

S O U T H E R N  
C O N S O R T I U M  
F O R I N J U R Y  
B I O M E C H A N I C S

**SCIB Repository for Pediatric  
Material and Structural  
Properties: Support of the SCIB  
Digital Child Project**

Presentation by

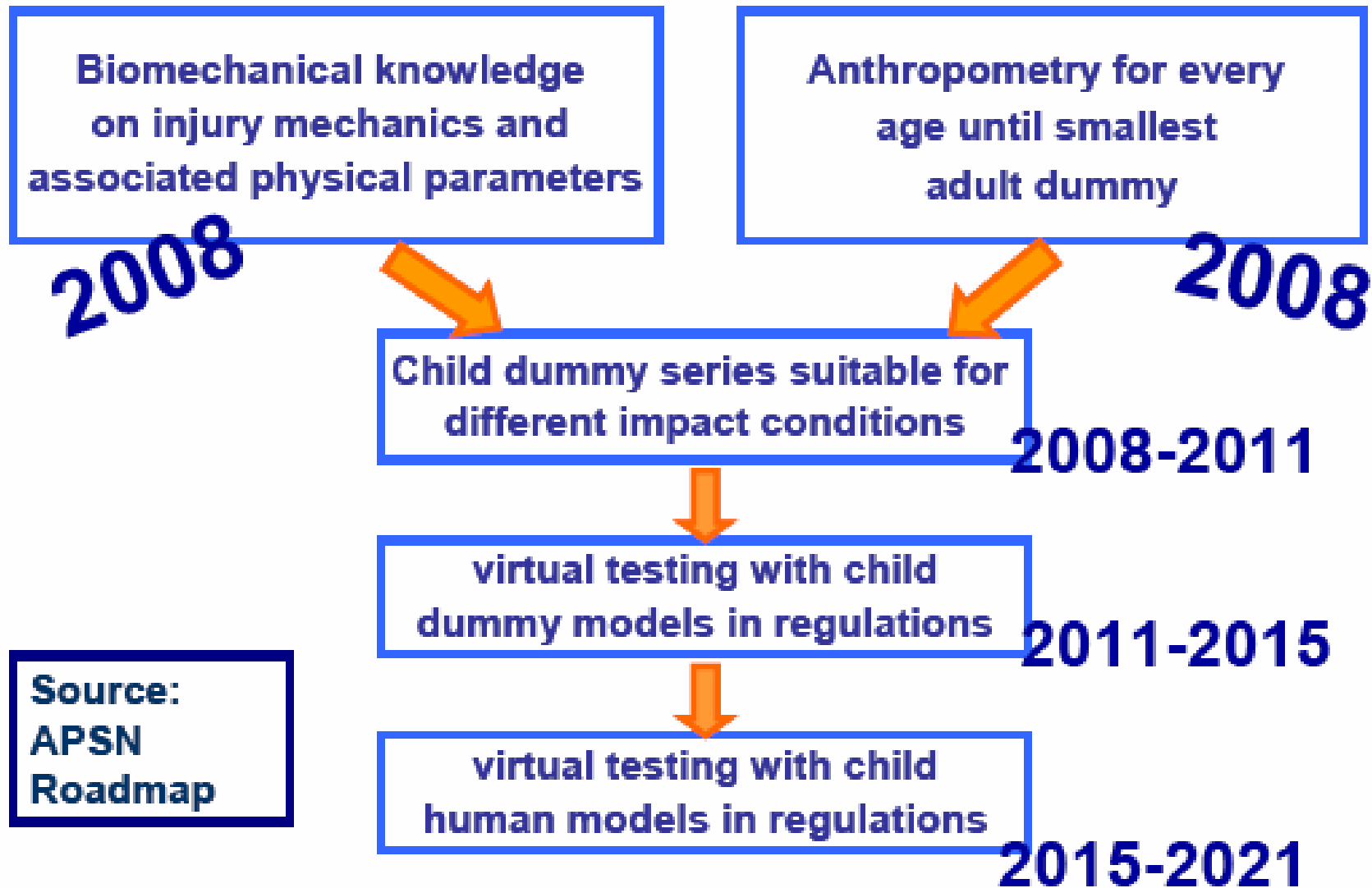
Jeff Crandall

December 14, 2006

# Worldwide Pediatric Research

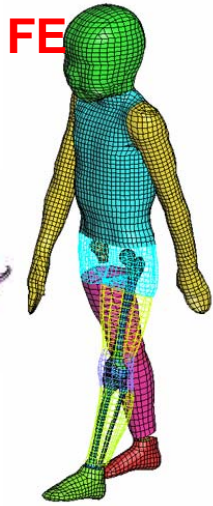
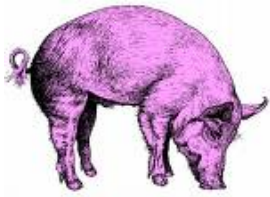
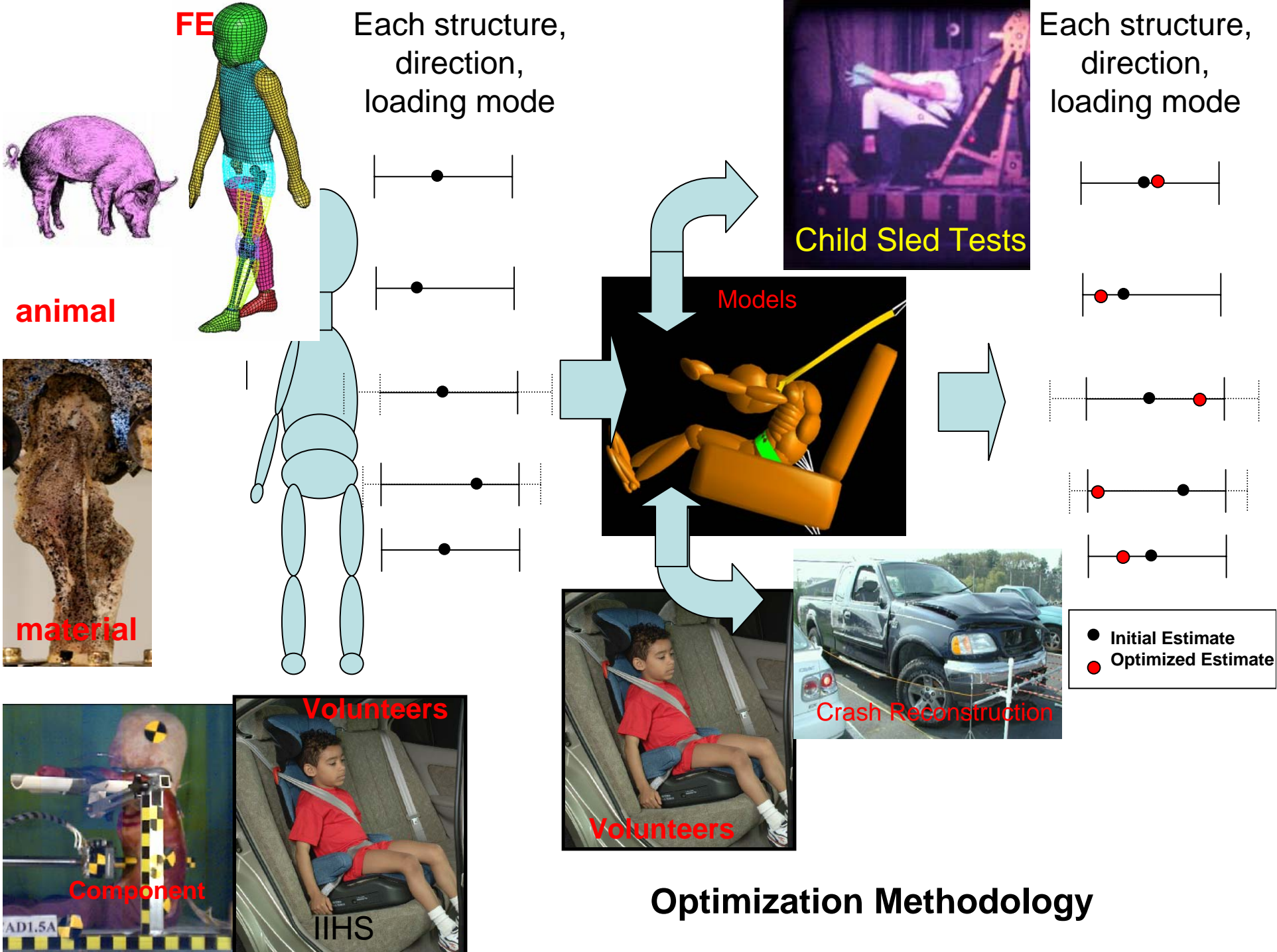
- EU consortium recently completed CHILD project (successor to CREST project) and is considering applying for CHILD II funding (7<sup>th</sup> Framework)
  - Epidemiology Investigations
  - Crash Reconstructions
  - Child Dummy Development Q series
  - Injury Criteria
  - Dummy and Human Numerical Models
- Conclusion: “review and consolidation of new geometrical data and mechanical properties of the biological tissues must be performed in order to not rely solely on scaling methods”

