Thoracic and Costovertebral Subluxation Syndromes

Chapter 23 Thoracic and Costovertebral Subluxation Syndromes

Key Words

Comparatively little is known about the neurologic, biomechanical, and physiologic relationships of this region of the spine. This is peculiar when one realizes that the thoracic spine houses the sympathetic nervous system and spinal dysfunction has been implicated in the development of somatovisceral reflex dysfunction, visceral dysfunction, and pain. What is known about thoracic physiology and biomechanics has been largely extrapolated from known functions of the cervical and lumbar spines. It would appear that our knowledge of spinal function has been driven by the need to understand the causes and treatment of spinal pain and therefore the lumbar spine. Secondarily, the cervical spine has captured most of our attention. Much of the literature relating to the thoracic spine is devoted to pathologic conditions and conditions that with a few exceptions have little to do with the clinical problems that are seen on a daily basis by the chiropractic clinician.

Clinical experience, however, demonstrates that pain syndromes and disorders of the thoracic spine and rib cage that do manifest themselves are quite frightening to the patient and produce anxiety about internal diseases that may or may not be relevant. Pain, pathology, and degenerative changes in this region of the spine have been shown to relate to postural changes, including scoliosis and kyphosis, autonomic and visceral dysfunction or pathologic condition, aberrant spinal static or dynamic function, or aberrant costovertebral function.[1–3] Aberrant static and dynamic function is related to dysfunction of the soft tissues, including ligaments, muscles, and discs. Joint function is regulated by sensorimotor reflex feedback loops.

The sensory proprioceptive system gets its main input from skin, muscles, ligaments, blood vessels, and fascia and it has been estimated to form 65% to 75% of the input; the special senses and viscera form the rest of the input. Thoracic spinal dysfunction therefore can be related to the overall neurologic regulation of the body’s static and dynamic physiologic and nonphysiologic responses of viscera, including cardiovascular and respiratory systems and the locomotor system as a whole. The relationship may be through neurologic reflex changes or through direct biomechanical muscular function; for example, diaphragm contraction in respiratory change produces direct biomechanical effects on the rib cage and spine.

Diagnostic evaluation of any segment or region of the thoracic spinal or rib cage therefore should consider the following:

Clinically Relevant Anatomy

The dorsal vertebrae are intermediate in size between the cervical and lumbar vertebrae, and they increase in size from above downward, a structural accommodation thought to relate to the increased demands of weight bearing.[4] The typical thoracic vertebra is so named because of the nature of rib attachments. The second to the eighth thoracic vertebrae are considered typical and contain two pairs of demifacets. One is located on the superior posterolateral aspect of the body and one on the inferior aspect directly below, forming the articulation with the head of the ribs on each side. Viewed from the superior aspect the typical vertebra shows a heart-shaped body with relative equal anterior-to-posterior dimensions; the spinal canal is round (Figure 23-1). The left side of the vertebral body sometimes has an impression formed by the aorta, which lies along the vertebral bodies and discs. From the lateral perspective, the vertebral body is slightly thicker on the posterior than the anterior. This vertebral shape functions in forming the primary normal thoracic kyphosis. The superior and inferior disc end plates should appear parallel on radiographs. The pedicles are directed backward from the body, and the inferior intervertebral notches are large and deeper than in other regions of the spine. This results in small but adequate intervertebral foramina that are circular in form (Figure 23-2).

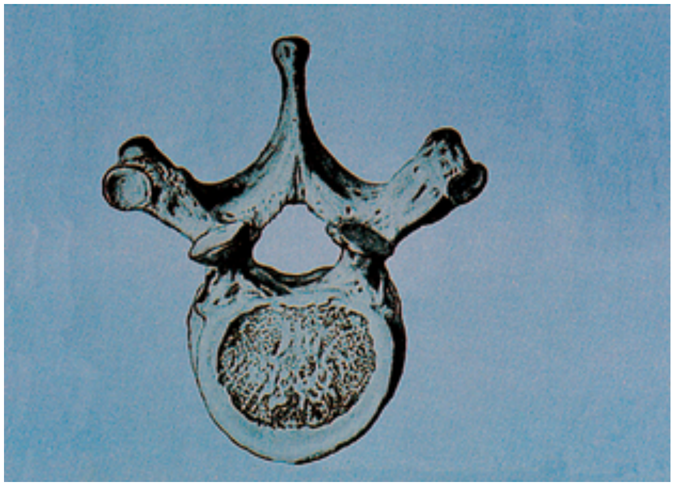

Figure 23-1 Superior view of typical thoracic vertebra.

(From Clemente C. Anatomy: a regional atlas of the human body. 4th ed. Baltimore: Lippincott Williams & Wilkins; 1997.)

