Spinal Biomechanics

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Introduction

Tradition

Science

Technology

Clinical Intervention

Clinical Outcomes Using the Biomechanical Analyses

Random Sample of 580 Patients

- The spinal model has been used clinically for 25 years helping over 10,000 patients recover from pain and dysfunction
- On average patients presented to the doctor rating their pain as <u>SEVERE</u>
  - Pain requires modification of activity and limits activity
- After ten treatments the majority of patients rated their pain as <u>MILD</u>
  - Pain is annoying sometimes but absent with activity
- The majority of patients also reported 90% improvement in ten treatments
- Patients with surgical failure and disc herniation had longer profiles for recovery but results were similar .

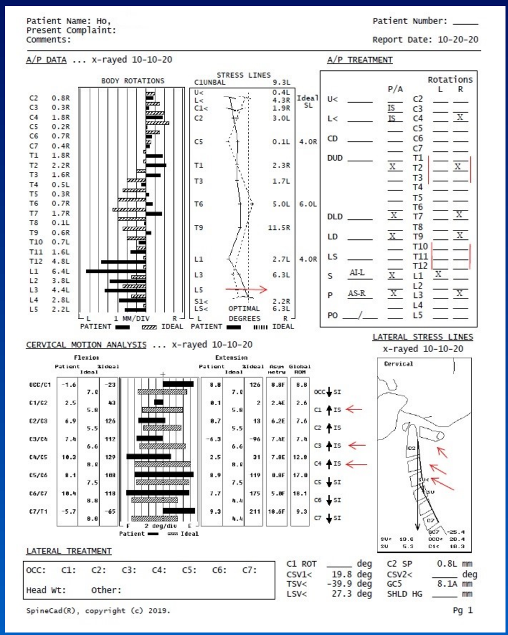
Presentation Content

This presentation will include the following

- Introduction
- Biomechanical Concepts
- Clinical application and case studies .

A structural engineering approach to measure and analyze the geometry, mechanical organization and function of the spine and pelvis for the purpose of determining clinical intervention strategies including spinal adjusting and soft tissue rehabilitation.

Biomechanical Summary and Teatment Reference

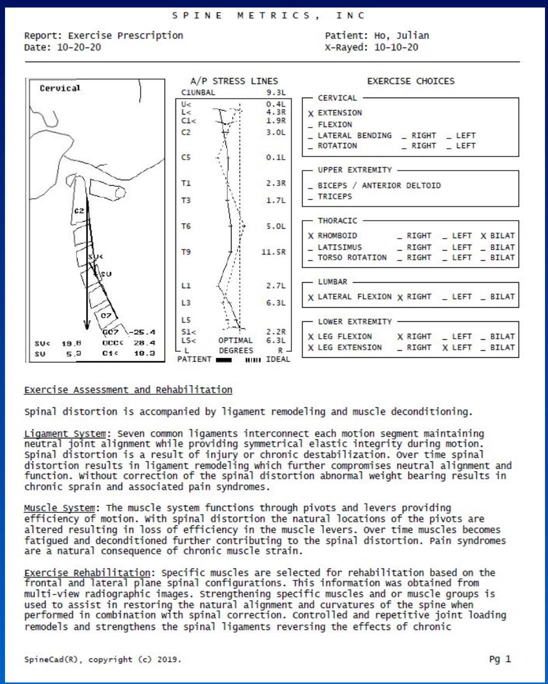


A clinical road map

- The biomechanical summary provides a graphical reference during each treatment session **showing the patient's spinal distortion** matched to the organization of a non-injured spine.
- It organizes over 500 measurements into graphics showing:
  - Segmental position,
  - Motion segment coupling,
  - Regional coupling,
  - Global balance
  - Sagittal curve alignment and function.
- It allows the doctor to **identify specific locations for spinal adjusting** .

Biomechanical Summary

Treatment reference and Exercise Prescription



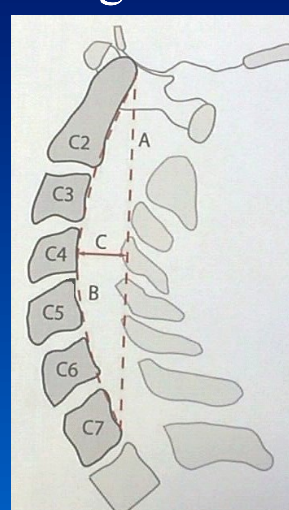
- The Exercise Prescription displays:
  - The cervical sagittal curve
  - The patient frontal plane distortion pattern compared to a fully organized compensatory pattern.
- Exercises are prescribed to aid in the rehabilitation process for conditioning and specific biomechanical changes.
  - Cervical extension for diminshed cervical curve and AHT
  - Unilateral exercises to organize the frontal plane distortion
  - Unilateral bending exerises to correct inter-regional coupling.

What is Chiropractic

- Chiropractic is a health care treatment that makes **physical adjustments to the spine and pelvis**
- It examines the relationship of **anatomical structures and function** and how it relates to **health and vitality**
- It is the study of normal **spinal biomechanics and joint function**

Chiropractic

- Is the **study of the structure and function of the spine and the pathologies** that result from abnormal alignment and loading



Normal

Subluxation or Compensation

- What is the optimum alignment and function of the spinal pelvic system ?
- How does the spinal pelvic system compensate to injury, loss of normal joint alignment or vertebral asymmetry ?
- How can one distinguish between subluxation, an initiating event and compensation, a reactionary event ?
- What are the mechanical components of compensation ?
- How can loss of normal structural alignment produce pain ?

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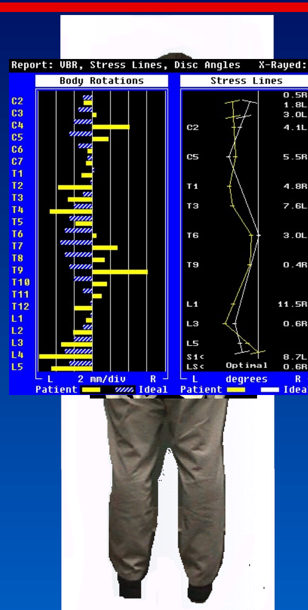
Computer Modeling

A structural engineering approach to measure and analyze the **geometry, mechanical organization and function** of the spine and pelvis



Rehabilitation to **restore spinal function,** promote healing and decreasing pain .

The analyses identify specific locations for spinal adjusting ..

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Purpose of the Spine Model

- The purpose of the spine model is to describe the **geometry, biomechanical organization and function** of the spinal system
- In combination with computer processing the spinal model is used as a diagnostic tool
  - To assess a patient's structural and functional condition
  - To determine specific spinal adjusting and rehabilitation procedures
- The clinical procedures are performed to
  - Restore normal spinal geometry
  - Restore normal joint function
  - Equalize and minimize spinal joint loading
  - Relieve acute and chronic pain .

Spine Model: Clinical Application

Computerized Data Analysis

- The spine model is used as a **reference to assess the alignment and functional properties** of the patient spine
- Architectural data of the patient vertebra are obtained from plane view radiographs
- The architectural data is used to produce linear and radial measurements of the motion segments which are combined to perform **structural and functional analyses**
- The patient and optimum spine model are compared to assess the patient's **segmental alignment, regional organization and global balance** .

Spine Injury

- The spinal system is injured from simple falls, accidents, sports and day to day activities. (More than 50% of patients deny accidents)
- When the spinal (mechanical) system is injured the following conditions result:
  - Altered spinal geometry (**global imbalance**)
  - Abnormal joint loading, (**loss of normal ranges of motion**)
  - Decreased functional efficiency (**muscle and ligament strain/sprain**)
  - That over time with gravity deteriorates the mechanical system (**degeneration**)
  - And causes tissue and joint dysfunction (**activating pain receptors**)
- Measuring the spinal geometry and assessing the mechanical organization can be obtained from plain view x-rays ..

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The Human Body

- Is made of three basic systems
  - **Mechanical** (skeletal/spinal system)
  - **Electro-chemical** (cellular and glandular system)
  - **Neurological**, electro-magnetic (central and peripheral nervous system)
- All these systems are coordinated to interact with each other to the highest level of efficiency
- Coordination of these systems meets the needs of the internal and external environments within the limits of each system .

The Human Body as a Machine

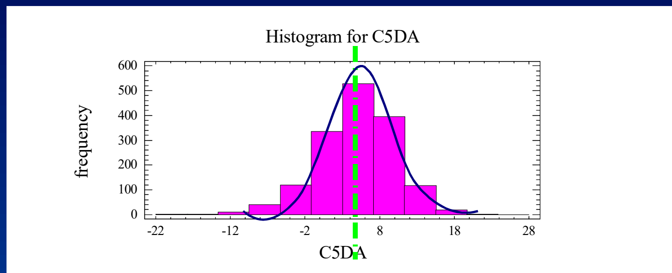
The Mechanical System

- The spine is a semi-rigid, elastic, multi-component mechanical system that is **genetically designed** to be functionally organized to provide strength and flexibility. These properties are dependent on the integrity of the hard and soft tissue systems
- Like a machine, each spinal component interacts with each other so that for every action there is a predictable combination of related inter-actions.
- When the spinal system compensates to injury it structurally re-balances using a combination of coupled motions involving the cervical, thoracic and lumbar regions.
- **The mechanical pathway of compensation is organized to the segmental, regional, and global motions of gait** .

The Spine Model References: A Starting Point

- The geometric properties of the optimum spine model are descriptive of normal anatomy and physiology. The model references include:
  - I. A. Kapandji "Physiology of the Joints" Vol 1,2,3
  - White and Panjabi "Spinal Biomechanics"
  - Spinal measurements and analyses as taught in chiropractic colleges
  - Clinical observations from developers such as Palmer, Gonstead, Logan, Pettibon, Pierce, and other independent chiropractic investigators
  - The principles of mechanical engineering including strength of materials, optimum loading and minimum energy states

Testing the Spinal Geometry for Normalcy. 500+ Geometric Variables



Frequency Distribution of Neutral C5 Disc Angle (n=1562)

- The geometry describing the optimum spinal model was initially refined using statistical analysis from a database of over 5,000 patients and 2.5 million spinal measurements.
- In this example the disc angle of C5 was analyzed from a sample of 1562 patient x-rays. The average disc angle value was found to be 5.5 degrees anterior after sorting and including only lordotic curves
- The database now contains more than 10 million measurements of the architecture, alignment and function of the spinal system .

Overview of the Spine Model

Skeletal System

- The skeletal system develops from a genetic code that gives it geometric form, function and efficiency
- These variables are expressed by the
  - shape of the bones, (**architecture)**
  - orientation of the joints, (**loading and weight bearing surfaces**)
  - position of the ligaments (**elastic forces)** and
  - attachment of the muscles (**efficiency of motion**) ..

