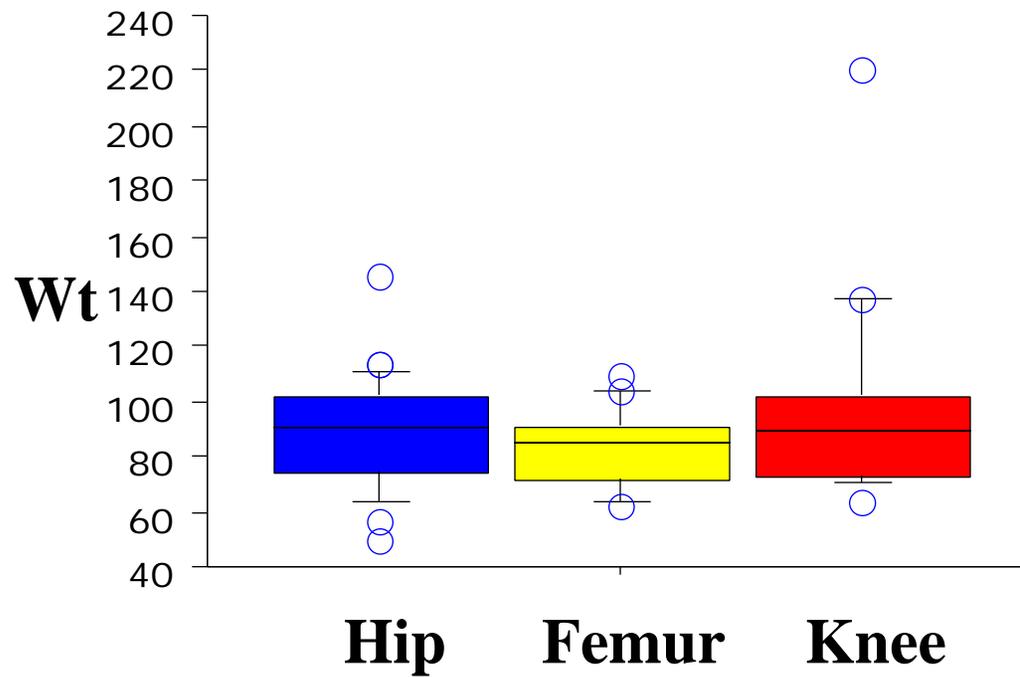
Crash Severity and KTH Injury Region



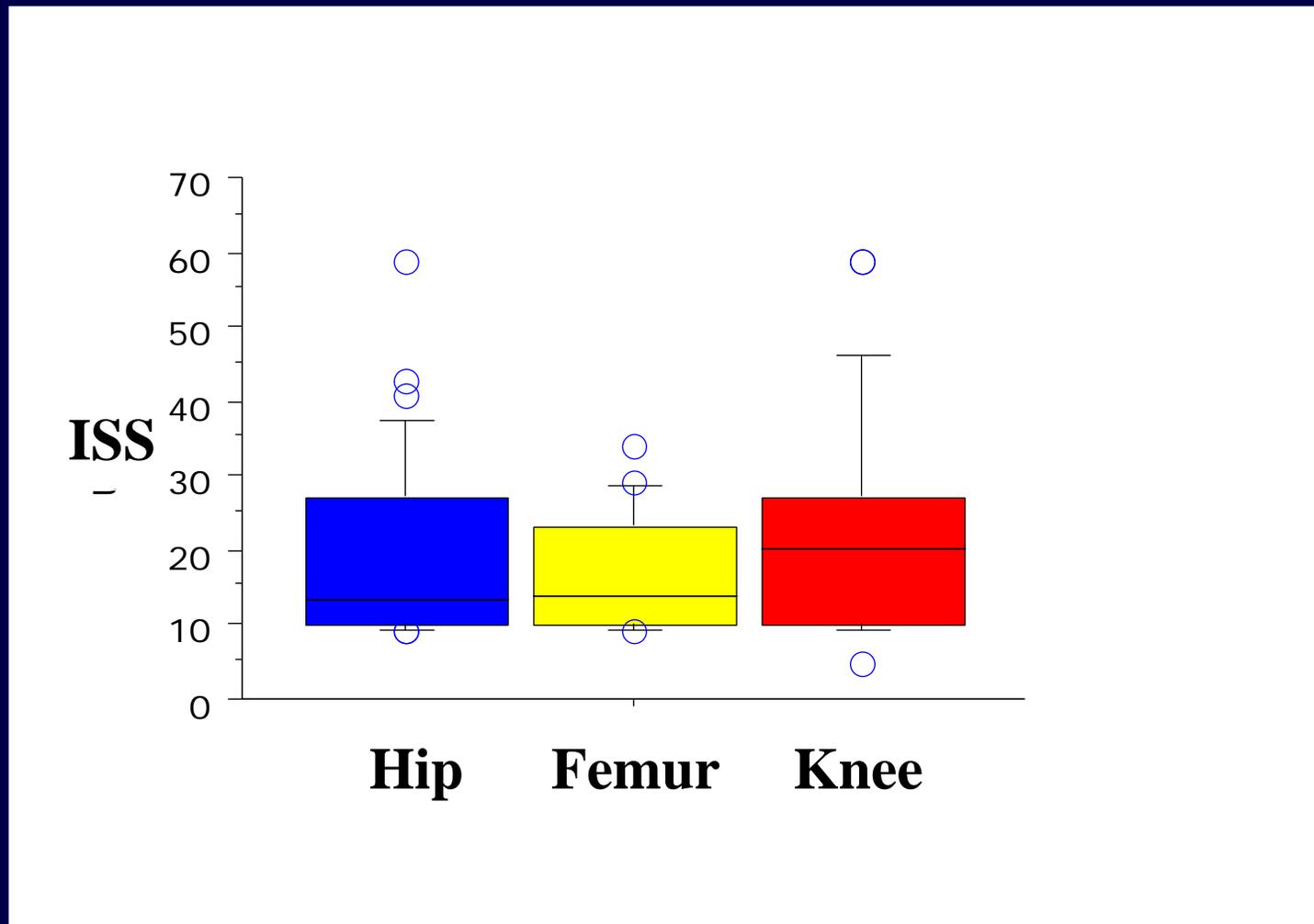
Frontal Offset % VOL and KTH Injury Region



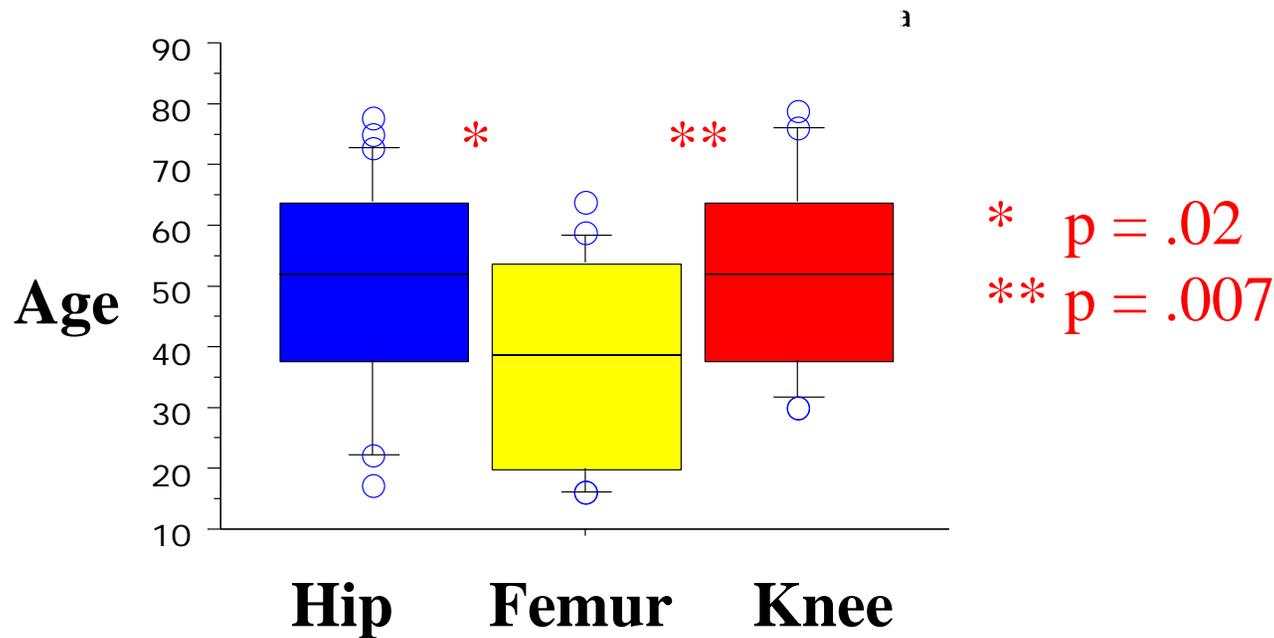
Occupant Weight and KTH Injury Region



Injury Severity (ISS) and KTH Injury Region



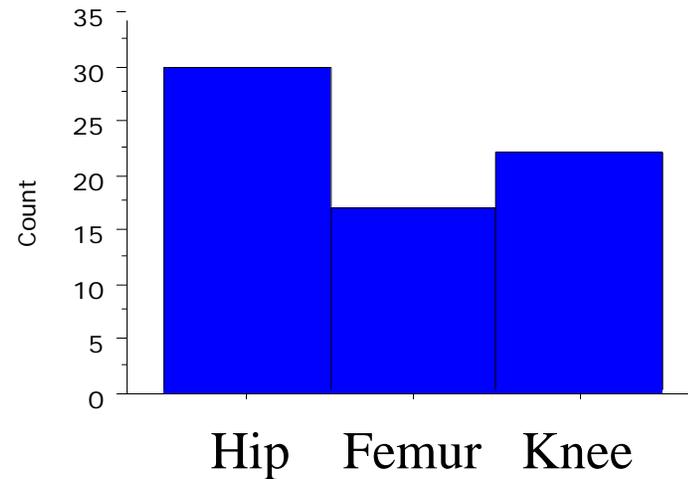
Occupant Age and KTH Injury Region



Average age observed for Femur fractures is less than that observed for Hip and Knee fractures

Does restraint use affect the type of KTH injuries in offset frontal crashes?

