Elderly DICOMs

Medical Imaging Studies Provide Insight Into Aging and Why Elderly Bodies May Tolerate Injurious Forces Differently

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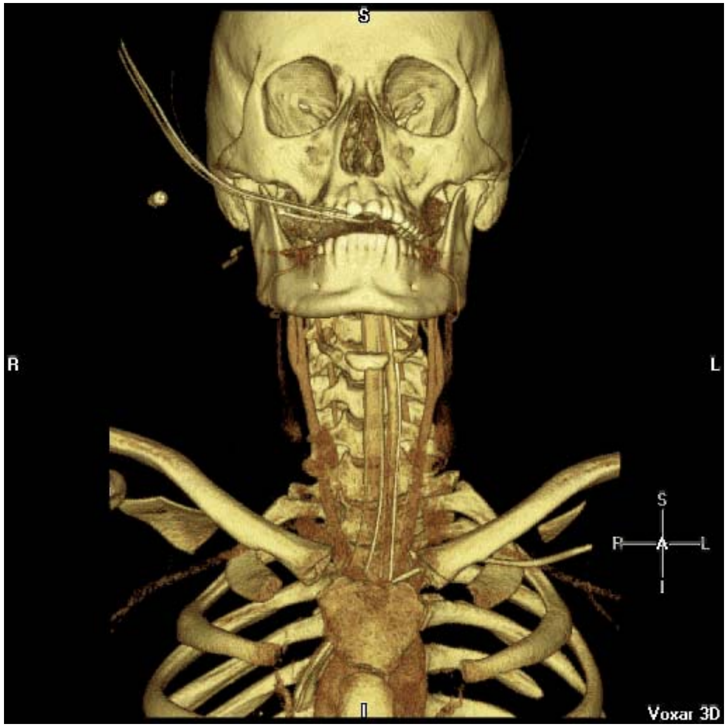
DICOM

- Digital Imaging and Communications in Medicine.
- A standard developed by the American College of Radiology Manufacturers Association to define the connectivity and communication protocols of medical imaging devices (CTs, MRIs, fluoroscopy, etc)



DICOMs

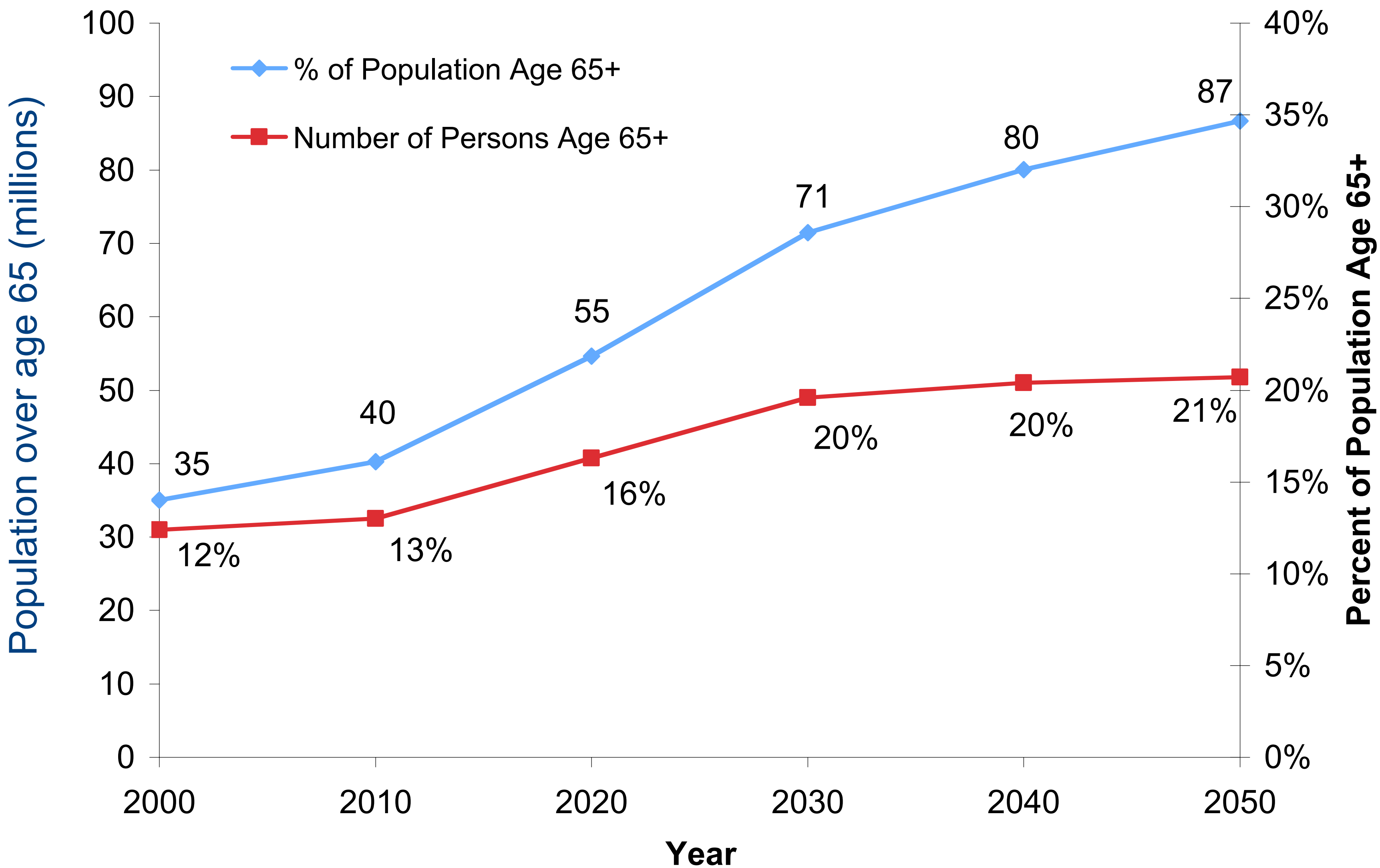
Limitations (minor)

- Subjects are scanned in the supine position, typically in a C-collar
- Some characteristics are altered by injury
  - Exclude injury-influenced measurements
  - Symmetry can often be used to determine normal state

Advantages (huge)

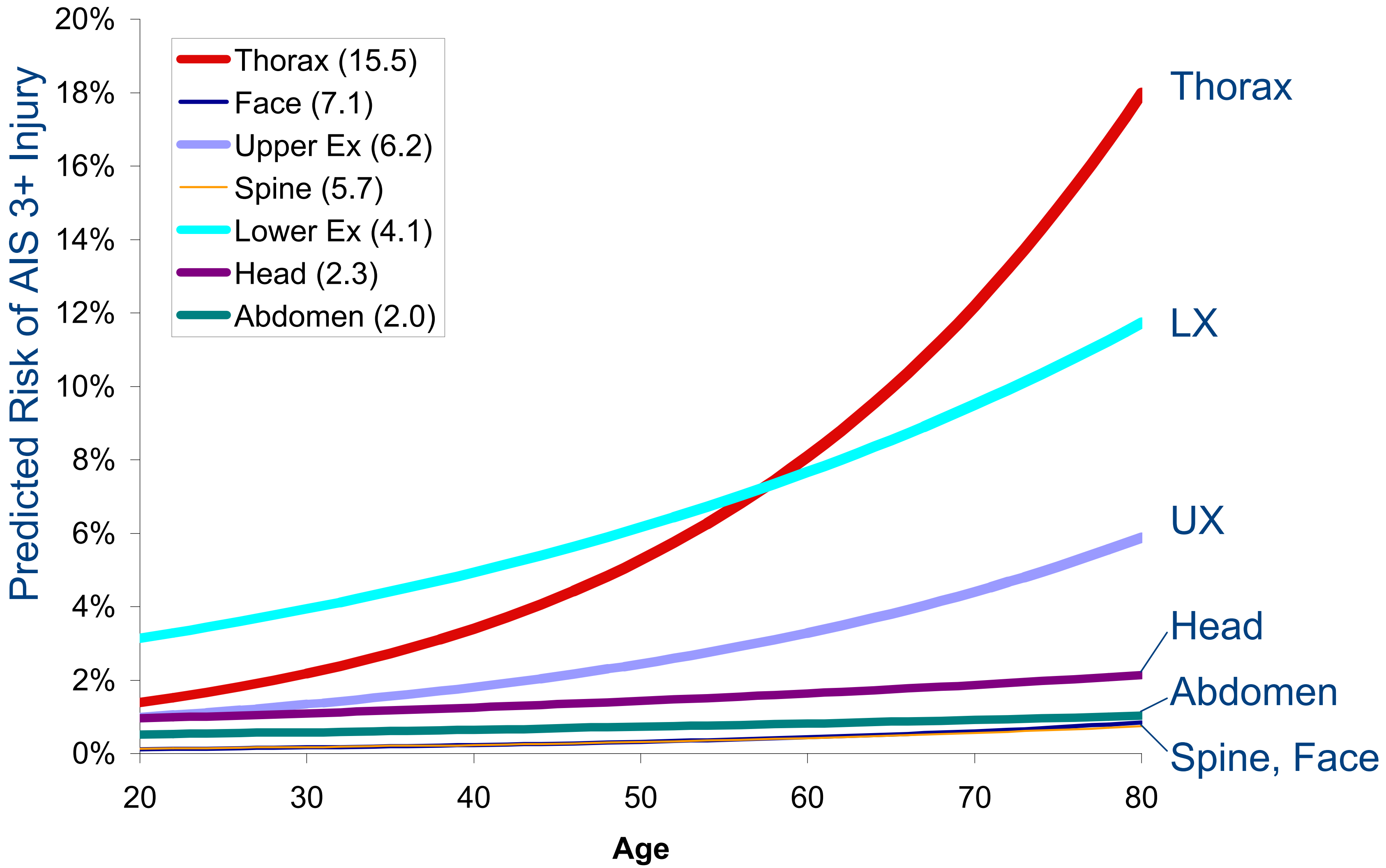
- The granularity and accuracy of injury diagnosis as well as injury mechanism determination are significantly enhanced by 3D CT. (30-40% of CIREN case analyses at Michigan are materially altered)
- Repeat analysis does not alter data
- CT data provides invaluable information regarding the subjects baseline body composition and provides insight into the influence of body composition on injury tolerance

Motivation



Source: US Census Bureau, 2004

Relationship Between Age and AIS 3+ Injury Risk by Body Region in **Frontal Crashes**
(Belted Drivers, 30 mph Crash Severity)



Injuries and Aging

The aging process compiles multiple changes:

Immaterial/Functional – maturity, wisdom, cardiovascular…..

Material/Physical – weight, muscle mass, bone density….

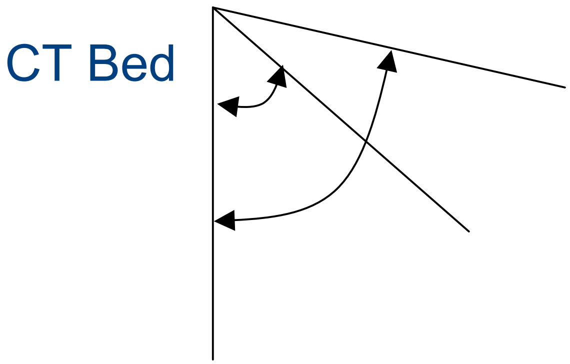
Injuries occur because of physical forces acting on a body comprised of different materials. The trend of increased injury with advanced age is therefore a summation of the effect of physical forces acting on bodies that have changed with aging.

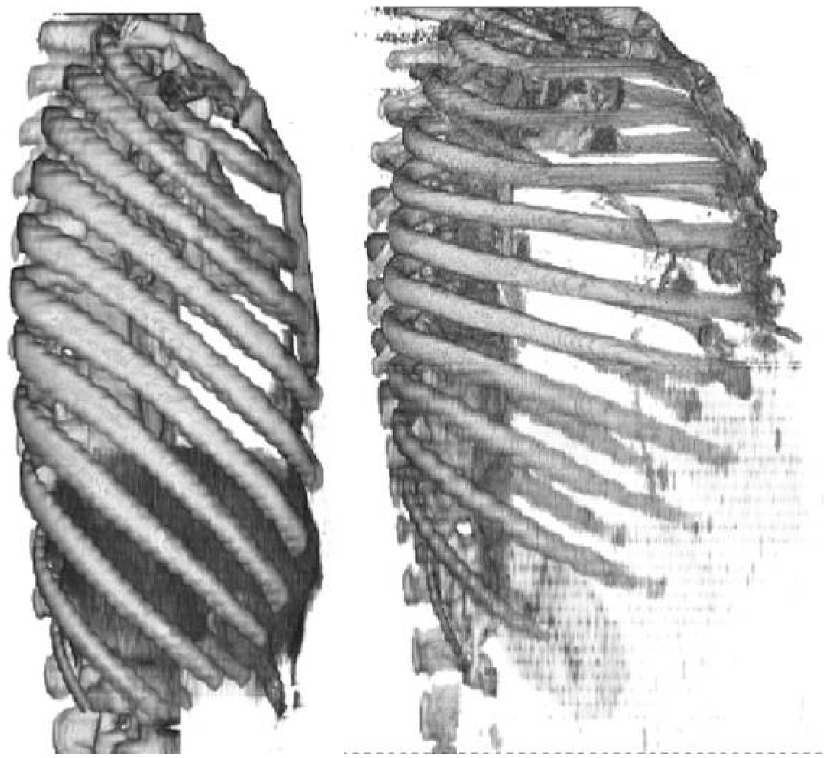
What are these aging-associated changes?

Why do we need to know?

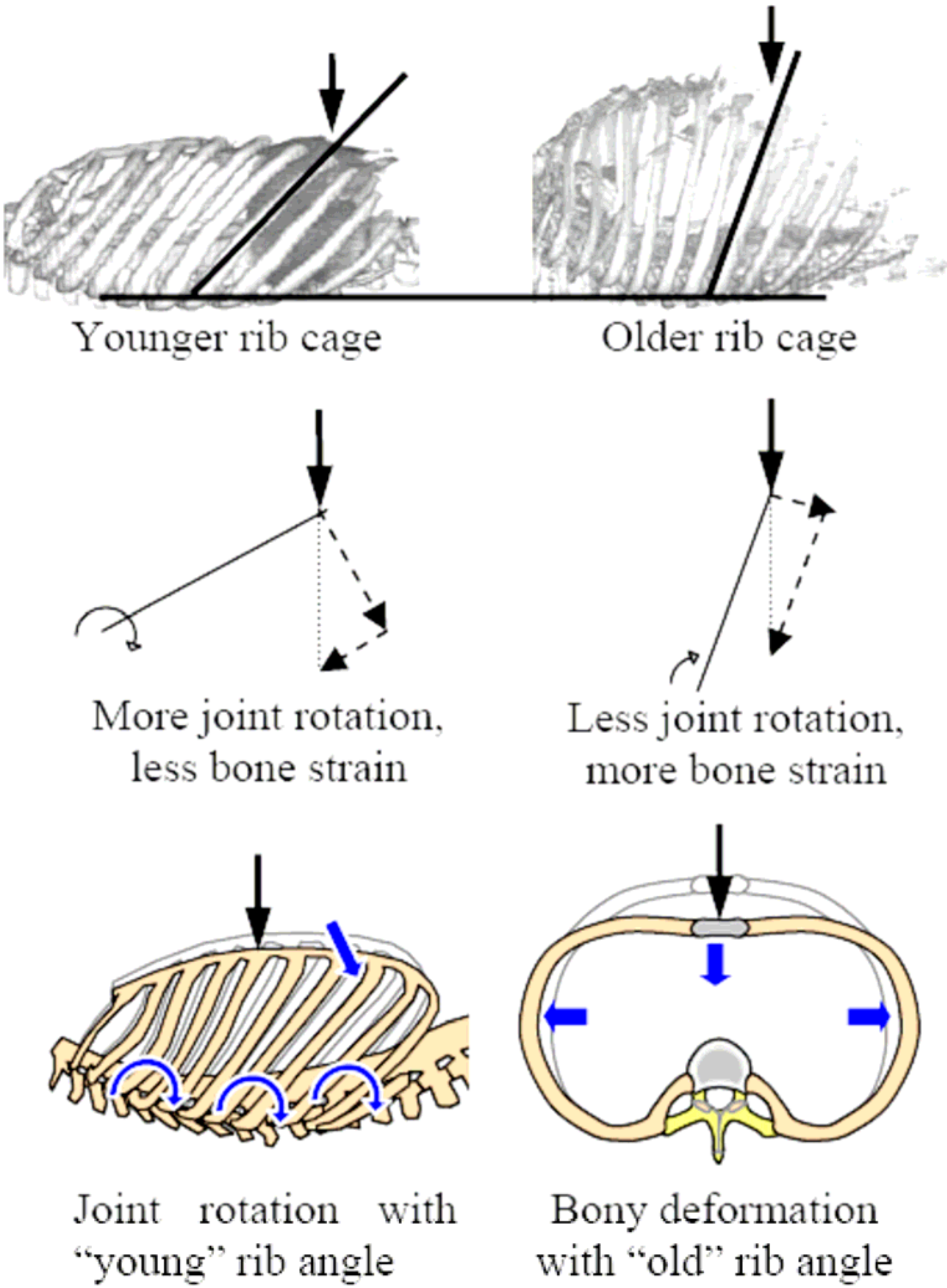
Improved bio-fidelity of ATDs and models, better prediction of population injury patterns and policy priorities, etc…..

Rib Angle Measurement





Young Old



Kent 2005, Stapp

Only a few degrees, does it matter?

- The rib angle change with aging can offset the effects of material changes and cortical thinning when the effective stiffness of the thorax is considered. Cortical thinning and decreased bone modulus both tend to decrease the stiffness of the thorax, while the change in rib angle tends to increase stiffness.
- Changing the rib angle to be more perpendicular to the spine increased the effective thoracic stiffness, while the “old” material properties and the thin cortical shell decreased the effective stiffness. All three effects tended to decrease chest deflection tolerance for rib fractures, though the material changes dominated (a four- to six-fold increase in elements eliminated using a maximum strain criterion). The primary conclusion, therefore, is that an older person’s thorax, relative to a younger, does not necessarily deform more in response to an applied force. The tolerable sternal deflection level is, however, much less.

Kent 2005, Stapp

The prior studies reported at Stapp were done on 111 CIREN and 50 non-CIREN adult subjects. *Were findings true or biased?*

We have now analyzed approximately 700 adult CTs for some (*but not all*) components.

