2nd International Congress on
Early Onset Scoliosis & Growing Spine (ICEOS)

# Biomechanical Consequences of Surgical Realignment of the Growing Spine

**Ian A.F. Stokes, PhD**
**Department of Orthopaedics and Rehabilitation**
**University of Vermont**

**Ian.Stokes@uvm.edu**

# DISCLOSURE:

**No Conflicts**

**Author supported by NIH R01 AR 053132**

U.S. Department of Health and Human Services

Supported by the

National Institutes of Health

NIAMS

National Institute of Arthritis and Musculoskeletal and Skin Diseases

## Questions to be addressed:

1. **What is the mechanism of scoliosis progression?**
2. **How can this process be halted or (better) reversed?**

# Scoliosis during growth

**Phase 1:**
**Initiation (various causes)**

**Phase 2:**
**Progression (Biomechanics – forces alter growth)**

**Phase 3:**
**Spinal Realignment – Straighter spine is less asymmetrically loaded**

## Progression of scoliosis:

- Where is the wedging - vertebrae or discs? (Cobb does not discriminate)

- Asymmetrical loading of spine in scoliosis – (How does scoliosis affect the forces acting on the spine)?

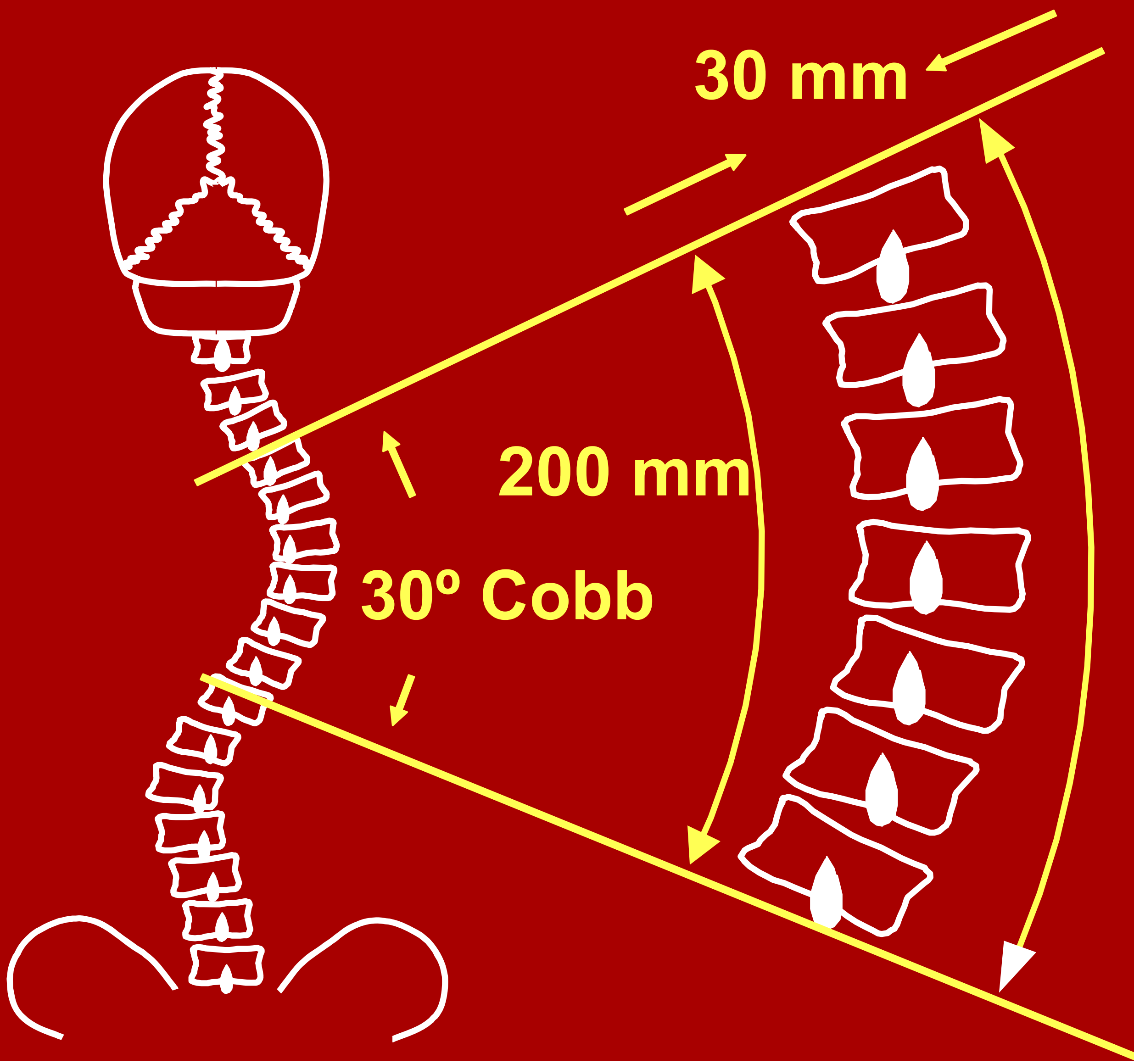
- How do vertebrae and discs grow and what is the growth response to abnormal forces?

