Pedestrian Knee Ligament Injuries in the U.S.

TRC next

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NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

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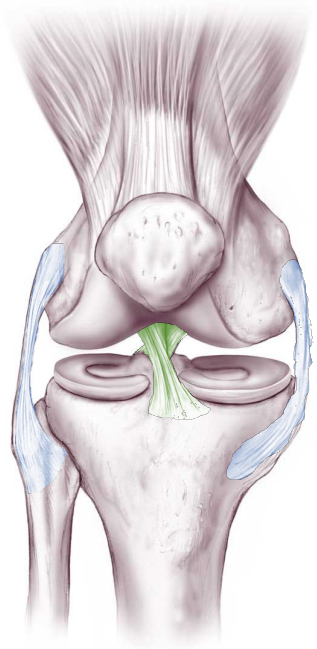
Agenda

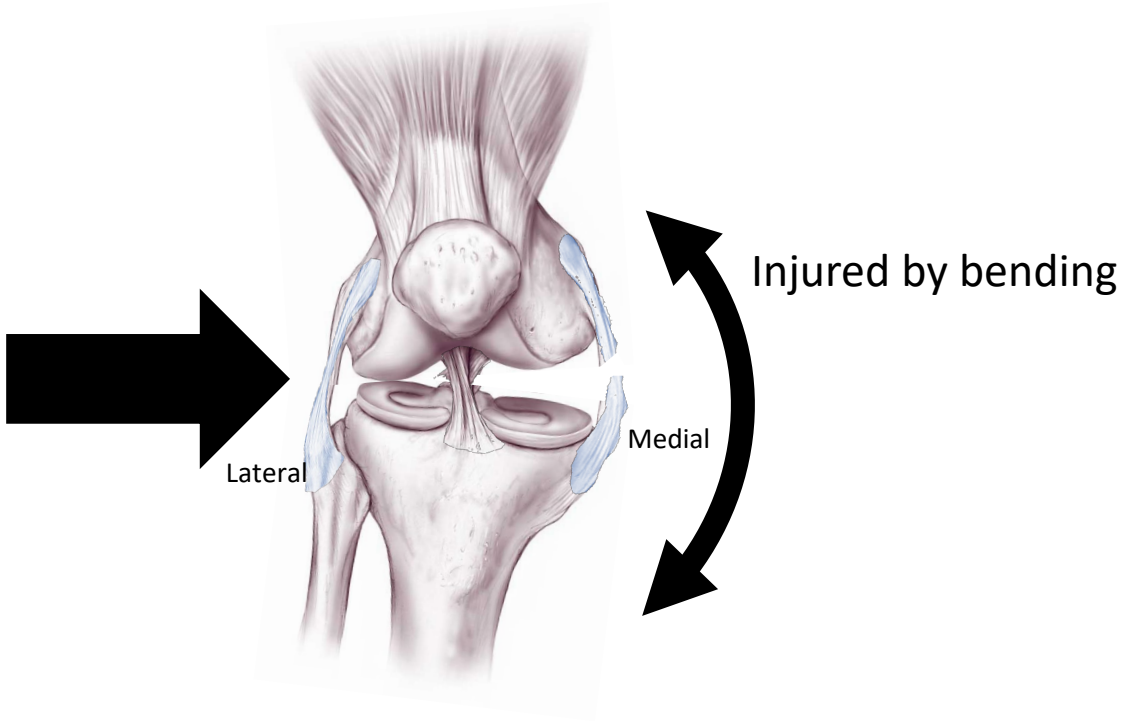
Pedestrian Knee Ligament Injuries in the U.S.:

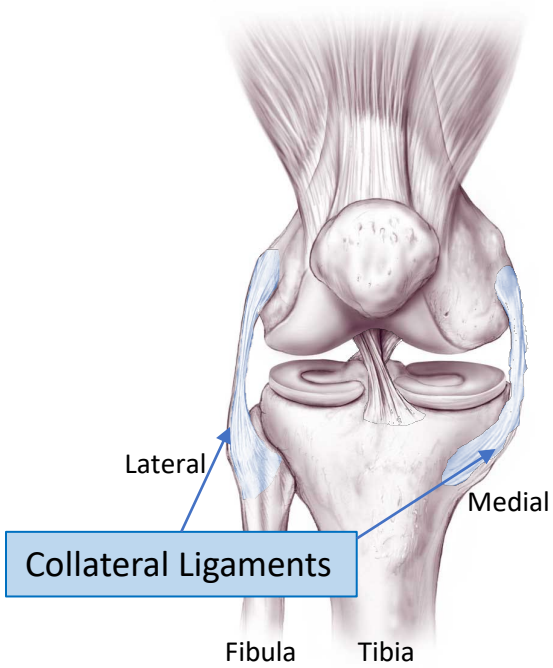
Cruciate ligament injuries without collateral ligament injuries

