he spine is a complex and functionally significant segment of the human body. Providing the mechanical linkage between the upper and lower extremities, the spine enables motion in all three planes, yet still functions as a bony protector of the delicate spinal cord. To many researchers and clinicians, the lumbar region of the spine is of particular interest because low back pain is a major medical and socioeconomic problem in modern times.

**STRUCTURE OF THE SPINE**

**Vertebral Column**

The spine consists of a curved stack of 33 vertebrae divided structurally into five regions (Figure 9-1). Proceeding from superior to inferior, there are 7 cervical vertebrae, 12 thoracic vertebrae, 5 lumbar vertebrae, 5 fused sacral vertebrae, and 4 small, fused coccygeal vertebrae. There may be one extra vertebra or one less, particularly in the lumbar region.

Because of structural differences and the ribs, varying amounts of movement are permitted between adjacent vertebrae in the cervical, thoracic, and lumbar portions of the spine. Within these regions, two adjacent
vertebrae and the soft tissues between them are known as a motion segment. The motion segment is considered the functional unit of the spine (Figure 9-2).

Each motion segment contains three joints. The vertebral bodies separated by the intervertebral discs form a synovial type of articulation. The right and left facet joints between the superior and inferior articular processes are diarthroses of the gliding type that are lined with articular cartilage.

**Vertebrae**

A typical vertebra consists of a body, a hollow ring known as the neural arch, and several bony processes (Figure 9-3). The vertebral bodies serve as the primary weight-bearing components of the spine. The neural arches and posterior sides of the bodies and intervertebral discs form a protective passageway for the spinal cord and associated blood vessels known as the vertebral canal. From the exterior surface of each neural arch, several bony processes protrude. The spinous and transverse processes serve as outriggers to improve the mechanical advantage of the attached muscles.

The first two cervical vertebrae are specialized in shape and function. The first cervical vertebra, known as the atlas, provides a reciprocally shaped receptacle for the condyles of the occiput of the skull. The atlanto-occipital joint is extremely stable, with flexion/extension of about 14°–15° permitted, but with virtually no motion occurring in any other plane (17). A large range of axial rotation is provided at the next joint between the atlas and the second cervical vertebrae, the axis. Motion at the atlantoaxial joint averages around 75° of rotation, 14° of extension, and 24° of lateral flexion (17).

There is a progressive increase in vertebral size from the cervical region down through the lumbar region (Figure 9-3). The lumbar vertebrae, in particular, are larger and thicker than the vertebrae in the superior regions of the spine. This serves a functional purpose, since when the body is in an upright position each vertebra must support the weight of not only the arms and head but all the trunk positioned above it. The increased surface area of the lumbar vertebrae reduces the amount of stress motion segment

Two adjacent vertebrae and the associated soft tissues, the functional unit of the spine:

- The spine may be viewed as a triangular stack of articulations, with synovial joints between vertebral bodies on the anterior side and two gliding diarthrodial facet joints on the posterior side.

- Although all vertebrae have the same basic shape, there is a progressive superior-inferior increase in the size of the vertebral bodies and a progression in the size and orientation of the articular processes.

- The orientation of the facet joints determines the movement capabilities of the motion segment.
to which these vertebrae would otherwise be subjected. The weight-bearing surface area of the intervertebral disc also increases with the weight supported in all mammals (129).

The size and angulation of the vertebral processes vary throughout the spinal column (Figure 9-4). This changes the orientation of the facet joints, which limit range of motion in the different spinal regions. In addition to channeling the movement of the motion segment, the facet joints assist in load bearing. The facet joints and discs provide about 80% of the spine’s ability to resist rotational torsion and shear, with half of this contribution from the facet joints (43, 61). The facet joints also sustain up to approximately 30% of the compressive loads on the spine, particularly when the spine is in hyperextension (Figure 9-5) (72). Contact forces are largest at the L5-S1 facet joints (77). Recent studies suggest that 15–40% of chronic low back pain emanates from the facet joints (11).