## Spinal Re-Alignment:

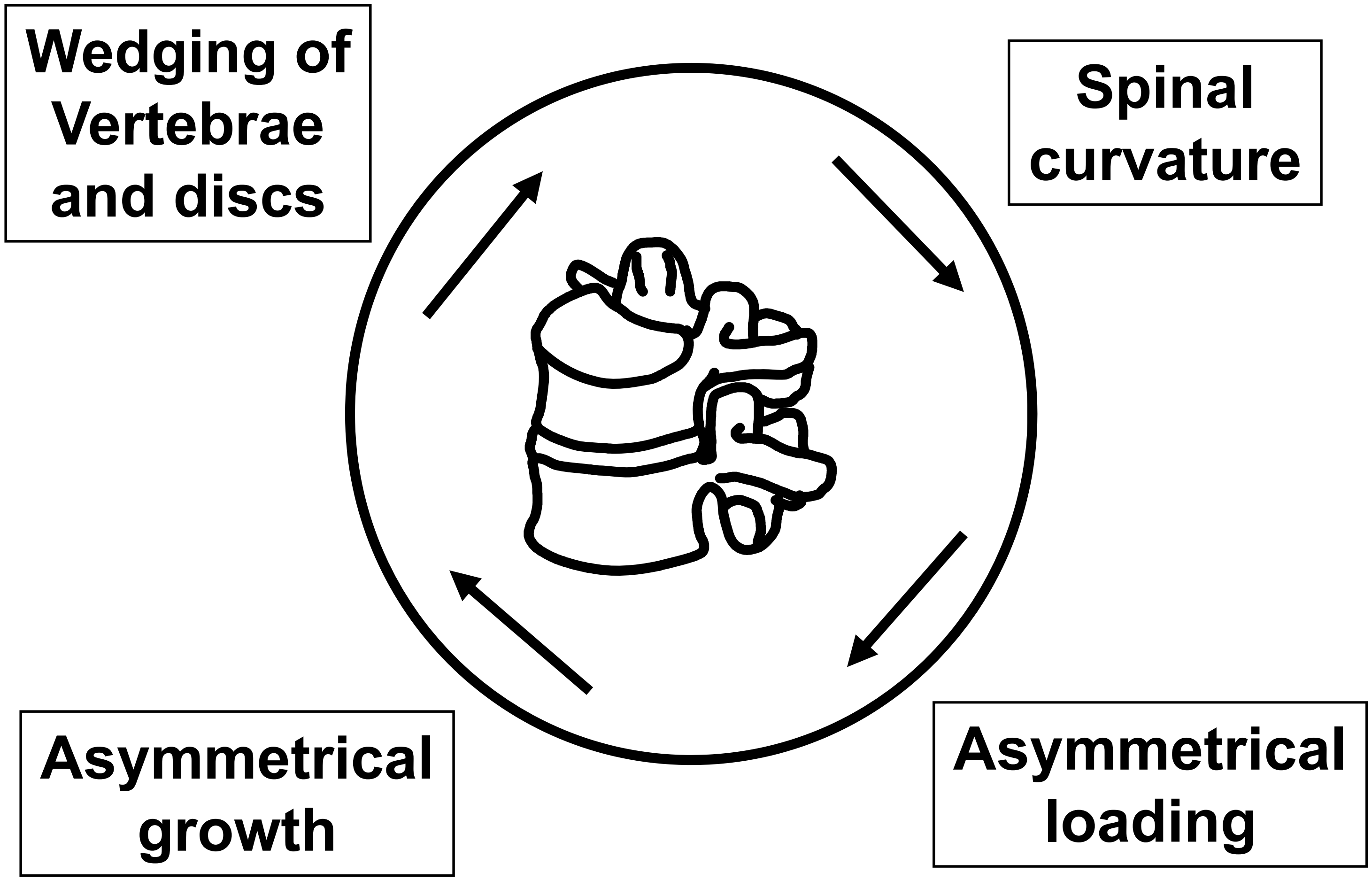
- Active forces applied to the spine

- Reduced curvature produces less asymmetrical loading

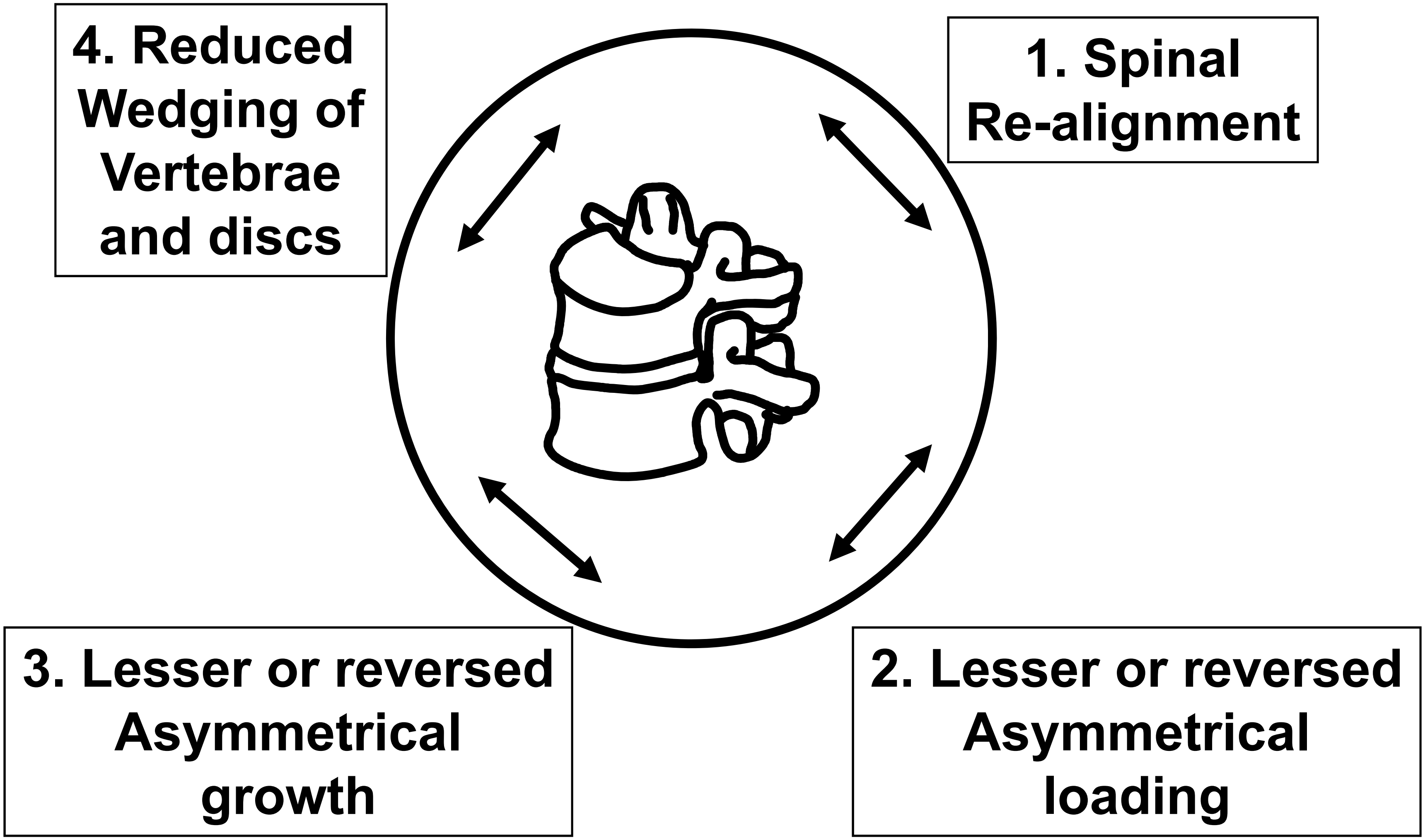
# 30º Cobb curve - 10% length difference