- Background:
  - Knee Ligament Anatomy
  - Ligament Injury Prediction with Pedestrian Legform
  - Motivation for Research Question
  - Relevant Previous Work
- Methods
- Results
- Conclusions

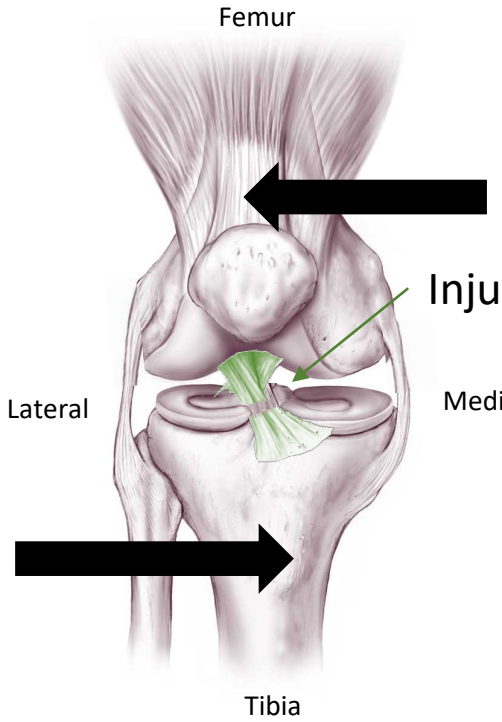


Background: Collateral Ligaments

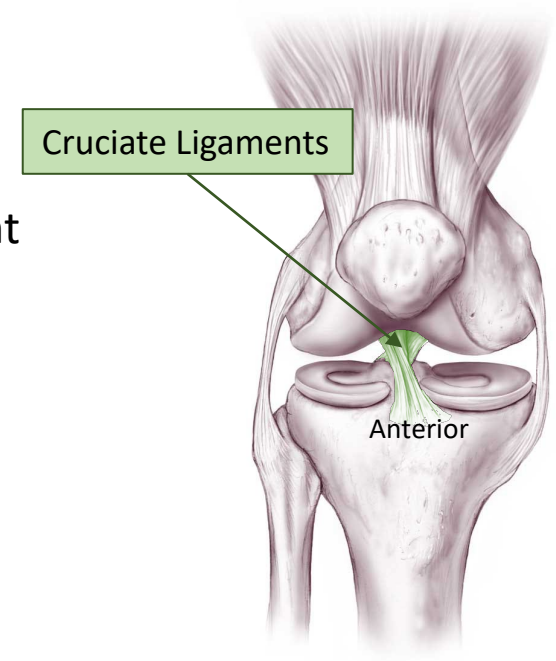




Background: Cruciate Ligaments

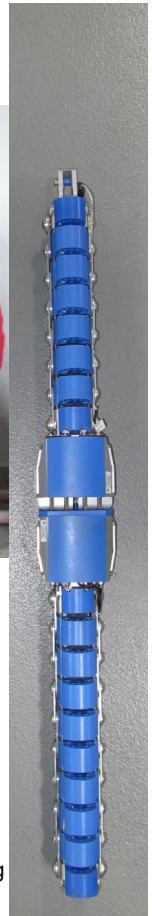


Injured by shear displacement



Background: Pedestrian Legforms

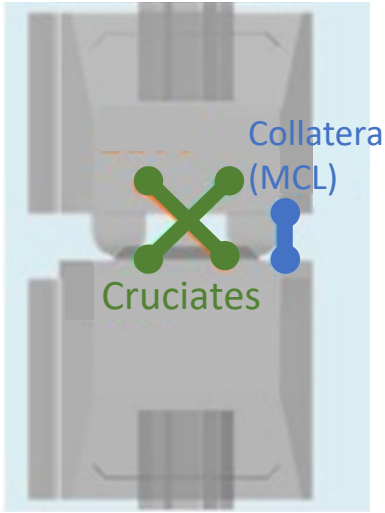
FlexPLI



aPLI

Background: Pedestrian legforms

FlexPLI

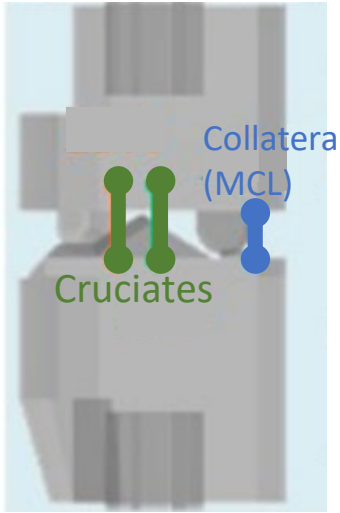


EuroNCAP (Current):

