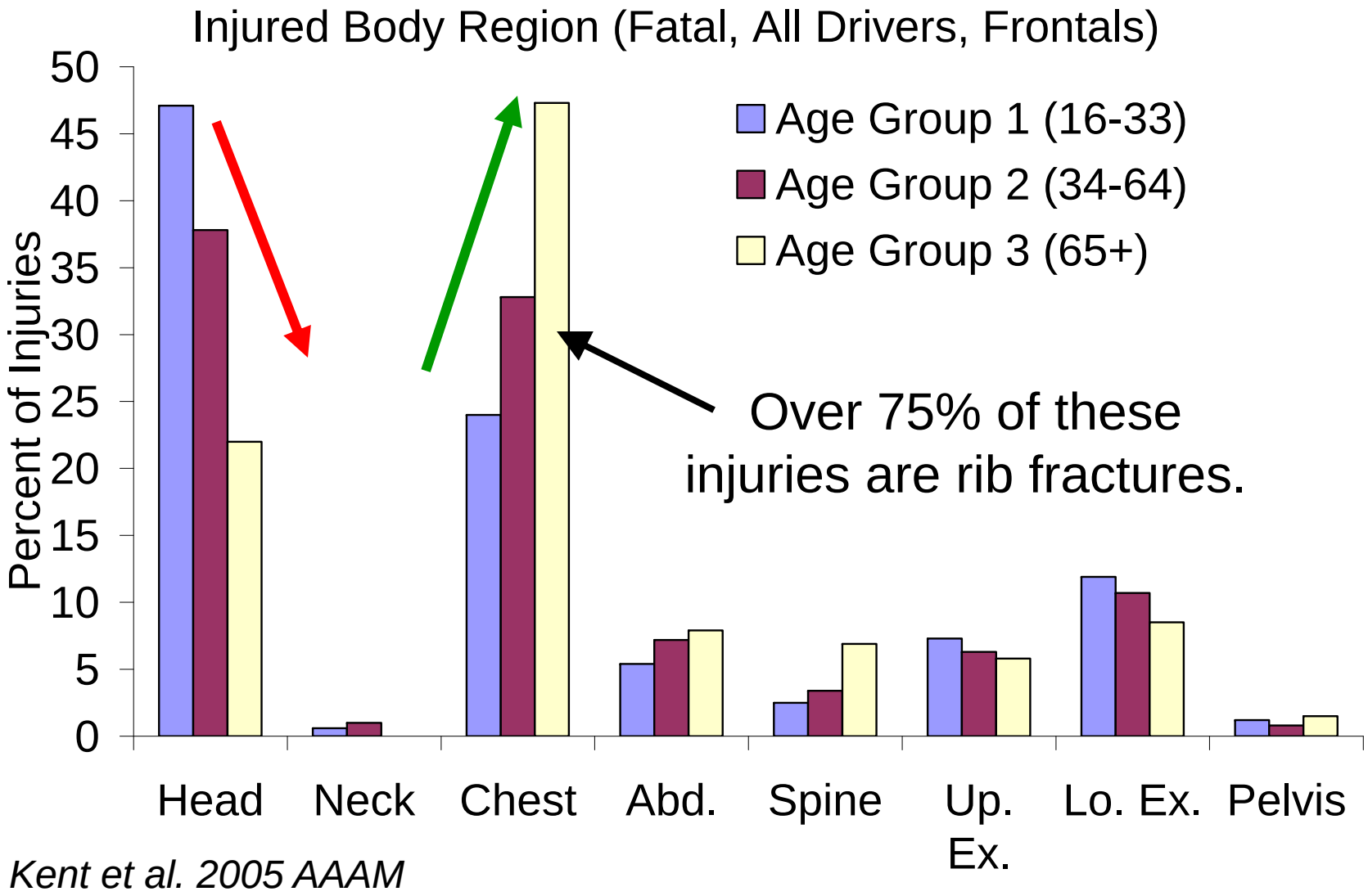
UNIVERSITY of VIRGINIA

The Biomechanics of Aging

Richard Kent, PhD
Professor

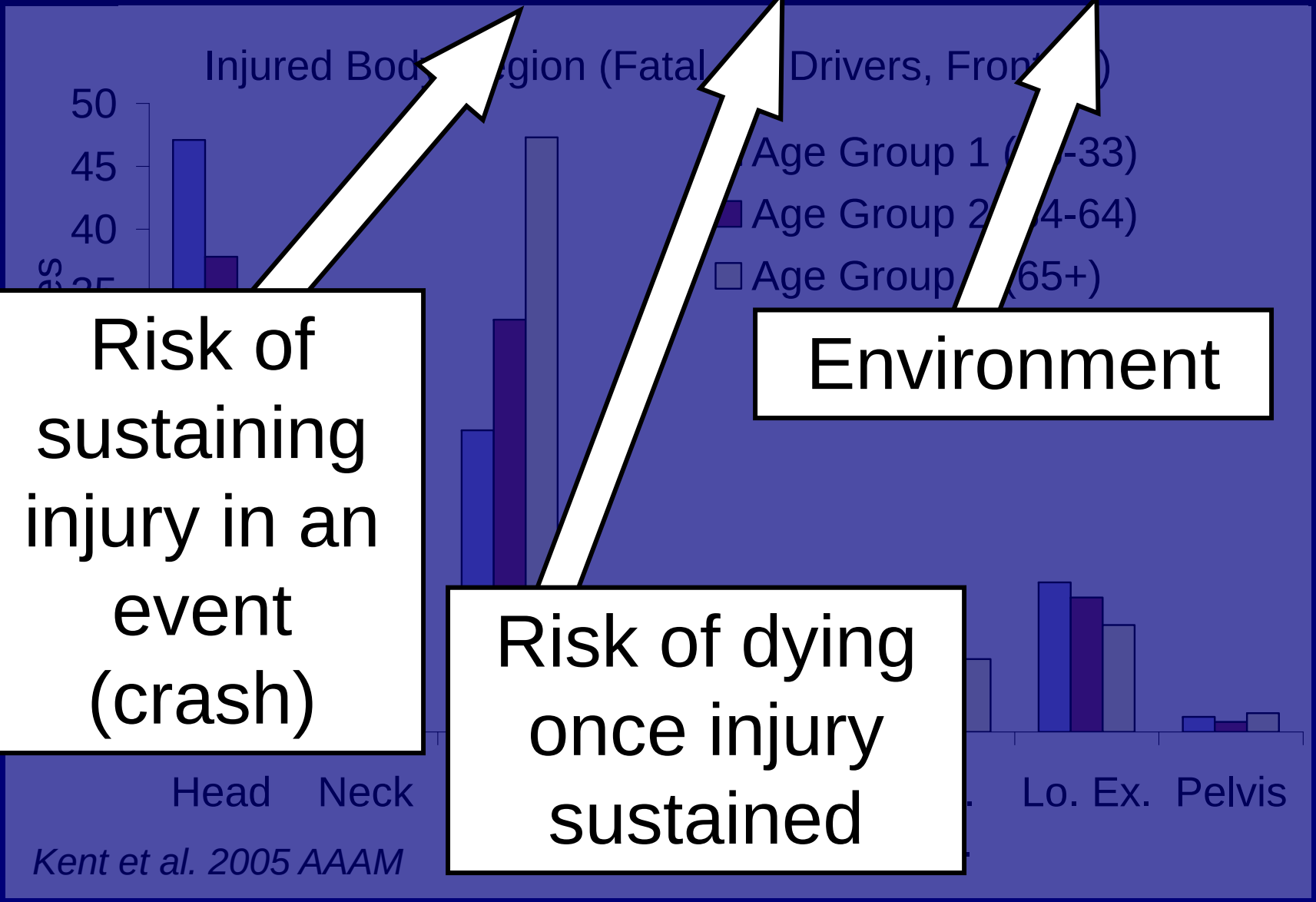
CENTER for APPLIED BIOMECHANICS

Distribution of Injuries Changes with Aging (*Fragility* + *Frailty* + *Exposure*)



Kent et al. 2005 AAAM

Distribution of Injuries in People who Die Changes with Aging (*Fragility + Frailty + Exposure*)



Risk of sustaining injury in an event (crash)

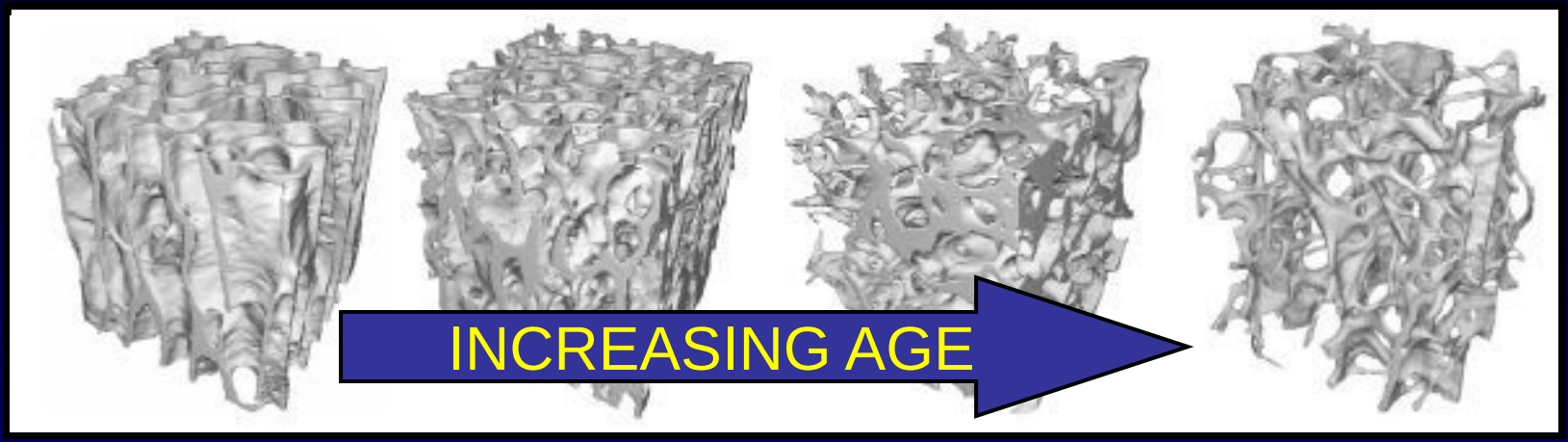
Risk of dying once injury sustained

Environment

Kent et al. 2005 AAAM

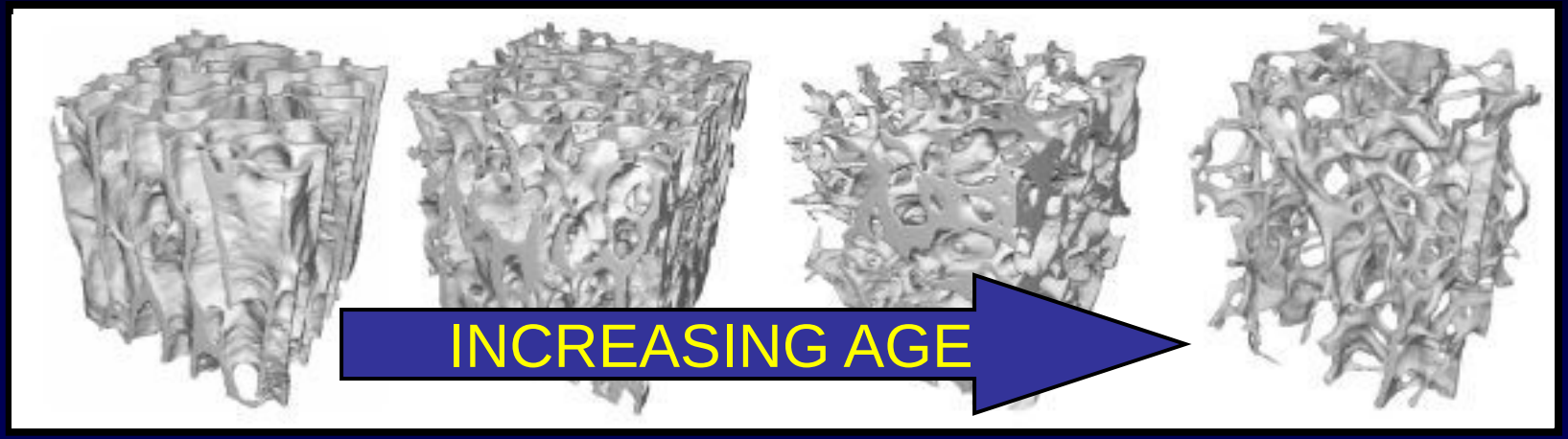
Biomechanics of *fragility* encompass a range of length scales

