3

Thoracic Spine

LEARNING OBJECTIVES

After the completion of the chapter, the readers will be able to:

- Understand the anatomy of the thoracic vertebrae, ribs, and sternum.
- Describe the structure and boundaries of the thoracic region.
- Explain the anatomy and functions of the diaphragm.
- Comprehend the mechanics of respiration, including pump-handle and bucket-handle movements.
- Analyze the biomechanics of the thoracic spine.
- Evaluate the effects of posture and spinal alignment on respiration.
- Understand the causes, classifications, radiological evaluation, prognosis, and management of scoliosis.
- Describe the types, clinical features, complications, and treatment of kyphosis.
- Recognize the causes, clinical presentation, diagnostic approach, and physiotherapy management of thoracic radiculopathy.

CHAPTER OUTLINE

- Introduction
- Anatomy
- Mechanics of Respiration
- Biomechanics
- Scoliosis
- Kyphosis
- Thoracic Radiculopathy
- Recent Advancements

INTRODUCTION

The thoracic spine, also known as the dorsal spine, forms the central portion of the vertebral column and plays a crucial role in protecting vital thoracic organs while providing structural support and stability. It is unique among spinal regions due to its articulation with the ribs, which creates a rigid yet flexible thoracic cage that assists in respiration and load transmission. Understanding the anatomy of thoracic vertebrae, their articulations, and associated rib structures is essential for comprehending spinal biomechanics, postural alignment, and clinical conditions, such as scoliosis, kyphosis, and thoracic injuries.

ANATOMY

There are twelve vertebrae in the dorsal region, characteristic features of thoracic vertebrae are heart-shaped vertebral body, and the spinous process projects downward to overlap one or two vertebrae below it. Each vertebral body has hemi-facets present on postero-superior and postero-inferior parts for the articulation with head of the rib forming the costovertebral joint. The articular facets in this region are oriented approximately 60° to the transverse plane and 20° to the frontal plane which allows side flexion and rotation movements. Extension is grossly restricted by approximation of spinous processes. Posteriorly, there are twelve pairs of ribs that articulate with the thoracic vertebrae. The first seven pairs of ribs, termed true ribs, articulate directly with the sternum through their individual costal cartilages. In contrast, the 8th to 10th pairs, referred to as false ribs, connect to the sternum indirectly by joining to the costal cartilage of the seventh rib. Eleventh and twelfth ribs are not connected to the sternum and are known as floating ribs. The intercostal spaces between the ribs contain intercostal muscles, corresponding nerves, arteries and veins. Posteriorly, the superficial surface of the rib cage is covered by thoracolumbar fascia, which provides attachment to abdominal, neck, back and pectoral muscles. Each rib is anatomically composed of a head, neck, and shaft. The rib's head articulates with the corresponding vertebral body, forming the costovertebral joint which is a synovial joint of the plane type. The facet of head of the 1st, 10th, 11th and 12th ribs articulates with the corresponding facet of respective thoracic vertebral body and each form a simple synovial joint, whereas hemi-facets of head of 2nd to 9th ribs articulate with the corresponding hemi-facets of corresponding thoracic vertebra and the vertebra above it to form compound synovial joint. The capsular ligament of the costovertebral joint is further reinforced by radiate ligament and intra-articular ligament. The tubercular facet of the rib articulates with the transverse process of the corresponding thoracic vertebra, forming the costotransverse joint which is a synovial joint of the plane variety. The capsular ligament is reinforced by costotransverse, superior costotransverse, lateral costotransverse and accessory ligaments. The thoracic region, comprising the sternum, ribs, thoracic vertebrae, and diaphragm, forms a protective framework for thoracic organs and provides attachment sites for muscles involved in respiration and posture.

Sternum

Sternum is a long flat bone present in the midline of anterior thoracic wall. The superior portion of the sternum which is the manubrium is wider and articulates with medial end of clavicle to form sterno-clavicular joint. Additionally, the first rib is also attached to the manubrium. A small cartilaginous extension of the lower part of body of sternum is known as xiphisternum. Rectus abdominis muscle, linea alba, and diaphragm are attached to it.

Thoracic Cage

The thoracic cage forms a protective framework around the thoracic organs. Its boundaries are as follows:

- **Posteriorly:** The thoracic vertebral column in the midline.
- **Postero-laterally:** The ribs along with the intercostal muscles and membranes.
- **Anteriorly:** The sternum in the midline.
- **Antero-laterally:** The ribs, costal cartilages, intercostal muscles, and membranes.
- **Superiorly:** The upper ribs, clavicles, and cervical fascia enclosing the esophagus and trachea.
- **Inferiorly:** The diaphragm.

Diaphragm

Diaphragm is a large dome-shaped muscle that separates the thoracic cavity from the abdominal cavity. It serves as the primary muscle of inspiration. Its nonrespiratory functions include vomiting, urination, defecation by increasing intra-abdominal pressure. Structurally, the diaphragm is composed of a peripheral muscular part that originates from the inferior thoracic aperture and converge to get inserted into central tendinous part. The muscular portion is divided into two main components:

1. **Costal part:** It originates from the costal cartilages of the 7th to 10th ribs, the 11th and 12th ribs, and the xiphoid process of the sternum.
2. **Crural part:** It arises from the upper three lumbar vertebrae and the arcuate ligaments.

The central tendon provides the insertion site for these muscular fibers and is superiorly attached to the pericardium, establishing an anatomical and functional link with the heart.

Accessory Muscles

The accessory muscles of breathing are divided into three groups–cervicothoracic that includes sternocledomastoid, scalene, scapulothoracic that includes trapezius, levators and thoracohumeral includes pectorals, serratus anterior. For these muscles to act effectively on thoracic cage, the head and neck and shoulder girdles must be stable so that these muscles will act over the thoracic cage.

In prone lying position, unrestricted movements of costovertebral joints facilitate thoracic cage expansion. Air entry to the lower basal segments that lie more posteriorly is also facilitated, as air tends to flow upward.

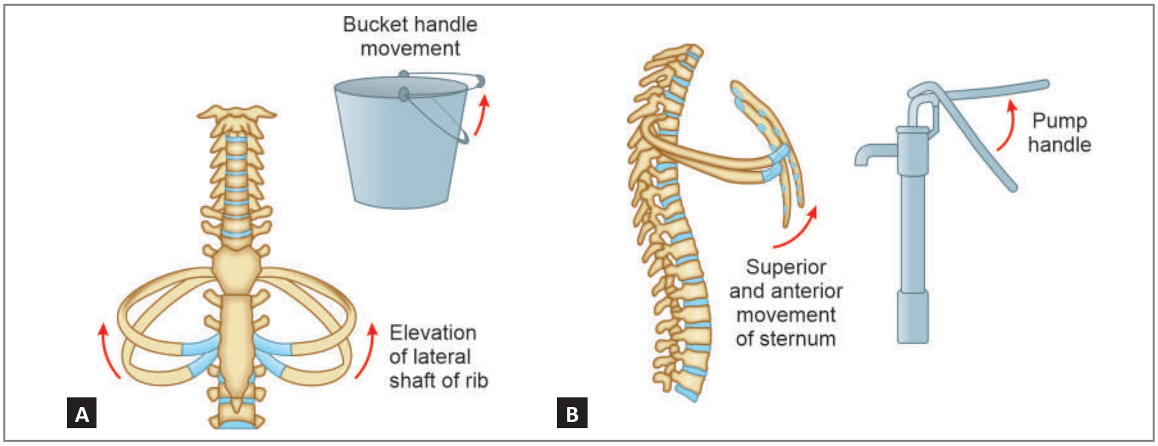
MECHANICS OF RESPIRATION

Role of Diaphragm

During inspiration, it contracts, flattens and descends downward, increasing vertical diameter of thoracic cavity, thus intrathoracic pressure decreases and air from atmosphere rushes into the lungs during inspiratory phase of respiration. On relaxation following contraction, it ascends upward, reducing volume of thoracic cavity and increasing intrathoracic pressure. As result, air from lungs is squeezed out, causing expiration.

