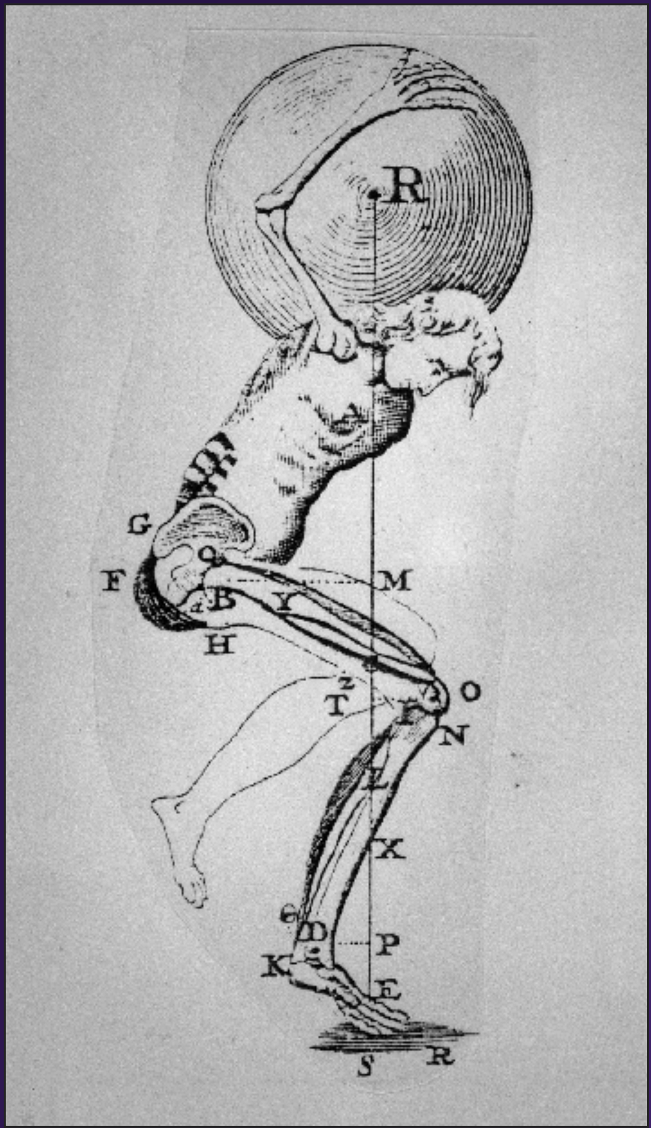


Musculoskeletal Biomechanics

BIOEN 520 | ME 599R

Session 12B

Biomechanics of the Spine

Review: Session 12A...

- Reviewed the types and function of joints...
- Discussed common features of synovial (diarthrodial) joints
- Discussed which mechanical properties of joints are generally of interest and why
- Examined the #1 joint disease and how abnormal mechanics might play a role
- Discussed joint replacement systems

Session 12B Discussion Questions…

[Q]: What are the anatomical regions and basic structures of the spine?

[Q]: What are the primary functions of the spine?

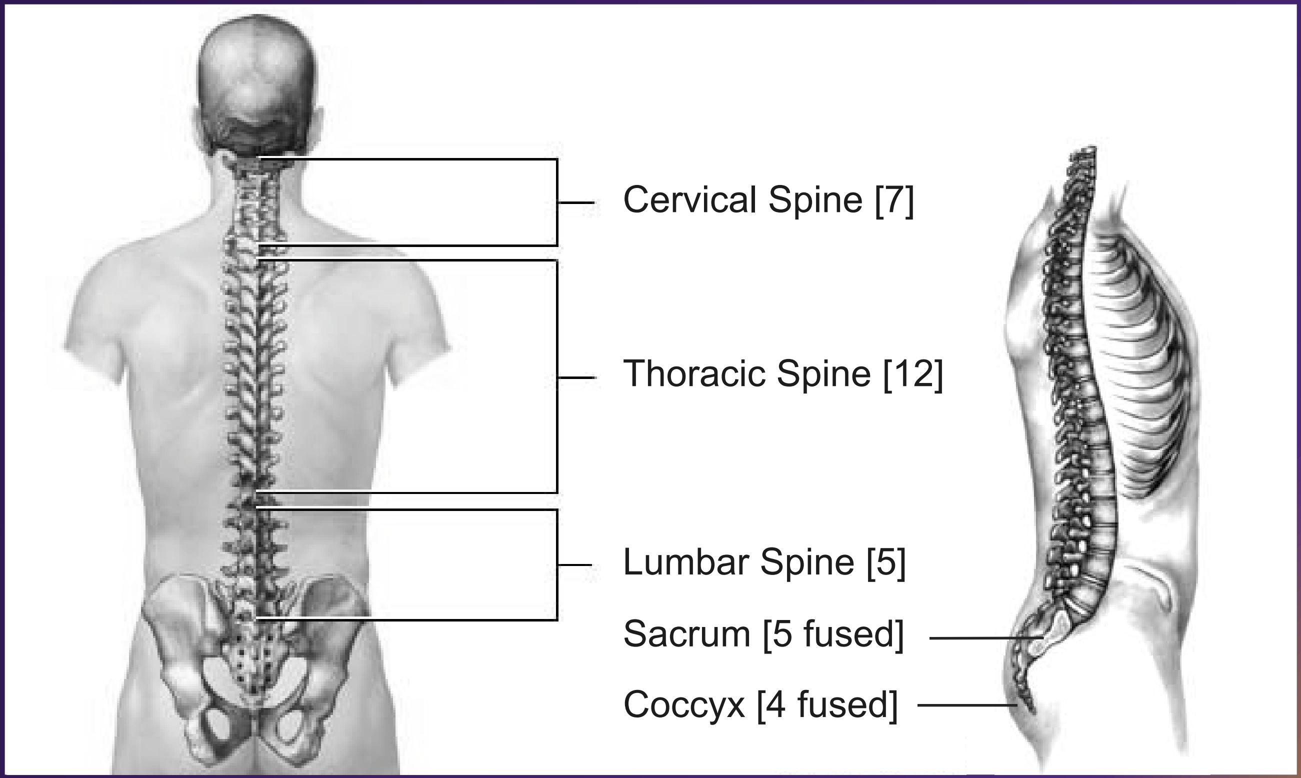
[Q]: How would we test the mechanical properties of the spine?

[Q]: What mechanical properties might we expect?

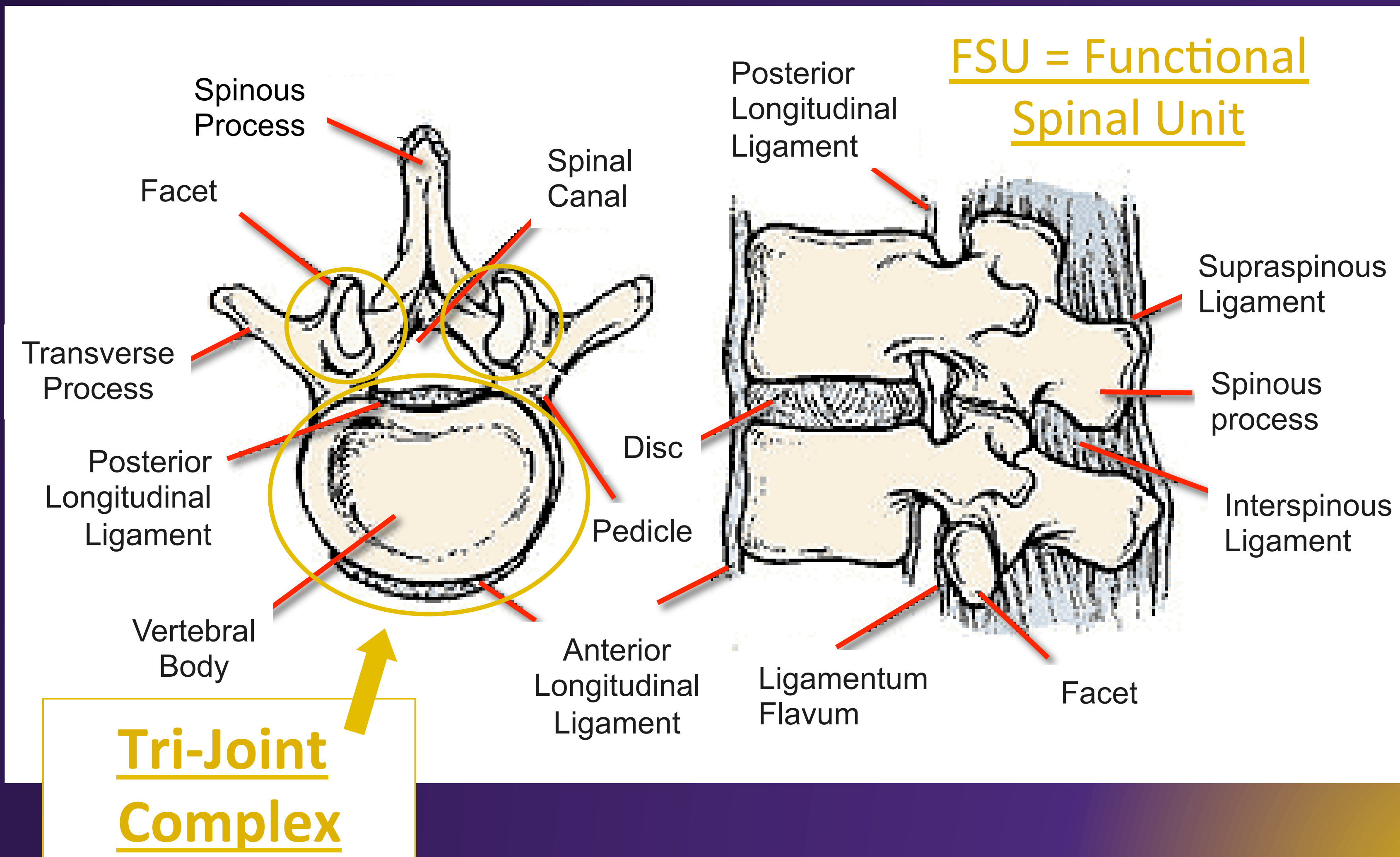
[Q]: Why would we care about these properties?

Structures of the Spine…

[Q]: What are the basic anatomical regions of the spine?