# APSN Schedule – Child Safety

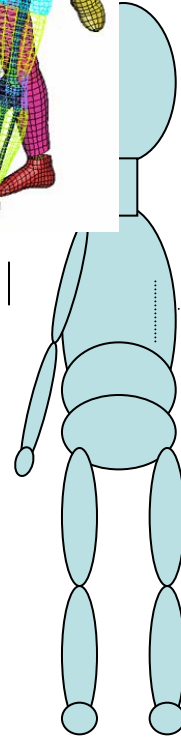
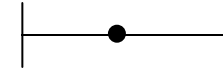
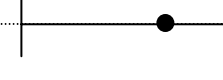
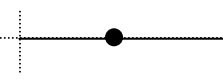
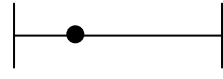
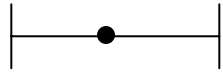


# NHTSA Child Protection Research

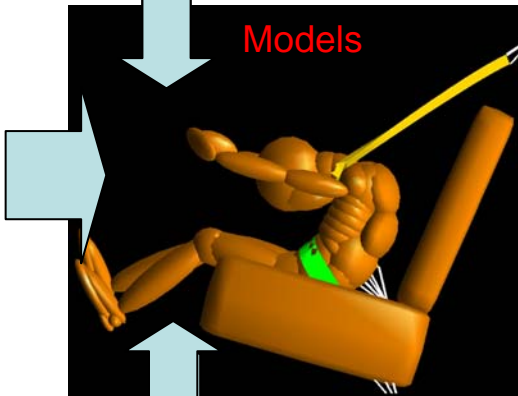
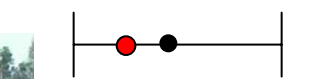
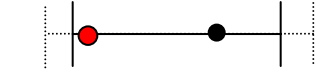
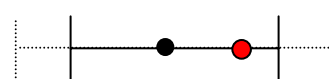
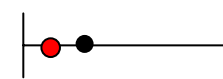
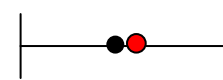
- Research focus is to develop performance specifications and injury criteria for a 6 year old child dummy
- Multi-university initiative plus TNO providing multi-body modeling
  - Pediatric Tissue Tests
  - Volunteer Tests
  - Crash Reconstructions
  - Reanalysis of pediatric sled test data
- Completion Target: 2010



Each structure, direction, loading mode



Each structure, direction, loading mode



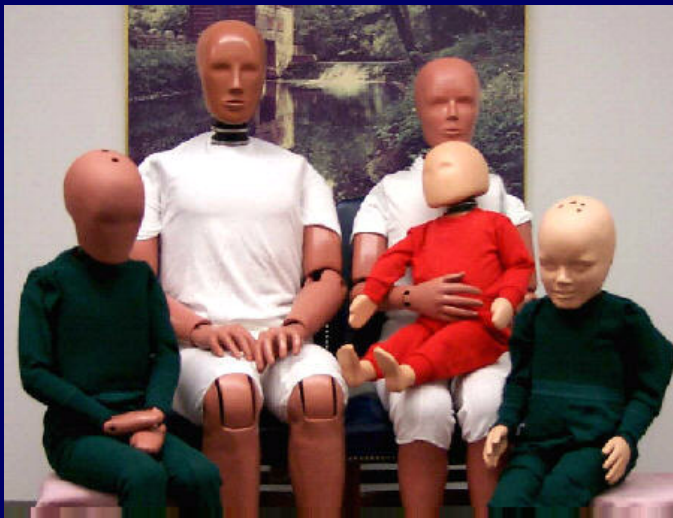
● Initial Estimate

● Optimized Estimate

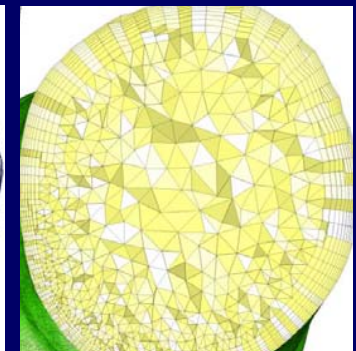
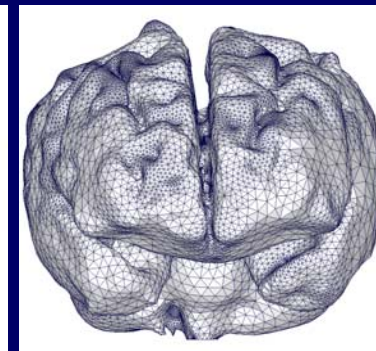
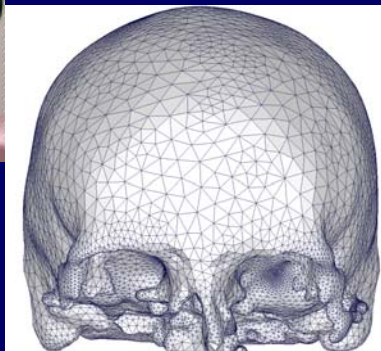
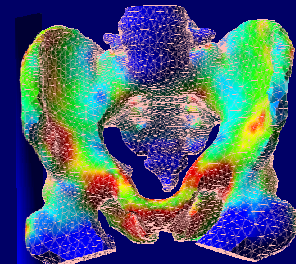
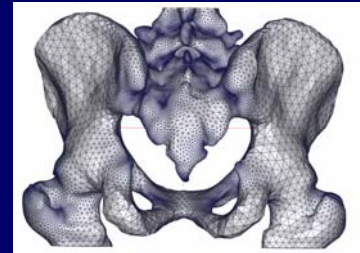
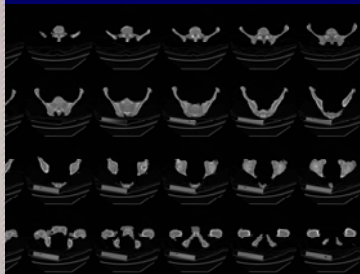
# SCIB Numerical model development (UAB, Wayne State University)

Wayne State University

Univ. of Alabama/Birmingham



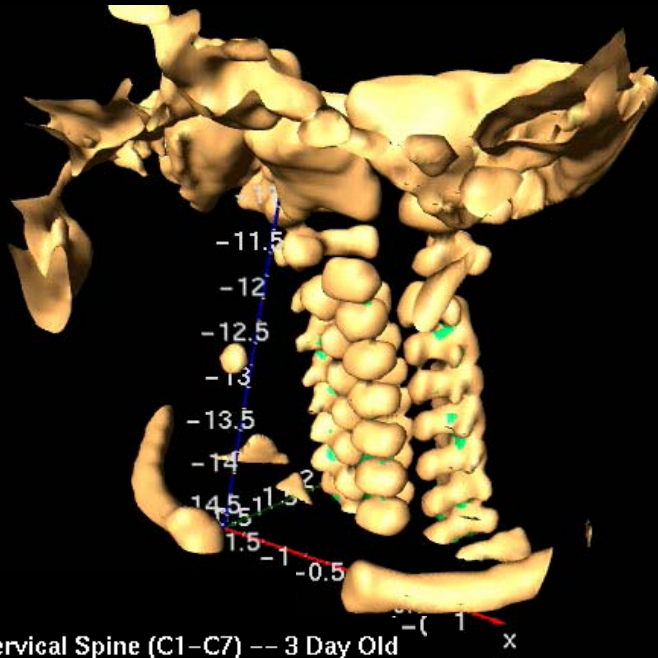
•Developing 3, 6, 10 y/old virtual model