Role of Ribs

The ribs move around costovertebral and costotransverse joints. The upper ribs are almost horizontal and their movements can be compared with pump handle movement (Fig. 3.1A). Elevation of these ribs causes upward and forward movement of the sternum increasing the antero-posterior diameter of thoracic cavity. The lower ribs are inclined and their movements are referred to as bucket handle movements, causing increase



Figs 3.1A and B: Bucket handle and pump handle movements

in lateral diameter of the thoracic cavity (Fig. 3.1B). Increase in all diameters during inspiratory phase of respiration reduces intrathoracic pressure and air from atmosphere rushes into the lungs. Elastic recoil of intercostal muscle following inspiration results in collapse of the rib cage and reduces volume of thoracic cavity increasing intrathoracic pressure that squeezes out the air inside the lungs causing expiration.

BIOMECHANICS

The line of gravity passes in front of the thoracic spine causing flexion moment that is resisted by posterior ligaments and muscles. The zygapophyseal articular facets in the upper six thoracic vertebrae lie almost parallel to the frontal plane causing more of side-flexion movements and limiting flexion-extension movements. However, the approximation of ribs on ipsilateral side and tension of the ribs on contralateral side restricts side flexion movements in thoracic region. Articular facets in the lower thoracic vertebrae are more oblique, limiting rotation more than flexion. Rotation in craniocaudal axis is increased in thoracic spine reaching its maximum at T8- T9 level.

Arthrokinematics

- **Flexion:** The body of the superior vertebra tilts and translates anteriorly over the vertebra below it, the inferior articular facets of the superior vertebra glide upward over the superior articular facets of the inferior vertebra.
- **Extension:** It involves opposite directional movements, wherein the superior vertebra tilts and translates posteriorly relative to the vertebra below. Simultaneously, the inferior articular facets of the upper vertebra glide inferiorly over the superior articular facets of the lower vertebra.
- **Lateral flexion:** On the right side, the inferior articular facet of the superior vertebra glides downward over the right superior facet of the vertebra below, while on the left side, the corresponding facet glides upward.
- **Rotation:** The left inferior articular facet of the superior vertebra impacts against the left superior articular facet of the vertebra below, restricting further rotation.

Spinal alignment significantly affects the mechanics of the thoracic cage and diaphragm during respiration. With the spine flexed, sternum tends to move toward the vertebral column reducing the antero-posterior diameter of thoracic cavity. Crowding of ribs anteriorly restricts rib excursion; increase in intra-abdominal pressure obstructs diaphragmatic excursion, that limits increase in intrathoracic volume and decrease in pressure, impairing inspiration. During spine extension, the spinal column tends to move toward the sternum, reducing antero-posterior diameter of thoracic cage, tension of abdominals pulls the lower ribs down to which it is attached limiting rib excursion. An increase in intra-abdominal pressure limits diaphragmatic excursion. As a whole, the intrathoracic volume fails to increase as it should, and pressure does not decrease as it should, impairing inspiration. During side flexion, ipsilateral hemithoracic volume decreases and contralateral hemithoracic volume increases, but rib excursion on both sides is restricted due to compression and tension respectively impairing inspiration.

CLINICAL INSIGHT

Optimal Posture for Breathing

For efficient breathing, an exaggerated military posture is considered most favorable. In this position, the thoracic cavity is optimally expanded, and rib excursion is maximized. To facilitate diaphragmatic movement, the hips and knees should remain slightly flexed, which helps in relaxing the abdominal and hamstring muscles.

SCOLIOSIS

Scoliosis refers to a sideways curvature of the spine (Fig. 3.2). When no specific cause can be determined, which occurs in approximately 80% of cases, is referred to as idiopathic scoliosis. Depending on the age of onset, scoliosis is classified into congenital, infantile, juvenile, adolescent, and adult onset scoliosis. Approximately 20–25% of scoliosis cases have identifiable causes. These include osteopathic anomalies, such as hemivertebrae and vertebral segmentation defects like blocked vertebrae. Neuropathic origins encompass conditions like cerebral palsy, syringomyelia, spinal muscular atrophy, tethered cord syndrome, Friedreich's ataxia, spina bifida, poliomyelitis, myelomeningocele, and athetosis. Myopathic scoliosis may arise from muscular dystrophies—Duchenne's type typically leads to non-ambulatory scoliosis, whereas Becker's type often results in ambulatory scoliosis due to asymmetric muscle involvement. Dermatogenic scoliosis is associated with contractures from burn scars, traumatic scars on the trunk or surgical incisions, such as anterolateral or posterolateral thoracotomies. Additionally, secondary or miscellaneous causes include degenerative spinal changes and infections like tuberculosis. It often develops during adolescence, between 10 and 12 years of age. Infantile scoliosis occurring below 3 years of age is rare.

Scoliosis often develops and progresses unnoticed until visible deformity, such as uneven shoulder height or pelvic asymmetry develops. The most prevalent form is adolescent idiopathic scoliosis, accounting for 80–90% of idiopathic cases. The deformity manifests during adolescent growth spurt. The second phase of pubescent growth spurt marked by longitudinal growth of axial skeleton is very crucial during which the deformity progresses rapidly. Scoliosis affects the rib cage and pelvis due to their proximity and eventually rib hump and pelvic obliquity develop that alters the alignment of other structures like facet joints, joint capsules, ligaments, muscles and fascia due to adaptive shortening on

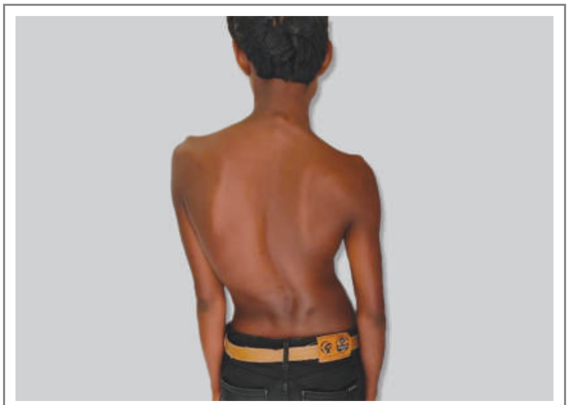


Fig. 3.2: Scoliosis

concave side and over-stretching on convex side. Over time, wedging of the vertebral body on concave side may develop.

Screening

Forward bending test (Adam's test): Forward bending in standing position that corrects the deformity suggests functional or correctable scoliosis. Scoliosis that does not get corrected on bending forward is known as structural scoliosis. Sitting and forward bending eliminates leg length discrepancy component resulting in scoliosis.

Hanging from an overhead bar tends to correct correctable scoliosis due to traction and the deformity persists in cases of structural changes.

Radiological Evaluation

- **Plain radiographs:** A diagnostic anteroposterior view is essential, with a full-length standing projection offering superior clinical insight.
- **Magnetic resonance imaging (MRI):** It is indicated in the presence of neurological deficits, such as sensory disturbances, motor impairment or involvement of bowel and bladder function.

Practical tip

Vertebral landmarks

End vertebrae refer to the superior and inferior vertebrae involved in the spinal curvature, identified by assessing the intervertebral spacing between adjacent vertebrae on both the concave and convex sides using a screw gauge—where the concave side exhibits reduced intervertebral distance compared to the convex side. The apex vertebra is the one demonstrating the greatest degree of axial rotation.