# Vicious Cycle - Progression



# Reverse Vicious Cycle –Re-alignment



## Spinal Re-Alignment:

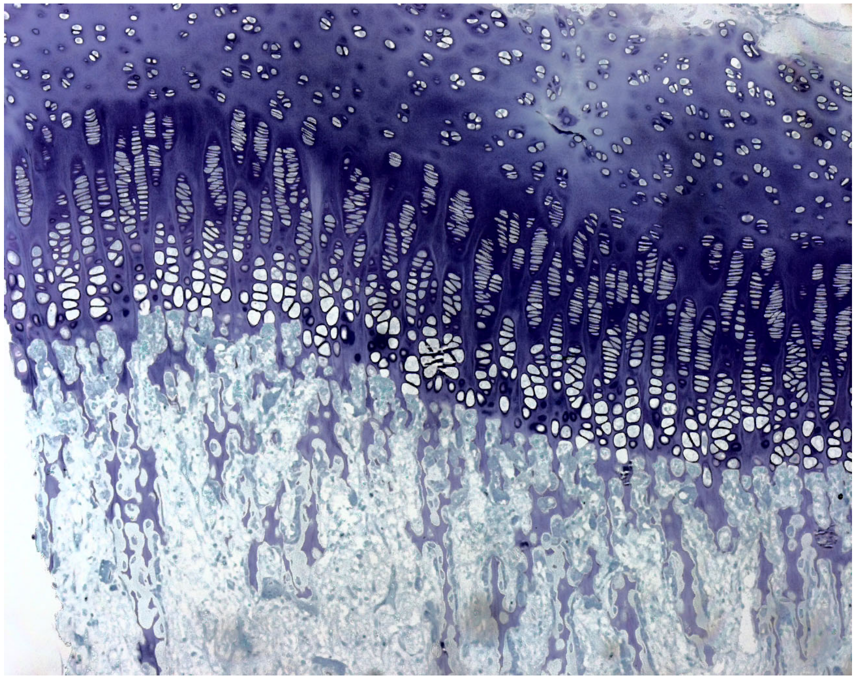
1. **Active forces applied to the spine**

2. **Reduced curvature produces less asymmetrical loading**

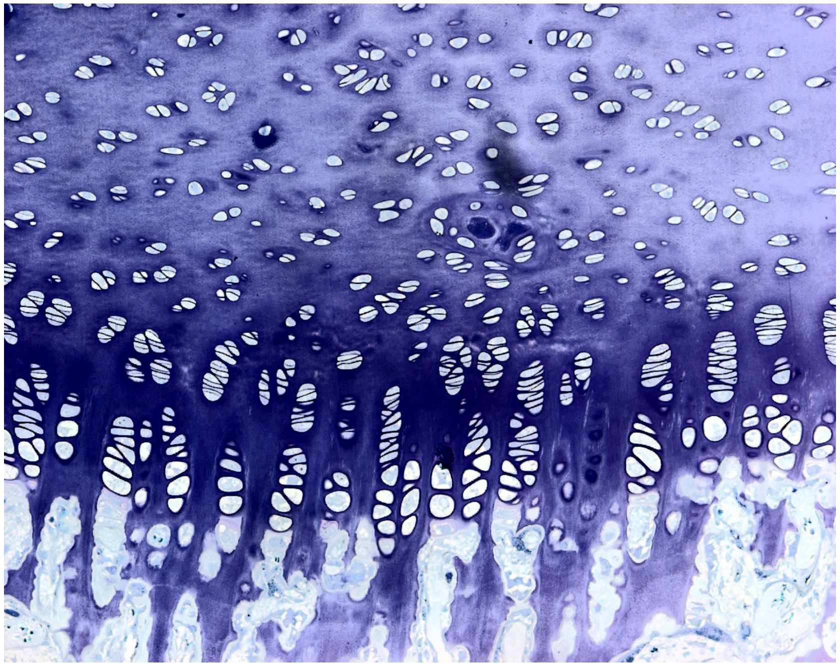
**e.g. bracing – Active and Passive effects**

# How do vertebrae grow?

Calf Proximal Tibia



Calf Tail Vertebra

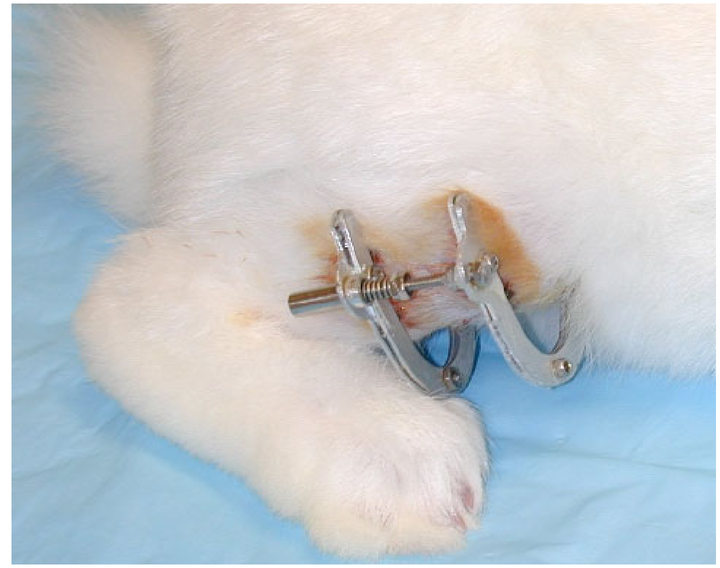


**Longitudinal growth of bones in growth plates**
**- chondrocytes proliferate**
**- chondrocytes enlarge (hypertrophy) and synthesize matrix**
**Bony growth in growth plates**
**Growth increment/day = New cells/day  * Final height**

# Altered kinetics of the growth plate with sustained mechanical loading

**Rat proximal tibia, tail vertebra**

**Rabbit proximal tibia**



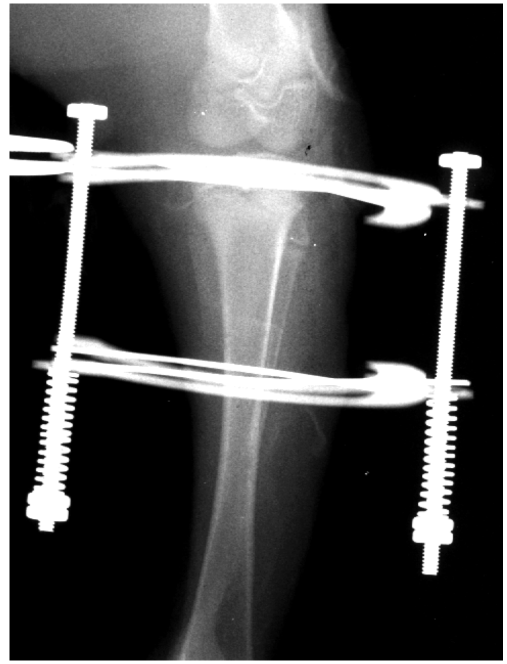
**Bovine proximal tibia, tail vertebra**

Endochondral Growth in Growth Plates of Three Species at Two Anatomical Locations Modulated by Mechanical Compression and Tension

Ian A.F. Stokes, David D. Aronsson, Abigail N. Dimock, Valerie Cortright, Samantha Beck

Department of Orthopaedics and Rehabilitation, University of Vermont, Burlington, Vermont 05405-0084