Structures of the Spine…

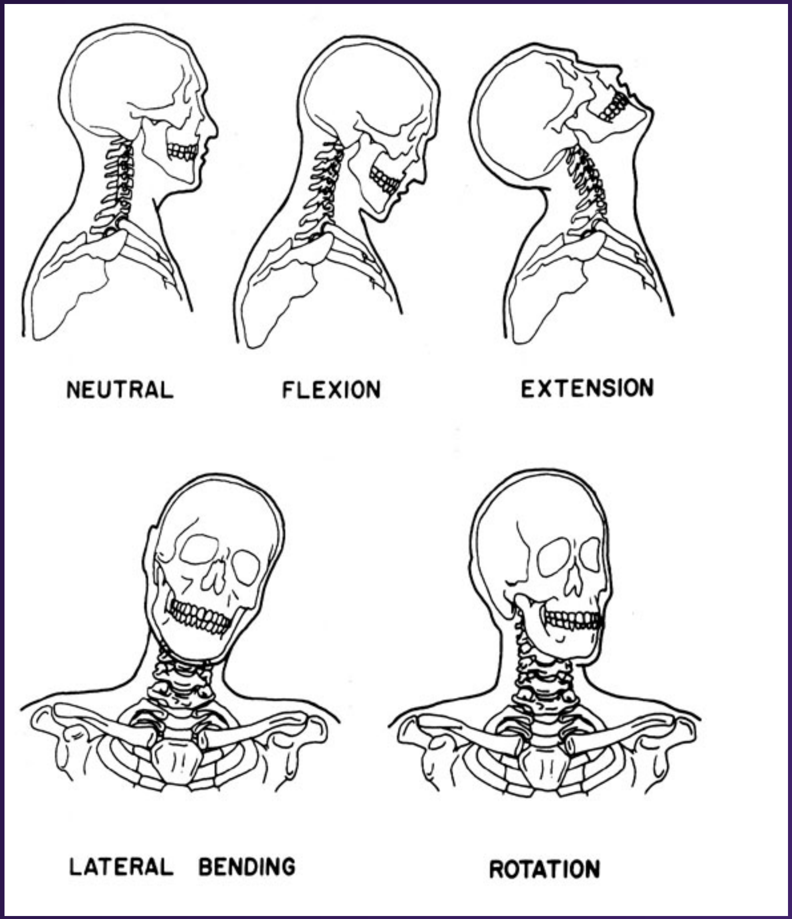


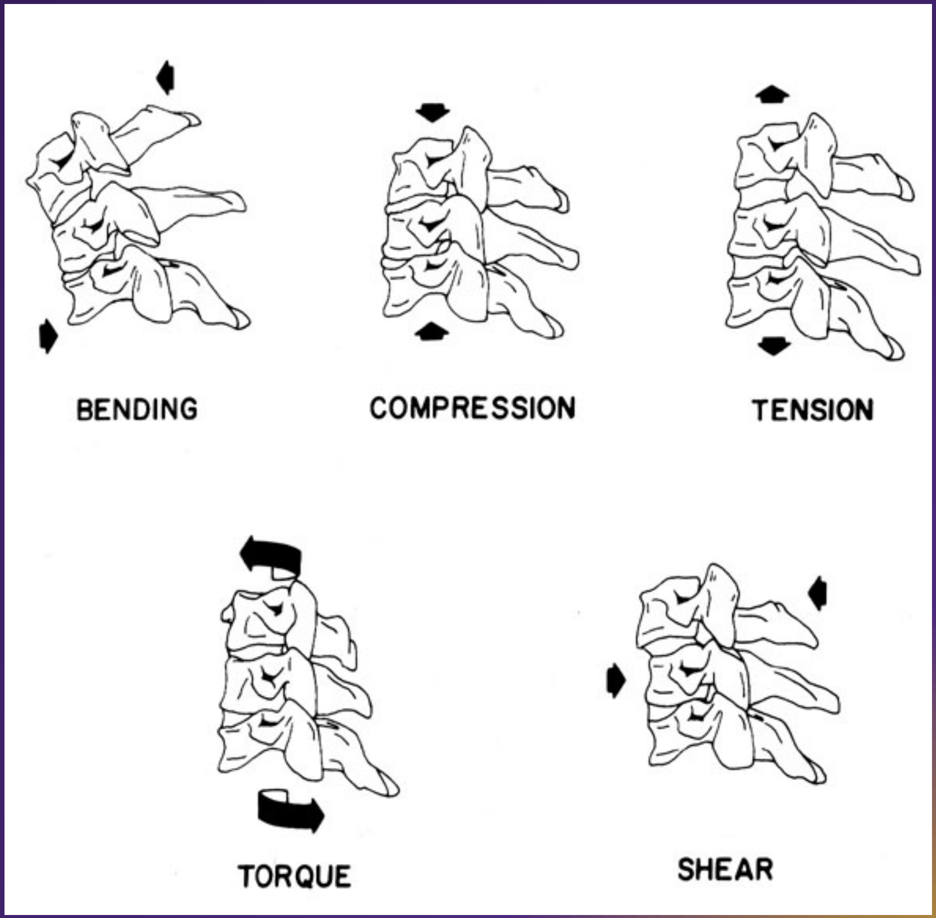
Function of the Spine…

[Q]: What are three primary functions of the spine?

- Support Physiologic Loads (while maintaining stability)…
- Facilitate Movement…
- Protect Neurological Tissues…

Movement of the Spine…





Adapted from Accidental Injury edited by Nahum and Melvin

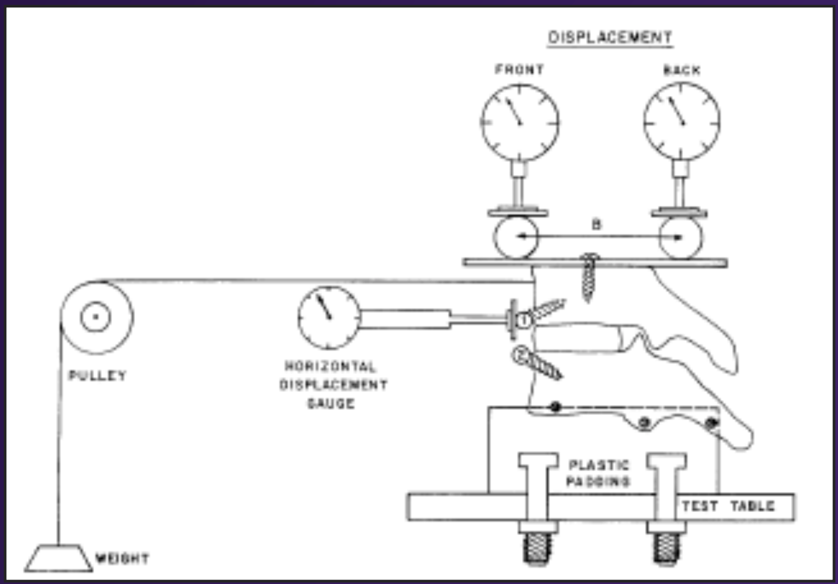
Biomechanical Testing…

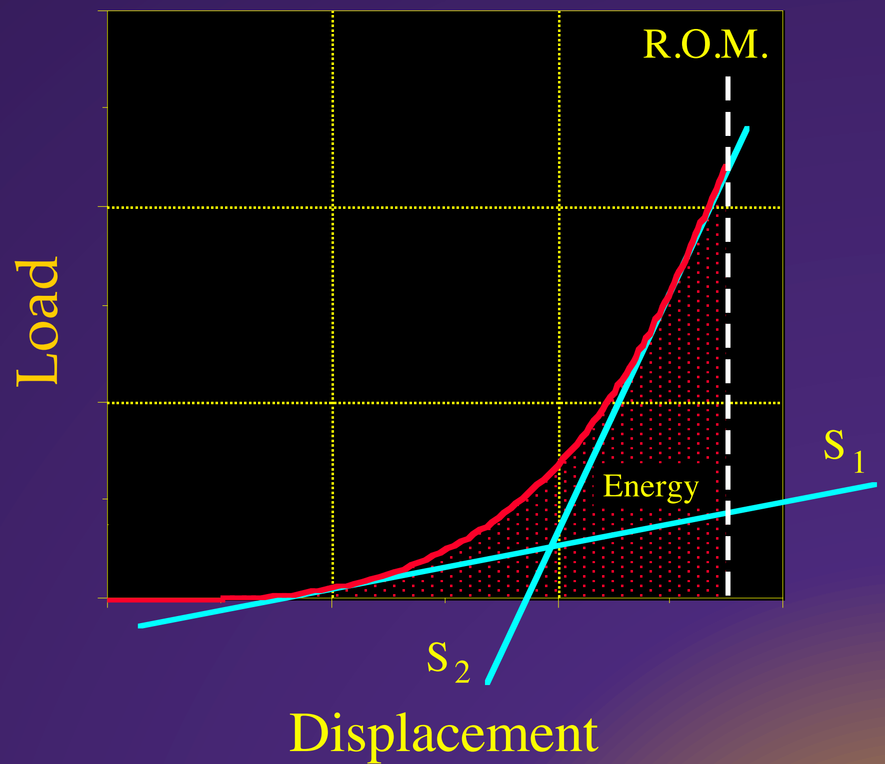
[Q]: How would we test the mechanical properties of the spine?

- Establish mode of testing… *[Tension, bending, etc.]*
- Obtain tissue samples… *[Type, age, gender, samples]*
- Prepare test specimens… *[Dissect, wire, potting]*
- Set up testing apparatus and fixturing… *[Test frame, fixtures, measurement devices, DAQ]*
- Choose test parameters… *[Preconditioning, loading rate, sampling rate, filtering]*
- Run tests…

Biomechanical Testing…

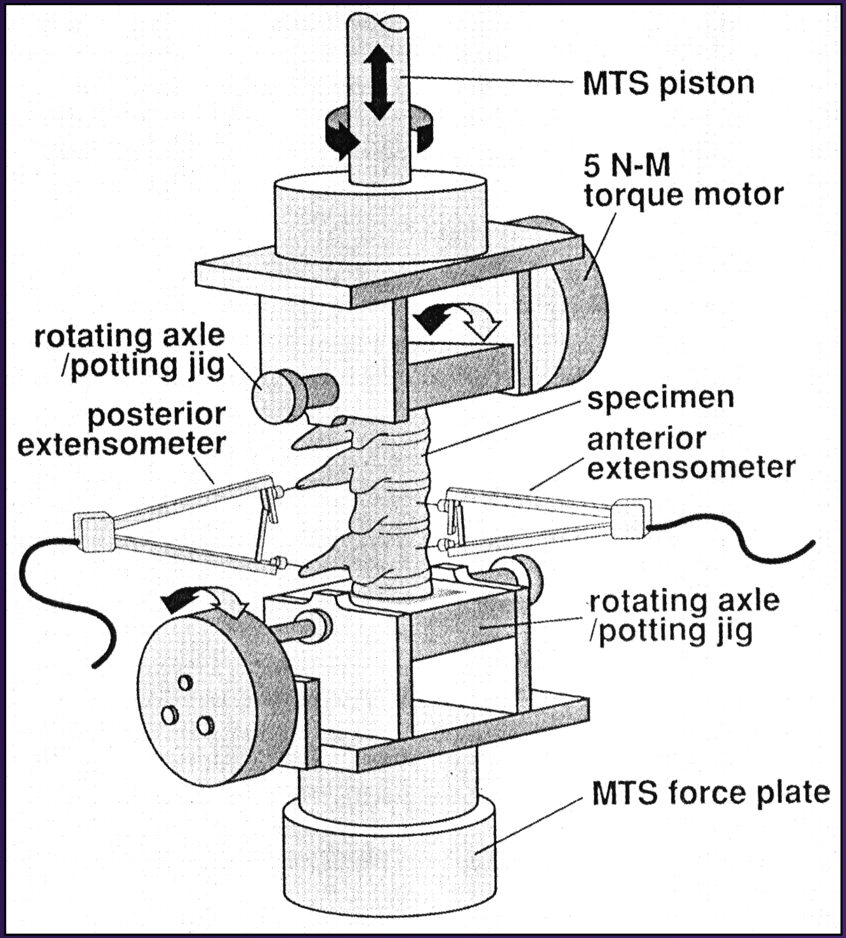
Traditional metrics

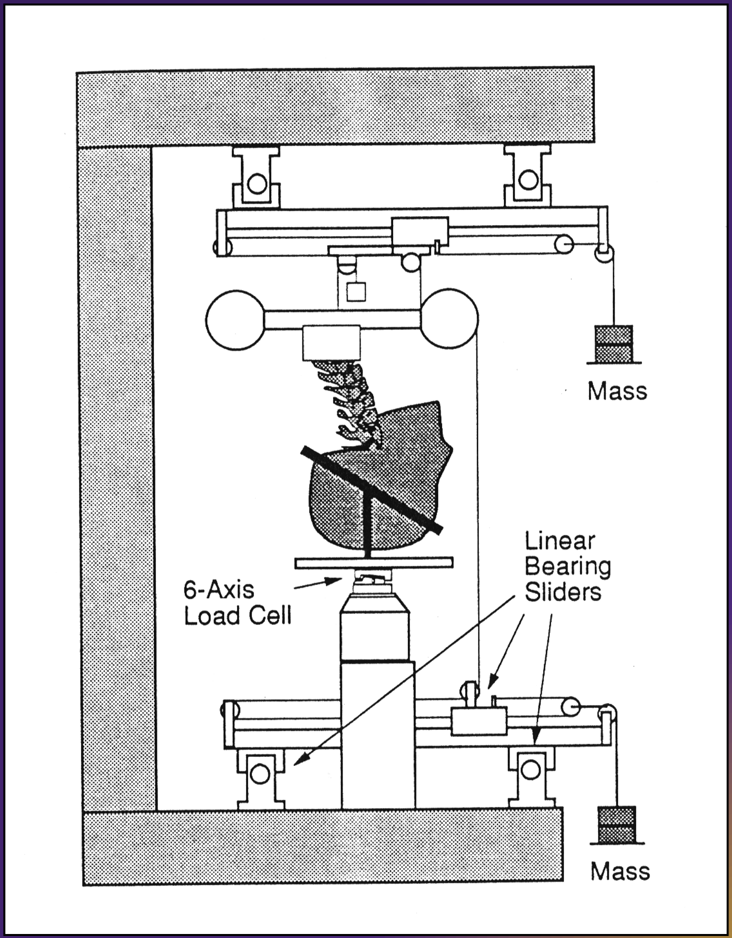




Panjabi (1975)

Biomechanical Testing…





Zdeblick (1992); Nightingale (1997)

Properties of the Spine…

[Q]: What mechanical properties would we expect?