Cobb Angle

Cobb angle is the standard method for quantifying the degree of spinal curvature in scoliosis (Fig. 3.3). It involves drawing a line along the superior border of the upper end vertebra and another along the inferior border of the lower end vertebra. Perpendicular lines are then constructed from each of these reference lines and extended until they intersect. The angle formed at their intersection, opening superiorly, is defined as the Cobb angle, which reflects the severity of the spinal deformity. Classification of scoliosis based on Cobb angle is as follows:

- **Mild scoliosis:** Cobb angle up to 20°
- **Moderate scoliosis:** Cobb angle between 20° and 40°
- **Severe scoliosis:** Cobb angle >40°

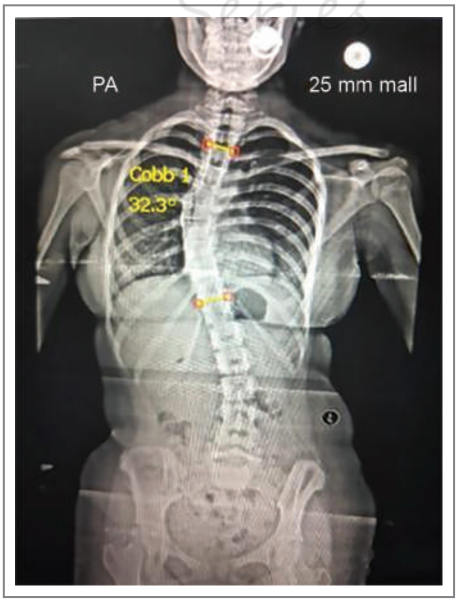


Fig. 3.3: X-ray showing a lateral curvature of the vertebral column that is convex to the left in the thoracic region and convex to the right in the lumbar region with a Cobb angle of 32°

Radiological Measurements

Sagittal Cobb Angle

- **Thoracic kyphosis:** Assessed on a lateral radiograph by measuring between the upper end plate of T4 and the lower end plate of T12.

- **Lumbar lordosis:** Assessed on a lateral radiograph by measuring between the upper end plate of L1 and the upper end plate of S1.

Spinal Balance

- **Coronal balance:** It is assessed on an anteroposterior radiograph by measuring the horizontal displacement between the central sacral vertical line (CSVL) and the C7 plumb line.
- **Sagittal balance:** It is assessed on a lateral radiograph, ideally using a full-length standing image of the spine.

Rib-Vertebra Angle Difference

Mehta (1972) introduced rib-vertebra angle difference (RVAD) as a prognostic marker for progression of early onset scoliosis.

- First, the apex vertebra of the scoliotic curve is identified.
- Next, the rib-vertebra angles are measured on both the convex and concave sides at the level of the apex vertebra.
- If the difference between two measurements exceeds 20°, it signifies a high risk of curve progression.

Risser–Ferguson Method for Skeletal Maturity Assessment

The Risser–Ferguson method is used to estimate the degree of skeletal maturity by evaluating the ossification of the iliac apophysis. It assigns stages from 0 to 5, with higher stages indicating greater skeletal maturity.

- **Stage 0:** No ossification center is visible in the iliac apophysis.
- **Stage 1:** Ossification of the lateral 25% of the iliac crest.
- **Stage 2:** Ossification of 25–50% of the iliac crest.
- **Stage 3:** Ossification of 50–75% of the iliac crest.
- **Stage 4:** Ossification of >75% of the iliac crest.
- **Stage 5:** Complete ossification and fusion of the iliac apophysis.

Ossification begins at the lateral end of the iliac crest and progresses medially.

Clinical Relevance

- Scoliosis <30° after skeletal maturity usually does not progress.
- Scoliosis >50° after skeletal maturity tends to progress at an average rate of approximately 1° per year.

Prognosis

- **Age of onset:** Early onset has a poor prognosis, the deformity progresses till skeletal maturity. Once skeletal maturity is achieved, the progression becomes slow.
- **Sex:** Girls have much higher risk of progression than boys.
- **Curve magnitude:** Larger curve is more likely to worsen with time. Double curves progress faster than single curve.
- **Region affected:** Thoracic scoliosis has a poorer prognosis than lumbar.

Howard King Classification

The Howard King classification system for adolescent idiopathic scoliosis (AIS), introduced in 1983, was derived from John Moe's clinical experience in surgically treating AIS using Harrington rod instrumentation. A vertebra is considered stable when it is nearly bisected by the central sacral vertical line (CSVL). Structural scoliosis refers to a fixed spinal curvature that cannot be corrected, whereas compensatory scoliosis arises above or below the structural curve to maintain postural balance and is typically reversible.

- **Type 1:** It is characterized by an S-shaped scoliosis where both thoracic and lumbar curves are structural and cross the central sacral vertical line (CSVL), with the lumbar curve being more pronounced than the thoracic curve.
- **Type 2:** This type also presents as an S-shaped deformity involving structural thoracic and lumbar curves that cross the CSVL, but the thoracic curve is equal to or greater in magnitude than the lumbar curve.
- **Type 3:** It is defined by a major structural thoracic curve that crosses the CSVL, with minimal or non-structural lumbar involvement.
- **Type 4:** It features a long, C-shaped thoracic curve. The fifth lumbar vertebra is aligned over the sacrum, while the fourth lumbar vertebra is angulated into the thoracic curve, indicating compensatory adaptation.
- **Type 5:** It involves double structural thoracic curves, both of which contribute to the overall spinal deformity.

Lawrence Lenke Classification

As segmental spinal instrumentation gradually replaced Harrington rod fixation, the existing classification system revealed significant limitations, particularly in its ability to provide consistent and precise guidance for determining fusion levels. To overcome these deficiencies, Lawrence Lenke introduced a revised classification system in 2001, which, for the first time, incorporated the sagittal spinal profile into the diagnostic framework for adolescent idiopathic scoliosis, based on the location and structural nature of the curves.

- **Type 1:** A structural main thoracic curve with compensatory curves either above or below it.
- **Type 2:** Double structural thoracic curves, where the main thoracic curve is dominant and the proximal thoracic curve is minor; a compensatory curve forms below.
- **Type 3:** Double major structural curves involving the main thoracic and thoracolumbar/lumbar regions, with the thoracic curve being dominant; compensation occurs above.
- **Type 4:** Triple major structural curves involving the proximal thoracic, main thoracic, and thoracolumbar/lumbar segments.
- **Type 5:** A single structural curve in the thoracolumbar or lumbar region, with a compensatory curve above.
- **Type 6:** A dominant structural thoracolumbar/lumbar curve accompanied by a minor structural thoracic curve.

To complement the six basic curve types, the Lenke classification incorporates two important modifiers: the lumbar modifier and the thoracic sagittal profile. These provide additional information for treatment planning.

- **Lumbar modifier (A, B, C):** Determined by the relationship of the lumbar curve apex to the central sacral vertical line (CSVL)
  - **Modifier A:** The CSVL intersects the pedicles of the apical lumbar vertebra.
  - **Modifier B:** The CSVL lies between the medial edge of the concave pedicle and the lateral border of the apical vertebral body.
  - **Modifier C:** The CSVL is positioned medial to the concave margin of the apical vertebral body.
- **Sagittal thoracic modifier (-, N, +):** Based on kyphosis angle from T5 to T12
  - **Negative (–):** Indicates hypokyphosis, with a kyphotic angle of $<10°$.
  - **Neutral (N):** Indicates normal thoracic kyphosis, ranging from 10° to 40°.
  - **Positive (+):** Indicates hyperkyphosis, with a kyphotic angle of $>40°$.

Lenke type 1 and type 5 can be treated either anteriorly or posteriorly; types 2, 3 4 and 6 should be treated with posterior instrumentation. Patients with lumbar modifier A or B can be recommended for selective thoracic fusion.

Clinical Evaluation

History

A detailed history should include the age of onset or the age at which the deformity was first noticed, as early onset scoliosis has different prognostic implications compared to adolescent or adult scoliosis. Inquire about the rate and pattern of progression, including any recent increase in spinal curvature, postural asymmetry or changes in appearance. Associated symptoms, such as back pain, breathing difficulty, fatigue, muscle weakness or reduced exercise tolerance should be specifically assessed, as these may indicate functional compromise. A thorough treatment history should be obtained, including previous physiotherapy, bracing, surgical interventions, and compliance with treatment. Family history of scoliosis, history of trauma, neuromuscular conditions or congenital abnormalities should also be noted, as they may help identify the underlying type and cause of scoliosis.

Physical Examination

Posture Assessment

- **Anterior view:** Inspect the patient from the front in a standing position. Assess for head alignment in the midline, shoulder level symmetry, trunk symmetry, nipple level, bilateral and symmetrical chest expansion, umbilicus position in the midline, symmetrical flank creases in both number and depth, arm-to-trunk distance, alignment of the anterior superior iliac spines (ASIS), patella orientation facing forward, and foot positioning.
- **Posterior view:** Inspect the patient from behind in a standing position. Evaluate head alignment in the midline, shoulder level symmetry, scapular positioning, trunk symmetry, flank creases for symmetry in number and depth, arm-to-trunk distance, level of posterior superior iliac spines (PSIS), gluteal fold symmetry and depth, and heel alignment.
- **Lateral view:** Observe the patient from the side in a standing position. Assess the alignment of the head on the neck and neck on the trunk, presence of forward head posture, cervical lordosis, thoracic kyphosis, and lumbar lordosis. Evaluate hip and knee flexion, as well as overall foot posture.

