Crash and Occupant Determinants of Body Regions of Injury

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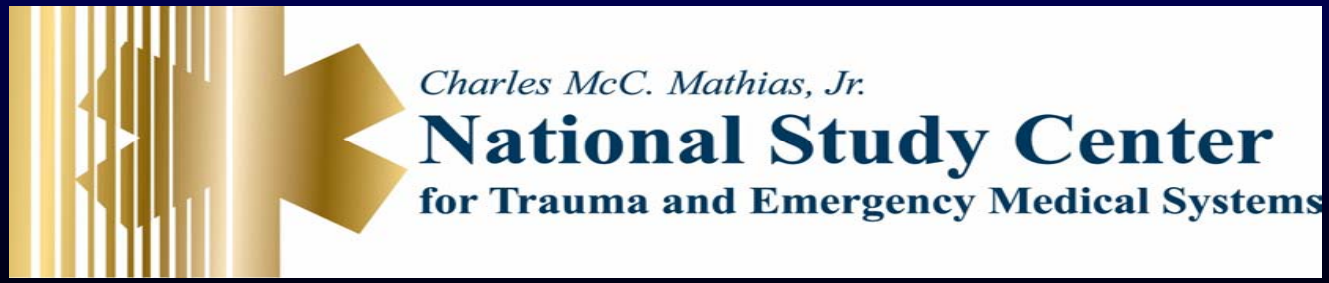



Harborview Injury Prevention & Research Center, Seattle, WA
Froedtert Hospital & Medical College of Wisconsin Milwaukee, WI
U of Michigan Program for Injury Research & Education, Ann Arbor, MI
Children's Hospital of Philadelphia, PA
University of Maryland Baltimore, MD
Honda Inova Fairfax Hospital, Falls Church, VA
San Diego County Trauma System, San Diego, CA
Toyota Wake Forest University School of Medicine Winston-Salem, NC

Objectives

- To identify crash and occupant characteristics that predict injuries in each body region.
- Exploratory: generate hypotheses for research.

What's unique about this study?

- The use of 5 years of CIREN data across all CIREN centers
- Comparison of CIREN findings with previous population-based study findings
- CIREN population: high severity crashes and injuries.

Population

- **CIREN** data extracts (n=2,299)
- **Focus**: adults in frontal and side collisions in vehicles with frontal airbags
- **Exclusion criteria:**
  - age < 16
  - rear collisions
  - unknown restraint use
  - unknown curb weight
  - unknown occup height
  - back seat occupant
  - no airbags
  - unknown PDOF
  - unknown occup weight

Methods

- Multiple logistic regression models
  (stepwise, selection stay 0.1)
- Dependent variables: each body region (1-8) with AIS $\geq$3.
- Independent variables:
  - Crash
  - Occupant

Independent Variables

CRASH:

- PDOF:
  - Front
  - Near side
  - Far side
- Delta V (Δ-V)
- Curb weight

OCCUPANT:

- Age
- Weight, height, BMI
- Gender
- Belt use

Study Group

Initial Population

(N=2299)

- exclusions

Final Group

(N=1656)

EXCLUSIONS

- back seat (n= 54)
- rear collisions (n=35)
- no airbags (n=273)
- unknown restraint (n=253)**
- unknown PDOF (n=117)
- unknown curb weight (n=3)
- Unknown weight (n=29)
- Unknown height (n=28)

**changes in NASS coding of restraint use not reflected in data extracts

Population

Age groups	(%)
16-30	39
31-40	16
41-50	15
51-60	11
61-70	8
71-80	8
81 plus	3

Gender	(%)
Female	48
Male	52

BMI	(%)
Underweight	4
Normal	37
Overweight	33
Obese	26

Crash Characteristics

Delta V

Km/h (mph)	(%)
<20 (<13)	6
21-30 (13-18)	15
31-40 (19-24)	18
41-50 (25-31)	13
51-60 (32-37)	10
61+ (38+)	12
Unknown	26

Restraints	(%)
Unrestrained	41
Restrained	59

PDOF	(%)
Near	21
Far	8
Front	71

Injuries

Cases with Body Region AIS>3	(%)
Head	26
Face	3
Neck	1
Thorax	30
Abdomen	18
Spine	9
Upper extremity	12
Lower Extremity	46

ISS group	(%)
0-9	16
10-19	43
20-29	20
30-39	9
40-49	5
50+	8

Body Regions

- Six body regions had significant associations with crash and occupant factors (α=0.05):
  - Head
  - Thorax
  - Abdomen
  - Spine
  - Upper extremity
  - Lower extremity
- Face & neck: numbers too small to study

* Tests of fit ranged from 0.09-0.99.