- “small” scale changes (“material properties”)



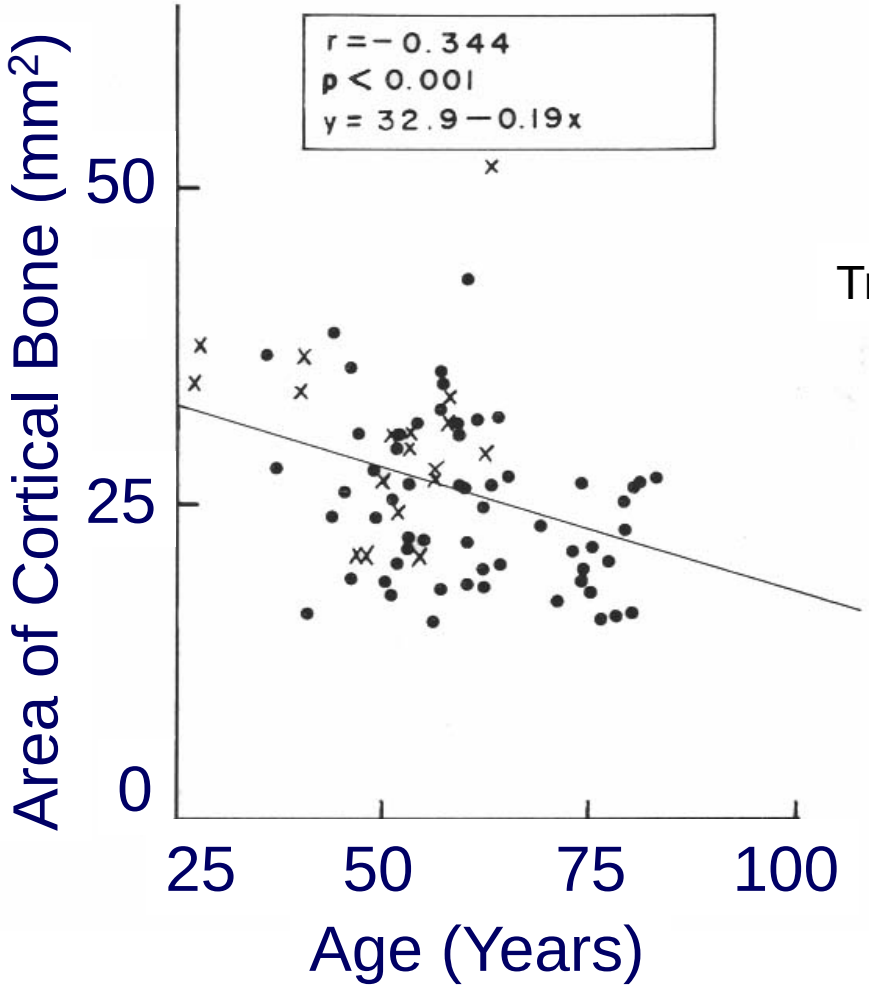
Biomechanics of *fragility* encompass a range of length scales

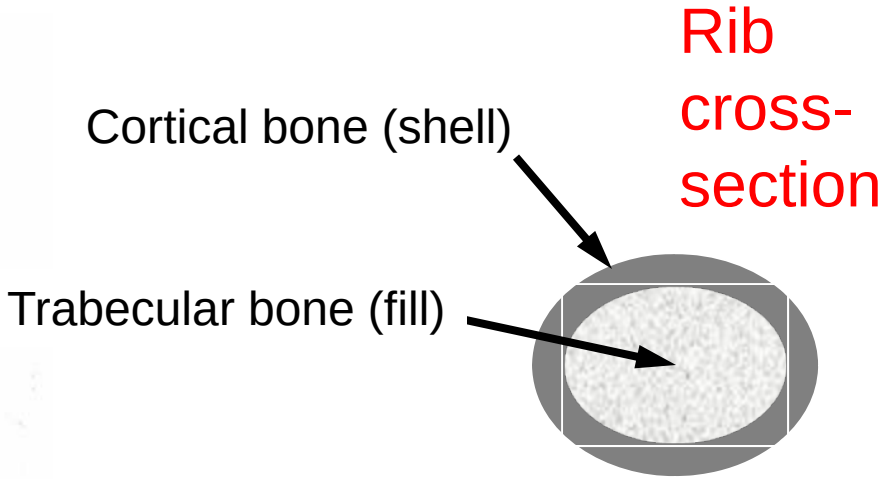
- “small” scale changes (“material properties”)