Collateral: 19/22 mm

Cruciates: 10 mm

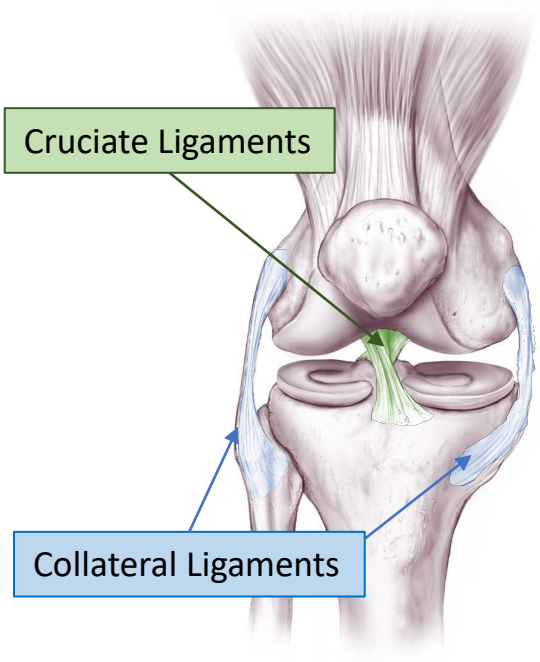
aPLI



EuroNCAP (2023):

Collateral: 27/32 mm

Cruciates: None



Research Question

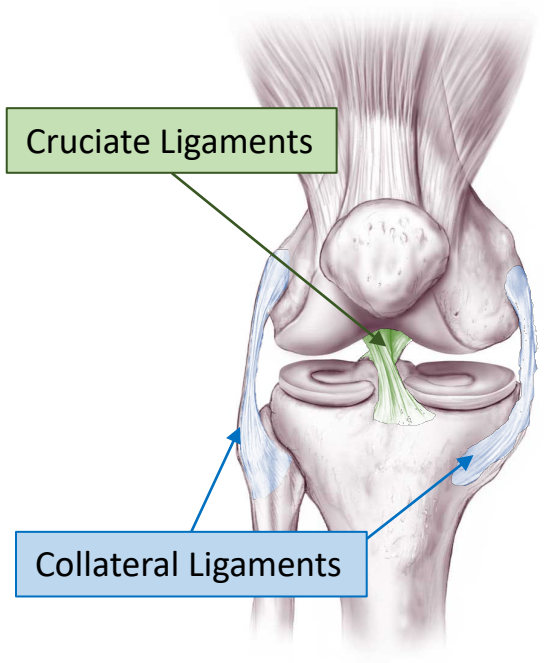
Do cruciate injuries occur without collateral ligament injuries?

NO?

Ensuring vehicle design prevents collateral ligament injury may be sufficient to prevent cruciate injury

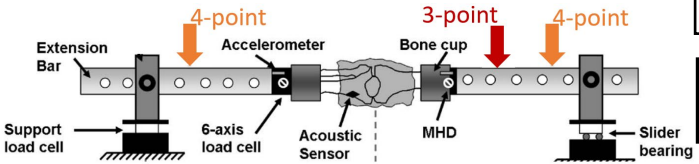
YES?

Protecting collateral ligaments may **not** be sufficient to prevent cruciate injury



Previous Work: Controlled Loading

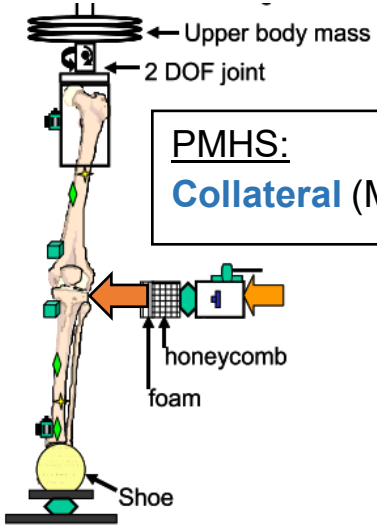
Bose et al, J of Biomech Eng (2008)