Significant associations: overview by body region

Risk factor	Head	Thorax	Abdomen	Spine	Upper extremity	Lower extremity
Age	✓	✓		✓	✓	
Gender					✓	✓
Unbelted	✓	✓		✓		✓
Side PDOF	✓	✓	✓		✓	✓
Delta-V	✓	✓	✓			✓
BMI			✓			✓

Other Variables

- Delta Δ 20-30 km/h, curb weight, occupant height and weight were not significant in any model.
- Airbag deployment excluded because it was highly correlated with delta V.

Thorax

Risk factors:

- Older age
- Unbelted
- Near side + far side
- Increasing Δ V

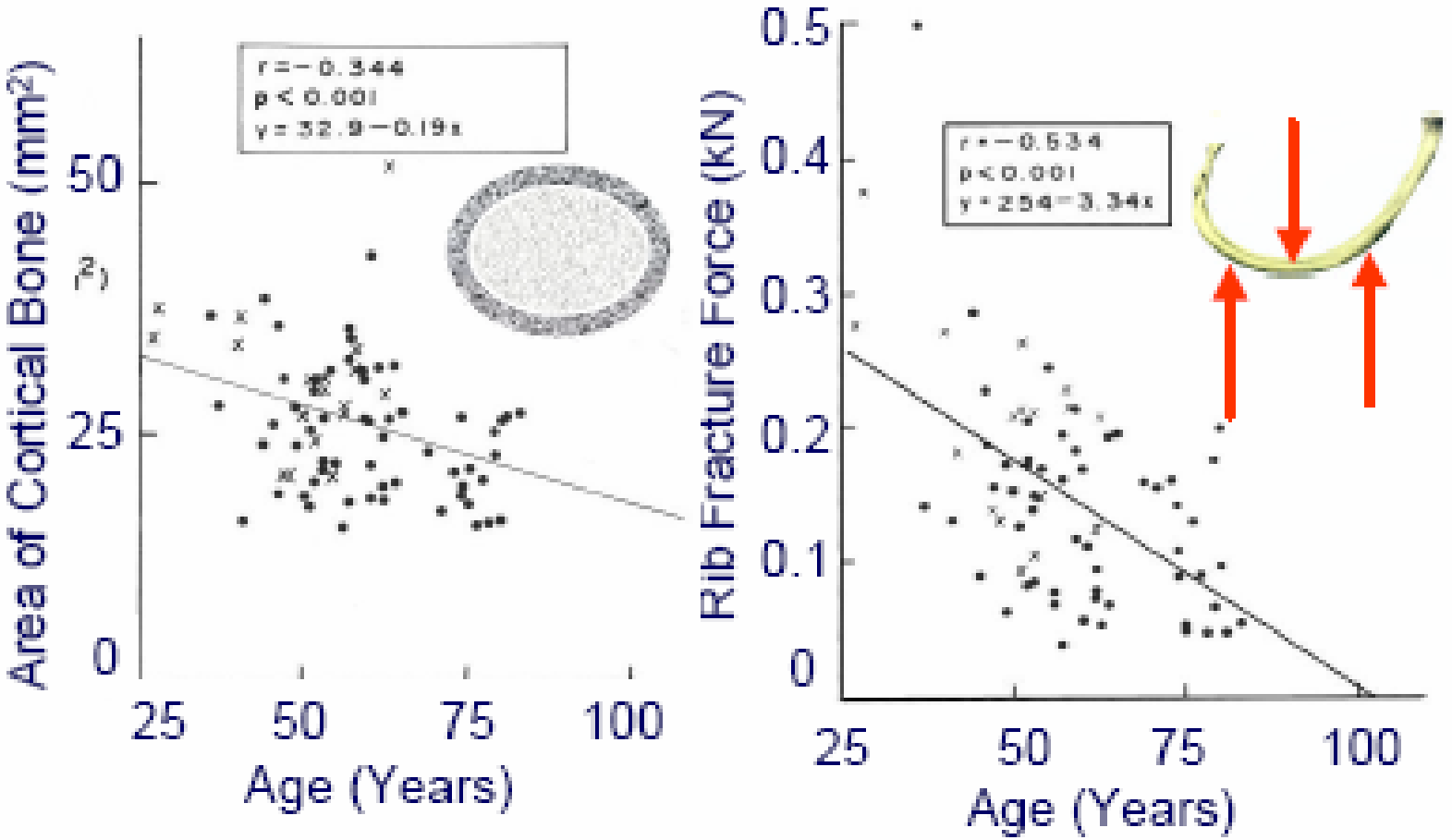
Not significant:

- Gender
- BMI
- Lower ages
- Lower Δ V

Variable	Odds ratios
Age 51-60	1.83
Age 61-70	2.49
Age 71-80	3.14
Age 81+	3.66
Unrestrained	1.40
Near side impact	4.12
Far side impact	2.55
Δ V 30-39 kph	1.85
Δ V 40-49 kph	2.74
Δ V 50-59 kph	2.90
Δ V 60+ kph	4.53
Δ V unknown	2.34

Reference population: Age 16-30, Female, restrained, Frontal impact, and Delta V 1-19 kph.