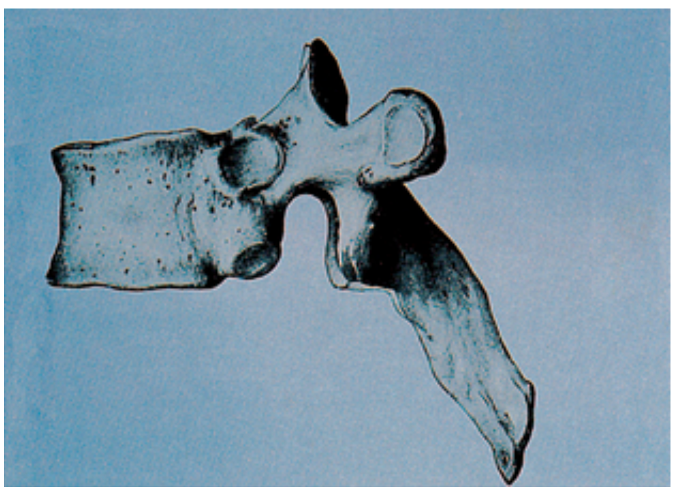

Figure 23-2 Lateral view of typical thoracic vertebra, wedge-shaped vertebral body.

(From Clemente C. Anatomy: a regional atlas of the human body. 4th ed. Baltimore: Lippincott Williams & Wilkins; 1997.)

The laminae are broad and thick, and they overlap one another like tiles on a roof. They give rise to the inferior and superior articular processes. The superior articular processes each have an oval hyaline cartilage–covered facet that is flat and faces posteriorly, slightly superiorly, and laterally. The inferior articular processes have on the anterior surface an oval hyaline cartilage articular facet that is slightly concave transversely and faces anteriorly, inferiorly, and medially. The superior and inferior facets overlap like shingles. When viewed laterally, the joints create an angle from horizontal reported to be from 60 degrees in the upper thoracic region up to 80 to 90 degrees in the lower thoracic region.[5](See Figure 23-2.)

The spinous processes are long, triangular, directed obliquely downward, and terminate in a bulbous extremity. The spinous tip in the mid-dorsal region is at the level of the facet of the vertebra below and produces an angle of 45 degrees up to 60 degrees or steeper in some cases. The bulbous tip of a typical thoracic vertebra is an excellent level for adjusting the intervertebral fixations/subluxations. The clinician by using an appropriate contact on the spinous process may develop an angle of force from right or left inferior to superior similar to the plane of the facet joints.

The transverse processes arise from behind the articular facets at the junction between the pedicles and the laminae. They are thick and strong, quite long, and directed obliquely backward and outward, with a clubbed extremity formed by the attachment of muscles. It is important to note that in the upper and mid-thoracic areas, the transverse processes are sometimes angled posteriorly and superiorly so that the tip is superior to the articular facet of that vertebra, a facet important in the angle to adjustive thrust. The purpose of both the spinous and transverse processes is for the attachment of muscles, and the shape of these structures is determined by the forces that act on them. The usual direction of thrust should be opposite to this direction of force. Most often a crossed bilateral is selected to facilitate the motion and not jam the facets, and the thrust delivered as torque directed from the superior is helpful. On the anterior surface, the typical thoracic transverse process contains a small concave articular facet that articulates with the tubercle of the rib.

The thorax, or chest cage, is an osseous cartilaginous structure whose principal function is to protect the principal organs of respiration and circulation. The rib cage is an important functional component of respiration, and Wyke[6] showed that by freezing the costovertebral joints the neurologic stimulus for respiration was suspended and respiration ceased. This fact may explain the benefit perceived by patients with chronic lung problems and asthma after adjustive care.

Viewed from the lateral aspect, the ribs form an angle of approximately 45 degrees as they move anteriorly and inferiorly, with a sharp superior angulation of the costal cartilages as they curve superior to attach to the sternum. The sternal costal joints of the true ribs (the first seven) unite at the sternum by hyaline cartilage. The next three or four ribs are false ribs and the hyaline cartilages connect, forming a more elastic attachment. The last two ribs have free endings without cartilaginous attachments; in some cases, the eleventh rib forms part of the false rib cartilaginous structure. The twelfth rib with the constant free distal end is sometimes called the floating rib. These costal cartilage attachments have a good deal of elasticity in the younger age-groups, but with increasing age, these cartilages become deeply yellow in color and tend to calcify and lose their elasticity. The female thorax differs from the male in that it usually has less capacity, the sternum is shorter, and the upper margin of the sternum is on the level of the lower body of the third dorsal vertebra, whereas in the male it is on the level of the lower part of the second dorsal vertebra. The upper ribs are more mobile in the female and allow greater movement of the upper thorax than in the male. These factors are important in consideration of prone adjustments in the female, particularly in the older osteoporotic or aging patient. All 12 thoracic vertebrae articulate with ribs; however, T2 through T9 have a double-rib articulation, forming a facet joint on the tip of each transverse process that articulates with the tubercle on the angle of ribs, and on the body on each side of the vertebrae as just described.

The first thoracic vertebra differs somewhat and is referred to as atypical. T1 is somewhat cervical-like, with the spinous process being thicker and proceeding posteriorly on a more horizontal plane. The vertebral body is broad transversely, with a concave superior surface slightly lipped on each side, causing the articular surfaces to be somewhat oblique. The clinician should consider the angle of the facets and the shape of the vertebral body in formulating the direction of the more effective adjustment. The concave body suggests an adjustment that includes distraction or longitudinal traction whereas a direction of thrust from superior to inferior is indicated to facilitate an adjustment with less discomfort to the patient, a factor very important in cervical adjusting as well.