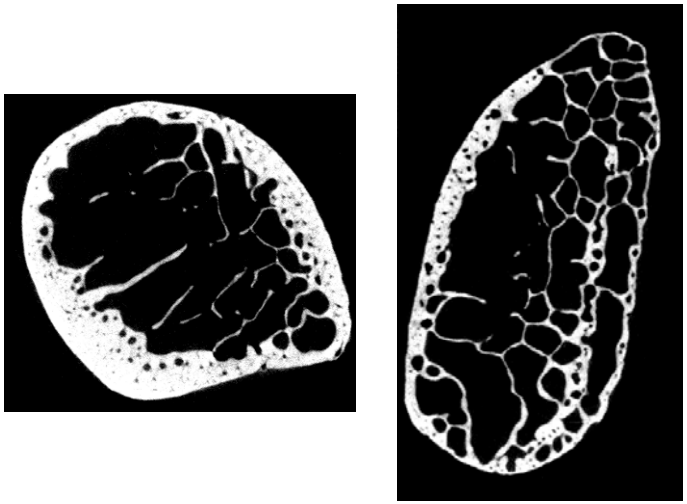


- “larger” scale geometry changes

Cortical bone area decreases

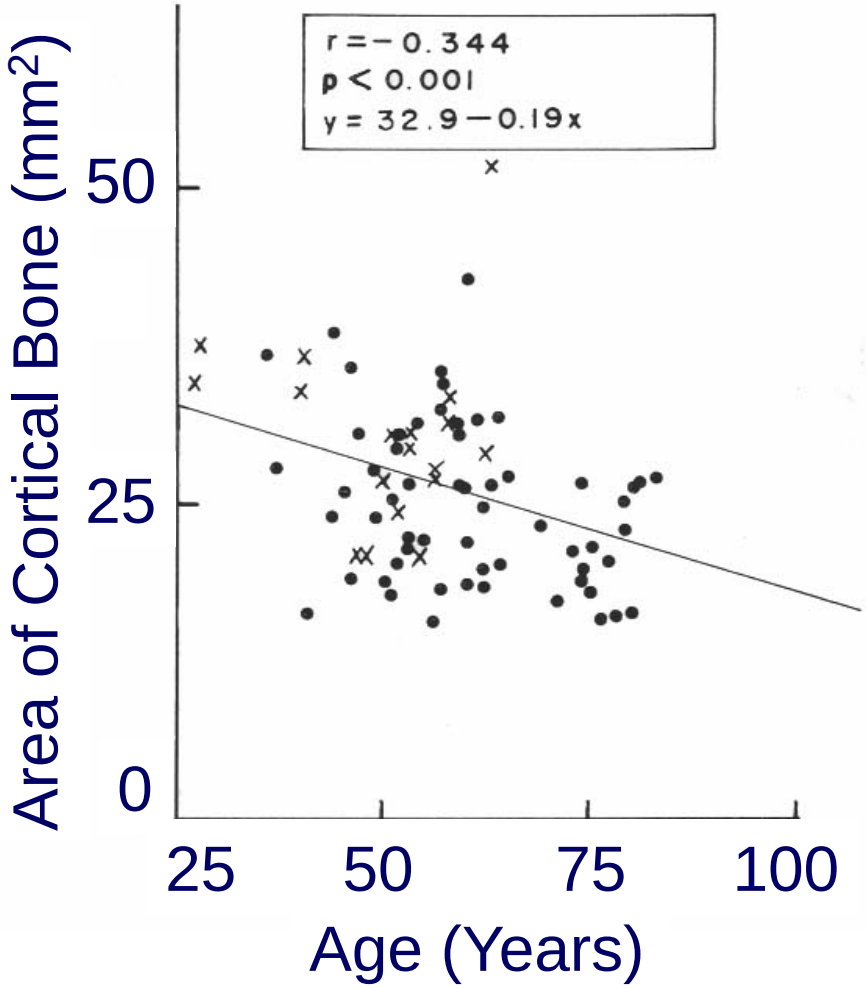




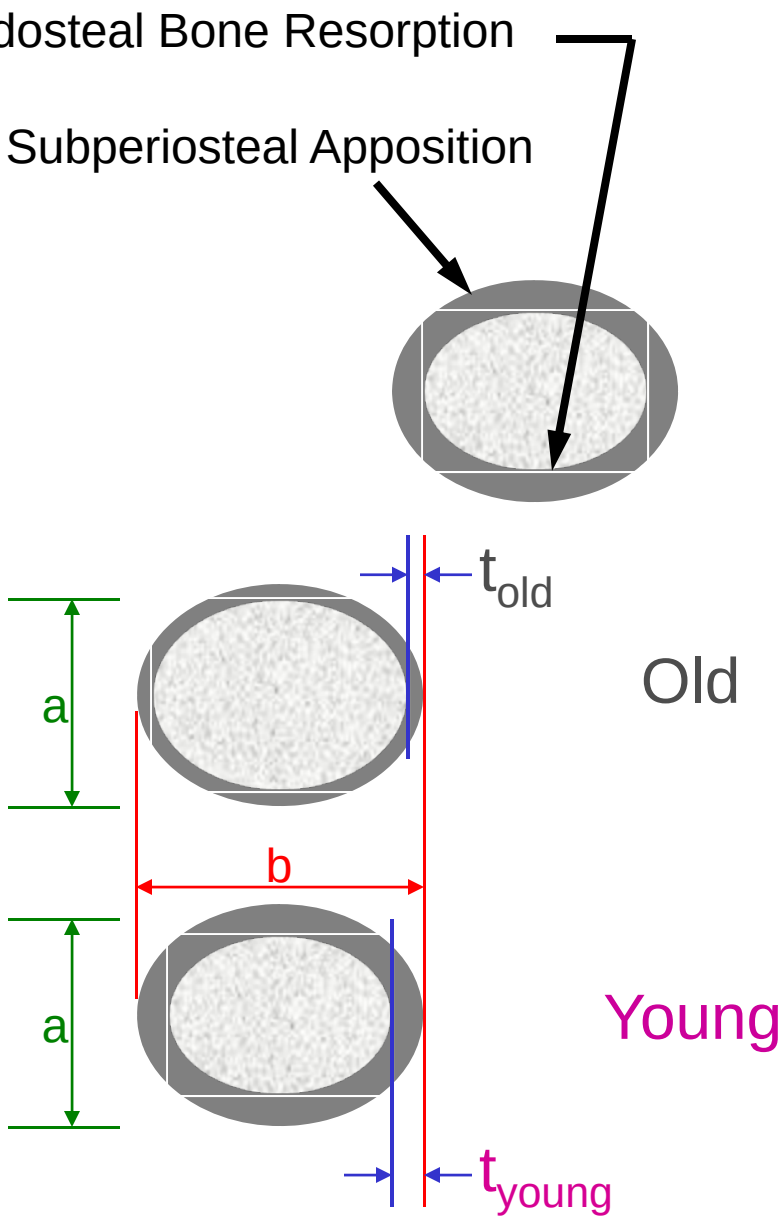


Stein and Granik, 1976

Cortical bone area decreases

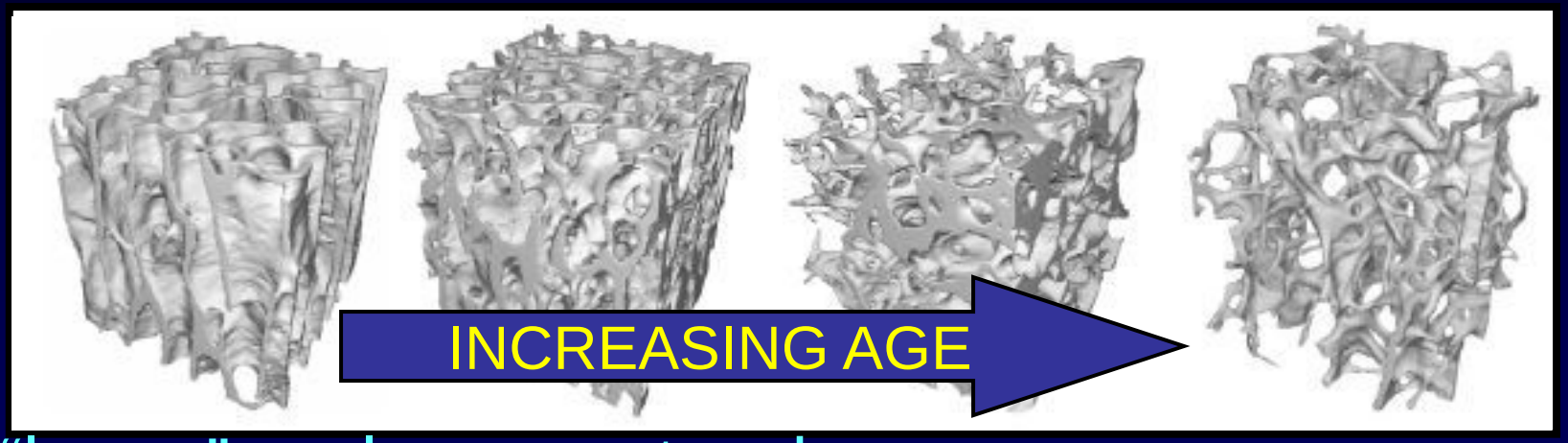


Stein and Granik, 1976

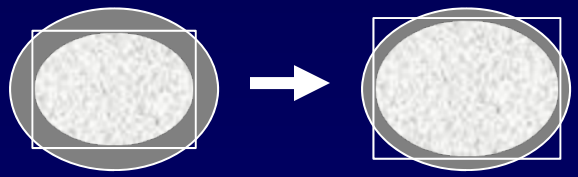


Biomechanics of *fragility* encompass a range of length scales

- “smaller” scale changes (“material properties”)



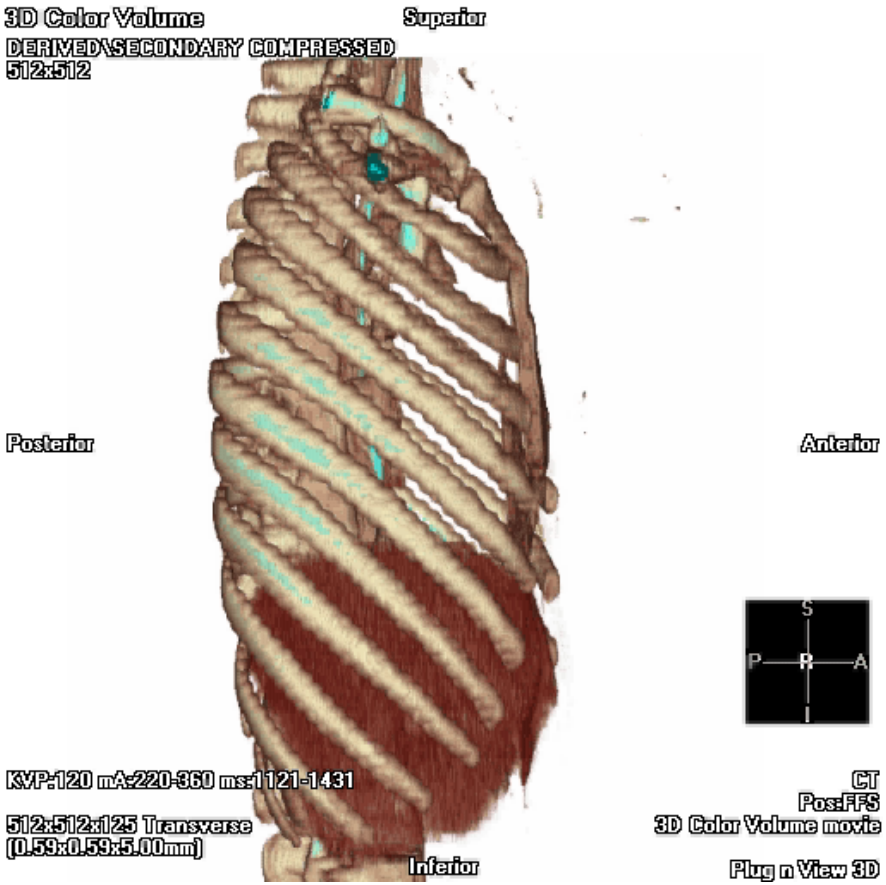
- “larger” scale geometry changes
  - Decrease in thickness of cortical shell



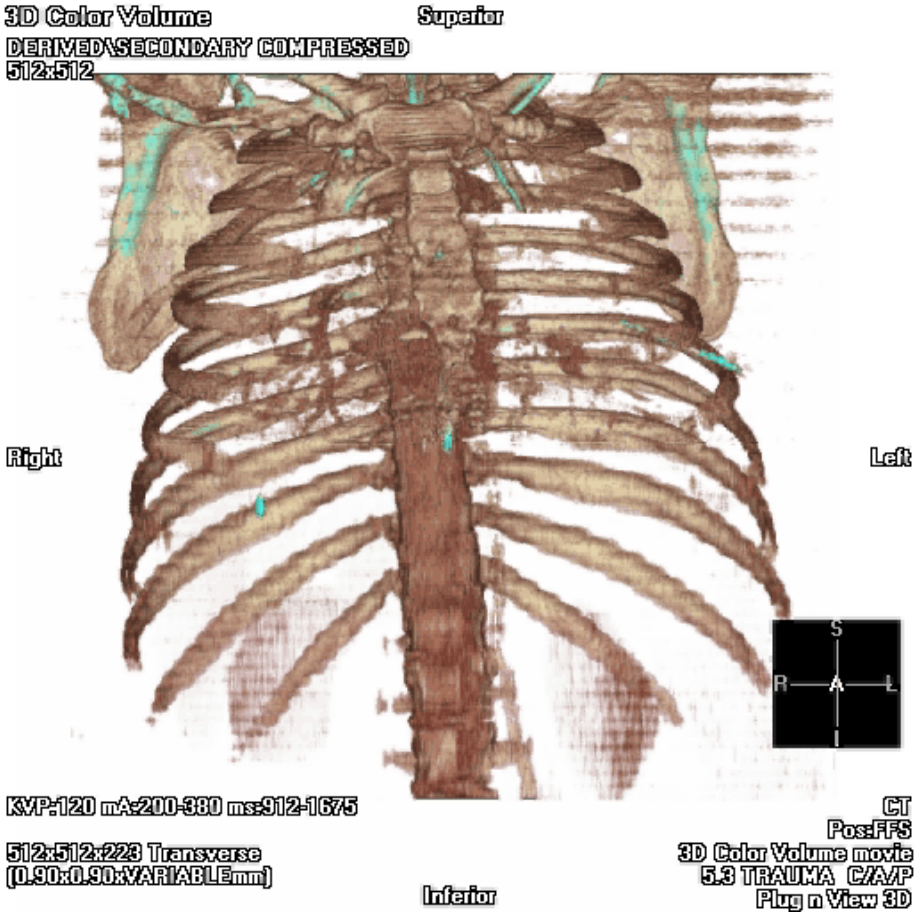
- “large” scale geometry changes
  - Changes in rib cage morphology

Extreme Examples of Age-Related Differences in Rib Cage Geometry

Young (17 Years)

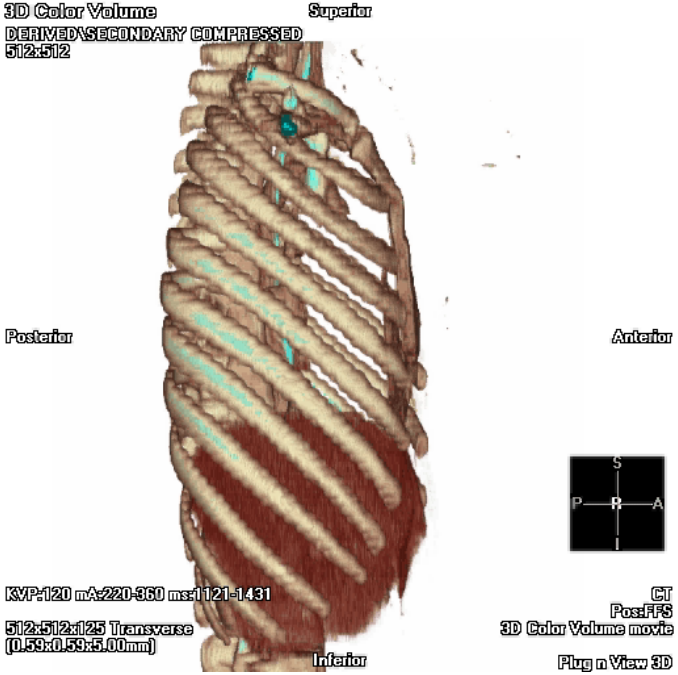


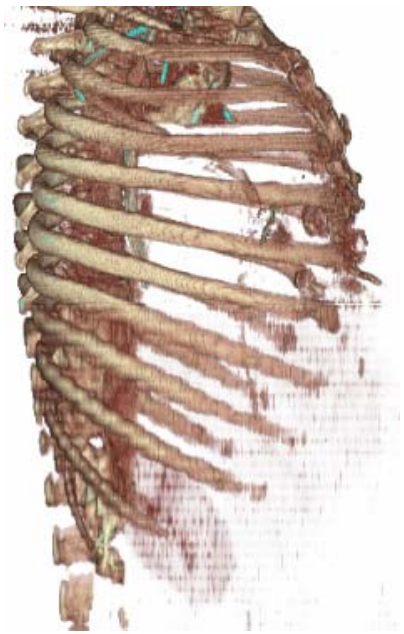
Older (64 Years)