Includes control population of 300 adult non-CIREN subjects with multiple CT studies

Current presentation includes data only on Adults aged:

16-40 or 55+

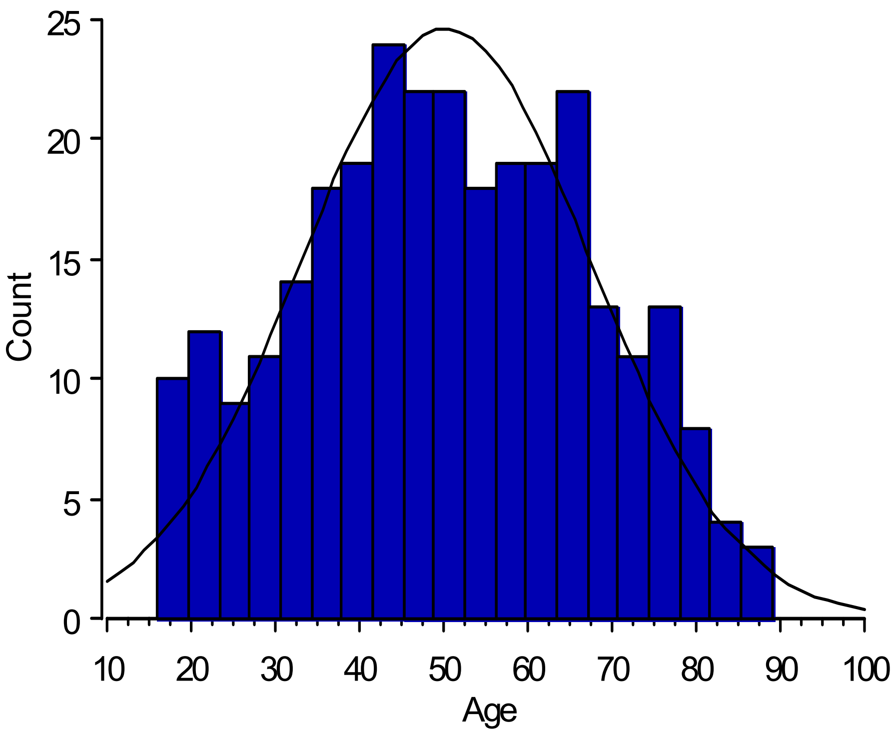
PURPOSE: To confirm and extend our earlier observations of aging differences in body geometry and composition

Control Populations

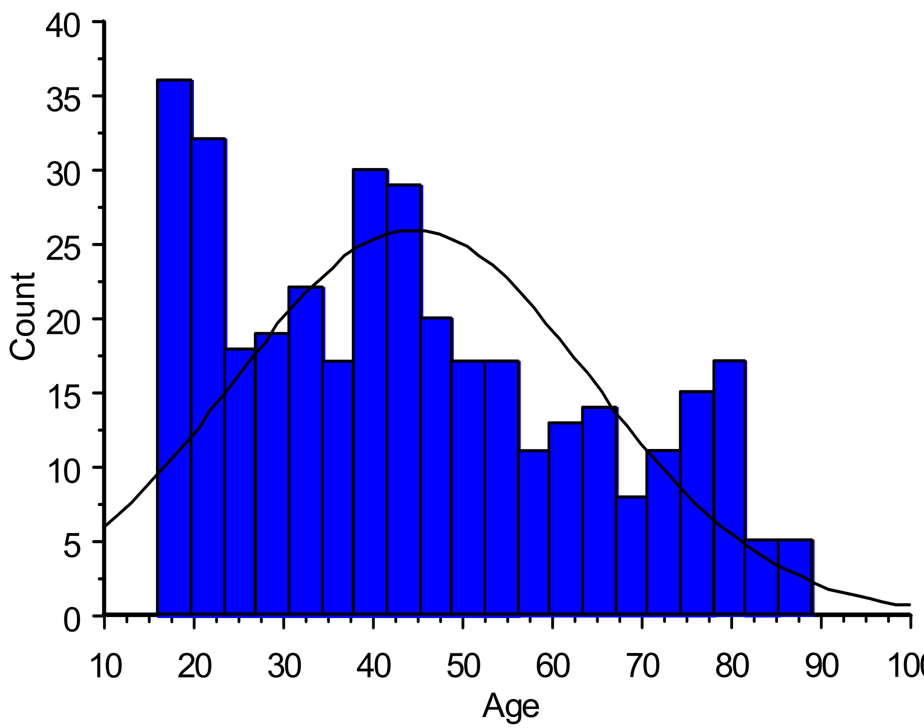
- CTs done for non-trauma purposes are biased toward the middle-aged and elderly population; higher incidence of co-existing disease.
- The main indication for CTs in the younger adult population is primarily trauma-related.
- CIREN CTs are highly enriched for individuals who sustained significant injuries and may therefore have inadequate representation of those segments of the population that have body composition/geometry with high injury tolerance.

Age Distribution

Control Non-CIREN

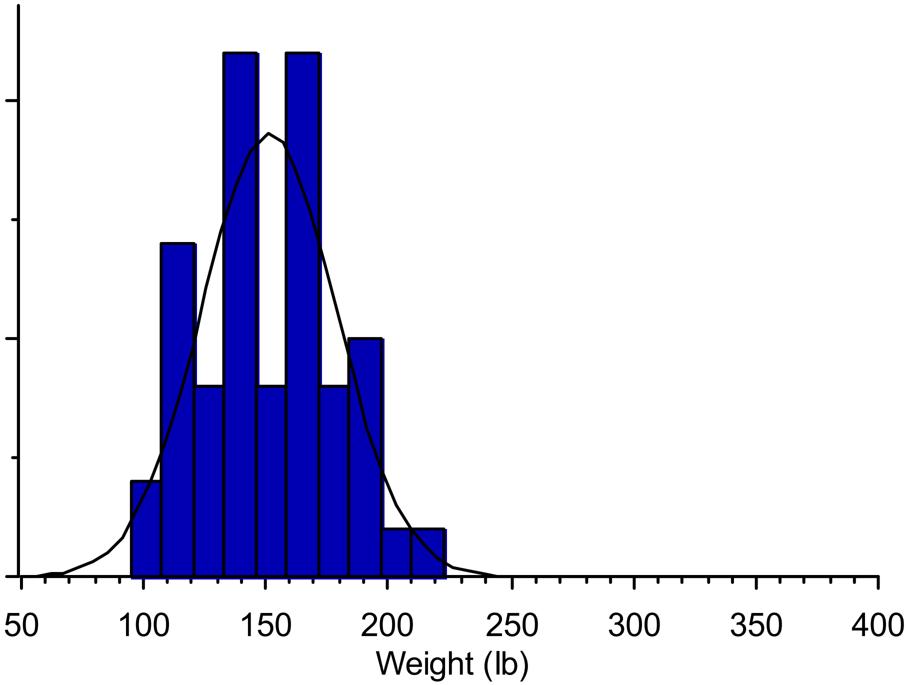


MI-CIREN

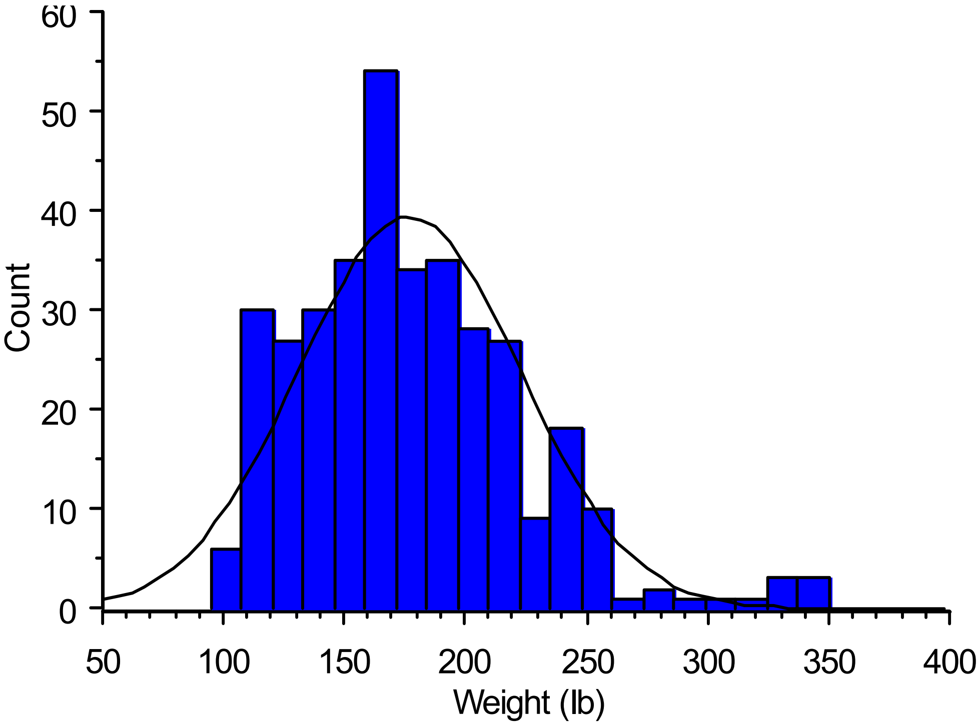


Weight Distribution

Control Non-CIREN

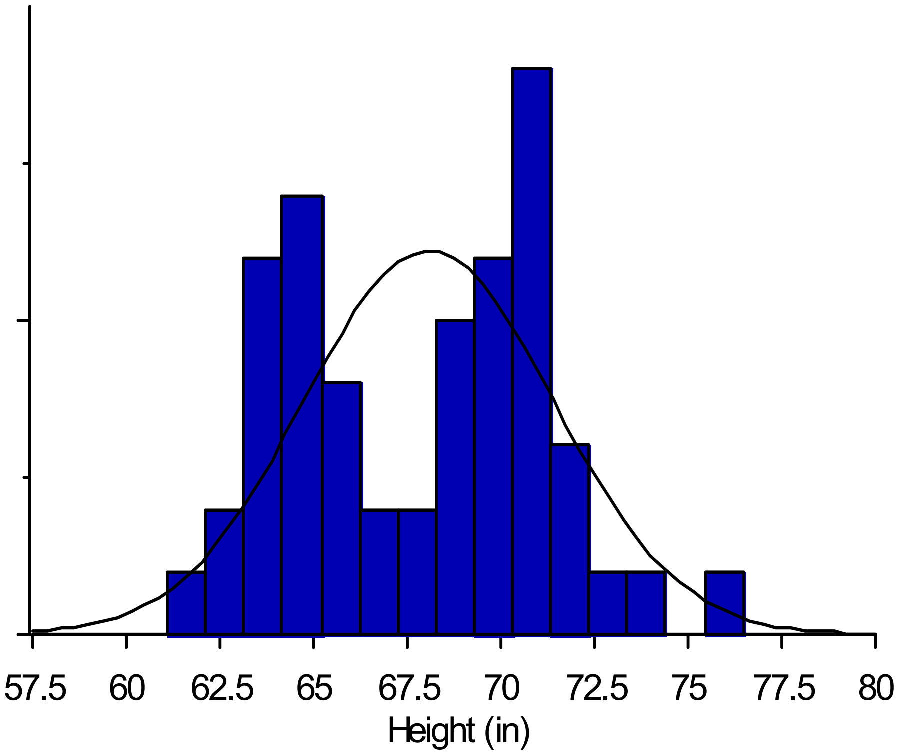


MI-CIREN

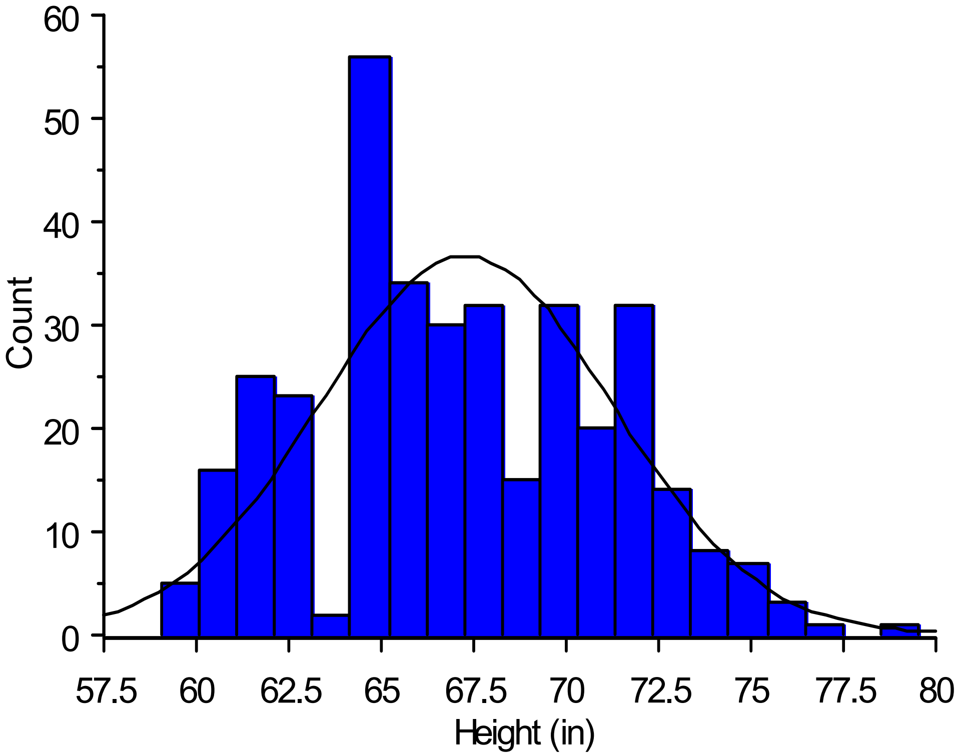


Height Distribution

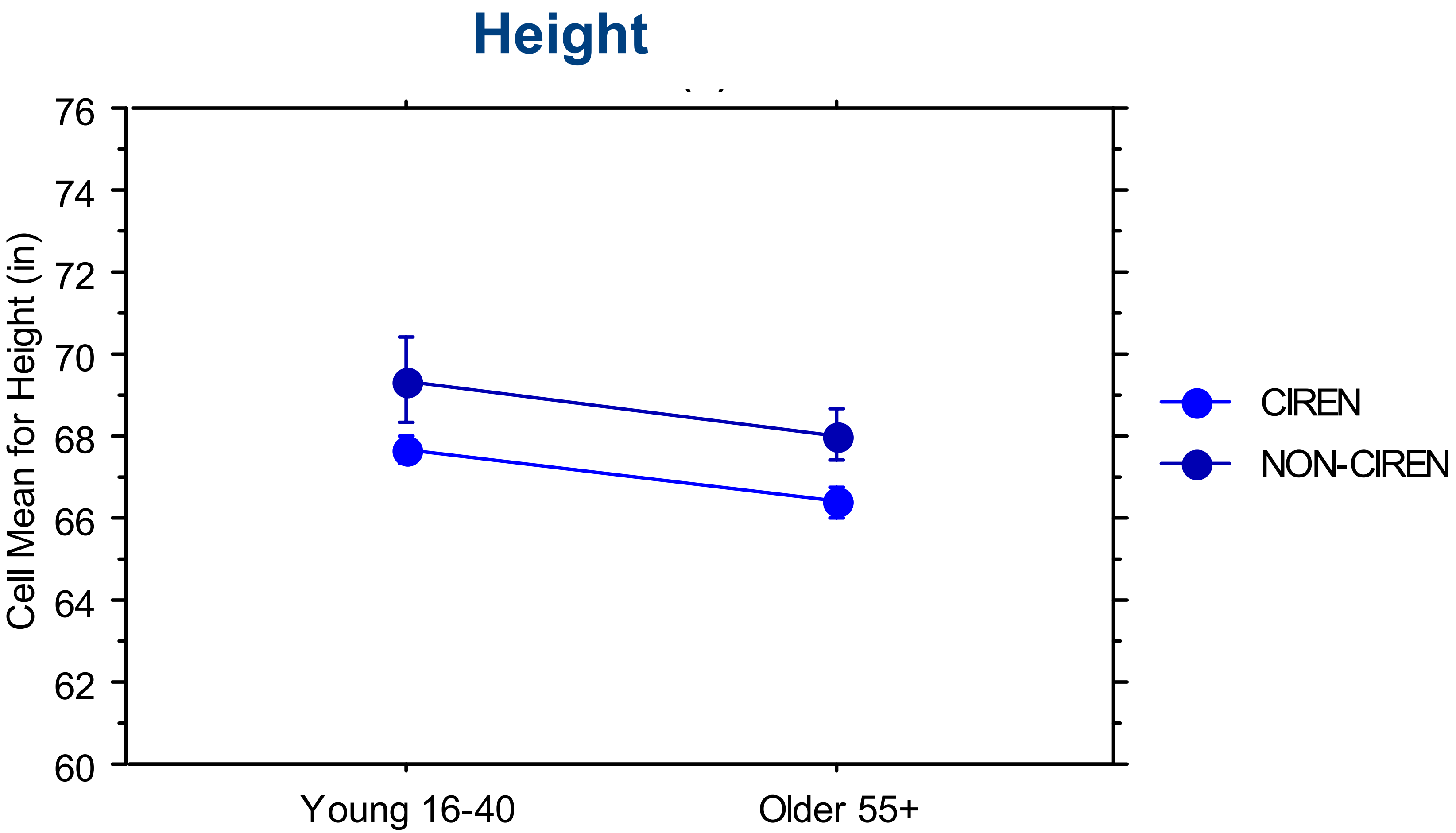
Control Non-CIREN



MI-CIREN



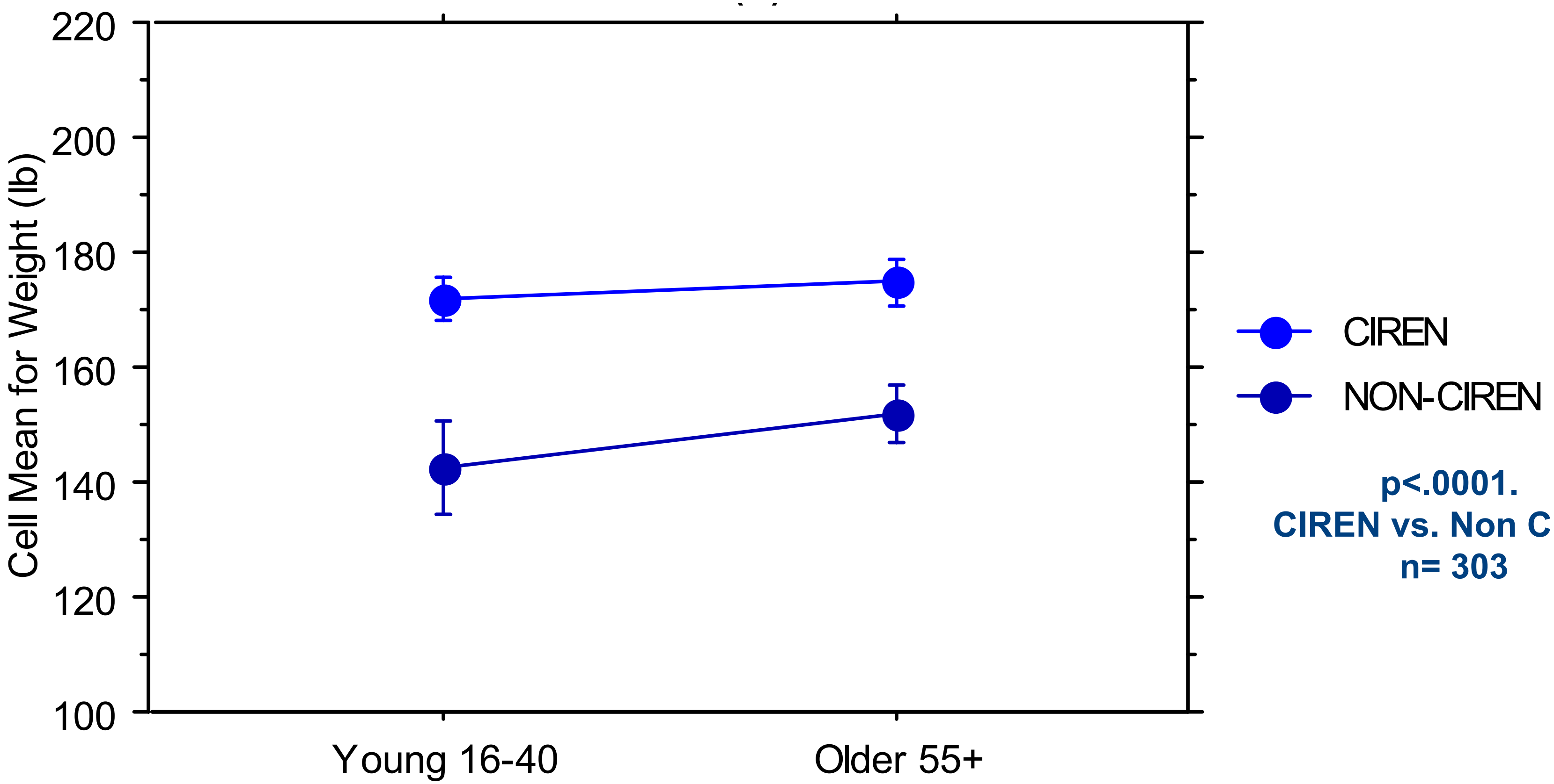
No Significant Difference in Height With Age