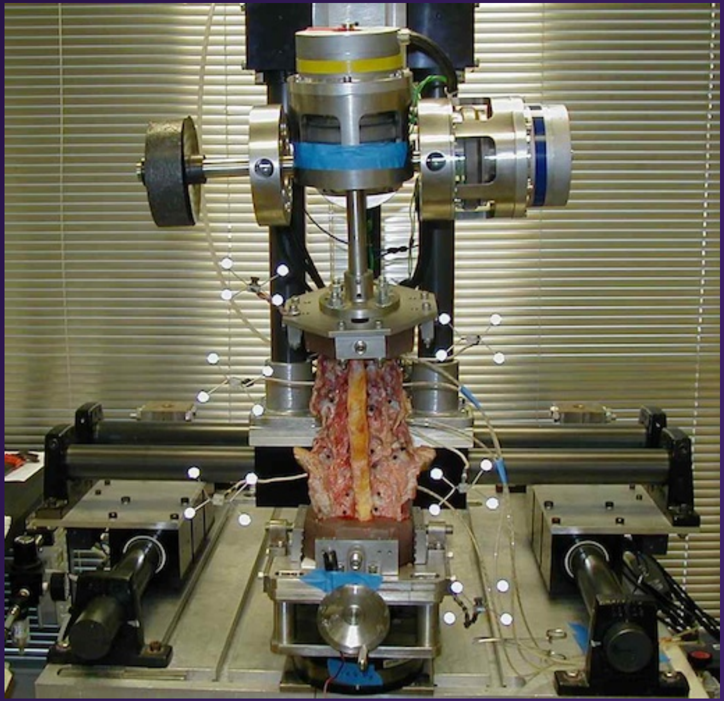
Stiff / Failure	Cervical	Thoracic	Lumbar
Flexion	.3-.5 / 15-20	1-3 / 30-40	2-3 / 75-200
Extension	.5-1 / 16-21	2-3	2-3
Lat. Bending	.5-1 / 24-28	2-3	2-3
Torsion	1-2	2-3	3-5

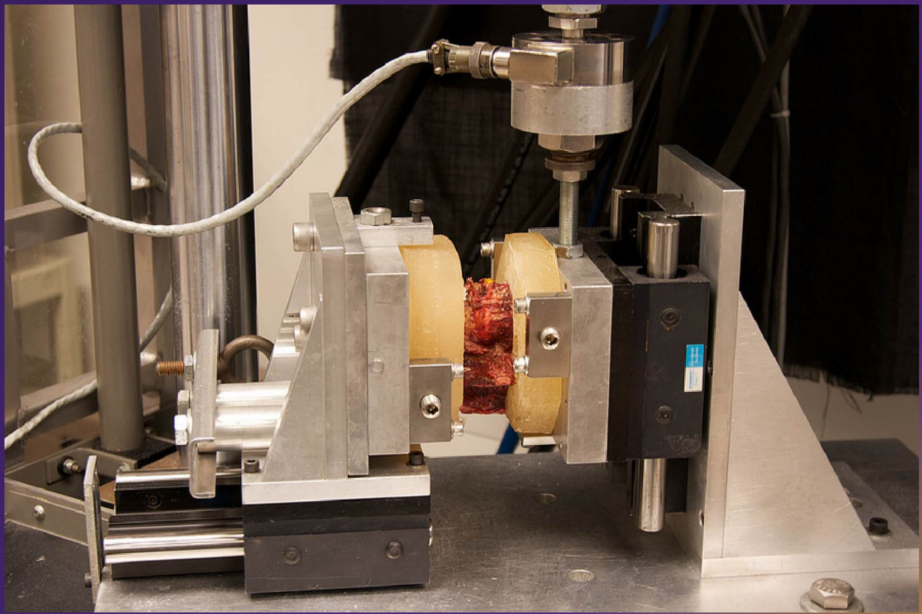
Stiffness: N-m/deg / Failure Load: N-m

White and Panjabi (1990), Adams (1994), Nightingale (2002), Ching (2004)