**Intervertebral Discs**

The articulations between adjacent vertebral bodies are symphysis joints with intervening fibrocartilaginous discs that act as cushions. Healthy intervertebral discs in an adult account for approximately one-fourth of the height of the spine. When the trunk is erect, the differences in the anterior and posterior thicknesses of the discs produce the lumbar, thoracic, and cervical curves of the spine.
Approximate orientations of the facet joints. A. Lower cervical spine, with facets oriented 45° to the transverse plane and parallel to the frontal plane. B. Thoracic spine, with facets oriented 60° to the transverse plane and 20° to the frontal plane. C. Lumbar spine, with facets oriented 90° to the transverse plane and 45° to the frontal plane.

Hyperextension of the lumbar spine creates compression at the facet joints.
In the intervertebral disc, the annulus fibrosus, made up of laminar layers of criss-crossed collagen fibers, surrounds the nucleus pulposus.

**annulus fibrosus**
thick, fibrocartilaginous ring that forms the exterior of the intervertebral disc

**nucleus pulposus**
colloidal gel with a high fluid content, located inside the annulus fibrosus of the intervertebral disc

The intervertebral disc incorporates two functional structures: A thick outer ring composed of fibrous cartilage called the annulus fibrosus, or annulus, surrounds a central gelatinous material known as the nucleus pulposus, or nucleus (Figure 9-6). The annulus consists of about 90 concentric bands of collagenous tissue that are bonded together. The collagen fibers of the annulus crisscross vertically at about 30° angles to each other, making the structure more sensitive to rotational strain than to compression, tension, and shear (43). These fibers, which are crucial for the mechanical functioning of the disc, display changes in organization and orientation with loading of the disc, as well as with disc degeneration (64, 90). The nucleus of a young, healthy disc is approximately 90% water, with the remainder being collagen and proteoglycans, specialized materials that chemically attract water (98). The extremely high fluid content of the nucleus makes it resistant to compression.

Mechanically, the annulus acts as a coiled spring whose tension holds the vertebral bodies together against the resistance of the nucleus pulposus, and the nucleus pulposus acts like a ball bearing composed of an incompressible gel (Figure 9-7) (74). During flexion and extension, the vertebral bodies roll over the nucleus while the facet joints guide the movements. As shown in Figure 9-8, spinal flexion, extension, and lateral flexion produce compressive stress on one side of the discs and tensile stress on the other, whereas spinal rotation creates shear stress in the
discs (Figure 9-9) (72). Stress on the discs is significantly higher with flexion as compared to rotation, with bending stress approximately 450 times greater than the twisting stress from the same angle of bending or twisting of the annulus fibers (26). During daily activities, compression is the most common form of loading on the spine.

When a disc is loaded in compression, it tends to simultaneously lose water and absorb sodium and potassium until its internal electrolyte concentration is sufficient to prevent further water loss (70). When this chemical equilibrium is achieved, internal disc pressure is equal to the external pressure (8). Continued loading over a period of several hours results in a further slight decrease in disc hydration (1). For this reason, the spine undergoes a height decrease of up to nearly 2 cm over the course of a day, with approximately 54% of this loss occurring during the first 30 minutes after an individual gets up in the morning (101).

Once pressure on the discs is relieved, the discs quickly reabsorb water, and disc volumes and heights are increased (70). Astronauts experience a temporary increase in spine height of approximately 5 cm while free from the influence of gravity (88). On earth, disc height and volume are typically greatest when a person first arises in the morning. Because increased disc volume also translates to increased spinal stiffness, there appears to be a heightened risk of disc injury early in the morning (38). Measurements of spinal shrinkage following activities performed for one hour immediately after rising in the morning yielded average values of −7.4 mm for standing, −5.0 mm for sitting, −7.9 mm for walking, −3.7 mm for cycling, and +0.4 mm for lying down (121). Body positions that allow rehydration and height increase in the discs are spinal hyperextension in the prone position and trunk flexion in the supine position (93).

The intervertebral discs have a blood supply up to about the age of 8 years, but after that the discs must rely on a mechanically based means...
It is important not to maintain any one body position for too long, since the intervertebral discs rely on body movement to pump nutrients in and waste products out.