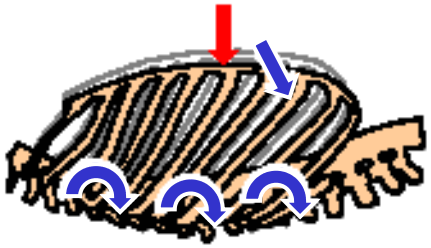


Kent et al. 2005 Stapp

Extreme Examples of Age-Related Differences in Rib Cage Geometry

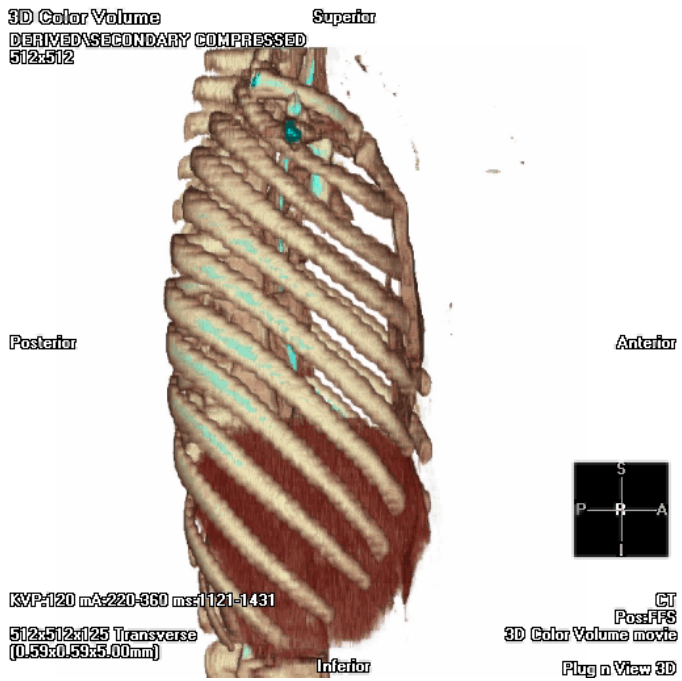


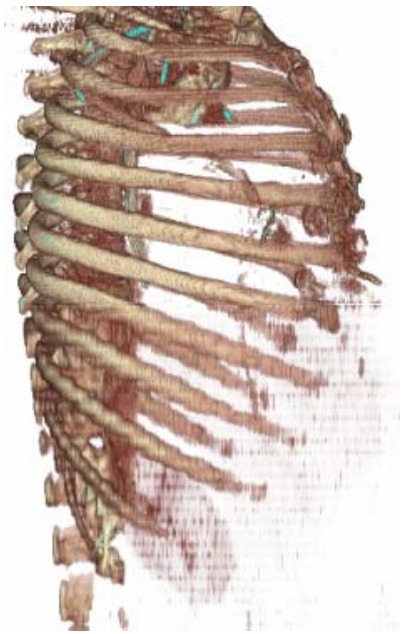


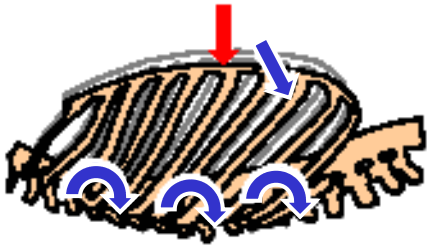


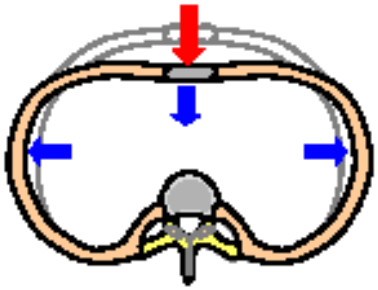
Kent et al. 2005 Stapp

Extreme Examples of Age-Related Differences in Rib Cage Geometry







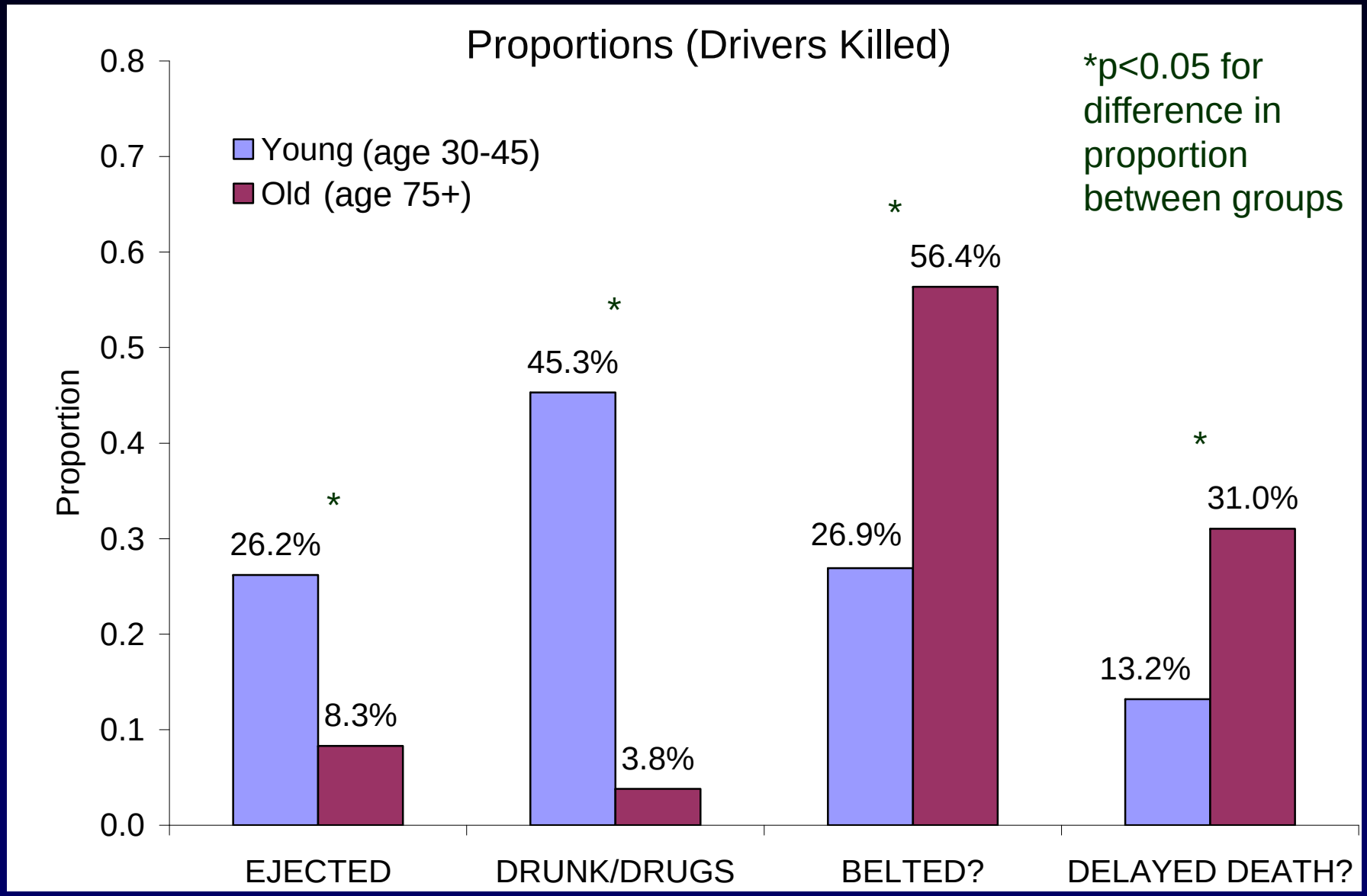


Kent et al. 2005 Stapp

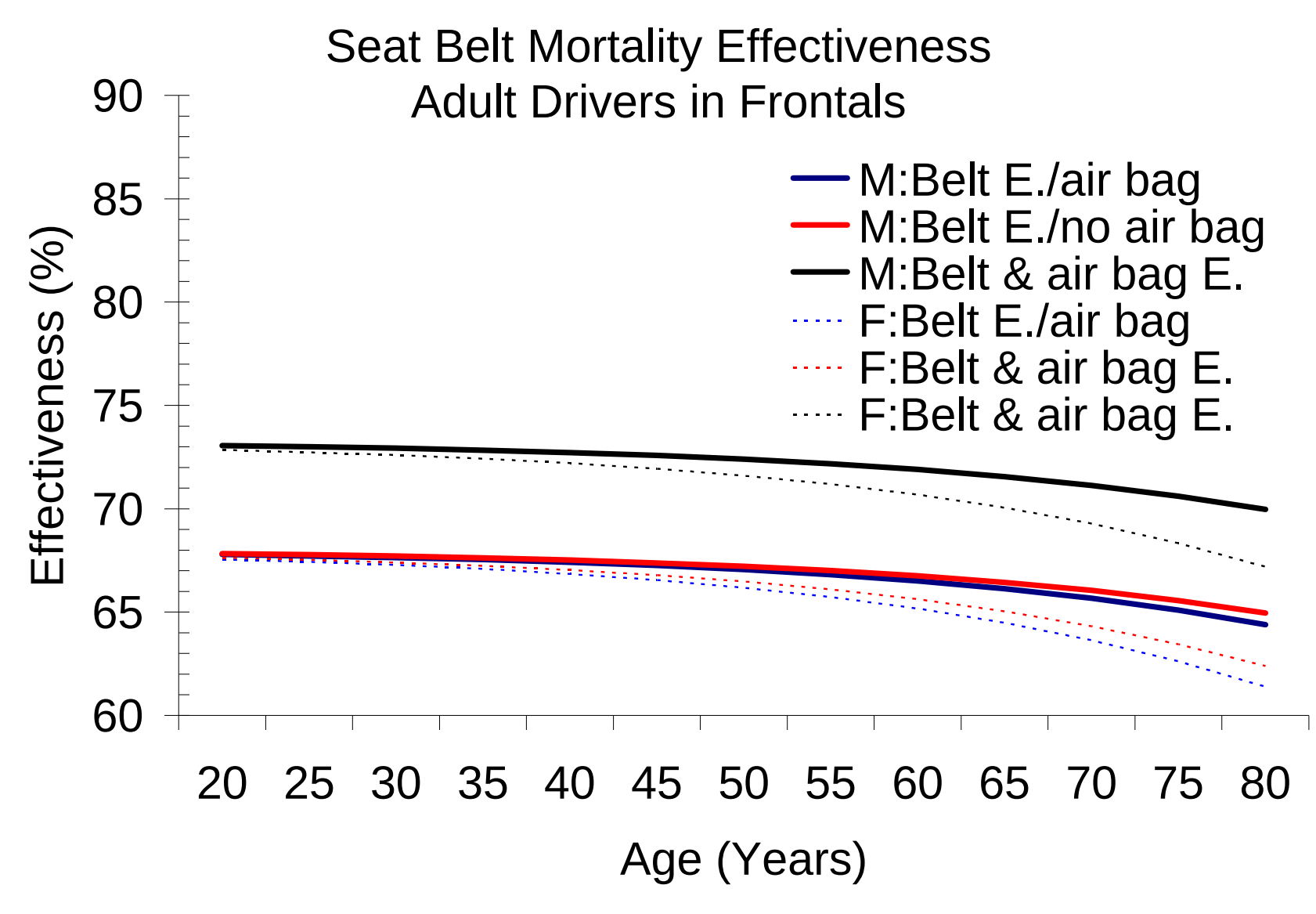
In conclusion…

- Mean age of U.S. population increasing by about 1 month/year.
- 2002-2012: Aging of America generated about half as many serious injuries as increased seatbelt use prevented.
- Unique set of challenges for crash protection
- Understanding the biomechanics of aging is a key part of solution