Biomechanical Testing…

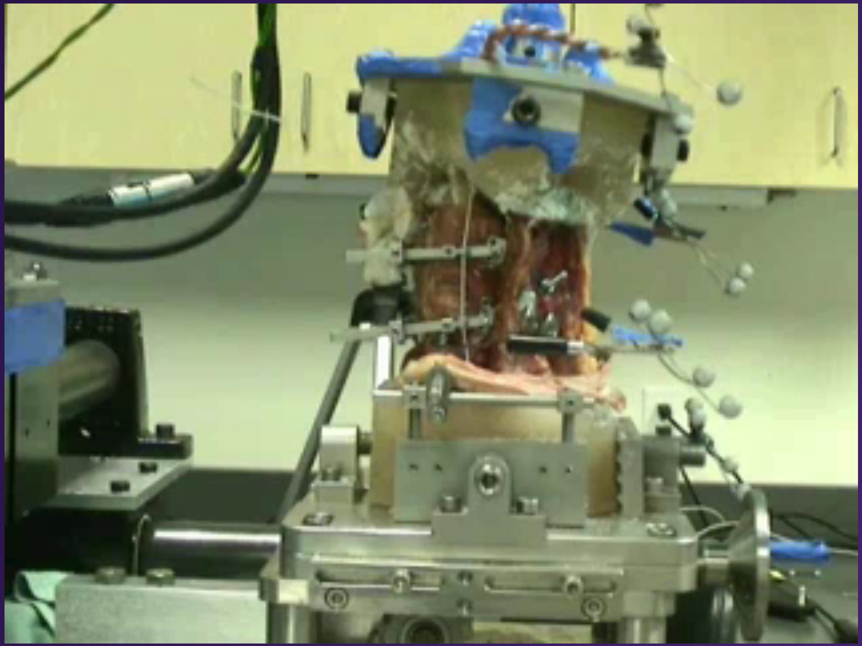
ABL Spine Simulator / Shear testing

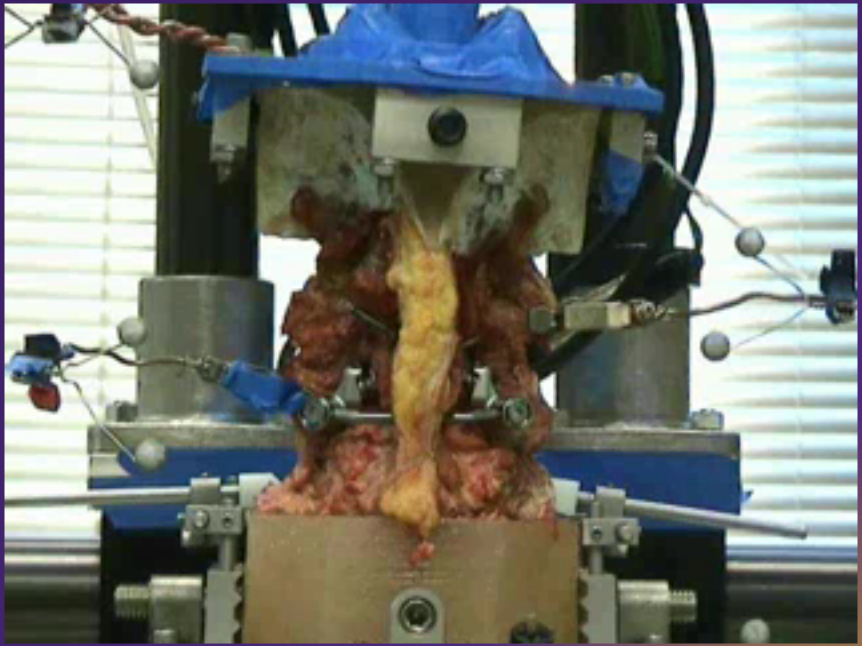




Biomechanical Testing…

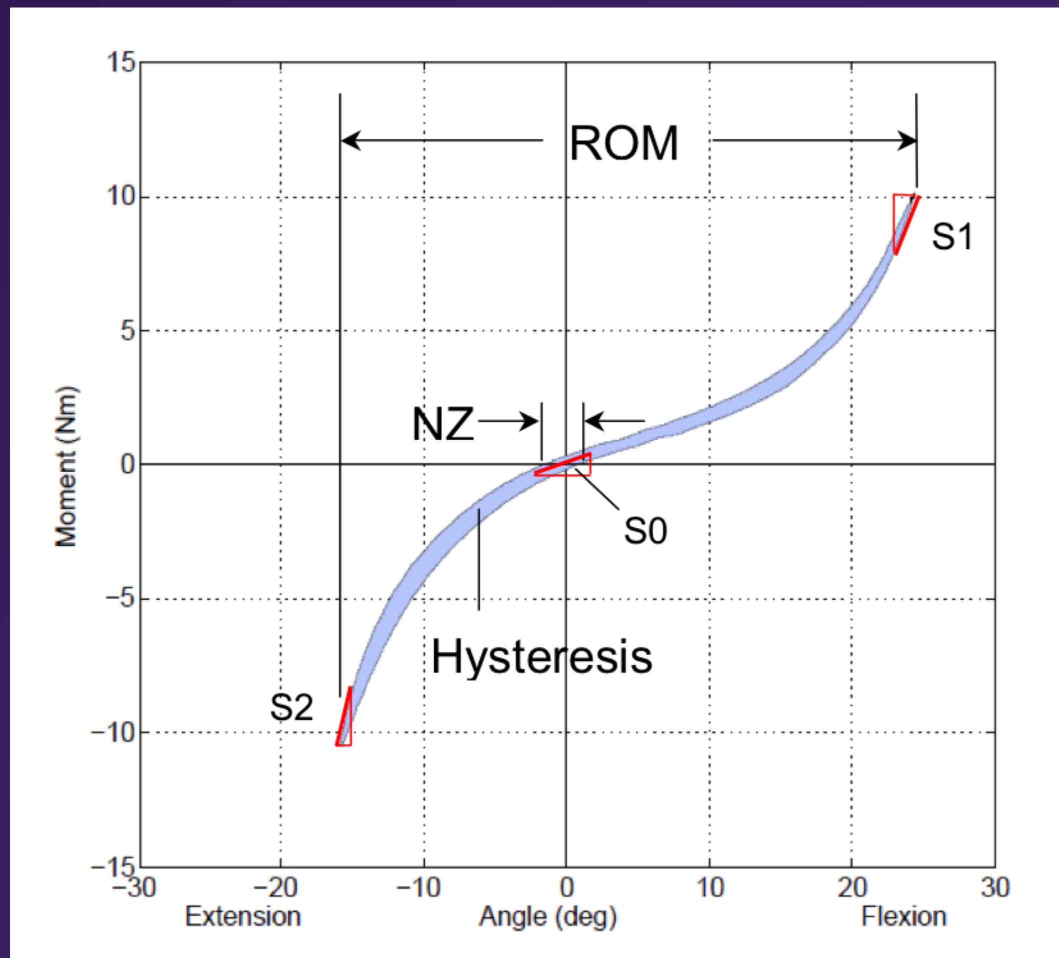
ABL Spine Simulator





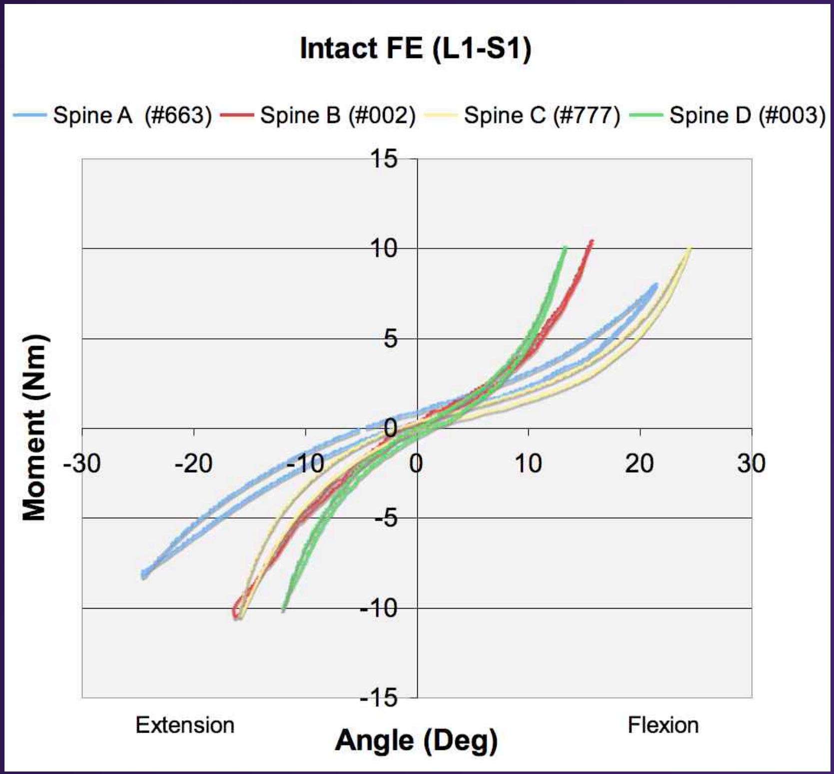
Biomechanical Testing…

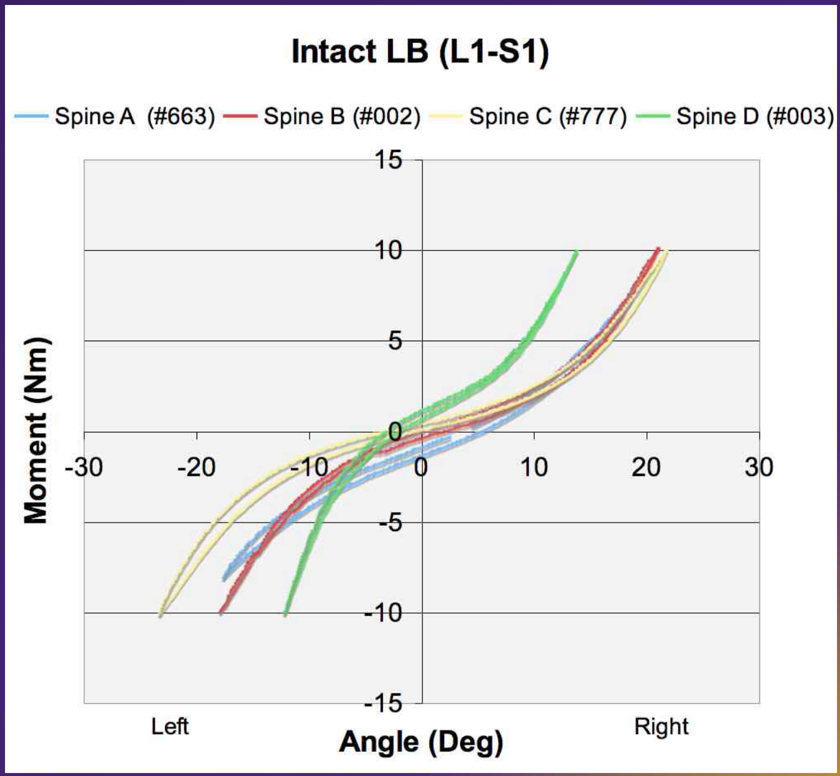
Our metrics



Properties of the Spine…

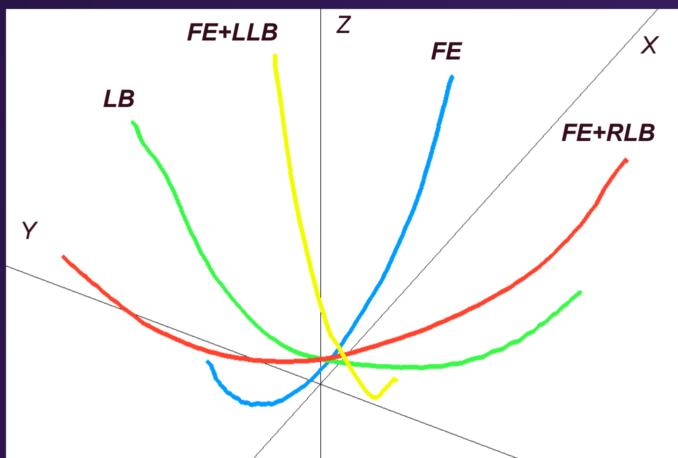
Typical plots…

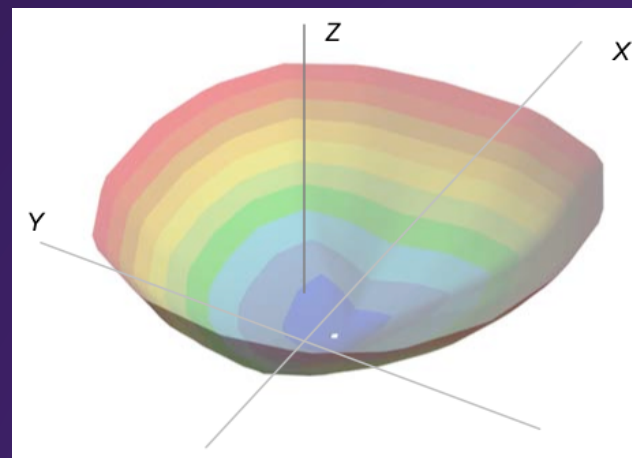


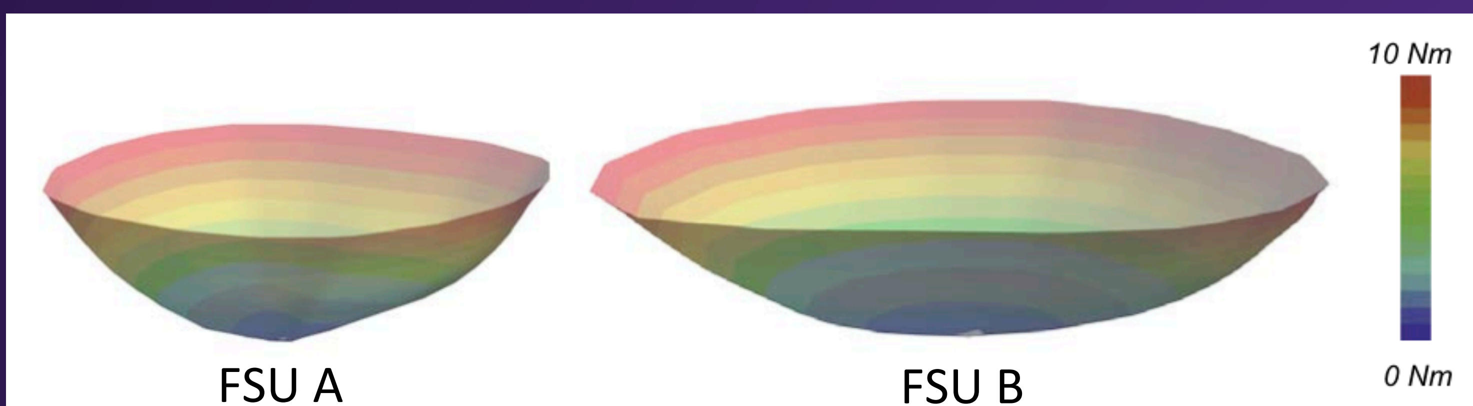


Properties of the Spine…

Non-traditional plots…



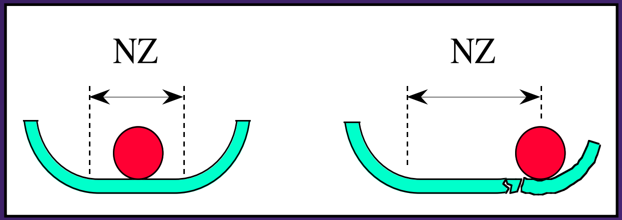




Properties of the Spine…

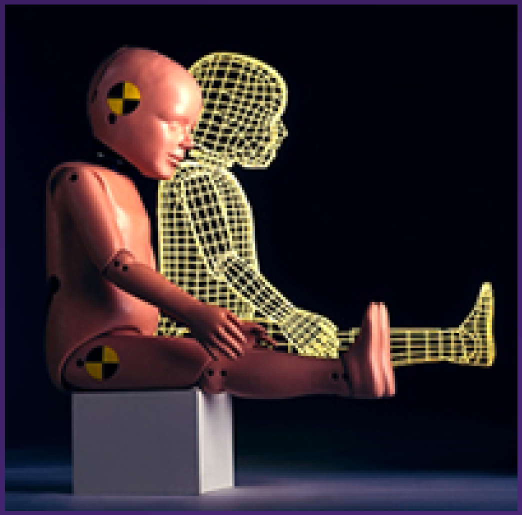
[Q]: Why would we care about their properties?

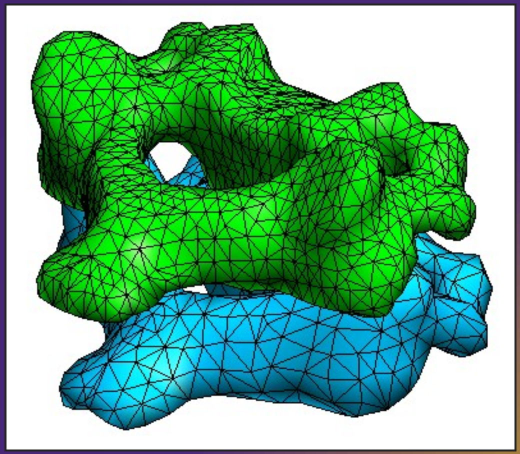
Stability → Treatment



- Design of spinal implants
- Evaluate effectiveness of surgical procedures
- Prevention of spinal injuries

Case Study #1: Pediatric Spine Biomechanics





- Assist in development of child crash test dummies…

- Develop pediatric FE models to evaluate neck inury risk...

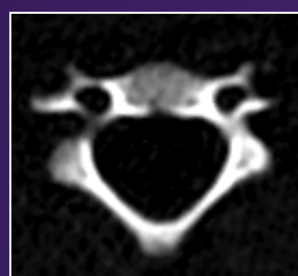
Greatest Challenge???

> Human Pediatric Tissues…

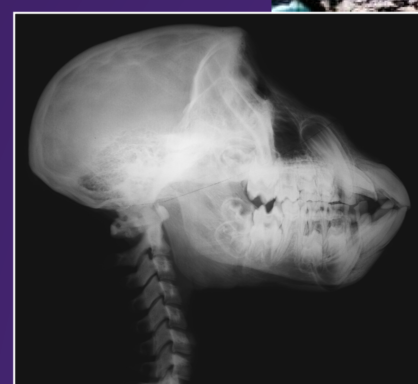
Case Study #1: Pediatric Spine Biomechanics

- Papio Anubis...
  - Similar vertebral architecture
  - Upright cervical alignment
  - Available across wide age range
- Human equivalent age...