NS. Young vs. Older
n= 304

CIREN Subjects Are Significantly Heavier

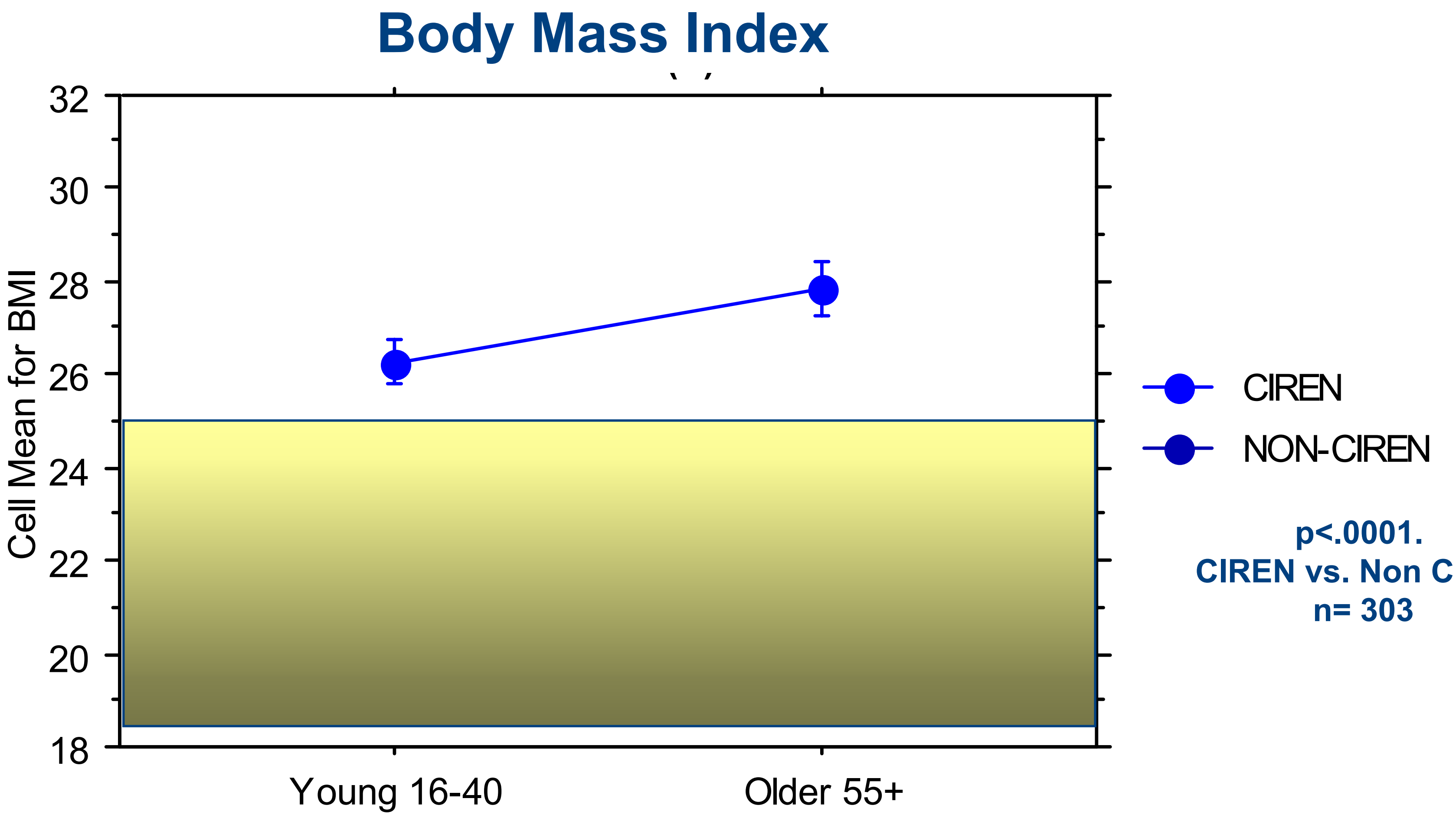
Weight



p<.0001.
CIREN vs. Non CIREN
n= 303

NS. Young vs. Older
n= 303

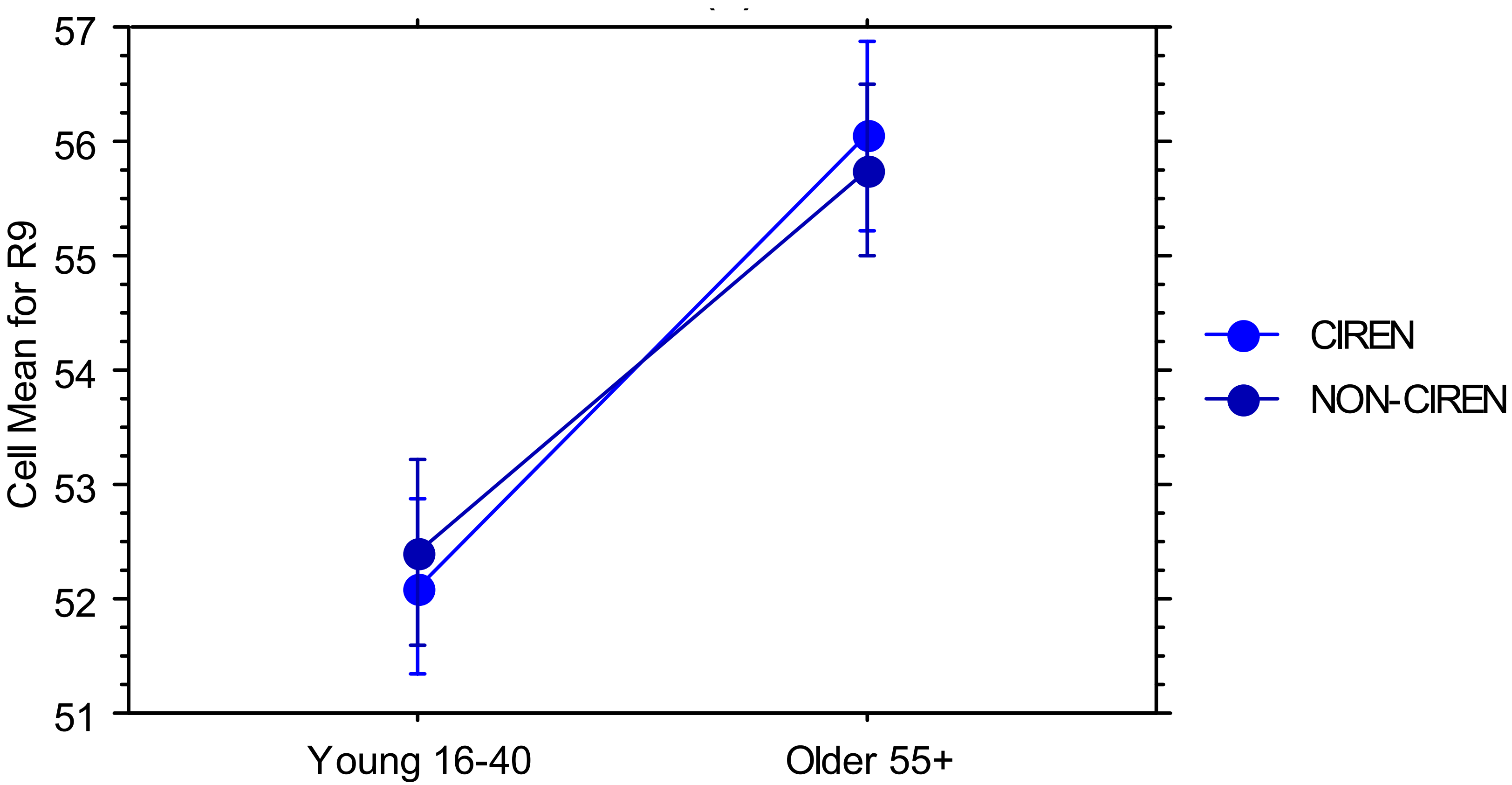
CIREN Subjects Have Significantly Higher BMI



p<.0001.
CIREN vs. Non CIREN
n= 303

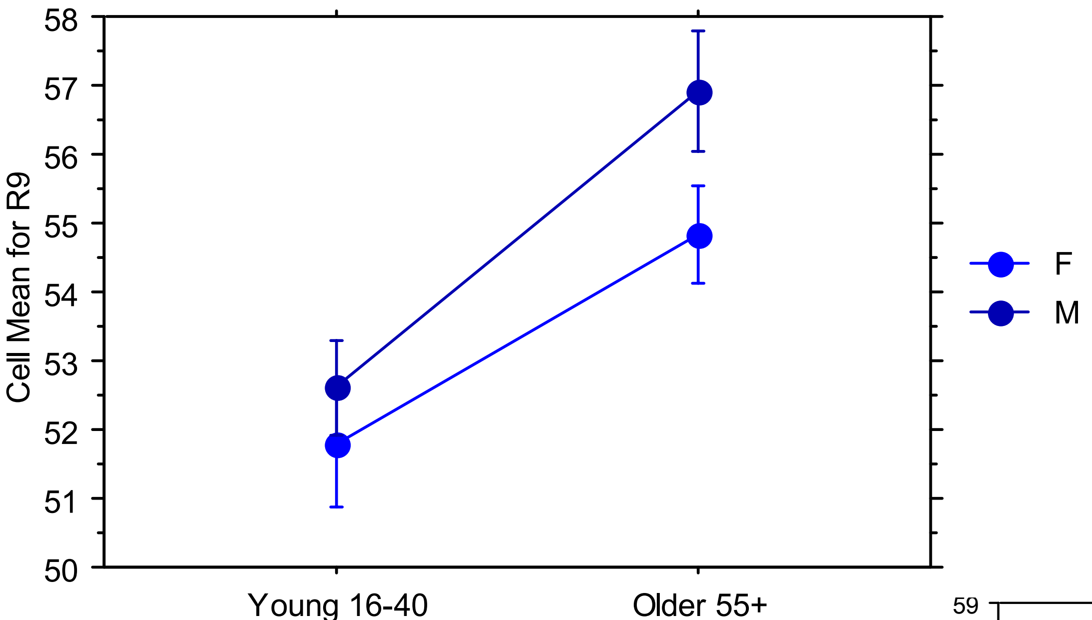
NS. Young vs. Older
n= 303

Older Ribs More Horizontal than Younger Ribs
CIREN similar to Non-CIREN
Right Rib 9 Angle

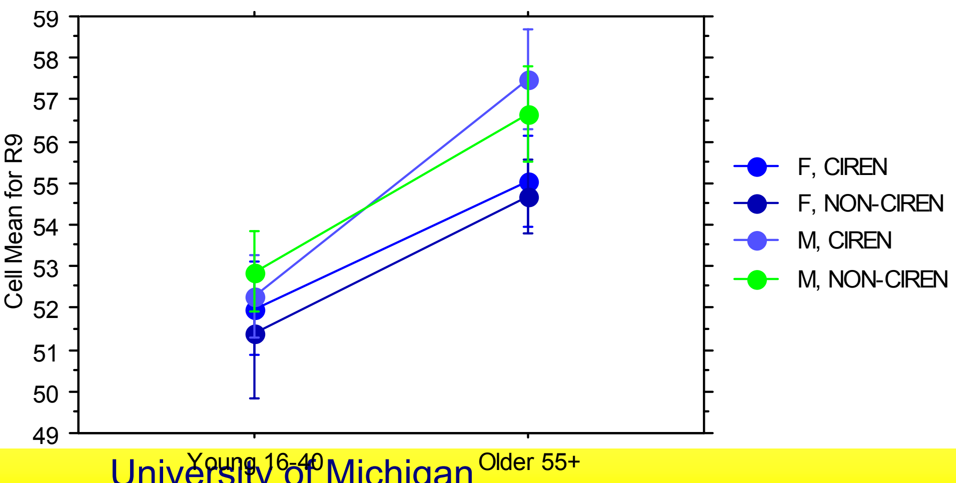


p<.0001, Young vs. Older
n= 339

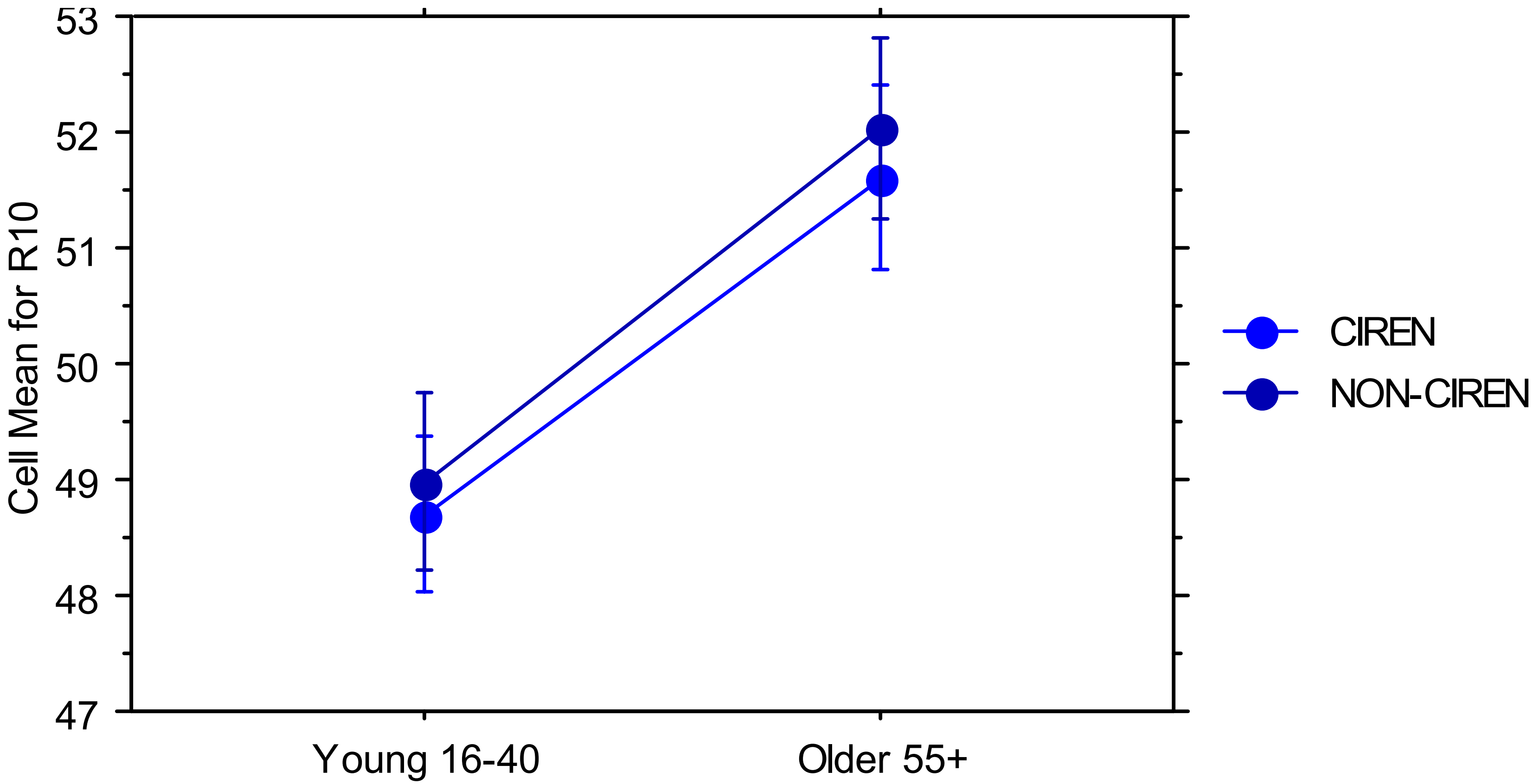
Older Ribs More Horizontal than Younger Ribs. Difference Greater in Males, But Significant in Females Too
Right Rib 9 Angle



p<.0001, Young vs. Older
n= 337

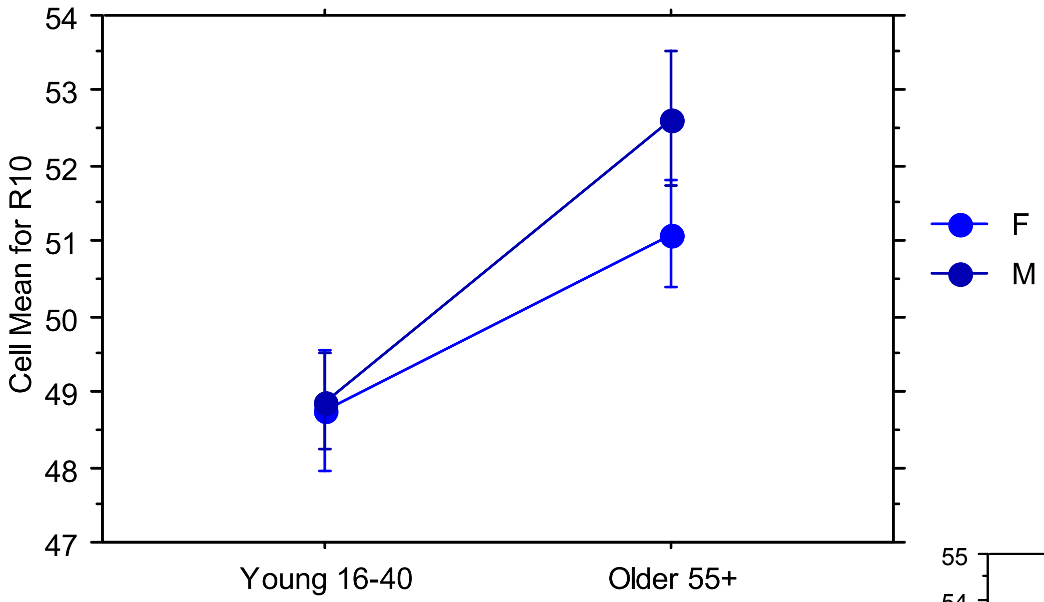


Older Ribs More Horizontal than Younger Ribs
CIREN similar to Non-CIREN
Right Rib 10 Angle