Rib Fracture Tolerance vs. Age



http://www-nrd.nhtsa.dot.gov/pdf/nrd-50/ciren/2001/1201INOVA.pdf

Lower extremity

Risk Factors:

- Female gender
- Unbelted
- Frontal
- Increasing Δ V
- Obesity

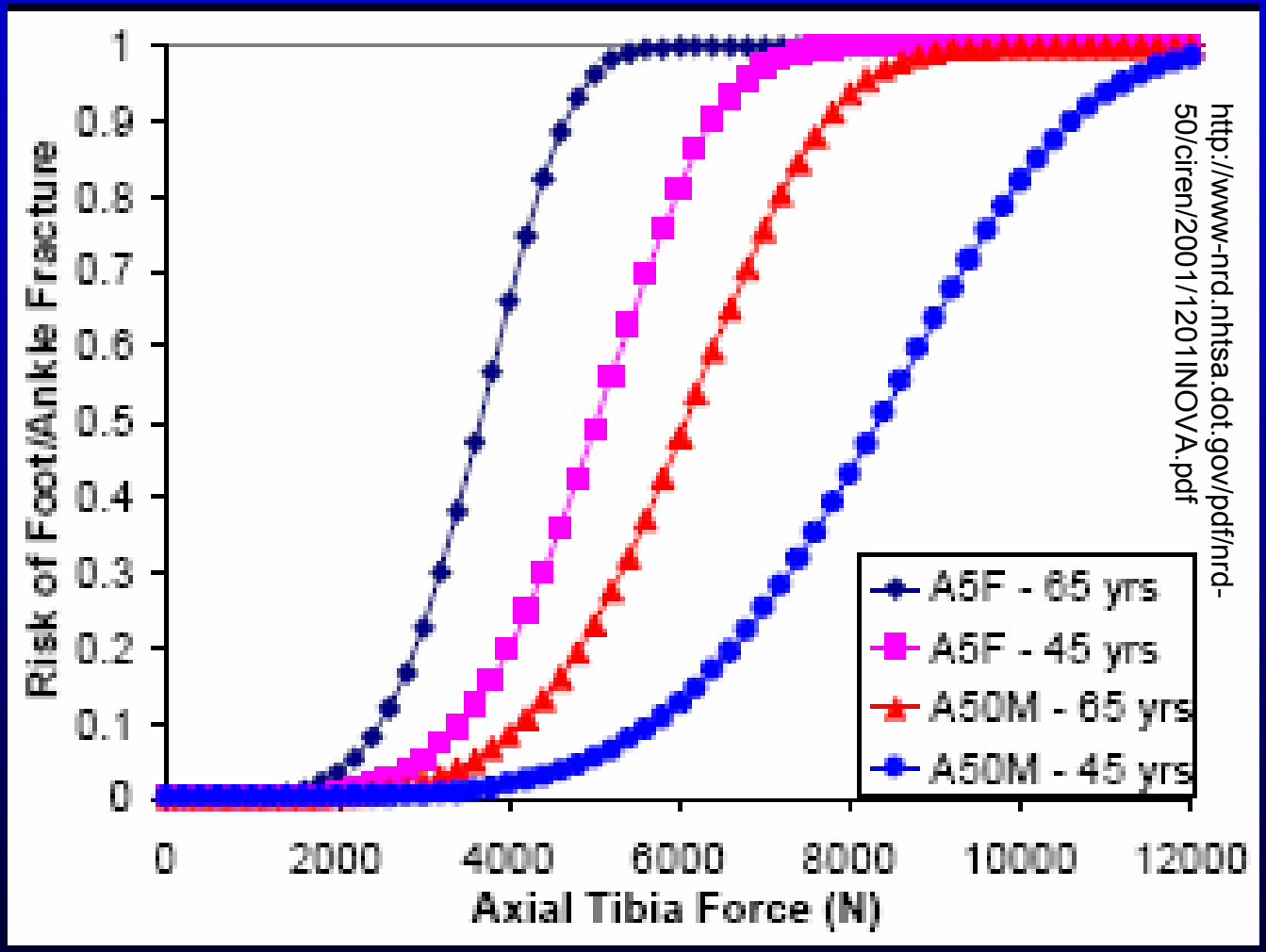
Not significant:

- Age
- Delta-V < 30 kph

Variable	Odds ratio
Male	**0.74**
Unrestrained	**1.30**
Near side impact	**0.77**
Far side impact	**0.24**
Δ V 30-39 kph	**1.44**
Δ V 40-49 kph	**1.86**
Δ V 50-59 kph	**1.85**
Δ V 60+ kph	**2.46**
Δ V unknown	**1.53**
Obese	**1.47**

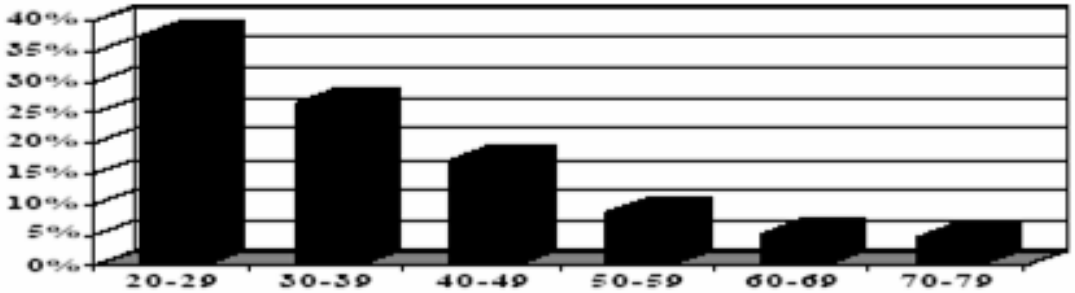
Reference population: Age 16-30, Female, restrained, Frontal impact, and Delta V 1-19 kph.

Our findings do not support the expected association between advanced age and LE injury.

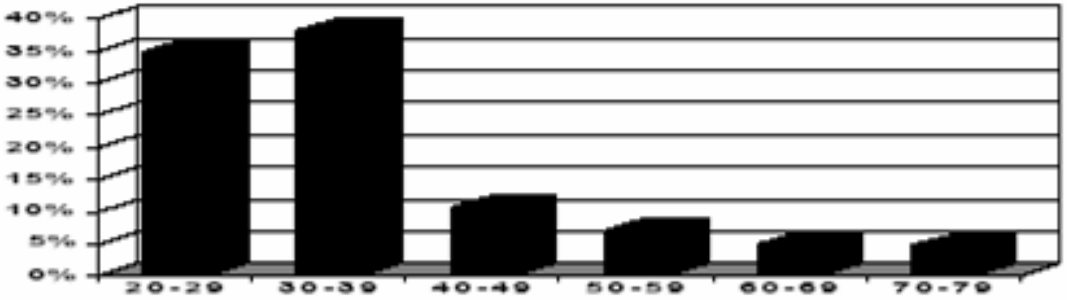


Lower extremity: age distribution NASS 1993-1996

Occupants



Femur fractures



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Lower extremity: age distribution NASS 1993-1996