The spinous process of the first thoracic vertebra is thick and may be almost as long as the vertebra prominens (spinous of C7), and during flexion of the neck, it also can appear to be quite prominent. This structure makes it an excellent contact for rotational and lateral flexion adjustments for fixations/subluxations between C7-T1 and T1-2. A thumb contact, commonly called a TM (thumb move), which is described later in this chapter, should concern itself with the thoracic vertebral shape, different patient head alignment, and thrust direction during positioning to specifically affect C7-T1 or T1-2. The head position and direction of thrust also change when we consider the holding elements involved, such as the direction of the muscle force. These factors are important for success and comfort in adjusting this region. As in all areas of the spine, the anatomy and the holding elements should be considered when applying an adjustment. This review does not deal with all the adjustments in the area; rather, special attention is drawn to areas that have been shown to produce particular difficulty for clinicians in efforts to develop efficiency, specificity, and ease of adjusting. The first thoracic vertebra is such an area. It has a complete facet for the first rib and a demifacet on the inferior of the body for the articulation of the second rib. The presence of a cervical rib may complicate pain syndromes involving the upper ribs and thoracic vertebrae but provides no particular problem for treatment and, in many cases, is present for years without symptoms. Thoracic outlet problems are common and clinically are often caused by irritation coming from the multiple pain-sensitive structures related to not only the vertebral facet joints but the rib attachments and the increased number of ligaments and muscles of this region. Muscle forces that act on these joints take their attachments from the cervical spine and occiput as well as from the thoracic spine and ribs. Correction should consider the related fixations in these regions of the spine and the interaction of the muscles. Further discussion of the cervical thoracic junction is presented in Chapter 22.

The inferior thoracic vertebrae, T9-12, are also considered atypical, particularly T11 and T12, which display characteristics of lumbar vertebrae. The ninth thoracic may or may not have an inferior demifacet, whereas the tenth usually has only one demifacet, often more laterally placed on the pedicle. The eleventh vertebra is more similar in size to a lumbar vertebra, and the articular facets for the ribs are larger and are located on the pedicle, which is also larger and stronger. The spinous process is short and nearly horizontal. The transverse processes of T11-12 are short and have no articulation with the rib. The twelfth thoracic vertebra differs from the other thoracic vertebrae in that the superior facets have a coronal facing, that of a thoracic vertebra, whereas the inferior facets have saggital facing, that of a lumbar vertebra. The biomechanical demands placed on this vertebra are unique and often necessitate special attention so that symptoms may be controlled. The thoracolumbar region exhibits the highest torsional stiffness and the highest frequency of fracture.[4] The transverse process is shorter, containing tubercles similar to mammillary or accessory processes formed by the attachments of muscles. These anatomic and biomechanical factors make this vertebra an important transitional vertebra for spinal curves and suggest that the optimal function of the spine occurs when the curves statically and dynamically make their transition at this level. Treatment should endeavor to restore or maintain this ideal function.

The presence of the anteroposterior (AP) curves in the spine gives it more resistance to weight-bearing forces, providing a springlike effect and reducing vibration. The thoracic kyphosis, unlike the lumbar spinal lordosis, ensures that in the neutral posture the facets carry little if any weight. Posture is such that when standing, we are inclined slightly forward. The result is that mild activity of posterior muscles, the erector spinae, maintains our posture. During unsupported sitting, there is slightly more activity of the posterior muscles.[7,8] This muscle also extends up the rib cage and helps posturally stabilize the spine and rib cage as a unit. During extension, the articulating facets form a close-packed system that limits motion.

The anterior compartment of the thoracic motion segment is formed by the vertebral bodies, the intervertebral disc, and longitudinal ligaments. The anterior ligament is a strong band made up of several layers, stretching from occiput to sacrum, narrower but thicker in the thoracic region, and serves to limit extension (Figure 23-3). The posterior longitudinal ligament up the posterior vertebra bodies is also thick, widens at the discal region, and narrows at the vertebral body. The axis of motion of the thoracic segment being anterior to this ligament allows it to limit flexion and translation.