**Rat**
Proximal Tibia
Caudal Vertebra

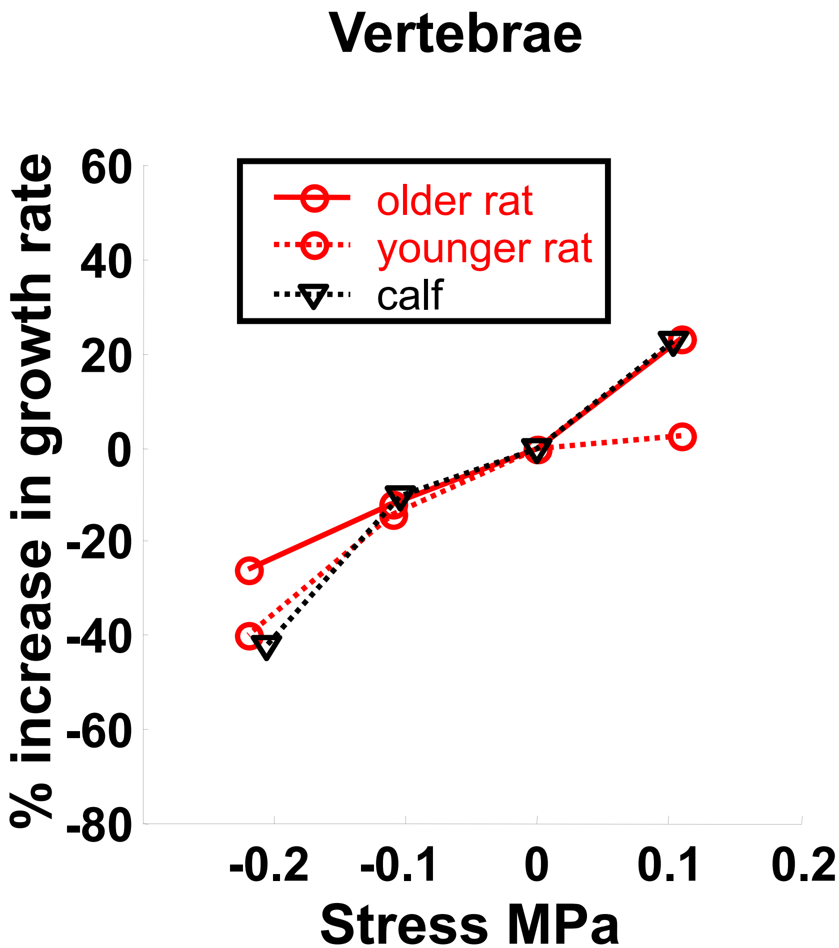


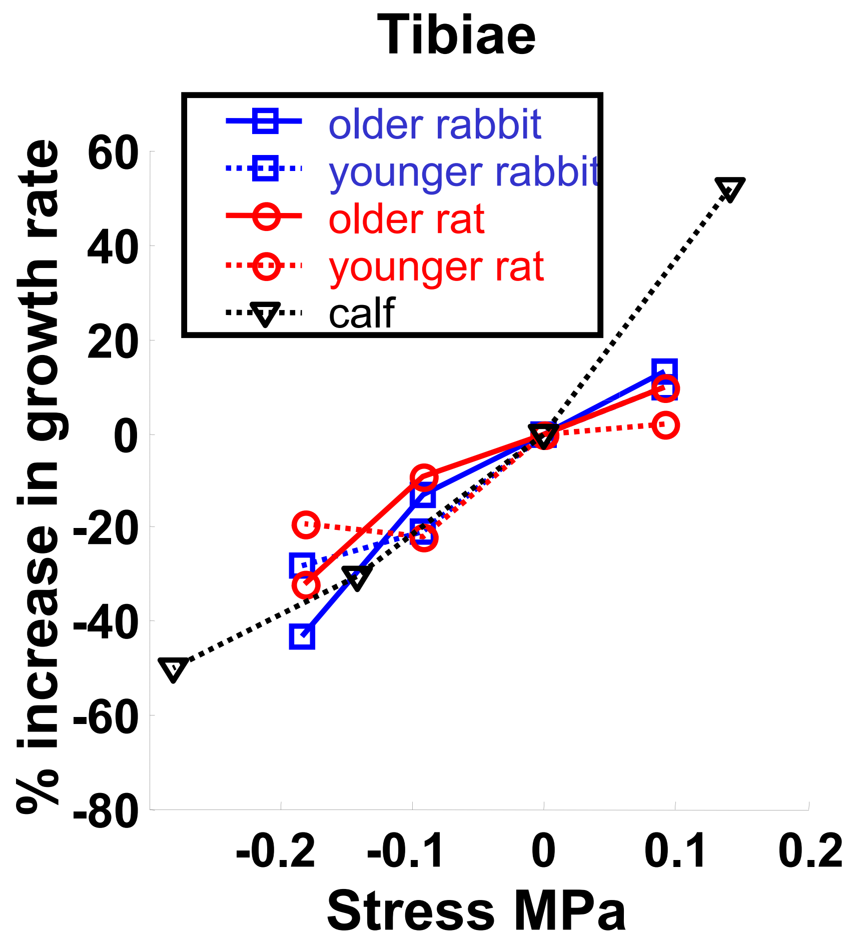
**Rabbit**
Proximal Tibia

**Calf**
Proximal Tibia
Caudal Vertebra

**Pins inserted under general anesthesia through the diaphysis and epiphysis of the right proximal tibia, and (rats and calves) through tail vertebrae.**

**External plates were attached to the pins. Springs on rods connecting the plates were tightened to achieve desired stress.**