3-HE Years



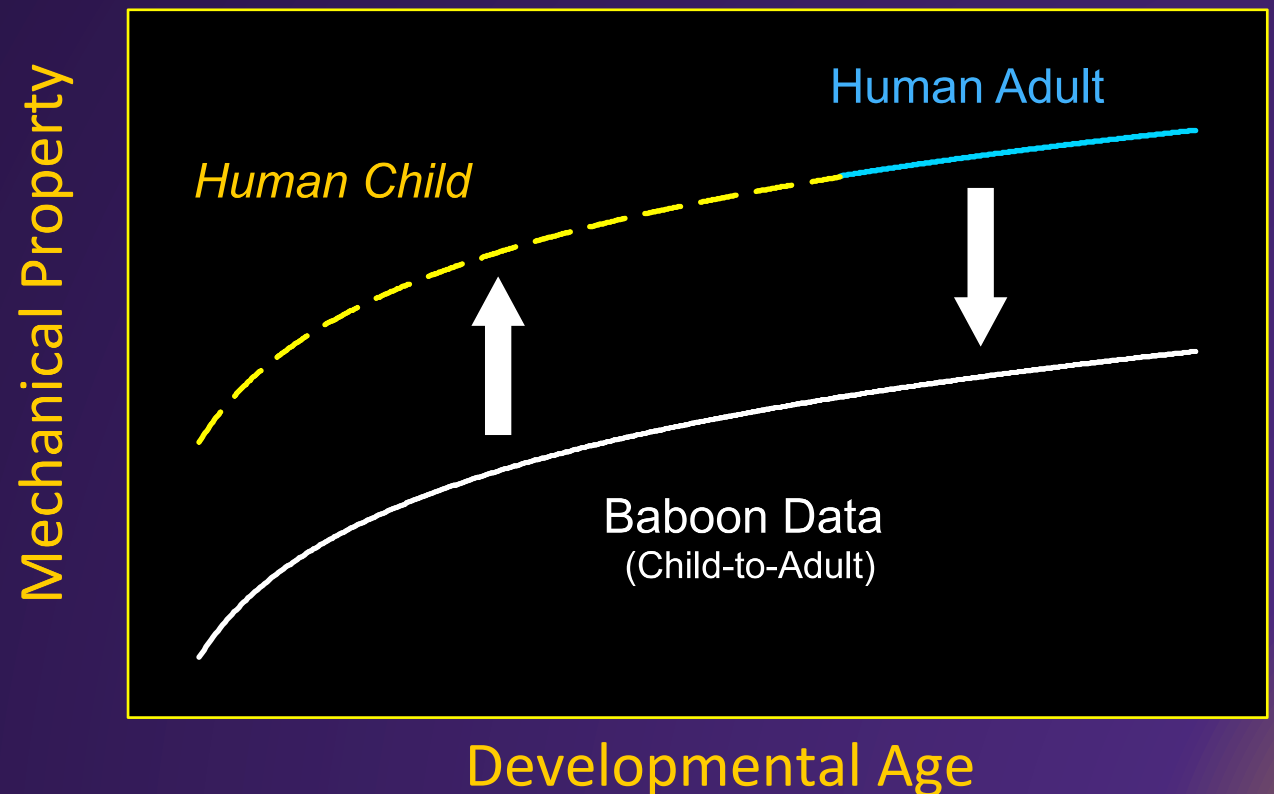
12-HE Years



Tominaga (1995), Svensson (1986), Swindler (1973), Kuhns (1998)

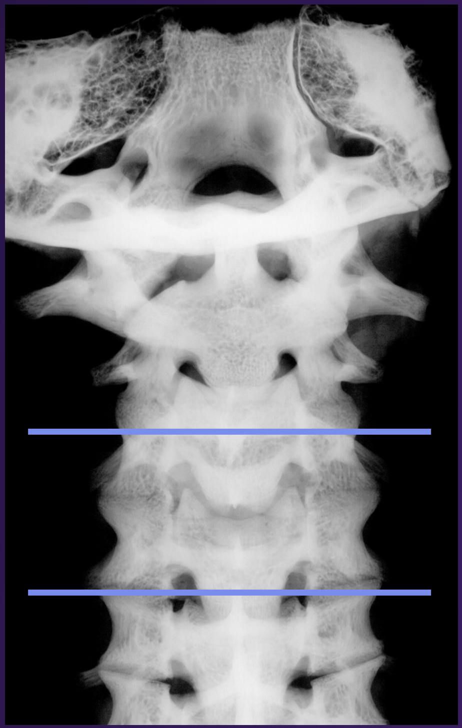
Case Study #1: Pediatric Spine Biomechanics

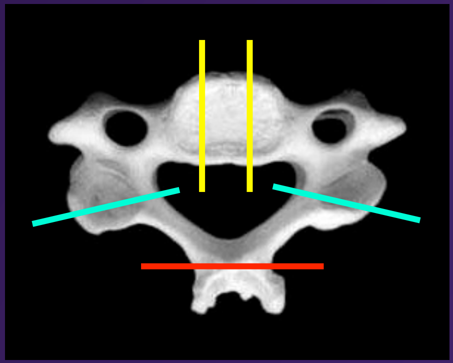
Strategy: Baboon Data to Estimate Human Child

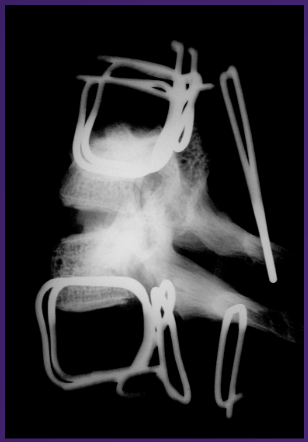


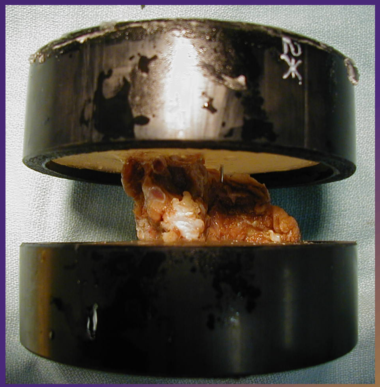
Case Study #1: Pediatric Spine Biomechanics

Specimen Preparation:



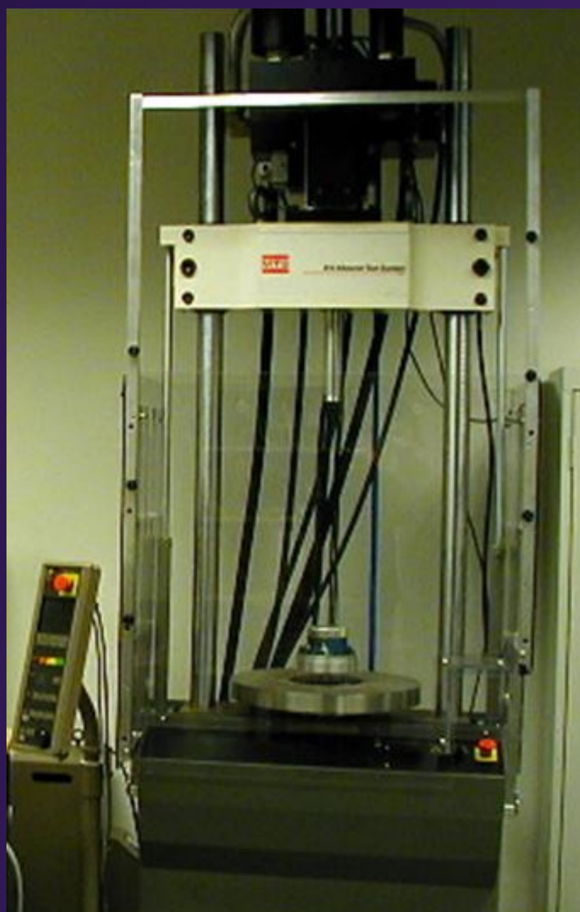


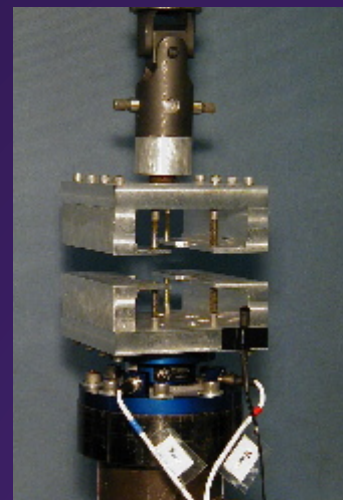


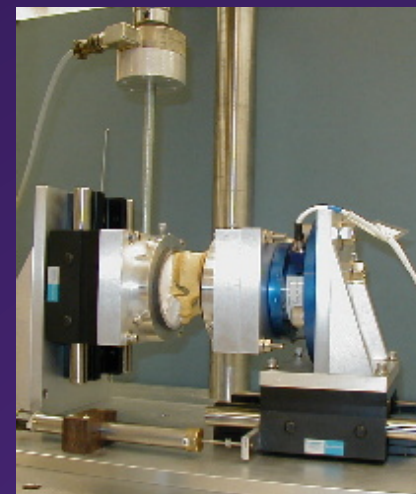


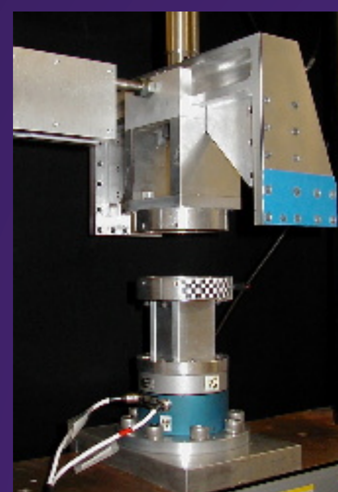
Case Study #1: Pediatric Spine Biomechanics