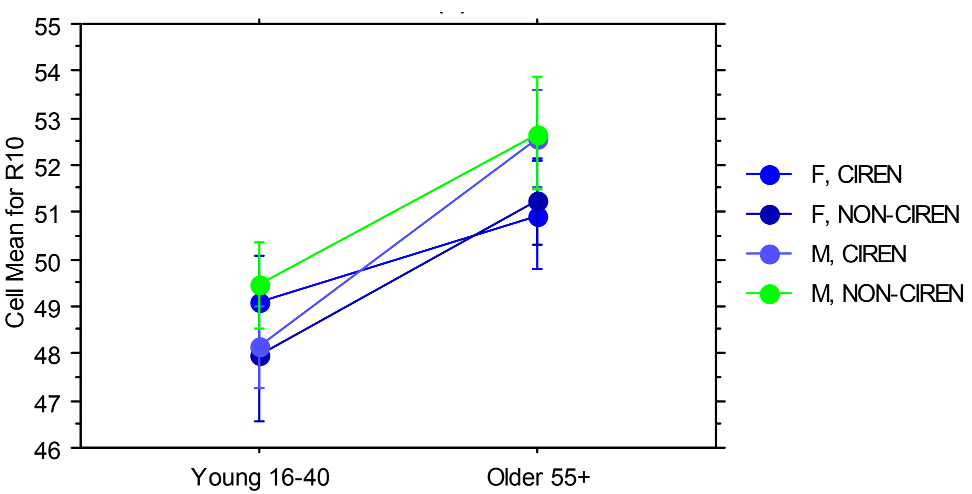


p<.0001, Young vs. Older
n= 337

Older Ribs More Horizontal than Younger Ribs. Difference Greater in Males, But Significant in Females Too Right Rib 10 Angle

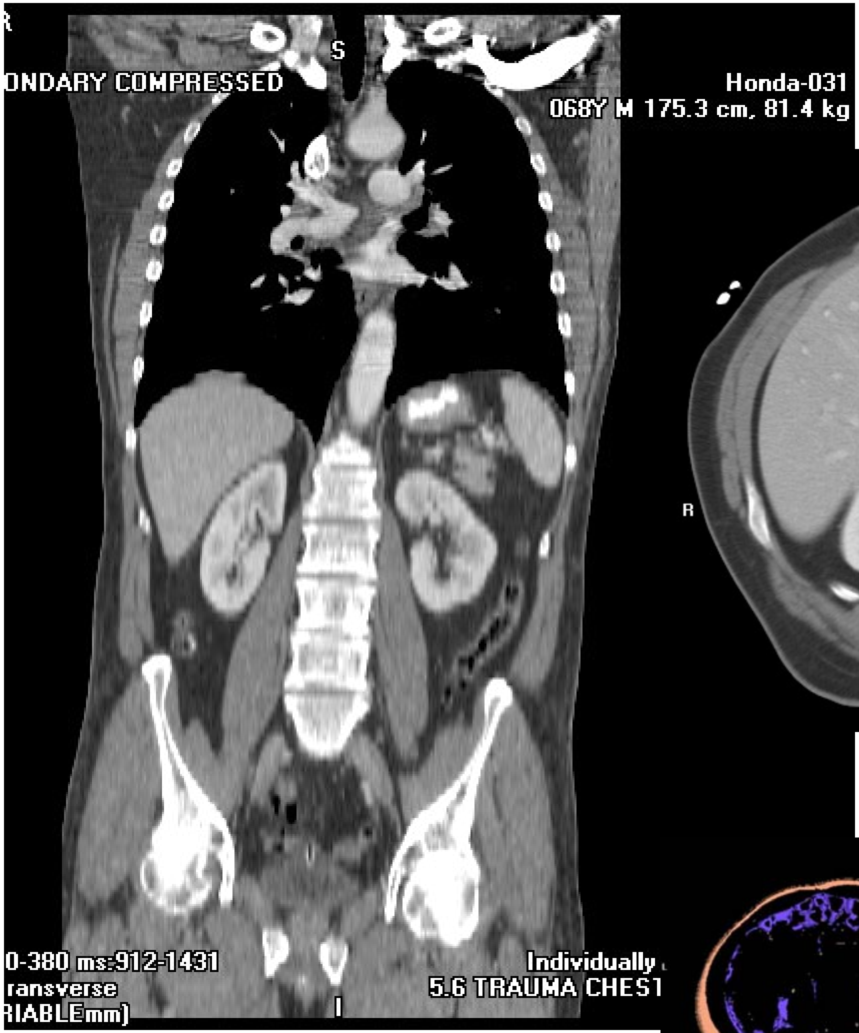


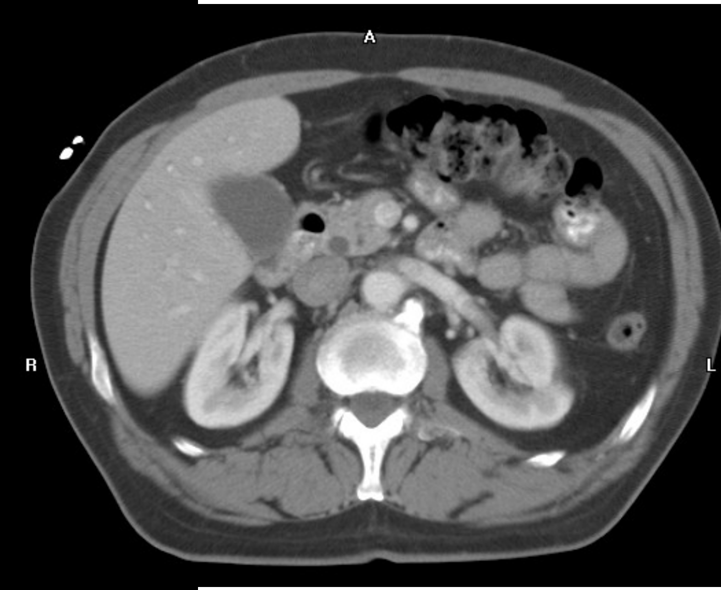
p<.0001, Young vs. Older
n= 337

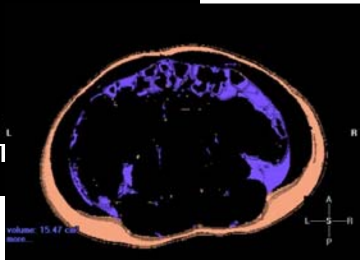


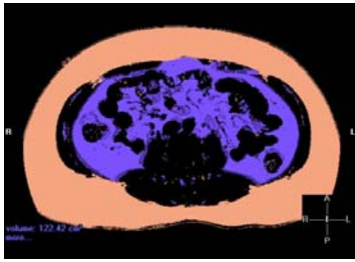
Why Do Ribs Become More Horizontal With Age?

Visceral Fat Accumulation?