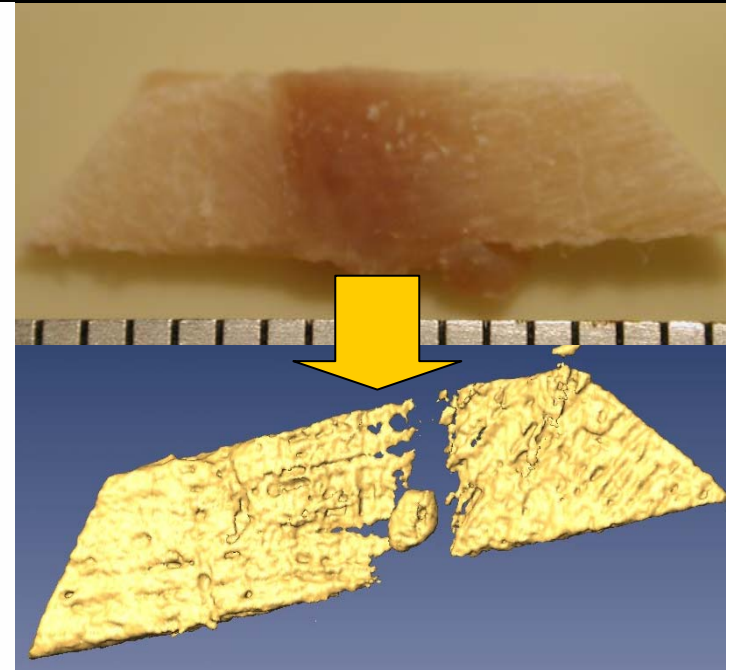
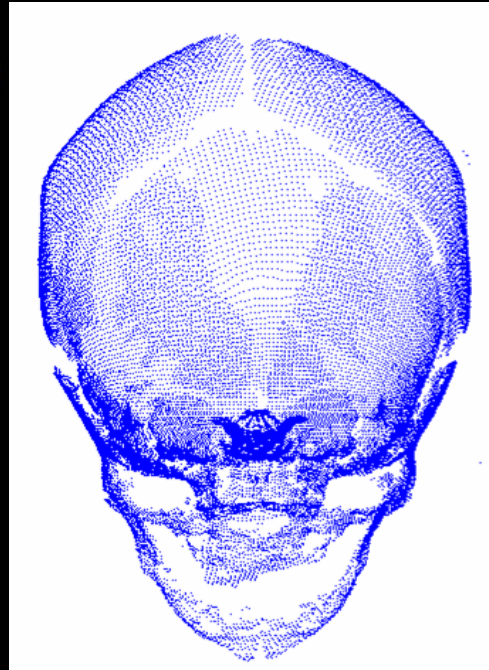
- Meshing the child
- Checking the simulation quality
- Material laws/incorporation from SCIB

# SCIB

- **SCIB history of contributions to pediatric biomechanics**



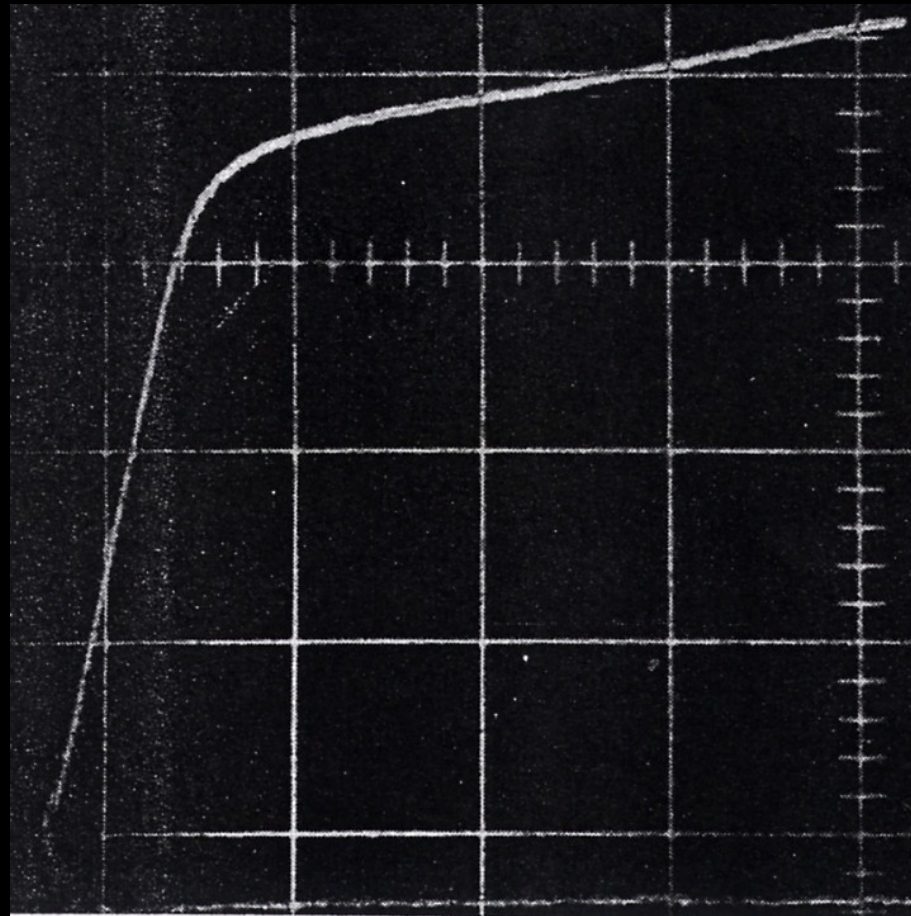
Cervical Spine (C1-C7) -- 3 Day Old  
Injury & Orthopaedic Biomechanics  
Duke University -- 12/2003



# SCIB Digital Child

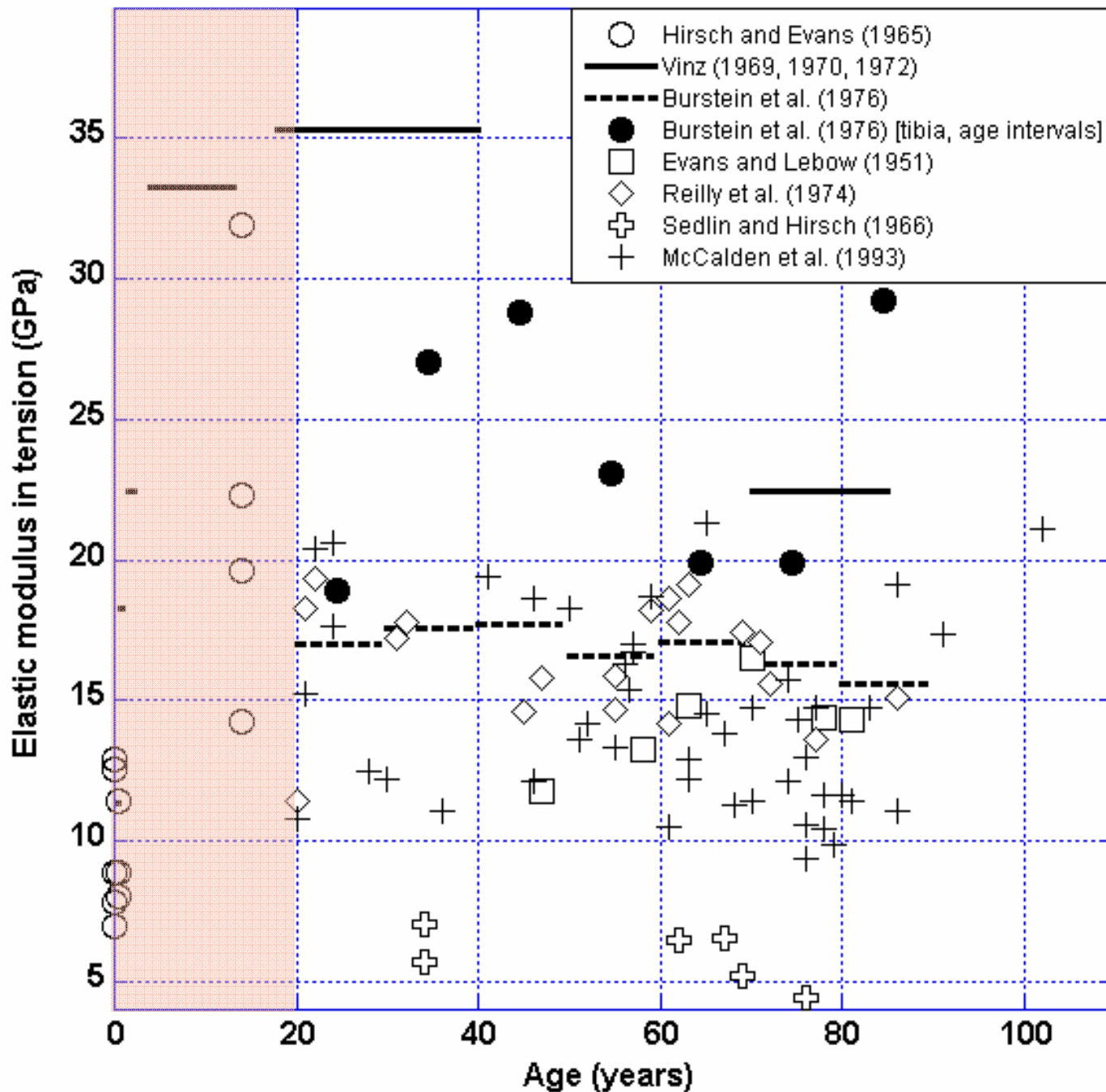
- Effort initiated on development of accurate FE child meshes for various ages and head/neck biomechanics
- Important to incorporate accurate material properties for all body regions into age specific models
- Develop a repository of pediatric tissue and component data
- Establish group of researchers to review, collect and evaluate data, collaborate with those developing the FE child models