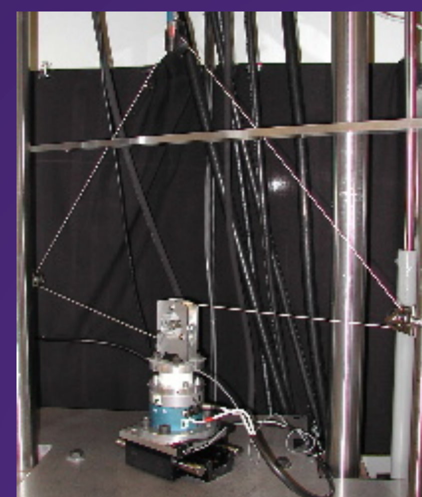
Test Apparatuses





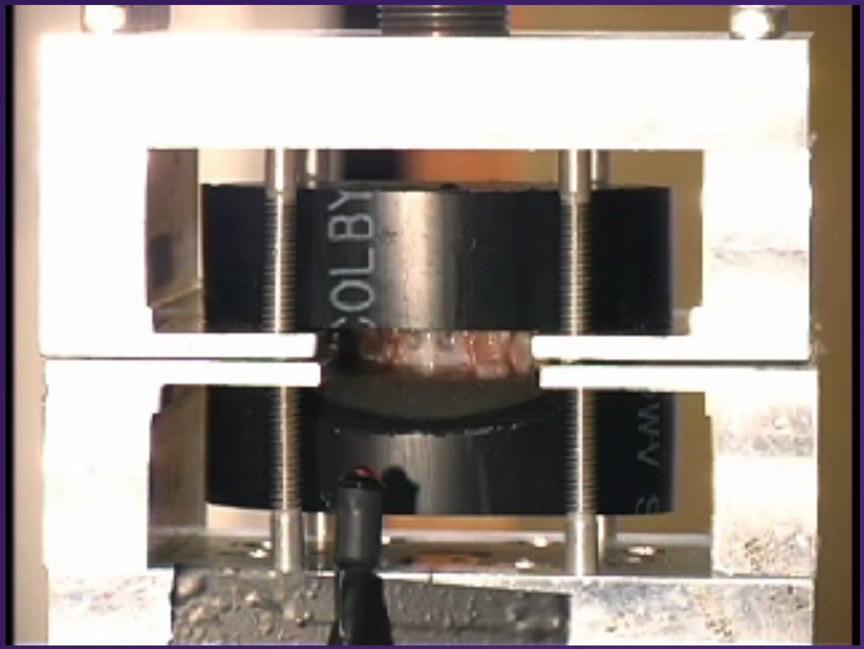




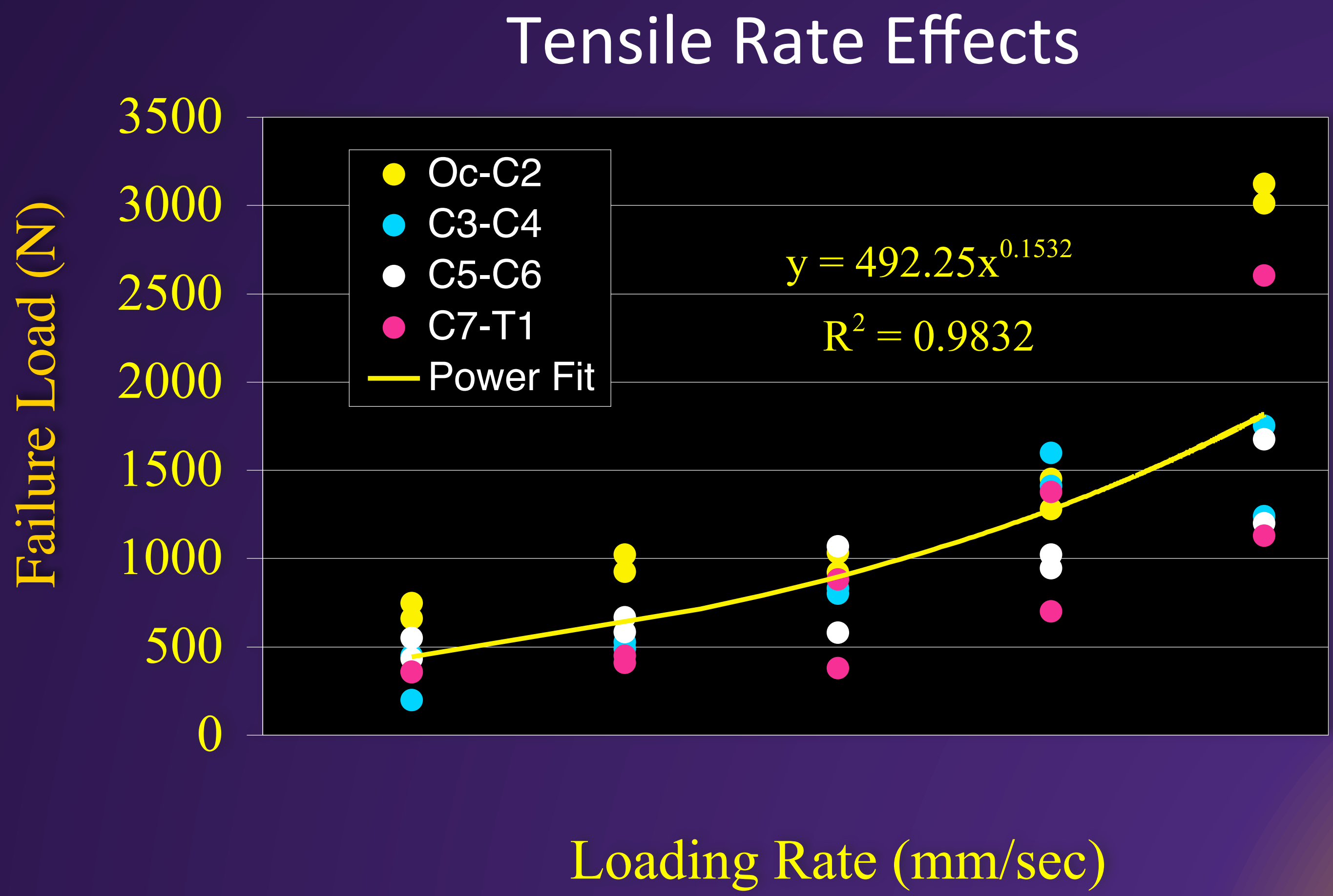


Case Study #1: Pediatric Spine Biomechanics

Tension: C5-C6



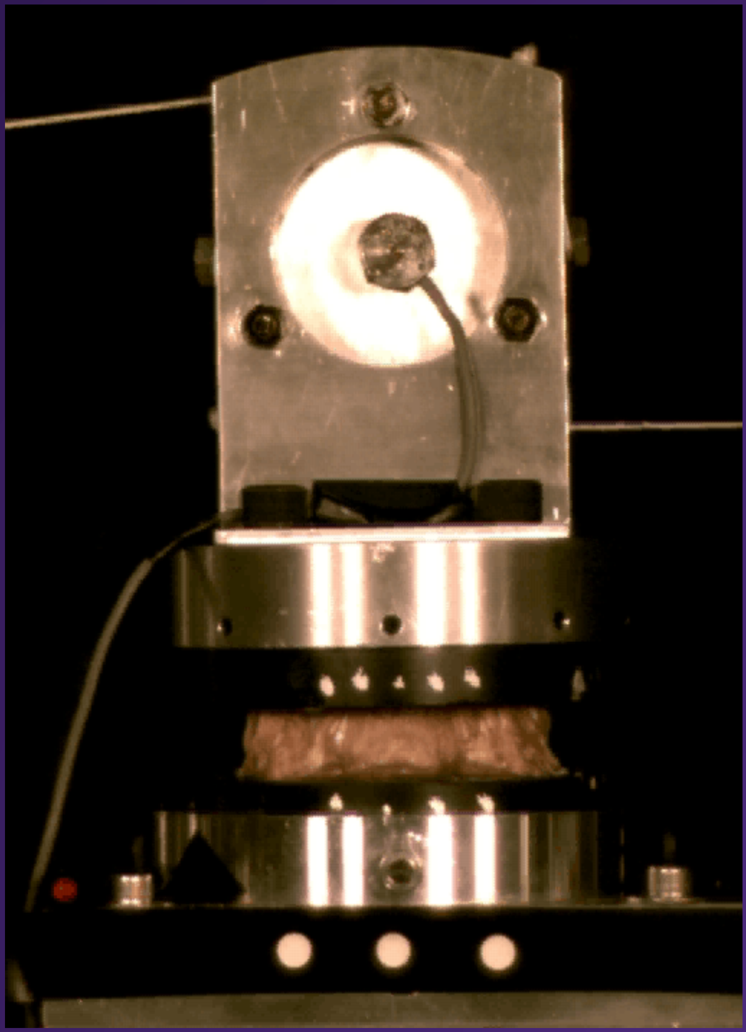
Case Study #1: Pediatric Spine Biomechanics



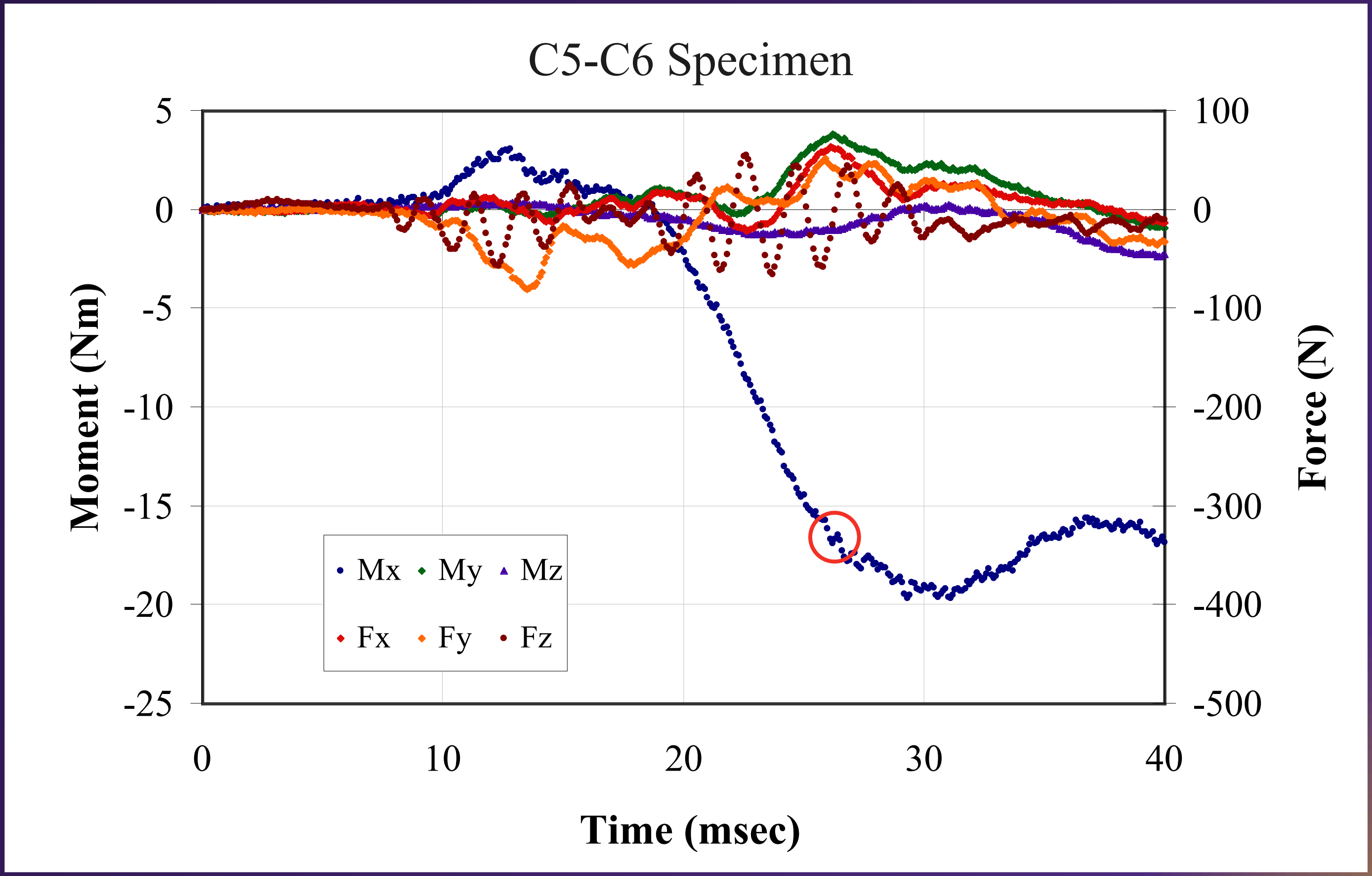
J. Biomechanics (2005)