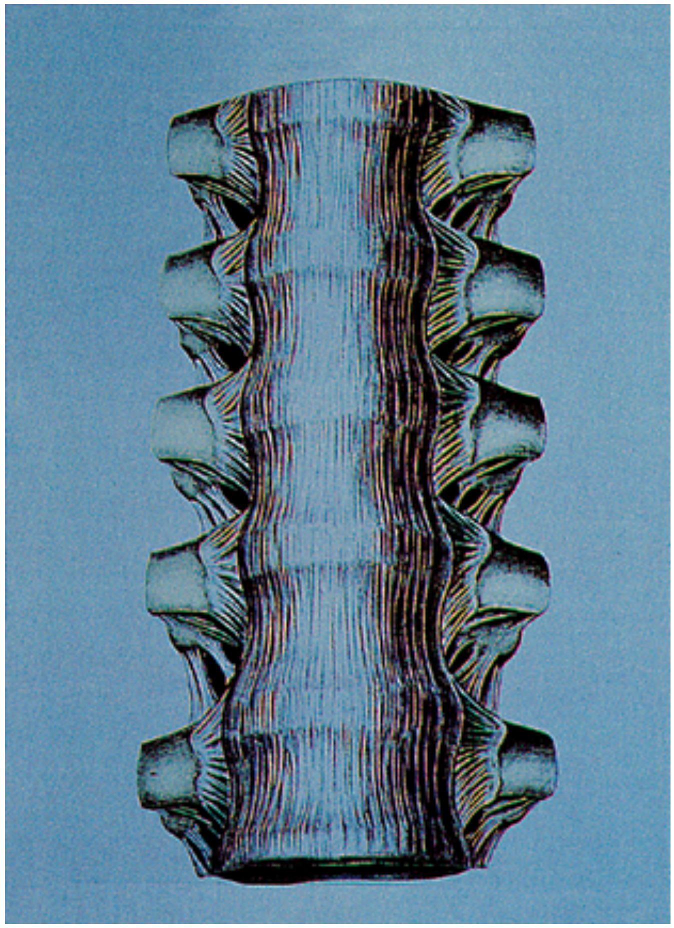

Figure 23-3 Anterior view of typical thoracic vertebra, anterior ligaments.

(From Clemente C. Anatomy: a regional atlas of the human body. 4th ed. Baltimore: Lippincott Williams & Wilkins; 1997.)

The posterior compartment is formed by the vertebral arch, the transverse processes, and the zygapophyseal joints. The articular capsules are important structures in this posterior compartment because they are pain-sensitive structures and are called on to limit the movement of the thoracic motion segments in all ranges. They are attached to the lateral margins of the articular processes and are reinforced by the ligamenta flava that connect the vertebral lamina (Figure 23-4). The latter ligaments limit flexion and, to some degree, lateral flexion and rotation, and are composed largely of yellow elastic fibers. In degenerative change, the ligament may bulge and cause irritation to the nerve root.

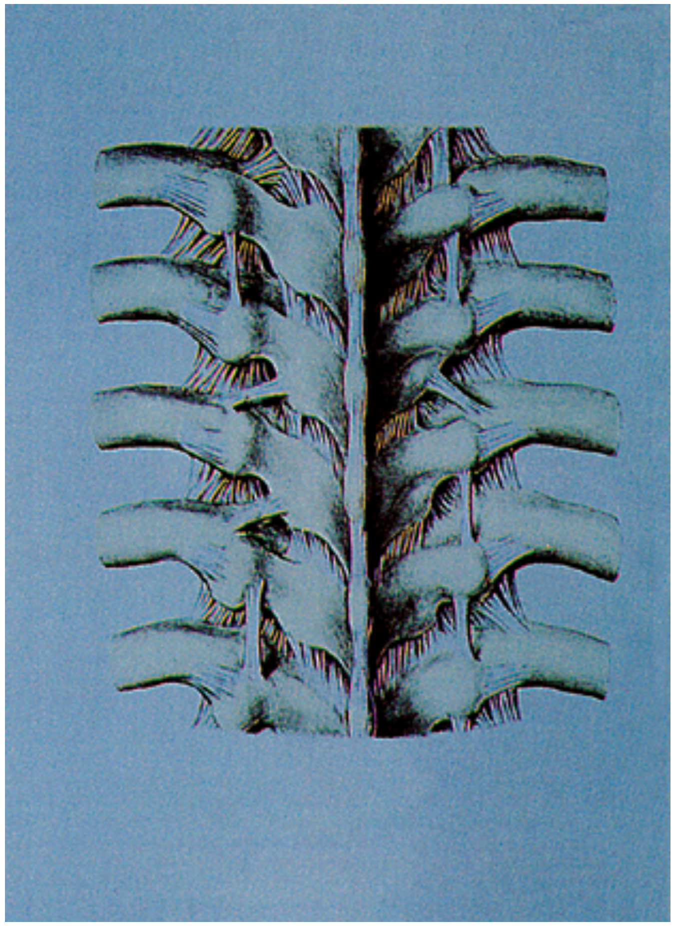

Figure 23-4 Posterior view of typical thoracic vertebra.

(From Clemente C. Anatomy: a regional atlas of the human body. 4th ed. Baltimore: Lippincott Williams & Wilkins; 1997.)

The intrinsic elements of the thoracic spine, the discs, ligaments, and vertebral structure provide the intrinsic stability that is significant up to a few kilograms.[4] As in other areas of the spine, Nachemson[9] showed that the nucleus exerts hydrostatic pressure that acts like a coil spring, separating the vertebrae and producing a preload stretch on the anterior and posterior compartment ligaments. Removal of the posterior ligaments, particularly the elastic ligamenta nuchae, demonstrates that the ligaments also exert compressive force or prestress on the disc, which provides for protection and enhancement of motion. As previously discussed, the rib cage also produces resistance to motion, adding to thoracic stiffness twofold and load-bearing capacity threefold (Figure 23-5).[10] All of these factors are probably why disc lesions and facet problems are less frequent in the thoracic spine. The interspinous and supraspinous ligaments limit flexion and are well developed in the thoracic region. Tenderness of the supraspinous in the mid-thorax, a common clinical finding, would seem to demonstrate that this region of the spine is frequently under flexion strain. Degenerative change in the anterior aspect of the dorsal vertebrae is also common, which may relate to increased compressive forces or at least to excessive anterior mobility of the body.