In forward bending in standing, if the deformity disappears, it is suggestive of functional or mobile or compensatory scoliosis. Traction by pulling the legs in lying position or by hanging from overhead bar determines correction ability of the deformity. If the scoliosis is present in standing and reduces on sitting, leg length discrepancy may be contributing the factor. Deformity that disappears in lying position could be due to muscle imbalance.

Plumb Line Assessment

Plumb line distance drawn from C7 to gluteal cleft to determine the major and minor curves.

Anthropometric Measurements

- **Height:** Often reduced in scoliosis.
- **Arm span:** Distance between tips of middle fingers with arms abducted to 90° in supine lying; corresponds to true height.

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- **Leg length discrepancy:** It should be assessed, as it may contribute to or mimic functional scoliosis by producing pelvic obliquity and apparent spinal curvature.
  - **True LLD:** Assessed by measuring the distance from the anterior superior iliac spine (ASIS) to the medial malleolus, ensuring the pelvis is level.
  - **Apparent LLD:** Measured from the xiphisternum to the medial malleolus, with both lower limbs aligned to the trunk and positioned parallel.

Spinal Mobility

A spondylometer is a diagnostic tool used to evaluate spinal alignment and range of motion across the sagittal, coronal, and transverse planes. It facilitates objective assessment of spinal configuration and mobility for clinical and rehabilitative purposes.

Respiratory Evaluation

Chest expansion, FEV_1 and peak flow are measured by spirometer.

Neurological Evaluation

Sensations, muscle tone, strength, superficial and deep tendon reflexes, bowel and bladder functions are assessed.

Management

The treatment of adolescent idiopathic scoliosis includes observations, exercises, bracing and surgery. The general principle is to maintain the curve below 50° at skeletal maturity.

- Curves below 25° are managed with observation and remedial exercises.
- Curves between 25° and 40° in growing children are managed with bracing to prevent progression.
- Curves of 45° or more in skeletally immature patients are managed with surgical intervention.
- Curves >50° in skeletally mature patients are managed with surgery to prevent further progression and complications.

Curve Corrective Exercises

Correction of all dimensions of pelvic obliquity precedes spine correction. A major thoracic curve often develops a compensatory curve above and below to balance the head over the sacral base, therefore a minor lumbar curve is an accompanied feature of a major thoracic curve, which may progress into another major curve in course of time. As the lumbar region is anatomically linked to the pelvis, any lumbar deviation can drive the pelvis along with it. In a lumbar curvature, the same-side pelvis is driven posteriorly in the transverse plane by the posterior rotation of lumbar vertebrae through the attachment of iliolumbar ligament, the pelvis linkage to the sacrum through the sacroiliac ligament forces the ilium to move along with the sacrum that has an oblique axis. As the sacrum is forced to move along the L5-S1 facet with the lumbar rotations through oblique axis, the pelvis is driven in a sagittal plane, creating posterior innominate on the convex side and anterior innominate on opposite side. The lumbar curvature might tilt the head down through the trunk bending, but through the head-righting reflex action, the head remains erect and pelvis is driven up in the frontal plane on the concave side, creating a costo-iliac impingement. Thus, a three-dimensional pelvic obliquity develops, and curve correction cannot be possible without the correction of the pelvis, the base.

The different components of the pelvic obliquity are described and represented in Figures 3.4A and B and 3.5, which helped in the design of corrective exercises.

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Standard spine strengthening exercises modification is based on asymmetrical glide, i.e., during flexion of scoliotic thoracic spine, vertebral bodies glide anteriorly, the malrotated thoracic segment that has rotated anteriorly from the concave side glide further anterior and in turn, push the convex side body more posterior exaggerating a thoracic curve. On account of posterior rotation of the bodies to the side of convexity in scoliotic spine, extension can exaggerate the curve by accompanying posterior glide compressing the facets on this side. As per this principle, extreme flexion and extension can create more rotation and may increase the curve, therefore, remedial exercises should be given avoiding extreme flexion and extension.

Curve-Specific Corrective Exercises Guided by Fryette's Laws

- **Fryette's first law:** In a neutral spine, lateral bending to the convex side of a scoliotic curve induces contralateral rotation of the superior vertebra—toward the concave side. This biomechanical response helps reduce the curvature. Conversely, side bending toward the concavity intensifies the deformity and should be avoided in corrective protocols.
- **Fryette's second law:** In a non-neutral spine (i.e., flexed or extended), lateral bending and vertebral rotation occur in the same direction. In scoliosis management, this implies that excessive flexion or extension can exacerbate vertebral rotation. Therefore, corrective exercises are designed to avoid end-range flexion or extension to prevent worsening of the rotational component.
- **Fryette's third law:** When motion is introduced in one anatomical plane, mobility in the other planes is reduced. This principle is particularly useful in managing double curves. For example, correcting pelvic obliquity through lower limb positioning induces transverse plane motion in the lower lumbar spine. This stabilizes the lumbar segments in the frontal plane, allowing targeted thoracic curve correction through upper trunk bending without destabilizing the lower spine.
- **Rotation kinematics applied to rotation reversal exercise:** In left-sided anterior spinal rotation, the right portion of the vertebral body translates anteriorly, while the left portion shifts posteriorly. To counteract this rotational asymmetry, a rotation reversal exercise can be implemented by applying a sustained passive anteriorly directed force on the convex side. Concurrently, the patient actively extends the arm and trunk from the concave side, promoting posterior vertebral glide and facilitating corrective spinal rotation.

Procedure

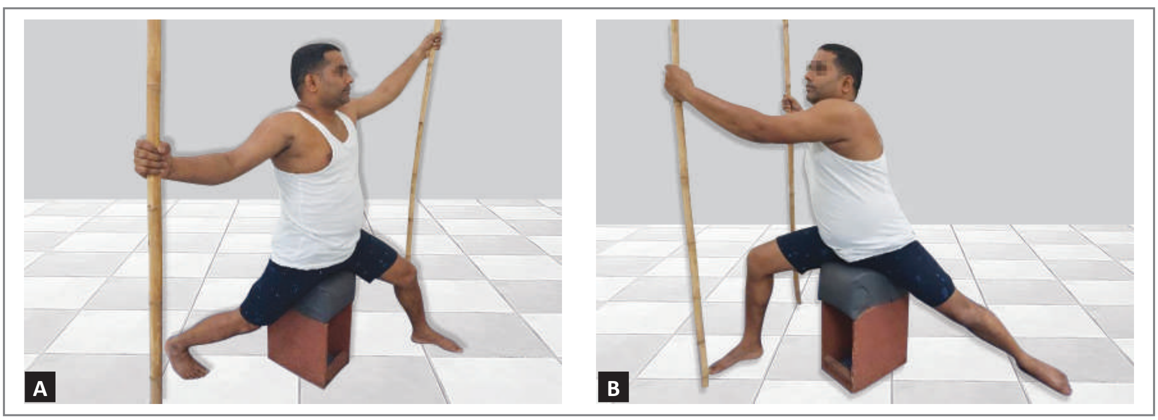
- **Correction in supine lying:** Corrective exercises performed in the supine position are tailored to specific spinal curves and should address all curve patterns concurrently to achieve optimal postural alignment. The recumbent posture offers a balanced muscle length–tension relationship, making it an ideal starting point for intervention.
  - **Correction of pelvic obliquity:** Radiographic assessment is essential to determine the direction of vertebral rotation within the lumbar curve, whether compensatory or primary. For instance, a left-sided lumbar convexity typically presents with posterior vertebral rotation from left to right, resulting in posterior displacement of the left pelvic ring. Correction begins in the transverse plane, which subsequently facilitates sagittal plane realignment. In supine lying, the left pelvis is advanced anteriorly by crossing the left leg over the right—left hip flexed and adducted, knee flexed, and foot positioned beside the right leg. The extended right leg, combined with the crossed left leg, functions as a unified lever arm to correct pelvic obliquity across both planes.
  - **Active correction of lumbar curve:** Medial pressure applied through the right foot against a stable surface activates the lever arm at the curve apex, functioning as a fulcrum to straighten the left lumbar curve. This correction is mediated by active engagement of the lower lateral trunk

flexors, which draw the right iliac crest downward in the frontal plane. These muscles also provide counterpressure during thoracic curve correction. Additionally, transverse plane correction of pelvic obliquity facilitates anterior translation of the lower lumbar vertebral bodies. In accordance with Fryette's Third Law, this stabilizes the lumbar spine and restricts motion in other planes. Collectively, these mechanisms prevent amplification of the lower curve during thoracic side bending. The same biomechanical principles are applied across all corrective positions.