Case Study #1: Pediatric Spine Biomechanics

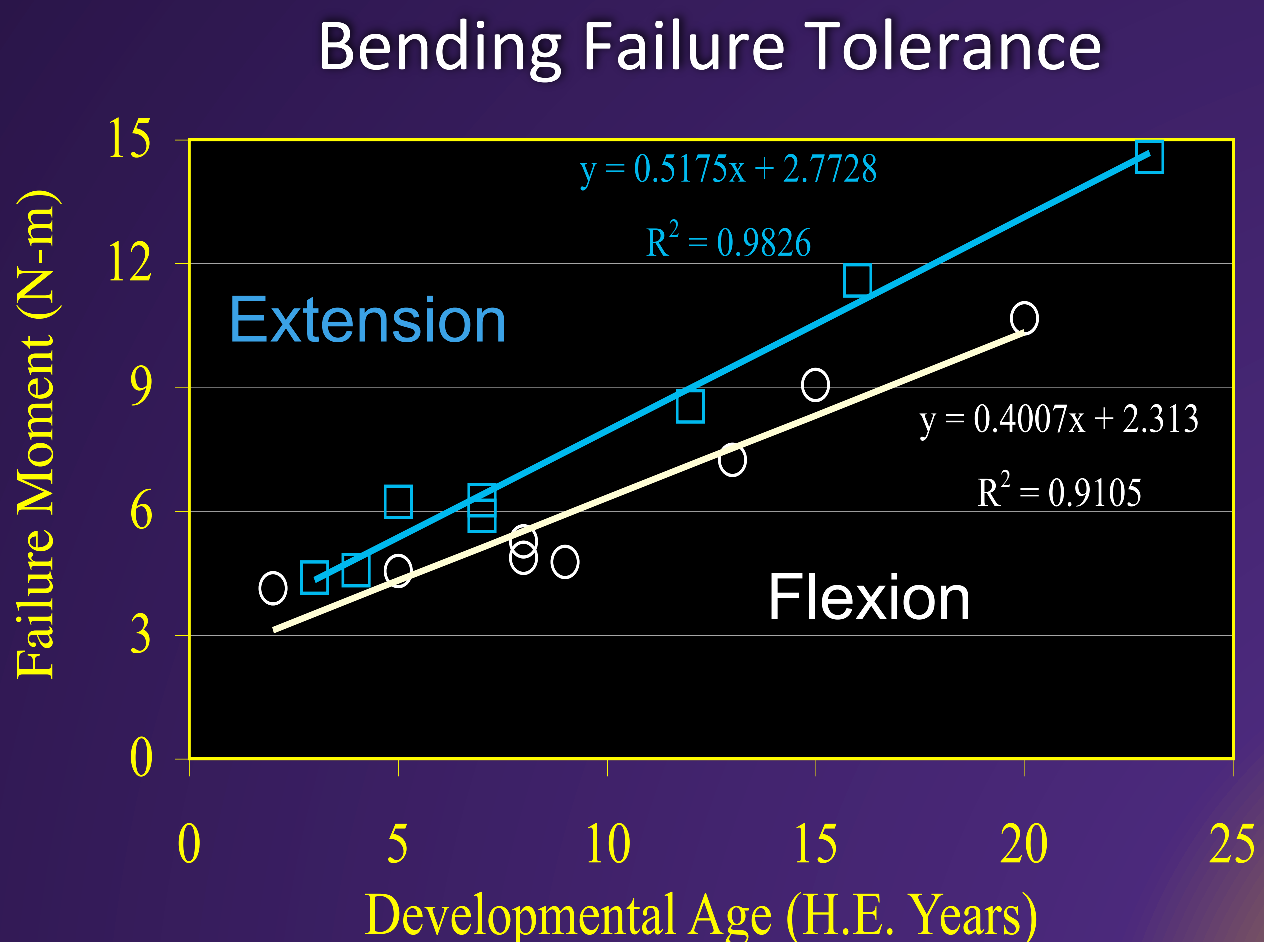
Lat Bending:
C5-C6, 10 rad/s



Case Study #1: Pediatric Spine Biomechanics



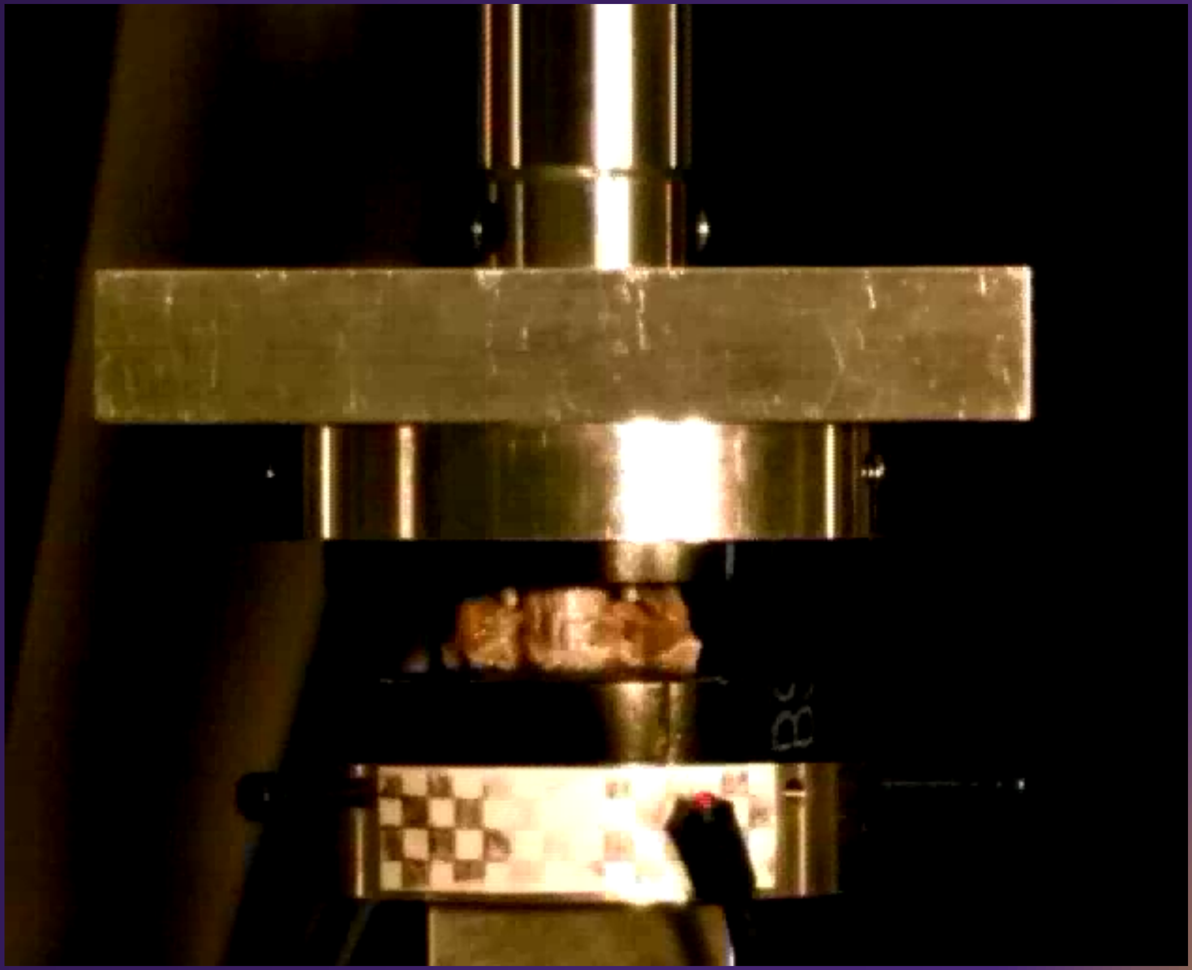
Case Study #1: Pediatric Spine Biomechanics



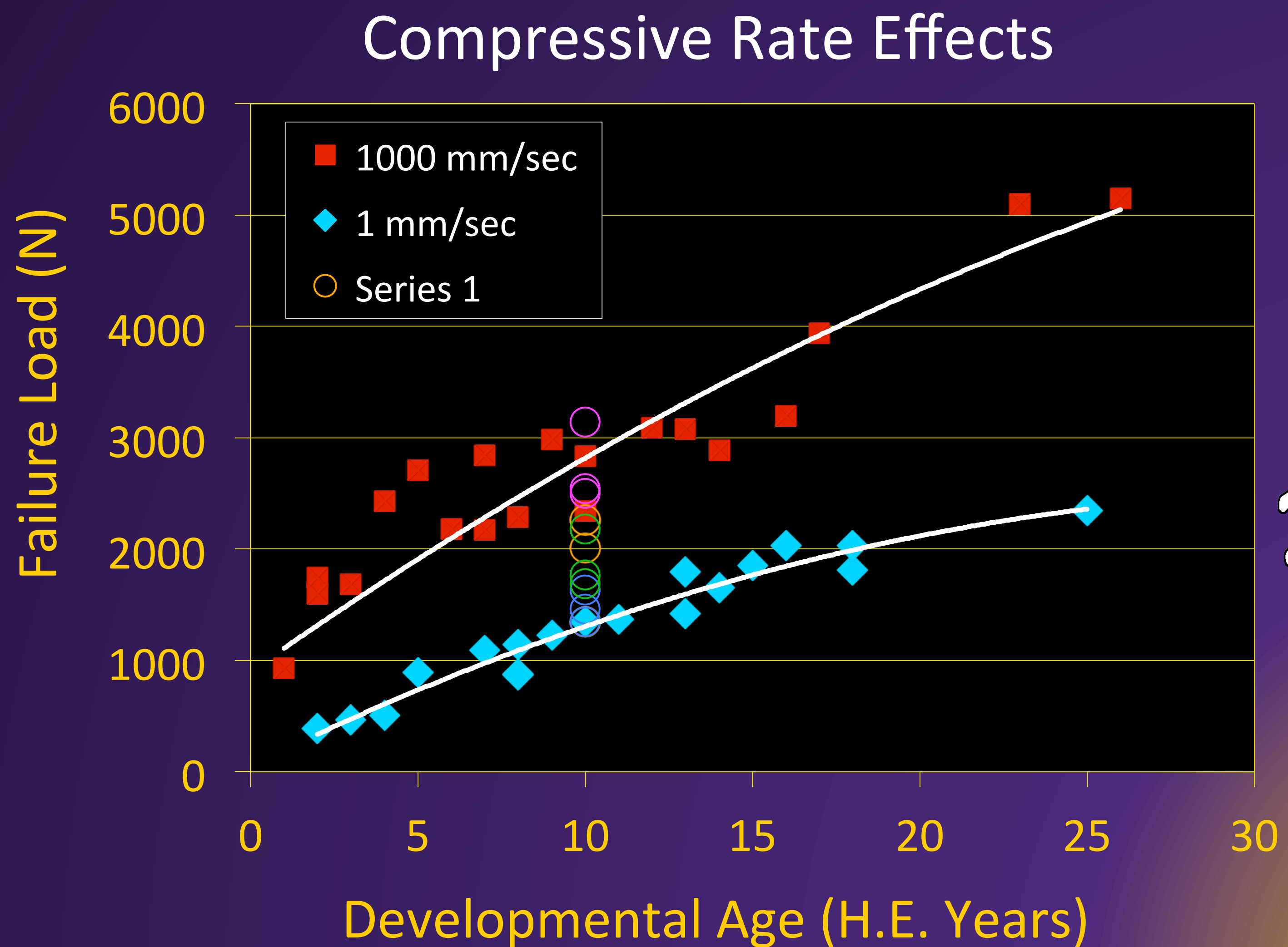
Human Subjects Biomechanics Workshop (2002)