Effect of Restraint on KTH Injury Region



Observed

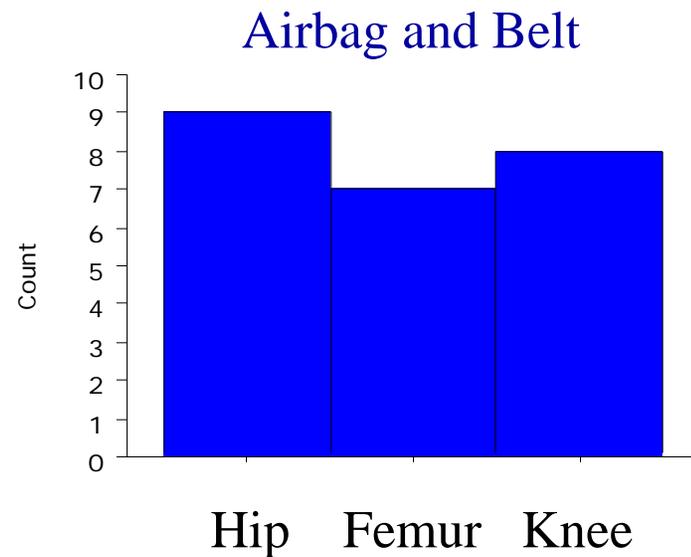
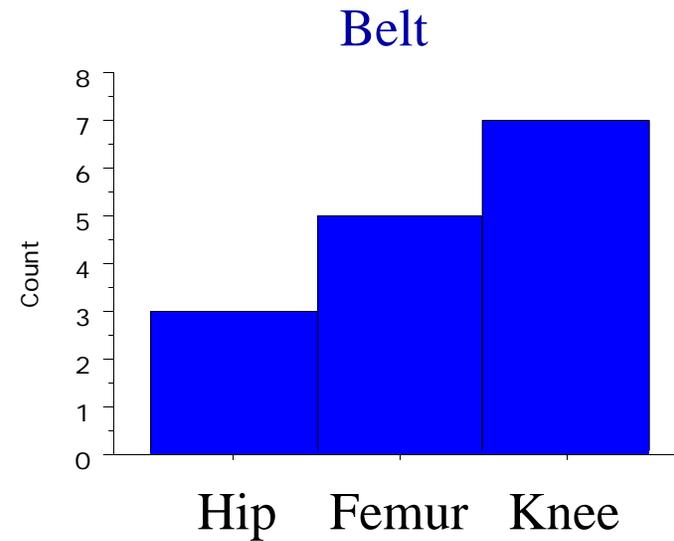
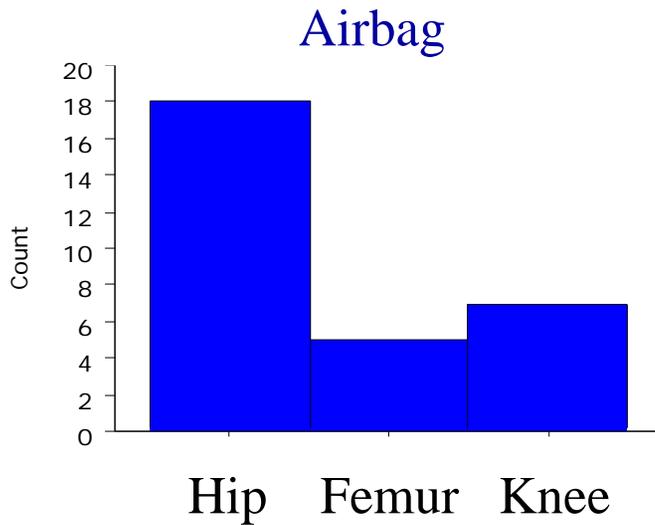
	Hip	Femur	Knee	Totals
Airbag	18	5	7	30
Combo	9	7	8	24
Belt	3	5	7	15
Totals	30	17	22	69

Expected

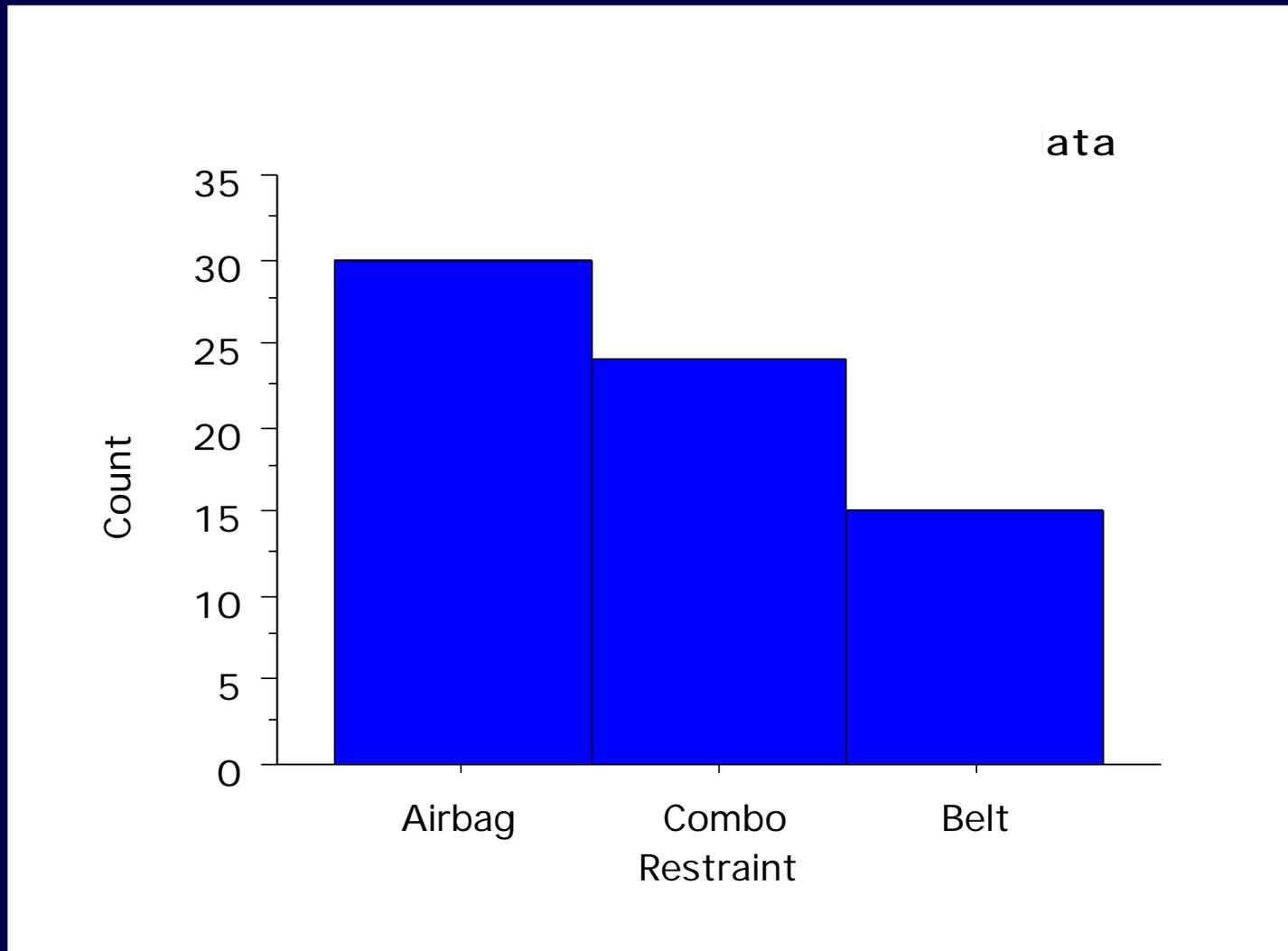
	Hip	Femur	Knee	Totals
Airbag	13.043	7.391	9.565	30.000
Combo	10.435	5.913	7.652	24.000
Belt	6.522	3.696	4.783	15.000
Totals	30.000	17.000	22.000	69.000

Observed incidence of HIP injuries was affected by RESTRAINT use. Hip injuries were more frequently found with airbag only restraint and uncommon with belt only restraint.

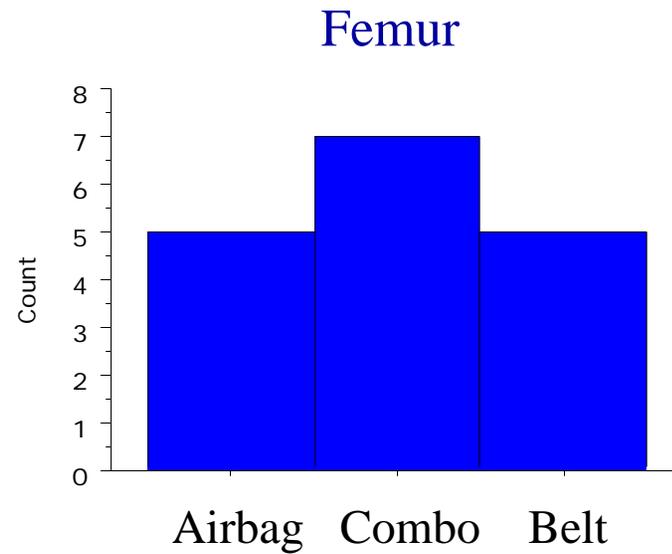
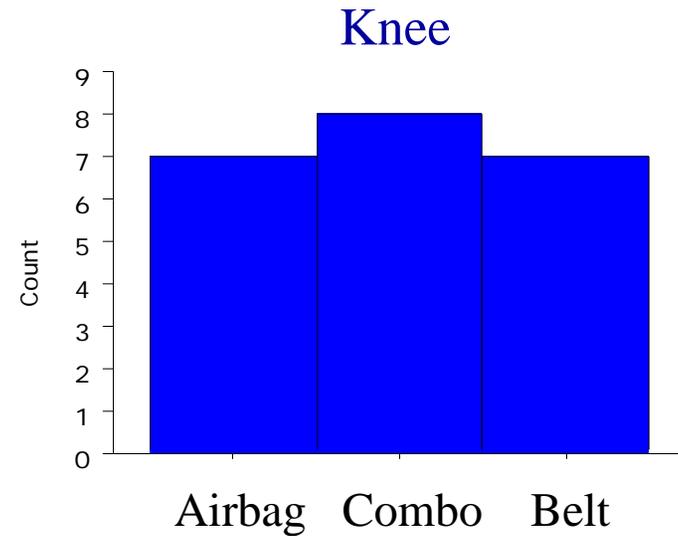
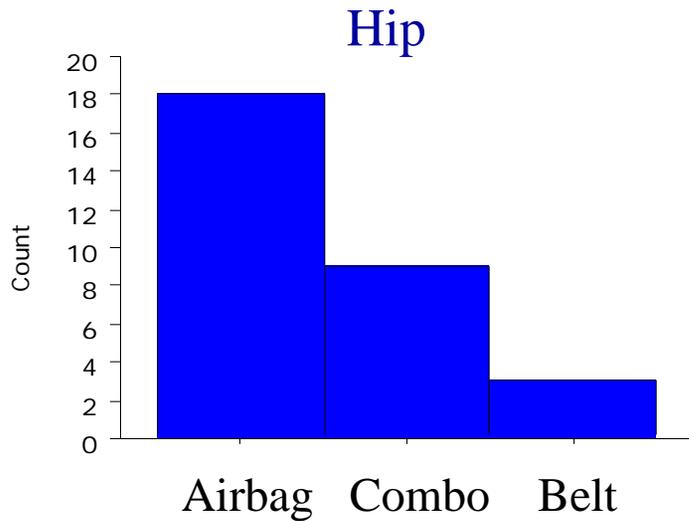
Effect of Restraint on KTH Injury Region



