Trends in Lower Extremity Injury Patterns in Motor Vehicle Crashes

University of Maryland CIREN team
Background

• What do we know about lower extremity injuries?
  – Common in frontal crashes, especially offset frontal
  – Frequently, but not always, associated with intrusion
  – Higher incidence in obese drivers
  – More ankle/foot fractures in women and shorter drivers
  – Often related to long-term disability, especially ankle/foot fractures involving articular surfaces
CIREN Report
Consequences and Costs of Lower-Extremity Injuries

OUTCOMES
Percent Decline from Baseline to 1 Year by Articular Involvement

Baseline

PF
BP
GH
V
SF
RE
MH

Percent Decline (AU)

Articular
Non-Articular

PF = Physical Functioning; RP = Role Functioning; BP = Bodily Pain; GH = General Health; V = Vitality; SF = Social Functioning; RE = Role Emotional; MH = Mental Health

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Adverse Outcomes of Physical Functioning
1 Year Post-injury

Percentage

Unable to work
Ambulation problems

NHTSA frontal NCAP ratings for drivers
Percent of results by star rating
Purpose

• To determine trends in lower extremity injuries by vehicle model year, controlling for crash and occupant characteristics

• To compare these trends in CIREN with NASS-CDS and Maryland CODES databases
Selection Criteria for this Analysis

3,510 CIREN Cases
(As of Feb. 2008)

SELECT:
- Drivers
- 1997-2007 model year automobiles
- Frontal no offset or offset frontal left

533 Cases
Definition of Frontal Impact

- Frontal (no offset)
  - Direct damage laterally distributed across frontal plane or primarily involving the center

- Frontal (offset left)
  - Direct damage to frontal plane, primarily left of the centerline
## Characteristics of CIREN Drivers (N=533)

<table>
<thead>
<tr>
<th></th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>51</td>
</tr>
<tr>
<td>Overweight (BMI)</td>
<td>66</td>
</tr>
<tr>
<td>Frontal airbag</td>
<td>93</td>
</tr>
<tr>
<td>Proper seatbelt use</td>
<td>64</td>
</tr>
<tr>
<td>Frontal-no offset</td>
<td>52</td>
</tr>
<tr>
<td>Offset frontal left</td>
<td>48</td>
</tr>
<tr>
<td>MY 1997-1998</td>
<td>31</td>
</tr>
<tr>
<td>1999-2000</td>
<td>29</td>
</tr>
<tr>
<td>2001-2002</td>
<td>24</td>
</tr>
<tr>
<td>2003-2004</td>
<td>10</td>
</tr>
<tr>
<td>2005-2007</td>
<td>6</td>
</tr>
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</table>
### Characteristics of Lower Extremity Injuries (LEI) Among CIREN Drivers (N=533)

<table>
<thead>
<tr>
<th>Description</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEI MAIS 1</td>
<td>13%</td>
</tr>
<tr>
<td>LEI MAIS 2</td>
<td>73%</td>
</tr>
<tr>
<td>Single MAIS 2+ LEI</td>
<td>17%</td>
</tr>
<tr>
<td>Multiple MAIS 2+ LEI</td>
<td>56%</td>
</tr>
<tr>
<td>Left side injury only</td>
<td>18%</td>
</tr>
<tr>
<td>Right side injury only</td>
<td>31%</td>
</tr>
<tr>
<td>Bilateral injury</td>
<td>24%</td>
</tr>
</tbody>
</table>
Lower Extremity Injury Type

**Foot (23%)**
Metatarsal bones, phalangeal bones, tarsal bones

**Metatarsal bones, phalangeal bones, tarsal bones**

**Ankle (31%)**
Distal tibia, distal fibula, talus

**Leg (20%)**
Shaft of tibia, shaft of fibula

**Shaft of tibia, shaft of fibula**

**Knee (25%)**
Femur condyles, patella, proximal tibia, proximal fibula

**Femur condyles, patella, proximal tibia, proximal fibula**

**Thigh (23%)**
Shaft of femur, subtrochanteric region, supracondylar region

**Shaft of femur, subtrochanteric region, supracondylar region**

**Hip/Pelvis (25%)**
Pelvic bones, head of femur, neck of femur, acetabulum, intertrochanteric region

**Pelvic bones, head of femur, neck of femur, acetabulum, intertrochanteric region**
Incidence (%) of Lower Extremity Injuries (MAIS 2+) by Model Year

Percentage

Vehicle Model Year

1997 (n=84) 1998 (n=80) 1999 (n=68) 2000 (n=87) 2001 (n=79) 2002 (n=48) 2003 (n=34) 2004 (n=20) 2005-07 (n=33)
Incidence (%) of Lower Extremity Injuries (MAIS 2+) by Type of Impact