Genetic Organization

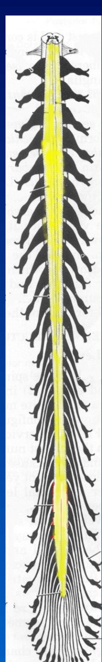
Physical and Neurological Coordination

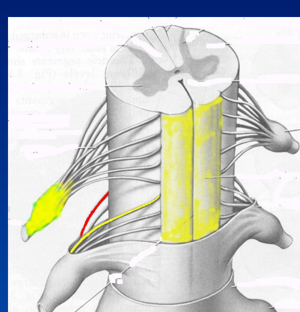
- The spinal system by design is organized
- The mechanical system is organized by bone (**hard tissue**) architecture
- The ligament system (**soft tissue**) is symmetrically oriented to provide neutral alignment, stability and flexibility from the architectural neutral position
- The muscle system (**soft tissue**) provides symmetrical ranges of motion from a neutral centerline position
- The neurological system adapts the hard and soft tissue systems within its mechanical constraints (ROM) to keep the spinal system balanced while keeping the head oriented horizontal and vertical .

Righting Reflexes Control Spatial Orientation of Spine

- The upright neutral posture is maintained by the **righting reflexes** which include
  - Visual processing
  - Auditory processing and
  - Proprioceptive processing
- In combination these sensory impulses are processed by the central nervous system to keep the **eyes level in a perpendicular relationship with gravity** i.e., looking forward to the horizon
- Balance is maintained at a **minimum energy state** when the skeletal system is optimum and vertical and the joints are aligned in a neutral position
- The minimum energy state is the least amount of muscle effort and ligament loading needed to maintain a neutral, upright, and balanced position .

The Nervous System





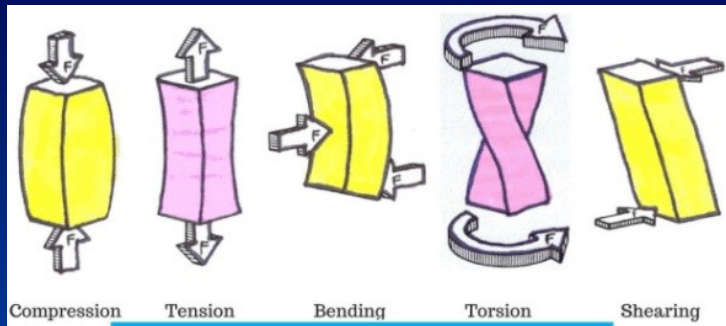
- The brain stem and spinal cord are encased in a **dynamic conduit**, the spine. The spine is an organized system of rigid and elastic components.
- The spinal cord communicates with the body's internal and external environments through the peripheral nervous system and related nerve pathways
- **The nervous system is at risk if the mechanical system is structurally or functionally compromised** ..

Developing the Spine Model

Mechanical Description of the Spinal System

- The spine is a **multiple component system interconnected by joints, held together by ligaments and moved by muscles.** During function the spinal cord and nerve roots are protected. It provides weight bearing, transmission of forces, and motion.
- The optimum anatomical design provides **symmetrical distribution of forces** through vertebra and discs and across joint surfaces
- The optimum design maximizes joint, ligament and muscle function
- Loss of segmental, regional or global alignment produces **abnormal joint loading, degeneration, chronic strain / sprain, and chronic pain syndromes** .

Mechanical Engineering and Physical Properties



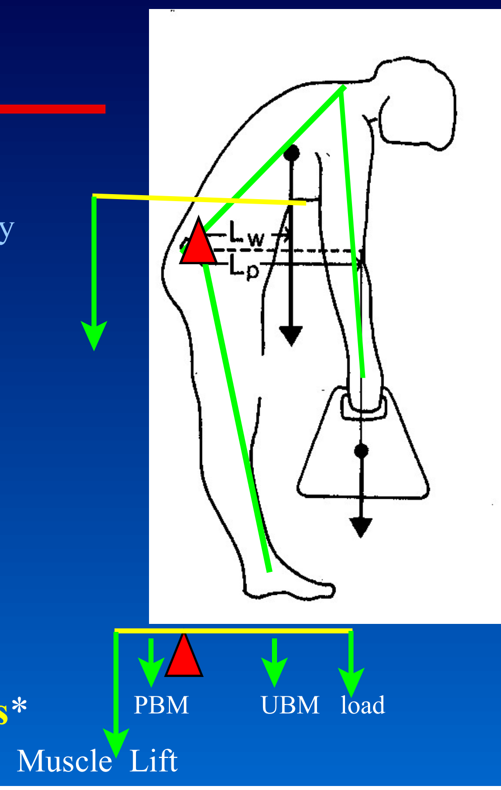
- The spine is a collection of physical components with inherent material characteristics.The **physical components are subject to tension, compression and shear forces.**
- The spine is a **system of pivots and levers** and as such works as a machine **designed for optimum efficiency.**
  - Changes to the length of the levers or the location of the pivots produce reactionary muscle activation to maintain balance.
  - Over time this produces abnormal forces on the structural components
- The mechanical efficiency of the spine can be assessed by **evaluating its structural and functional integrity** ..

Regional and Global Balance

- Regional and global balance of the spinal system is maintained by two inherent mechanisms
  - 1) **muscle tension and**
  - 2) **off-setting of body masses**
- These two actions produce equal and opposite torques around key pivot points
- Global balanced is maintained by 1) and 2) through a central pivot within the pelvis at approximately S2, the center of the sacro-iliac joint
- These same mechanisms are active during normal activities and during reactive compensation to balance the spinal system ..

Lifting a Load: Mass Displacements and Muscle Contraction

- When a load is lifted
  - The body leans forward moving the upper body center of mass forward (UBM)
- The reaction at S2 to lift the load includes
  - Leaning backwards and moving the pelvic center of mass (PBM)
  - Lifting the weight of the body (BW),
  - Lifting the weight of the load
- The load is lifted by leaning backwards (mass displacement) and contracting the lumbar and hip extensors
- **Pressure in the discs is increased proportional to the load and the torques***



Optimum Symmetry and Balance

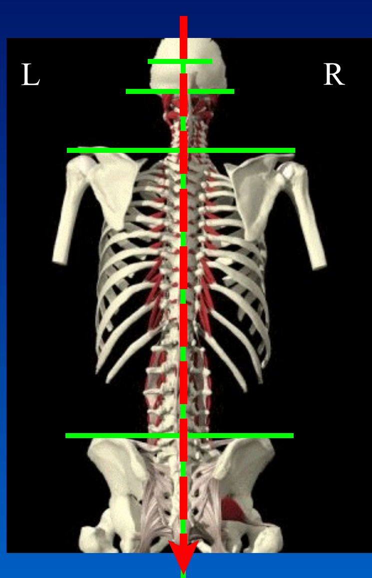
- The spinal system **demonstrates an optimum centered position that is symmetrical and balanced**. The loading on each material is within its physical properties.
- When this condition exists, the spinal system
  - maximally resists gravity at a minimum energy state,
  - Efficiently carries and transfers loading forces across joint surfaces and
  - provides symmetrical ranges of motion
- **Optimum alignment at the motion segment provides maximum space for the spinal cord (central canal) and spinal nerve roots (intervertebral foramina) without abnormal tension, compression or shear forces .**

The Spinal System in an Optimum Neutral Position

- In an optimum upright neutral position the spine is
  - balanced front to back and left to right
  - The head is upright with the eyes looking forward
  - The motion segments are aligned one to another in a centered neutral position. There is a symmetrical reserve of full range of motion at each spinal joint
  - The ligaments are symmetrically loaded and at a minimum energy state
  - Prime mover muscles are at a minimum energy state of inactivity. Intrinsic muscles are maintaining balance
  - Loading across joint surfaces is evenly distributed
- **The neurological system maintains this mechanical minimum energy state through the righting reflexes ..**

Optimum Spine Geometry: Frontal Plane

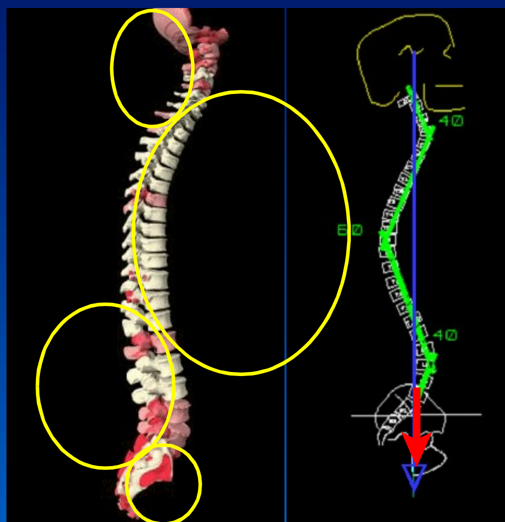
Viewing the spine from the back



- The optimum spine demonstrates the following geometry in the frontal plane
- Spine is vertical
- Pelvis level
- Shoulders level
- Head level
- Eye line level
- **Balanced and symmetrical .**

Optimum Spine Geometry: Sagittal Plane

Optimum Geometry and Alignment Produces **Optimum Joint Function**



- In the sagittal plane there are four reciprocating curves.Three are functional curves
  - Cervical
  - Thoracic
  - Lumbar
- One is a static curve
  - Sacral
- The head is positioned over the center of the pelvis
- **The spine is balanced front to back** at a minimum energy state .

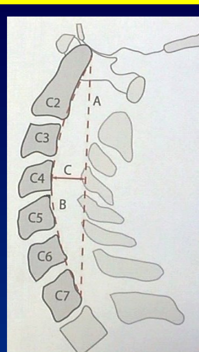
Spine Injury and Compensation

- From a sample of over 900 chiropractic students average age 23, over 95% demonstrated a MODERATE to SEVERE loss of the cervical curve with anterior head translation (AHT).
- This injury is only the tip of the iceberg as AHT disrupts normal balance, activates compensation, reduces mechanical efficiency throghout the entire system and creates abnormal joint pressures.
- Only 25% compained of cervical shoulder discomfort. Clinical experience suggests they will seek care for low back pain by average age 30 ..