Data is sparse and what is available is not well documented



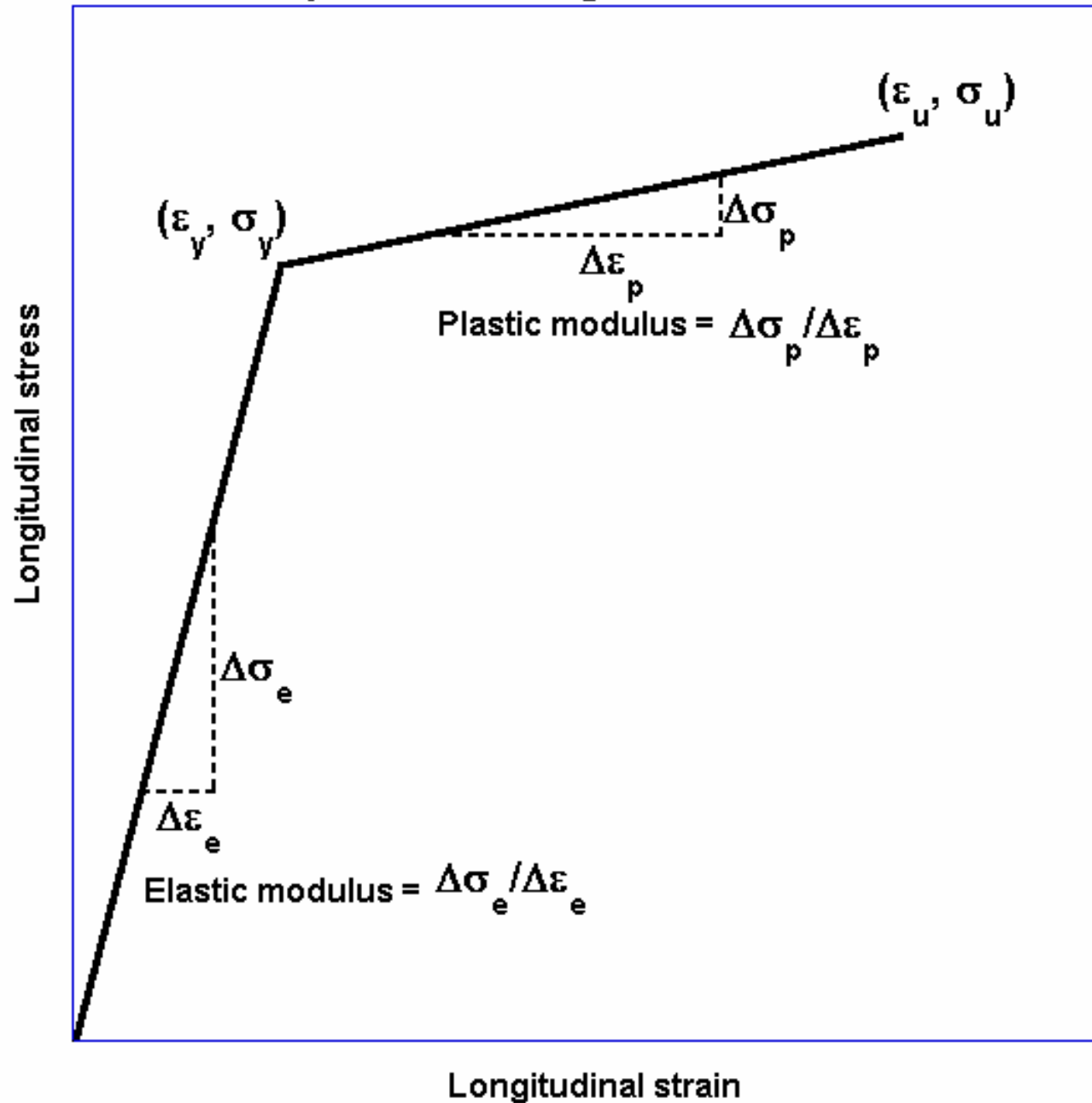
Stress-strain curve from tensile test with sample of child cortical bone

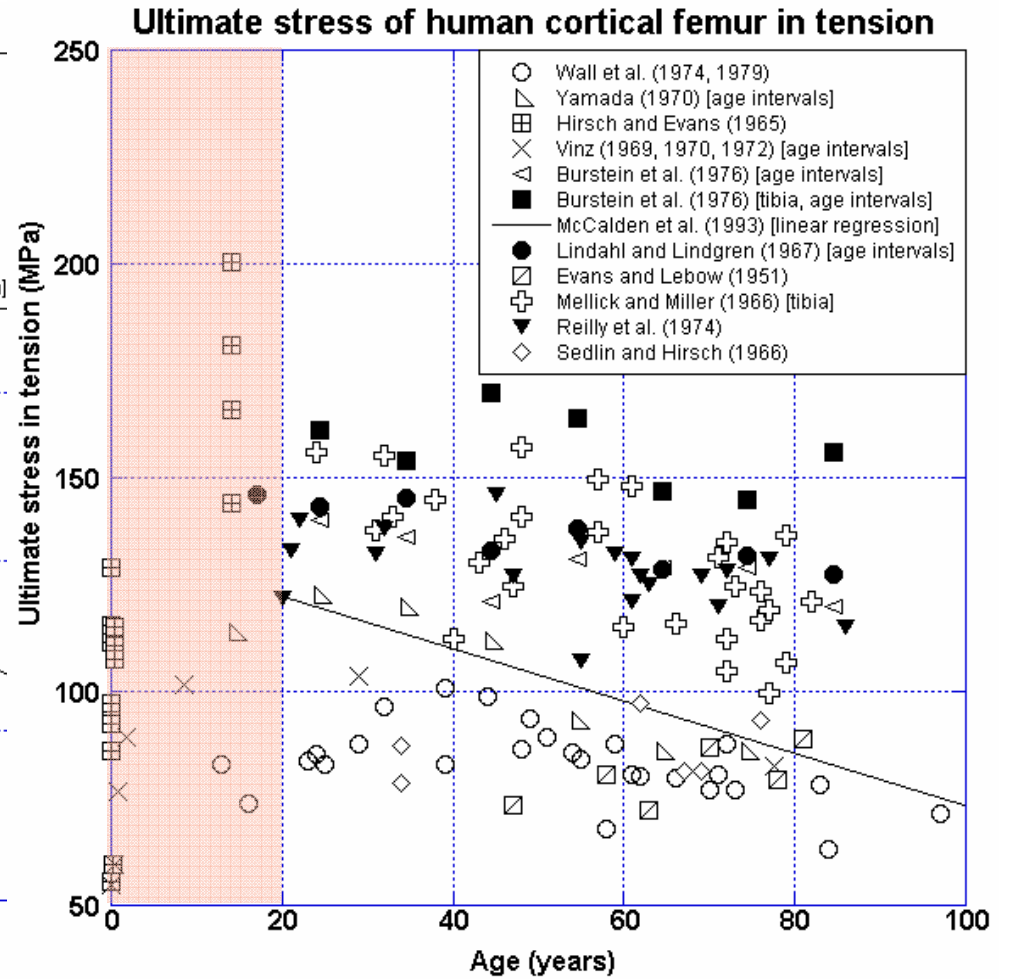
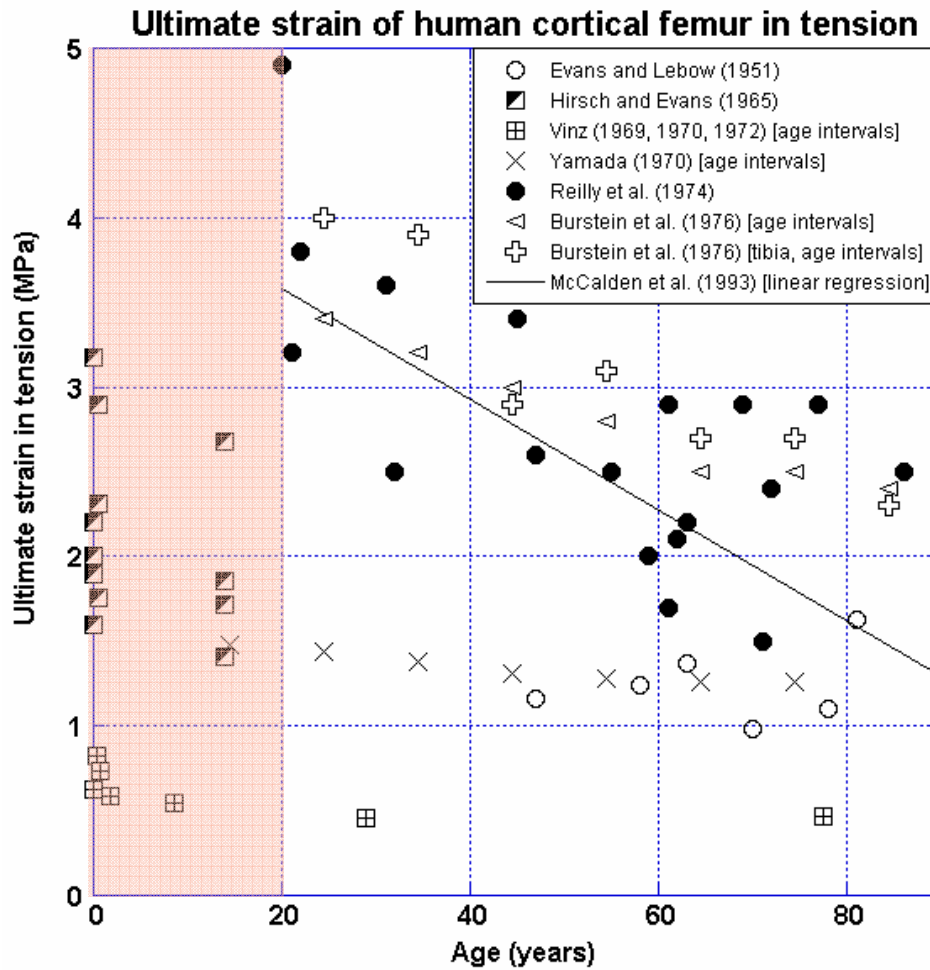
# Elastic modulus of human cortical femur in tension