Restraint use in KTH injured case occupants

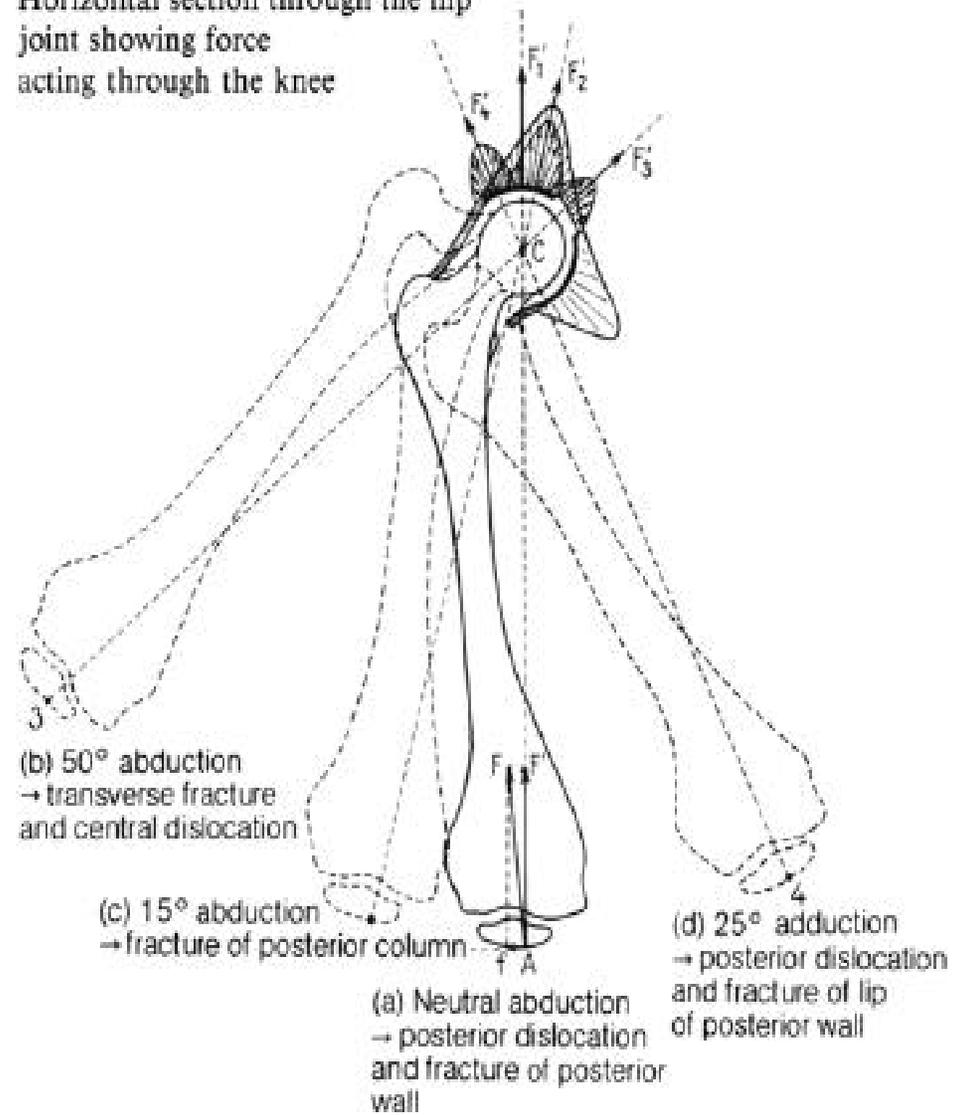


Effect of Restraint on KTH Injury Region

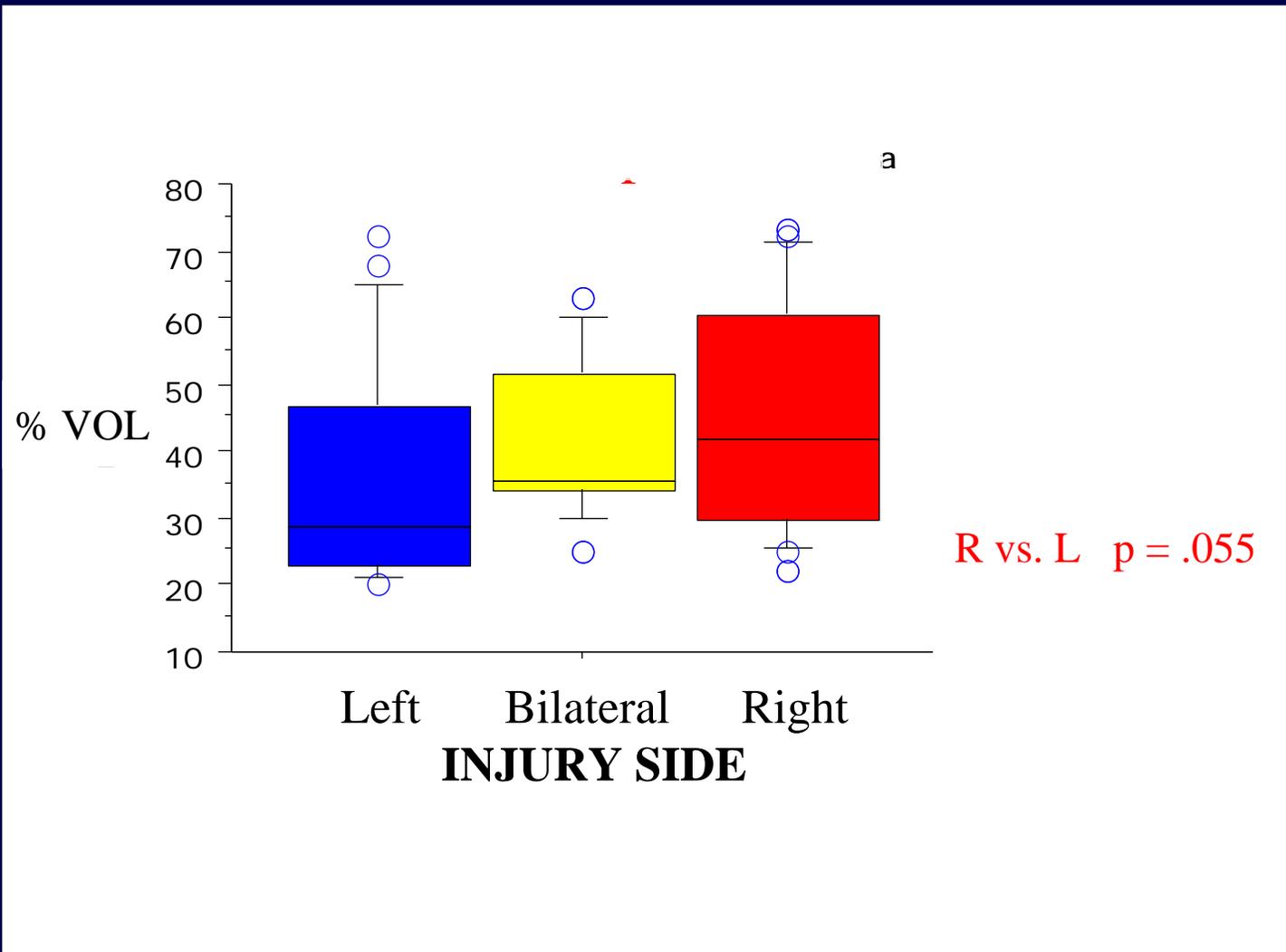




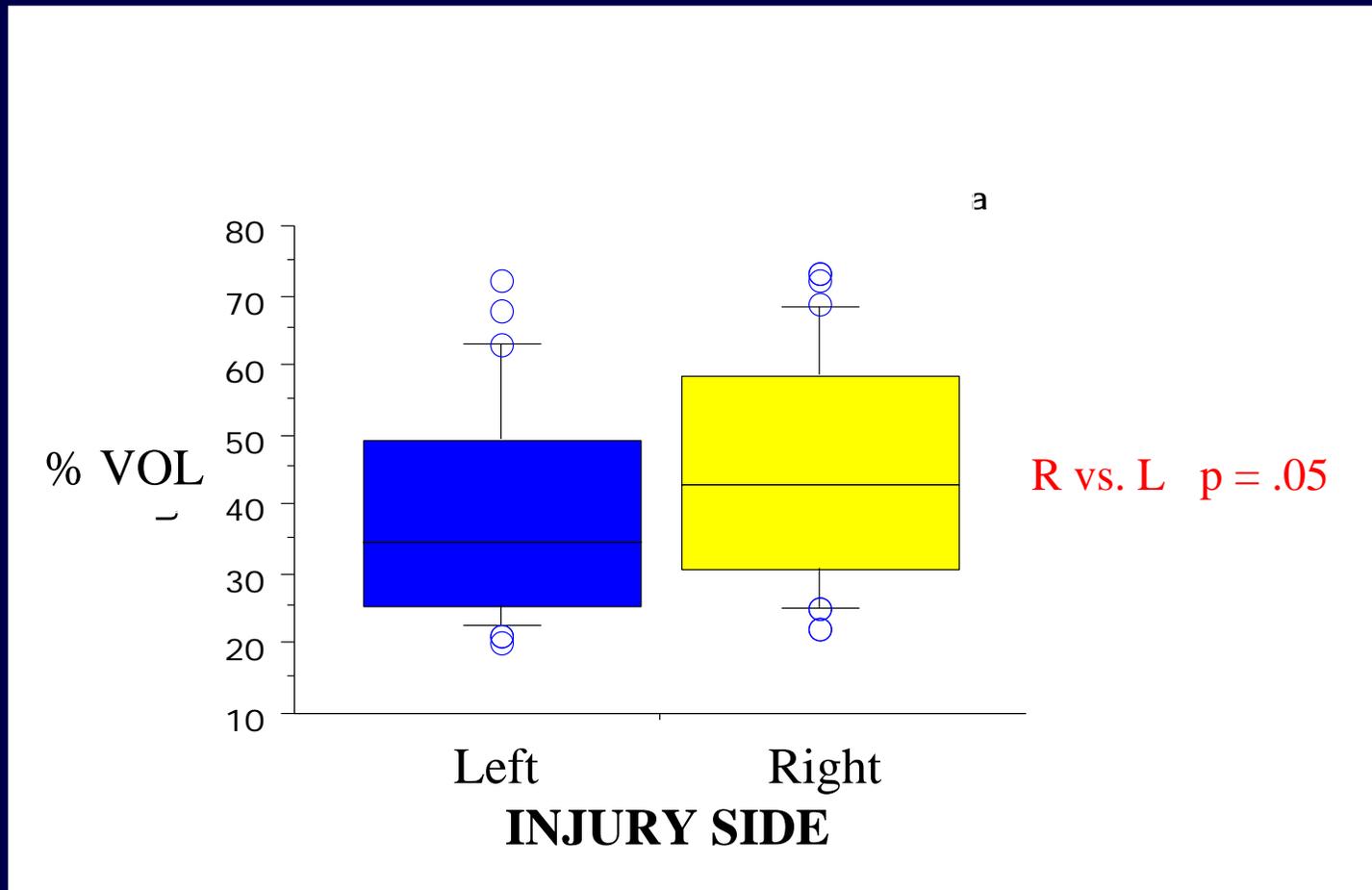
Horizontal section through the hip joint showing force acting through the knee