Spine Injury and Spinal Compensation

- The most common injury to the spinal system is injury to the cervical spine.
  - This is due to a sudden impact or acceleration injury that overcomes the strength of the ligaments
- Ligament damage typically occurs to the intra and supra spinous ligaments at C4/C5
  - The curve breaks into two curves. An upper C2-C4 and lower C5-C7.
  - The head moves anterior and flexed. This anterior loading sustains the abnormal posture and joint loading
  - **The righting reflex is disturbed**
- The spinal system mechanically compensates (shifting of body masses and muscle contraction) in an attempt to achieve balance and horizontal gaze.
- Resulting with
  - Chronic strain / sprain
  - Chronic pain syndromes
  - Degeneration

Most Common Patient Injury



Normal
Neutral

13 YO F
scoliosis

79 YO F
lumbar disc

17 YO M
Scoliosis

43 YO M
lumbar Disc

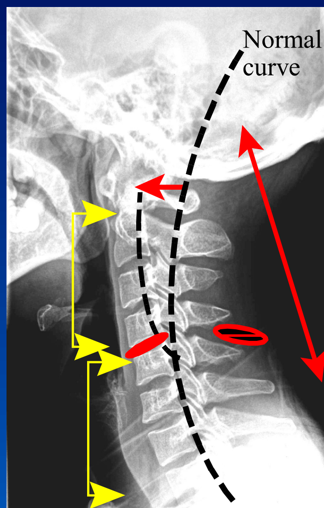
40 YO M
lumbar disc

58 YO F
neck, shld lbp

13 YO F neck
shld , lbp

Pain Symptoms Common to Injured Cervical Curve

Injury to C4/5 interspinous ligament



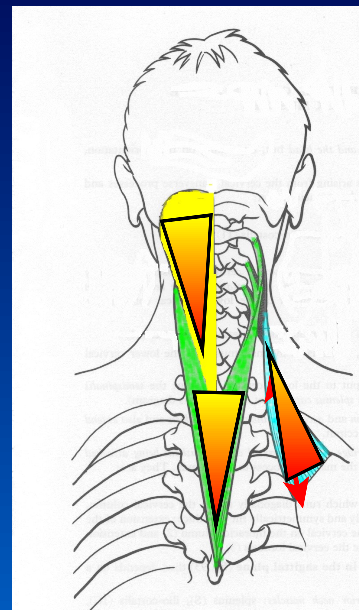
Cervical curve and head go anterior. Two distinct upper and lower curves noted

Stretches splenius capitus and cervicus ms

Chronicly pulls on origin and insertion causing pain

Stretches levator scapula causing pain

Abnormal anterior disc joint loading and facet separation. Joint stabilization compromized



3D reactive compensation in the thoracic, lumbar and pelvic regions .

The Building Blocks of the Spinal System

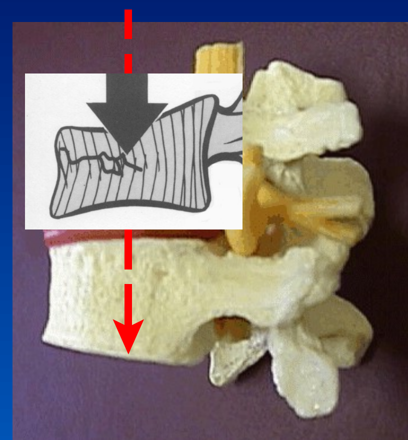
The Motion Segment

- The spinal system is composed of **alternating, interconnected hard (rigid) and soft tissue (elastic) components**
  - The hard tissue includes the vertebra, skull and pelvis
  - The soft tissue includes the intervertebral discs, intervertebral ligaments and pelvic ligaments
- Collectively the hard and soft tissue components form a **semi-rigid structure that provides strength and flexibility**
- The strength of the spinal system is based on the physical properties of each of the spinal components working singularly and collectively
- **Injury to any spinal component decreases the strength, flexibility and efficiency of the spinal system** .

Rigid Materials

Bones

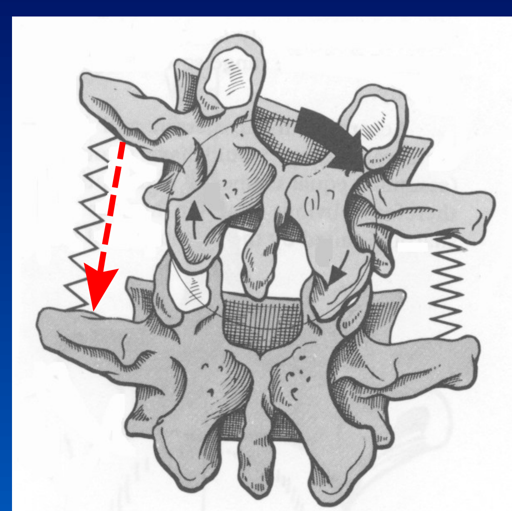
- Bones are **rigid materials**.
- They primarily carry and transmit **compressive loads** with little deformation.
- Bone strength is determined by its molecular structure.
- When rigid materials are overloaded they **permanently deform or fracture** and do not return to their original shape.
- If deformed, they permanently alter the normal distribution of forces across joint surfaces and **alter the global balance** of the spinal system (example: vertebral collapse) .



Elastic Materials

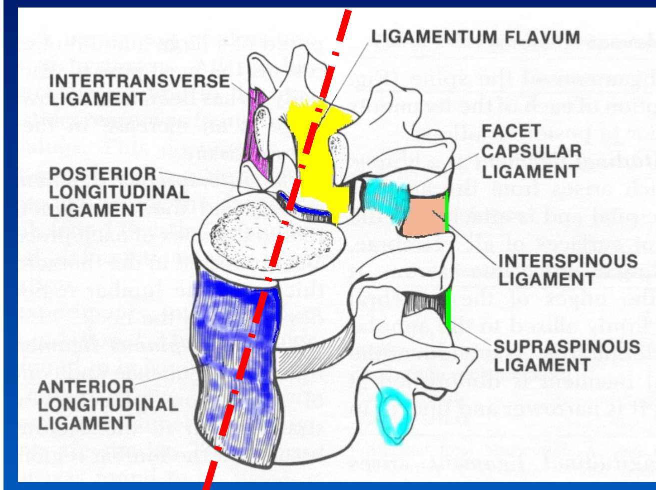
- **Ligaments are elastic materials** that primarily resist tensile (pulling) forces.
- Elastic materials
  - when subjected to tensile forces elongate and store energy.
  - When the tension is removed the stored energy is released and the material returns (recoils) to its original shape.
- **Elasticity of the ligament system maintains the mechanical organization (neutral joint alignment) of the spinal system**
- When the spinal system becomes misaligned there is stored energy in multiple ligaments pulling the spine toward neutral alignment .

Ligaments



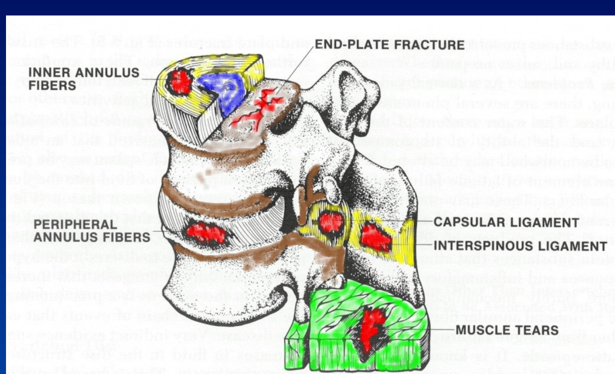
Elasticity of Spinal Ligaments

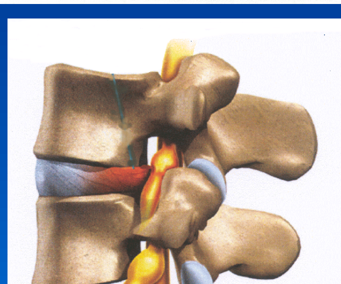
Ligament System



- A mid-line cut through the motion segment demonstrates the intervertebral **ligaments are attached symmetrically**
- This provides elastic strength and stability to **maintain a three dimensional neutral position**
- When a vertebra moves off center the elastic energy in the ligaments has a **restoring force** that pulls the motion segment towards its neutral position
- This stored energy assists the doctor when making spinal adjustments .

Physical Sources of Pain Driven by Abnormal Mechanical Loading

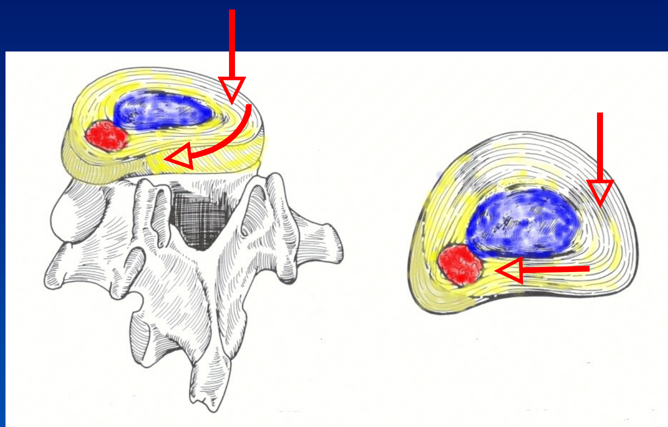




- **Abnormal alignment** results in abnormal **structural loading**
- These variables produce pain from
  - Chronic sprain / strain of the ligaments and muscles
  - Abnormal joint pressure on the vertebral facet and stretching of the capsular ligament
  - Irritation to the nerve root at the intervertebral foramina
  - Irritation to the nerve root from disc bulging or herniation
  - Irritation to the inervating tissue.

Rotational Misalignment Between Two Vertebra

Mechanical Disruption of the Disc



- A rotational misalignment creates rotational **shear stresses** in the disc.
- Over time and in combination with other unbalanced forces the lamina of the annulus cracks from the inside out and the nucleus begins to migrate outward
- The disc bulge moves in a direction from a high to a low pressure zone
- This is the beginning of chronic disc failure .

Spinal Compensation

- When the spinal system gets injured and optimum balance is disturbed it predictably rebalances or compensates. **The primary mechanism of compensation is the coupled motions of gait**
- The coupled motions of gait act individually and collectively in a symphony of motion including pelvic rotation, torso rotation and segmental ROM.
- This hard wired (facet architecture) symphony of gait is the natural pathway available for compensation.
- **Compensation continues until mass displacements and muscle activation achieves balance**
- Over time **compensation deteriorates and disorganizes** segmentally, regionally, and globally. This is minimally due to unbalanced gravitational forces .