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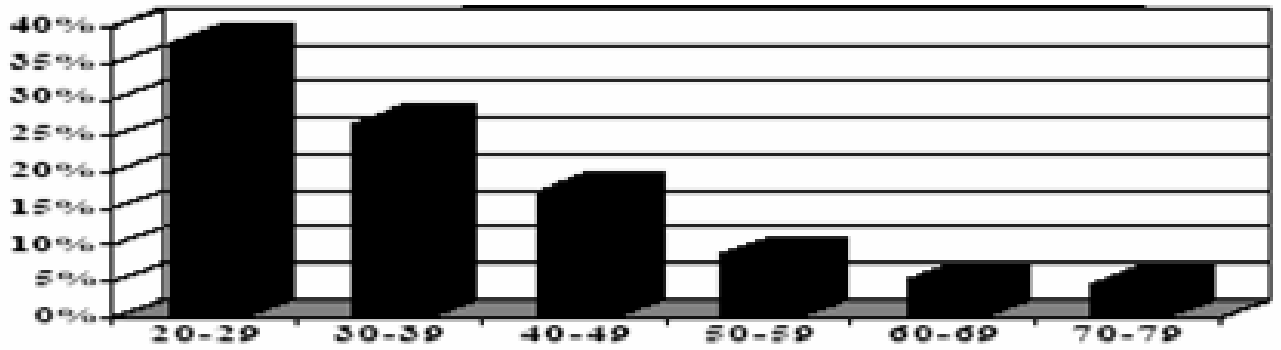
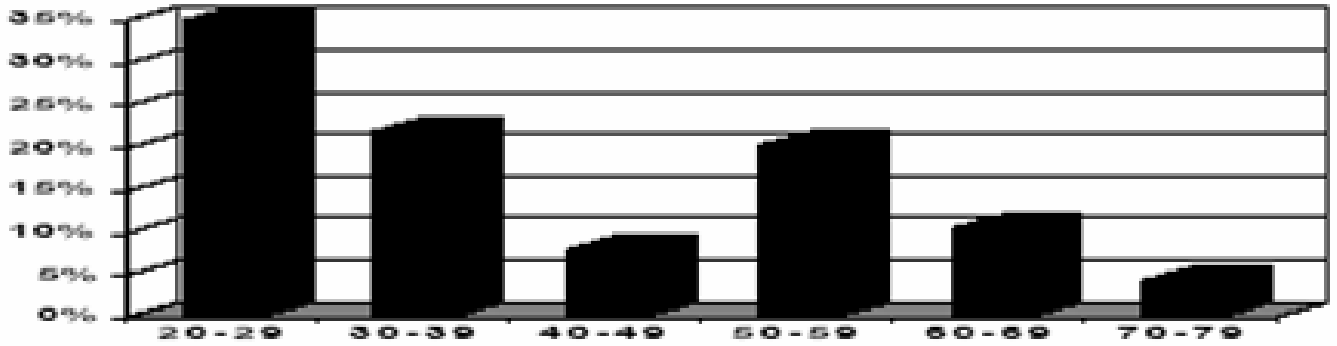


Tibial fractures



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Head Region

Risk factors:

- Side impacts
- Unbelted
- Very high Delta V
- Ages < 30, 61+

Not significant:

- Δ V <60

Variable	Odds ratio
Age 31-40	**0.70**
Age 41-50	**0.57**
Age 51-60	**0.55**
Unrestrained	**1.79**
Near side impact	**2.86**
Far side impact	**4.36**
Δ V 60+ kph	**1.45**
Δ V unknown	**1.40**

Reference population: Age 16-30, Female, restrained, Frontal impact, and Delta V 1-19 kph.

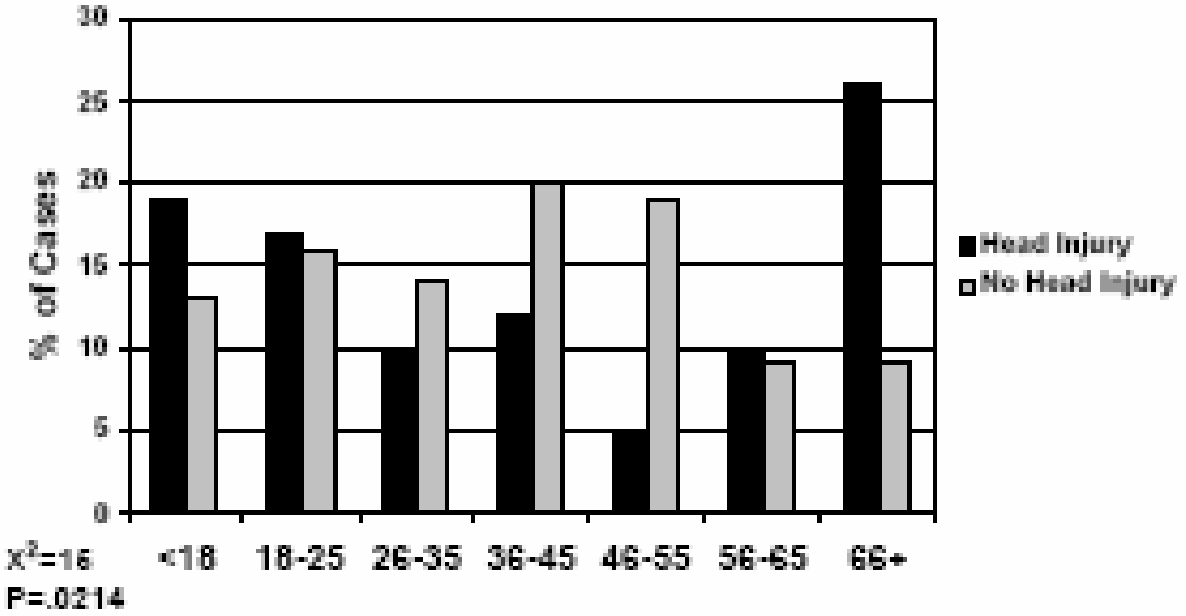
Head Injury: Age

- **Both age extremes seem to have a negative effect.**

Head with age 51-60 as reference

Effect	Estimate	95% Confidence Limits
Age 16-30	***1.55***	***1.21 – 1.99***
Age 71-80	***1.83***	***1.17 - 2.81***
Age 81plus	***2.52***	***1.34 - 4.65***
Obesity	0.77	0.58 – 1.01
Unrestrained	1.80	1.42 - 2.28
Δ V unknown	1.40	1.07 - 1.82
Δ V 60+ kph	1.50	1.03 - 2.17
Near	2.83	2.15 - 3.74
Far	4.31	2.92 - 6.38