Even for widely studied tissues – trends and mean responses can be difficult to discern

## Bi-linear elasto-plastic representation of the relationship between longitudinal stress and strain





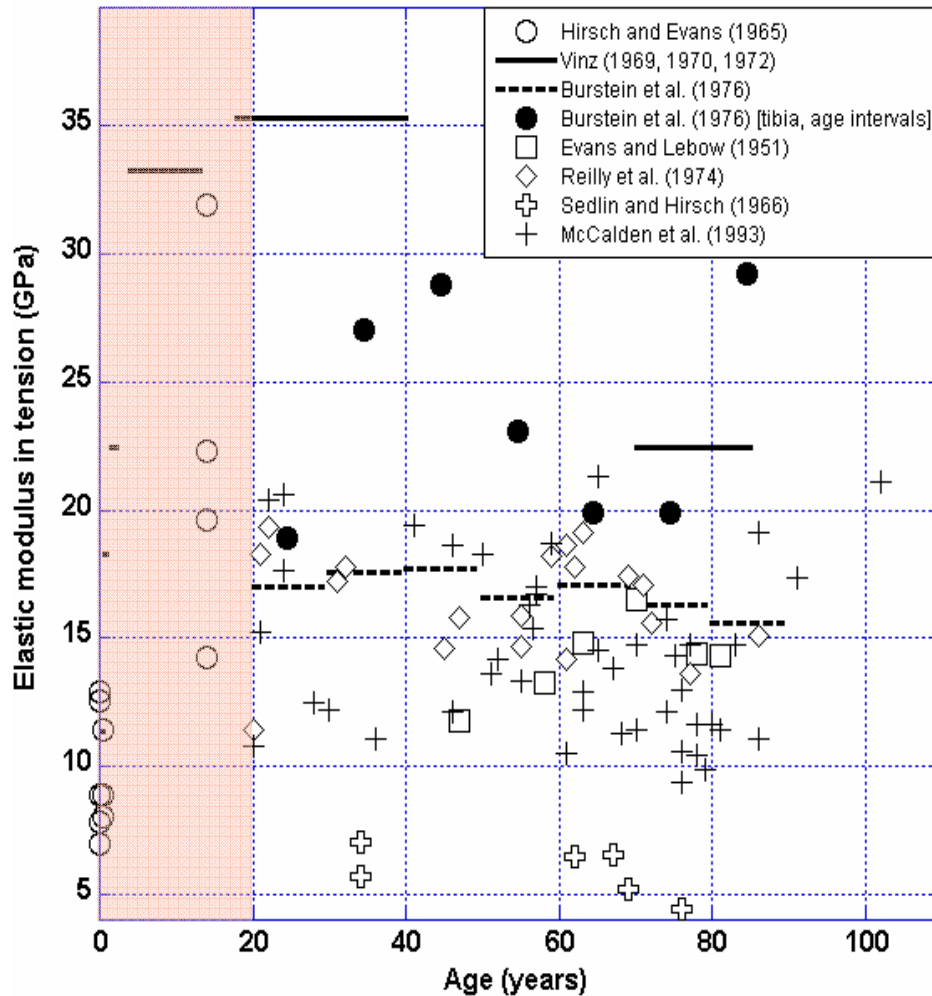
# Given Variance What Can be Done?

- Critical review of methodologies – Are there technical explanations for variance?
- Work with variability in material property data for FE validation efforts
  - Include range of data using optimization processes with structural data
  - Provide modelers with entire data set rather than single (mean) values unless review identifies technical explanation for variance