PMHS: **Collateral** (MCL), **Collateral** (MCL) + **Cruciate** (ACL)

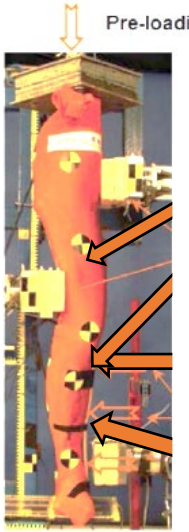
Model: **Cruciate** (ACL) failed first with ↑ shear

Bhalla et al, SAE World Congress (2005)



PMHS:
Collateral (MCL) + **Cruciate** (ACL)

Mo et al, Traffic Inj Prev (2013) & Saf Sci (2014)



Model:

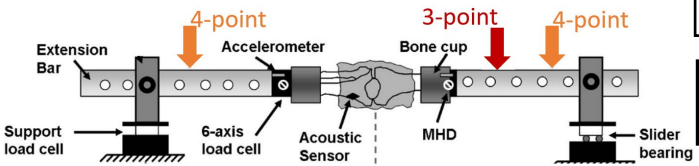
Above-knee & proximal tibia:
Cruciate (ACL) fails first

PMHS:
Proximal tibia:
Collateral (MCL) + **Cruciate** (ACL)

Mid & distal tibia:
Collateral (MCL)

Previous Work: Controlled Loading

Bose et al, J of Biomech Eng (2008)



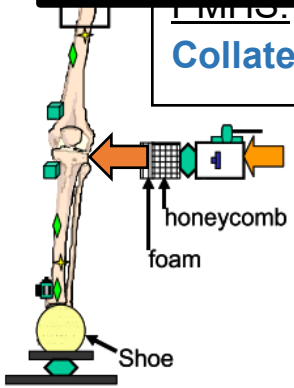
PMHS: **Collateral** (MCL), **Collateral** (MCL) + **Cruciate** (ACL)

Model: **Cruciate** (ACL) failed first with ↑ shear

PMHS: Lateral loading injured **Collateral** or **Collateral** + **Cruciate** ligaments
Models: **Cruciates** can fail first in some loading conditions

Depends on impact height and severity

PMHS:
Collateral (MCL) + **Cruciate** (ACL)



Above-knee & proximal tibia:
Cruciate (ACL) fails first

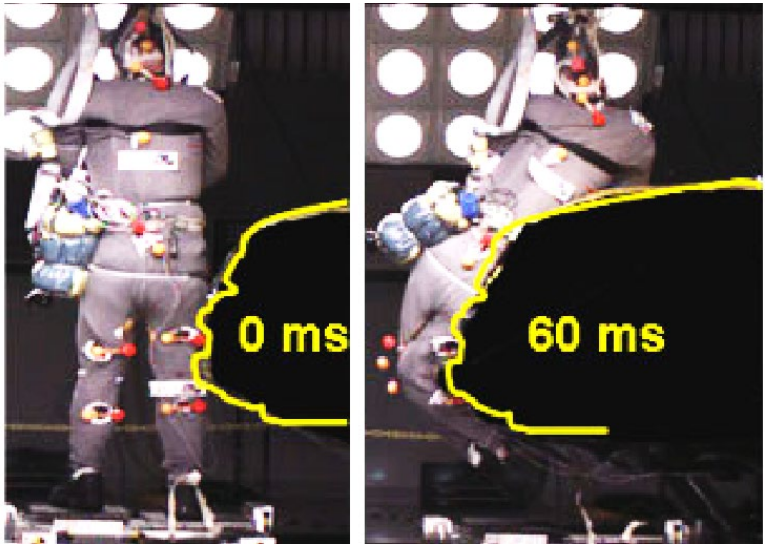
PMHS:
Proximal tibia:
Collateral (MCL) + **Cruciate** (ACL)

Mid & distal tibia:
Collateral (MCL)

Previous Work: Full-body PMHS Testing

Kerrigan et al, IRCOBI (2012)

- Analysis of whole-body PMHS vehicle tests:
  - 17 UVa
  - 24 other institutions
- Struck side knee:
  - 9 **cruciate** + **collateral** injuries
  - 5 **collateral** injuries (only)
  - 4 **cruciate** injuries (only)