- **Major thoracic curve correction:** In cases where the primary curve is located in the right lower thoracic region, a compensatory cervicothoracic curve often develops in the opposite direction. Correction of vertebral rotation in the cervicothoracic area is achieved by rotating the head to the right and elevating the left arm. The major thoracic curve is then addressed through right-sided lateral bending in the supine position, combined with application of Muscle Energy Technique (MET) targeting the convex side.
- **Muscle energy technique application:** An isometric contraction of the right erector spinae muscle group is performed at the end range of lateral bending, using self-resistance (e.g., pressing a stick against the ground or a fixed surface) for approximately 10 seconds. This is paired with Valsalva breathing to enhance neuromuscular engagement.
- **Valsalva breathing mechanism:** During the Valsalva maneuver, the diaphragm contracts isometrically, aiding in the release of diaphragmatic adhesions and strengthening the spinalis thoracis on the convex side.
- **Progression:** After approximately 10 sessions, the subject transitions to perform side bending exercises with normal breathing patterns.

• **Correction in Sitting (Figs 3.4A and B):** Corrective exercises performed in the sitting position are useful as subject can maintain this corrective posture at home and in the workplace. In sitting, bending ipsilaterally is aided by gravity, which helps in controlling creep on the convex-side muscles.

- **Pelvic and lumbar correction:** Subject is seated on a small stool or an armless chair, left leg positioned forward at the edge, and right leg placed behind. The right leg should be kept as far back as possible so that the left side pelvis and lumbar bodies naturally move forward. Active pressure for curve correction is generated by pressing left foot laterally against a fixed surface. This sitting posture prevents back pain and helps maintain prolonged sitting in desk based jobs.



Figs 3.4A and B: Pelvic and lumbar correction exercises

- **Thoracic curve correction:** The subject bends toward the convex side while maintaining right trunk forward and left trunk is held backward replicating the corrective mechanism as used in lying.

- **Correction in standing:**
  - **Lumbar and pelvic correction:** The subject assumes a standing position with the right leg positioned posteriorly and adducted, while the lateral border of the left foot is placed against a wall or stable surface to facilitate alignment.
  - **Major thoracic and upper cervicothoracic correction:** This is performed using the same technique as in the seated posture. Exercise dosage—repetitions and hold duration—is gradually increased as pain subsides.

Muscle Energy Technique (MET)

Utilizing the neurophysiological principles of post-isometric relaxation and reciprocal inhibition, restrictions in ipsilateral side bending and contralateral rotation were improved. This led to a reduction in frontal plane translation and reversal of vertebral rotation. To counter postural collapse, the spinalis thoracis on the convex side was activated at its optimal length, while the concave counterpart was simultaneously stretched.

Myofascial Release Techniques

The technique may be applied using fingers, wrist pads, knuckles, elbows or a manual massager to alleviate fascial restrictions, which can contribute to mechanical stress and dysfunction in anatomically distant tissues.

Suggested Exercise Routine

- **Breathing with core:** This technique is essential for strengthening deep local stabilizers, such as the rotatores, intertransversarii, and multifidus. Performed in a recumbent position, the breathing exercise involves drawing the navel inward, forcing the diaphragm to move against resistance from the transversus abdominis through synergistic deep core activation. Beyond ventilation, the diaphragm's stabilizing role, along with deep muscle contraction, aids in correcting rotated vertebrae. The exercise is best done on an empty stomach for 15–20 minutes.
- **Aerobics:** Aerobics help in scoliosis by improving posture, spinal mobility, and muscular balance to support spinal alignment and function.
  - **Yoga cycling:** This exercise involves a dynamic sequence of yoga postures performed in a flowing, repetitive cycle. It combines movement with controlled breathing to improve flexibility, strength, balance, and low-impact aerobic fitness.
  - **Lunges to standing:** This exercise is initiated by positioning the leg corresponding to the lumbar convexity in a forward stance. This alignment helps correct posterior pelvic rotation on the convex side and promotes optimal length-tension relationships in the associated connective tissues and musculature.
- **Stretching upper trapezius:** A self-administered stretch for the elevated shoulder utilizing the muscle energy technique based on post-isometric relaxation.
- **Scapular stabilizer strengthening:** Conducted in a prone position with the arm raised to 120° abduction, held just above the surface and aligned with the torso. The scapula is maintained in posterior tilt to facilitate optimal torque generation. This approach helps prevent anterior scapular tilt and reinforces the stabilizing force couple of the scapulothoracic articulation.
- **Rotation reversal exercise for the major thoracic/lumbar curves:** In the prone position, the arm on the thoracic convex side is extended and abducted, gripping the edge of the couch, while the concave

side arm is similarly positioned. Manual corrective force is applied by the clinician at the apex of the curve to push the malrotated vertebrae anteriorly. Simultaneously, the patient actively extends the concave side arm and trunk, promoting posterior vertebral rotation from that side. A comparable technique is used for lumbar curves, where passive pressure is applied to the lumbar convexity as the patient extends the concave side leg and lower trunk. Directionally specific asymmetrical exercises aid in correcting rotational asymmetries and help optimize tension in the superficial global musculature (Fig. 3.5).

Fig. 3.5: Rotation reversal exercise

- **Plank variations (front, reverse, and side planks):** These exercises are performed with the convex side of the curve positioned downward, promoting elongation of the upper concave-side musculature while strengthening the convex-side muscles. Both front and reverse planks engage core and limb musculature in a coordinated manner.
- **Straight leg raise (unilateral and bilateral) against the wall:** Unilateral straight leg raises targeting the lumbar convex side facilitate stretching of shortened hamstrings *via* Muscle Energy Technique (MET), addressing posterior pelvic rotation. Bilateral leg raises, performed with abdominal compression against the wall, enhance activation of the lower abdominals and deep core stabilizers.
- **Strengthening of trunk flexors and extensors:** Executed in a neutral trunk or quadruped position with the head slightly elevated from the surface, this exercise avoids extremes of flexion and extension to prevent aggravation of vertebral rotation. It supports balanced activation of spinal stabilizers.

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Ergonomic Considerations

- **Lying on left side:** When lying on the left side with the compensatory lumbar curve downward, a rolled towel is positioned beneath the torso to facilitate optimal activation of the quadratus lumborum. The left arm is elevated in alignment with the body, promoting stretch of the thoracic concave-side musculature and the right quadratus lumborum.
- **Lying on right side:** In this position, with the thoracic convexity downward, the lower arm is placed forward and the upper arm backward. The upper leg is positioned forward while the lower leg is extended backward. This configuration supports corrective rotation across both thoracic and lumbar segments.
- **Sitting and standing:** While seated, the leg corresponding to the lumbar convexity is placed forward, consistent with corrective exercise principles. Elevating this leg on a tabletop with the knee flexed helps correct pelvic obliquity in all three planes and supports prolonged, pain-free sitting during academic or occupational tasks. In standing, a walk-stance posture is adopted with the lumbar convex side leg positioned anteriorly and the opposite leg posteriorly.
- **Carrying weights and picking objects from floor:** Holding weights in the hand on the thoracic convex side shifts the line of gravity toward the midline, thereby reducing gravitational torque. When lifting objects from the floor, forward movement of the right side of the trunk minimizes mechanical strain.
- **Staircase walking:** Initiate ascent with the leg on the lumbar convex side to promote balanced pelvic and spinal mechanics.