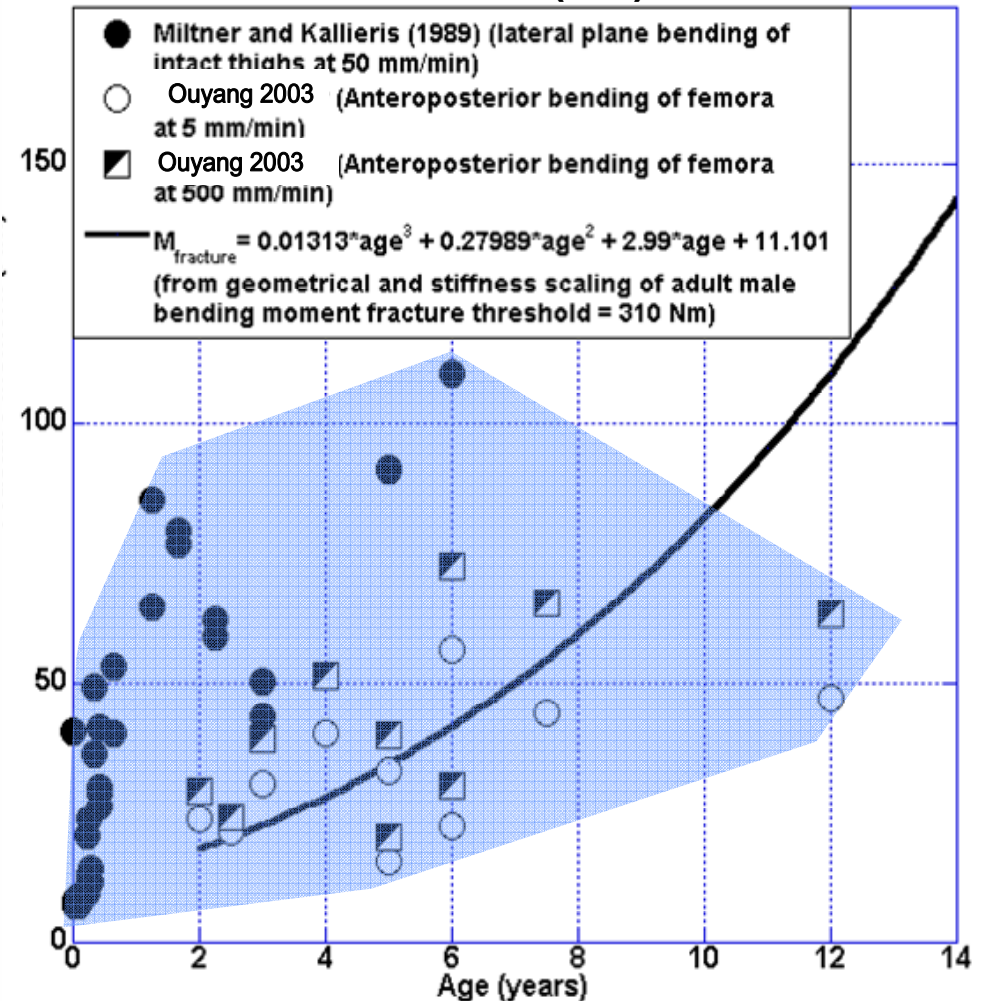
# Material Property Data

Elastic modulus of human cortical femur in tension

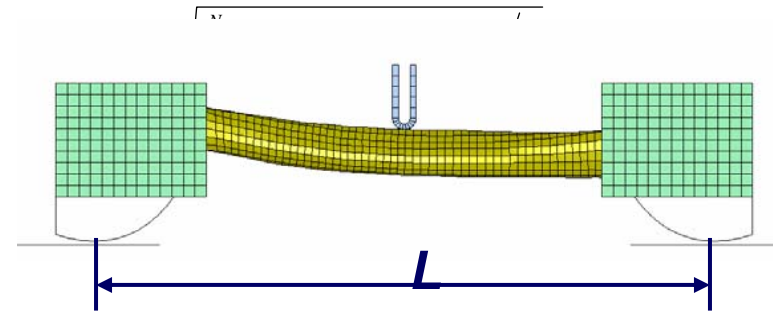
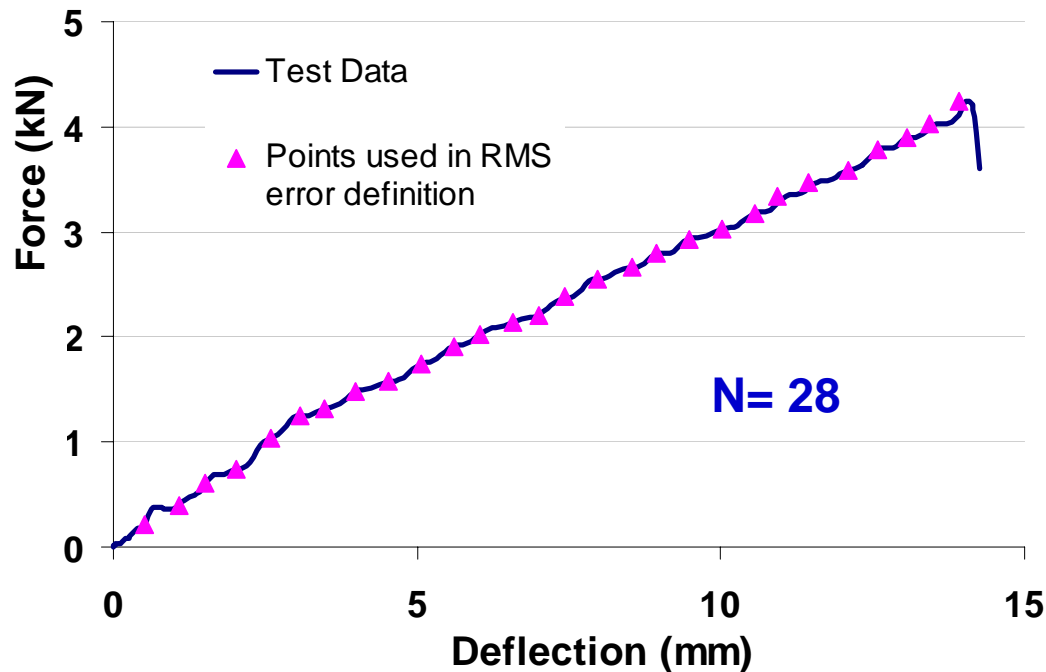


# Structural Validation Data

Failure moment (Nm) of femur



# Optimization of Material Property Parameters



the root-mean square (RMS) error

$$f(x) := \sqrt{\sum_{k=1}^N [F_{sim}(d_k) - F_{test}(d_k)]^2 / N}$$

**Objective function**

$$\min f(x)$$

# Cortical Bone – Isotropic Elastic-Plastic Material Model

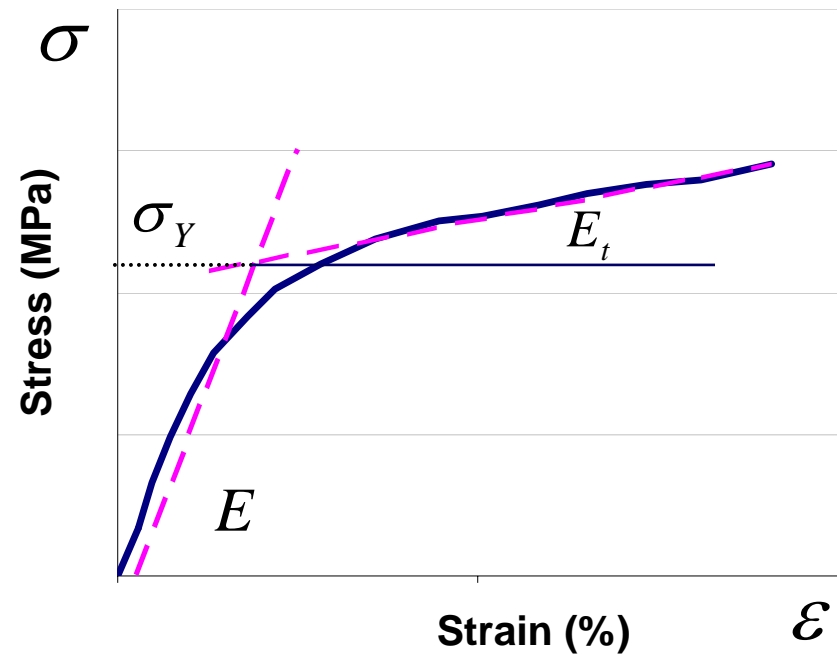
Design Variables



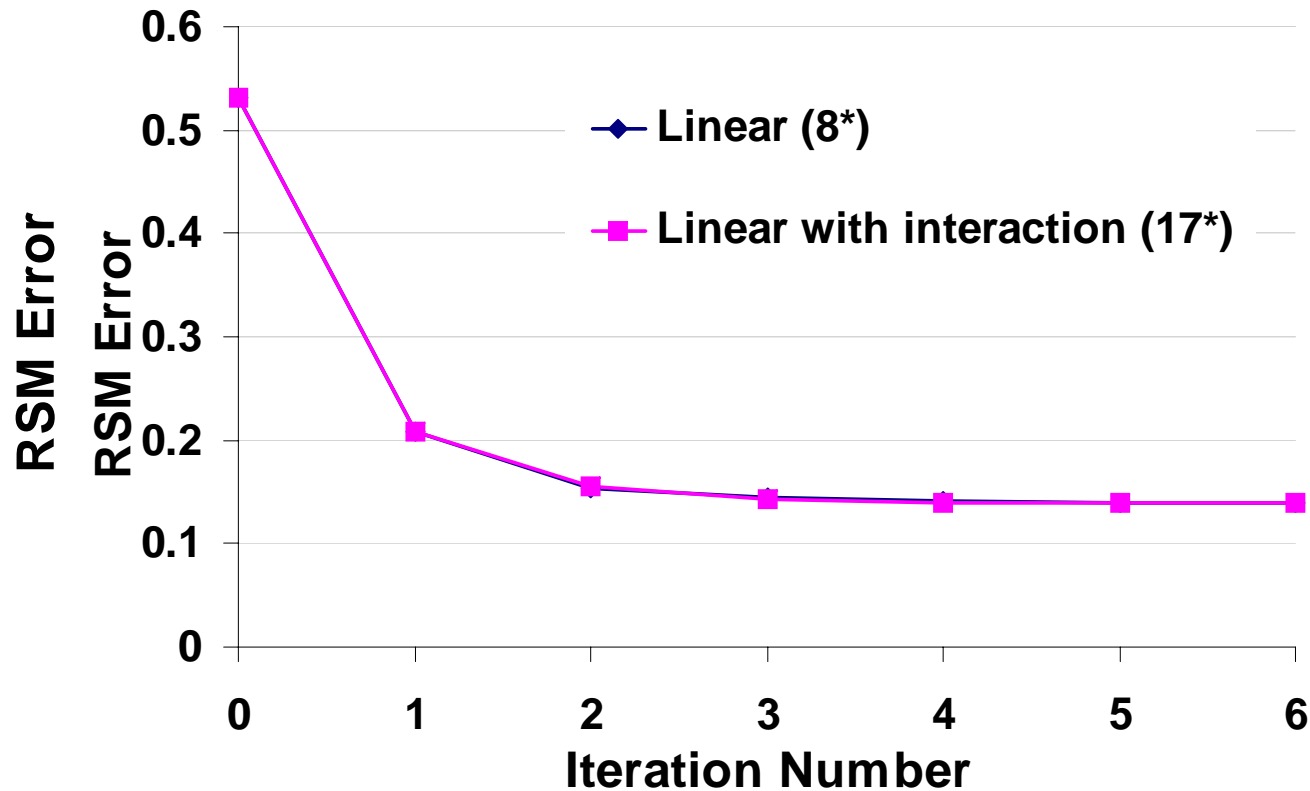
Design Ranges



Material Parameter	Units	Test Data
$E$	GPa	6-21
$\sigma_Y$	MPa	87-139
$E_t$	MPa	0.63-1.3
$\nu$	-	0.34-0.38



# Iterative Parameter Identification – Isotropic Elastic-Plastic Material Model



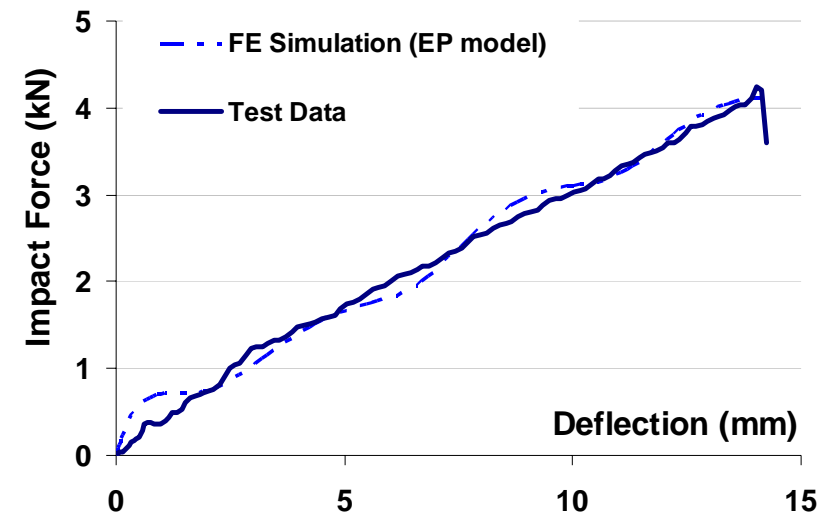
$$f(x) \approx a_{00} + a_{10}x_1 + \dots + a_{0n}x_n + a_{12}x_1x_2 + \dots + a_{nn-1}x_nx_{n-1}$$

$$f(x) \approx a_{00} + a_{10}x_1 + \dots + a_{0n}x_n + a_{12}x_1x_2 + \dots + a_{nn-1}x_nx_{n-1}$$

$$+ a_{11}x_1^2 + a_{21}x_1x_2 + \dots + a_{1n}x_1x_n + a_{22}x_2^2 + \dots + a_{nn}x_n^2$$