FARS Study – Results



Restraint Effectiveness Drops with Age



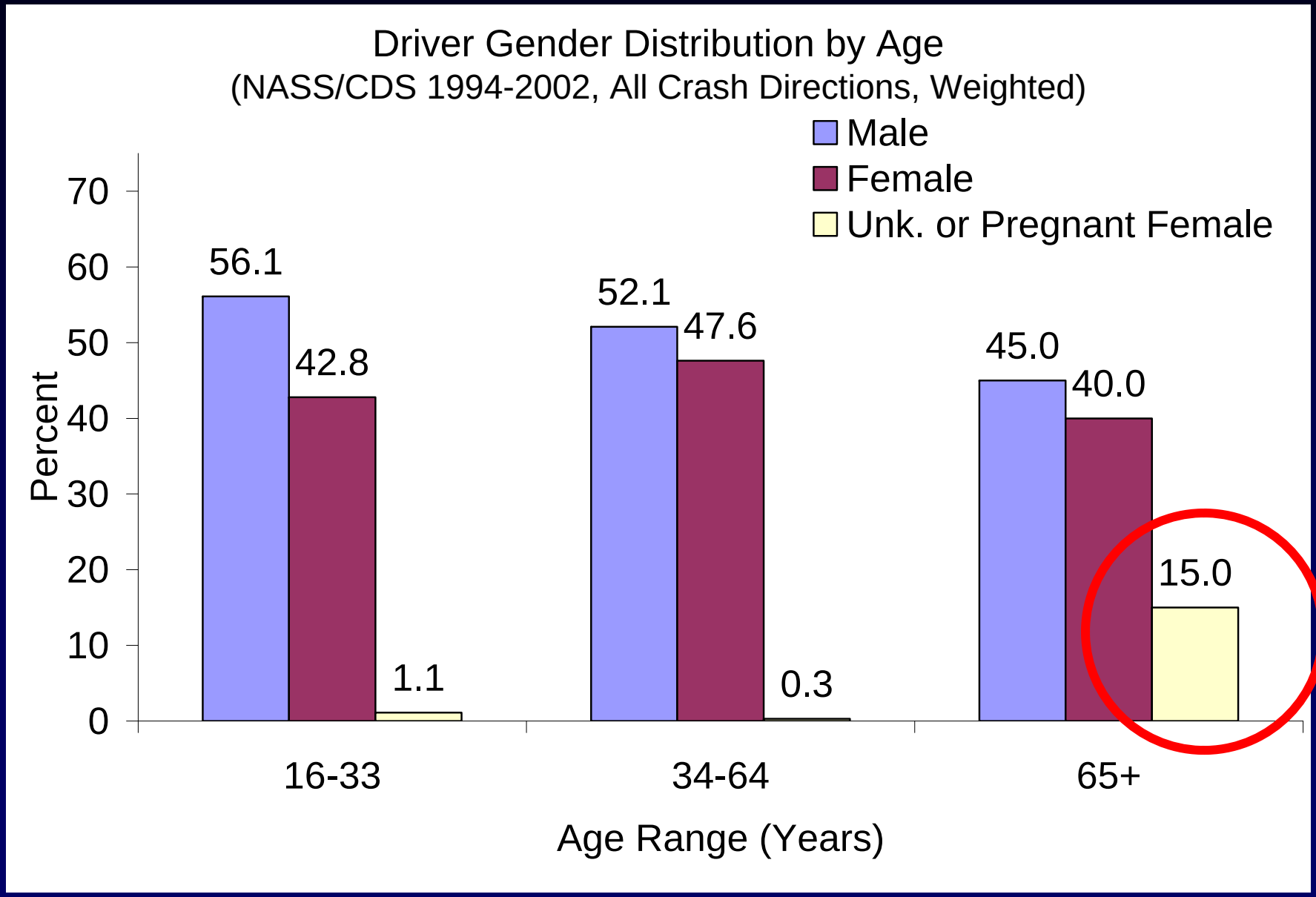
“Younger” Group

- Case 171158, Age 39, Female
  - Vehicle went roof-first into tree. Impact at location of driver’s head. Massive intrusion at driver’s position and extensive head/neck injuries noted at autopsy.

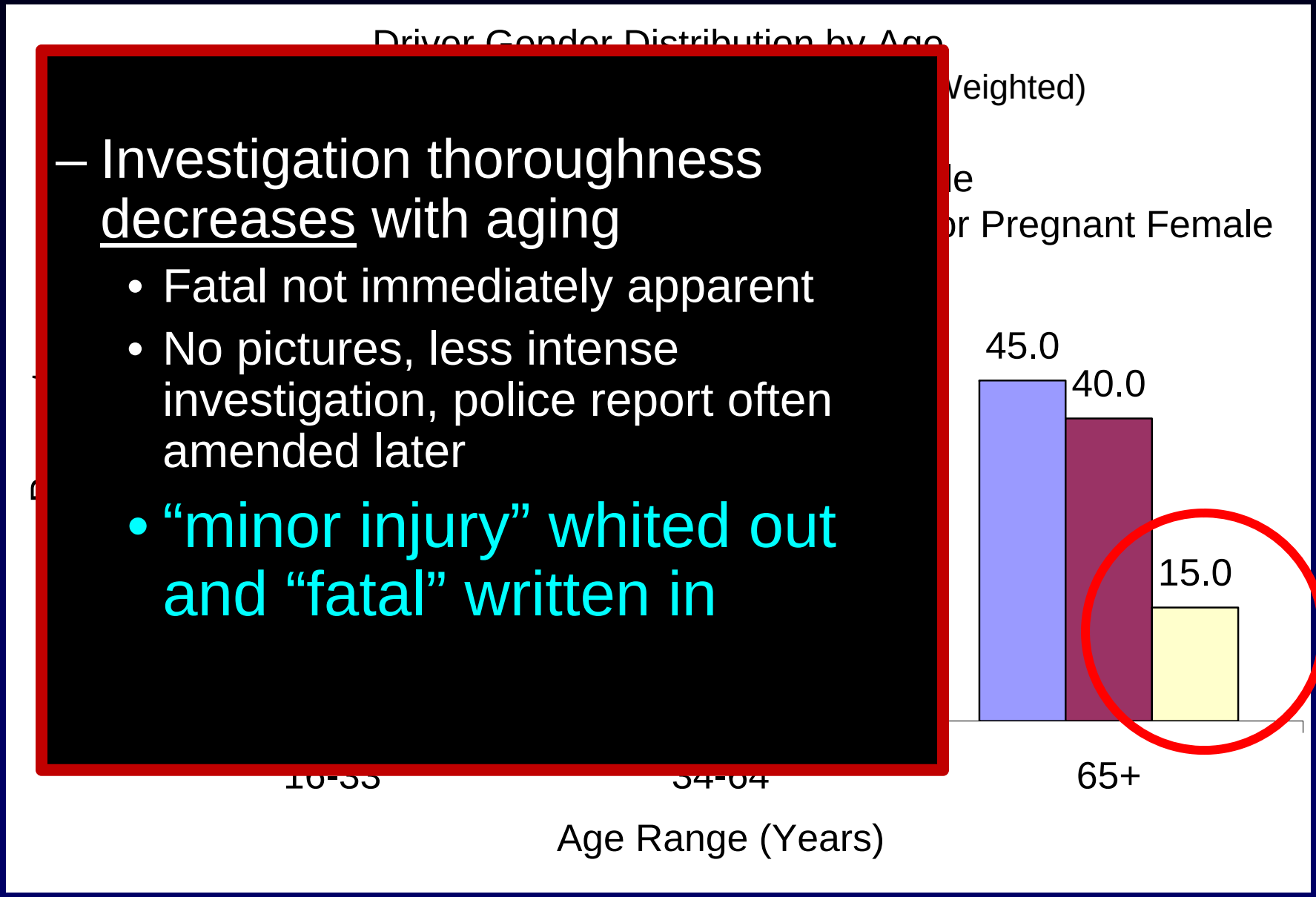
“Older” Group

- Case 330012, Age 75, Male
  - Minor crash, died 16 days later of complications from pre-existing bowel condition
- Case 391055, Age 89, Male
  - Driver drove into house, backed up and hit house 2 more times. Died 6 days later of unknown cause.
- Several cases with “heart attack” as a co-factor or noted <u>explicitly as cause of death</u>
- Several cases of moderate severity, belted occupant, but elderly fatality