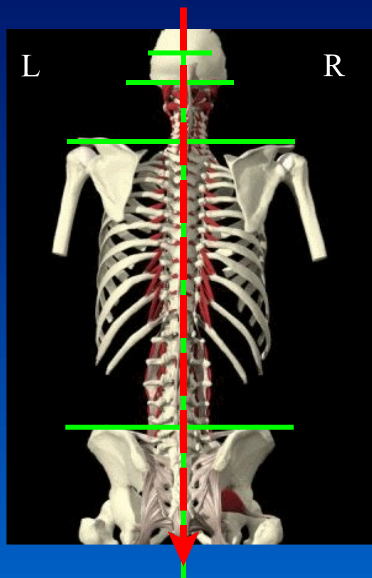
Describing the Optimum Spine

The Spinal System in an Optimum Neutral Position

- In an optimum upright neutral position the spine is
  - balanced front to back and left to right.
  - The head is upright with the eyes looking forward
  - The motion segments are aligned one to another in a centered neutral position. There is a symmetrical reserve of full range of motion
  - The ligaments are symmetrically loaded and at a minimum energy state
  - The muscles are in a minimum energy state
- **The neurological system maintains this mechanical minimum energy state.**

Optimum Spine Geometry: Frontal Plane

Viewing the spine from the back



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- Spine is vertical
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- **Balanced and symmetrical .**

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Optimum Spine Geometry: Sagittal Plane

Optimum Geometry and Alignment Produces
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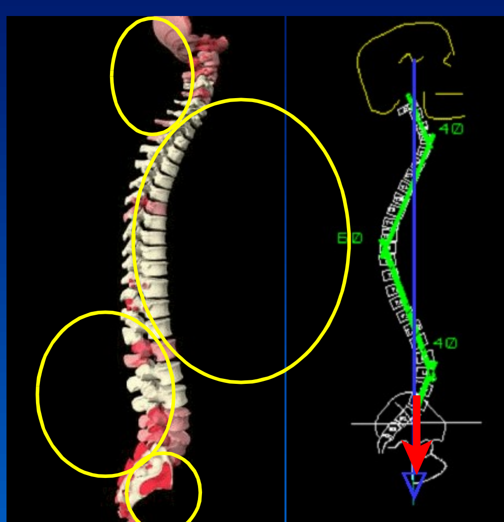

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  - Lumbar
- One is a static curve
  - Sacral
- The head is positioned over the center of the pelvis
- **The spine is balanced front to back .**

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Tissue and Joint Loading

- Loading occurs as **tension, compression and shear forces**. Each tissue type has physical properties that determine a **safe load carrying capacity**.
- Loading to any tissue of the body produces excitation of receptors that can produce **sensations of pressure, pain or temperature**
- Sudden severe loading can rupture connective tissue causing acute pain
- Prolonged **tissue loading** causes tissue **fatigue, chronic pain and tissue failure**
- Prolonged and abnormal **joint loading** causes remodeling and **degeneration** (Piezo electric effect).

Optics and Particle Physics

- The spine is a **three dimensional object** that when x-rayed is **collapsed to a two dimensional image.** The two dimentional image records the three dimensional characteristics.
- The image is subject to the principles of particle physics and optics. Therefore the effects of distortion to an x-ray image are predictable
- The optimum three dimensional spine model produces only two **predictable geometric patterns** in the frontal plane. This resulted when the patient was malpositioned and a consequence of x-ray properties.
- The two dimensional geometric patterns represent the full three dimensional alignment organization of the optimum spine **when viewed from any angle**.
- These two dimensional optimal patterns can be **used for comparison to assess the structural and functional efficiency** of the patient .

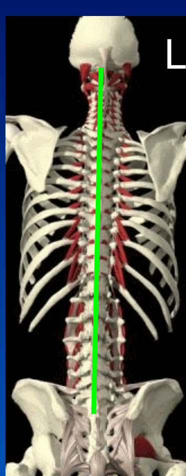
Geometric Characteristics of the Optimum Spine from Various Viewing Angles (Torso Rotation)

Projected Lateral Bending

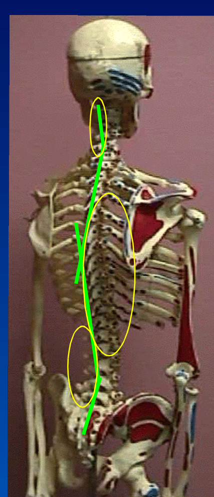
Neutral Left rotation Right rotation

- On x-ray the optimum spine demonstrates two mirror images of projected lateral bending (functional scoliosis) when the torso is rotated to either the left or right
- **Decreased and increased torso rotation changes the amplitude of the projected lateral bends but not the organizational characteristics** .

Regional and Global Geometry of the Compensated Spine due to Torso Rotation



Neutral



Compensatory Torso Rotation

Projected Frontal Plane

- On x-ray the effects of right torso rotation produces a **projected image of a <u>balanced scoliosis</u>**
- This occurs as the sagittal plane spinal curves **<u>project</u>** into the frontal plane
- The x-ray image demonstrates **<u>organized regional and global distortion</u>** (reciprocating lateral bends)
- The organized geometry of the compensatory spine provides an **<u>optimum reference</u> for patient comparison** .

Frontal Plane: Analyzing the Optimum Spine in a Non-neutral Position (NP)

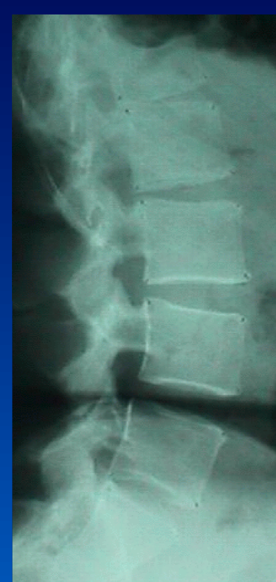
- What is the rationale for analyzing the optimum spine model in a non-neutral position?
- The rationale for describing the non-neutral position is, in theory it is **impossible to place the patient in an optimum neutral position during the x-ray procedure.**
- The reasons are:
  - The center of the patient spine can only be approximated from external landmarks
  - The center of the buckey can not be seen
  - **The patient has a compensated / distorted spine which precludes optimum neutral placement to the central beam and bucky**.

Pure Plane and Hybrid Projections

A-P

Off axis patient placement due to patient spinal distortion produces a hybrid x-ray projection

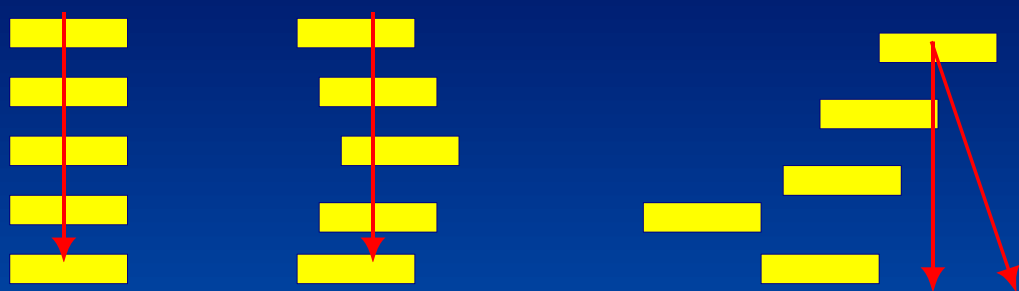
Hybrid: an x-ray view that is mostly A-P plane with partial projection of the sagittal plane curves



LAT

Organizational Concepts

Strength and Balance of multi-component systems



- A vertical column provides maximum support to resist gravity and maintain balance

An offset column can maintain balance but its load carrying capacity is reduced

Too much offset of one component removes the foundation for the components above and the system fails due to gravity

The nature of motion segment alignment and misalignment closely resemble this concept of stacking and offsetting

Plotting Spinal Geometry for Patient Assessment

- Data points (x,y coordinates) representing the architecture of the vertebra are obtained from x-rays and transferred to a computer spine model
- Measurements and graphical analyses are performed
- The patient findings are correlated to the biomechanical data
- **Adjustment vectors are determined for specific misaligned vertebra to restore normal position and function**

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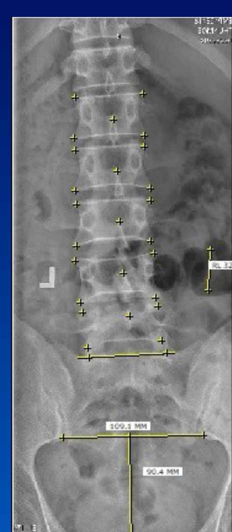
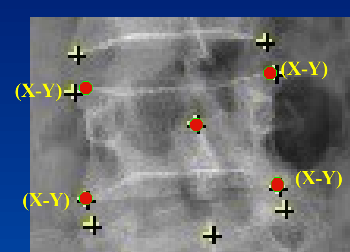
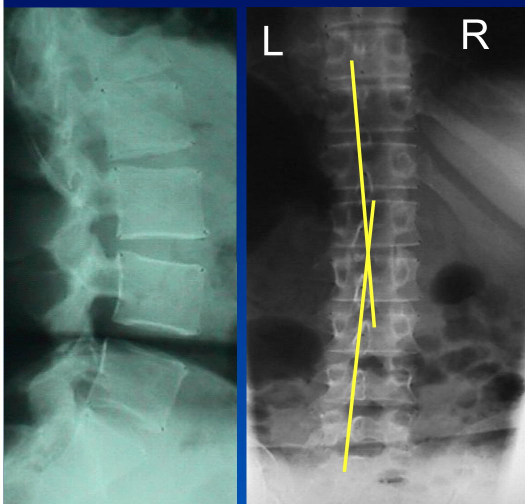
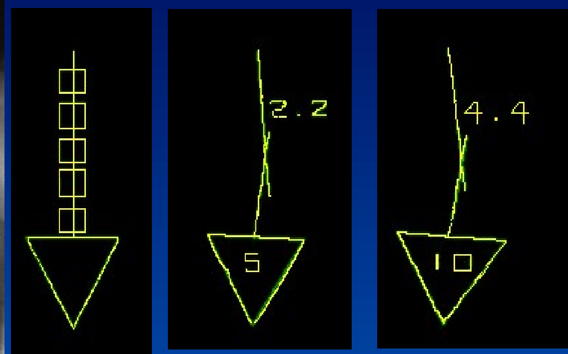




The Effects of Rotational Malposition





Optimum 5° R rotation 10° R rotation

- The amplitude of the convex curve is proportional to the amount of torso rotation and the sagittal plane curvature.

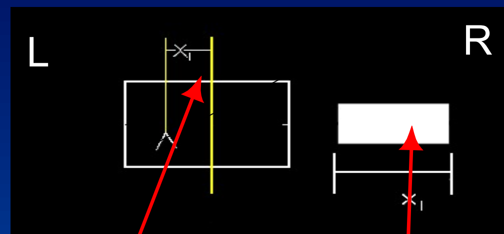
The Purpose of Analyzing the Geometry of the Optimum Spine Model in Compensatory Torso Rotation

All patients present with the spine in a non-neutral position of gait that has segmental and or regional disorganization

- The projection of torso rotation and its coupled motions of gait create a **common frame of reference** for patient comparison.
- The patient presents in a non-neutral position of gait.
- The patient is being compared to the geometry of an optimum, uninjured spine in a non-neutral position of gait
- Adjusting the patient to the mechanical organization of the optimum spine model **rehabilitates the spine three dimensionally both mechanically and functionally** .