Case Study #1: Pediatric Spine Biomechanics

Compression: C6-T1, 500 mm/s



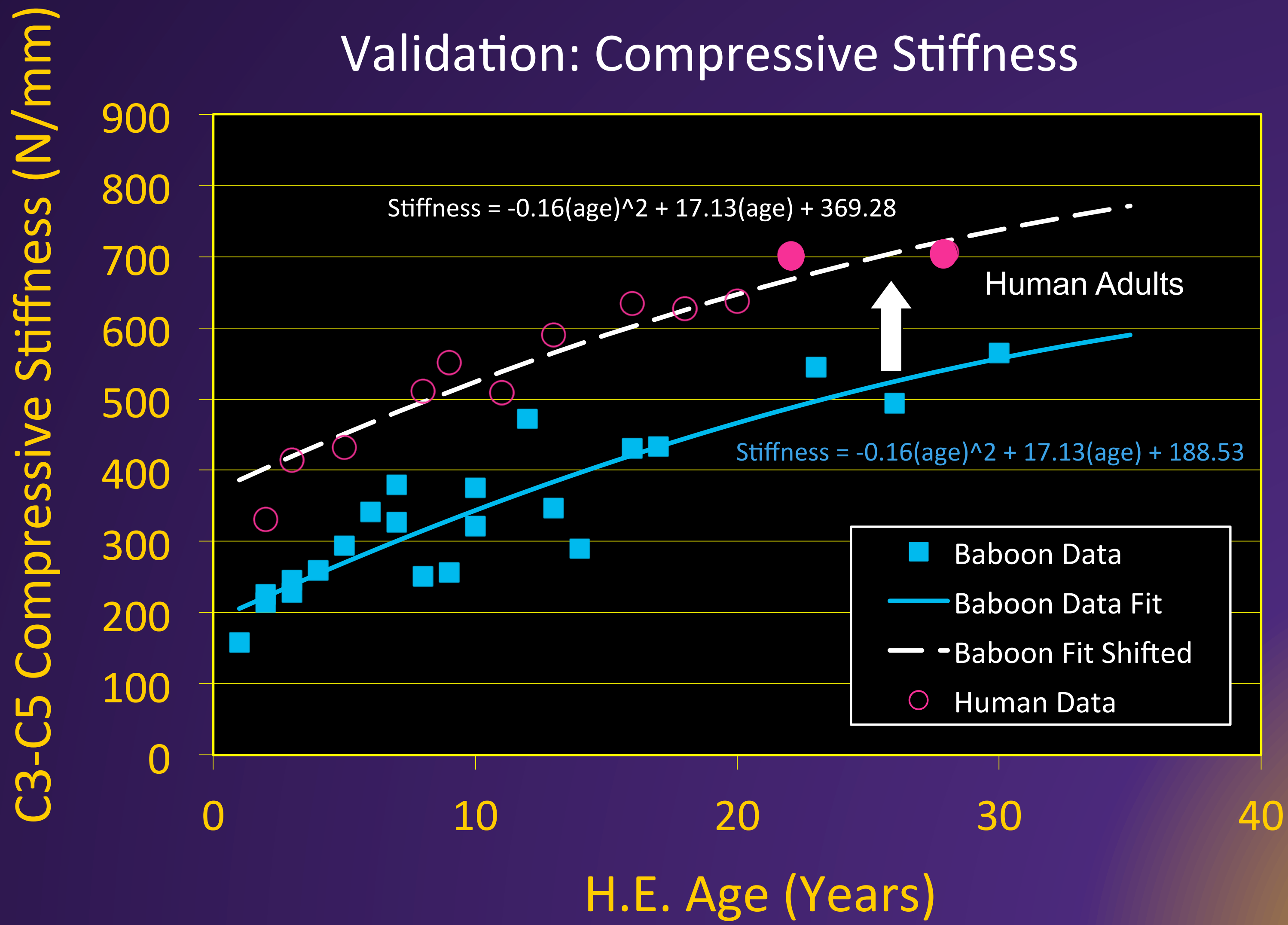
Case Study #1: Pediatric Spine Biomechanics



n = 48

J. Biomech Engr (2006)

Case Study #1: Pediatric Spine Biomechanics



Case Study #2: Spinal Arthroplasty

Spinal Fusion

- Standard of care (1950s)…
- 430,000 fusions in 2009…
- ~1/2 in cervical spine…
- Limits motion…
- Adjacent-disc disease…

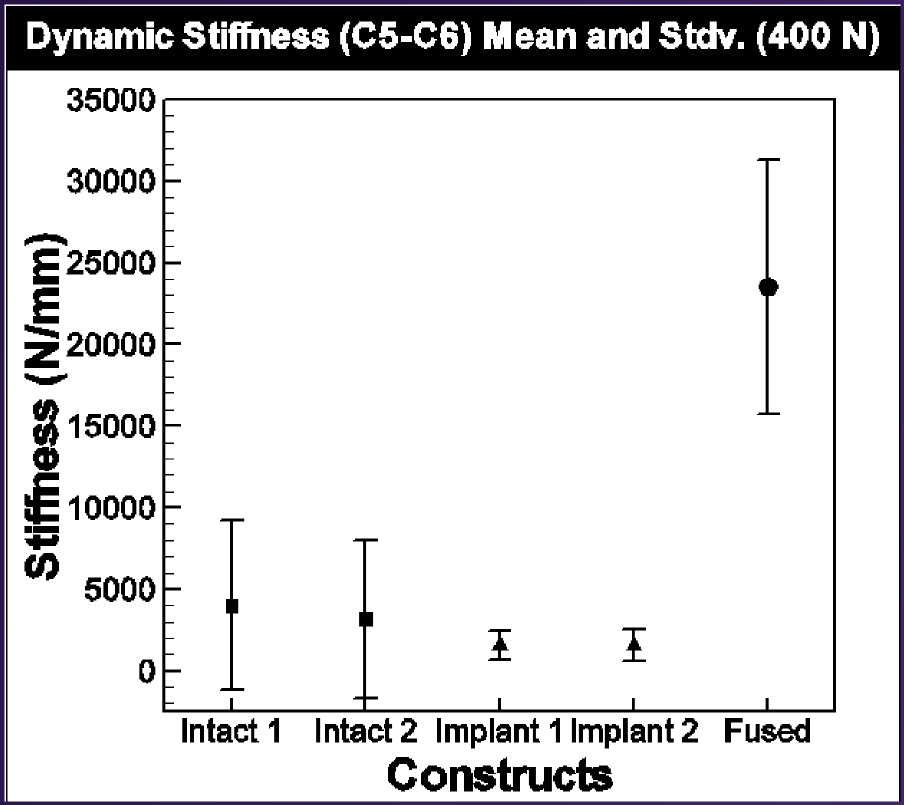
Case Study #2: Spinal Arthroplasty

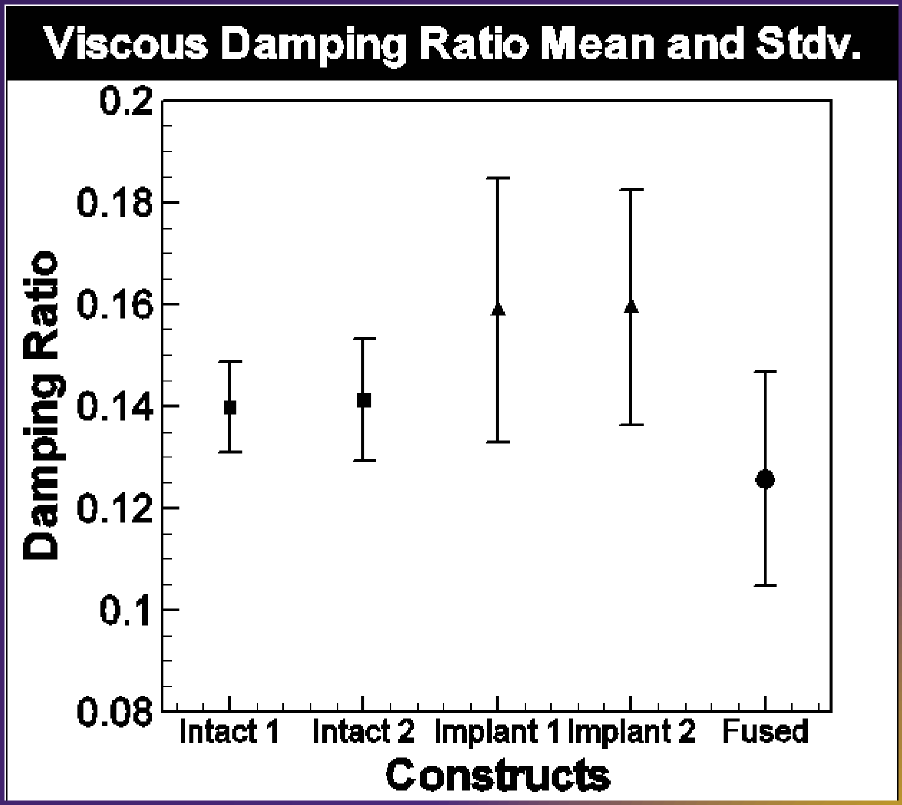
Spinal Dynamics Corp.

- Vince & Alex (1997)…
- Bryan Cervical Disc…
- Testing and development…

Case Study #2: Spinal Arthroplasty

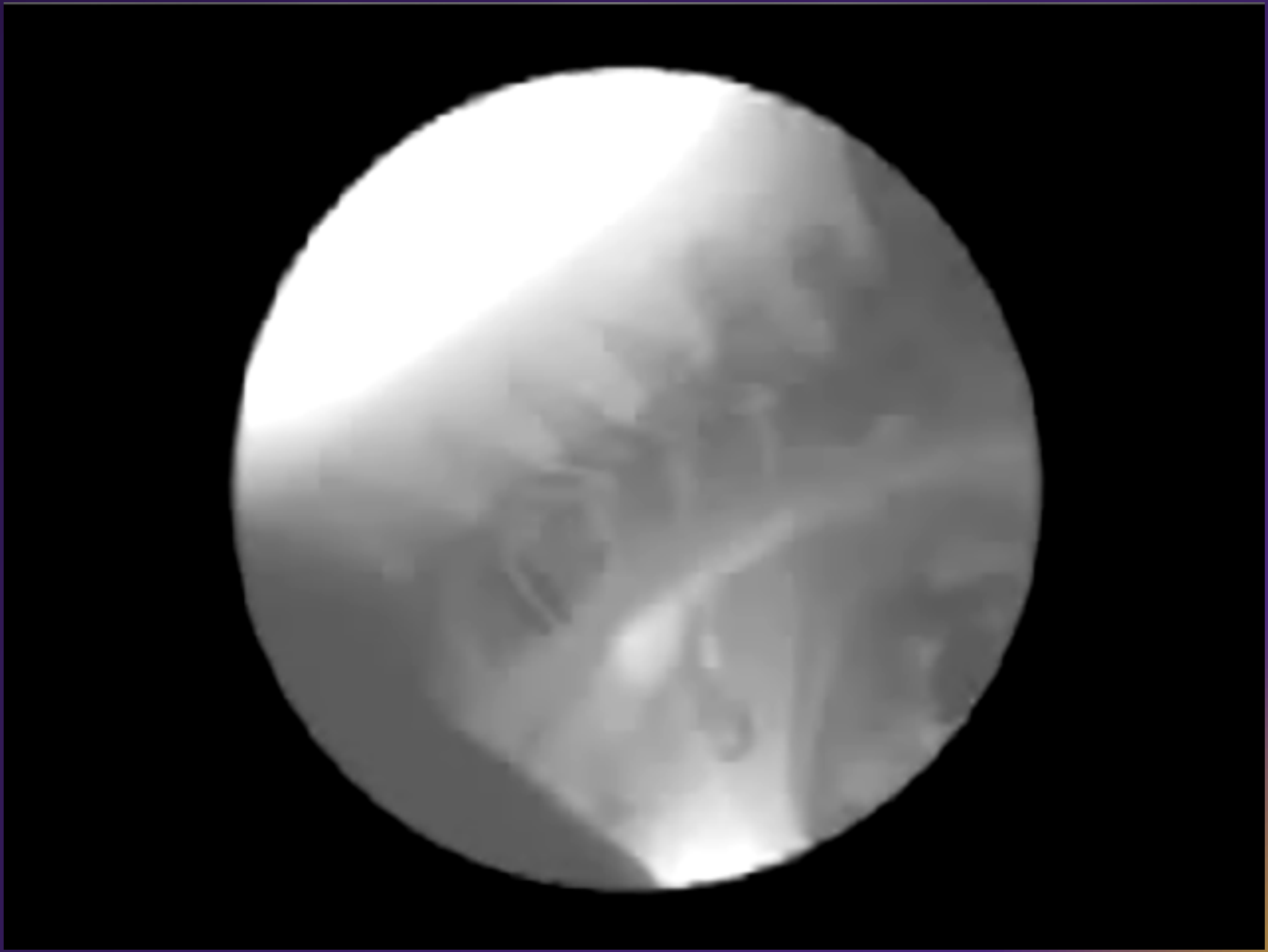
Test Results





Dahl et al., 5th Combined Meeting O.R.S. (2004)

Case Study #2: Spinal Arthroplasty



http://www.carolinaneurosurgery.com/spine/bryandisc.html