Age Distribution on Head Injury



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Head Injury: Far-Side Impacts

- **Far-side impacts seem to be linked more often to head injury than near-side impacts. Is this because many far-side occupants are unbelted?**

Effect	Estimate	95% Confidence Limits
Age 16-30	1.55	1.21 – 1.99
Age 71-80	1.83	1.17 - 2.81
Age 81plus	2.52	1.34 - 4.65
Obesity	0.77	0.58 – 1.01
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Head Injury: Far-Side Impacts

- **Far-side impacts seem to be linked more often to head injury than near-side impacts. Is this because many far-side occupants are unbelted?**

Belted only

Effect	Estimate	95% Confidence Limits
Age 31-40	2.09	1.28 - 3.41
Age16-30	1.92	1.30 - 2.85
Age 71-80	2.45	1.37 - 4.33
age81plus	2.64	1.16 - 5.84
Δ V unknown	1.96	1.34 - 2.87
Δ V 60+ kph	2.46	1.41 - 4.24
Δ V 40-49	1.65	1.01 - 2.67
Near	***3.18***	***2.20 - 4.56***
Far	***3.25***	***1.88 - 5.53***

Far-side and near-side impacts produce similar risk among belted occupants; contradicts NASS/CDS data. May be artifact of CIREN database or a new finding.

AIS 3+ Distribution Front Occupants in Side Crashes Restrained Occupants

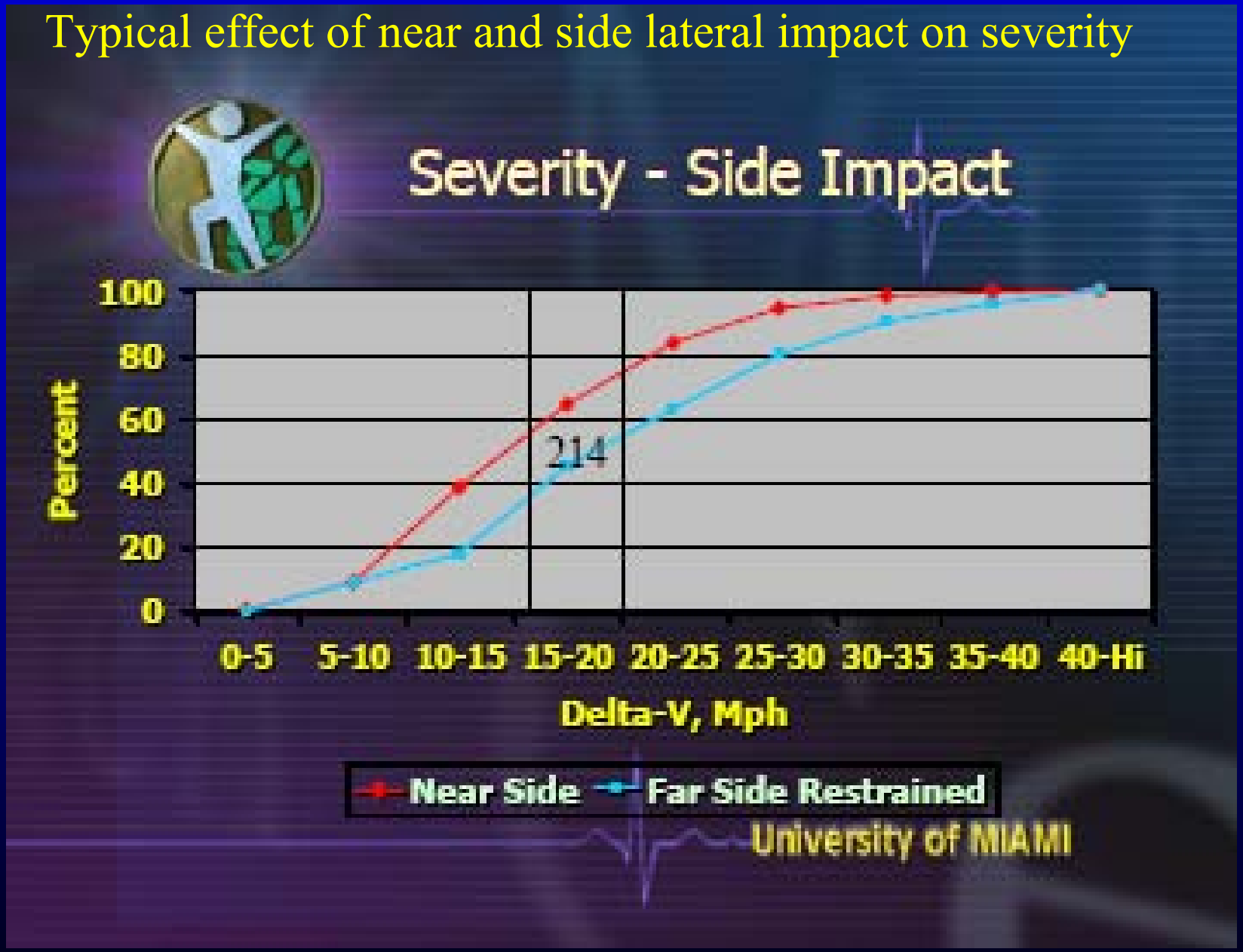
Position	Frequency	AIS 3+
Near	66%	70.0%
Far	34%	30.0%