Although most of the load sustained by the spine is borne by the symphysis joints, the facet joints may play a role, particularly when the spine is in hyperextension and when disc degeneration has occurred.

The enlarged cervical portion of the supraspinous ligament is the ligamentum nuchae, or ligament of the neck.

FIGURE 9-10
The major ligaments of the spine. (The intertransverse ligament is not visible in this medial section through the spine.)

Ligaments
A number of ligaments support the spine, contributing to the stability of the motion segments (Figure 9-10). The powerful anterior longitudinal ligament and the weaker posterior longitudinal ligament connect the vertebral bodies in the cervical, thoracic, and lumbar regions. The supraspinous

for maintaining a healthy nutritional status. Intermittent changes in posture and body position alter internal disc pressure, causing a pumping action in the disc. The influx and outflux of water transports nutrients in and flushes out metabolic waste products, basically fulfilling the same function that the circulatory system provides for vascularized structures within the body. Maintaining even an extremely comfortable fixed body position over a long period curtails this pumping action and can negatively affect disc health. Research has shown that there is a zone of optimal loading frequency and magnitude that promotes disc health (125).

Injury and aging irreversibly reduce the water-absorbing capacity of the discs, with a concomitant decrease in shock-absorbing capability. Magnetic resonance imaging (MRI) studies show degenerative changes to be the most common at L5-S1, the disc subjected to the most mechanical stress by virtue of its position (104). However, the fluid content of all discs begins to diminish around the second decade of life (8). A typical geriatric disc has a fluid content that is reduced by approximately 35% (128). As this normal degenerative change occurs, abnormal movements occur between adjacent vertebral bodies, and more of the compressive, tensile, and shear loads on the spine must be assumed by other structures—particularly the facets and joint capsules. Results include reduced height of the spinal column, often accompanied by degenerative changes in the spinal structures that are forced to assume the loads of the discs. Postural alterations may also occur. The normal lordotic curve of the lumbar region may be reduced as an individual attempts to relieve compression on the facet joints by maintaining a posture of spinal flexion (128). Factors such as habitual smoking and exposure to vibration can negatively affect disc nutrition, while regular exercise can improve it (98).
ligament attaches to the spinous processes throughout the length of the spine. This ligament is prominently enlarged in the cervical region, where it is referred to as the *ligamentum nuchae*, or ligament of the neck (Figure 9-11). Adjacent vertebrae have additional connections between spinous processes, transverse processes, and laminae, supplied respectively by the interspinous ligaments, the intertransverse ligaments, and the ligamenta flava.

Another major ligament, the *ligamentum flavum*, connects the laminae of adjacent vertebrae. Although most spinal ligaments are composed primarily of collagen fibers that stretch only minimally, the *ligamentum flavum* contains a high proportion of elastic fibers, which lengthen when stretched during spinal flexion and shorten during spinal extension. The *ligamentum flavum* is in tension even when the spine is in anatomical position, enhancing spinal stability. This tension creates a slight, constant compression in the intervertebral discs, referred to as prestress.

**Spinal Curves**

As viewed in the sagittal plane, the spine contains four normal curves. The thoracic and sacral curves, which are concave anteriorly, are present at birth and are referred to as primary curves. The lumbar and cervical curves, which are concave posteriorly, develop from supporting the body in an upright position after young children begin to sit up and stand. Since these curves are not present at birth, they are known as the secondary spinal curves. Although the cervical and thoracic curves change little during the growth years, the curvature of the lumbar spine increases approximately 10% between the ages of 7 and 17 (124). Spinal curvature (posture) is influenced by heredity, pathological conditions, an individual's mental state, and the forces to which the spine is habitually subjected. Mechanically, the curves enable the spine to absorb more shock without injury than if the spine were straight.