Vehicle Model Year

- Frontal No Offset
- Offset Frontal Left

Year: 1997 (n=84), 1998 (n=80), 1999 (n=68), 2000 (n=87), 2001 (n=79), 2002 (n=48), 2003 (n=34), 2004 (n=20), 2005-07 (n=33)
Incidence (%) of Hip, Thigh and Knee Injuries (MAIS 2+) by Model Year

Percentage

Vehicle Model Year

1997 (n=84) 1998 (n=80) 1999 (n=68) 2000 (n=87) 2001 (n=79) 2002 (n=48) 2003 (n=34) 2004 (n=20) 2005-07 (n=33)
Incidence (%) of Leg, Ankle and Foot Injuries (MAIS 2+) by Model Year

Vehicle Model Year

- Leg
- Ankle
- Foot

1997 (n=84)
1998 (n=80)
1999 (n=68)
2000 (n=87)
2001 (n=79)
2002 (n=48)
2003 (n=34)
2004 (n=20)
2005-07 (n=33)
Incidence (%) of Ankle Injuries (MAIS 2+) by Gender

Vehicle Model Year

Percentage

1997 (n=84)
1998 (n=80)
1999 (n=68)
2000 (n=87)
2001 (n=79)
2002 (n=48)
2003 (n=34)
2004 (n=20)
2005-07 (n=33)

Females
Males
Incidence (%) of Ankle Injuries (MAIS 2+) by Weight Category

Percentage

Vehicle Model Year

1997 (n=84) 1998 (n=80) 1999 (n=68) 2000 (n=87) 2001 (n=79) 2002 (n=48) 2003 (n=34) 2004 (n=20) 2005-07 (n=33)

Normal Weight

Overweight
Incidence (%) of Ankle Injuries (MAIS 2+) by Delta V Category

Percentage

Vehicle Model Year

1997 (n=84) 1998 (n=80) 1999 (n=68) 2000 (n=87) 2001 (n=79) 2002 (n=48) 2003 (n=34) 2004 (n=20) 2005-07 (n=33)
IIHS Testing Indicates Intrusion Reduction

MEASURES OF OCCUPANT COMPARTMENT INTRUSION (cm), 40 MPH FRONTAL OFFSET TEST

<table>
<thead>
<tr>
<th></th>
<th>A-pillar Movement</th>
<th>Footwell Intrusion</th>
<th>Brake Pedal Intrusion</th>
<th>Instrument Panel Movement</th>
<th>Steering Column Movement</th>
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<tr>
<td></td>
<td>Rearward</td>
<td>Left</td>
<td>Center</td>
<td>Right</td>
<td>Footrest</td>
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<tr>
<td>2000 Cadillac Seville</td>
<td>3</td>
<td>17</td>
<td>15</td>
<td>16</td>
<td>6</td>
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<tr>
<td>1997 Cadillac Seville</td>
<td>9</td>
<td>31</td>
<td>37</td>
<td>31</td>
<td>21</td>
</tr>
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</table>
Mean Intrusion of Toe Pan by Delta V and Model Year (n=274)
Mean Intrusion of Left Instrument Panel by Delta V and Model Year (n=212)

Mean Intrusion of Left Instrument Panel by Delta V and Model Year (n=212)

- <=30 KPH (n=29)
- 31-40 (n=41)
- 41-50 (n=50)
- 51-60 (n=41)
- 61-89 (n=51)

- 1997-2000
- 2001-2003
- 2004-2007
Comparison of CIREN and NASS-CDS
Higher Crash Severity in CIREN
Comparison of CIREN and NASS-CDS

Crash-Severity Distribution

Frontal Crashes

Flannagan, C. University of Michigan CIREN Center, presented at CIREN Quarterly Meeting, March 2007, NHTSA
Greater Injury Levels in CIREN
Comparison of CIREN and NASS-CDS

Injury-Severity Distribution

Maximum AIS (Frontal)

Flannagan, C. University of Michigan CIREN Center, presented at CIREN Quarterly Meeting, March 2007, NHTSA
Comparison of CIREN and NASS-CDS

<table>
<thead>
<tr>
<th></th>
<th>CIREN</th>
<th>NASS-CDS (unweighted)</th>
<th>NASS-CDS (weighted)</th>
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</thead>
<tbody>
<tr>
<td>N</td>
<td>533</td>
<td>838</td>
<td>82,715</td>
</tr>
<tr>
<td>MY 1997-2003</td>
<td>480</td>
<td>728</td>
<td>73,678</td>
</tr>
<tr>
<td>MY 2004-2007</td>
<td>53</td>
<td>110</td>
<td>9,037</td>
</tr>
<tr>
<td>%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LEI</td>
<td>73%</td>
<td>51%</td>
<td>40%</td>
</tr>
<tr>
<td>Ankle injury</td>
<td>31%</td>
<td>21%</td>
<td>15%</td>
</tr>
<tr>
<td>ΔV&lt;25 mph</td>
<td>44%</td>
<td>64%</td>
<td>74%</td>
</tr>
</tbody>
</table>
Incidence (%) of Lower Extremity Injuries (MAIS 2+)