NASS/CDS 1988-1997

University of MIAMI

http://www-nrd.nhtsa.dot.gov/pdf/nrd-50/ciren/2000/1100Miami.pdf

Typical effect of near and side lateral impact on severity



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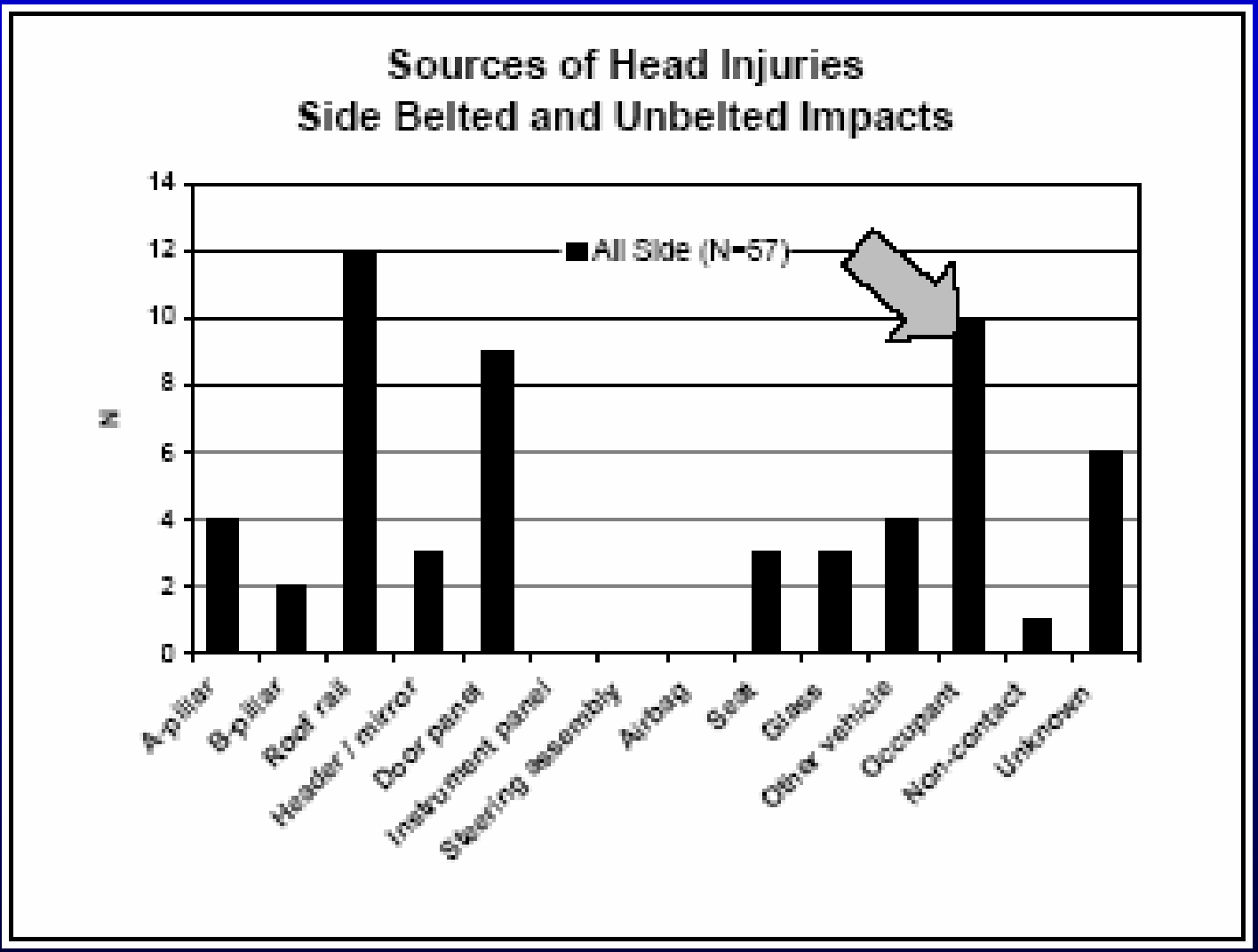