As discussed in Chapter 4, bones are constantly modeled or shaped in response to the magnitudes and directions of the forces acting on them. Similarly, the four spinal curves can become distorted when the spine is habitually subjected to asymmetrical forces.
lordosis

*extreme lumbar curvature*

kyphosis

*extreme thoracic curvature*

scoliosis

*lateral spinal curvature*

Exaggeration of the lumbar curve, or lordosis, is often associated with weakened abdominal muscles and anterior pelvic tilt (Figure 9-12). Causes of lordosis include congenital spinal deformity, weakness of the abdominal muscles, poor postural habits, and overtraining in sports requiring repeated lumbar hyperextension, such as gymnastics, figure skating, javelin throwing, and swimming the butterfly stroke. Because lordosis places added compressive stress on the posterior elements of the spine, some have hypothesized that excessive lordosis is a risk factor for low back pain development. Limited range of motion in hip extension is associated with exaggerated lumbar lordosis (45). Obesity causes reduced range of motion of the entire spine and pelvis, and obese individuals resulting display increased anterior pelvic tilt and an associated increased lumbar lordosis (123). Similarly, increased anterior pelvic tilt and increased lordosis are greater during running than during walking (45).

Another abnormality in spinal curvature is kyphosis (exaggerated thoracic curvature) (Figure 9-12). The incidence of kyphosis has been estimated to be as high as 8% in the general population, with equal distribution across genders (2). Kyphosis can result from a congenital abnormality, a pathology such as osteoporosis, or Scheuermann's disease, in which one or more wedge-shaped vertebrae develop because of abnormal epiphyseal plate behavior. Scheuermann's disease typically develops in individuals between the ages of 10 and 16 years, which is the period of most rapid growth of the thoracic spine (35). Both genetic and biomechanical factors are believed to play a role (7). The condition has been called swimmer's back because it is frequently seen in adolescents who have trained heavily with the butterfly stroke (119). Scheuermann's disease is not limited to swimmers, however, with research showing a strong association between incidence of this pathology and cumulative training time in any sport (130). Treatment for mild cases may consist of exercises to strengthen the posterior thoracic muscles, although bracing or surgical corrections are used in more severe cases. Kyphosis also often develops in elderly women with osteoporosis, as discussed in Chapter 4. Both the thoracic vertebrae and the intervertebral discs in the region develop a characteristic wedge shape (110).

Lateral deviation or deviations in spinal curvature are referred to as scoliosis (Figure 9-12). The lateral deformity is coupled with rotational deformity of the involved vertebrae, with the condition ranging from mild

**FIGURE 9-12**

Abnormal spinal curvatures.
to severe. Scoliosis may appear as either a C- or an S-curve involving the thoracic spine, the lumbar spine, or both.

A distinction is made between structural and nonstructural scoliosis. Structural scoliosis involves inflexible curvature that persists even with lateral bending of the spine. Nonstructural scoliotic curves are flexible and are corrected with lateral bending.

Scoliosis results from a variety of causes. Congenital abnormalities and selected cancers can contribute to the development of structural scoliosis. Nonstructural scoliosis may occur secondary to a leg length discrepancy or local inflammation. Small lateral deviations in spinal curvature are relatively common and may result from a habit such as carrying books or a heavy purse on one side of the body every day. Approximately 70–90% of all scoliosis, however, is termed idiopathic, which means that the cause is unknown (133). Idiopathic scoliosis is most commonly diagnosed in children between the ages of 10 and 13 years, but can be seen at any age. It is present in 2–4% of children between 10 and 16 years of age and is more common in females (100). Low bone mineral density is typically associated with idiopathic scoliosis and may play a causative role in its development (28).

Symptoms associated with scoliosis vary with the severity of the condition. Mild cases may be asymptomatic and may self-correct with time. A growing body of evidence supports the effectiveness of appropriate stretching and strengthening exercises for resolving the symptoms and appearance of mild to moderate scoliosis (133). Severe scoliosis, however, which is characterized by extreme lateral deviation and localized rotation of the spine, can be painful and deforming, and is treated with bracing and/or surgery. As is the case with kyphosis, both the vertebrae and the intervertebral discs in the affected region(s) assume a wedge shape (114).