Injury Side and % VOL

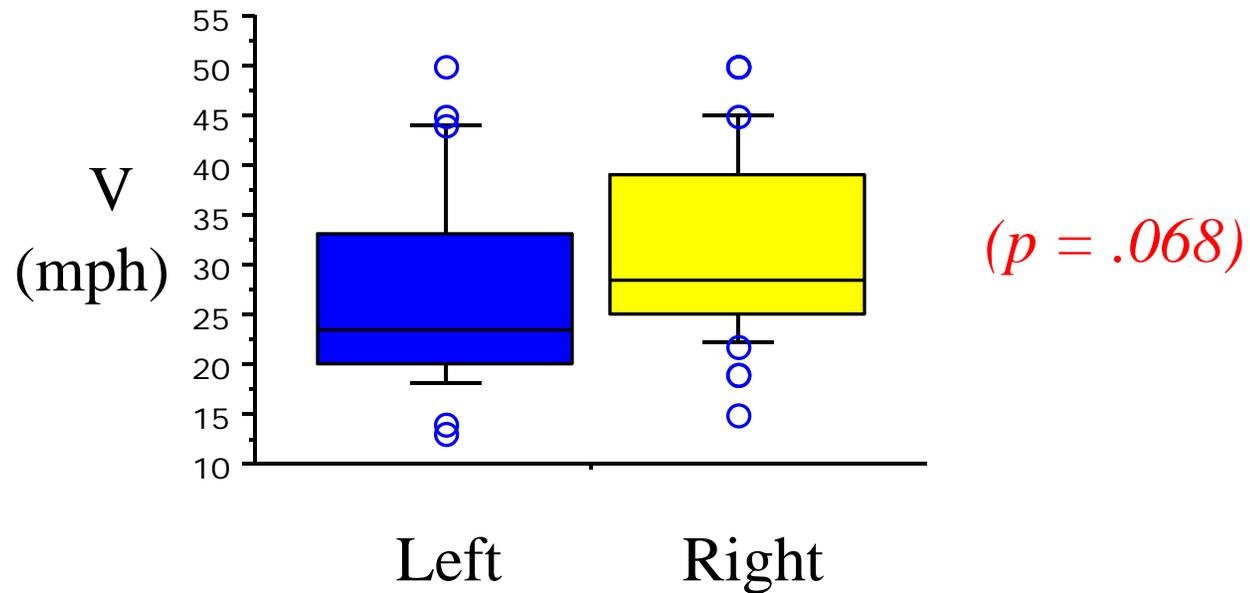


Injury Side and % VOL

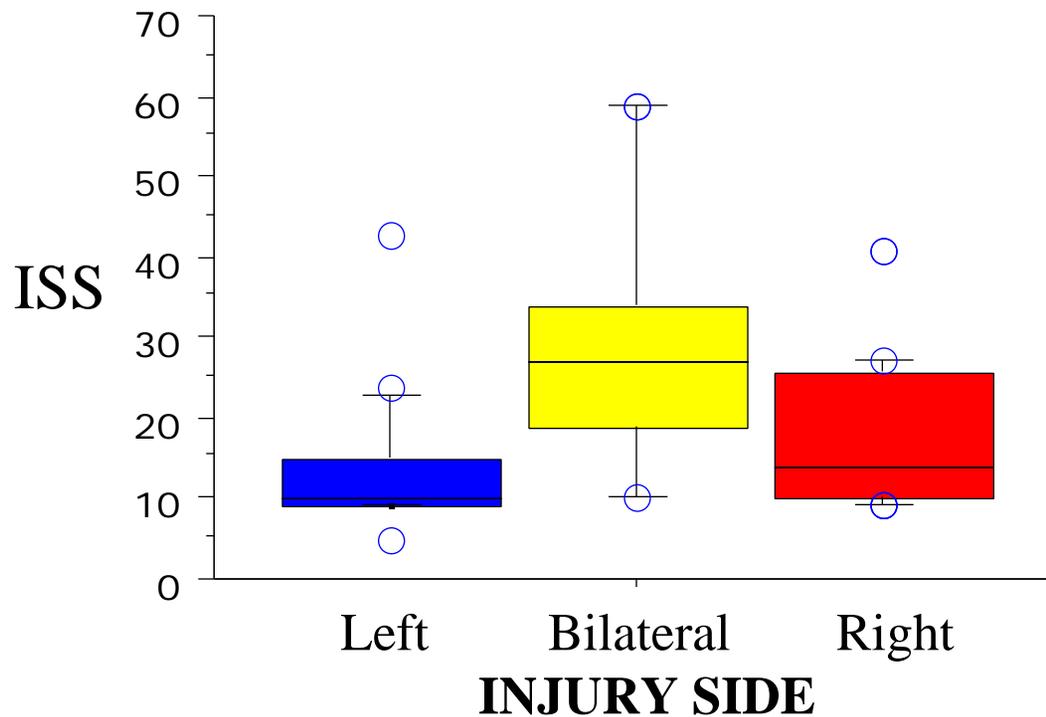


Less % VOL sufficient to cause L sided injuries compared to R.

Crash Severity (V) and Side of Injury



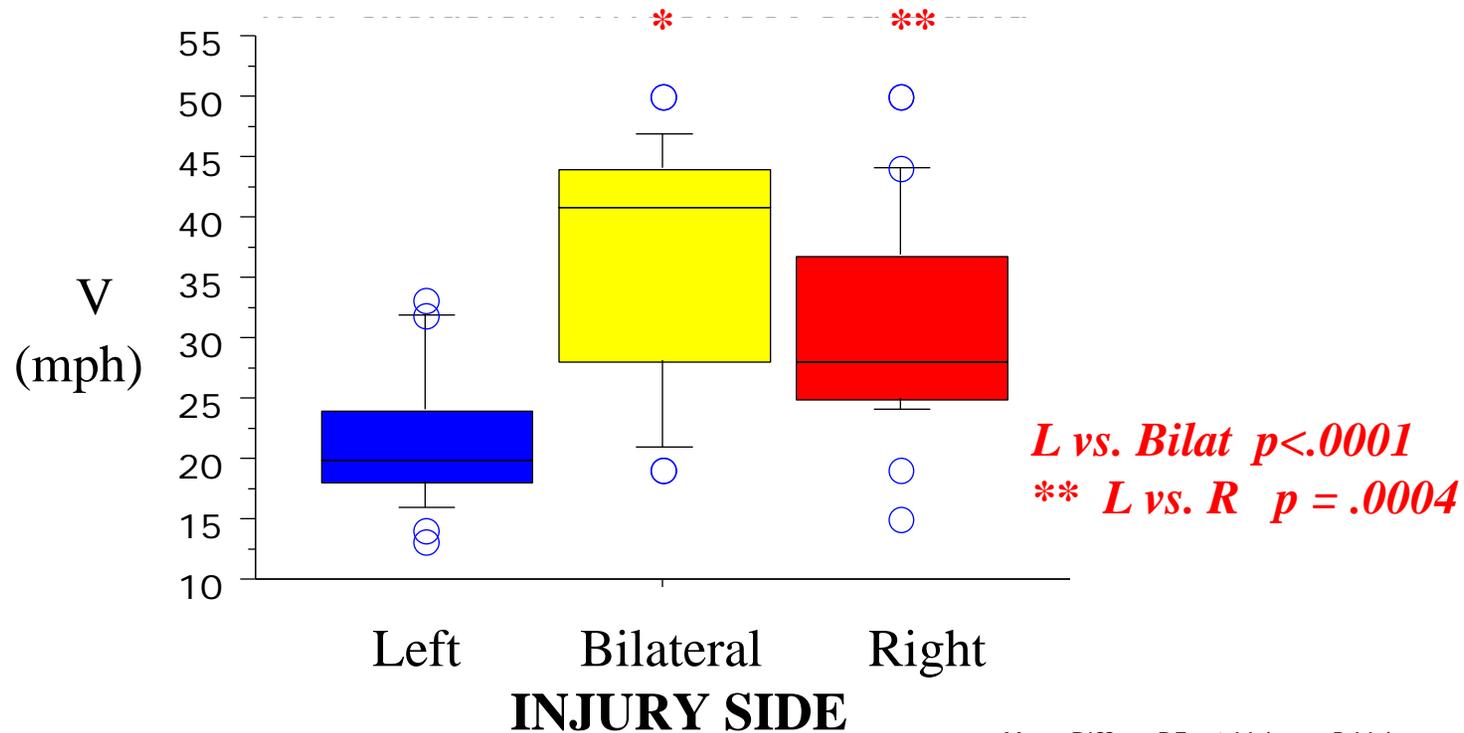
Injury Severity (ISS) and Side of Injury



L vs. Bilateral; p=.0005 L vs. R; p = .0033

Occupants with LEFT sided KTH injuries were generally less severely injured than occupants sustaining RIGHT sided or BILATERAL injuries

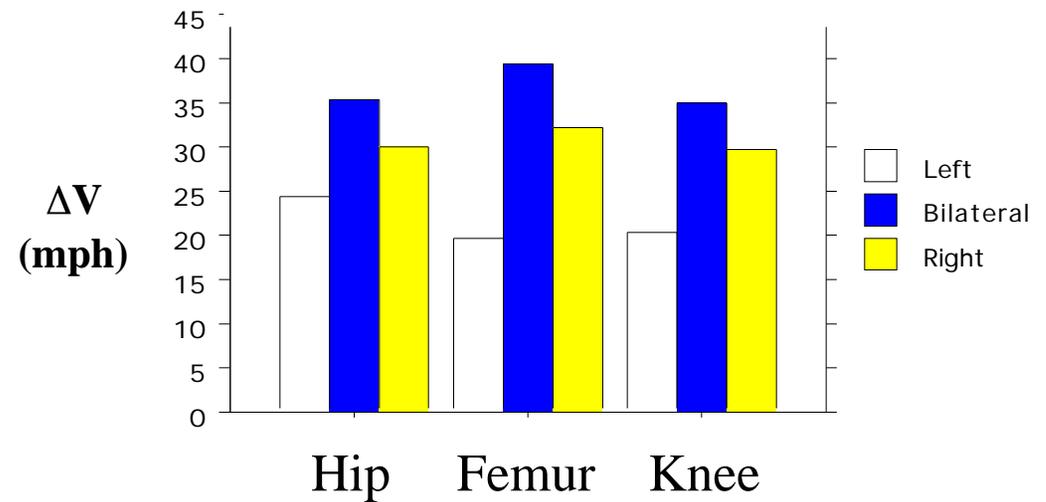
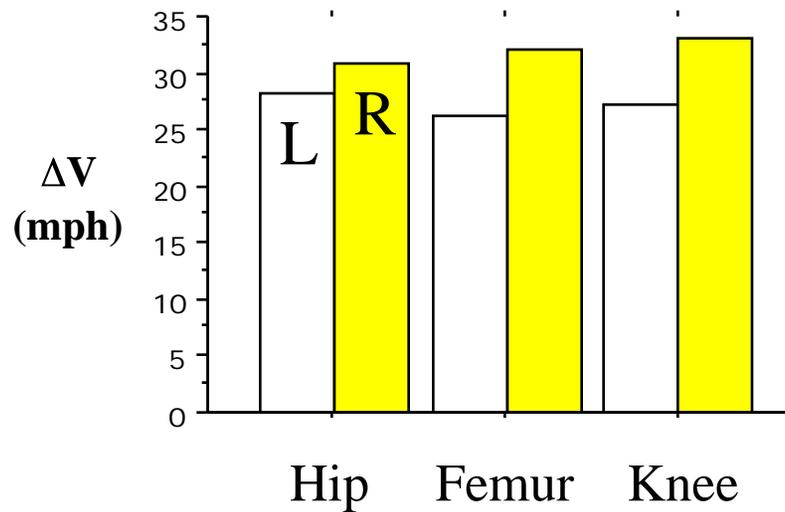
Injury Side & Crash Severity



	Mean Diff.	DF	t-Value	P-Value
Left, Bilateral	-13.862	39	-5.371	<.0001
Left, Right	-8.804	45	-3.805	.0004
Bilateral, Right	5.058	46	1.825	.0745

Less severe crashes (avg only 20 mph) were sufficient to cause LEFT sided KTH injuries than RIGHT sided or BILATERAL injuries.