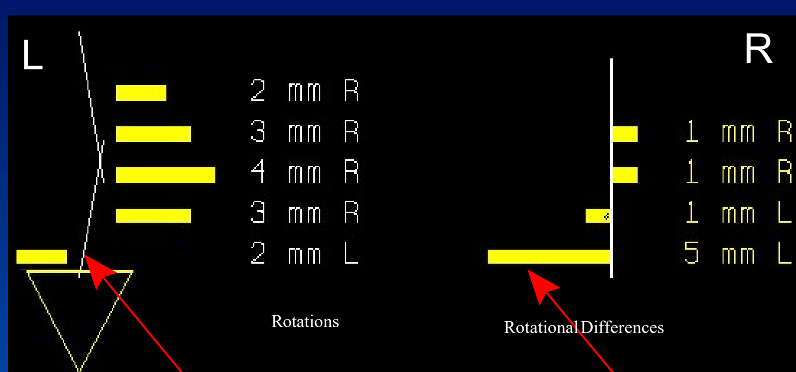
Measuring Vertebral Body Rotation

Graphical Display



- Measured as an offset of the interlamina junction to the centerline
- Displayed as a proportional horizontal bar graph
- Graphing will be used to assess regional motion segment coupling

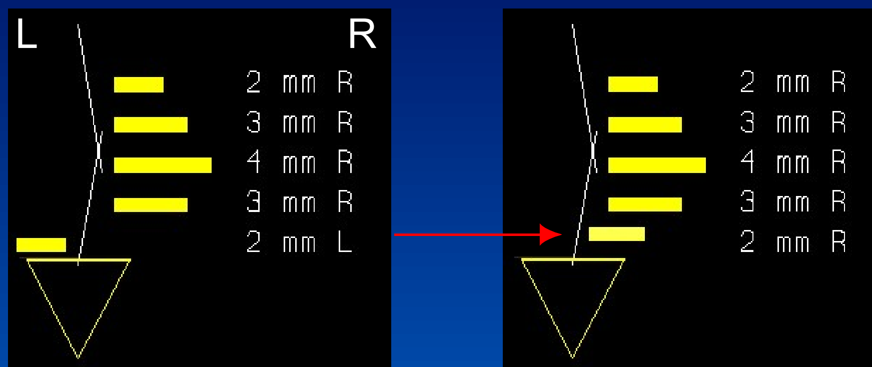
Disorganized Rotations and Subluxation



- Abrupt rotational misalignment, rotational differences can be measured and displayed graphically to identify compensatory patterns, segmental failure and vertebra for adjustment

Correction of Subluxation

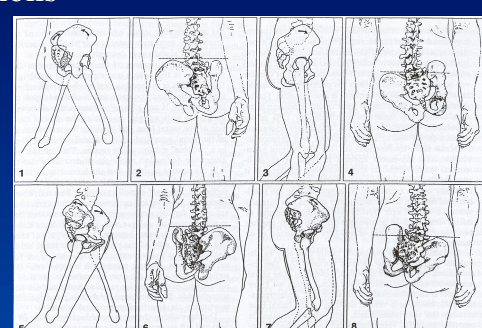
Left lateral bend should have right vertebral body rotations



- Correction of L5 from left rotation to right rotation with spinal adjusting restores normal vertebral coupling

Gait: The Mechanical Pathway of Compensation

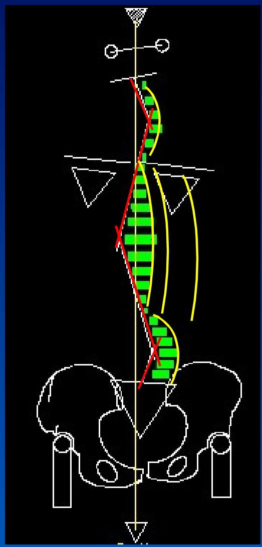
- The primary spinal distortion patterns observed on x-ray are related to the normal combined (coupled) motions of gait. These motions
- include:
  - Pelvic motions including:
    - Posterior / anterior rotation of the ilium (AS, PI)
    - Tilting and rotation of the sacrum (AI sacrum)
  - Lateral flexion of the lumbar spine, coupled with
  - Rotation of the lumbar vertebra, coupled with
  - Torso rotation with arm swing
  -



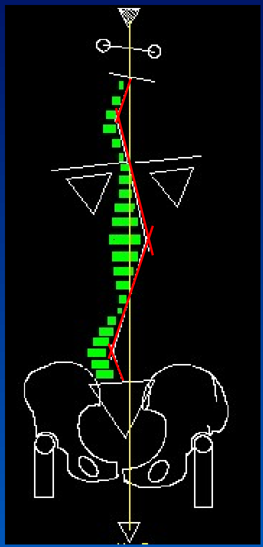
- Torso rotation is a primary spinal distortion (compensation) seen on x-ray During gait the torso can rotate up to 35 degrees.
- **<u>When the spinal system compensates to injury or anatomical deficiencies it rebalances by rotating the torso including all the coupled motions of gait until the system is balanced at a minimum energy state by mass offsets and muscle contraction .</u>**

The Geometry of Compensatory Torso Rotation Demonstrates Segmental and Regional Organization

- On x-ray the compensatory spine demonstrates full geometric organization from left or right torso rotation
  - There are reciprocating lateral bends in the (C,T,L) regions
  - The vertebral body rotations are
    - All on one side
    - Have increasing and decreasing amplitude within each spinal region
  - The head is balanced over the sacrum
- **The geometric organization is an indirect measure of the mechanical efficiency of the spine** .



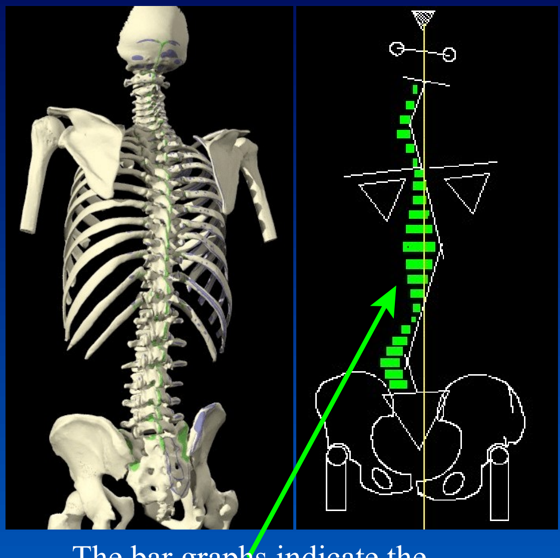
Right torso rotation



Left torso rotation

Segmental Organization of an Optimum Spine

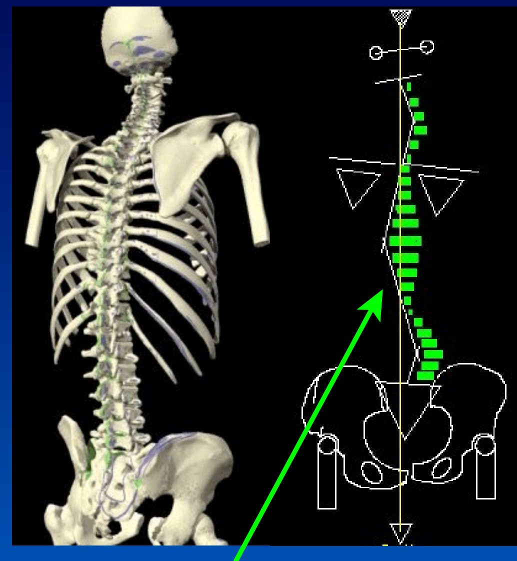
- On x-ray a left torso rotation of the optimum spine produces a **projected image of <u>left vertebral body rotations</u>**
- This occurs as all the spinous processes project a right rotational offset
- **The vertebral body rotations demonstrate segmental, regional and global alignment organization**
- There is smooth transition of minimum and maximum rotations. Maximum rotations occur at the apices of the sagittal curves C5, T6, L3
- The organization of the vertebral body rotations provide an **<u>optimum reference</u> for patient comparison** .



The bar graphs indicate the direction and relative amplitude of vertebral body rotation

Image of Right Torso Rotation

- On x-ray a right torso rotation of the optimum spine produces a **projected image of right vertebral body rotations**
- This occurs as all the spinous processes project a left rotational offset
- **The vertebral body rotations demonstrate segmental, regional and global alignment organization**
- Maximum rotations occur at the apices of the sagittal curves C5, T6, L3
- The organization of the vertebral body rotations provide an **optimum reference for patient comparison** .



The bar graphs indicate the direction and relative amplitude of vertebral body rotation

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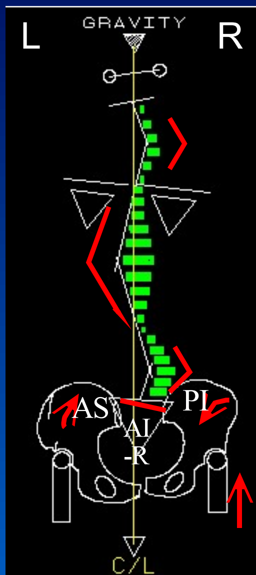
The Optimum Spine in a Non-Neutral Position of Gait mimics Patient Compensation Patterns

The x-ray geometry is predictable

- The geometry of the optimum spine when x-rayed in a non-neutral position mimics the findings of the compensatory spine in a non-nutral position:
  - Both demonstrate the same regional lateral bends that are reciprocating left and right in the C,T,L regions.
  - Both demonstrate the same motion segment organization in vertebra rotation throughout the C,T, L regions*.
- X-ray physics predicts these image findings due to the diverging nature of the central ray and object position.

Biomechanical Findings of Organized Compensation

Right Compensatory Pattern Associated with Right Torso Rotation and coupled motions of Gait



Right inferior sacrum (AI-R)

Right ilium rotated posterior (PI)

Resulting in functional right short leg

Left ilium rotated anterior (AS)

Right lumbar convex curve with right vertebral body rotations

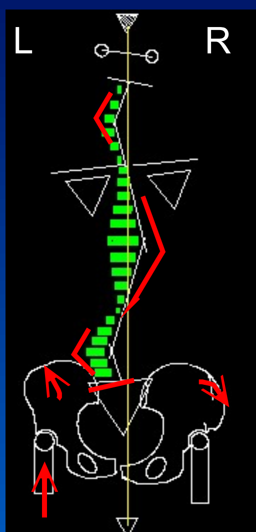
Left thoracic convex curve with right vertebral body rotations

Right cervical convex curve with right vertebral body rotations

These geometric characteristics and physical findings are compared to the patient to assess spinal organization and to determine specific spinal adjustments .