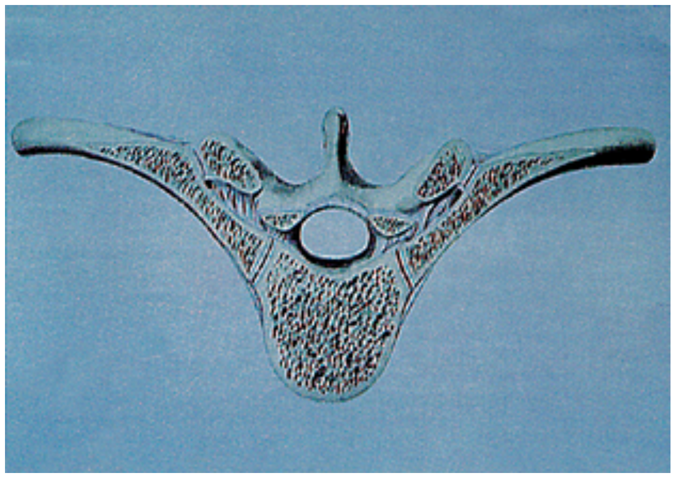

Figure 23-5 Cross-section of costovertebral connection.

(From Clemente C. Anatomy: a regional atlas of the human body. 4th ed. Baltimore: Lippincott Williams & Wilkins; 1997.)

Biomechanics of the Thoracic Spine

Static Concepts

In general, it is often considered that the normal AP view of the thoracic spine should be relatively straight and balanced, whereas the normal lateral view should have a posterior curve. The thoracic kyphosis and the sacral curve are formed during the embryonic stage and are called the primary curves. The thoracic kyphosis, as stated previously, is attributable primarily to the wedge shape of the thoracic vertebrae, particularly characteristic in the mid-thorax. Growth changes as seen on radiograph in this normal vertebral wedging should be evaluated when an alteration in this so-called normal kyphosis is seen. A flat thoracic spine may be a normal variant in young girls who otherwise have normal posture and may result from loss of this normal vertebral wedging. The optimal thoracic curve should be an even curve that extends from T1 to T12, with C7-T1 and T12-L1 being the transition points for the primary kyphotic curve as the spinal curves become the secondary cervical or lumbar curve, respectively. The apex of the thoracic curve should be at the level of T6-7. Common variations are seen: (1) Flattening of mid-dorsal kyphosis is more common in females than in males; (2) elongation of the thoracic primary curve into the lumbar spine, producing a short radius lumbar curve, is also common. Clinical experience suggests that these variations may well lead to symptoms or biomechanical stress that manifests as degenerative changes. Some variation in opinion is seen in the literature on what constitutes normal or optimal statics and dynamics, and because of our lack of knowledge, it is difficult to draw precise correlations between aberrant biomechanics and pathologic conditions and render a good theoretical basis for pathogenesis in this region of the spine. The anatomic shape of the vertebrae, as well as the muscular attachments and their postural functions, would in theory dictate concepts of optimal posture for the thoracic spine. Because few studies are available that establish normal and optimal posture for this region, we must rely on structural and functional integration to develop clinical models of optimal function.

Gray's Anatomy[11] holds that the cervical curve starts at C2 and ends at T2, the thoracic curve starts at T2 and extends to T12, and the lumbar curve starts at T12 and ends at L5. The normal apex of the thoracic curve is T7. The spine was normally seen to have a very slight lateral curve convexity to the right, thought to be caused by muscular development related to dominant right-handedness. Schmorl and Junghanns[12] reported that it was normal for 80% of spines to have a mild physiologic scoliosis, left in the cervical thoracic region and right in the thoracic and lumbar regions, whereas 20% of spines showed the reverse of this curve. These curves begin developing at 6 years of age; they were thought to be related to greater strength of right thoracic musculature caused by dominant right-handedness. It is interesting to note, however, that Figure 51 of their text, depicting these curves in a preparation by Virchow, is more representative of the four opposed rotational scolioses seen as normal and presented in chiropractic literature by Carver,[13] Beatty,[14] and Homewood.[15]