MOVEMENTS OF THE SPINE

As a unit, the spine allows motion in all three planes of movement, as well as circumduction. Because the motion allowed between any two adjacent vertebrae is small, however, spinal movements always involve a number of motion segments. The range of motion (ROM) allowed at each motion segment is governed by anatomical constraints that vary through the cervical, thoracic, and lumbar regions of the spine.

Female gymnasts undergo extreme lumbar hyperextension during many commonly performed skills. Photo courtesy of Royalty-Free/Corbis.
Flexion, Extension, and Hyperextension

The ROM for flexion/extension of the motion segments is considerable in the cervical and lumbar regions, with representative values as high as 17° at the C5-C6 vertebral joint and 20° at L5-S1. In the thoracic spine, however, due to the orientation of the facets, the ROM increases from only approximately 4° at T1-T2 to approximately 10° at T11-T12 (127).

It is important not to confuse spinal flexion with hip flexion or anterior pelvic tilt, although all three motions occur during an activity such as touching the toes (Figure 9-13). Hip flexion consists of anteriorly directed sagittal plane rotation of the femur with respect to the pelvic girdle (or vice versa), and anterior pelvic tilt is anteriorly directed movement of the anterior superior iliac spine with respect to the pubic symphysis, as discussed in Chapter 8. Just as anterior pelvic tilt facilitates hip flexion, it also promotes spinal flexion.

Extension of the spine backward past anatomical position is termed hyperextension. The ROM for spinal hyperextension is considerable in the cervical and lumbar regions. Lumbar hyperextension is required in the execution of many sport skills, including several swimming strokes, the high jump and pole vault, and numerous gymnastic skills. For example, during the execution of a back handspring, the curvature normally present in the lower lumbar region may increase twentyfold (53).

Lateral Flexion and Rotation

Frontal plane movement of the spine away from anatomical position is termed lateral flexion. The largest ROM for lateral flexion occurs in the cervical region, with approximately 9–10° of motion allowed at C4-C5. Somewhat less lateral flexion is allowed in the thoracic region, where the ROM between adjacent vertebrae is about 6°, except in the lower segments, where lateral flexion capability may be as high as approximately 8–9°. Lateral flexion in the lumbar spine is also on the order of 6°, except at L5-S1, where it is reduced to only about 3° (127).

Spinal rotation in the transverse plane is again freest in the cervical region of the spine, with up to 12° of motion allowed at C1-C2. It is next freest in the thoracic region, where approximately 9° of rotation is permitted among the upper motion segments. From T7-T8 downward, the range of rotational capability progressively decreases, with only about 2° of motion allowed in the lumbar spine due to the interlocking of the articular
processes there. At the lumbosacral joint, however, rotation on the order of 5° is allowed (127). Since the structure of the spine causes lateral flexion and rotation to be coupled, rotation is accompanied by slight lateral flexion to the same side, although this motion is not observable with the naked eye.

Studies of activities of daily living have quantified ROMs in the cervical and lumbar regions of the spine. Among these activities, backing up a car was found to require the most motion in the cervical region, with approximately 32% of sagittal, 26% of lateral, and 92% of rotational motion capability involved (13). Similarly, the task requiring the greatest lumbar motion was picking up an object from the floor (14). ROM in the cervical spine has been found to decrease linearly with increasing age, with a loss in passive range of motion of about 0.5 degrees per year (103).

**MUSCLES OF THE SPINE**

The muscles of the neck and trunk are named in pairs, with one on the left and the other on the right side of the body. These muscles can cause lateral flexion and/or rotation of the trunk when they act unilaterally, and trunk flexion or extension when acting bilaterally. The primary functions of the major muscles of the spine are summarized in Table 9-1.

**Anterior Aspect**

The major anterior muscle groups of the cervical region are the prevertebral muscles, including the rectus capitis anterior, rectus capitis lateralis, longus capitis, and longus colli, and the eight pairs of hyoid muscles (Figures 9-14 and 9-15). Bilateral tension development by these muscles results in flexion of the head, although the main function of the hyoid muscles appears to be to move the hyoid bone during the act of swallowing. Unilateral tension development in the prevertebrals contributes to lateral flexion of the head toward the contracting muscles or to rotation of the head away from the contracting muscles, depending on which other muscles are functioning as neutralizers.