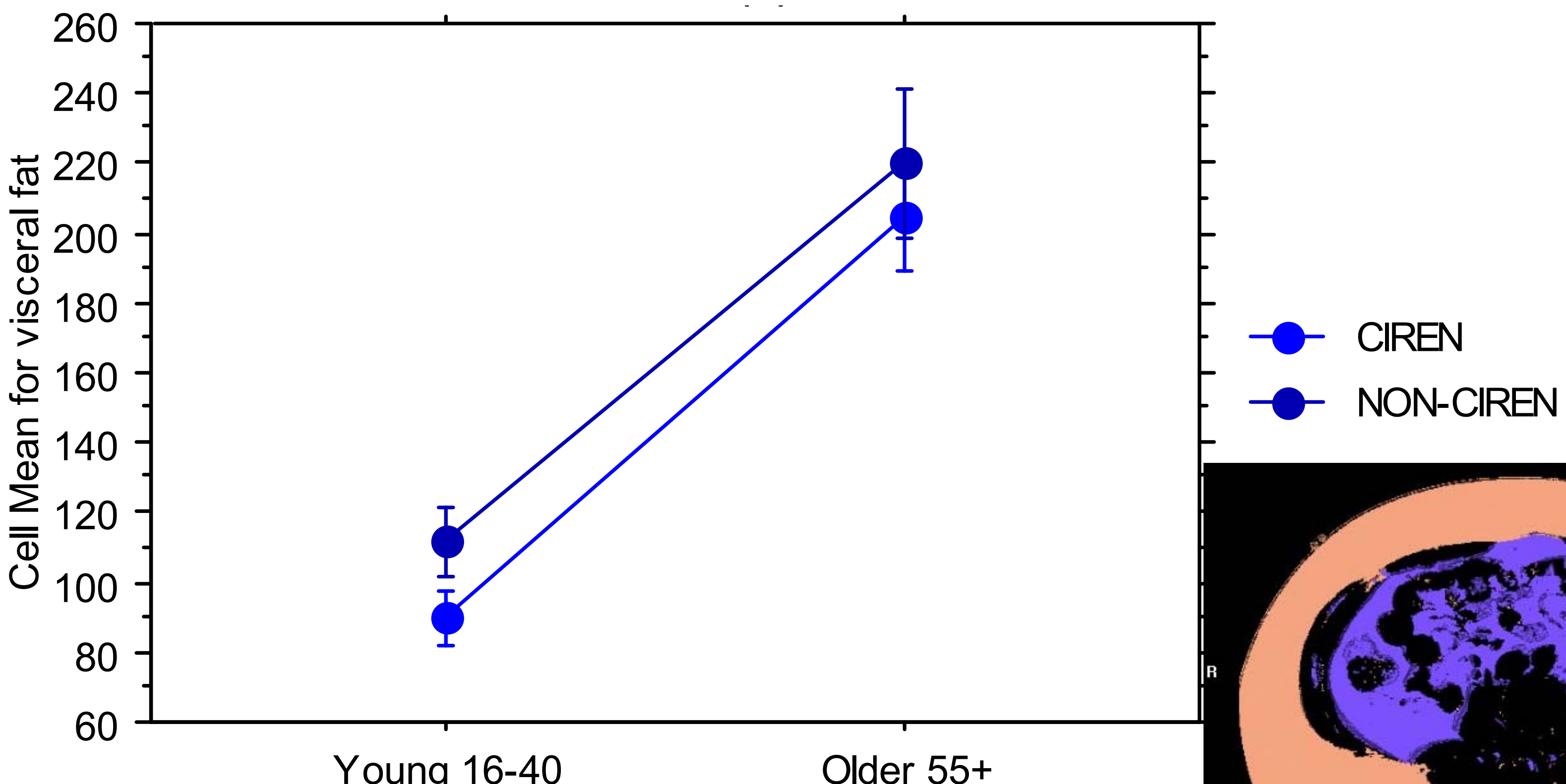


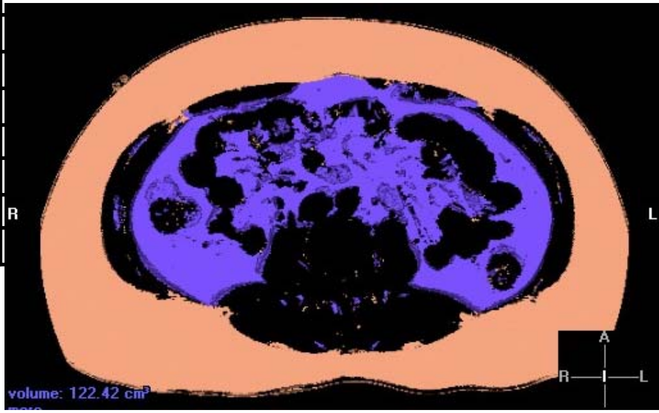




Abdominal Visceral Fat Volume Is Double in the Older Subset

Abdominal Visceral Fat Volume



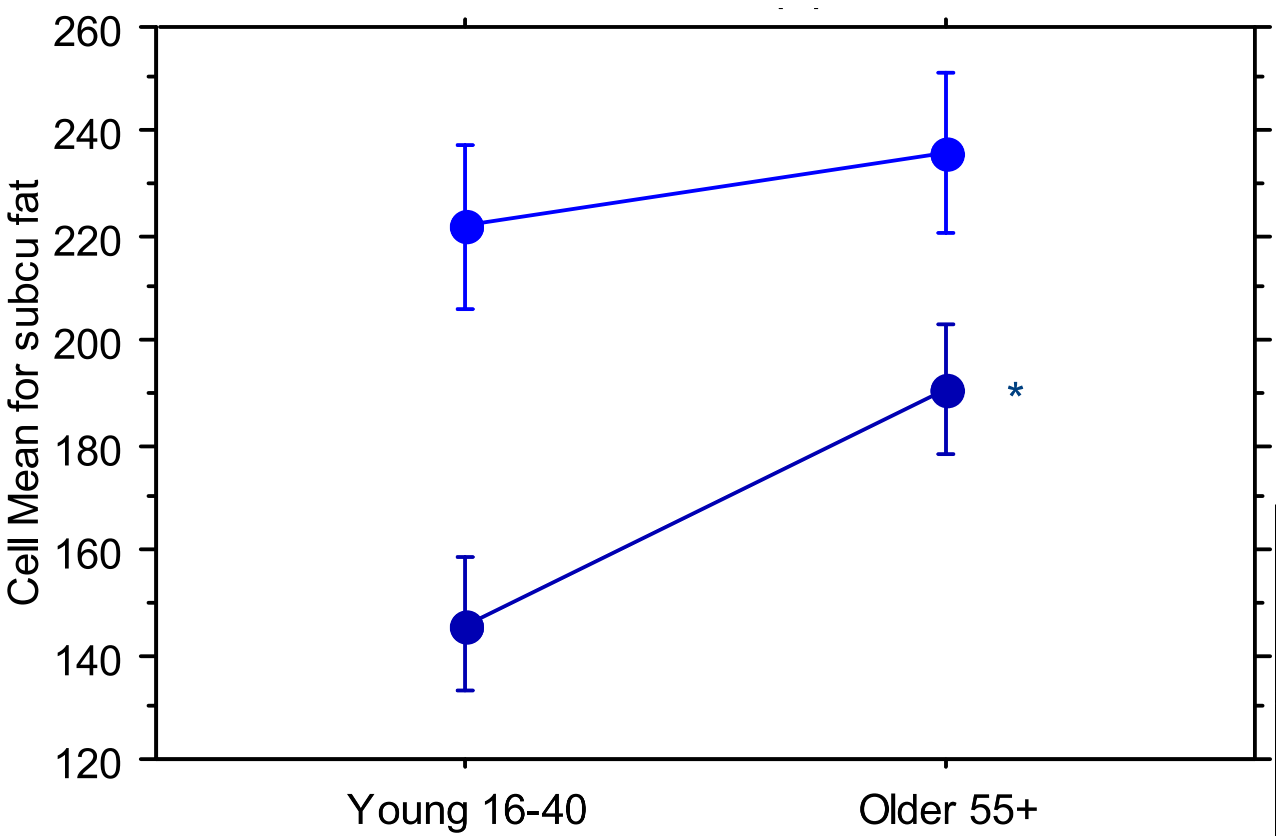


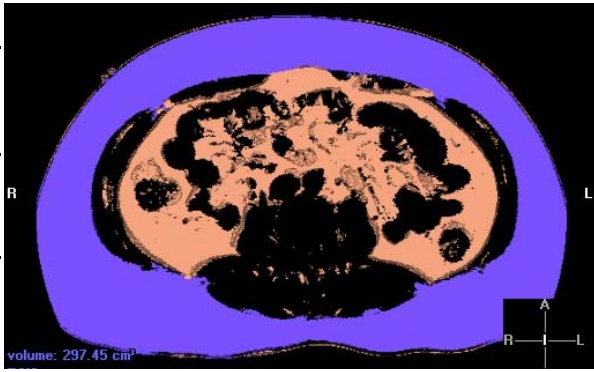
p<.0001, Young vs. Older
n= 277

Study Methods

2 inch slab selected at L3

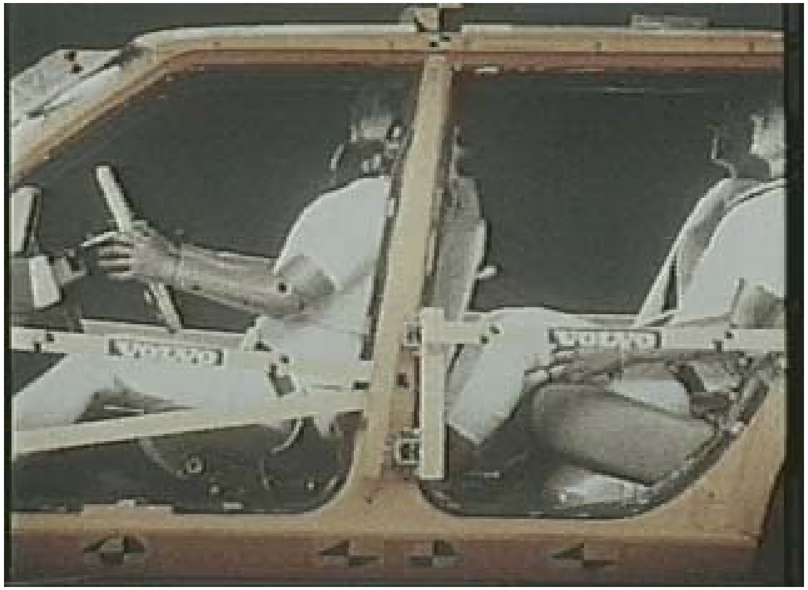
Abdominal Subcutaneous Fat Volume

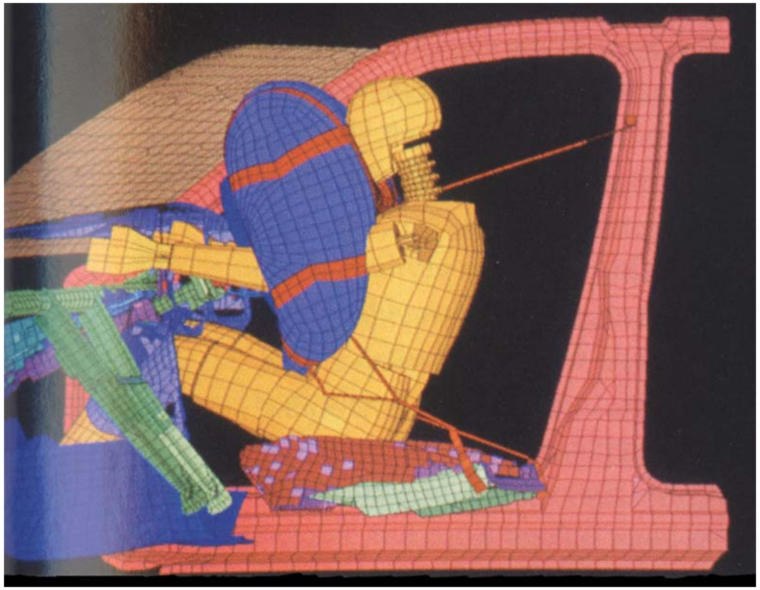




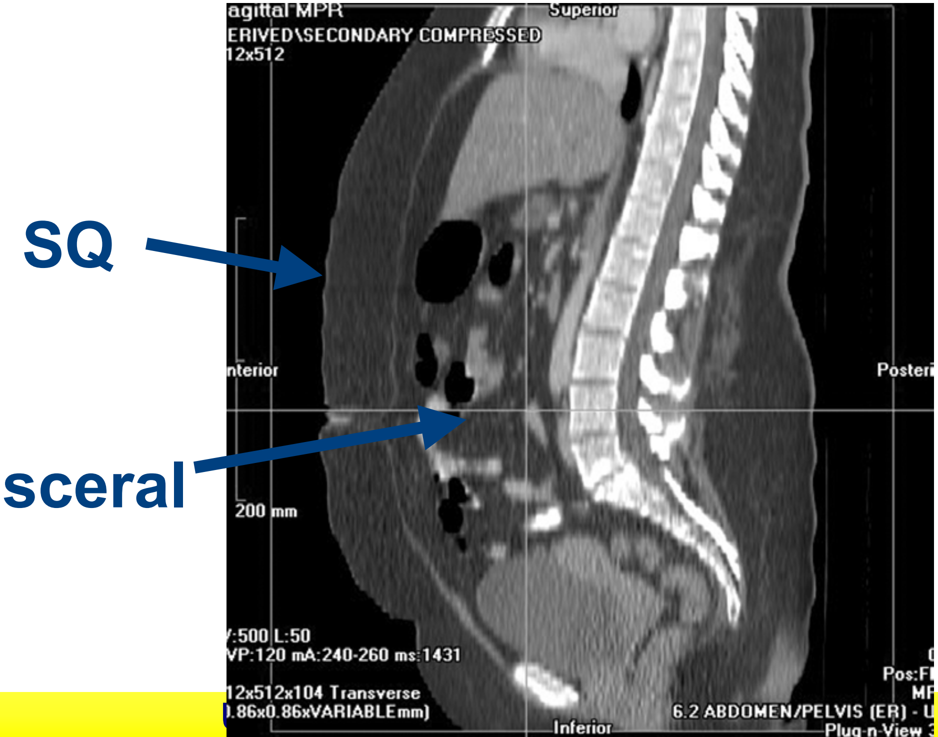
n.s. Young vs. Older
n= 230

*p=.02 for Non-CIREN


VOLVO
VOLVO

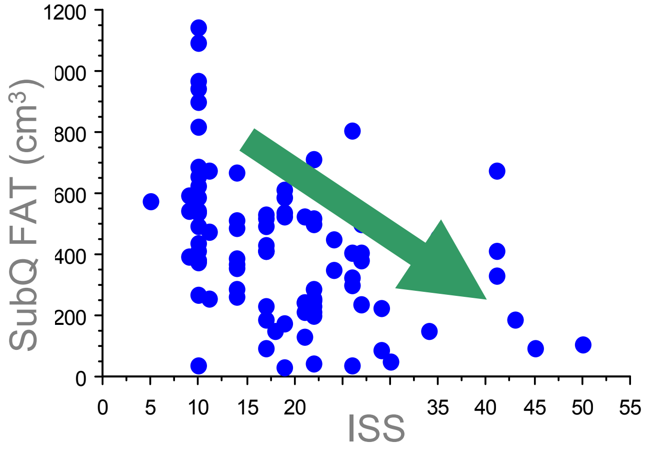



0-380 ms:912-1431
ransverse
IABLEmm)
5.6 TRAUMA CHES
Inferior

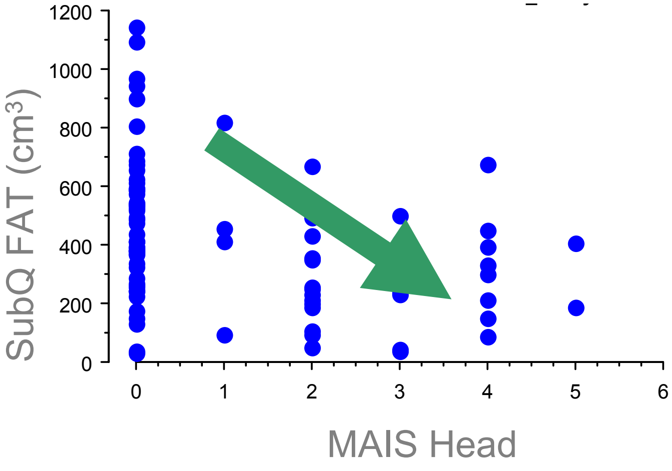

SQ
Visceral
agittal MPR
Superior
ERIVED\SECONDARY COMPRESSED
12x512
nterior
Posteri
200 mm
:500 L:50
VP:120 mA:240-260 ms:1431
12x512x104 Transverse
.86x0.86xVARIABLEmm)
Inferior
6.2 ABDOMEN/PELVIS (ER) - U
Plug-n-View

Effect of SubQ FAT on Injury Severity in Frontal Crashes

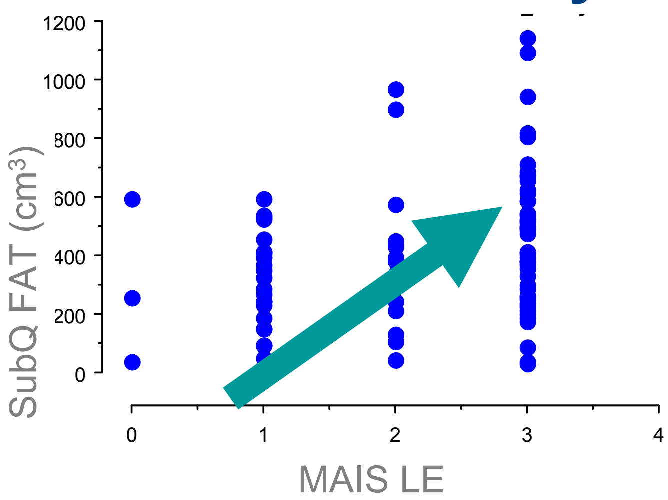
Overall



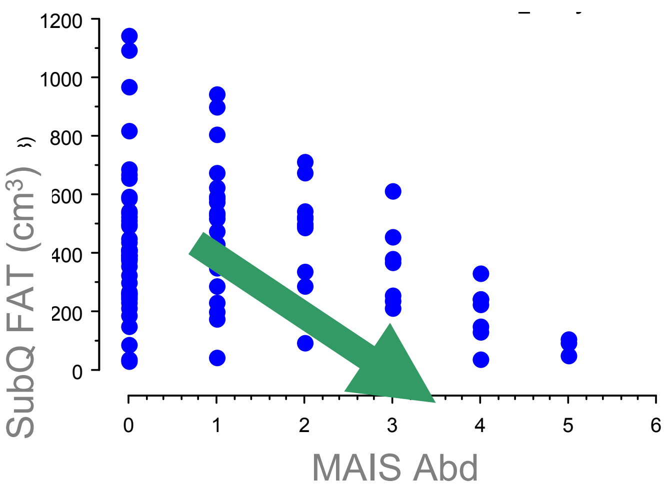
Head



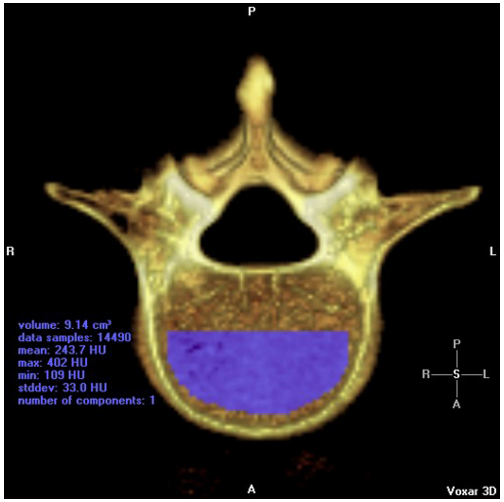
Lower Extremity



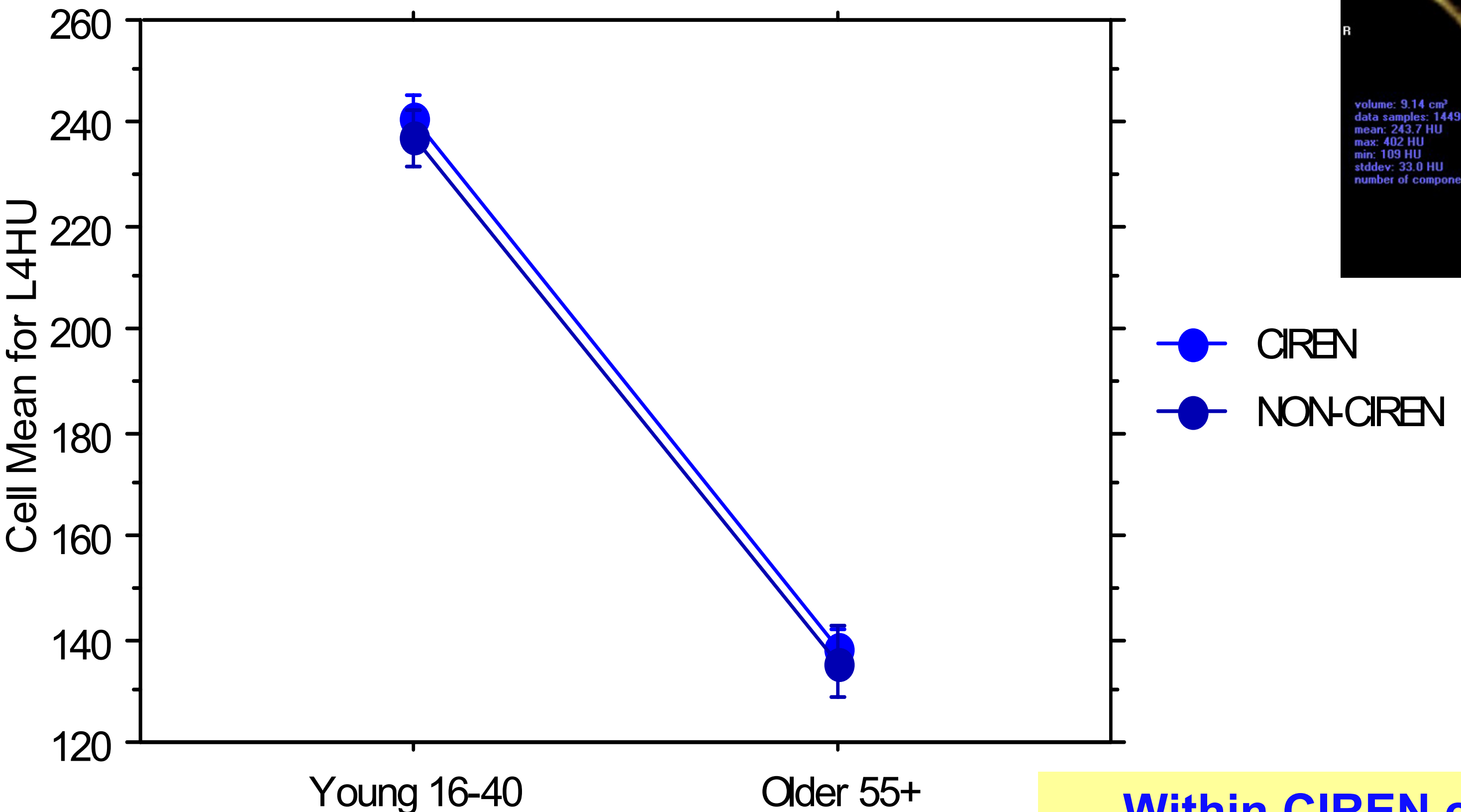
Abdomen



Bone Mineralization Decreases with Aging



Bone Mineralization (L4HU)

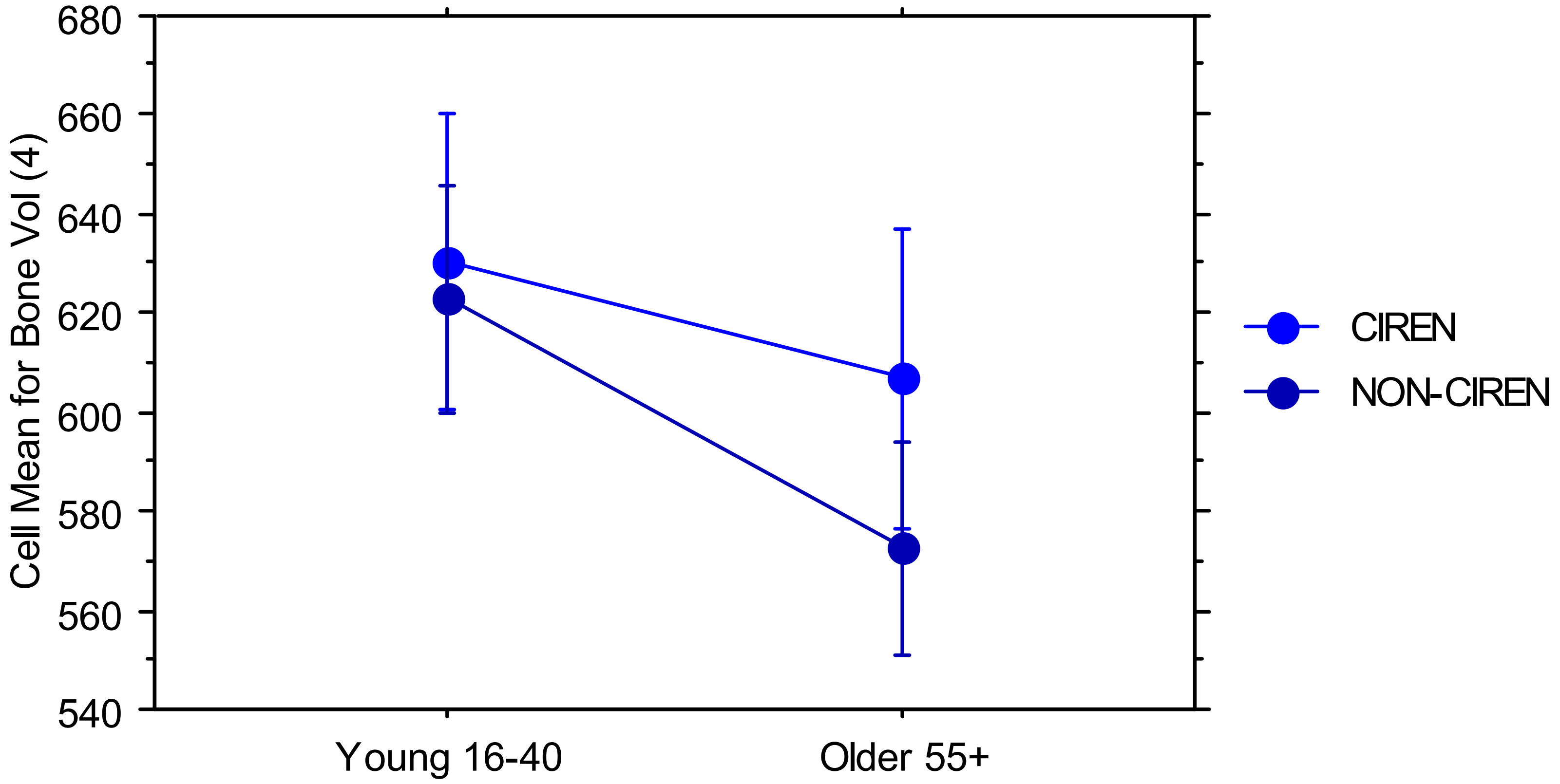


p<.0001, Young vs. Older
n= 285

Within CIREN cases, L4HU is significantly associated with increased number of rib fractures

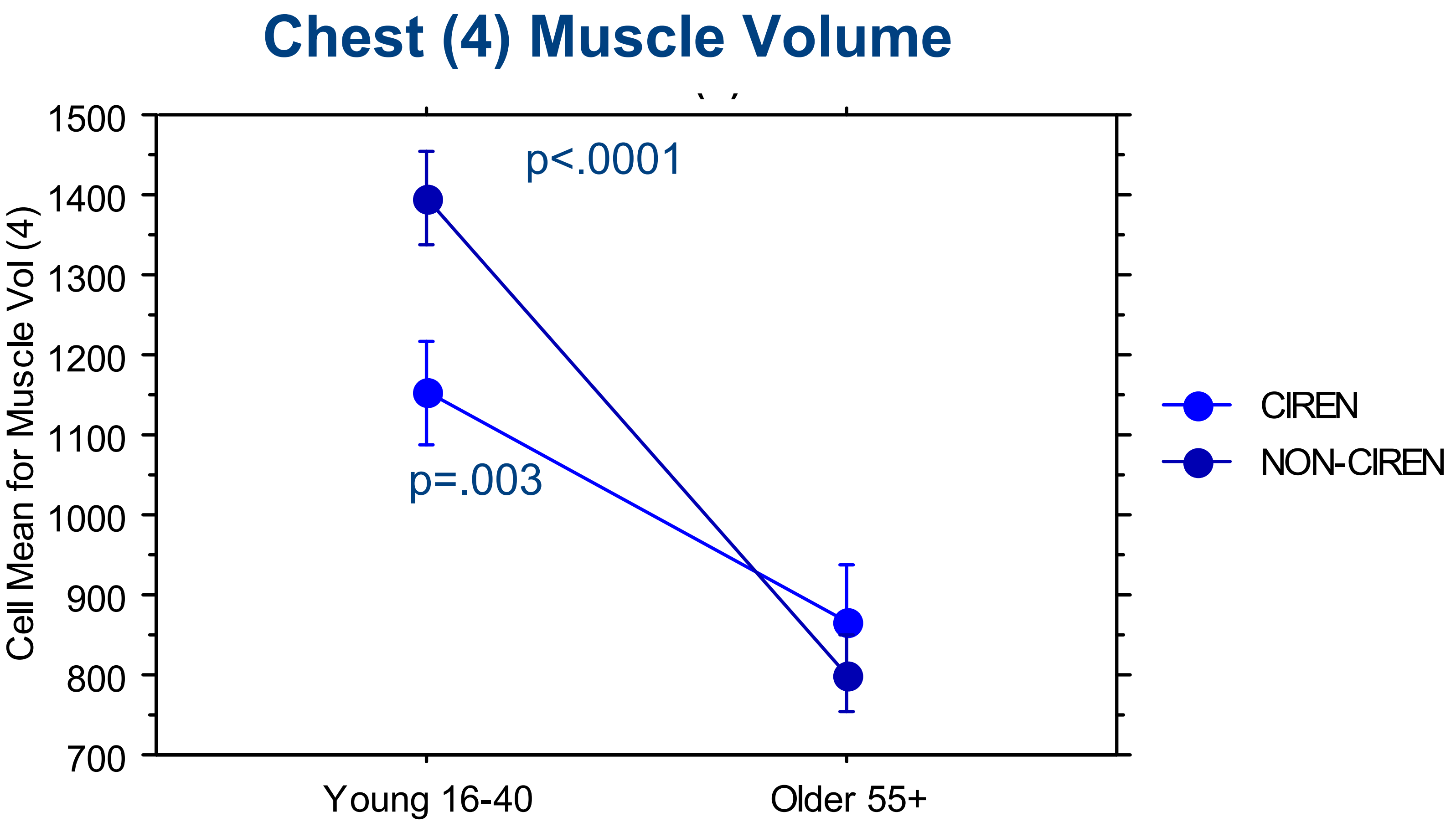
Slight Chest Bone Volume Changes with Aging

Chest (4) Bone Volume



n.s. Young vs. Older
n= 226

Chest Muscle Volume Decreases with Aging



p<.0001 Young vs. Older
n= 226

Effect of Soft Tissues on Chest Injury Tolerance

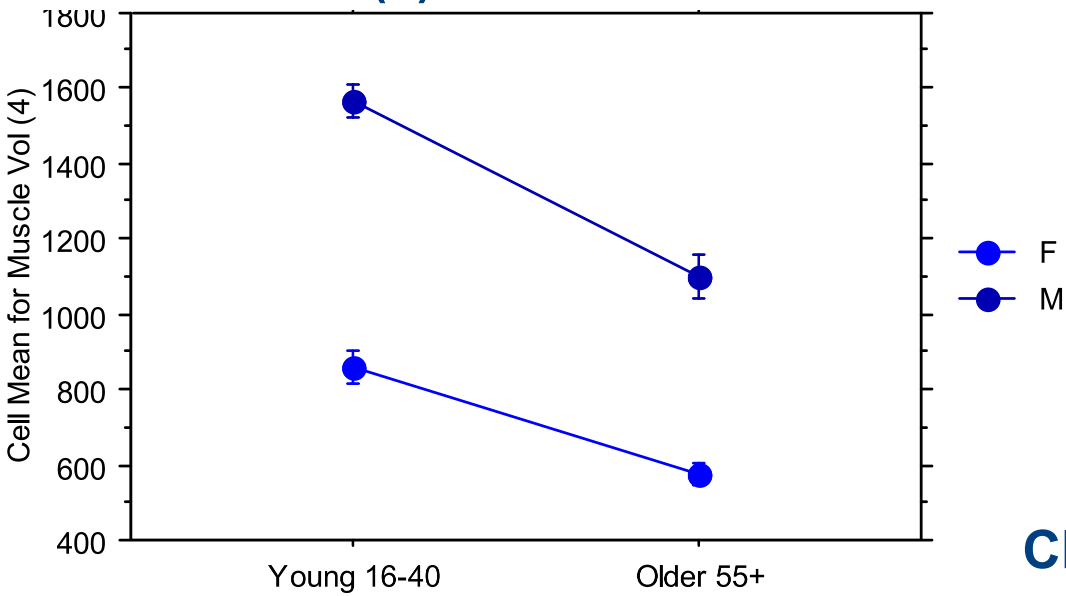
- Verriest and Chapon (1985) found that the resistance offered by the rib cage alone is by far lower than the resistance of the intact thorax. Although soft tissue elastic moduli and ultimate strengths might be much lower than those of bones, soft tissues significantly affect the body's overall resistance to applied forces by coupling with the bony structures.