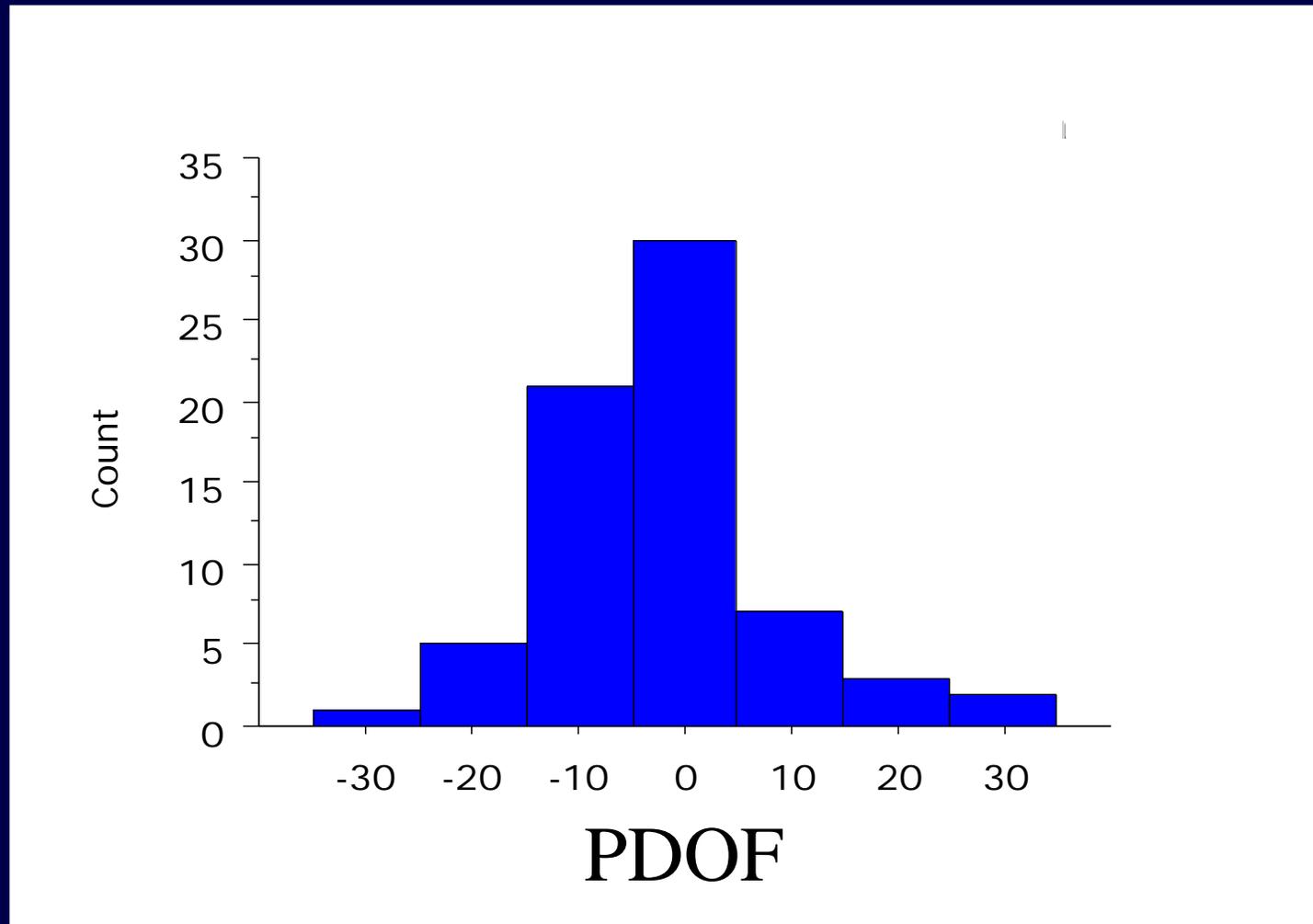
Injury Side, Injury Region & Crash Severity



Why are less severe crashes
sufficient to cause L sided injuries?

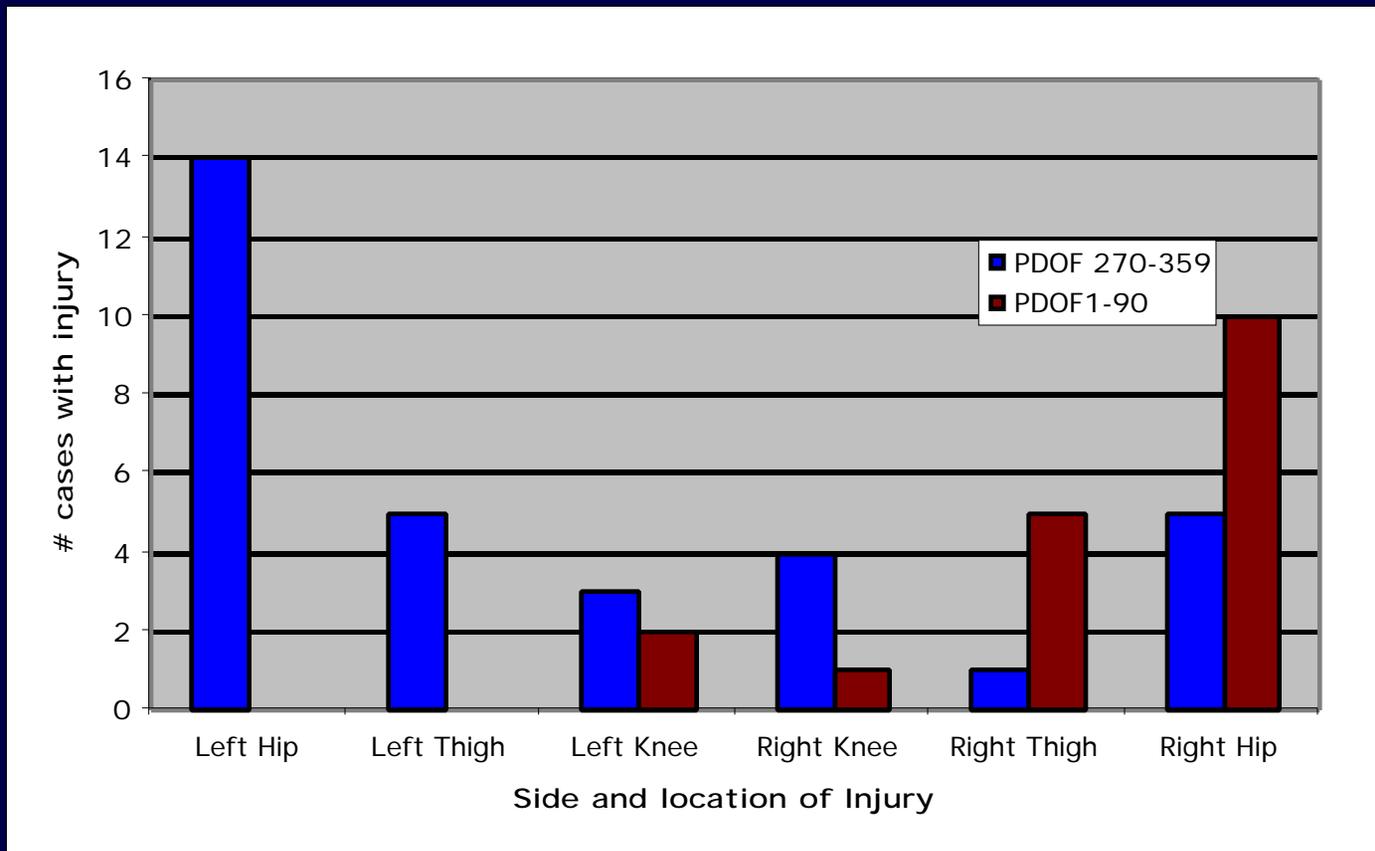
How important is PDOF?

Distribution of Offset Frontal Crashes by PDOF



Site and Side of Frontal Offset KTH Injuries

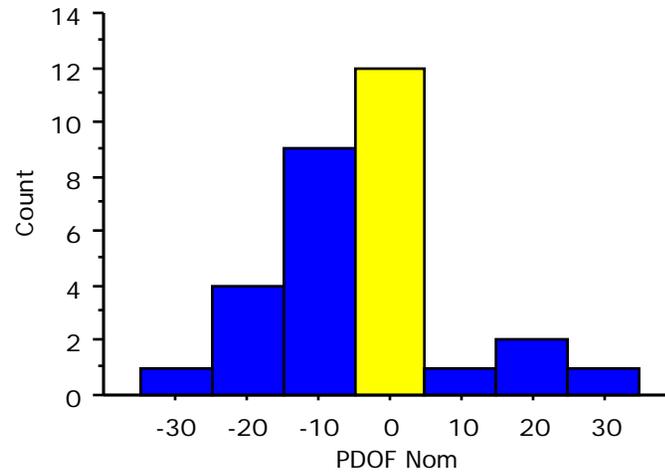
Effect of PDOF (excluding 0)



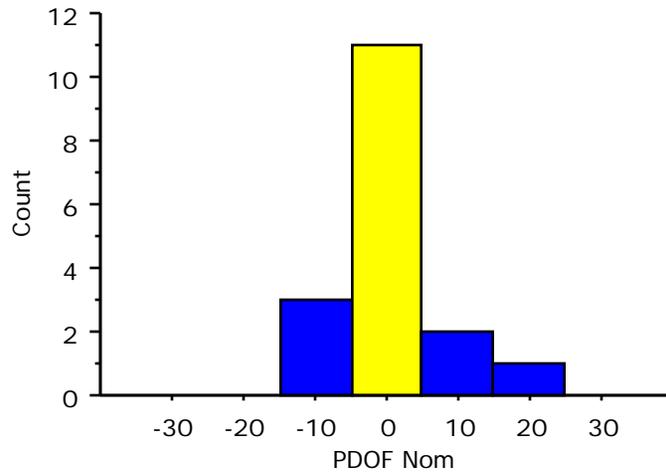
Negative PDOF associated with LEFT sided Hip fractures.