Biomechanical Findings of Organized Compensation

Left Compensatory Pattern Associated with Left Torso Rotation



Left inferior sacrum (AI-L)

Left ilium rotated posterior (PI)

Resulting in functional left short leg

Right ilium rotated anterior (AS)

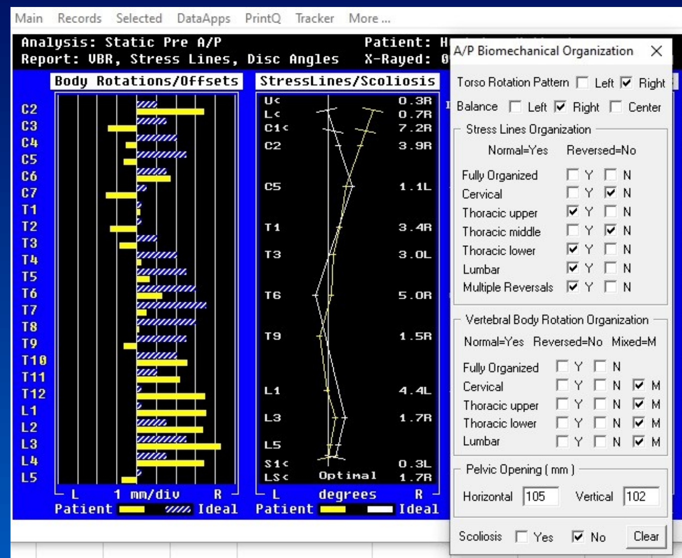
Left lumbar convex curve with left vertebral body rotations

Right thoracic convex curve with left vertebral body rotations

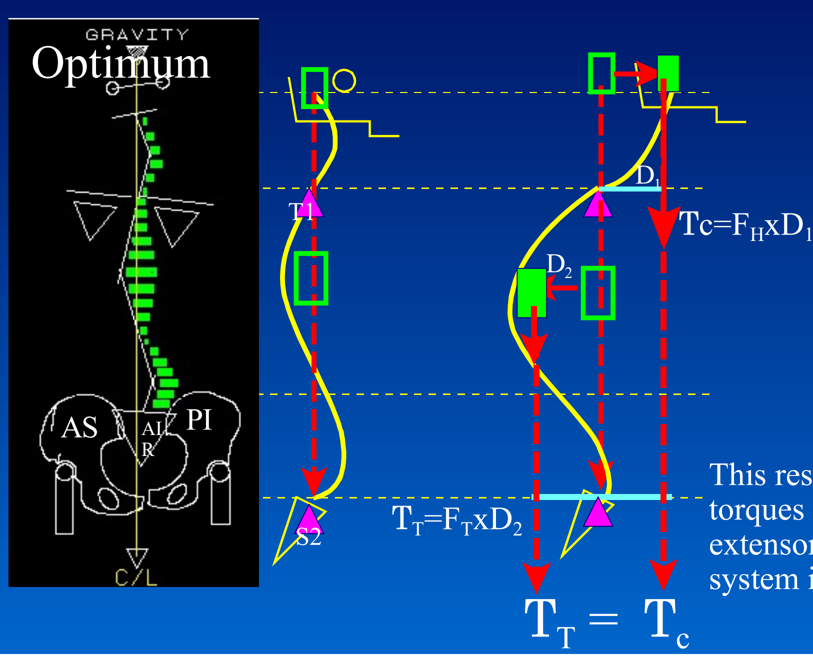
Left cervical convex curve with left vertebral body rotations .

Patient Example L5, L2 Rotational Malposition

- The most common rotational failure in the lumbar spine is L5 rotated to the opposite side of normal coupling.
- This patient was matched to a right torso rotation pattern.
- VBR coupling is disrupted at L5 rotating to the left instead of the right.
  - This is a chronic subluxation driven by the reverse rotation of S1 in compensation.



Compensation: Static Equilibrium Achieved by Balance of Masses and Muscle Contraction



With cervical injury center of gravity / mass of head moves forward

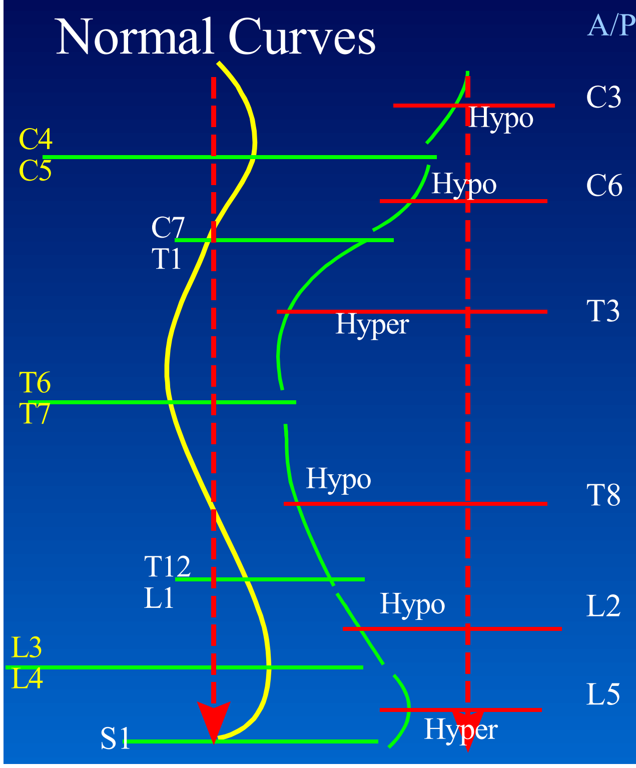
This creates unbalanced torque at T1 and S2
Cervical, lumbar and pelvic extensors activated

This results in forced compensation in the frontal plane to balance the system. This includes torso rotation, pelvic coupling and lumbar extension

The torso center of mass moves backwards

This results in opposite and balanced torques around S2. Lumbar and pelvic extensors are deactivated and the spinal system is balanced .

Breakdown of the Sagittal Curves



- When the normal sagittal curves are intact the highest loading occurs at the apex of the curves C4/5, T6/7 and L3/4
  - Neutral A/P position maintained by ligament integrity
- When the sagittal curves breakdown the highest loading is at the mid point of the altered curve
  - C3, T3, T8, L2, L5
- In the frontal plane the vertebra rotate to stabilize againnst abnormal loading
- Other rotation combinations exists as the sagittal curve continue to destabilize and normal coupling is lost.

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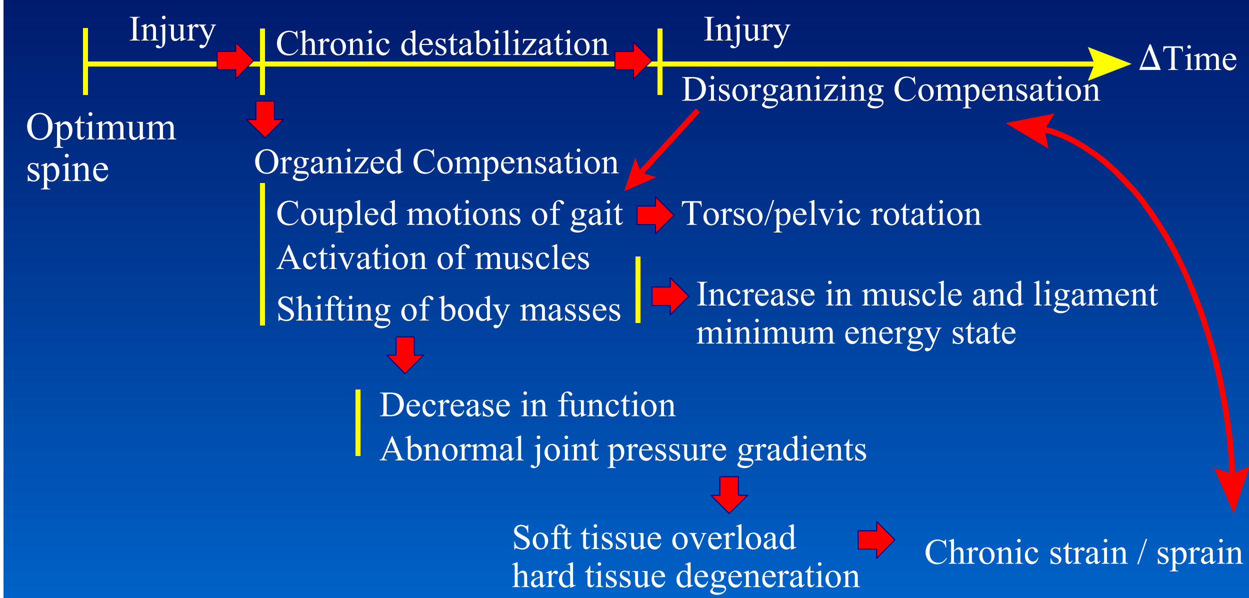
Spinal Compensation

- When the spinal system compensates the following occurs:
  - Loss of joint symmetry
  - Abnormal joint loading
  - Diminished joint function
  - Decreased and unbalanced ranges of motion
  - Unbalance and increase of ligament forces
  - Unbalance and increase of muscle forces
- Prime mover muscles activated for postural stabilization.

Spinal Compensation: Organized to Disorganized

Pain may occur anywhere or anytime along the injury process



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Seven A/P Distortion Have Been Identified

For each Left and Right Torso Rotation Pattern

- They include:
- 1 Compensation fully expressed
- 2 Cervical curve reversed
- 3 Upper thoracic curve reversed
- 4 Mid thoracic curve reversed
- 5 Lower thoracic curve reversed
- 6 Lumbar curve reversed
- 7 Multiple curves reversed

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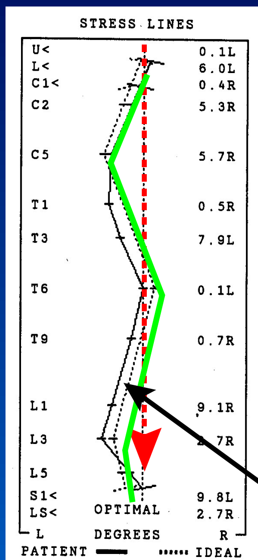
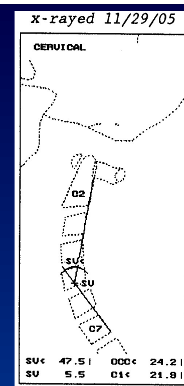
#1 Left Pattern
Normal Lateral Bending C,T,L



- **Reciprocating lateral bends C,T,L (normal compensation)**
- Head balanced over the pelvis
- AI sacrum (L)
- AS pelvis (R)

Solid black line is patient distortion pattern



Effertz, Elizabeth

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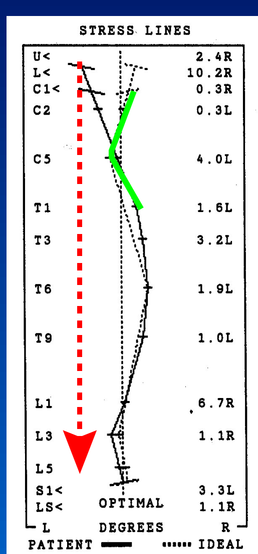
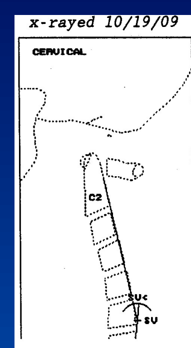
#2 Left Pattern
Lateral Bend in Cervical Region Reversed