Crandall et al., Int J Crashworthiness, 2006

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- Analysis of whole-body PMHS vehicle tests:
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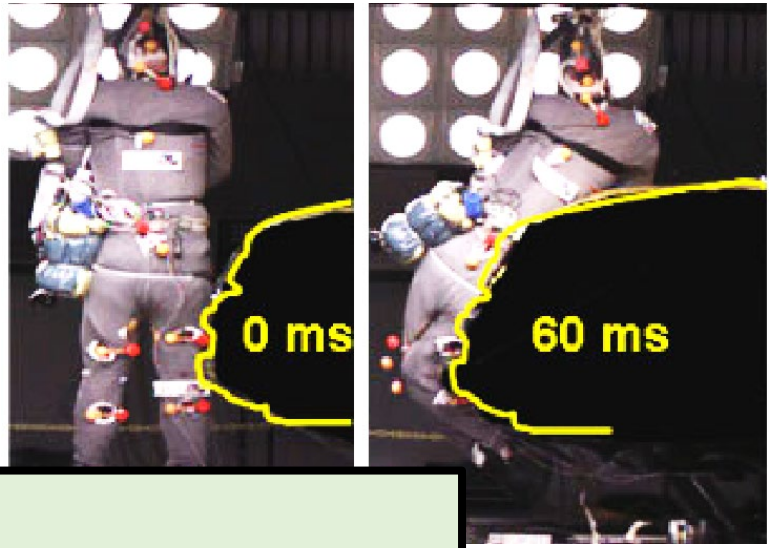
- Struck side knee:
  - 4 cruciate injuries (only)
  - 5 collateral injuries (only)
  - 9 cruciate + collateral injuries



shworthiness, 2006

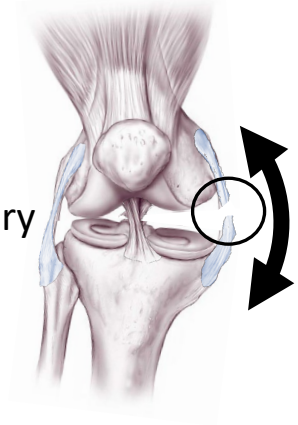
Full-body PMHS: Collateral and cruciate ligament injuries can occur separately or together

Previous Work: Epidemiology

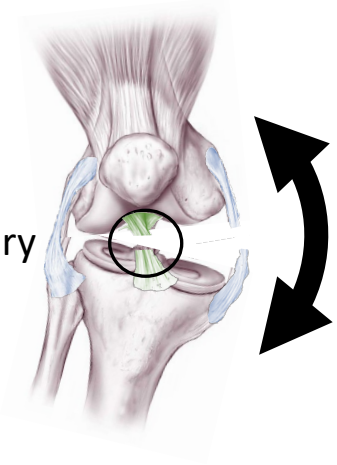
Teresiński & Mądro, Forensic Sci Int (2001)

- Autopsies:
  - 357 fatally-injured pedestrians in Poland
  - Most common mechanism: bending in medial or lateral impact

Bending:
Collateral injury



More Bending:
Collateral + Cruciate injury



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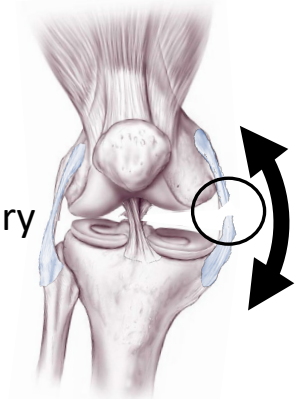

More Bending:
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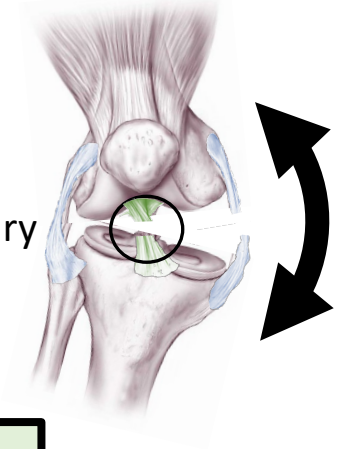


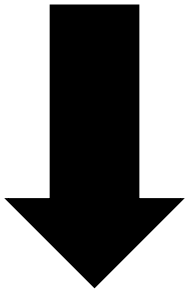
Epidemiology: Isolated **cruciate** injury in only 7% of injured knees

Isolated Cruciate Ligament Injury in US Pedestrian Crashes

NTDB (National Trauma Data Bank)