CLINICAL INSIGHT

Schroth Method

The Schroth method is a scoliosis-specific exercise program based on three-dimensional correction of the spine.

Key Principles

- **Auto-elongation:** Actively lengthening the spine to reduce compression.
- **3D correction:** Corrects curves in frontal, sagittal, and transverse planes.
- **Rotational angular breathing (RAB):** Directing breath into concave areas to expand collapsed ribs and aid derotation.
- **Muscle balance:** Strengthening weak (concave) muscles and stretching tight (convex) muscles.
- **Postural integration:** Applying corrective posture and breathing into daily activities.

Complications

Scoliosis manifests and progresses painlessly until visible uneven shoulder level, chest asymmetry or pelvic asymmetry appears or one develops back pain or it is identified during physical examinations for some other problem.

Musculoskeletal Complications

Back pain occurs due to adaptive shortening of soft tissue structures on concave side, stretch weakness of muscles on convex side, limitation of movements, foraminal stenosis on concave side, wedging of vertebral body on concave side.

Cardiopulmonary Complications

- In severe scoliosis greater than 90–100°, there is a risk of cor pulmonale and right heart failure.
- Pulmonary functions are also limited due to reduced hemithorax volume on concave side, restricted thoracic cage excursion due to overcrowding of ribs on concave side and flaring of ribs on convex side.

Neurological Complications

Neurological deficit may develop in severe scoliosis due to foraminal stenosis on concave side that may compress the exiting spinal nerve root.

Cosmetic and Psychological Impact

- Visible body asymmetry, reduced height, and rib hump deformity contributes to poor body image.
- These cosmetic concerns may lead to psychological distress and reduced quality of life, especially in adolescents.

KYPHOSIS

Excessive convexity of the spine in sagittal plane is known as kyphosis, i.e., spine bends forward, also referred to as hunched back or round back.

Classification

- **Postural:** It is the most common type, often seen in adolescent girls who adopt a slouched posture to hide anterior chest masses. Poor posture in childhood, such as leaning back in an improperly designed chair, leaning forward on a low-height chair or studying on floor, carrying heavy school bag, low vision, studying in poor lighted space, etc., predispose to kyphosis. Compensatory kyphosis develops in case of forward head posture, increased lumbar lordosis, pregnancy, obesity, protruded abdomen to maintain postural balance the body segments.

- **Scheuermann's kyphosis:** There is wedging of the vertebral bodies, i.e., anterior height of vertebral bodies is lesser than posterior height. The exact cause is not known, there is osteonecrosis of vertebral apophysis. This begins to occur during the growth spurt and male children are more affected than female children. Rounded upper back develops in otherwise healthy adolescents, otherwise known as juvenile kyphosis. Male-to-female ratio is 2:1. The characteristic lateral radiograph findings include three or more adjacent vertebrae wedged >50°, irregular vertebral end plates, Schmorl's nodes, and loss of disc height. Type I Scheuermann's disease affects thoracic spine, whereas Type II affects thoraco-lumbar spine.

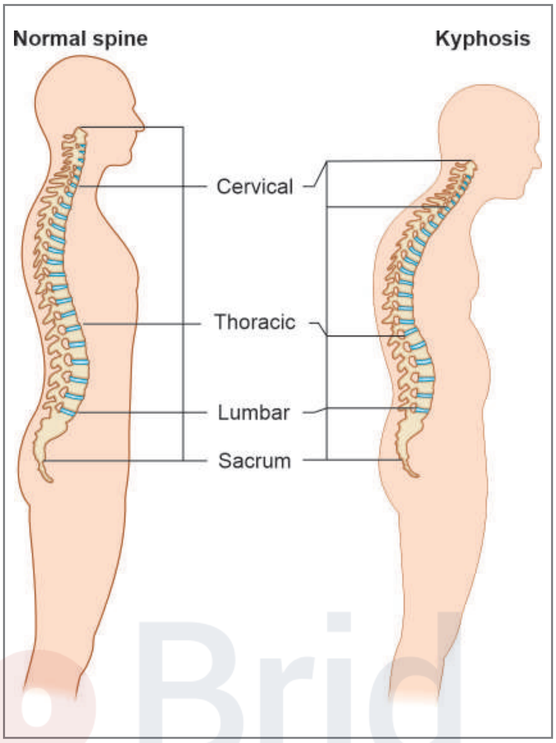

Fig. 3.6: Spine posture in kyphosis

- **Senile kyphosis:** It is seen in elderly persons due to osteoporosis, particularly in postmenopausal women. As such vertebral bodies are weaker anteriorly and become further weaker due to osteoporosis. Anterior wedge compression results in kyphosis (Fig. 3.6).
- **Fracture:** Anteriorly vertebral bodies are weaker due to poor trabeculae. Anterior wedge compression fracture occurs from flexion injury resulting in localised kyphosis known as gibbus. Anterior wedge compression in tuberculosis of spine, carcinogenic secondary also results in localized kyphosis.
- **Congenital kyphosis:** It occurs due to improper development of spine, such as hemivertebra or blocked vertebrae during intrauterine life that worsens as the child grows.
- **Paget's disease of bone (osteitis deformans):** It is a chronic disorder that causes one or more bones to grow abnormally and become weak. Pelvis, skull, spine, femur and tibia are more commonly affected. It is uncommon under the age of 40 and commonly occurs in families. The osteoclasts absorb bone at a faster rate than the usual and osteoblasts produce new bone at a faster rate, but the new bone is larger and weaker than normal and the bone is fragile. Head size is increased, besides bowing of long bones, and kyphosis. Hearing loss may develop with the involvement of skull. Severe kyphosis can compress the digestive tract, causing problems, such as difficulty in swallowing and acid reflux. X-ray is diagnostic. Serum alkaline phosphatase level is high. Bone scan determines severity of the disease.

Clinical Features

Kyphosis can be classified into (1) mobile or correctable and (2) fixed or structural. Postural and compensatory kyphosis are correctable, whereas kyphosis due to Scheuermann's kyphosis, Paget's disease, wedging of vertebra due to fracture, collapse, TB spine, cancer spine, etc., are structural and not correctable.

Increased thoracic kyphosis is associated with rounded shoulders, i.e., protracted and depressed scapulae. With depression of shoulder girdles, dimension of thoracic outlet reduces, compressing its neurovascular contents–brachial plexus and subclavian artery, referred to as thoracic outlet syndrome. Unilateral terminal shoulder abduction-elevation is associated with side flexion of thoracic spine to opposite side and bilateral elevation is associated with thoracic extension. In kyphosis, terminal shoulder elevation is limited. Depression of scapula diminishes subacromial space, leading to impingement of suprahumeral structures.

Normally, the tension of superior joint capsule and superior glenohumeral ligament supports the weight of the upper extremity in standing position with arms by the side provided the glenoid fossa faces upwards and there is minimal or no activity of rotator cuff muscles. With depression of shoulder girdle, tension of superior joint capsule and superior glenohumeral ligament is lost, that impairs glenohumeral stability, demanding activity of rotator cuff muscles even at rest to support the weight of the upper extremity. Overactivity of rotator cuff, fibers of which blend with joint capsule, exert tensile stress at its attachment over greater tuberosity resulting in chronic inflammation and lying down of fibrous tissues due to fibroblastic proliferation that leads to fibrous thickening and contracture of joint capsule, limiting glenohumeral movements in capsular pattern, i.e., external rotation and abduction are more limited than internal rotation and flexion; extension is free.

Protraction of scapulae overstretches the periscapular muscles, producing microtrauma that predisposes to myofascial pain. Injury to sarcolemma exposes calcium channel producing sustained muscle contraction without relaxation. Depletion of stored energy produces energy crisis. Accumulation of metabolic waste products gives rise to pain. Sustained muscle contraction creates ischemia, necrosis of muscle fibers, which is replaced by fibrous tissues. Muscle becomes weak with loss of extensibility that produces skeletal deformity.