- **Lateral bend in cervical region reversed**
- Head unbalanced left
- Normal thoracic and lumbar compensation
- AI sacrum (L)
- PI pelvis (L)
- Lateral cervical curve usually reversed



Chisley, Cassandra

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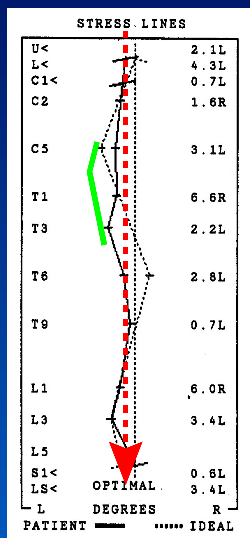
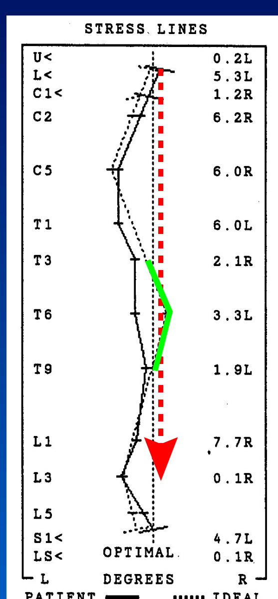
#3 Left Pattern
Lateral Bend in Upper Thoracic Region Reversed



- **Lateral bend in upper thoracic region reversed**
- Head unbalanced left
- Normal lateral bends in cervical and lumbar regions
- AI Sacrum (L)
- PI Pelvis (L)

Birkenmeier, Ron

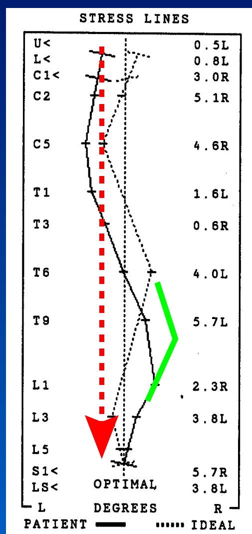
#4 Left Pattern
Lateral Bend in Mid Thoracic Region Reversed



- **Lateral bend in mid thoracic region reversed**
- Head unbalance left or right
- Normal lateral bends in cervical and lumbar regions
- AI sacrum (L)
- PI pelvis (L)

Gyimesi, Joel

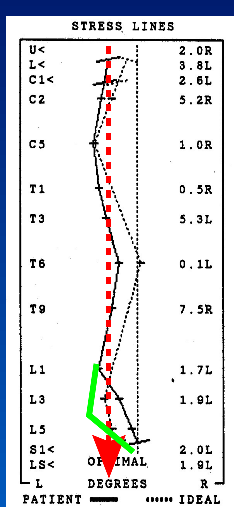
#5 Left Pattern
Lateral bend in Lower Thoracic Region Reversed



- **Lateral bend in Lower Thoracic Region Reversed**
- Head unbalanced left or right
- Normal lateral bends in cervical, upper thoracic, and lumbar regions
- AI sacrum (L)
- AS pelvis ®)

Brooks, Karle

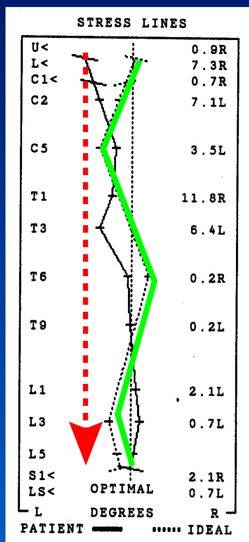
#6 Left Pattern
Lateral Bend in Lumbar Region Reversed



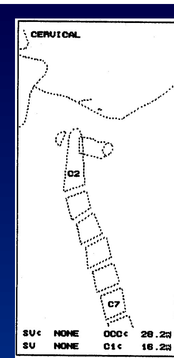
- **Lateral bend in lumbar region reversed**
- Head unbalanced left or right
- Normal lateral bends in cervical, thoracic regions
- AI sacrum (L)
- AS pelvis ®)

Berry. Krystal

#7 Left Pattern Lateral Bends Reversed in Multiple Spinal Regions



- **Lateral bends reversed in multiple spinal regions**
- Head unbalanced left or right
- AI sacrum (L)
- AS pelvis ®)
- Lateral cervical curve usually reversed



Bauer, Darrin

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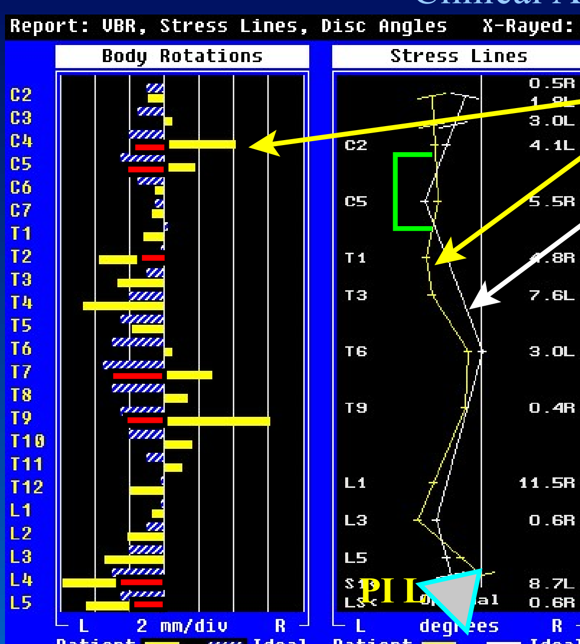
Spinal Analysis

Clinical Application



A global match of the **patient geometry** to the **ideal compensatory** pattern is determined in the frontal plane

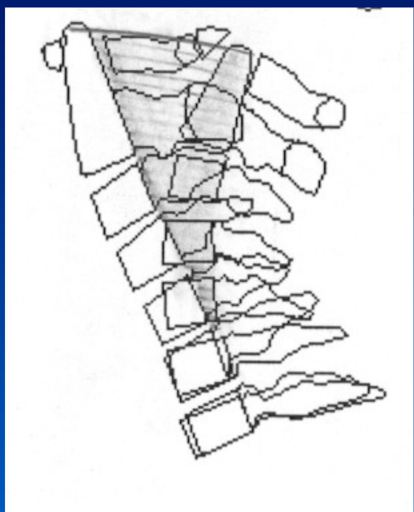
Abnormal vertebral body rotations are identified
C4, C5, T2, T7, T9, L4, L5

Abnormal lateral bends are identified **(cervical region)**

Pelvic distortion is determined
AI Sacrum (L)
PI (L) .

Sagittal Plane Analysis

Measuring patient difference to balanced curve



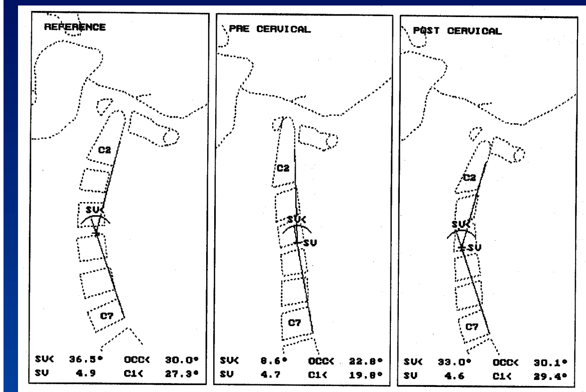
- Patient geometry compared to geometry of balanced spinal curve
- Patient difference reported over 19 variables.
- Patient quantified and qualified into severity categories
- Inter examination documents changes, progress and residual deficits.

Sagittal Plane Analysis

- Sagittal plane analysis for each region of the spine includes measurements of:
  - Curvature
  - Intervertebral alignment
  - Offsets of optimum gravitational transfer points
  - Disc angles
- The difference of the patient findings to the optimum spine model is used to determine a quantitative scale of severity
- Motion study analysis of cervical and lumbar spinal regions are performed to determine segmental dysfunction and adjustment vectors
  - Hypo and hyper mobile segments are identified for rotation and translation .

Lateral Cervical Data Analysis

Pre / Post Comparison   58% improvement in abnormal spinal geometry



Cervical Pre/Post

		Patient		Range		%Ideal		SSU	
		Pre	Post	Average	Ideal	Pre	Post	Pre	Post
CDL<	(deg)	22.8	30.1		30.0				
CDL/C1<	(deg)	3.0	0.7		2.5	120	28	0.5	1.8
C1<	(deg)	19.8	29.4	20.3	27.3	73	108	7.5	2.1
C2<	(deg)	-1.8	15.1	0.8	9.1	-20	166	10.9	6.0
C1/C2<	(deg)	21.6	14.3	19.7	17.9	121	80	3.7	3.6
Rc	(cm)	58.3	42.0		18.0	-324	233		
Rc up	(cm)	18.4	29.1		18.0	102	162		
Rc lo	(cm)	-233.5	24.7		18.0	-1297	137		
Rc ideal	(cm)	18.2	17.8						
CL<Rc	(deg)	-4.3	-2.1		0.0			4.3	2.1
CL<Rc up	(deg)	14.3	-3.2		0.0				
CL<Rc lo	(deg)	-1.8	1.1		0.0				
SV<	(deg)	8.6	33.0	21.8	36.5	24	90	27.9	3.5
SV		4.7	4.6	3.9	4.9				
GC5	(mm)	-7.4	5.8					7.4	0.0
GC7	(mm)	14.5	-4.1		0.0			14.5	4.1
C4<	(deg)	16.9	-12.8		-10.0			6.9	2.8
C7<	(deg)	13.0	-20.7		-27.0	48	77	14.0	6.3
T1<	(deg)	16.6	-28.2		-30.0	55	94	13.4	1.8
C2 Disc<	(deg)	5.3	2.6	3.8	6.6	80	39	1.3	4.0
C3 Disc<	(deg)	3.3	6.6	4.5	6.7	49	99	3.4	0.1
C4 Disc<	(deg)	-1.1	2.7	3.1	7.2	-15	38	8.3	4.5
C5 Disc<	(deg)	1.2	5.5	2.4	4.2	29	131	3.0	1.3
C6 Disc<	(deg)	4.0	9.6	2.7	4.2	95	229	0.2	5.4
C7 Disc<	(deg)	3.6	7.4	1.5	2.0	180	370	1.6	5.4

Cervical SSU Sum		Severity	
Pre:	128.8	Pre:	Severe
Post:	54.8	Post:	Minimum
%Chg:	-58		

1 SSU is 1 UNIT (deg/mm/cm) difference from IDEAL !!

Patient values calculated and compared to **ideal reference**

Numerical difference used to quantify biomechanical severity .