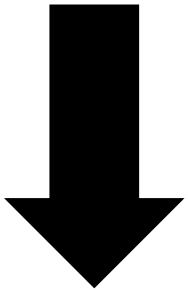
AMERICAN COLLEGE OF SURGEONS
Inspiring Quality: Highest Standards, Better Outcomes

NTDB
NATIONAL TRAUMA DATA BANK



How often cruciate injuries occur in absence of collateral injuries

PCDS (Pedestrian Crash Data Study)



Impact conditions associated with isolated cruciate injury

Methods: NTDB

NTDB (National Trauma Data Bank)

AMERICAN COLLEGE OF SURGEONS
Inspiring Quality: Highest Standards, Better Outcomes

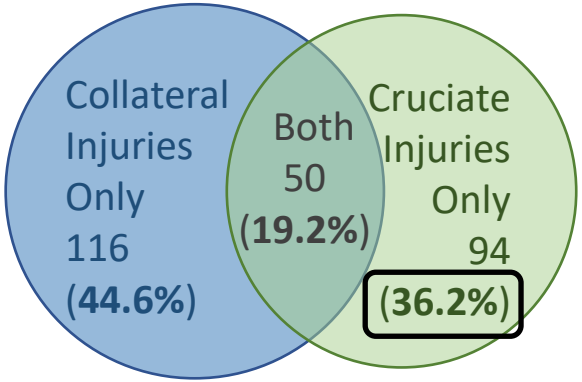
NTDB®
NATIONAL TRAUMA DATA BANK

- 2007-2016: Research Data Set (RDS)
- 2017: Trauma Quality Programs (TQP)
- Trauma Center admissions:
  - Pedestrians
  - Known age
- Knee injuries identified with ICD-9 & ICD-10 diagnostic codes

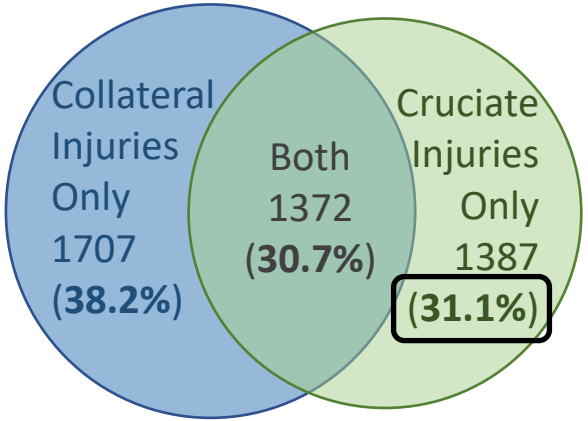
4,726 pedestrians with knee ligament injury

(No information about vehicle or crash)