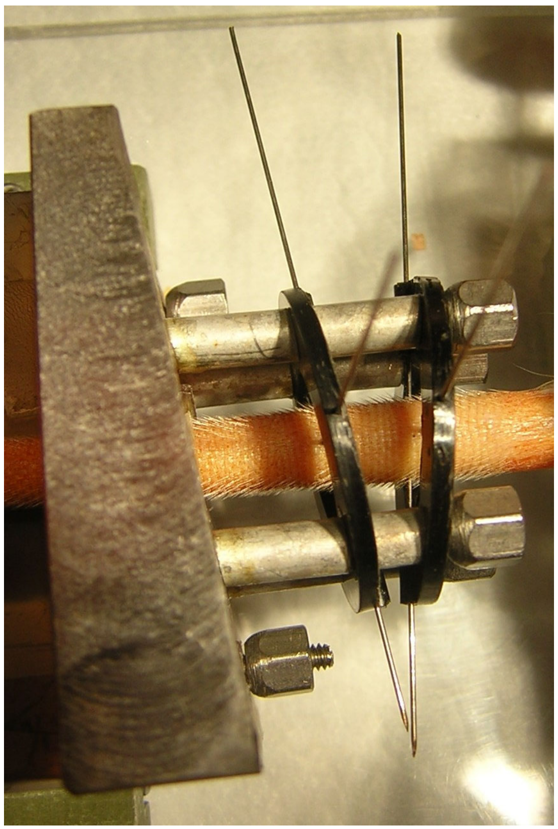



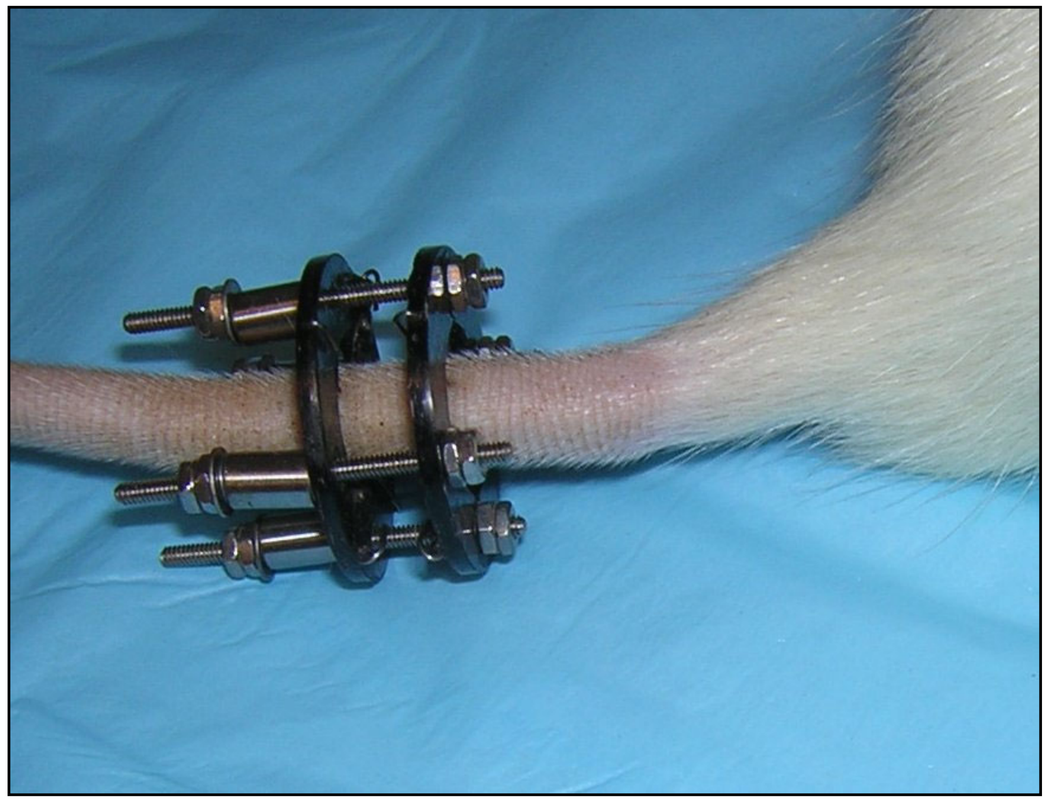

Stokes IA, Aronsson DD, Dimock AN, Cortright V, Beck S. Endochondral growth in growth plates of three species at two anatomical locations modulated by mechanical compression and tension. J Orthop Res. 2006;24(6): 1327-34.

# Effects of altered loading on intervertebral discs

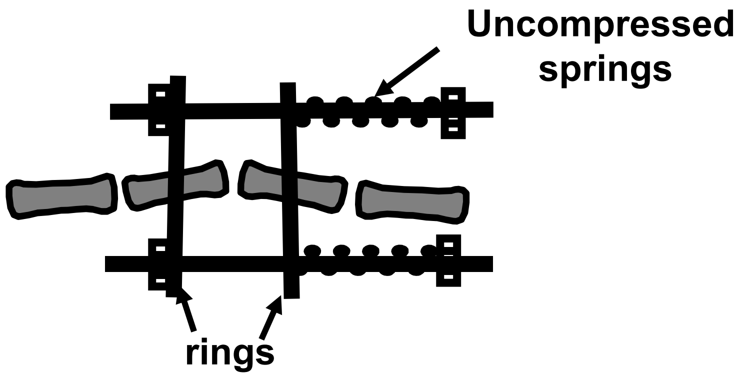
**Rat tail model:**

- External rings
- Imposed angulation and compression
- Initially 5 week old, apparatus installed for 5 weeks