Site of Offset KTH Injuries: Effect of PDOF

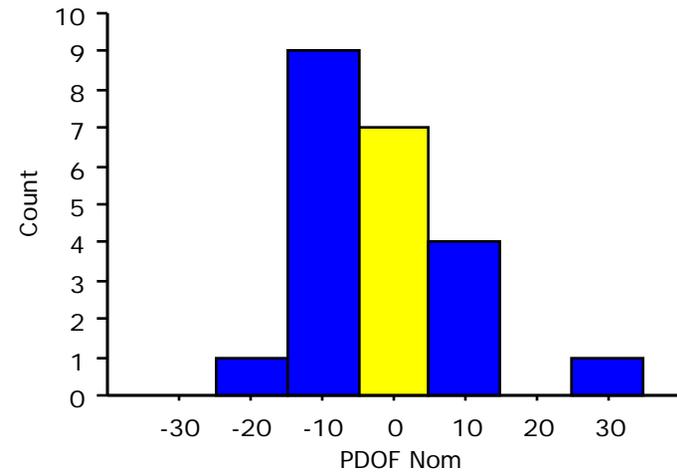
Hip



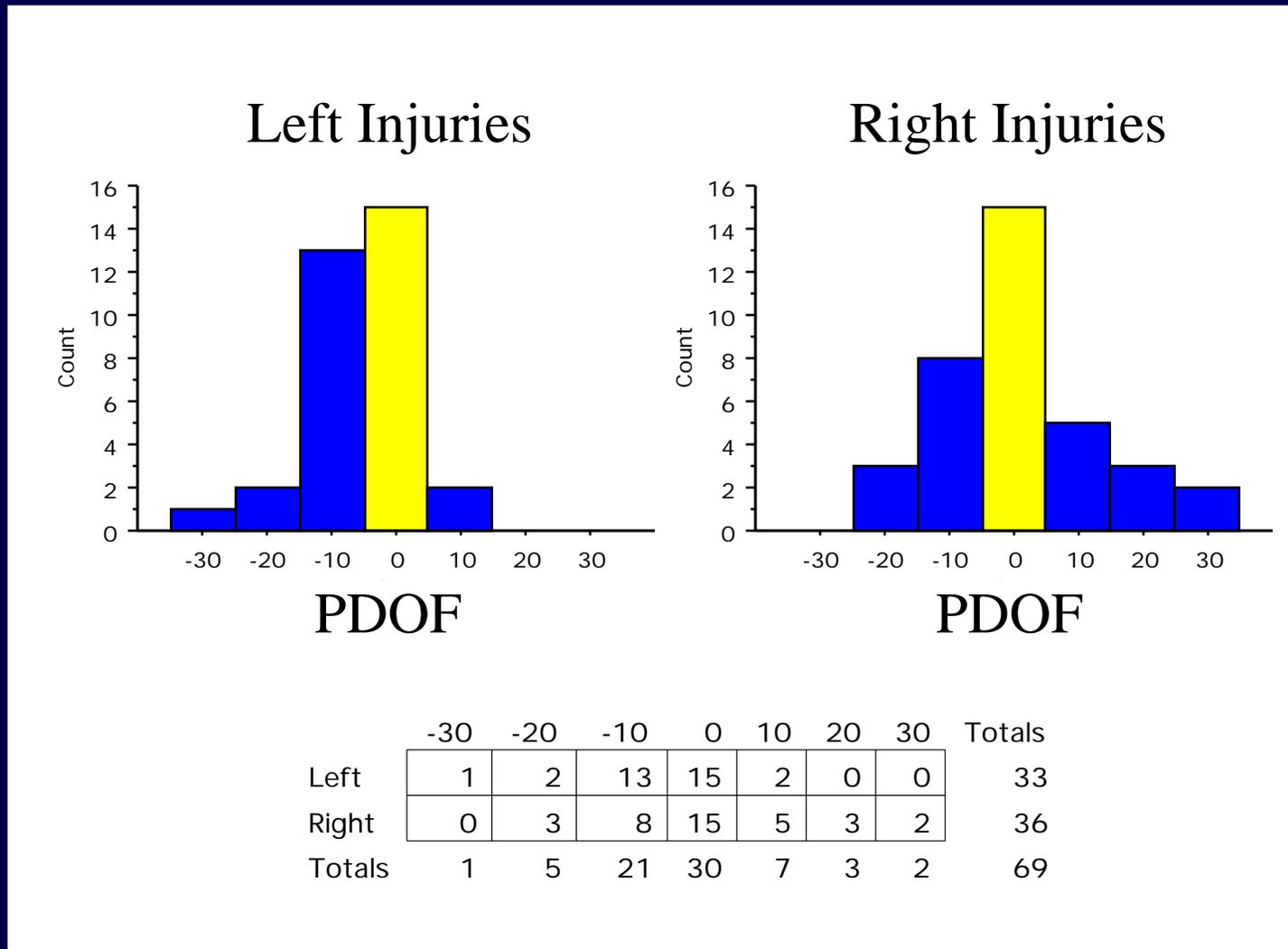
Femur



Knee



Side of Offset KTH Injuries: Effect of PDOF



PDOF contributes to determining side of injury
(*particularly L sided injuries*), but only in part.

Also: Large subset of injuries have a 0 degree PDOF.

CDC

12F_ *xxx*

L Y D Z R



PDOF: 0

CDC: 12FYEW5

Bilateral KTH fx: L > R

30 yo F, Driver, S/L belts

1992 Saturn SL2

(vs. 1987 Ford Mustang)

Impact Type: offset frontal, 50% VOL

DDL: 60 cm; Max Crush: 125 cm (49 in)

Severity: 44 ΔV ; 54 EBS

Relevant Intrusions:

Steering column: 9 cm rear

Instrument panel: 21 cm rear

Left toepan: 63 cm rear

Right toepan: 55 cm rear



PDOF: 0

CDC: 12FDEW6

KTH fx: R

55 yo M, Driver, airbag and belts

1995 Ford F-150

(vs. 1986 Dodge Caravan)

Impact Type: frontal, 73% VOL

DDL: 138 cm; Max Crush: 168 cm

Severity: 50 ΔV ; 64 EBS

Relevant Intrusions:

Instrument panel: 33 cm rear

Right toepan: 73 cm rear



PDOF: 0

CDC: 12FZAW5

KTH fxs: R

43 yo M, Driver, Airbag

**1993 Dodge Intrepid
(vs. Tree)**

**Impact Type: offset frontal, 42% VOL
DDL: 59 cm; Max Crush: 119 cm
Severity: 37 ΔV**

Relevant Intrusions:

Hood edge: 60 cm rear

Instrument panel: 37 cm rear

Vertical console: 7 cm left

Toe pan: 10 cm rear



PDOF: 0

CDC: 12FREE4

KTH fx: R

59 yo M, Driver, Airbag

1991 Lincoln Towncar vs. Tree

Impact Type: offset frontal

DDL: 41 cm, Max Crush: 112 cm

Severity: 31 ΔV

Relevant Intrusions:

Floor pan: 10 cm up



PDOF: 0

CDC: 12FLEW3, 00TYDO2

KTH fxs: L

48 yo M, driver, Airbag

1995 Ford F-150 (vs. 1994 Buick Regal)

**Impact: offset frontal, 27% VOL
(2-qtr rollover)**

DDL: 46 cm, Max Crush: 60 cm

Severity: 18 ΔV

Relevant Intrusions:

Steering column: 38 cm rear

Instrument panel: 36 cm rear

Kickpanel: 33 cm right

Toe pan: 19 cm rear



PDOF: 0

CDC: 12FLAE7

KTH fx: L

46 yo F, Driver, Airbag and belts

**1998 Lincoln Navigator
(vs. 1997 Kenworth hauling excavator)**

Impact: offset frontal, 20% VOL

DDL: 33 cm, Max Crush: 103 cm

Severity: 23 EBS

Relevant Intrusions:

Windshield header: 21 cm rear

A-pillar: 25 cm rear

Roof: 9 cm down

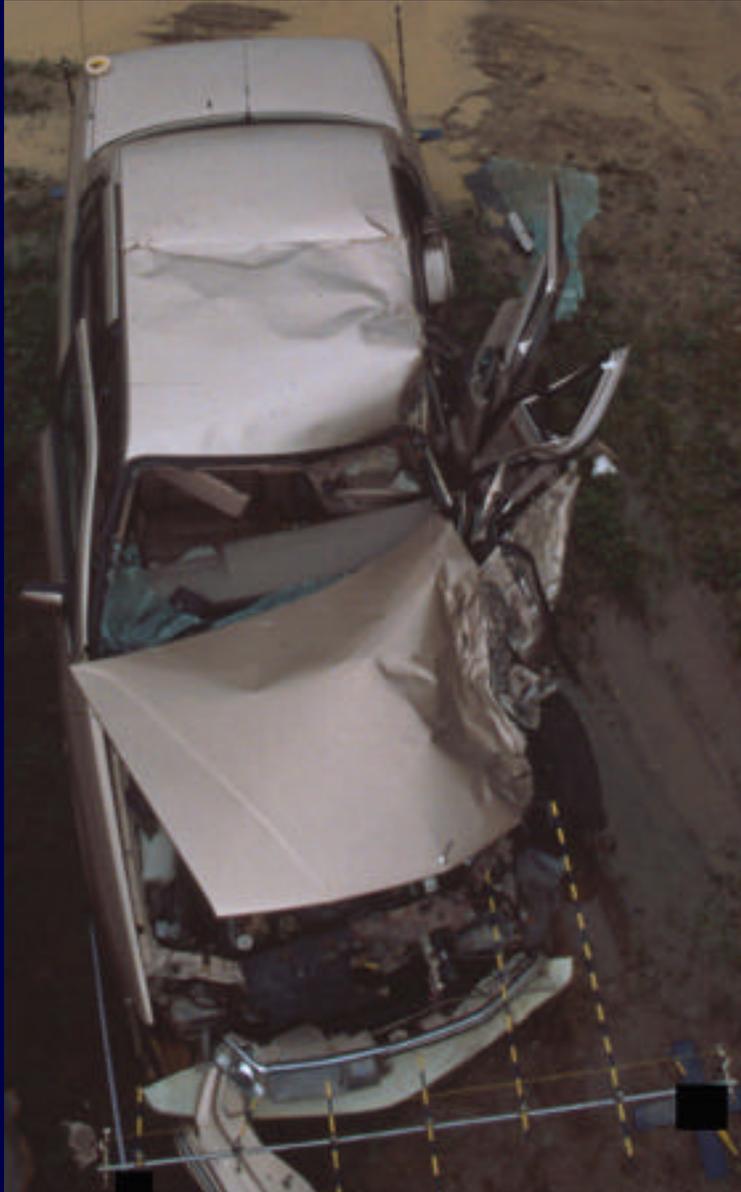
Roof siderail: 9 cm down

Instrument panel: 45 cm rear

Steering wheel hub: 44 cm rear

Parking brake: 21 cm rear

Brake pedal: 51 cm rear



PDOF: 0

CDC: 12FLAW7

KTH fxs: L

67 yo F, Driver, Airbag and belts

**1993 Lincoln Continental
(vs.1997 Mack tractor w/trailer)**

**Impact: offset frontal, 35% VOL
DDL: 50 cm, Max Crush: 61 cm
Severity: 18 EBS**

Relevant Intrusions:

Roof: 16 cm down

Windshield header: 32 cm rear

A-pillar: 25 cm rear

Instrument panel: 24 cm rear

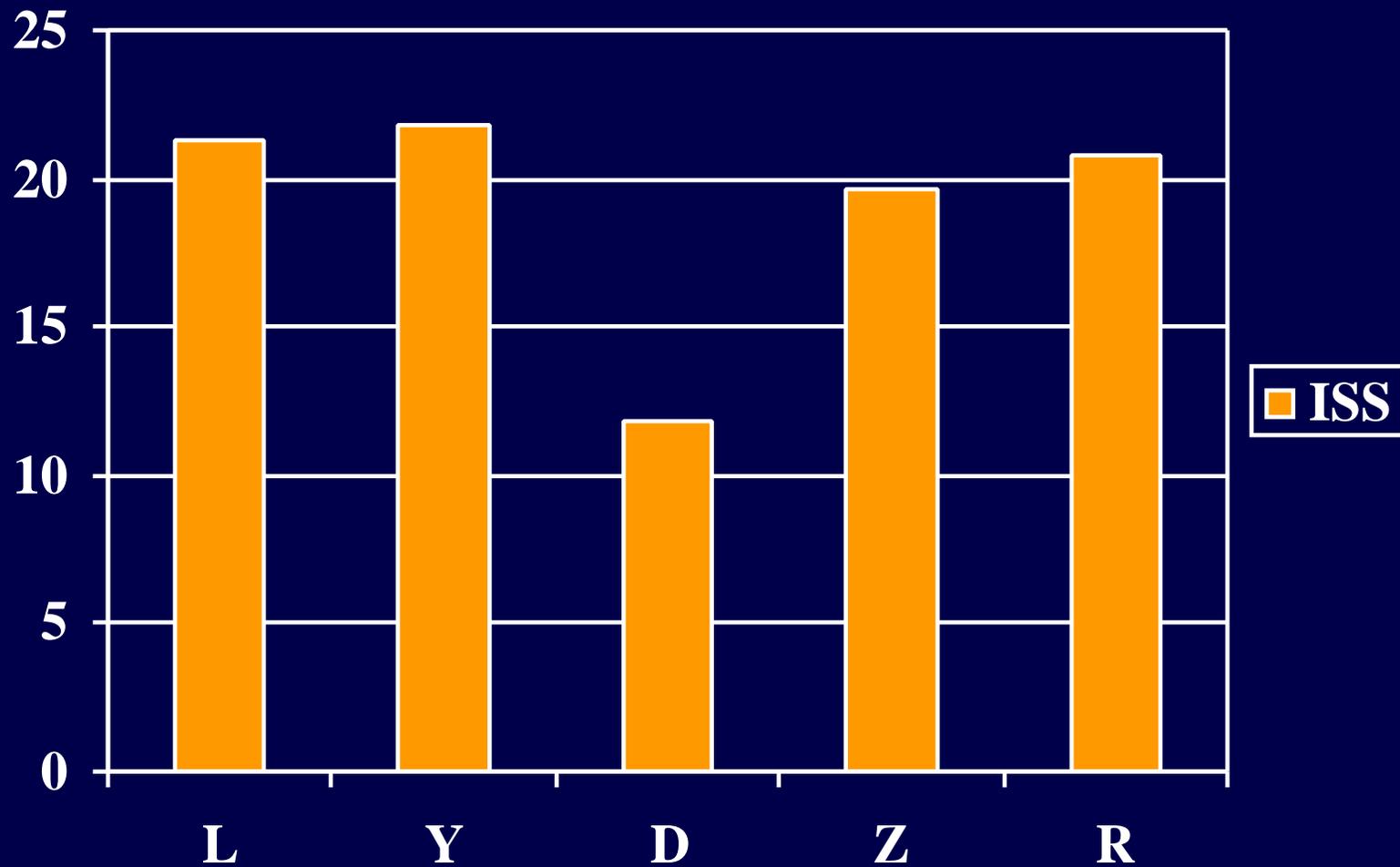
Steering wheel hub: 11 cm rear

Left knee bolster: 21 cm rear

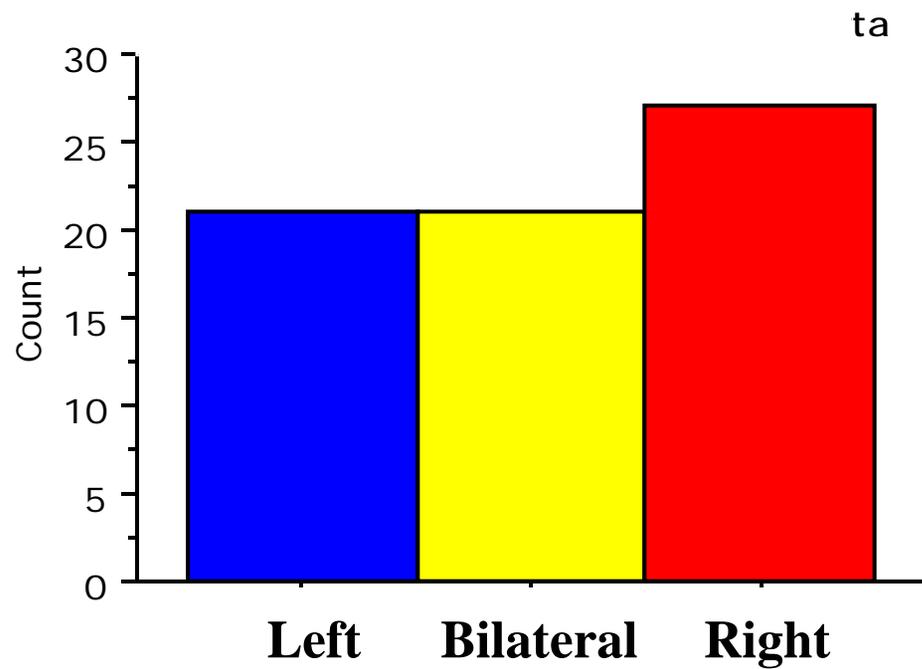
Right knee bolster: 18 cm rear

Effect of CDC Collision Class on ISS

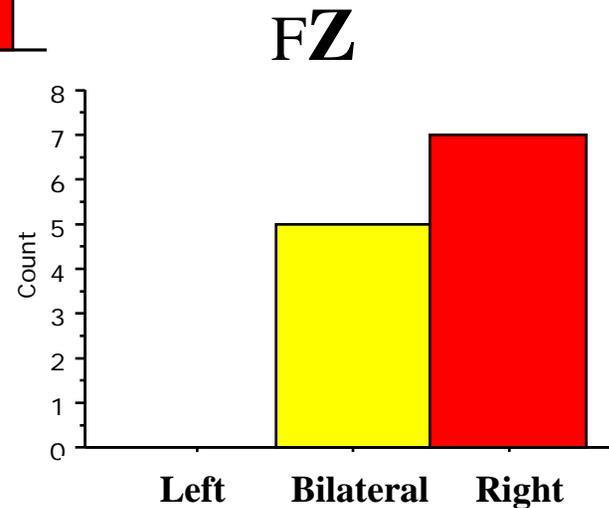
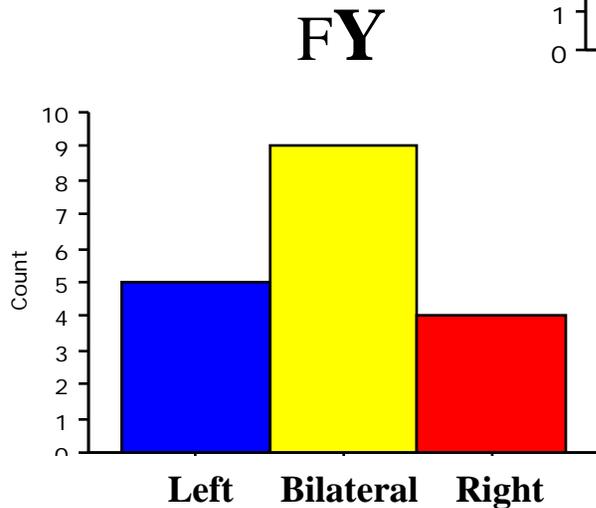
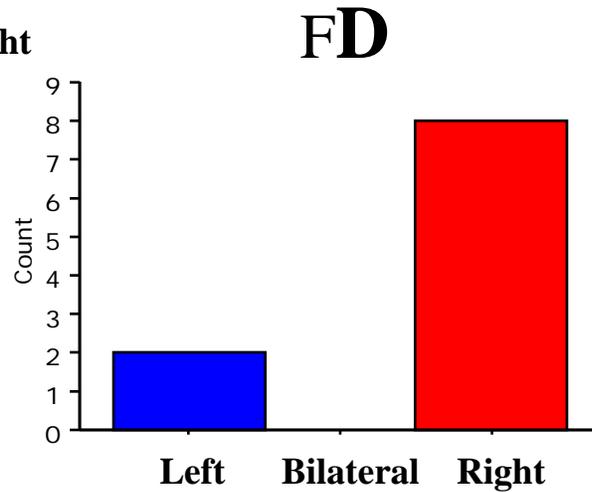
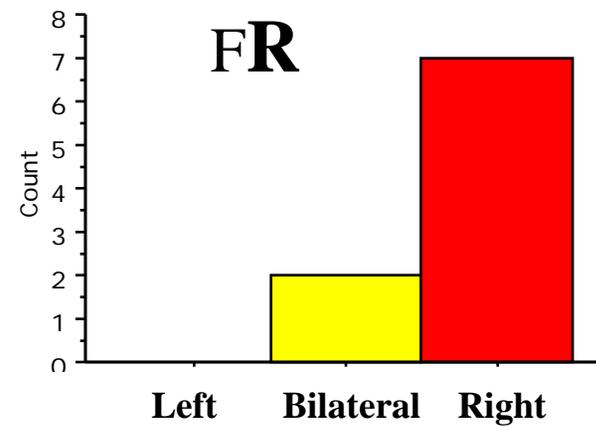
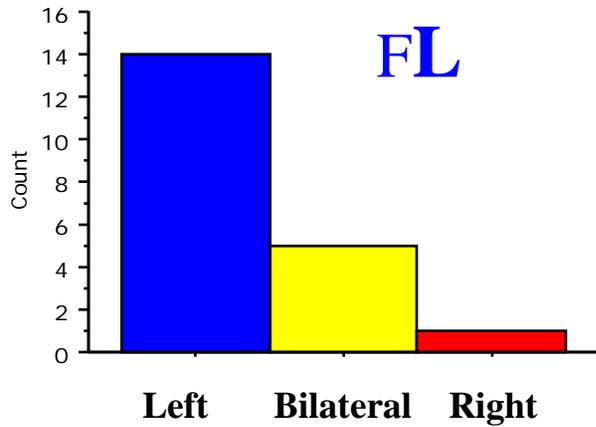
(Offset Frontal Crashes with KTH injury)