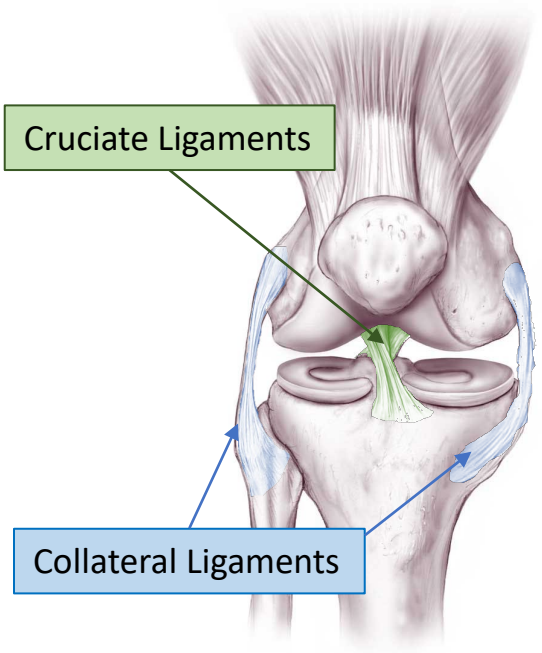
Results: NTDB



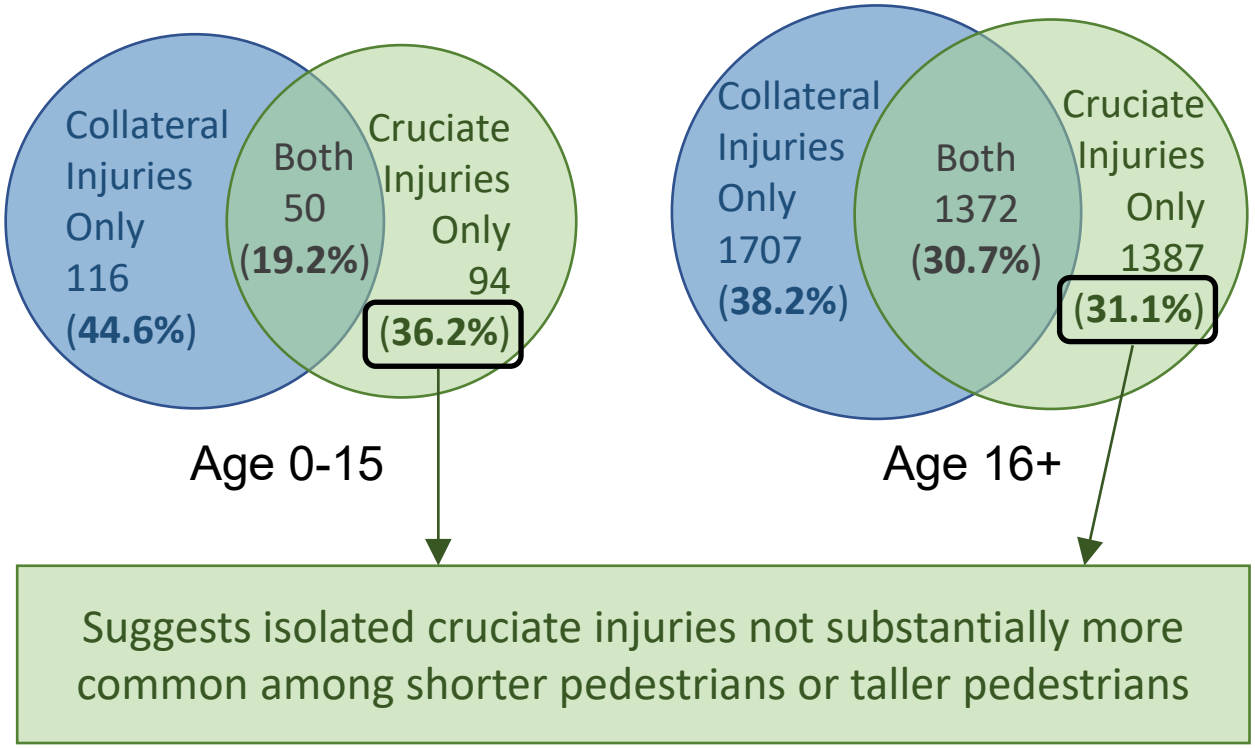
Age 0-15

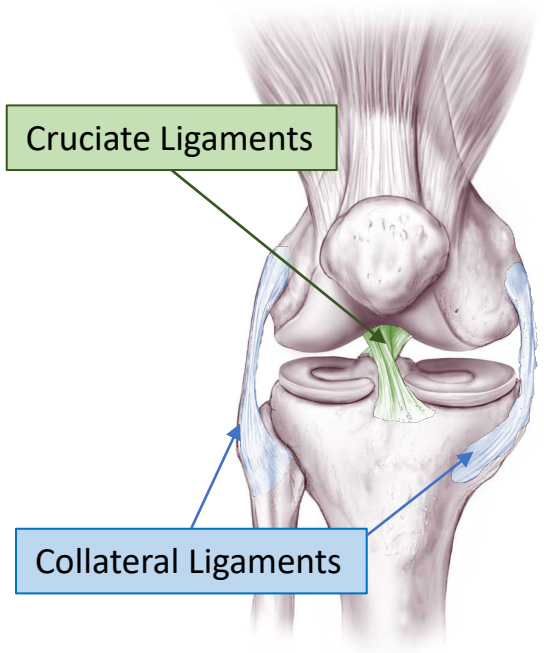


Age 16+



Results: NTDB





Methods: PCDS

PCDS (Pedestrian Crash Data Study)

- 1994-1998
- Knee ligament injuries identified with AIS-90
  - Cruciate/collateral injuries not differentiated
    - ➢ Narrative case documentation searched for injury detail
- Isolated cruciate injury: detailed case review