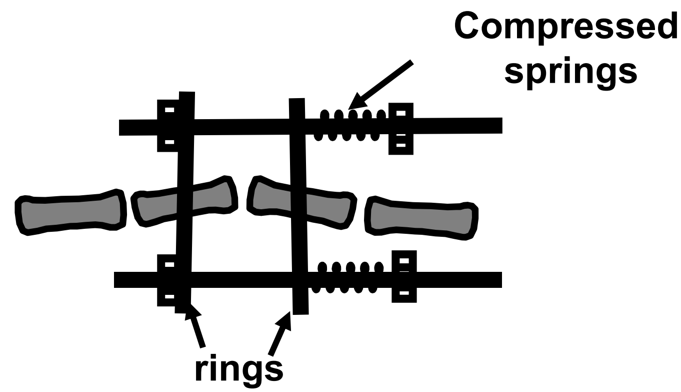




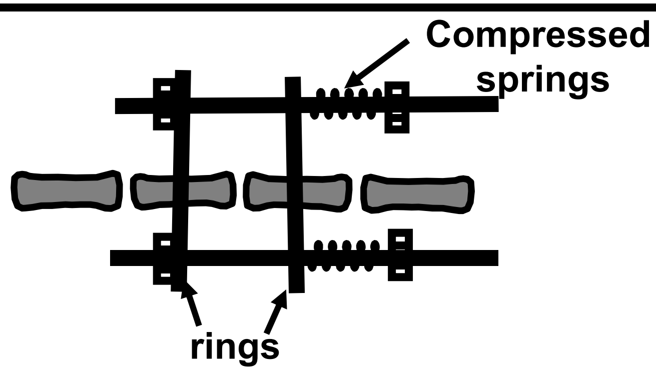
# 4 Groups of animals



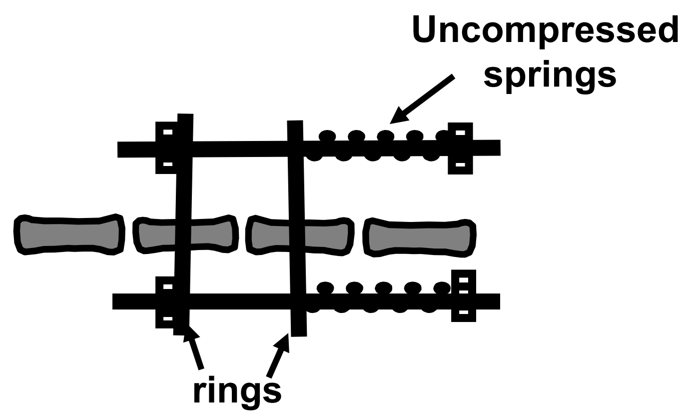

Group A – Angulation only




Group B – Both Compression and Angulation




Group C – Compression only




Group D – Reduced mobility only

# Findings:

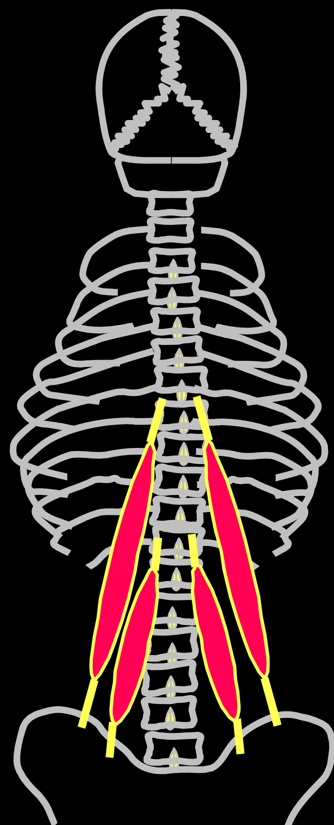
**All experimental interventions produced substantial changes**

- **Narrowing of disc space**
- **Increase lateral bending stiffness**
- **Evidence of collagen remodeling (collagen crimp)**

**<u>Reduction of mobility</u> is common to all versions of the model, so it appears to be the major source of changes within the disc.**

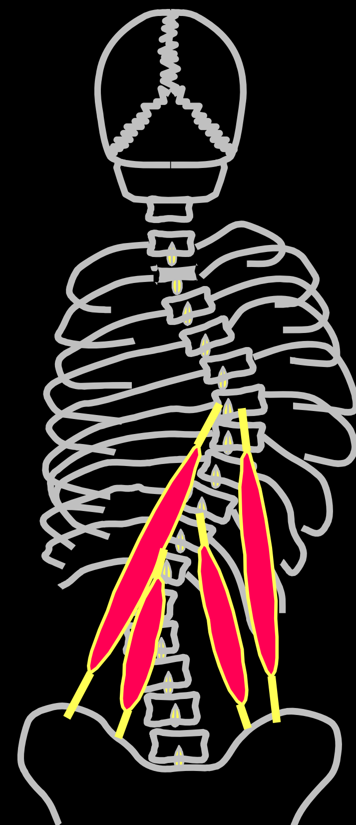
**How does scoliosis affect the forces acting on the growth plates and discs?**