# Iterative Parameter Identification – Isotropic Elastic-Plastic Material Model

Material Parameter	SRSM Approximations*			
	L	LI	E	Q
$E$ (GPa)	14.635	14.644	14.624	14.628
$\sigma_Y$ (MPa)	133	132.6	133	132.9
$E_t$ (MPa)	1024	1230	801	874
$\nu$ (-)	0.3435	0.358	0.371	0.365
<b>RMS Error</b>	0.1386	0.1387	0.1387	0.1388

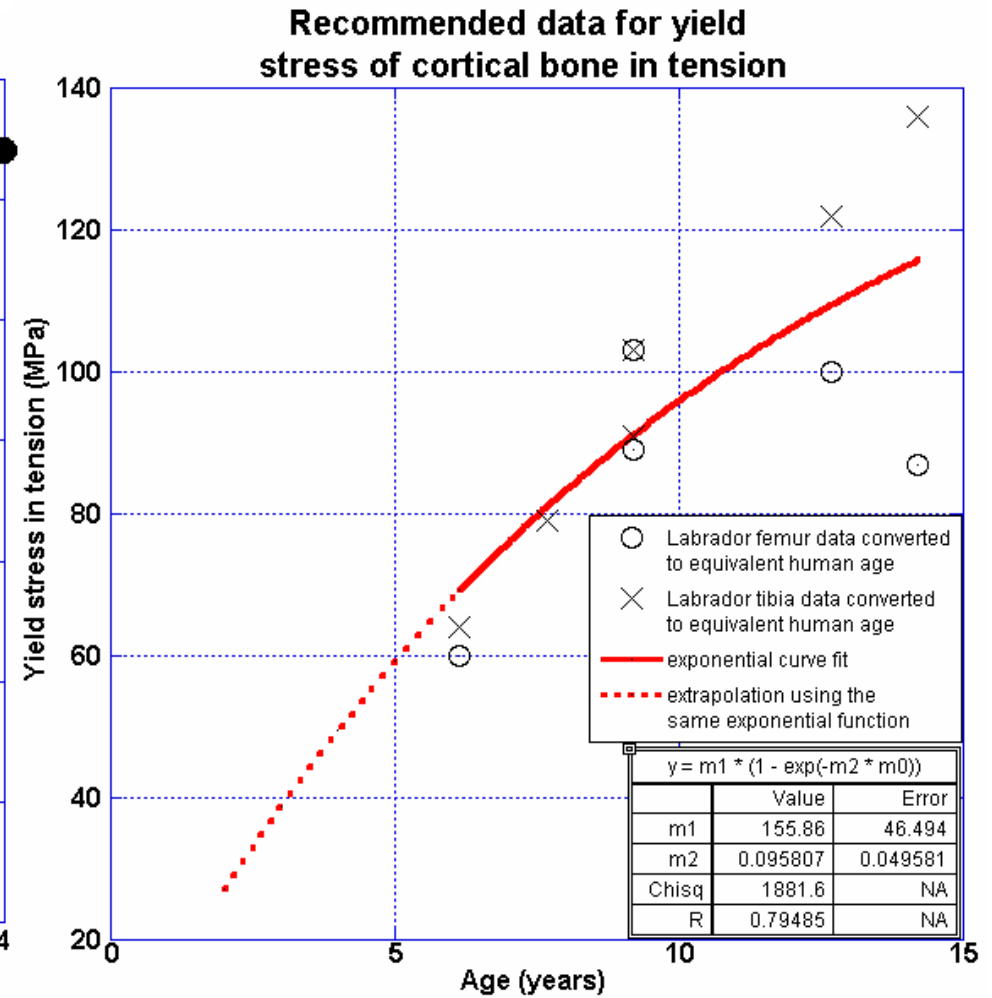
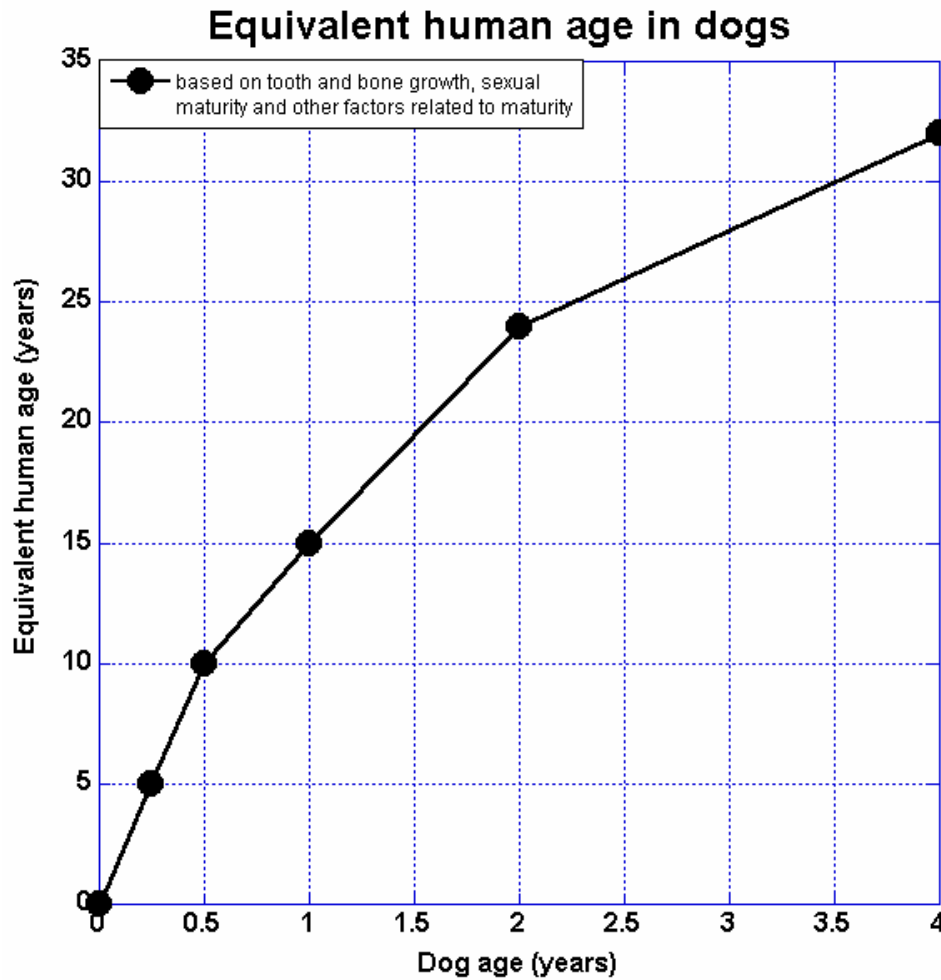