Comparison of CIREN and NASS-CDS at $\Delta V < 25$ mph
Incidence (%) of Lower Extremity Injuries (MAIS 2+)

Comparison of CIREN and NASS-CDS at $\Delta V = 25+$ mph
Incidence (%) of Ankle Injuries (MAIS 2+)
Comparison of CIREN and NASS-CDS at ΔV < 25 mph
Incidence (%) of Ankle Injuries (MAIS 2+)

Comparison of CIREN and NASS-CDS at \( \Delta V = 25+ \text{ mph} \)
Comparison of CIREN, NASS-CDS and CODES
## Comparison of CIREN, NASS-CDS and CODES

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<tr>
<th></th>
<th>CIREN</th>
<th>NASS-CDS (unweighted)</th>
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<th>MD CODES</th>
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<tr>
<td><strong>N</strong></td>
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<td>1,905</td>
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<tr>
<td><strong>MY 1997-2003</strong></td>
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<td>728</td>
<td>73,678</td>
<td>1,743</td>
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<tr>
<td><strong>MY 2004-2007</strong></td>
<td>53</td>
<td>110</td>
<td>9,037</td>
<td>162</td>
</tr>
<tr>
<td><strong>%</strong></td>
<td>73%</td>
<td>51%</td>
<td>40%</td>
<td>32%</td>
</tr>
<tr>
<td><strong>LEI</strong></td>
<td>31%</td>
<td>21%</td>
<td>15%</td>
<td>11%</td>
</tr>
<tr>
<td><strong>Ankle injury</strong></td>
<td>44%</td>
<td>64%</td>
<td>74%</td>
<td>--</td>
</tr>
<tr>
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<td>15%</td>
<td>11%</td>
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Incidence (%) of Lower Extremity Injuries
Comparison of CIREN, NASS-CDS and CODES

<table>
<thead>
<tr>
<th>Percentage</th>
<th>CIREN</th>
<th>NASS Unweighted</th>
<th>NASS Weighted</th>
<th>CODES</th>
</tr>
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<tbody>
<tr>
<td>1997</td>
<td></td>
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<td>1998</td>
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<tr>
<td>2005-07</td>
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</table>

Vehicle Model Year
Incidence (%) of Lower Extremity Injuries
Comparison of CIREN, NASS-CDS and CODES

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>CIREN</td>
<td>75</td>
<td>60</td>
</tr>
<tr>
<td>NASS</td>
<td>52</td>
<td>44</td>
</tr>
<tr>
<td>Unweighted</td>
<td>41</td>
<td>30</td>
</tr>
<tr>
<td>Weighted</td>
<td>p&lt;0.001</td>
<td>p=0.10</td>
</tr>
<tr>
<td>CODES</td>
<td>33</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>p=0.03</td>
<td>p=0.03</td>
</tr>
</tbody>
</table>
Incidence (%) of Ankle Injuries
Comparison of CIREN, NASS-CDS and CODES

Vehicle Model Year

Percentage

CIREN  NASS Unweighted  NASS Weighted  CODES
Incidence (%) of Ankle Injuries
Comparison of CIREN, NASS-CDS and CODES

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>CIREN Unweighted</td>
<td>32</td>
<td>21</td>
</tr>
<tr>
<td>NASS Unweighted</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>NASS Weighted</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>CODES</td>
<td>11</td>
<td>8</td>
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</table>

Percentage

p=0.09
p=0.97
p=0.95
p=0.22
Summary

- Declining trend in lower extremity injuries over last 5 years noted in CIREN, CODES and NASS databases
- Ankle injuries appear to be declining in CIREN, although this trend is not as apparent for the CODES and NASS/CDS databases
- Improved NCAP ratings and decreased toe pan and knee bolster intrusion rates in recent years
Limitations

- Number of lower extremity injury cases in later model years is small
  - Need more years of data to validate trend
- Vehicles included by model year and not by specific make/model modifications (NCAP ratings)
- Injury definition varies by data source
  - AIS & ICD-9 in CIREN
  - AIS in NASS-CDS
  - ICD-9 in CODES
This study illustrates the value of CIREN:
the ability to monitor injury trends over time in relation to changes in the vehicle fleet
Future Research

• Repeat analyses based on NCAP ratings instead of model year

• Examine Bio-tab database for mechanisms of foot and ankle fractures

• Utilize OTA codes to see whether declines in ankle injuries reflect those affecting articular surfaces
Disclaimer

• Funding has been provided by NHTSA under Cooperative Agreement Number DTNH22-05-H-01001

• Views expressed are those of the authors and do not represent the views of the NHTSA
Thanks….

WE WOULD LIKE TO THANK THE INVESTIGATORS AT THE OTHER CIREN CENTERS FOR THEIR HARD WORK AND DEDICATION TO THIS PROJECT.