**Small scoliosis**

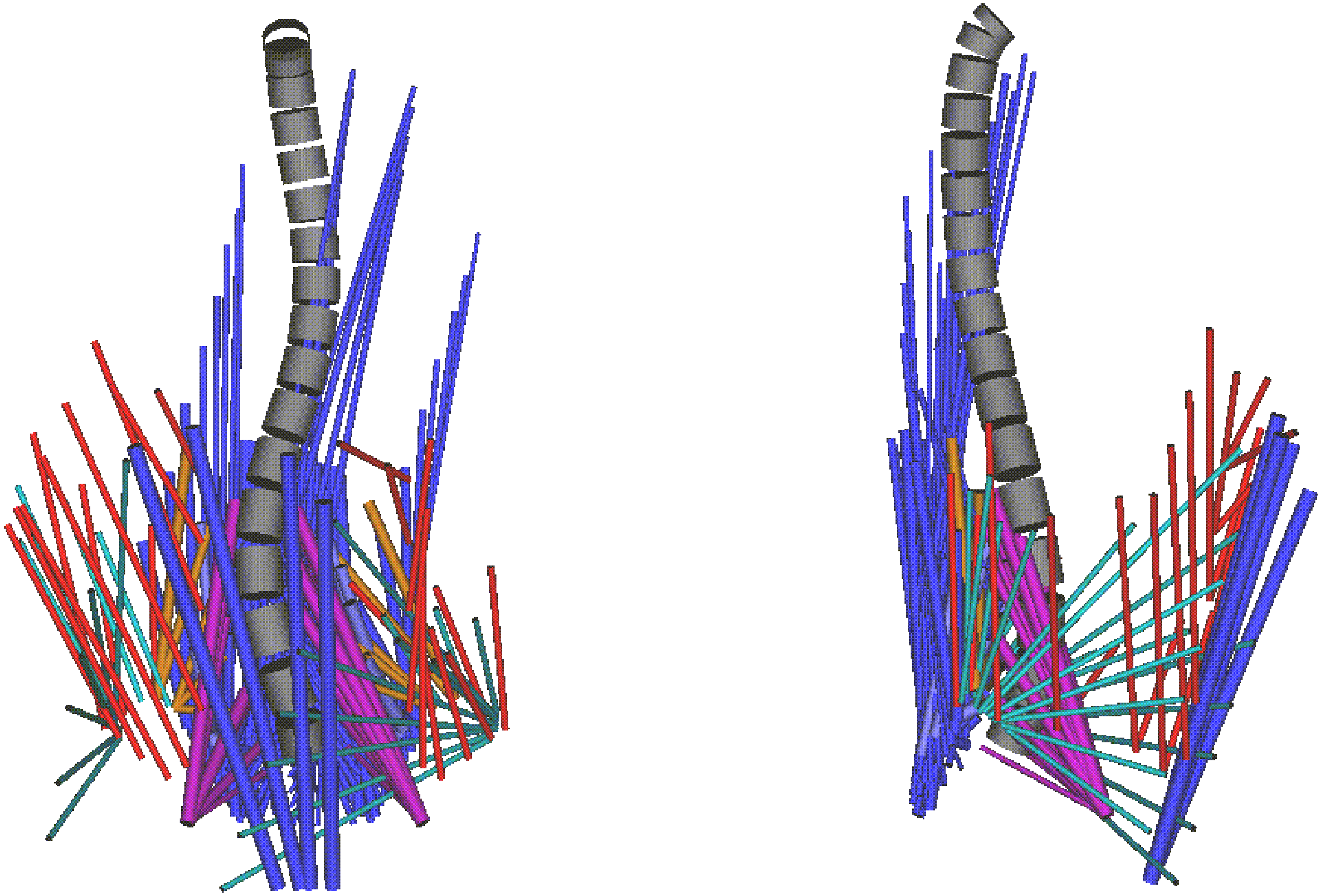


**Symmetrical loads**

**Large scoliosis**



**Asymmetrical loads**



**‘Redundant’ (Abundant*) number of muscles**
**-> Activation strategy?**

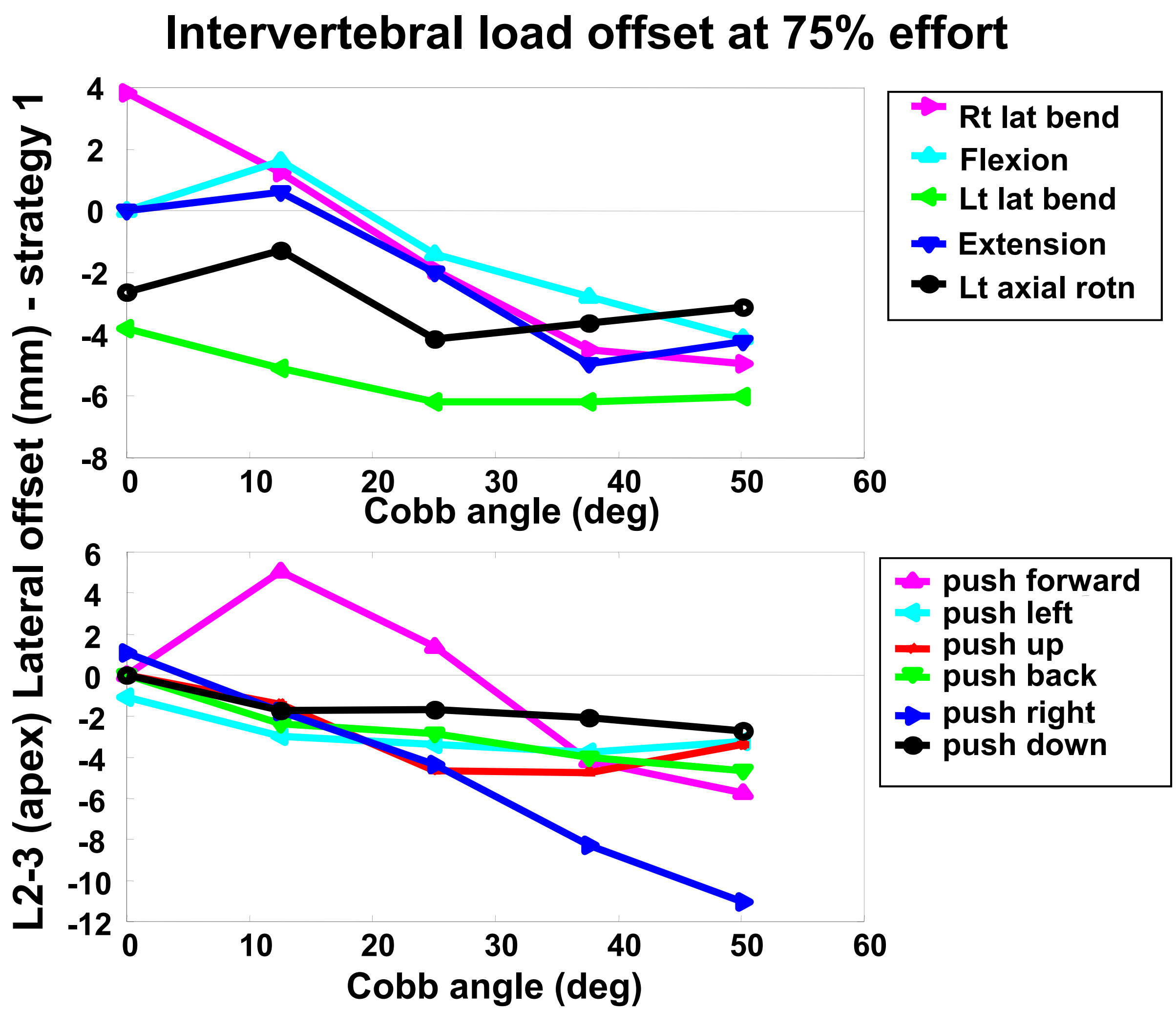
***Mark Latash**

**RESULTS: MUSCLE ACTIVATION STRATEGIES AND SYMMETRY OF SPINAL LOADING IN THE LUMBAR SPINE WITH SCOLIOSIS**

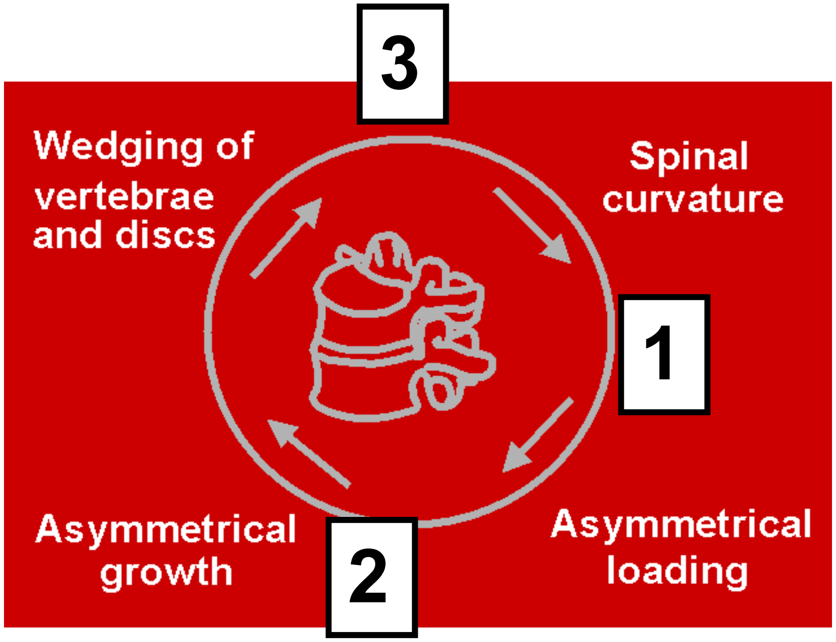
Ian A.F. Stokes and Mack Gardner-Morse, Spine 2004, 29(19) 2103-2107

**Strategy 1: Minimum muscle stress strategy**

**Segmental bending moments produce compression load offset up to 12 mm from endplate center at the curve apex for the largest scoliosis curvature.**