- Like bones, the reductions in ultimate tensile strength of the soft tissues start between 30 to 40 of age (Yamada, 1970).

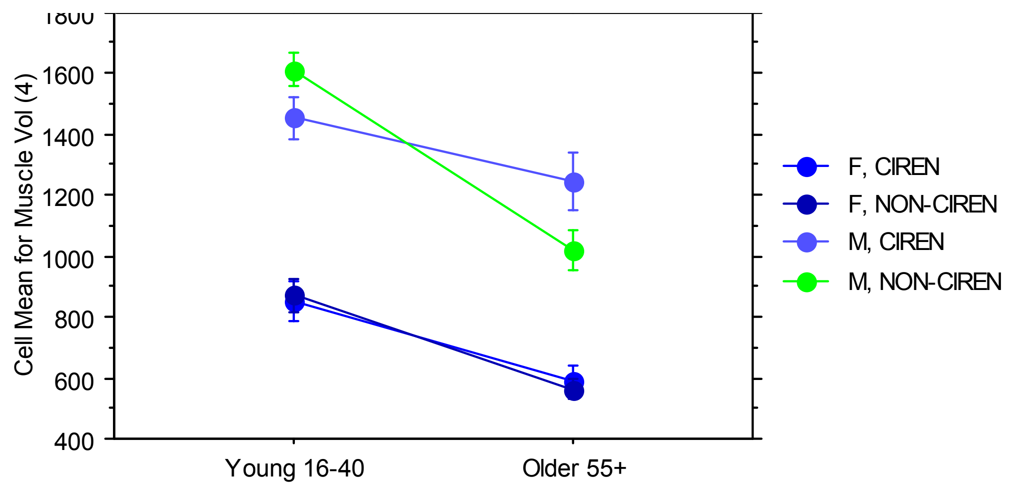
- Zhou, Rouhana & Melvin (1996) found that the reduction of tolerance with aging observed under blunt loading and side impact loading of the chest were comparable to the reductions of the soft tissue strength

Large Gender Differences in Chest Muscle Volume

Chest (4) Muscle Volume

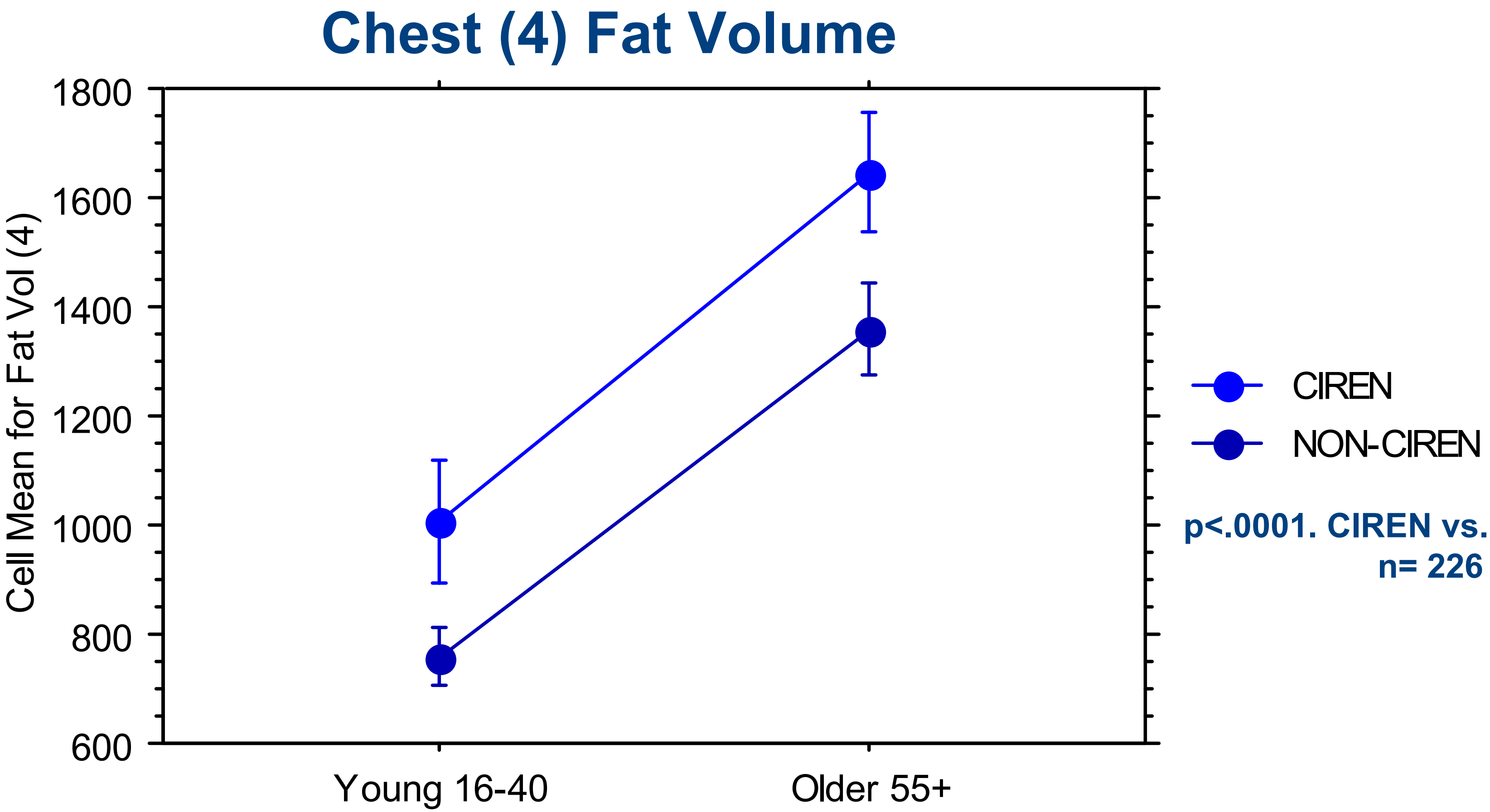


Chest (4) Muscle Volume



p<.0001 Young vs. Older for both Males and Females

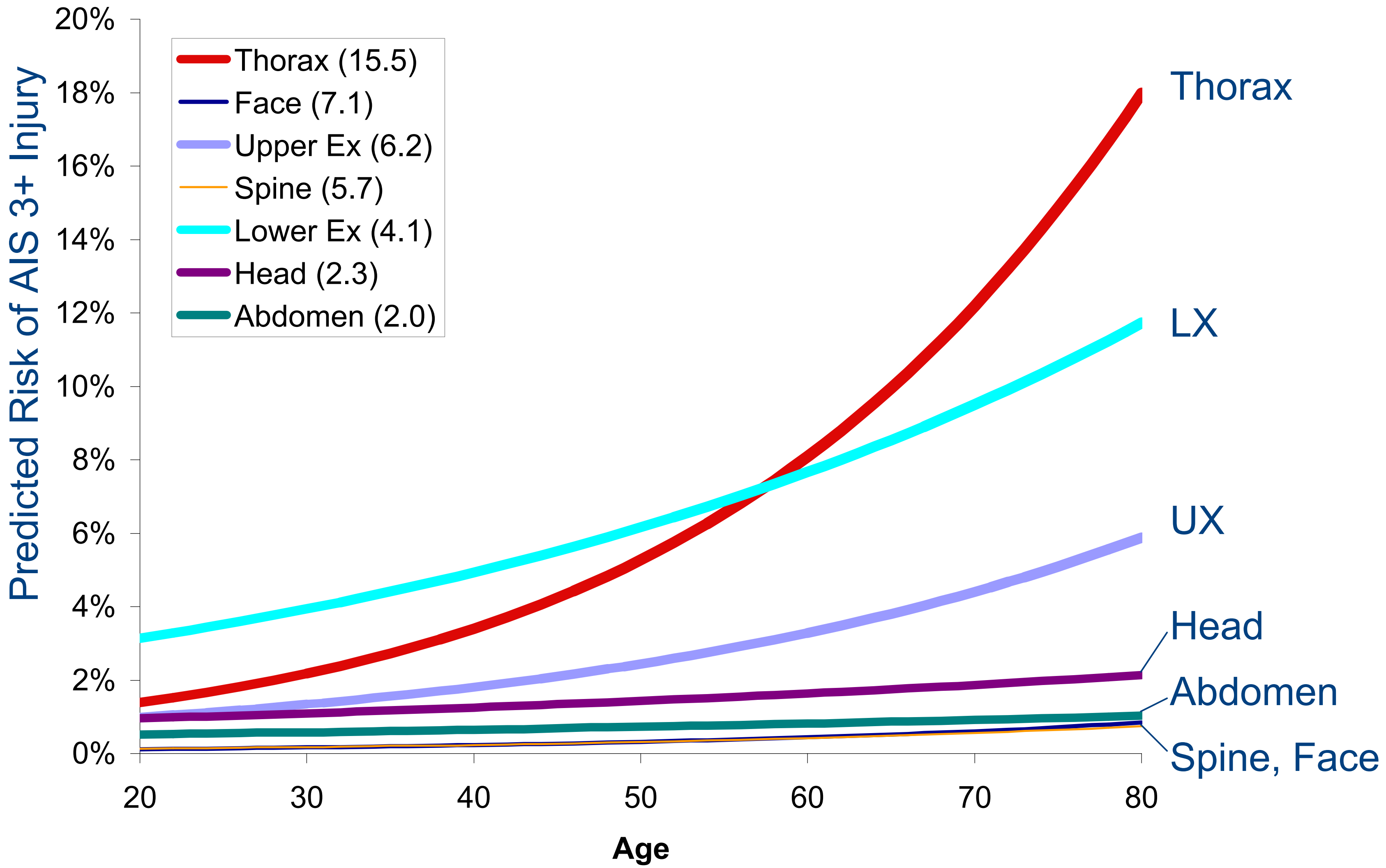
Older Subjects Have More Chest Fat Than Younger
CIREN Subset Significantly Fatter



p<.0001. CIREN vs. Non CIREN
n= 226

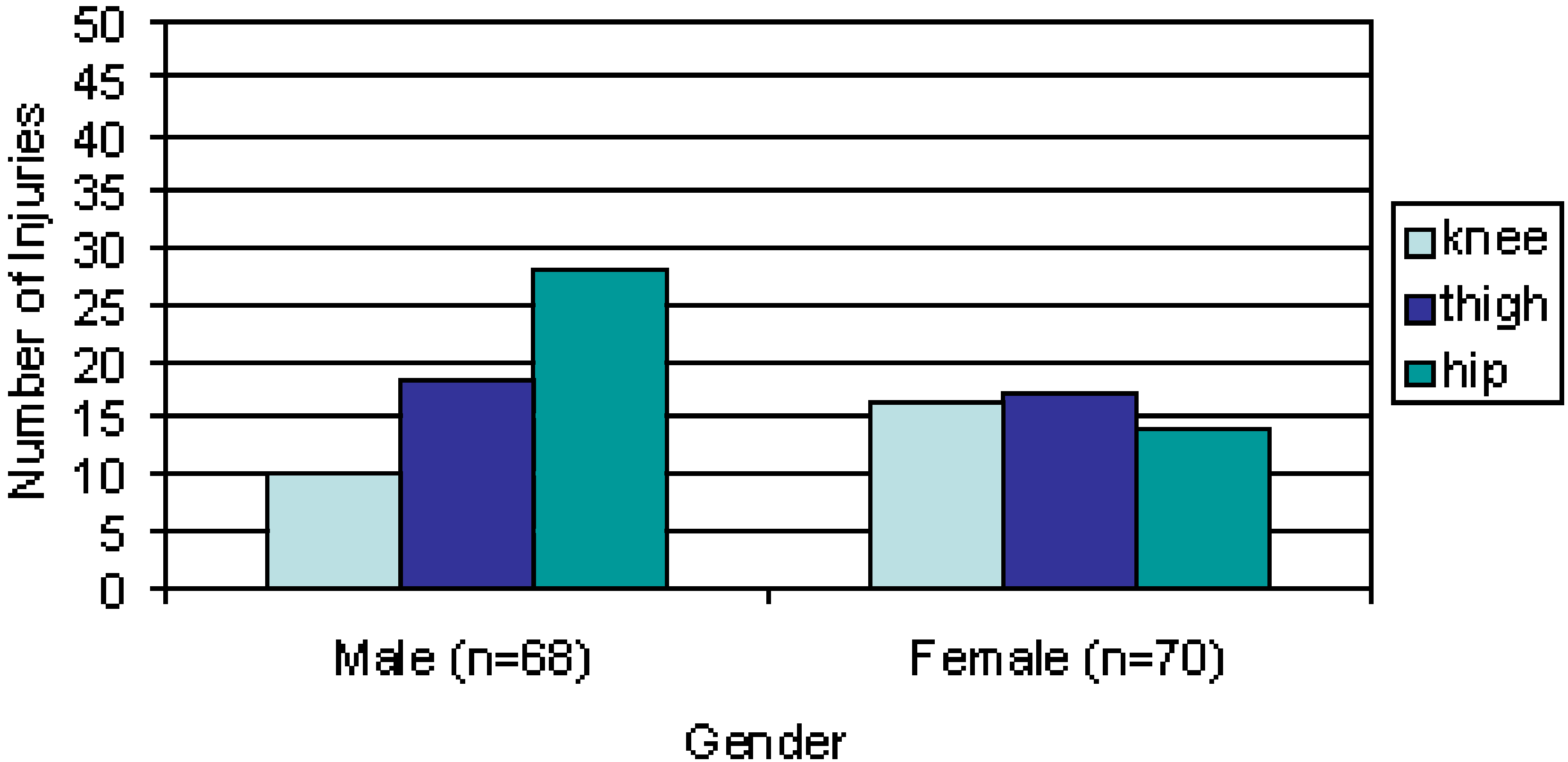
p<.0001. Young vs. Older
n= 226

Relationship Between Age and AIS 3+ Injury Risk by Body Region in **Frontal Crashes**
(Belted Drivers, 30 mph Crash Severity)



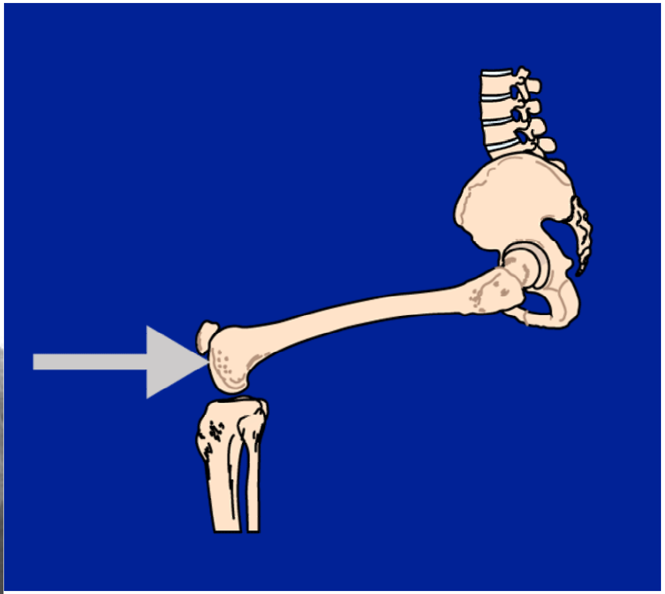
Pelvis Geometry also Changes with Aging

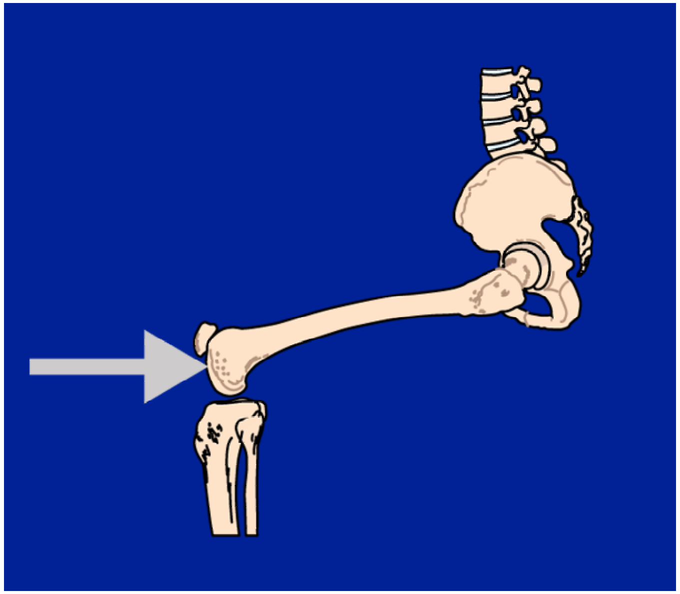
Gender distribution of Knee, Thigh, and Hip injuries in UM CIREN frontal crashes