Dynamics of the Thoracic Spine

The thoracic spine is the longest region of the spine but the least mobile. This lack of mobility is caused primarily by the fact that the height of the disc is approximately 20% to 25% that of the height of the thoracic vertebral body, a ratio that is the lowest in the spine. Additionally, the rib cage with the double posterior and anterior costosternal attachments limits rotation and lateral flexion. When the sternum is removed, the stiffness of the thoracic spine imparted by the rib cage is negated.[4] These movements are slightly less limited in the lower thoracic region, where the elasticity of the costal cartilages allows for a slightly greater degree of mobility in certain ranges. The thoracic vertebral facet facings limit flexion and extension to some degree but do little to impede rotation and lateral flexion of the thoracic segment, which is mainly limited by the ribs. During extension the facets are seen to make contact, which limits movement along with the anterior longitudinal ligament. All motion in the thoracic spine is accompanied by movement in the ribs, which at times amounts to only a few millimeters of translational motion. Thoracic biomechanical dysfunctions, whether vertebral or costovertebral, are intimately related because of the osseous structural arrangement and the muscular attachments. When correcting dysfunction, concern for static alignment, joint motion, and the extrinsic forces that block the movement are of importance. White and Panjabi[16] emphasized six degrees of freedom in the thoracic motion segment similar to the findings in the lumbar spine: (1) anterior/posterior motion or translation along the Z axis; (2) lateral to medial motion around the X axis; and (3) superior to inferior motion around the Y axis. The traditional descriptors flexion, extension, lateral flexion, and rotation do not conform to the actual movements in the spine because all movements are combined or coupled movements. The primary coupled motion is easily detected on a motion study plain film radiograph, and it is well understood that lateral flexion is combined with rotation and vice versa. It is important to note that tertiary motions in translation, flexion or extension, or motion along the Y axis also accompany these main motions. Clinicians often believe that when the tertiary motion is lost in a motion segment (joint blockage or subluxation), the neurologic reflex changes that take place are the most significant to the patient and explain some of the dramatic results obtained by the dynamic adjustive thrust when evaluation demonstrates little static or dynamic change other than the restoration of the paraphysiologic or tertiary motion. Panjabi et al.[17] showed that the average intervertebral translation motion was 1 mm in the sagittal plain. This amount of motion can be felt only through the end feel challenge method and clinically can be appreciated as altered after a dynamic adjustive correction. At times the palpable restoration of motion may represent restoration of tertiary motion, paraphysiologic motion, or translatory motion that may prove sometimes to be the same motions.

The axis of motion for rotation and lateral flexion is located in the center of the body of the vertebra and under normal circumstances very little shearing or translatory motion of the disc takes place. The axis of motion for flexion-extension is located in the center of the disc of the vertebra below and does not allow or require much shearing or translation. Clinically, anterior disc lipping and degeneration are common radiographic findings in middle age.[18,19] One cause of these pathologic changes is probably a shift of the axis of motion posteriorly and laterally caused by alteration in muscular activity that results in hypermobility of the anterior body during movement with resultant increased shearing force to the disc and stress and strain to all of the intrinsic structures. The alteration of movement or function produces a change in structure, resulting in the degenerative changes commonly seen in the anterior body of the thoracic spine and the osteophytic changes at the costotransverse joints.

The musculature of the thoracic spine is dealt with in detail in most anatomy texts. The action is usually described on a kinesiologic basis with such descriptions as extensors/rotators or lateral flexors of the spine. For the clinician involved in spinal correction, the specific attachment of these muscles and their individual actions and effects on the motion and biomechanics of the individual vertebra are important. Some of the discussion in this area must be theoretical at this stage because of limited experimental research and technology to validate our opinions; however, speculation based on structure, function, and observation is an important first stage. The Quiring and Warfel series[20,21] on musculature is a very good reference source for the clinician to use for the details of origin, insertion, nerve supply, and motor points. The detailed drawings allow us to speculate on the biomechanical action these muscles exert on the individual motion segment.

It is interesting to note that the trapezius, latissimus dorsi, and rhomboids, which always receive much attention from clinicians in clinical and legal reports on spinal dysfunction, are listed in these texts as extremity muscles, and in my opinion, rightly so. Under normal circumstances these muscles have little effect on spinal posture or movement biomechanics except when the upper limb is active or load bearing. As such, these muscles are not very often causative of spinal subluxation, whereas the deeper layers of spinal muscles are much more important and should capture the attention of clinicians.

It would appear that the reason the trapezius gets so much of our attention is because of its broad origin from the external occipital protuberance superior nuchal line, nuchal ligament, spinous processes, C7, and spinous process of all 12 thoracic vertebrae. The insertion is into the lateral third of clavicle, spine of scapula, and acromion. Palpable tenderness and spasm in the back musculature is often mistakenly related to this muscle, resulting in neglect of the more important deep muscles.

The latissimus dorsi arises from the lower six thoracic spinous processes, the lumbosacral fascia, the crest of the ilium, and the lower three or four ribs. The insertion is into the bicipital groove of the humerus. Rib fixations related to this muscle are common with sports or activities that require torsion and arm motion. Treatment is difficult because of the ease of trauma on returning to the sports activity. Rehabilitation of the patient with lower back or lumbodorsal problems, who must return to lifting tasks, should strengthen this muscle to stabilize the back.

The rhomboids arise from the ligamentum nuchae, the spinous process of C7, and the spinous processes of T1-5. They insert into the medial border of the scapula. In the prone position, elevation of the scapula and palpation of these muscles as well as of the trapezius can help determine if hypertonicity is present in these more superficial muscles or the deep muscles of the back.

The main muscles that control thoracic biomechanics are the trunk muscles, the erector spinae, and the transversospinal group (Figure 23-6).