Evaluation

Assessment of kyphosis should be comprehensive and include evaluation of the curve's correctability to determine its flexibility. Muscle length should be assessed for the pectorals, suboccipitals, and hamstrings, while muscle strength should be evaluated for the back extensors, abdominals, deep neck flexors, and scapular retractors. Chest expansion should be measured, and respiratory function can be assessed using spirometry. A neurological evaluation is necessary to identify any deficits. Radiographic assessment with lateral X-rays helps determine the end vertebrae, apex vertebra, and the kyphosis angle, which can be accurately measured using the Cobb method.

Management

Scapular circumduction (anticlockwise), bilateral arm elevation, chin tucking, McKenzie extension in prone, stretching of pectorals, strengthening of back extensors tend to correct kyphosis. One can lie supine with a roll under the apex of thoracic curve which tends to correct the deformity by gravity. Breathing exercise with arm elevation is useful to correct the deformity and improve respiratory function. Swimming is useful.

One can use Milwaukee brace or an ASH brace. An ASH brace has sternal pad and symphysial pad connected by a vertical metallic bar and the orthosis is adjusted posteriorly by strap placed at the apex of the curve applying anteriorly directed corrective force that tends to correct the deformity by 3-point pressure principle. It is otherwise known as hyperextension orthosis.

Complications

Severe kyphosis can compress the digestive tract, causing problems, such as difficulty in swallowing and acid reflux. There will be crowding of ribs anteriorly with increased thoracic kyphosis that impairs breathing.

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Increased thoracic kyphosis is often associated with increased lumbar lordosis, hip and knee flexion. Increased lumbar lordosis may create flexion dysfunction, increased vertical compression force over posterior annular fibers which can lead to tear through which nucleus pulposus may bulge, and increased vertical compression load over posterior element may result in failure and spondylolysis. Overloading of facet joint predisposes to degeneration and facet arthropathy. Hyperextension narrows the size of intervertebral foramen, known as stenosis and may compress the exiting spinal nerve root, known as radiculopathy. Kyphosis is also associated with increased cervical lordosis and neck pain.

THORACIC RADICULOPATHY

Radiculopathy is a common condition that involves compression of spinal nerve root due to excessive pressure caused by surrounding bones, tissue, muscles or intervertebral discs. Thoracic radiculopathy is an uncommon spinal disorder that is frequently overlooked in the evaluation of spinal pain syndromes. The pressure over thoracic spinal nerve root disrupts the nerve functioning giving rise to pain, numbness, and tingling along the ribs, lateral trunk (flank), and abdomen. The causes of thoracic radiculopathy include herniated disc lesion, degeneration, osteophytes, trauma, tumors, and tuberculosis. The symptoms often mimic those due to intrathoracic origin (cardiovascular, pulmonary, mediastinal) or intraabdominal (hepatobiliary, gastrointestinal, retroperitoneal) pathology.

Physical examination is not the best way to evaluate thoracic radiculopathy. Unlike lumbosacral and cervical radiculopathies, the affected muscles cannot be tested in isolation. Therefore, the examination is more helpful to exclude other diagnoses instead of confirming thoracic radiculopathy. Thus, the examination will be done with more medical strategies by using investigation procedures, such as EMG, MRI, CT, radiographs, etc.

Degenerative thoracic pathology can be overdiagnosed and overtreated when based solely on imaging findings rather than clinical presentation. Asymptomatic degenerative changes (such as disc herniation, osteophyte formation, and mild stenosis) are common on thoracic magnetic resonance imaging (MRI). Therefore, in suspected symptomatic thoracic spondylosis, it is essential to combine clinical findings with radiographic findings before drawing conclusions. There are no motor or reflex changes to look for specifically in thoracic radiculopathy. A sensory examination may reveal a unilateral loss of pinprick or light touch sensation in a dermatomal pattern around the chest on the affected side. This does not represent a true sensory level rather, it appears as a band-like sensory loss along the course of rib, with preserved sensation above the band.

With thoracic radiculopathy, there is no risk of developing motor weakness and prolonged conservative management is often reasonable. Thoracic spine surgery is not risk-free, potential complications, such as blood loss and pulmonary complications can occur. Physiotherapy can be very effective in treating thoracic radiculopathy.

Physiotherapy treatment is aimed at mobilization of hypomobile segment, stabilizing the hypermobile spinal segments, using exercise strategies to unload the spine and reduce pressure on the spinal nerve roots, soft tissue manipulation, joint mobilization/manipulation, home exercises and graded exposure-to-load program.

RECENT ADVANCEMENTS

Correlation of Thoracic Spine–Sympathetic Nervous System in Physiotherapy Practice

The thoracic spine (T1–T12) forms the primary origin of sympathetic outflow (T1–L2). Because of this, dysfunction in the thoracic region does not remain purely musculoskeletal—it can produce autonomic, visceral, and systemic effects.

For physiotherapists, this region represents a critical interface between structure and function, where joint mobility, posture, and neural regulation intersect.

Neuroanatomical Basis

- **Sympathetic outflow from thoracic segments:** The sympathetic outflow originates from the preganglionic neurons located in the lateral horn of the spinal cord from T1 to L2 segments. These fibers exit through the ventral roots, pass into the spinal nerve, and then enter the sympathetic chain *via* the white rami communicantes. Synapsing may occur either in the paravertebral ganglia or in the prevertebral ganglia, depending on the target organ.
- **Segmental visceral connections:** The thoracic spine demonstrates a clear segmental relationship with various visceral organs.

The different thoracic levels, their relationship with different organs, and their clinical relevance are presented in Table 3.1.

Pathophysiological Mechanisms

- **Somatovisceral reflex:** Thoracic joint dysfunction alters sympathetic output and affects visceral organs; for example, T4 stiffness may increase heart rate.
- **Viscerosomatic reflex:** Visceral pathology can produce referred pain in the thoracic spine; for example, cardiac ischemia may cause upper thoracic pain.
- **Sympathetic facilitation:** Persistent irritation leads to hyperexcitable spinal segments, resulting in chronic pain, muscle guarding, and autonomic imbalance.

Clinical Correlations

- **Cardiovascular system:**
  - The cardiovascular system is related to T1–T5 segments and may present with chest pain, tachycardia, and palpitations.
  - **Conditions:** Angina (which must be ruled out) and postcardiac surgery states.
  - **Physiotherapy management:** Thoracic mobility exercises, breathing retraining, and relaxation therapy.
  - **Red flag:** Cardiac causes must always be ruled out before treatment.

TABLE 3.1: Different thoracic levels, their relationship with different organs, and their clinical relevance

Thoracic Levels	Organs or Systems	Clinical Relevance
T1–T4	Heart and lungs	Cardiac and respiratory symptoms
T5–T9	Liver and stomach	Epigastric pain
T10–T12	Intestine and kidneys	Lower abdominal symptoms

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- **Respiratory system:**
  - Thoracic spine mobility directly affects rib cage mechanics.
  - **Conditions:** Chronic obstructive pulmonary disease, bronchial asthma, and postCOVID fibrosis.
  - **Dysfunction presentation:** Kyphosis leading to reduced lung expansion and sympathetic overactivity causing bronchoconstriction.
  - **Physiotherapy interventions:** Segmental breathing, costovertebral mobilization, and postural correction.
- **Gastrointestinal system:**
  - The gastrointestinal system is associated with T5–T9 segments and may present with epigastric pain and indigestionlike discomfort.
  - **Clinical conditions:** Peptic ulcer disease and gastritis.
  - **Physiotherapy management:** Midthoracic mobilization, stress reduction techniques, and diaphragmatic breathing.
- **Renal and lower abdominal system:**
  - The renal and lower abdominal region corresponds to T10–T12 segments and may present with flank pain and lower abdominal discomfort.
  - **Clinical consideration:** Renal colic should be suspected and referred when necessary.
  - **Physiotherapy focus:** Pain differentiation and gentle mobilization.
- **Musculoskeletal and postural syndromes:**
  - Thoracic kyphosis is common in elderly individuals and desk workers.
  - **Effects:** It leads to reduced rib mobility, increased sympathetic activity, and fatigue with pain.
  - **Management:** Extension exercises, scapular stabilization, and ergonomic correction.
- **Chronic pain syndromes:**
  - Conditions such as fibromyalgia and myofascial pain syndrome involve sympathetic overactivity and central sensitization.
  - **Physiotherapy management:** Graded mobilization, relaxation therapy, and breathing exercises.