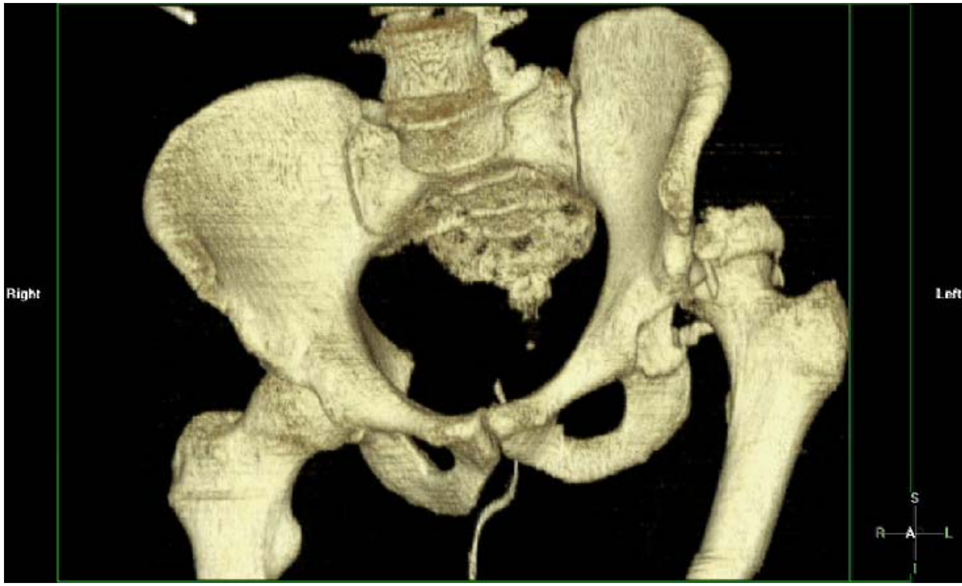


2002: 81 occupants, 138 injuries

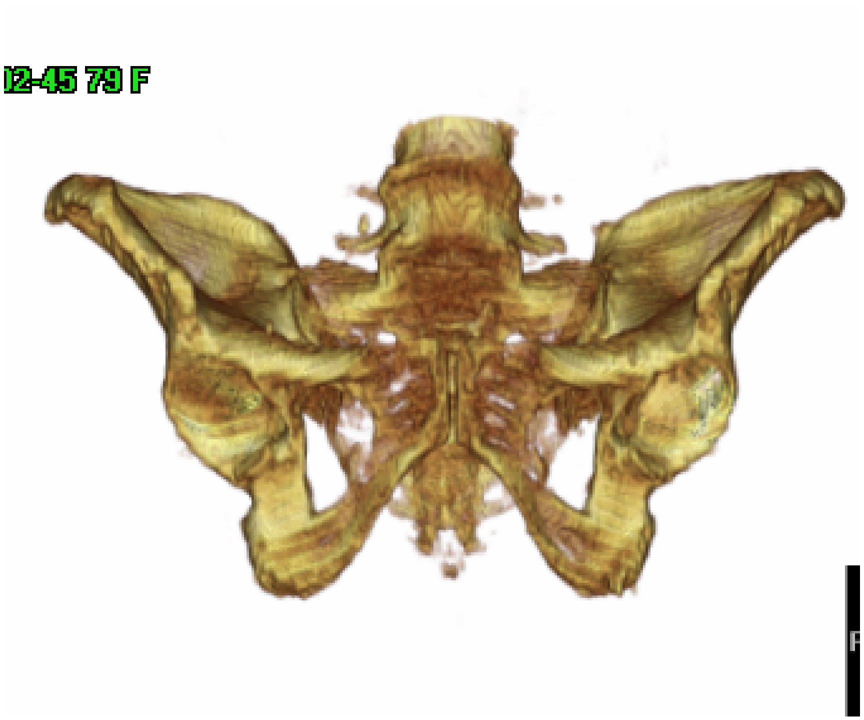

R





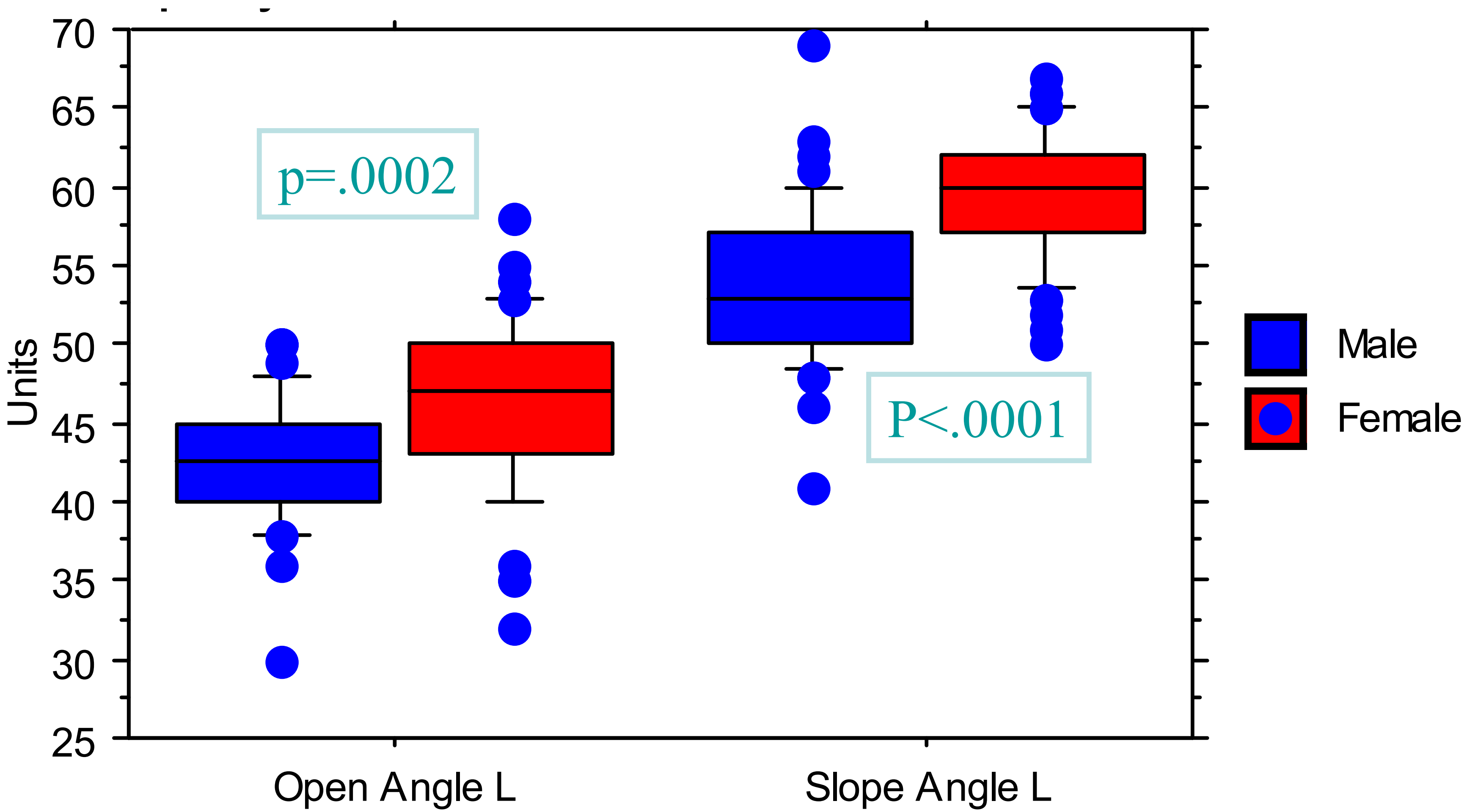

Right
Left

MALE



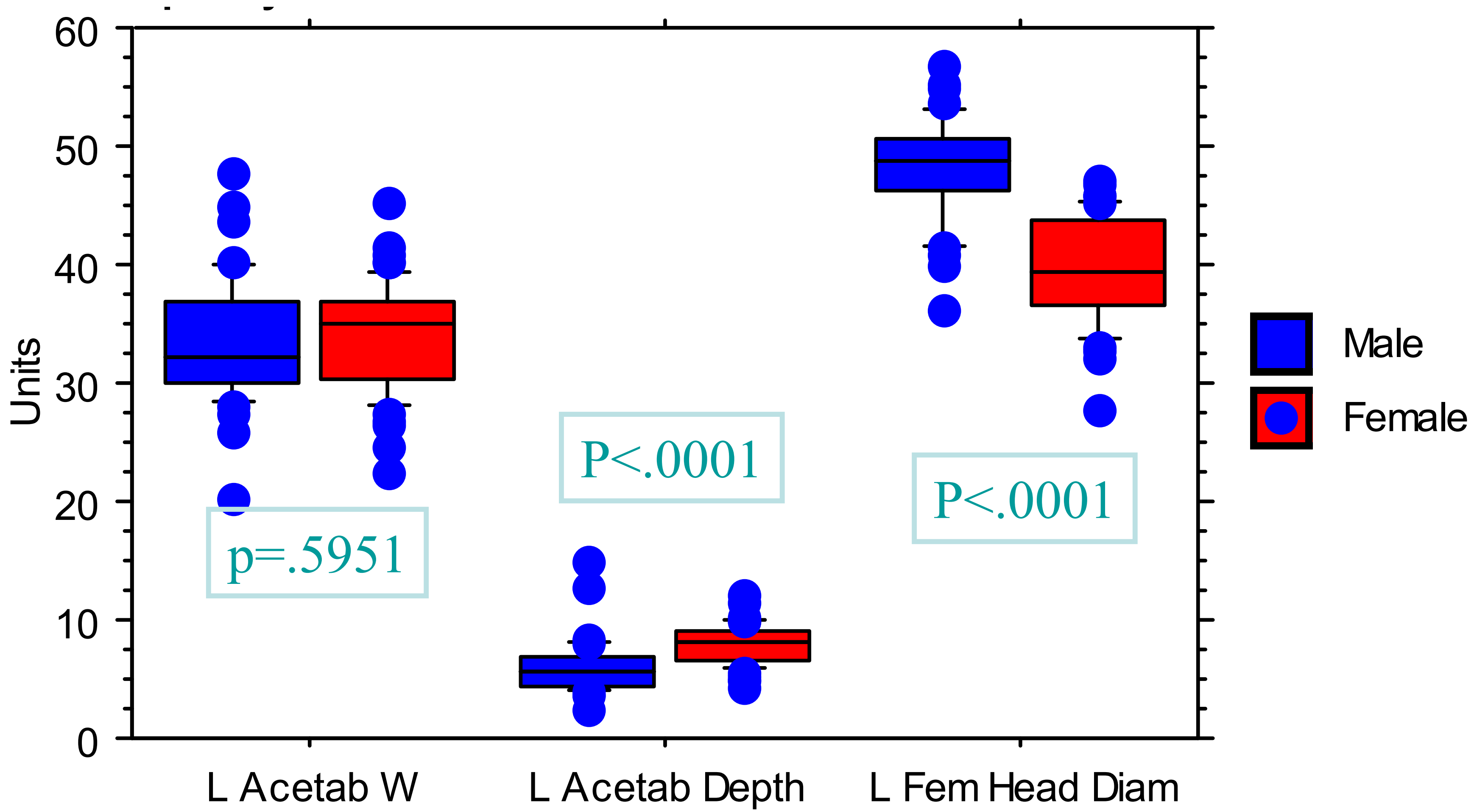
FEMALE

Acetabular Cup Angles by Gender



n=92

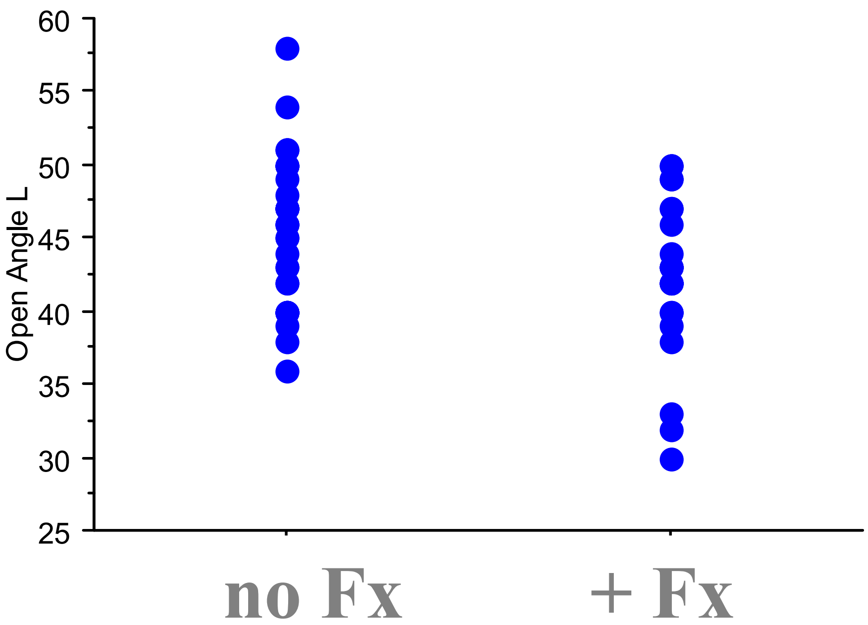
Acetabular Cup Dimensions by Gender



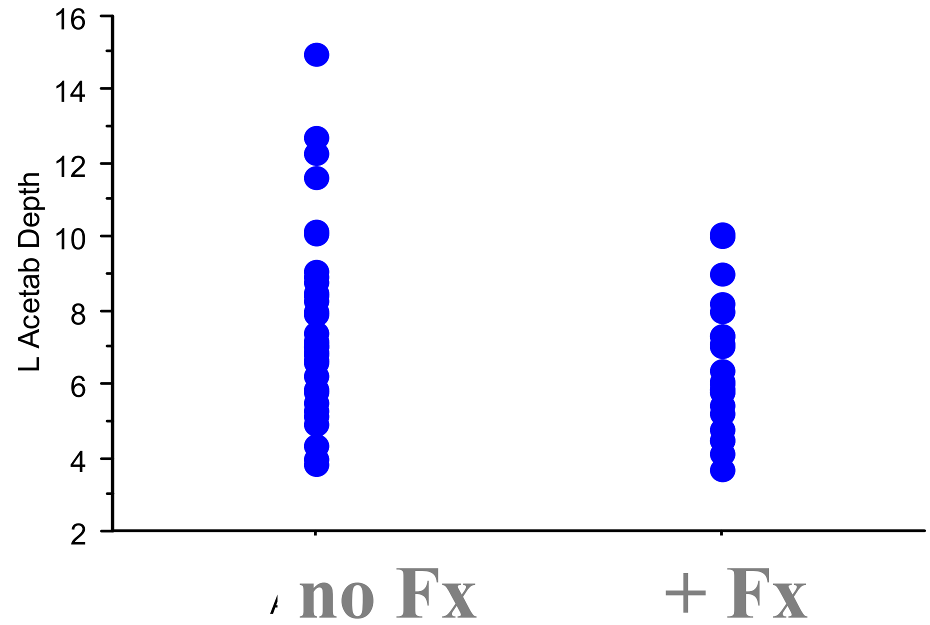
n=92

Frontal Crashes

Open Angle



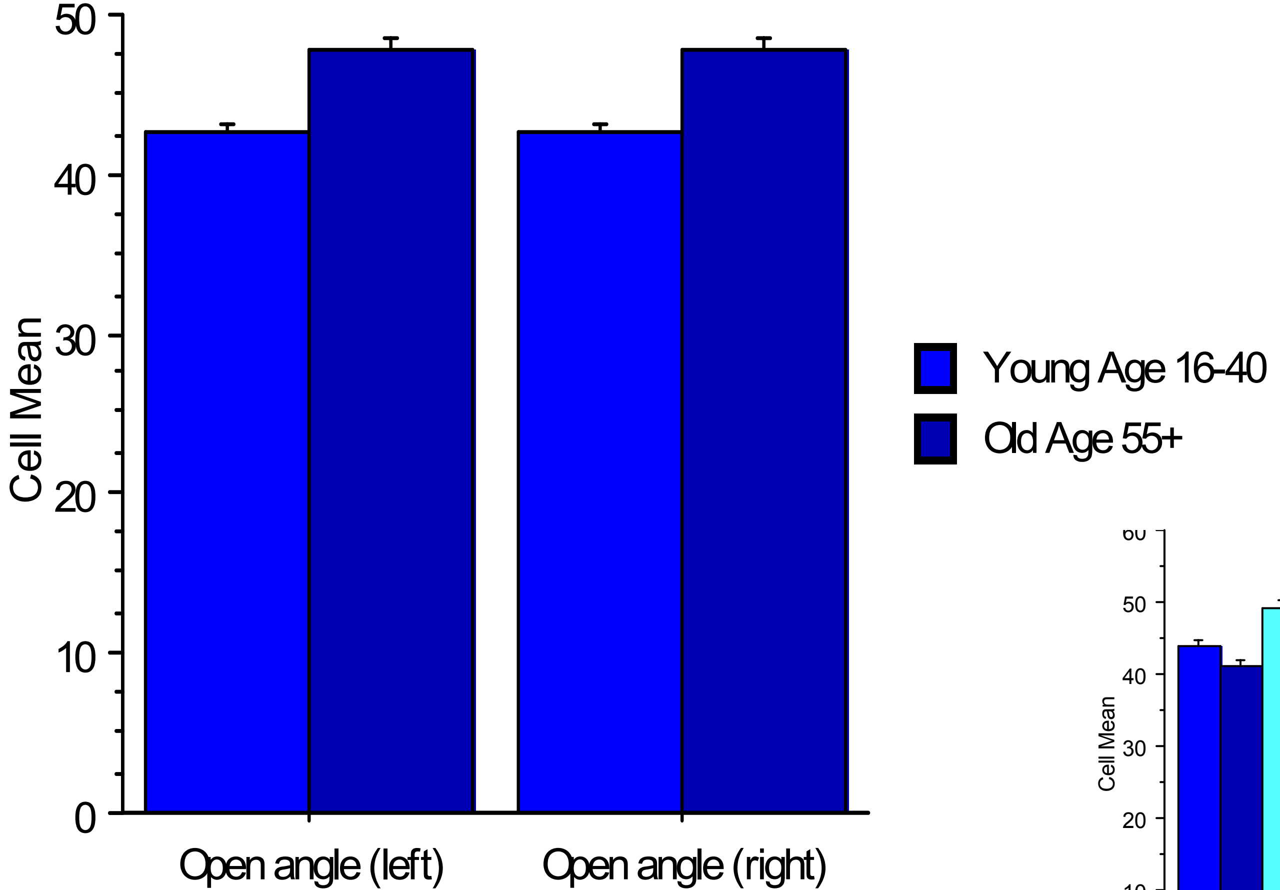
Acetab Depth



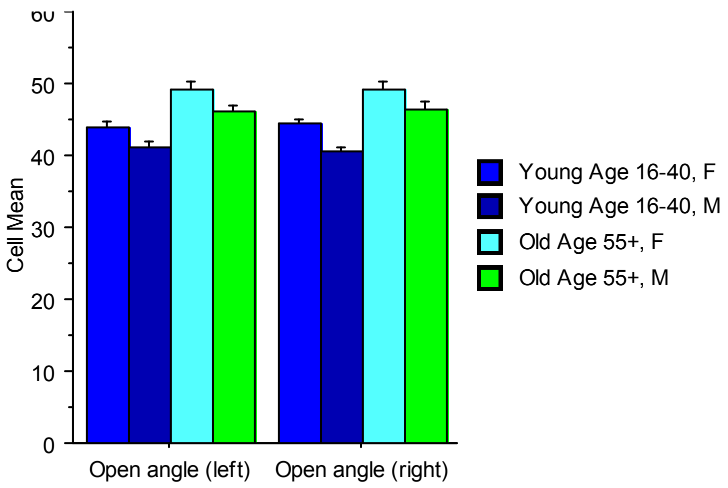
2004: n=56, frontal crashes

Hip Socket Orientation Changes with Aging!