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Head Injury: Role of Delta-V

Is the lack of Δ V effect below 60 kph due to belted occupants having lower risk?

If yes, Δ V should have greater effect on the unbelted occupants.

Effect	Estimate	95% Confidence Limits
Age 16-30	1.55	1.21 – 1.99
Age 71-80	1.83	1.17 - 2.81
Age 81plus	2.52	1.34 - 4.65
Obesity	0.77	0.58 – 1.01
Unrestrained	1.80	1.42 - 2.28
Δ V unknown	***1.40***	***1.07 - 1.82***
Δ V 60+ kph	***1.50***	***1.03 - 2.17***
Near	2.83	2.15 - 3.74
Far	4.31	2.92 - 6.38

Head Injury: Delta-V

Unbelted only

Effect	Estimate	95% Confidence Limits
Age 31-40	0.49	0.29 - 0.80
Age 81+	2.47	0.87 -7.03
Obese	0.54	0.36 - 0.80
Near	2.72	1.75 - 4.21
Far	6.29	3.44 - 11.86
Δ V levels	*(1.1-1.4)*	*p values >0.4*

Among unbelted, Delta-V does not appear to increase head injury risk.

Head Injury: Delta-V and Airbags

Is the lack of Delta V effect due to protective effects of front or side airbag deployment?

- Delta V effect should be seen in lateral impact crashes among vehicles without side airbags.

Head Injury: Delta-V and Side Impacts (side airbag excluded)

Lateral impact only

Effect	Estimate	95% Confidence Limit	
Age 31-40	1.785	0.920	3.473
Age 16-30	2.275	1.367	3.844
Age 61-70	2.103	0.879	4.961
Age 71-80	2.226	0.988	4.975
Age 81+	4.001	1.517	10.642
Overweight	1.422	0.937	2.157
Unrestrained	2.130	1.411	3.229
Δ V unknown	1.522	0.951	2.433
Δ V 40-49	***2.379***	***1.314***	***4.336***
Δ V 50-59	***3.364***	***1.496***	***7.884***
Δ V 60+ kph	***2.934***	***1.011***	***9.199***
Far	1.536	0.988	2.388

In side impacts, Delta-V of 40+ increases head injury risk.

Conclusions: Thoracic Injuries

Risk factors:

- Increasing age
- Lateral impact
- Unbelted status
- Increasing Δ Vs

Conclusions: Lower Extremity Injury

Lower extremity injury:

- **Not** associated with older age (*within CIREN*).

Risk factors:

- Female gender
- Frontal impact
- Increasing Δ V
- Obesity
- Unbelted status

Conclusions: Head Injuries

Risk factors (*within the CIREN cohort*):

- Lateral crashes and unbelted occupants.
- Youngest and oldest age groups
- More common on far side than near side lateral crashes (unrestrained occupants).
- In lateral impacts, Delta-V of 40+ increases head injury risk.
- Among unbelted, Δ V does not appear to increase head injury risk.

General Conclusions

- CIREN database: some expected and unexpected findings with regard to associations with injuries in different body regions.
- Findings should be re-examined using population-based data sets (i.e. NASS/CDS).
- Need to explore biomechanical causative links between these factors and injuries.

Areas for further research

Risk factor	Head	Thorax	Abdomen	Spine	Upper extremity	Lower extremity
Age	✓	✓		✓	✓	
Gender					✓	✓
Unbelted	✓	✓		✓		✓
PDOF	✓	✓	✓		✓	✓
Delta-V	✓	✓	✓			✓
BMI			✓			✓

Research recommendations

- Explore the apparent lack of age effect on lower extremity injuries
- Explore why both younger and older occupants have ↑ head injury risk
- Do head injury types differ by PDOF (far vs. near side impact)?
- Further investigate the link between head injury, Δ V, PDOF and Airbag systems

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