\* L-Linear; LI-Linear with Interaction; E-Elliptic; Q-Quadratic

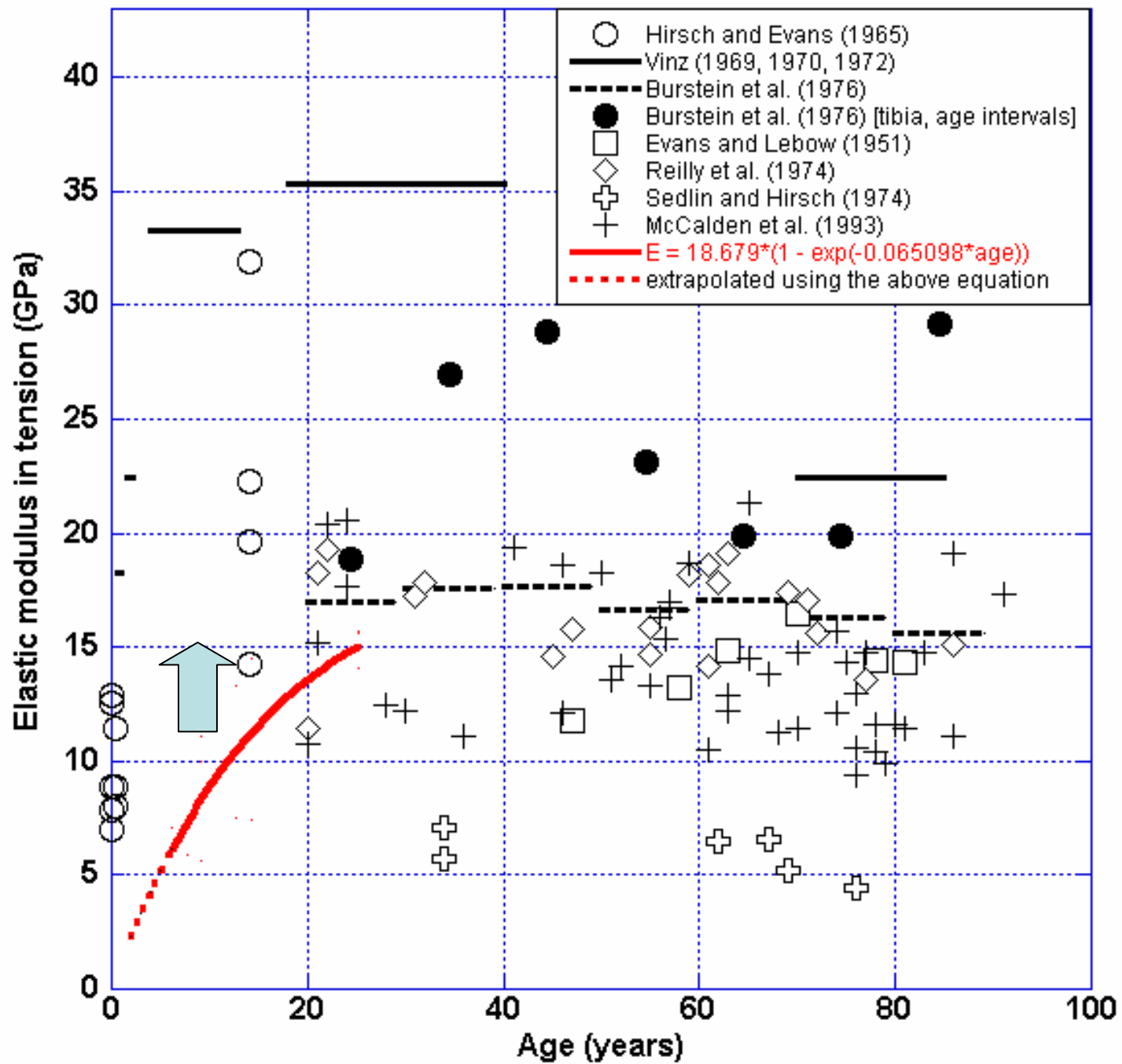
# Given Lack of Data What Else Can be Done?

- Fill in gaps with Animal Data?
  - Questions related to anthropometric and physiologic differences that prevent direct interpretation of age-related factors
  - However, general form of age-related material property changes may be applicable (e.g., U of Washington)

# Canine Bone Tests



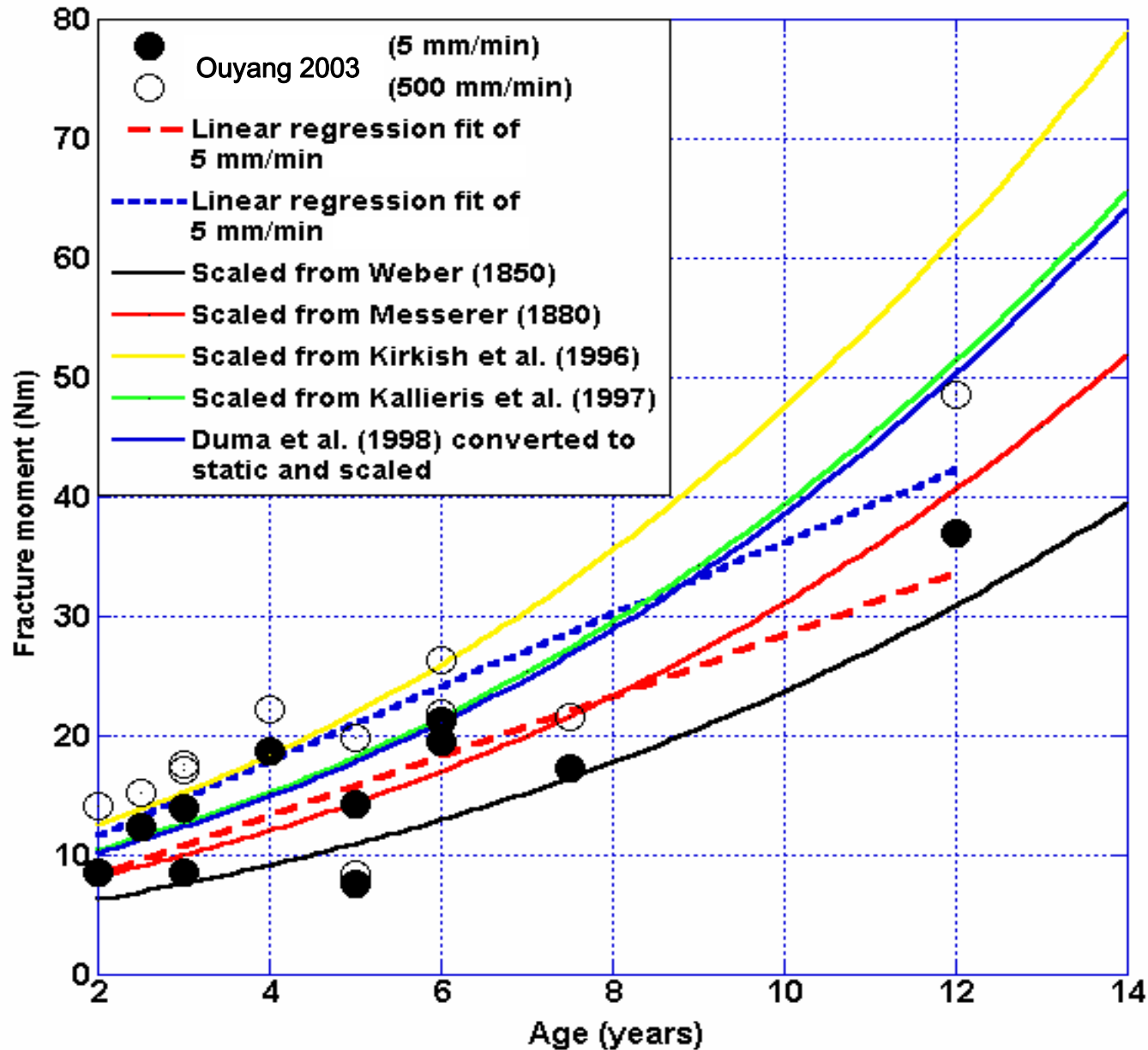
# modulus of cortical bone in tension



# Scaling of Data

- We know that data scaling (geometric, material property) from adult to child is not applicable in certain body components/tissues
- Are there tissues and structures for which it is appropriate?
- If so, can we generalize for areas in which we are currently lacking actual data

# Validation of Geometric and Modulus Scaling



# SCIB Pediatric Data Repository

- Consolidation of data to facilitate accessibility and to complement ongoing FE model development
- Inclusion/Exclusion of data and assessment of data variance
- Expansion of data pool by animal tests (shape functions) and scaling (subsequent to validation)

# SCIB Digital Child

**SCIB  
Modeling  
Group**

**Core Group**

**Head/  
Brain**

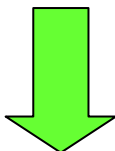
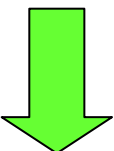
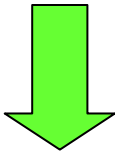
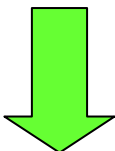
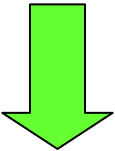
**Neck**

**Thorax**

**Abdomen**

**Pelvis/  
Ext**

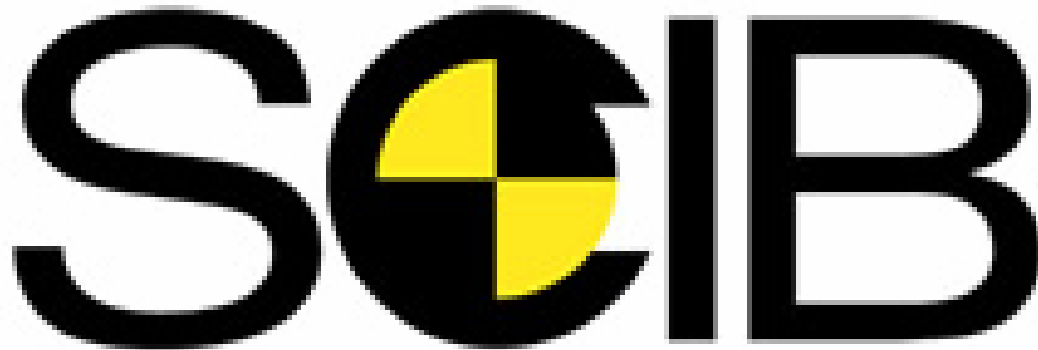
**Whole  
Body**



**Tissue Specific Properties**

# SCIB Pediatric Data Repository

- Develop SCIB resources to assist Digital Child Modeling Efforts
  - Regional or Tissue specific groups
  - Core Group (Scaling, optimization, validity)
- Data stored digitally for widescale accessibility among SCIB members and beyond
- Text (book chapter) providing overview of the process, techniques, and data



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