8 pedestrians with knee ligament injury

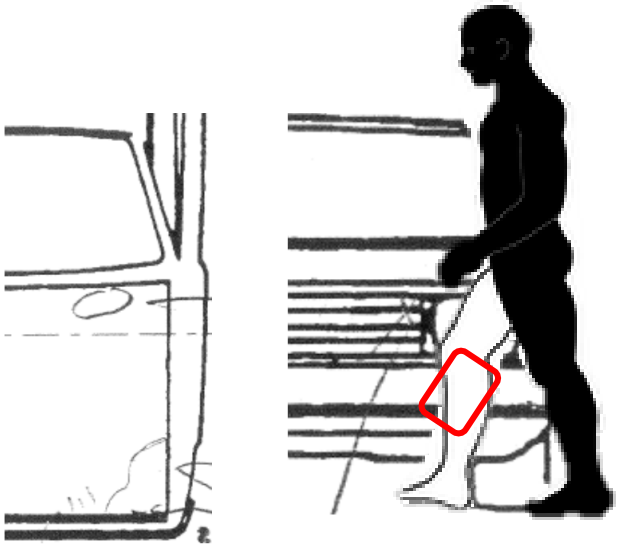
1 case with isolated cruciate injury

(Detailed vehicle & crash information)

Results: PCDS case with isolated cruciate injury

1990 Hyundai Sonata

- Impact speed 50 km/h (30 mph)
- No braking
- First contact at left bumper



65 year-old male, 170 cm (5’7”)

- Walking slowly
- Struck on right side, with right leg forward
- Cruciate injury to right knee

Results: PCDS case with isolated cruciate injury

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- Impact speed 50 km/h (30 mph)
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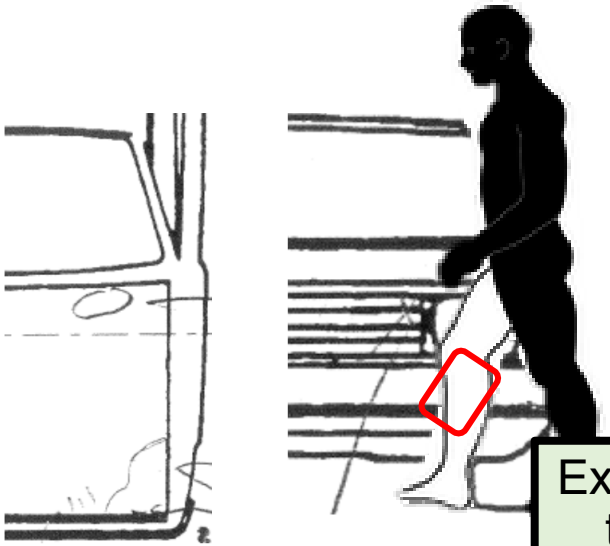
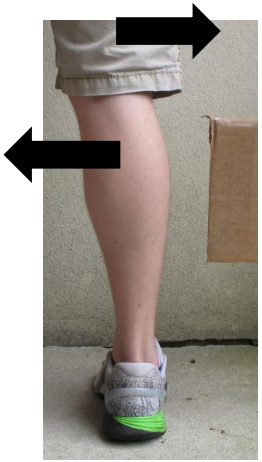


65 year-old male, 170 cm (5’7”)

- Walking slowly
- Struck on right side, with right leg forward
- Cruciate injury to right knee
- Knee height 4 cm above top of bumper

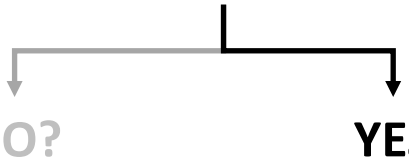
Shear displacement at knee



Example of isolated cruciate injury in a typical pedestrian impact scenario

Conclusion #1

Do cruciate injuries occur without collateral ligament injuries?



Cruciate injuries do occur without collateral ligament injury in real-world cases

- NTDB: Almost ⅓ of pedestrian knee ligament cases
- PCDS: Common pedestrian impact scenario

Supports consideration of cruciate injury in assessments of pedestrian knee injury risk

Conclusion #2

Risk of isolated cruciate ligament injury & relative knee/bumper height

- PCDS: Isolated cruciate injury in below-knee impact
- Previous modeling: Isolated cruciate injury in above-knee & below-knee impacts
- NTDB: Similar proportions of children & adults sustained isolated cruciate injuries

- Suggests isolated cruciate injury can occur at a broad range of impact heights

Unclear whether legform testing at a single launch height could predict cruciate injury risk for taller or shorter pedestrians

Conclusion #3

- Combined data from 2 sources
  - NTDB → very large number of recent cases (but only medical records)
  - PCDS → crash and injury detail (but on small number of older cases)

Large-scale, comprehensive, representative pedestrian dataset could improve analyses of pedestrian injuries with modern vehicles

Contact Info

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Questions and follow-up:

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