Gender distribution by age

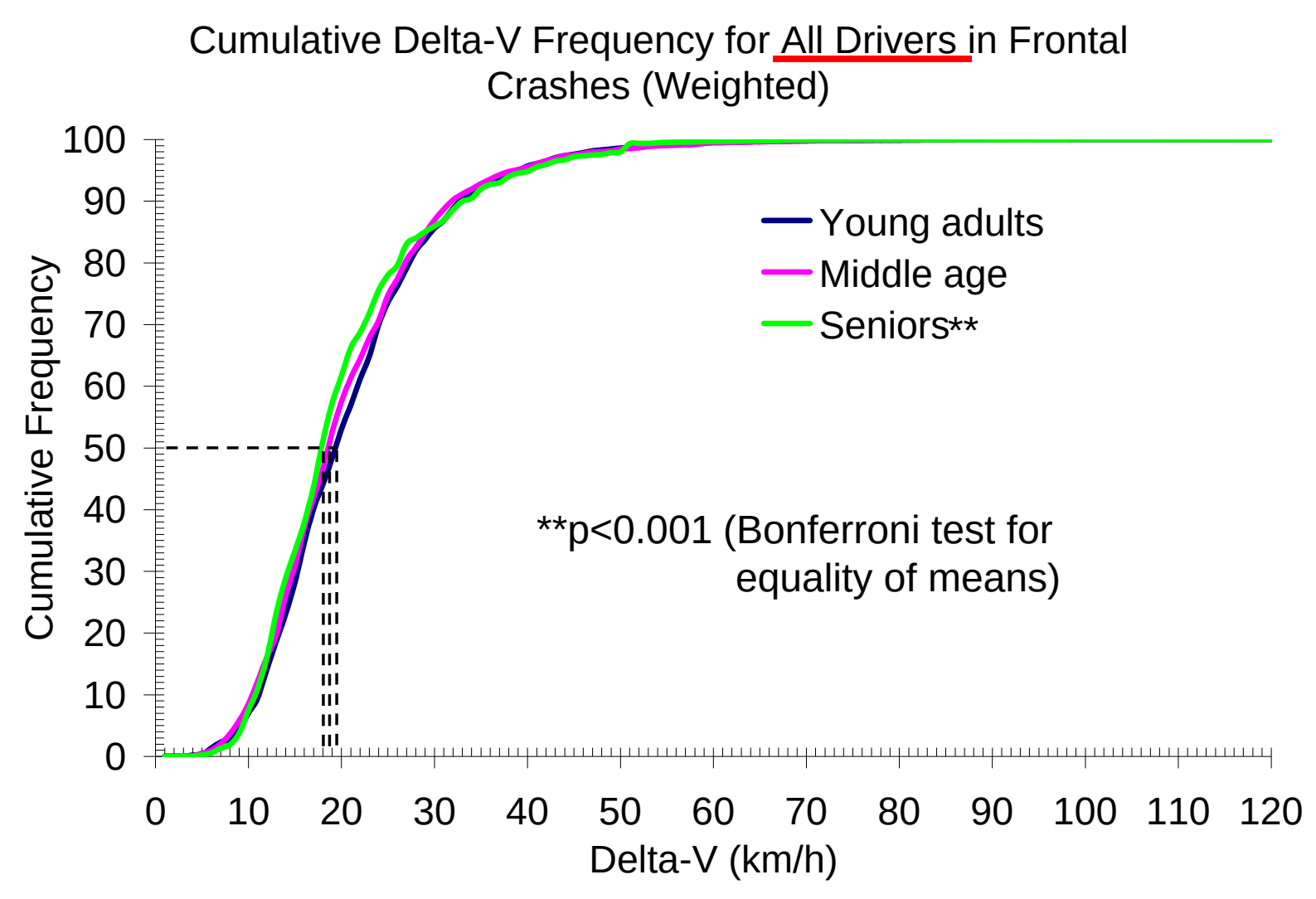


Gender distribution by age

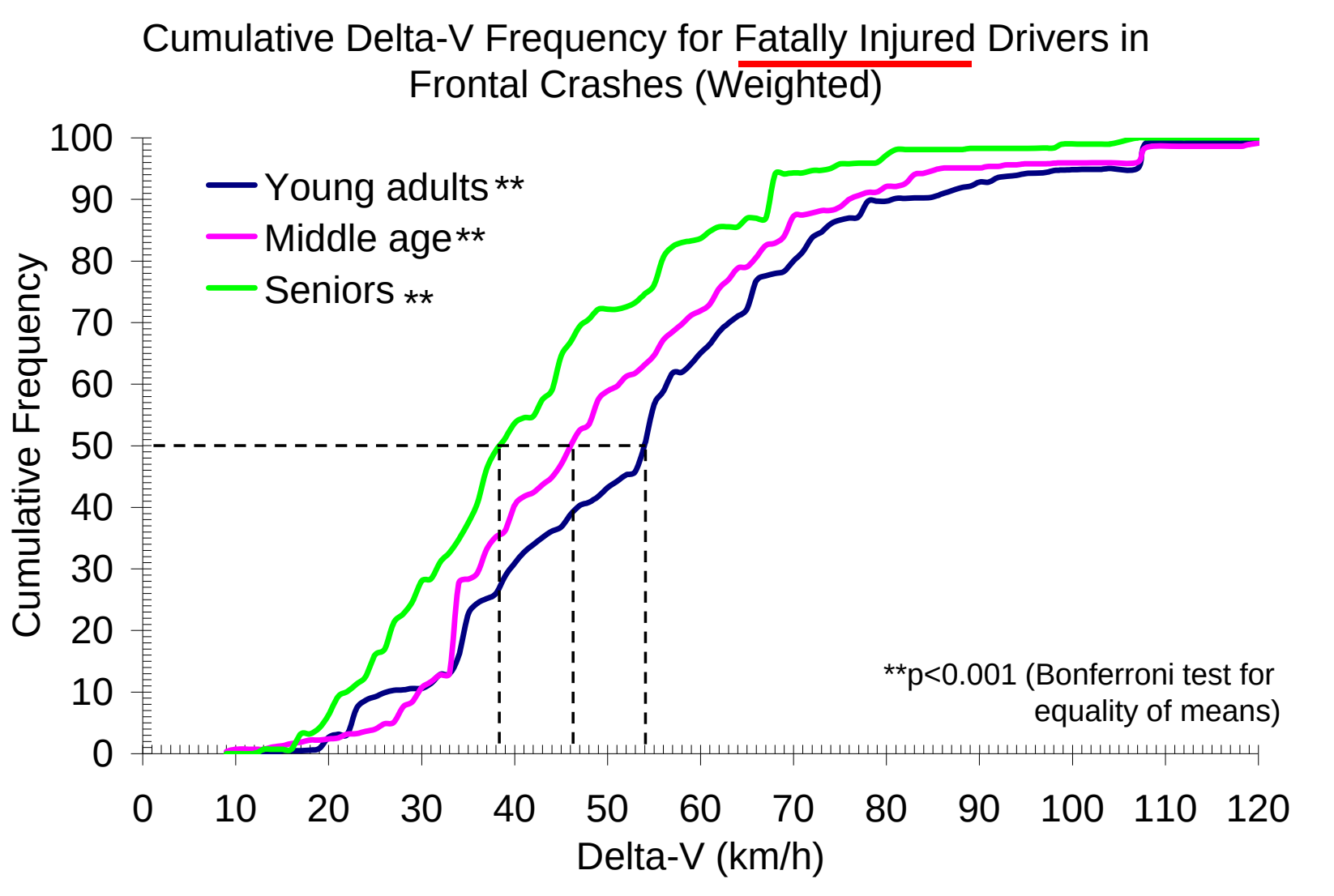


– Investigation thoroughness <u>decreases</u> with aging
  - Fatal not immediately apparent
  - No pictures, less intense investigation, police report often amended later
  - “minor injury” whited out and “fatal” written in

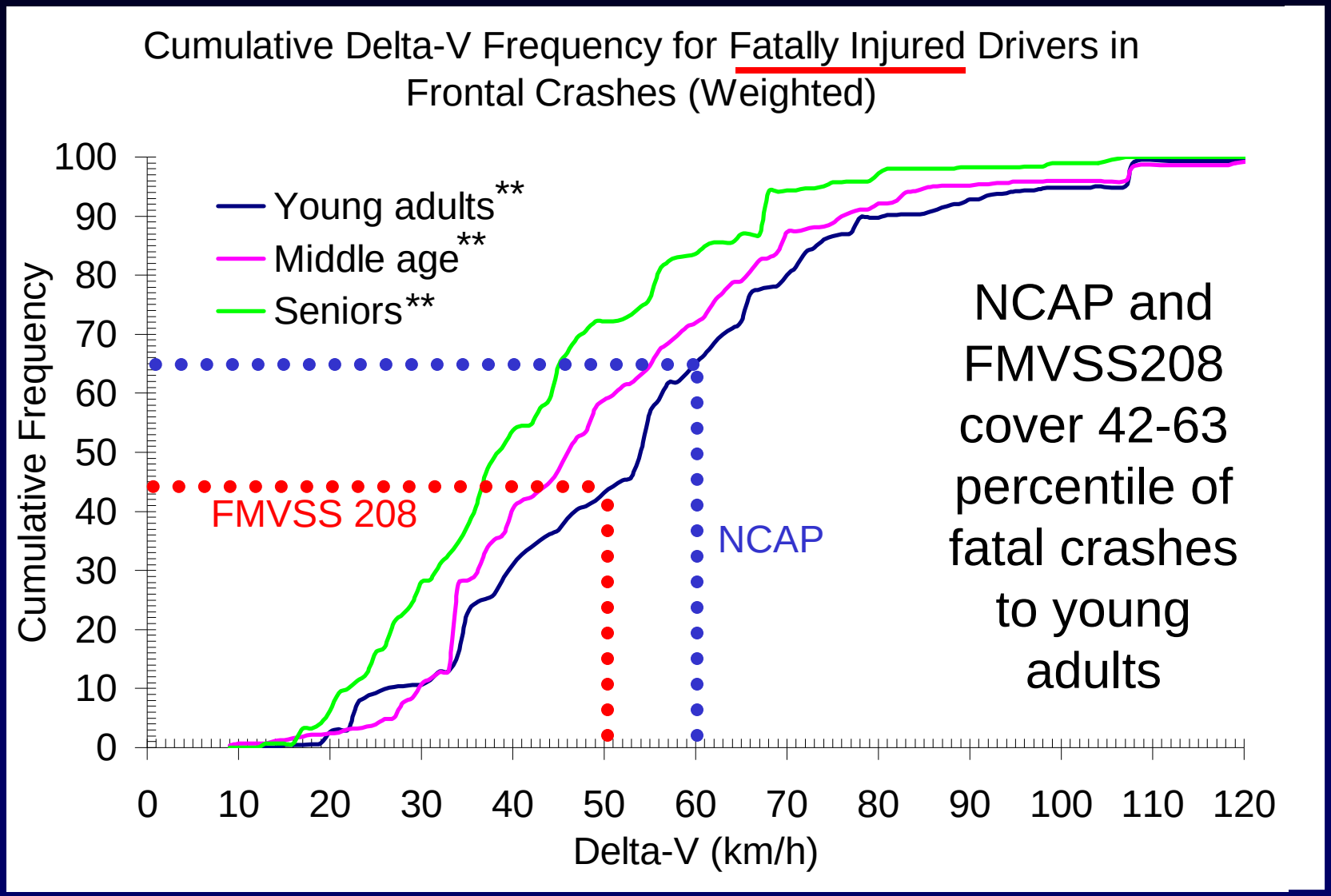
Cumulative ΔV Distribution by Age and Injury Severity



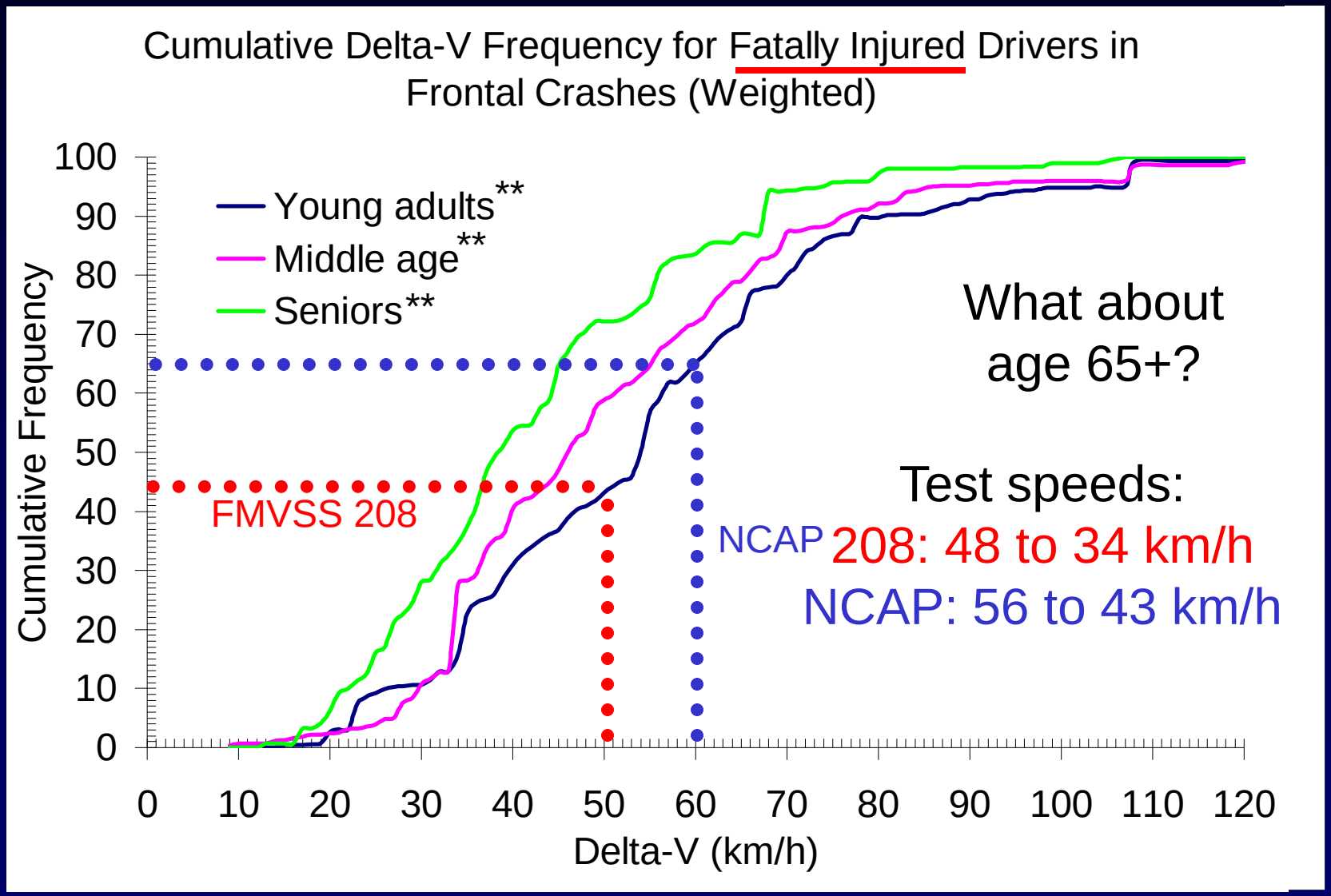
Cumulative ΔV Distribution by Age and Injury Severity