![Figure 9-14](image-url)  
*Anterior muscles of the cervical region.*
<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>PROXIMAL ATTACHMENT</th>
<th>DISTAL ATTACHMENT</th>
<th>PRIMARY ACTION(S) ABOUT THE HIP</th>
<th>INNERVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevertebral muscles (rectus capitis anterior, rectus capitis lateralis, longus capitis, longus coli)</td>
<td>Anterior aspect of occipital bone and cervical vertebrae</td>
<td>Anterior surfaces of cervical and first three thoracic vertebrae</td>
<td>Flexion, lateral flexion, rotation to opposite side</td>
<td>Cervical nerves (C1–C4)</td>
</tr>
<tr>
<td>Rectus abdominis</td>
<td>Costal cartilage of ribs 5–7</td>
<td>Pubic crest</td>
<td>Flexion, lateral flexion</td>
<td>Intercostal nerves (T5–T12)</td>
</tr>
<tr>
<td>External oblique</td>
<td>External surface of lower eight ribs</td>
<td>Linea alba and anterior iliac crest</td>
<td>Flexion, lateral flexion, rotation to opposite side</td>
<td>Intercostal nerves (T5–T12)</td>
</tr>
<tr>
<td>Internal oblique</td>
<td>Linea alba and lower four ribs</td>
<td>Inguinal ligament, iliac crest, lumbo dorsal fascia</td>
<td>Flexion, lateral flexion, rotation to same side</td>
<td>Intercostal nerves (T5–T12)</td>
</tr>
<tr>
<td>Splenius (capitis and cervicis)</td>
<td>Mastoid process of temporal bone, transverse processes of first three cervical vertebrae</td>
<td>Lower half of ligamentum nuchae, spinous processes of seventh cervical and upper six thoracic vertebrae</td>
<td>Extension, lateral flexion, rotation to same side</td>
<td>Middle and lower cervical nerves (C4–C7)</td>
</tr>
<tr>
<td>Suboccipitals (obliquus capitis superior and inferior, rectus capitis posterior major and minor)</td>
<td>Occipital bone, transverse process of first cervical vertebrae</td>
<td>Posterior surfaces of first two cervical vertebrae</td>
<td>Extension, lateral flexion, rotation to same side</td>
<td>Suboccipital nerve (C1)</td>
</tr>
<tr>
<td>Erector spinae (spinalis, longissimus, iliocostalis)</td>
<td>Lower part of ligamentum nuchae, posterior cervical, thoracic, and lumbar spine, lower nine ribs, iliac crest, posterior sacrum</td>
<td>Mastoid process of temporal bone, posterior cervical, thoracic, and lumbar spine, twelve ribs</td>
<td>Extension, lateral flexion, rotation to opposite side</td>
<td>Spinal nerves (T1–T12)</td>
</tr>
<tr>
<td>Semispinales (capitis, cervicis, thoracis)</td>
<td>Occipital bone, spinous processes of thoracic vertebrae 2–4</td>
<td>Transverse layers of thoracic vertebrae</td>
<td>Extension, lateral flexion, rotation to opposite side</td>
<td>Cervical and thoracic spinal nerves (C1–T12)</td>
</tr>
<tr>
<td>Deep spinal muscles (multifidi, rotatores, interspinales, intertransversarii, levatores costarum)</td>
<td>Posterior processes of all vertebrae, posterior sacrum</td>
<td>Spinal processes and transverse processes of vertebrae below those of proximal attachment</td>
<td>Extension, lateral flexion, rotation to opposite side</td>
<td>Spinal and intercostal nerves (T1–T12)</td>
</tr>
<tr>
<td>Sternocleidomastoid</td>
<td>Mastoid process of temporal bone</td>
<td>Superior sternum, inner third of clavicle</td>
<td>Flexion of neck, extension of head, lateral flexion, rotation to opposite side</td>
<td>Accessory nerve and C2 spinal nerve</td>
</tr>
<tr>
<td>Levator scapulae</td>
<td>Transverse processes of first four cervical vertebrae</td>
<td>Vertebral border of scapula</td>
<td>Lateral flexion</td>
<td>Spinal nerves (C1–C4), dorsal scapular nerve (C1–C4)</td>
</tr>
<tr>
<td>Scaleni (scaleni anterior, medius, posterior)</td>
<td>Transverse processes of cervical vertebrae</td>
<td>Upper two ribs</td>
<td>Flexion, lateral flexion</td>
<td>Cervical nerves (C1–C4)</td>
</tr>
<tr>
<td>Quadratus lumborum</td>
<td>Last rib, transverse processes of first four lumbar vertebrae</td>
<td>Iliolumbar ligament, adjacent iliac crest</td>
<td>Lateral flexion</td>
<td>Spinal nerves (T11–L4)</td>
</tr>
<tr>
<td>Psoas major</td>
<td>Sides of twelfth thoracic and all lumbar vertebrae</td>
<td>Lesser trochanter of the femur</td>
<td>Flexion</td>
<td>Femoral nerve (L1–L4)</td>
</tr>
</tbody>
</table>
The main abdominal muscles are the rectus abdominis, the external obliques, and the internal obliques (Figures 9-16, 9-17, and 9-18). Functioning bilaterally, these muscles are the major spinal flexors and also reduce anterior pelvic tilt. Unilateral tension development by the muscles produces lateral flexion of the spine toward the tensed muscles. Tension development in the internal obliques causes rotation of the spine toward the same side. Tension development by the external obliques results in rotation toward the opposite side. If the spine is fixed, the internal obliques produce pelvic rotation toward the opposite side, with the external obliques producing rotation of the pelvis toward the same side. These muscles also form the major part of the abdominal wall, which protects the internal organs of the abdomen.
Posterior Aspect