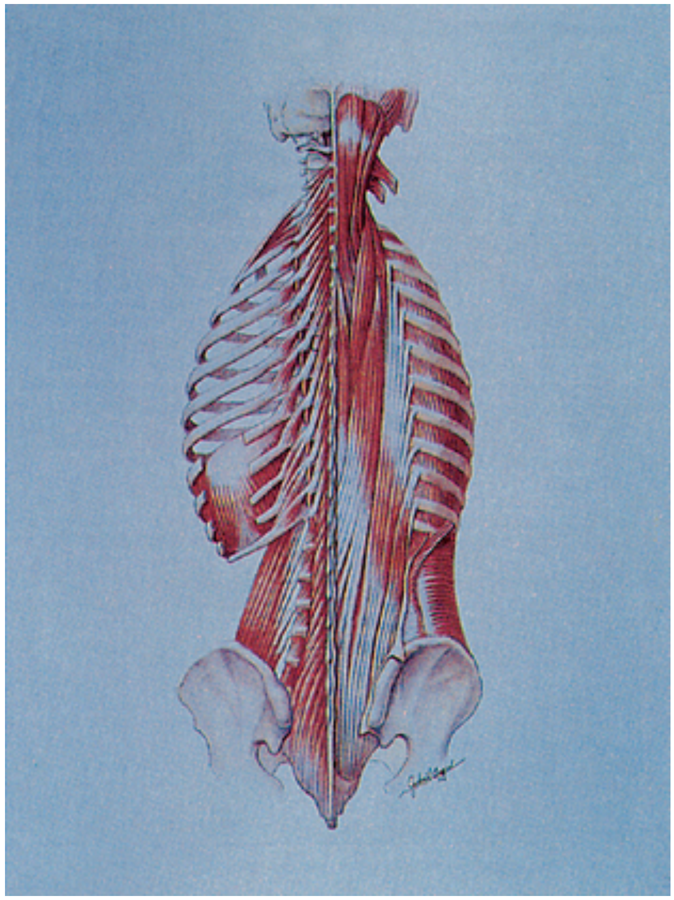

Figure 23-6 Erector spinae and transversospinal muscles.

(From Seeley RR, Stephens TD, Tate P. Anatomy and physiology. 3rd ed. St. Louis: Mosby; 1995.)

The erector spinae group is made up of the (1) iliocostalis, (2) longissimus, and (3) spinalis.

Kinematics of the Thoracic Spine

Kapandji[22] reports movement of the spine as a whole. His diagrams demonstrate 45 degrees of flexion-extension, 20 degrees of lateral flexion to each side (total of 40 degrees), and 35 degrees of rotation to each side (total of 70 degrees). Gregerson and Lucas's study[23] of normal medical students using Steinmann's surgical pins inserted into the spinous processes showed an average segmental rotation of 6 degrees. They showed a slight difference between sitting and standing, with sitting showing less motion in the lower thoracic vertebrae. They reported a total range of motion similar to the figures suggested by Kapanji[22](37 degrees to one side, or a total of 74 degrees of rotation). In this same study, rotation during gait was observed. During normal walking, T7-8 was seen to stay relatively stable and formed the transition point for total body rotation developed by the pelvis, opposed to the counter-rotation seen in the shoulders with normal arm swing. With each step, the gross rotation motion of the body at the sacrum is approximately 8 degrees, which reduces to 0 degree at T7-8. The arm swing and shoulder motion produce an opposite rotation of 6 degrees at T2. Therefore T7-8 would show the most rotation segmentally during normal walking (approximately 2.5 degrees). The segmental rotation at T11-12 and T1-2 during walking amounts to about 0.5 degree. These biomechanical observations would lend logical support to the concept that T7 should be the optimal apex of the thoracic kyphosis. The most definitive study of the biomechanics and the range of segmental motion in the thoracic region comes from White and Panjabi[24](Table 23-1).

Table 23-1 Segmental Motion in the Thoracic Spine

	Flexion/extension		Lateral bending		Axial rotation	
Interspace	Limits of ranges (degrees)	Representative angle (degrees)	Limits of ranges (degrees)	Representative angle (degrees)	Limits of ranges (degrees)	Representative angle (degrees)
T1-T2	3-5	4	5	6	14	9
T2-T3	3-5	4	5-7	6	4-12	8
T3-T4	2-5	4	3-7	6	5-11	8
T4-T5	2-5	4	5-6	6	4-11	8
T5-T6	3-5	4	5-6	6	5-11	8
T6-T7	2-7	5	6	6	4-11	8
T7-T8	3-8	6	3-8	6	4-11	8
T8-T9	3-8	6	4-7	6	6-7	7
T9-T10	3-8	6	4-7	6	3-5	4
T10-T11	4-14	9	3-10	7	2-3	2
T11-T12	6-20	12	4-13	9	2-3	2
T12-L1	6-20	12	5-10	8	2-3	2

From White AA III, Panjabi MM. Spine 1978;3:12.

Flexion-Extension Range of Motion: Sagittal Plane

Rotation

Median figures are 4 degrees of motion for the upper thoracic segments, 6 degrees for the mid-thoracic segments, and 12 degrees of motion each for the T11, T12, and L1 segments. White and Panjabi[25] suggested that the instantaneous axis of motion for flexion is located in the anterior one third of the superior aspect of the vertebral body of the vertebra below; for extension, the location is in the anterior one third of the inferior aspect of the vertebra of the superior motion segment (Figure 23-7).