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Physiotherapy Assessment

- **Subjective examination:** Assessment includes the nature of pain (sharp, dull, or referred) and associated autonomic symptoms such as sweating, palpitations, and temperature changes.
- **Objective examination:** Objective examination includes observation of thoracic kyphosis and rib cage movement, palpation for segmental tenderness and muscle spasm, and mobility testing using passive accessory intervertebral movements (PAIVMs). Special tests include the rib spring test and chest expansion measurement.
- **Red flag screening:** Always refer if:
  - Suspected cardiac pain
  - Severe unexplained abdominal pain
  - Neurological deficits
  - Sudden autonomic instability

Physiotherapy Management Protocol

- **Manual therapy:** Manual therapy includes Maitland mobilization (Grades I–IV) and thoracic manipulation, which help reduce sympathetic tone and improve mobility.
- **Exercise therapy:** Exercise therapy includes mobility exercises such as thoracic extension over a roller and rotation stretches, along with strengthening of scapular stabilizers.

- **Breathing techniques:** Breathing techniques include diaphragmatic breathing and segmental expansion, which promote parasympathetic dominance.
- **Relaxation and autonomic regulation:** Relaxation strategies include yoga, meditation, and biofeedback to regulate autonomic function.

Case Study

A 45-year-old patient presents with mid-thoracic stiffness, non-cardiac chest tightness, and anxiety. Findings include hypomobility at T3–T5 and reduced chest expansion. Management includes thoracic mobilization, breathing exercises, and postural correction, resulting in reduced symptoms and improved autonomic balance.

CLINICAL INSIGHT

The thoracic spine acts as a key center for sympathetic regulation; dysfunction in this region can lead to both musculoskeletal and visceral symptoms. Physiotherapy interventions can help normalize sympathetic activity, improve organ function, and reduce pain and stress.

Relationship between Deep Fascia, Thoracolumbar Fascia, and Dura Mater: A Systematic Review

The concept of a continuous fascial network linking musculoskeletal and neural structures has gained increasing attention. The relationship between deep fascia, the thoracolumbar fascia, and the Dura mater is particularly relevant in understanding pain mechanisms and neuromechanical interactions. The following study highlights the relationship between deep fascia, thoracolumbar fascia, and dura mater

Objective

To systematically review the anatomical and clinical evidence supporting continuity and interaction between deep fascia, thoracolumbar fascia, and dura mater.

Methods

- **Search strategy:** A structured review of peer-reviewed literature was conducted using databases such as PubMed, Scopus, and Web of Science with keywords including 'thoracolumbar fascia', 'deep fascia continuity', 'dura mater biomechanics', 'myodural bridge', and 'fascial system and nervous system'.
- **Inclusion criteria:** Peer-reviewed articles, cadaveric and imaging studies, systematic reviews, and English-language publications were included.
- **Exclusion criteria:** Non-scientific literature, case reports without anatomical basis, and non-human studies (unless highly relevant) were excluded.

Results

- **Fascial continuity:** Studies confirm that fascia forms a continuous body-wide network integrating musculoskeletal structures. The thoracolumbar fascia shows continuity with paraspinal muscles, abdominal fascia, and pelvic fascia, supporting a tensegrity-based system.
- **Thoracolumbar fascia as a central hub:** The thoracolumbar fascia plays a key role in load transmission, spinal stability, and force distribution. Its high density of mechanoreceptors suggests involvement in proprioception and pain modulation.

- **Myodural bridge:** The most significant anatomical evidence of fascia–dura connection is the Myodural Bridge, which links suboccipital muscles, deep cervical fascia, and the spinal dura mater. It helps prevent dural infolding, maintains cerebrospinal fluid dynamics, and transmits mechanical forces.
- **Dura mater as a fascial structure:** Emerging evidence suggests that the dura mater has a collagenous composition similar to fascia, responds to mechanical stress, and may be considered part of the fascial continuum.
- **Biomechanical and neurophysiological interaction:** Movement generates fascial tension that can be transmitted to the dura mater, potentially altering neural mobility, cerebrospinal fluid flow, and pain perception.

Discussion

- **Integration of systems:** The findings support functional integration between the musculoskeletal, fascial, and nervous systems.
- **Clinical implications:**
  - **Low back pain:** Thoracolumbar fascia stiffness may alter load transfer and contribute to dural tension.
  - **Headaches:** Involvement of the myodural bridge and cervical fascial tension may lead to dural irritation.
  - **Neural tension disorders:** Fascial restriction may reduce nerve mobility.
  - **Postural dysfunction:** Chronic fascial tension may alter spinal mechanics.

Conclusion

There is strong anatomical and moderate clinical evidence supporting continuity between deep fascia and thoracolumbar fascia, direct connection between fascia and dura *via* the Myodural Bridge. Functional interaction influencing biomechanics and neural function. The fascia–dura continuum represents an important paradigm in modern physiotherapy and rehabilitation science

- **Physiotherapy relevance:** Interventions targeting fascia may improve neural mobility, reduce pain, and help normalize autonomic function.
- **Limitations of current evidence:** Most available studies are cadaveric and anatomical, with limited high-quality clinical trials. There is a need for longitudinal and imaging-based research to strengthen clinical evidence.

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SUMMARY

- The thoracic spine consists of 12 vertebrae, ribs, and sternum, forming a protective cage for thoracic organs.
- Diaphragm is the primary muscle of respiration, assisted by intercostal and accessory muscles.
- Pump-handle and bucket-handle rib mechanics expand thoracic dimensions for inspiration.
- Thoracic spine movement is restricted by facet orientation and rib articulations, allowing limited flexion, extension, side flexion, and rotation.
- Posture strongly influences breathing; optimal expansion occurs in erect posture with relaxed abdominals.
- Scoliosis is a lateral curvature, often idiopathic, diagnosed radiologically with Cobb's angle. Progression depends on age, sex, curve magnitude, and region. Management includes exercises, bracing, and surgery.
- Kyphosis is excessive sagittal curvature, caused by poor posture, Scheuermann's disease, osteoporosis, fractures or congenital anomalies. It produces musculoskeletal pain, respiratory restriction, and postural deformity.
- Thoracic radiculopathy is rare, presenting as band-like chest or abdominal pain without motor weakness. Physiotherapy emphasizes mobilization, stabilization, and conservative management.
- Overall, the thoracic spine plays a vital role in respiration, posture, and spinal stability, with disorders often affecting multiple systems.

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STUDENT ASSIGNMENT

LONG ANSWER QUESTIONS

1. Discuss the physiotherapy management of scoliosis under:
    a. Breathing techniques
    b. Corrective exercises
    c. Ergonomic modifications in ADLs
    d. Strengthening and stretching strategies
2. Describe the types of kyphosis with etiology, clinical features, and physiotherapy management.
3. Write a detailed note on thoracic radiculopathy including:
    a. Causes
    b. Clinical presentation
    c. Differential diagnosis
    d. Role of physiotherapy

SHORT ANSWER QUESTIONS

1. Write about Fryette's Laws with clinical applications in scoliosis management.
2. Enumerate the potential complications of severe scoliosis with a Cobb angle exceeding 90°.
3. What are the radiological features of Scheuermann's disease?

MULTIPLE CHOICE QUESTIONS

1. **Fryette's First Law states that in a neutral spine:**
    a. Lateral bending to convex side causes ipsilateral rotation
    b. Lateral bending to convex side causes contralateral rotation
    c. Rotation always follows extension
    d. Rotation is independent of side-bending
2. **In scoliosis, severe curves >90° may lead to:**
    a. Stroke
    b. Right heart failure (cor pulmonale)
    c. Cervical radiculopathy
    d. Frozen shoulder
3. **Classic feature of Scheuermann's disease on X-ray is:**
    a. Hemivertebra
    b. Three (3) or more vertebrae wedged by ≥5°
    c. Increased disc height
    d. Posterior hemangioma
4. **Thoracic radiculopathy differs from cervical/lumbar radiculopathy because:**
    a. It produces band-like sensory loss without motor weakness
    b. It is always bilateral
    c. It causes reflex loss in the chest wall
    d. It can be diagnosed by manual muscle testing