The splenius capitis and splenius cervicis are the primary cervical extensors (Figure 9-19) (89). Bilateral tension development in the four suboccipitals—the rectus capitis posterior major and minor and the obliquus capitis superior and inferior—assist (Figure 9-20). When these posterior cervical muscles develop tension on one side only, they laterally flex or rotate the head toward the side of the contracting muscles.

The posterior thoracic and lumbar region muscle groups are the massive erector spinae (sacrospinalis), the semispinalis, and the deep spinal muscles. As shown in Figure 9-21, the erector spinae group includes the spinalis, longissimus, and iliocostalis muscles. The semispinalis, with its capitis, cervicis, and thoracis branches, is shown in Figure 9-22. The deep spinal muscles, including the multifidi, rotatores, interspinales, intertransversarii,
**FIGURE 9-19**
The major cervical extensors.

**FIGURE 9-20**
The suboccipital muscles.

**FIGURE 9-21**
The erector spinae group.
The prominent erector spinae muscle group—the major extensor and hyperextensor of the trunk—is the muscle group of the trunk most often strained. 

and levatores costarum, are represented in Figure 9-23. The muscles of the erector spinae group are the major extensors and hyperextensors of the trunk. All posterior trunk muscles contribute to extension and hyperextension when contracting bilaterally and to lateral flexion when contracting unilaterally.

Lateral Aspect

Muscles on the lateral aspect of the neck include the prominent sternocleidomastoid, the levator scapulae, and the scalenus anterior, posterior,
and medius (Figures 9-24, 9-25, and 9-26). Bilateral tension development in the sternocleidomastoid may result in either flexion of the neck or extension of the head, with unilateral contraction producing lateral flexion to the same side or rotation to the opposite side. The levator scapulae can also contribute to lateral flexion of the neck when contracting unilaterally with the scapula stabilized. The three scalenes assist with flexion and lateral flexion of the neck, depending on whether tension development is bilateral or unilateral.

In the lumbar region, the quadratus lumborum and psoas major are large, laterally oriented muscles (Figures 9-27 and 9-28). These muscles function bilaterally to flex and unilaterally to laterally flex the lumbar spine.

- Many muscles of the neck and trunk cause lateral flexion when contracting unilaterally but either flexion or extension when contracting bilaterally.