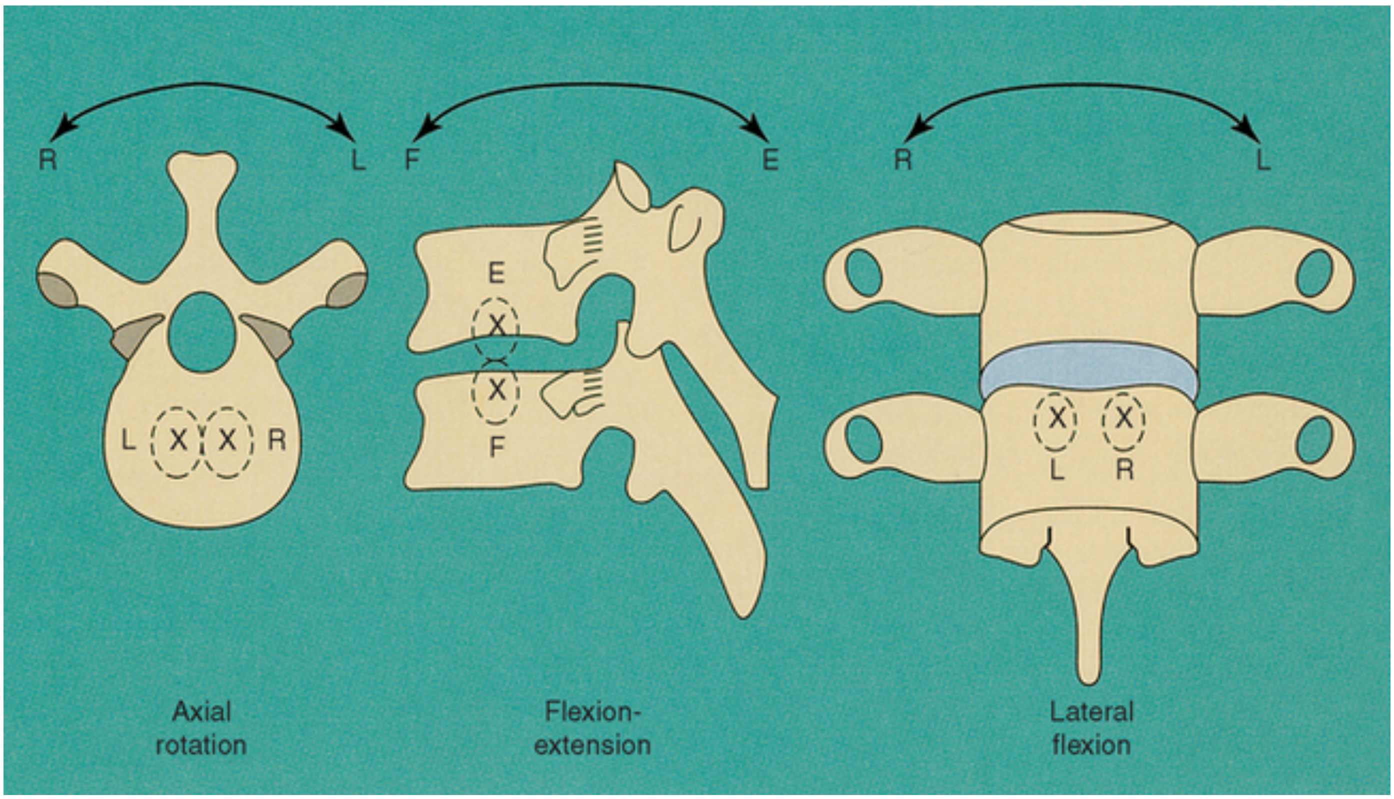

Figure 23-7 Instantaneous axis of motion (flexion-extension, rotation, lateral flexion).

Rotation Range of Motion: Motion in the Horizontal Plane

Rotation in the thoracic spine also produces coupled motions, the prime motion being that of lateral flexion. These patterns of coupled motion, as in the case of lateral flexion, can be altered voluntarily by postural change.

Vertical axial rotation of the thoracic spine to the right results in lateral flexion to the left, particularly in the lower thoracic region. Clinically, it must be remembered that there is an additional coupled motion in the sagittal plane during rotation. In the lower thoracic region, this motion appears to be extension, whereas in the upper thoracic region it appears to be flexion. The coupled pattern in the upper thoracic region can be altered by slight flexion, producing lateral flexion on the same side. The transition point for these movements in the transverse and sagittal plane is approximately T6-7. This transition point and T5-6 are often clinically found to demonstrate marked spinous tenderness and subluxation. A flattening, or saucer effect, also may occur in the region of the spine and is usually related to the extensor group of thoracic muscles being overactive.

The rotation range of motion for the whole thoracic spine is 41 degrees. Each vertebral segment in the upper half of the thoracic spine moves approximately 4 degrees to each side with a total of 8 to 9 degrees, whereas the lower three thoracic segments move only about 2 degrees to each side.[4]