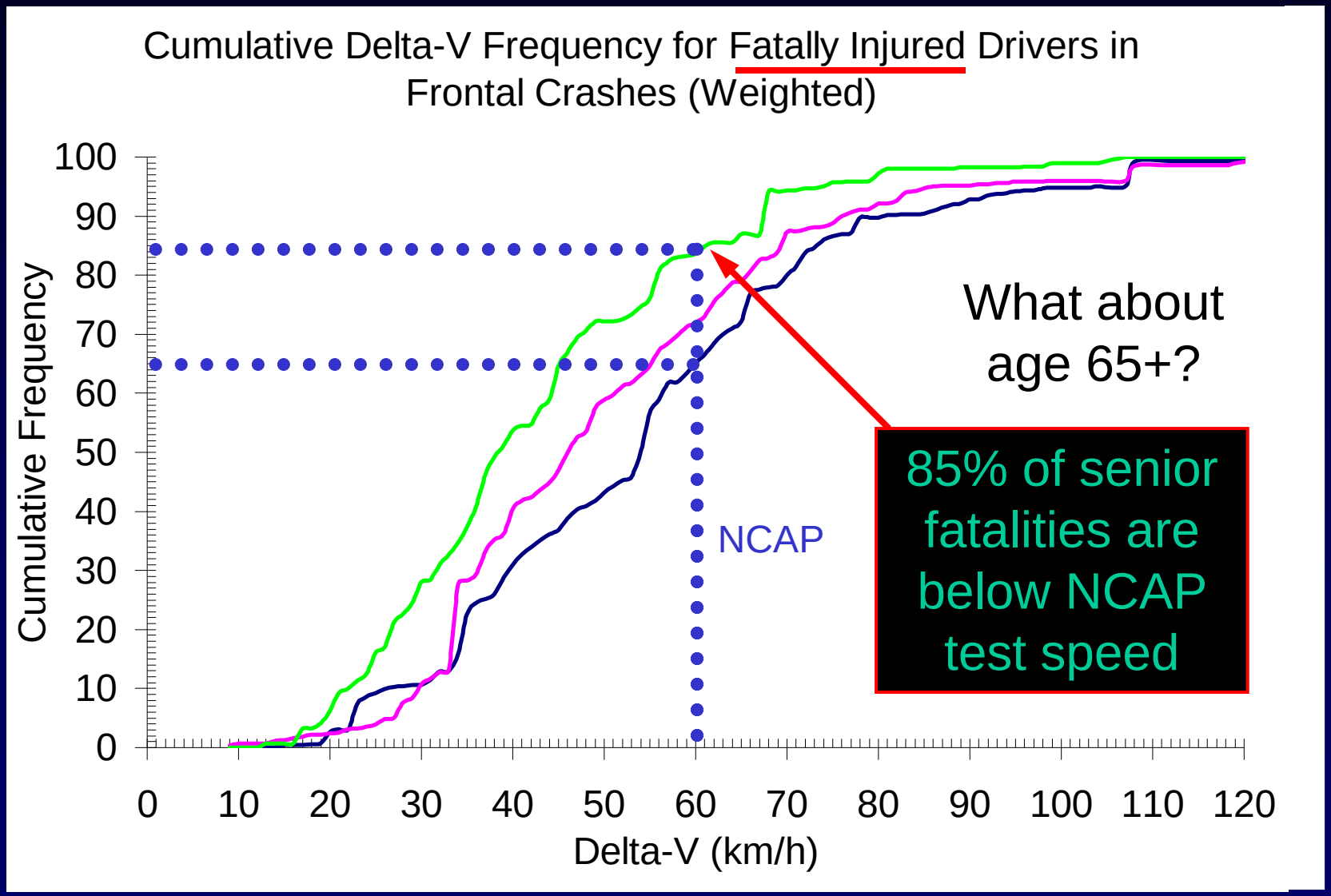
Cumulative ΔV Distribution by Age and Injury Severity



Cumulative ΔV Distribution by Age and Injury Severity



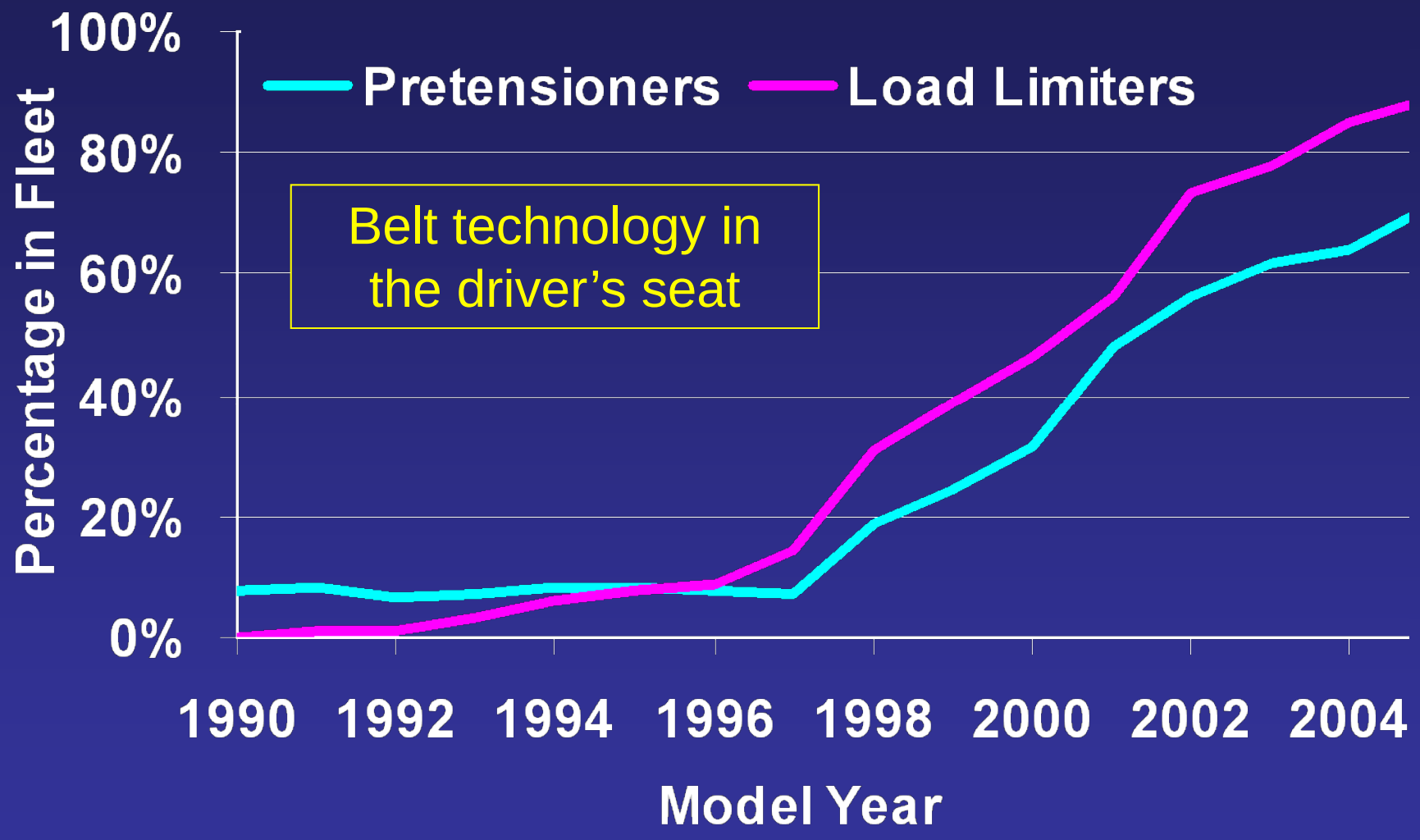
Cumulative ΔV Distribution by Age and Injury Severity



Fatality Effectiveness of Rear Seats Compared to Front Seats – Restrained Occupants

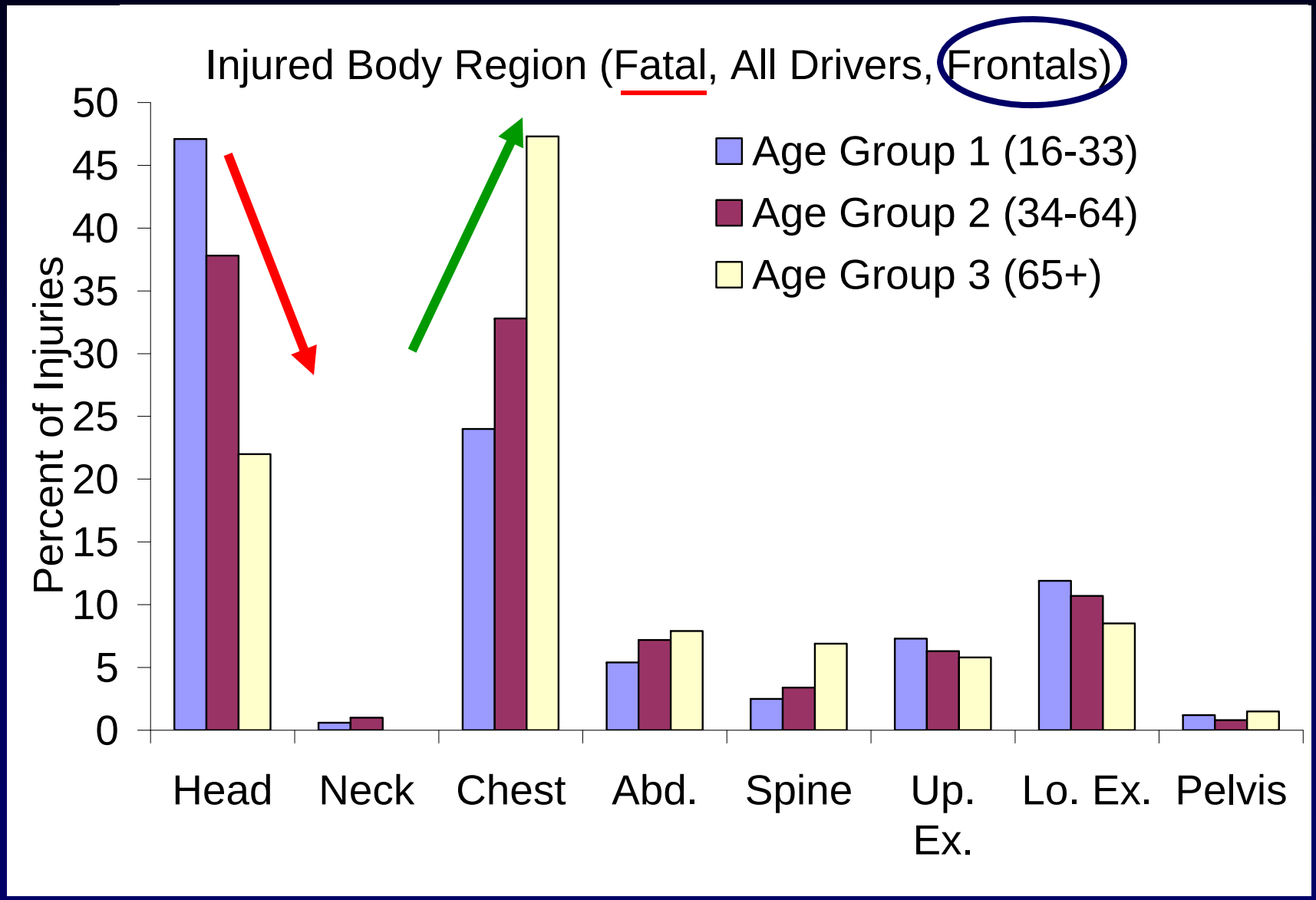
Kuppa et al., *ESV*, 2005

Vehicles Tested in U.S. Frontal NCAP

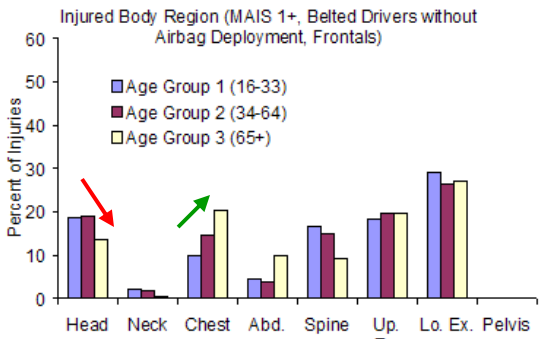


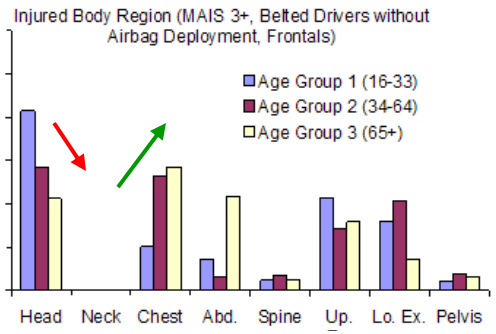
Kent et al., *ESV*, 2007

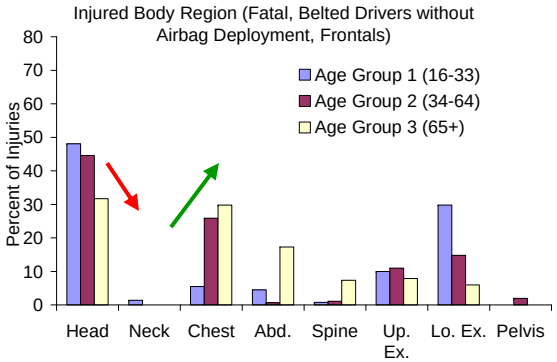
Injured Body Region (Fatal)