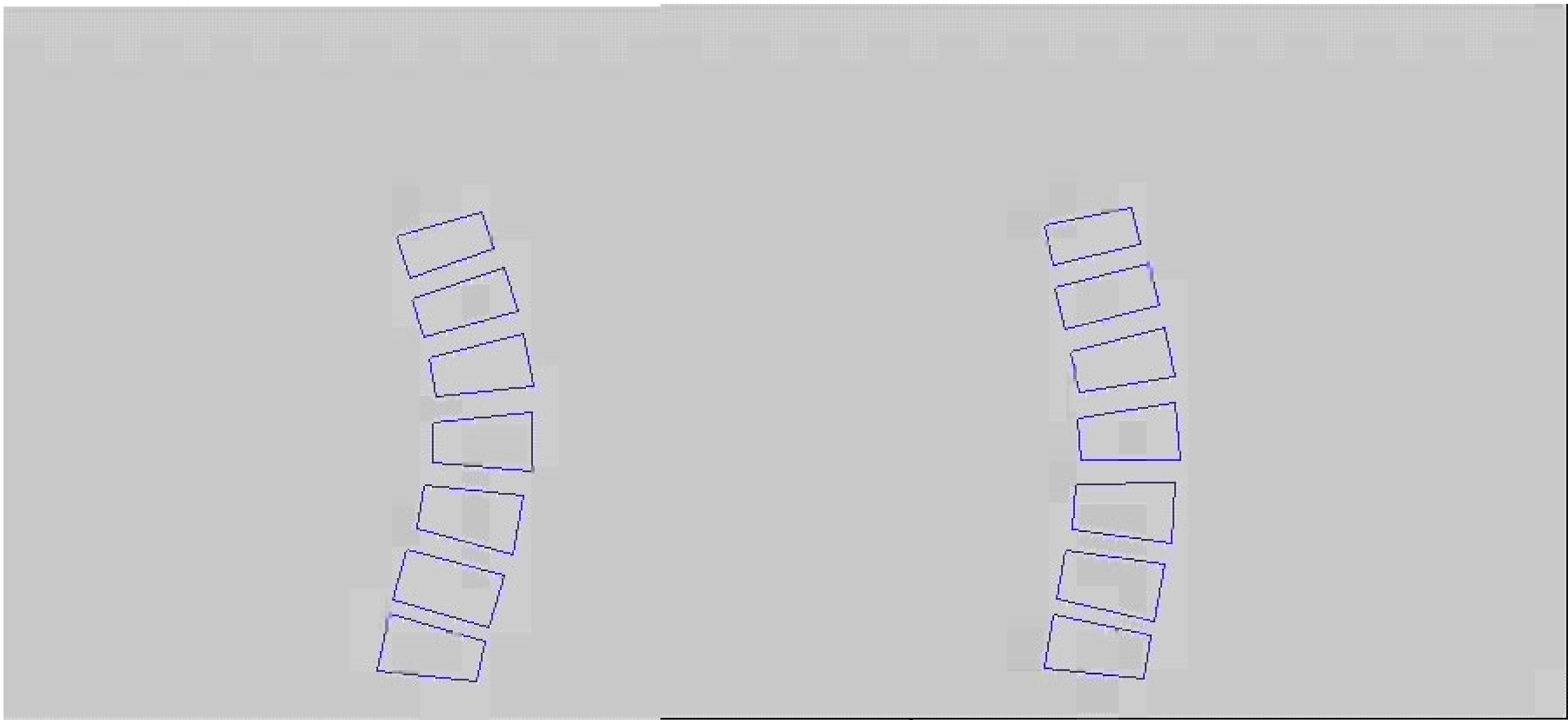
# Scoliosis Biomechanical Progression model




1. Calculate spinal loading asymmetry as a function of spinal shape.

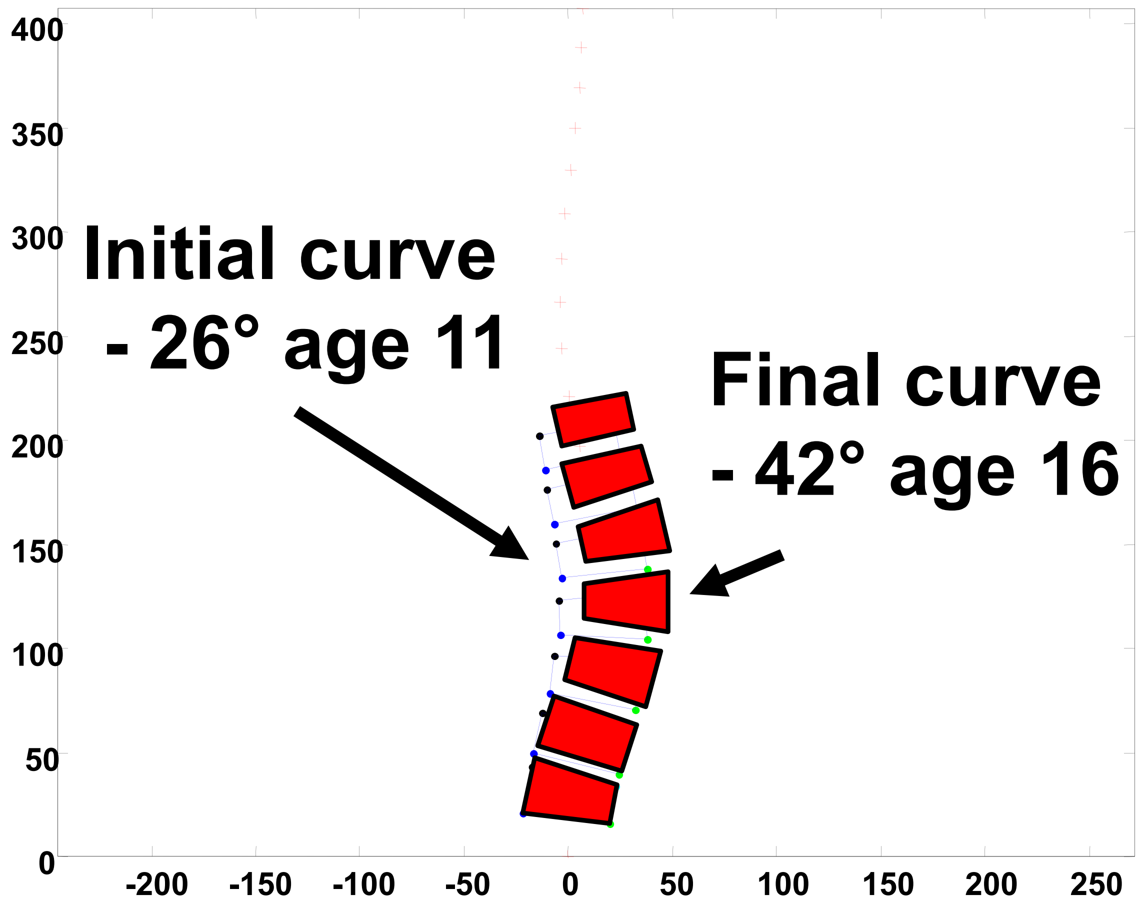
2. Calculate vertebral growth as a function of stress

3. Calculate Spinal curvature during growth



**Push right** **Lateral bend effort**

# 2-D Lumbar Scoliosis Progression model



## Biomechanical effects of realignment:

**Staples**
- – direct application of forces
- - growth modulation or arrest

**'Growing' rods**
- – Realign spine
- – Less asymmetrical loading?

**Braces**
- – some of both (direct loading and realignment)

**Tethers**
- - both direct forces and realignment

## CONCLUSIONS:

1. Biomechanics (growth modulation) explains a large part of scoliosis progression during growth

2. According to our understanding of normal muscular control, re-alignment should reduce the degree of spinal loading asymmetry.

3. Braces, implants etc. all to a greater or lesser extent apply forces directly to growing spine.

4. Realignment should reduce asymmetrical loading; hence tendency to progression (Probably greater effect)