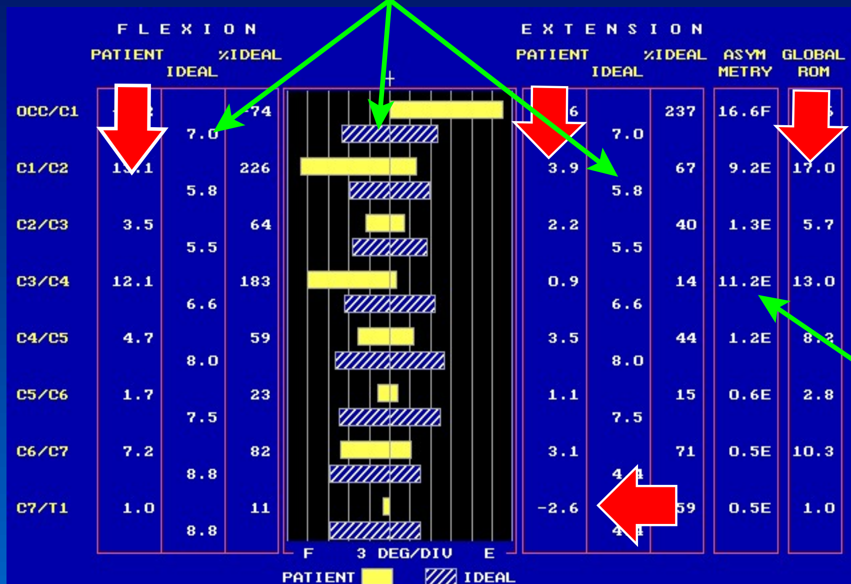
Serial examination demonstrates changes, improvements, and residuals deficiencies.

Cervical Motion Study Analysis

- The cervical motion analysis is performed to determine
  - Segmental range of motion for flexion and extension
  - Identify dysfunctional motion
  - Determine adjusting vector to return motion segment to neutral position .

Displaying the Cervical Motion Analysis in Graphical and Tabular Formats

Flexion values · Ideal Range of Motion · Extension values



Global range of motion

Motion dysfunction .

Paradoxical Motion

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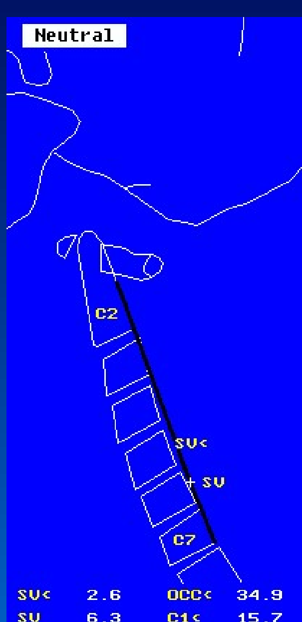
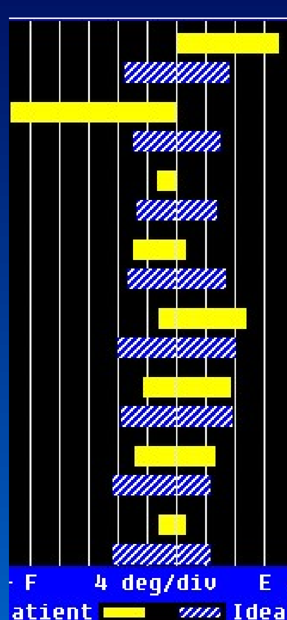
Motion Study and Adjusting





- Overall loss of cervical curve C5 PA SI (drop table)
- C1 fixated in extension IS LOC (instrument adjusting)
- C4 flexion fixation SI LOC (instrument adjusting)
- Posterior cervical compression .

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Clinical Goal

Spinal Adjusting and Soft Tissue Rehabilitation

- The goal of clinical intervention is to introduce specific physical forces (spinal adjustments) that three dimensionally rehabilitate the spinal system toward organized compensation
- This includes correcting rotational misalignments, abnormal lateral bends and abnormal sagittal curves
- As the spine organizes it equalizes joint loading, disc pressure and relieves chronic stress and strain of the ligament and muscles
- It diminishes the functional component of stenosis
- Support therapies are included to promote tissue healing, diminish pain and strengthen specific muscle groups

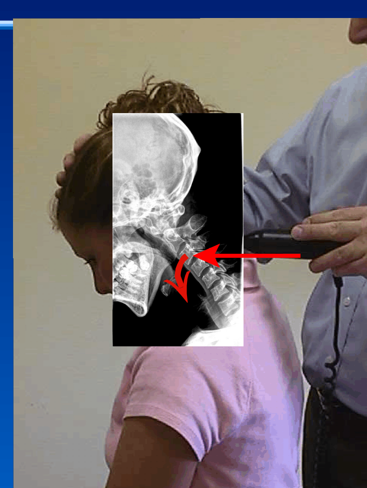
Adjusting the Patient with Specific Cervical Adjustment Vectors

Flexion fixation:
Superior to Inferior
correction vector

Vertebra rotates into extension

Extension fixation:
Inferior to superior
correction vector

Vertebra rotates into flexion



Clinical Application

Diagnostic Procedures

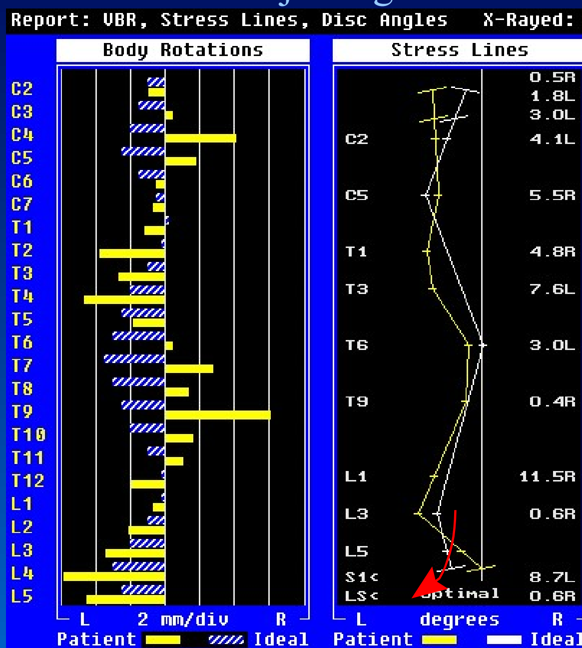
- The patient spinal configuration is compared to the spinal patterns of the optimum spine
  - A closest match is found to identify the ideal compensatory pattern as a right or left torso rotation
  - Specific locations and adjustment vectors are determined to realign the patient to the organization of a spine in ideal compensation
- As the patient is adjusted the spinal system reorganizes and becomes
  - More efficient and functional
  - Decreases abnormal joint loading
  - Decreases abnormal ligament and muscle tension
  - Decreases pain .

Adjusting Procedures

- Specific vectors (force and direction) are applied to the spinal system
- Patients are adjusted using a combination of the following procedures
  - Drop table; cervical, pelvic, lumbar, thoracic
  - Flexion distraction
  - Instrument adjusting with lateral flexion
  - Instrument adjusting with flexion distraction
  - Cervical instrument adjusting
  - Extremity adjusting .

Clinical Example: Adjusting Procedures

Order of Adjusting



- Lateral flex pelvic portion to left and elongate spine
  - This produces tension in the spine and slightly separates facet joints
- 1) Posterior to anterior drop on C5 ®)
  - Correction of cervical curve
- 2) Instrument adjusting to sacral tuberous ligament on side of inferior sacrum (L)
  - Correction of sacral / pelvic misalignment
- 3) Pelvic drop on side opposite inferior sacrum (AS R)
  - Correct pelvic misalignment .

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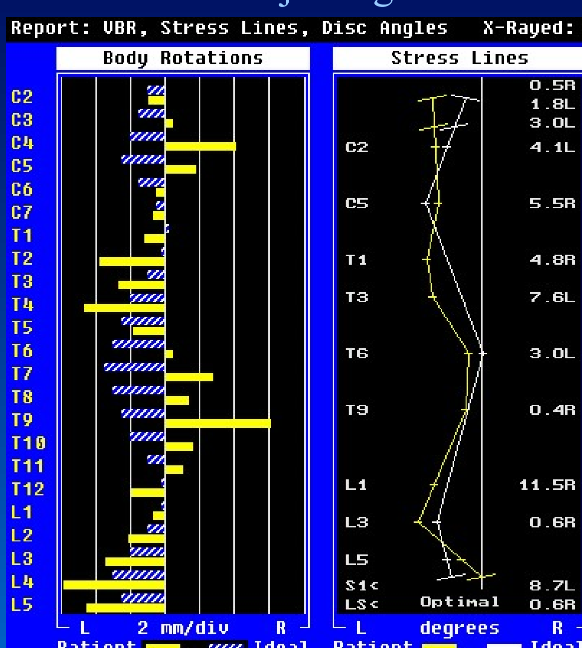
Clinical Example: Adjusting Procedures

Order of Adjusting



- 4) Lumbar, thoracic drop
  - To promote / correct normal coupling
- 5) Flexion distraction full spine
  - Stretching of ligaments and muscles
  - Disc decompression
  - Identify locations of guarding and pain
- 6) Instrument adjusting (L/R) to lumbar / thoracic vertebra at specific locations with lateral flexion
  - To promote / correct normal coupling .

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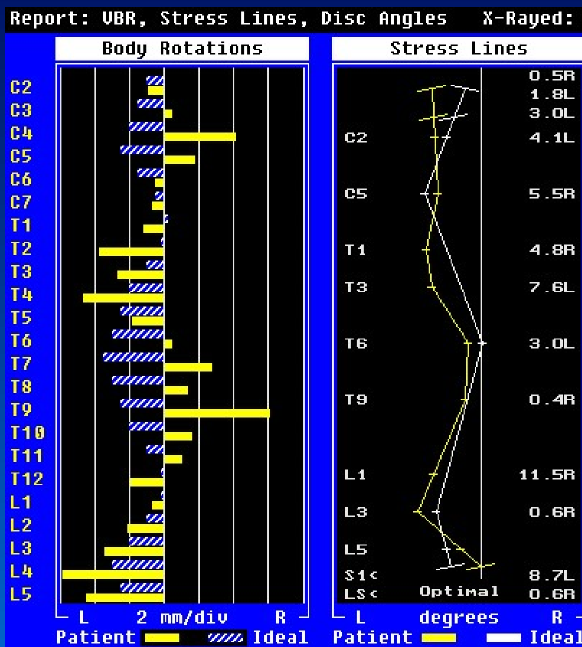
Clinical Example: Adjusting Procedures

Order of Adjusting



- 7) Flexion distraction with instrument adjusting (PA) T9-T12, T1-T4
  - Mobilize hypomobile segments
- 8) Flexion distraction full spine to check for residual guarding
- Patient sits up
- 9) Instrument adjusting cervical spine from motion analysis
- 10) Extremity adjusting
- Support therapies
  - Interferential, ice
  - Cold laser, Specific exercises
  - Whole body vibration therapy