Different Restraint Configurations and Injury Levels

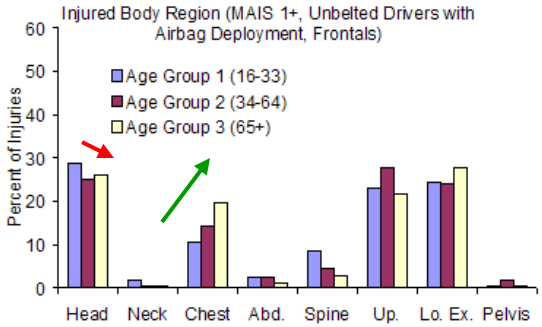


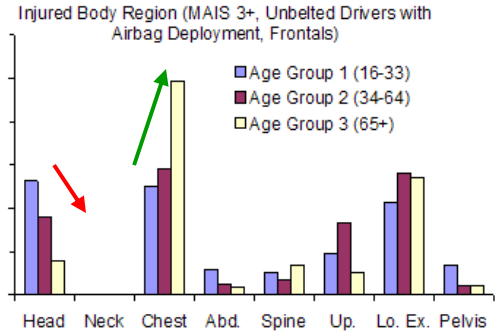


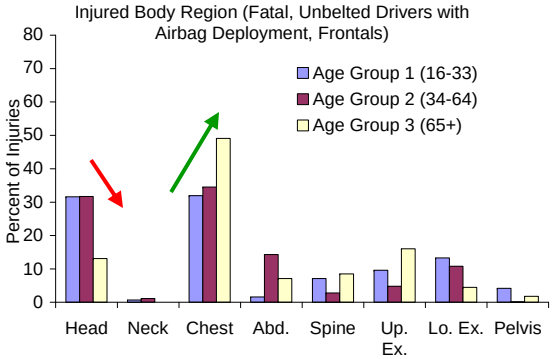


Belt, No Airbag

MAIS 1+

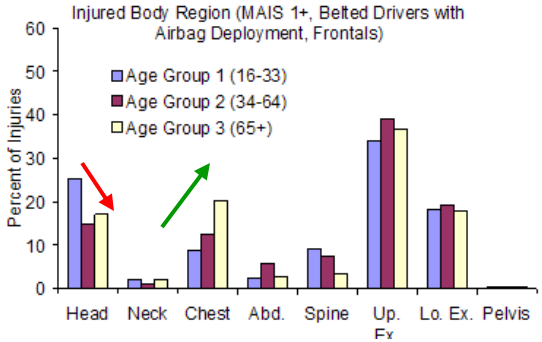


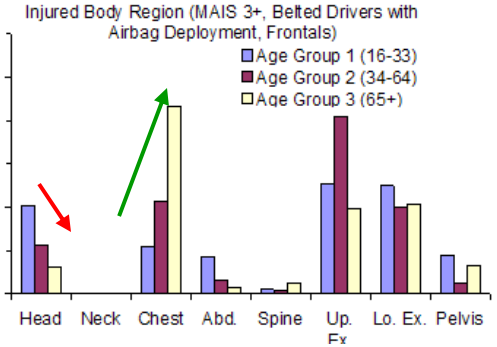


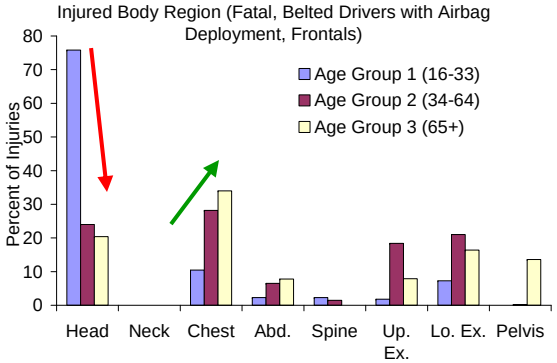


FATAL

Airbag, No Belt





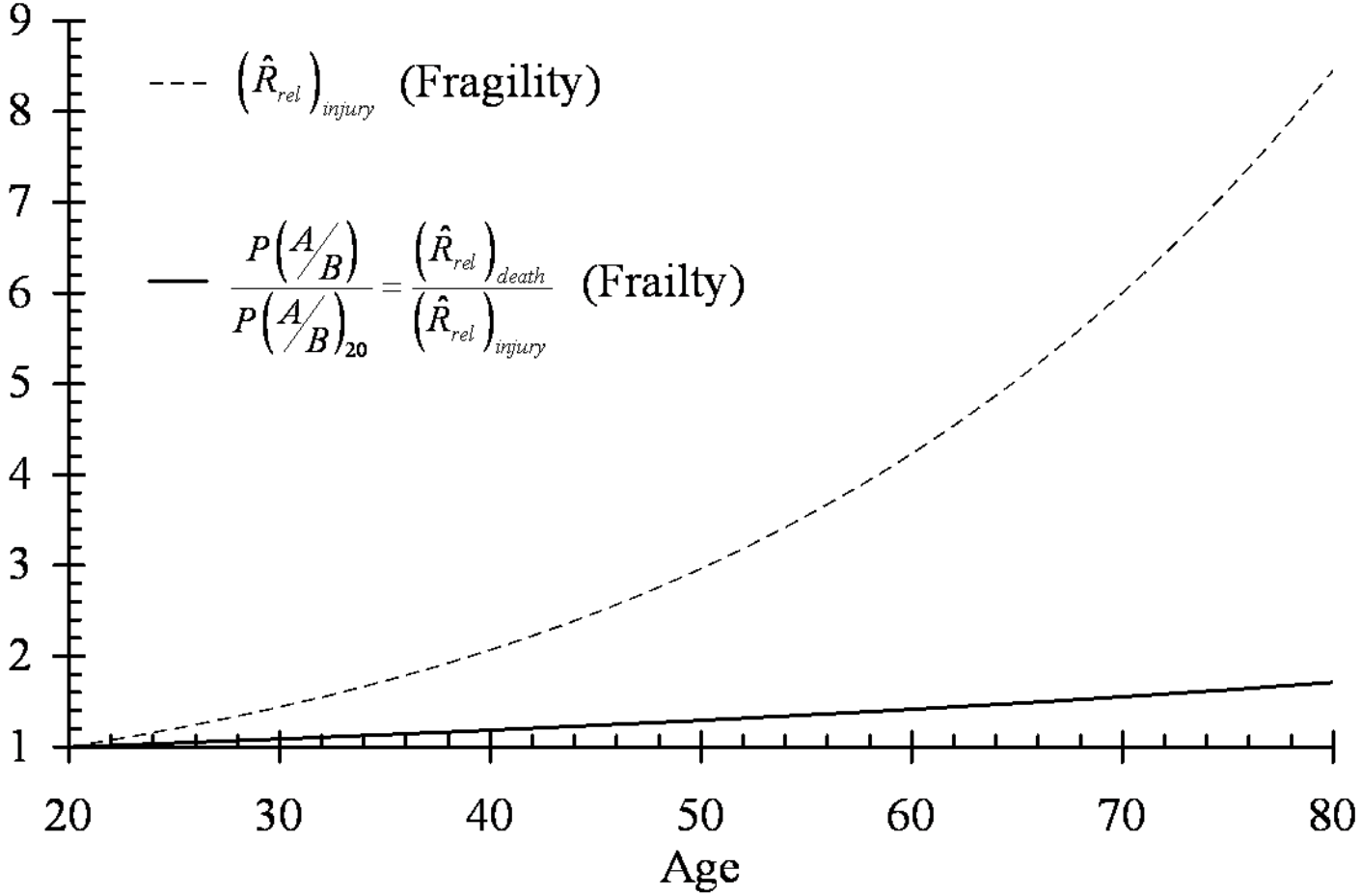


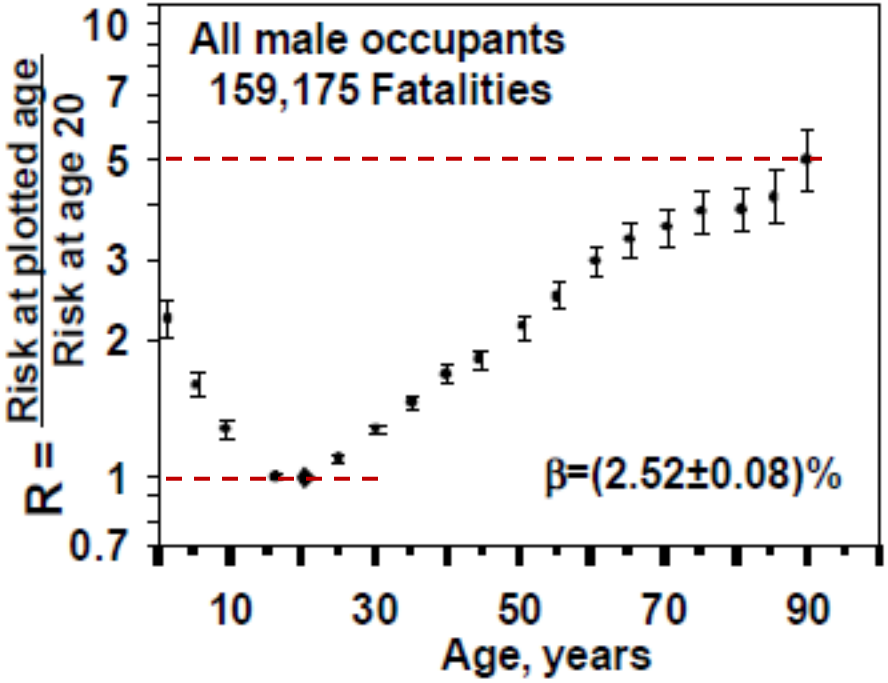
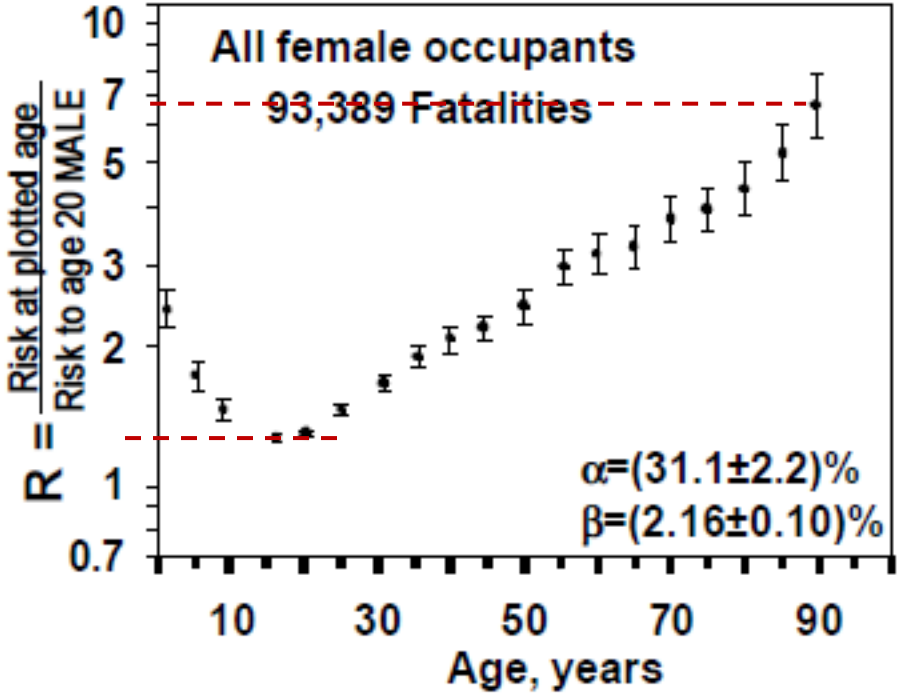
Airbag, With Belt

What's the problem, fragility or frailty?
(i.e., how do we prioritize prevention vs. treatment?)

<u>Fragility:</u> Probability of sustaining an <u>injury</u> given an <u>exposure</u>

<u>Frailty:</u> Conditional probability of <u>death</u> given an <u>injury</u>



Age-Gender Relationship in Risk (Evans 2001)

Female risk ~ 20% greater than male at all adult ages