Distribution of KTH Injuries by Side

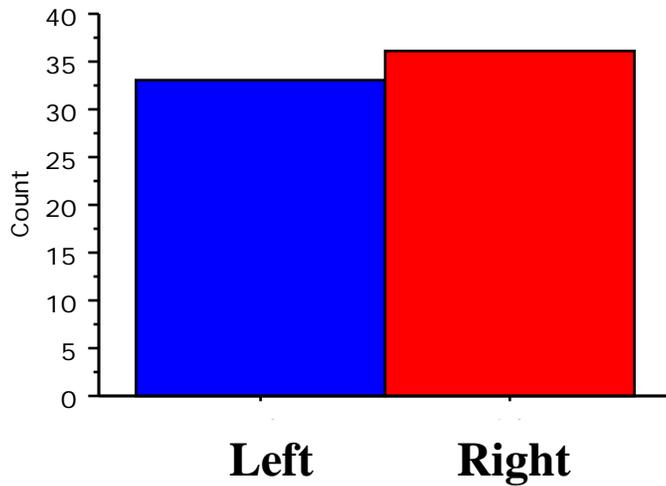


Distribution of KTH Injury Side: Split by CDC

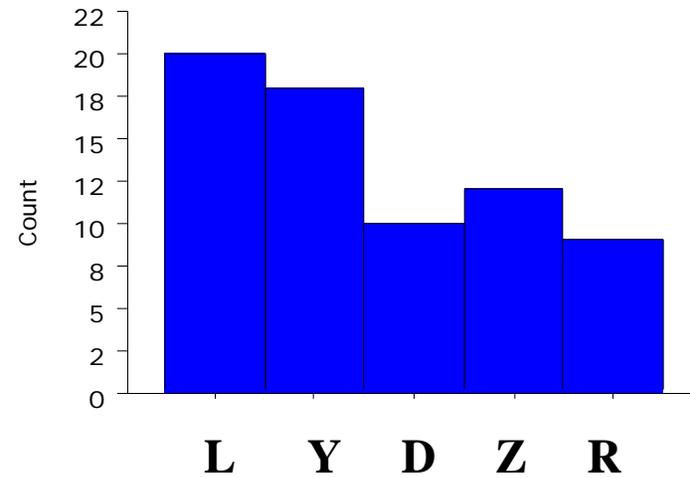


Distribution of Offset KTH Injuries by Side & CDC

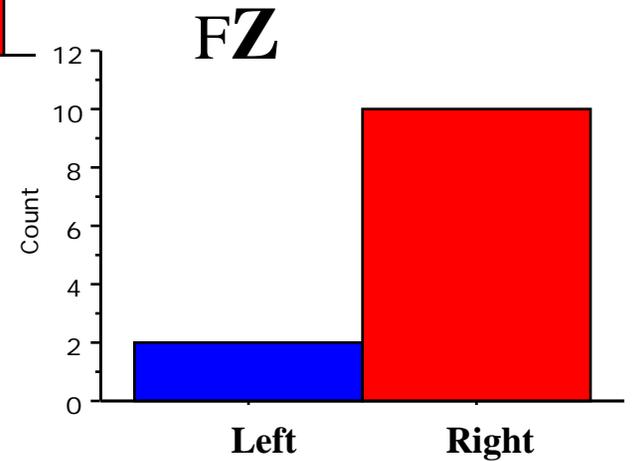
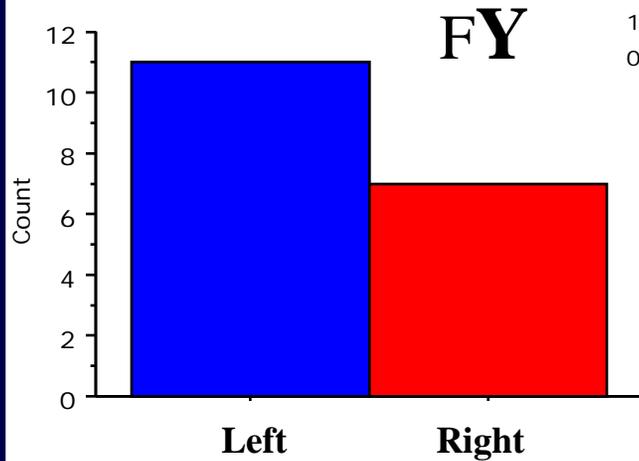
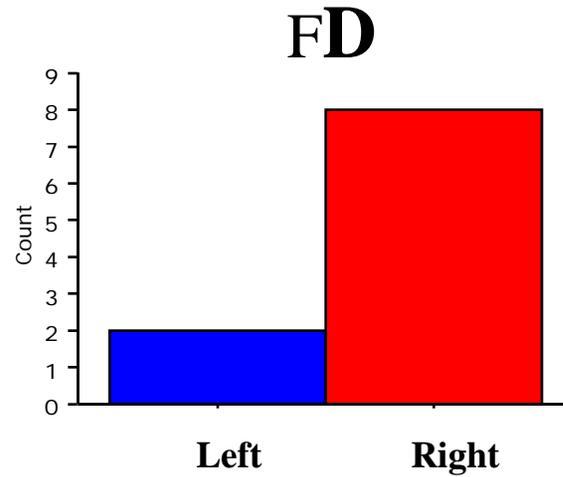
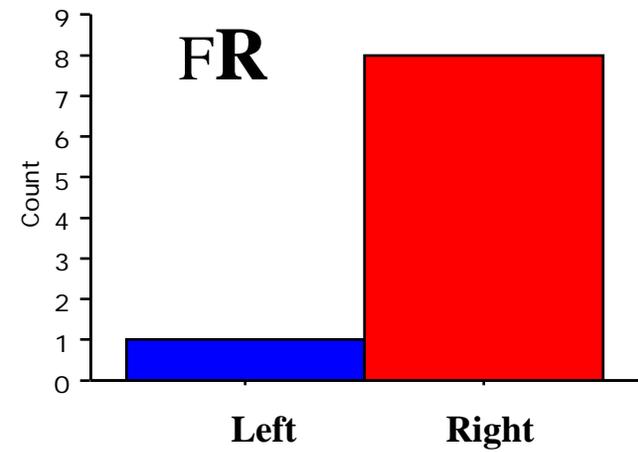
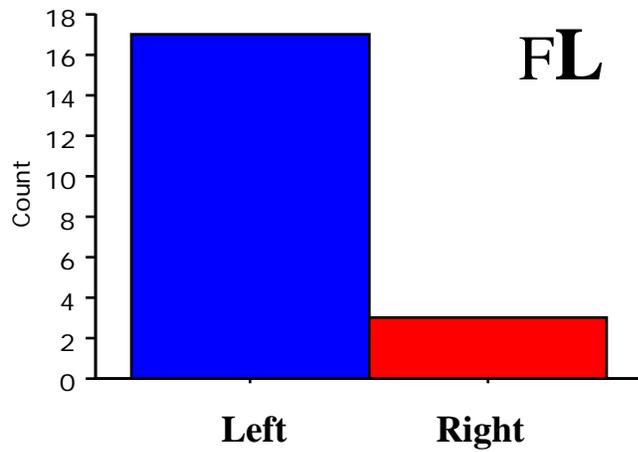
INJURY SIDE



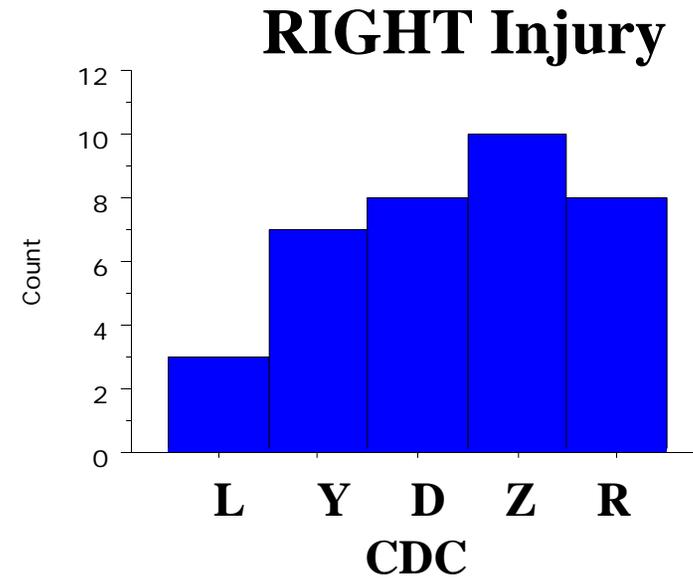
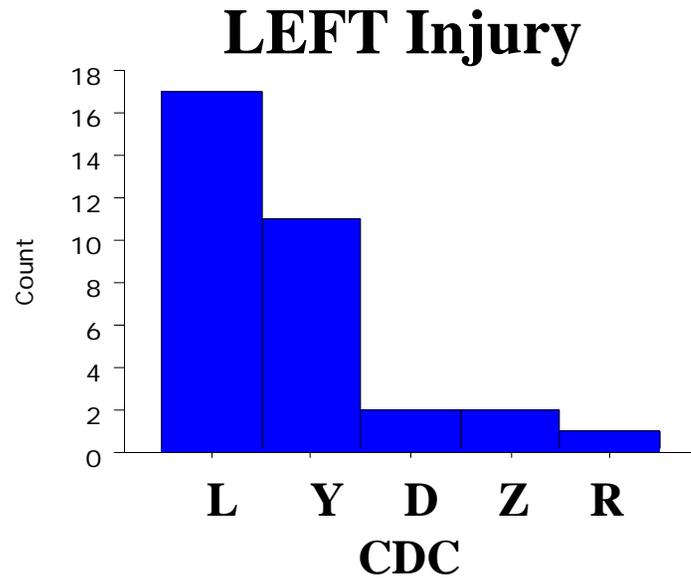
CDC



Distribution of KTH Injury Side: Split by CDC



Left and Right Sided KTH Injuries: Split by CDC



	L	Y	D	Z	R	Totals
Left	17	11	2	2	1	33
Right	3	7	8	10	8	36
Totals	20	18	10	12	9	69

Summary

- AGE affects KTH region injured. Average age for Femur fractures is less than that for Hip and Knee fractures.
 - *(No effect for crash severity, %VOL, weight)*
- Incidence of HIP injuries was affected by RESTRAINT use. Hip injuries were more frequently found with airbag only restraint and uncommon with belt only restraint.
- Less % VOL sufficient to cause LEFT sided injuries compared to Right.
- Occupants with LEFT sided KTH injuries were generally less severely injured (ISS) than occupants sustaining RIGHT sided or BILATERAL injuries.
- Less severe crashes (**avg only 20 mph**) were sufficient to cause LEFT sided KTH injuries than RIGHT sided or BILATERAL injuries.

Summary

- Negative PDOF associated with LEFT sided Hip fractures.
- Vehicle overlap (as classified by CDC) is highly correlated with side of KTH injury observed in occupant.
 - FL crashes are highly associated with LEFT sided injuries.
 - FR, FZ and FD crashes are associated with RIGHT sided injuries.

Conclusion

- Relatively small differences in offset frontal crash configuration can have a significant impact on the side and type of Knee, Thigh, Hip injuries observed in occupants.
- There is a need for better understanding of the biomechanics of hip injuries (instrumentation, injury criteria)
- A wide variety of offset frontal crashes were observed in real-life Michigan CIREN cases.
- Selection of a single standard offset frontal crash configuration for vehicle testing will be challenging.