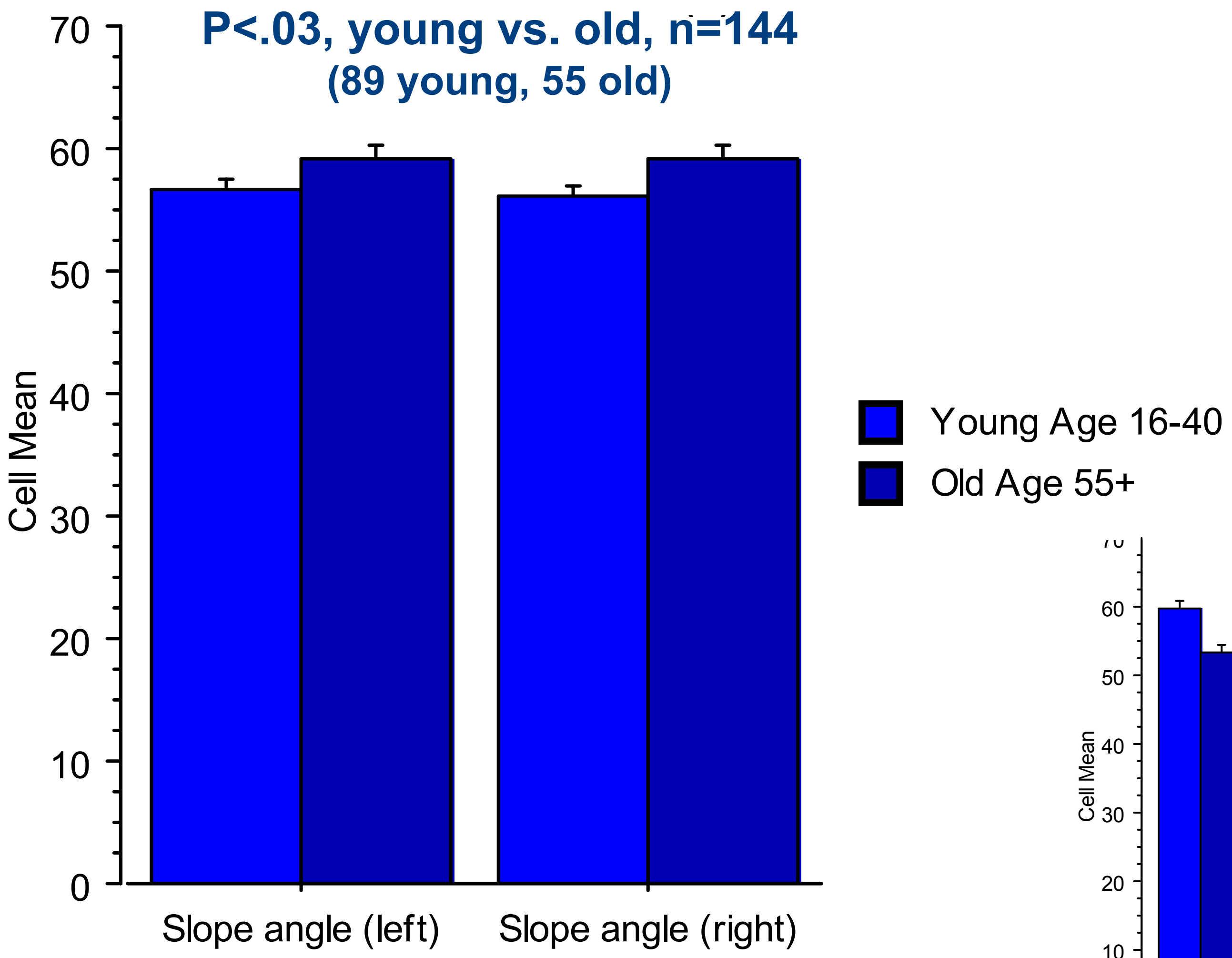
P <.0001, young vs. old, n=252
(152 young,100 old)



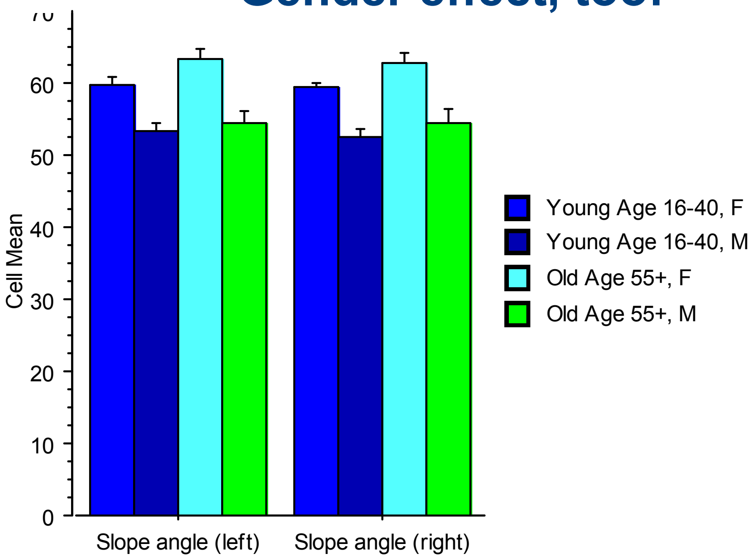
Gender effect, too!



Hip Socket Orientation Changes with Aging! (2)

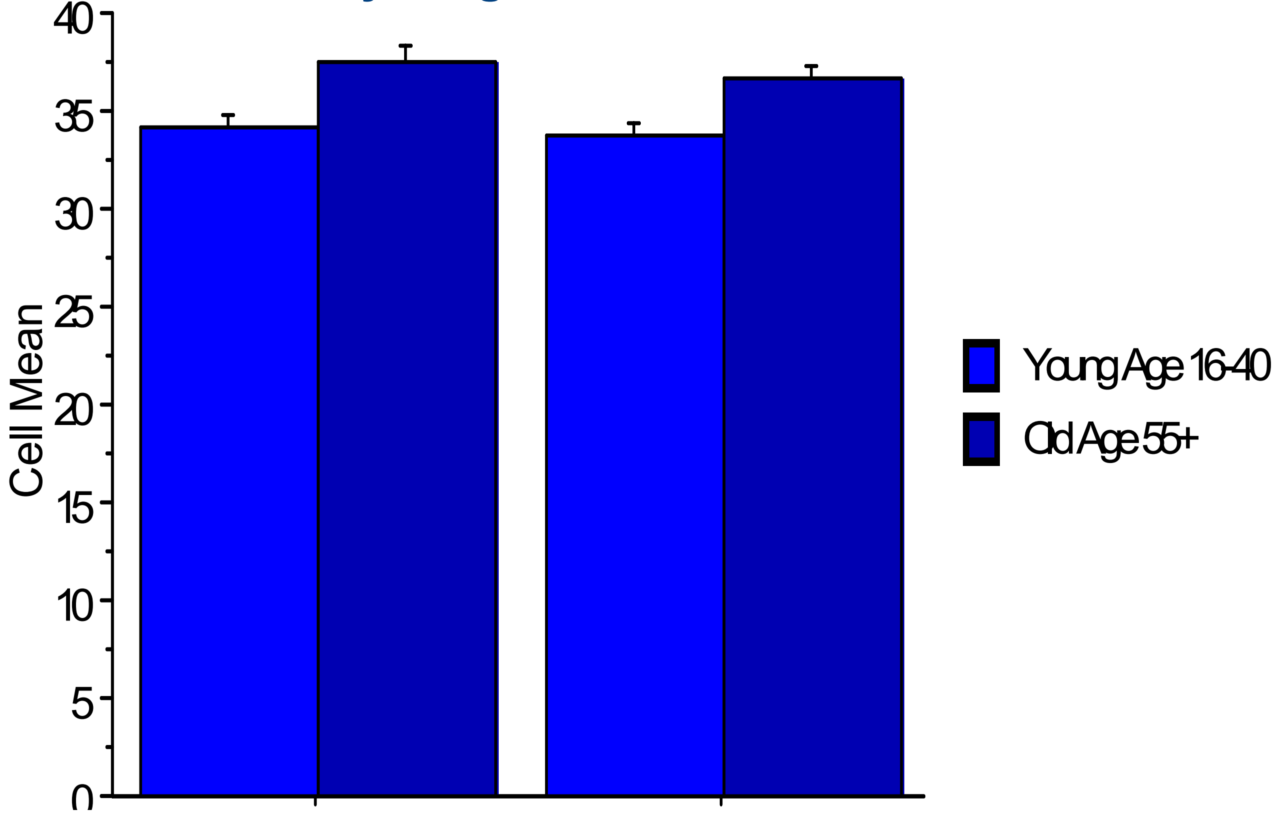


Gender effect, too!



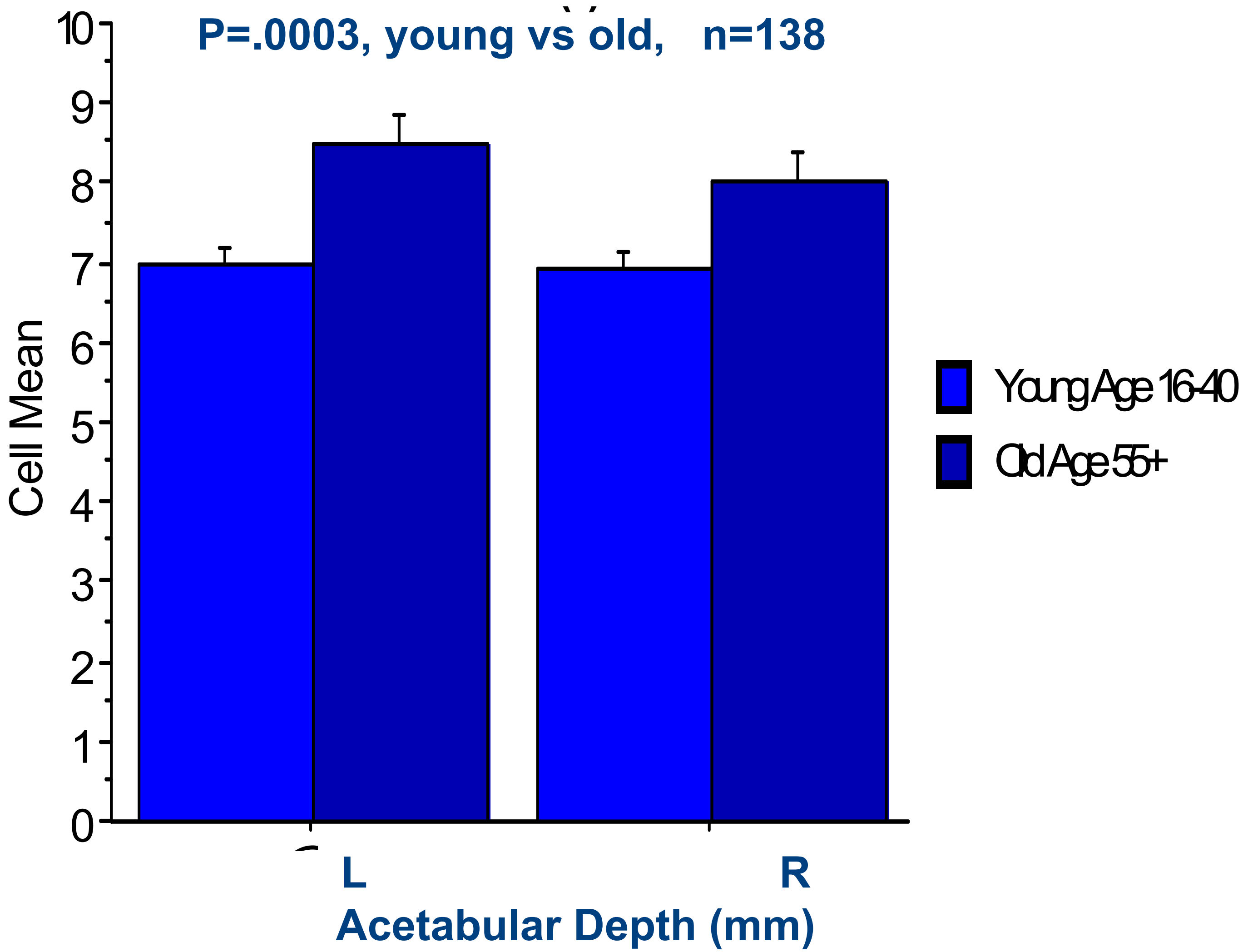
Hip Socket Dimensions Change with Aging!
1. Acetabular Width

P=.0007, young vs. old, n=138



Acetabular Width (mm)

Hip Socket Dimensions Change with Aging!
2. Acetabular Depth



Summary

- There are many body composition and geometry changes with aging.
- Using DICOM, Age can be broken down into components that are measurable and usable for biomechanical research and development.
- Men and women age differently
- The Michigan *(?all?)* CIREN population is skewed toward fatter individuals.

DICOM is Indispensible for CIREN

- DICOM provides unmatched objective injury detail
- DICOM data provides valuable insight regarding injury mechanisms.
- DICOM data can inform the development of more anatomically correct and biofidelic ATDs
  - Rib orientation, rib design & coupling, chest deflection instrumentation, abdominal insert size and properties, soft tissue jacket, hip joint anatomy and instrumentation…
- DICOM data can provide great insight into injury tolerance, especially once DICOM data from appropriate control populations are gathered.

Do Injury Patterns in Models or Cadaver Testing Resemble Real-life Injuries?

DICOMS are Fundamental for the Development of Finite Element Human Body Models

- DICOMS will provide the foundation for more detailed and anatomically accurate FE human body models.
- FEM models that incorporate factors which appear to affect injury tolerance will provide further insight into how body geometry and composition affects injury tolerance, especially once a large and representative control population (of DICOM) can be selected and verified.
  - We have cataloged over 30,000 CTs and are adding >10,000 CT/MRI studies per year
  - We are collecting essential (biomechanically relevant) patient information on a large subset of these patients – difficult but absolutely critical.
  - We have begun to analyze selected (control population) CTs to determine population distributions and trends/differences associated with aging, gender, etc. prioritizing factors that are associated with differences in injury levels in CIREN subjects.

Model Validation Process

- Test Case: Frontal collision, male driver restrained by 3-point belt and airbag.

Model Outcome

Femur fracture,
open book pelvic fracture

Real-life Outcome

Posterior acetabular fracture

Alter model parameters

Re-examination of case characteristics

seating position, belt tension, occupant kinematics, cargo, avoidance maneuvers…

DICOM

Re-examination of occupant characteristics

pelvic geometry, femoral head size, acetabular orientation & wall thickness, hip subQ fat, bone mineral density…

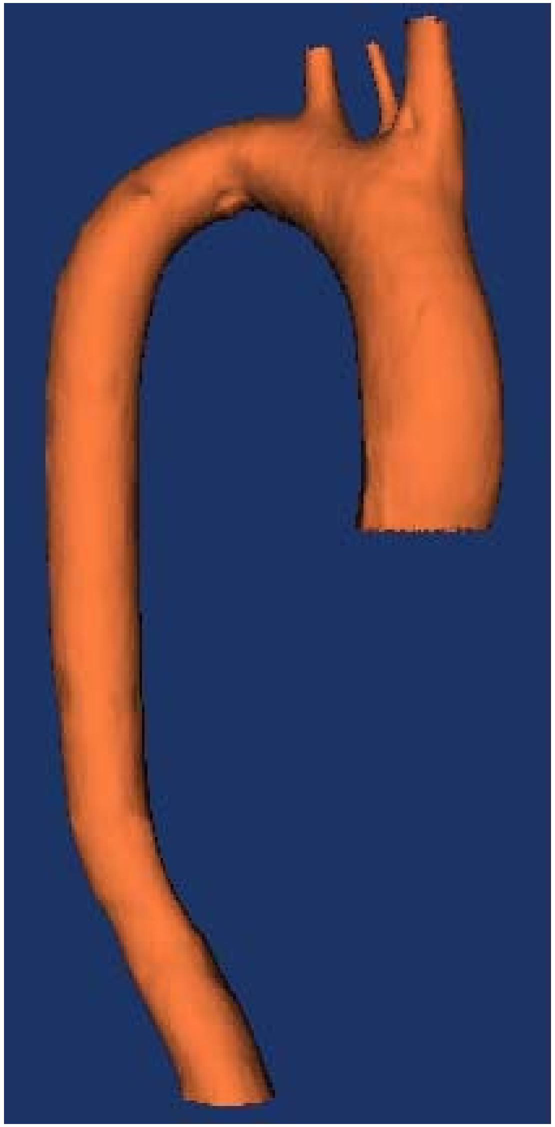
Examine occupant for effects predicted by model

evidence of belt loading, surface loading marks, additional injuries…

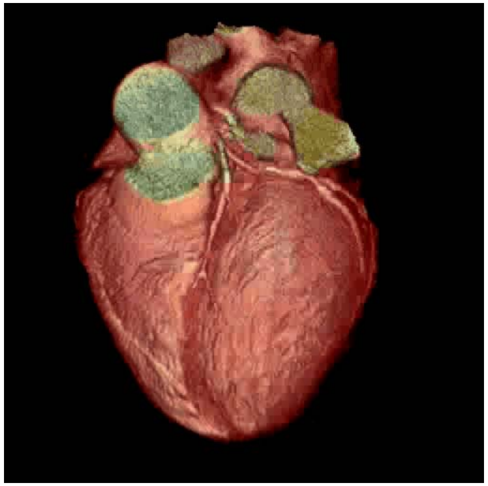
Future Priorities

- Collection and analysis of data from crashes where occupants were un-injured but CTs were performed. This is possible because CTs are routinely used for the evaluation of patients triaged from the field with significant mechanism of trauma.
- Incorporation of body composition data into FEMs for research and validation.
- Utilization of 3D DICOM injury data to guide model development and validation.
- 4D DICOM

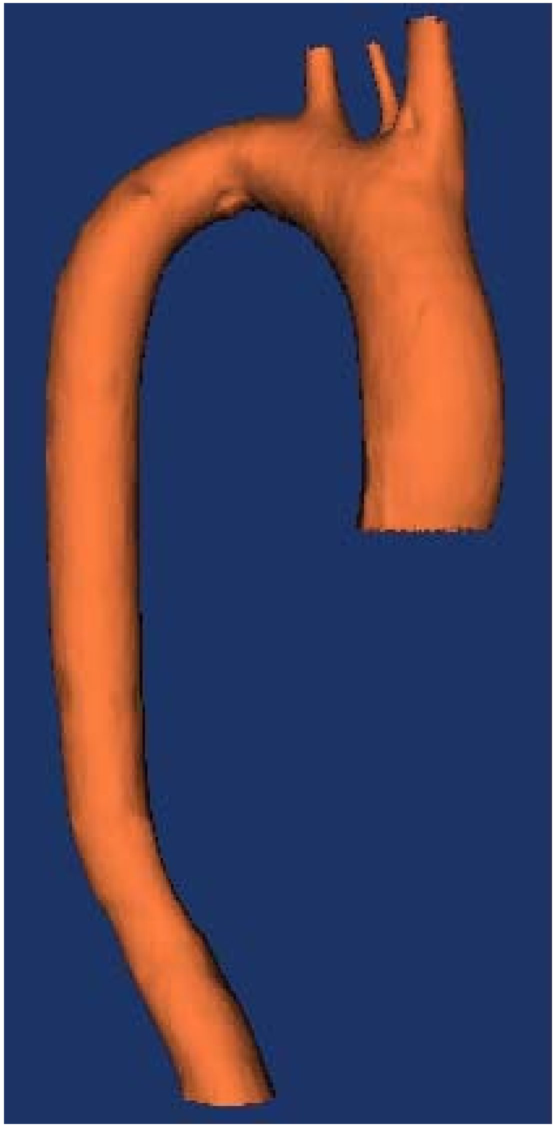
Another Added Dimension



It is difficult to obtain the material properties of living tissues, especially *in situ*.



Another Added Dimension



- Combined with blood pressure information (*which we have been collecting for several years*), we can determine the **compliance** of this tissue in its **normal** location in a **live** person.
- We can determine the fixation points for the aorta as a whole.
- We have started collecting our trauma CTs using this gated technique.

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- The views expressed are those of the authors only.