The Anatomy of the Lumbar Vertebral Column

The lumbar portion of the vertebral column has an ideal structure aiming at maintaining stability and mobility. This region has a solid structure designed to carry the weights of the head, the neck, the trunk and the extremities. The pains associated with this region are very common complaints affecting 80% of the population at least one time during their lifetimes.¹

The functional unit of the backbone is the smallest segment that provides for all the mechanical features of the vertebral column. Functional spinal unit consists of two neighboring vertebrae, between them lies the intervertebral disc to the anterior and bilateral facet joints to the posterior forming a triple joint complex.² Functional spinal unit has two segments: the anterior (static) and the posterior (dynamic). The anterior segment consisting of the two neighboring vertebral bodies and the intervertebral discs between them has the responsibility to bear weight and to give flexibility to the vertebral column. The posterior segment protects the neural structures and controls the movements of the lumbar region.²³

Lumbar spine has 3 basic biomechanical functions.⁴⁵
1. Transfers any external load carried by the head and the upper part of the trunk and any related bending momentums to the pelvis.
2. It allows for movements between the head, the trunk and the pelvis.
3. Maintains the integrity of the spinal cord and prevents any forces or movements that might cause damage.

The Lumbar Vertebra

The lumbar vertebral column has five active vertebrae. The sizes of these vertebrae increase as we proceed distally. The lumbar vertebra constitutes 25% of the whole backbone length. When approached from the lateral, it has an angulation with a posterior concavity called the lumbar lordosis.² Most of the bone structures contained in the lumbar vertebrae are cancellous bones creating vulnerability for collapses due to trauma or osteoporosis. Thin but dense cortical bone usually proliferates around ligament attachment sites forming osteophytes as a result of aging. Neural arch consists of pedicles, superior and inferior facet joints and laminas. The localization of facet joints change based on the level of the vertebra. At the midthoracic region, they are located on the frontal plane whereas at the lumbar region they are on the sagittal plane. This allows for anteroposterior sliding of the facet joints thereby increasing the flexion and the extension capacity of the lower lumbar region. The superior facet joint is smaller than the inferior. It has a concave cartilaginous articular surface and it forms the ceiling of the lateral recess. This is where the nerve root leaves the central canal and enters the neural foramen. The pedicles form the base and the ceiling of the neural foramen. The laminae complete the neural arch from the posterior. This part protects the neural structures and is the site for the attachment of paraspinous muscles. Laminae have very limited contributions on the spinal stability. If they are affected by fractures or removed during surgery (laminectomy), this does not lead to any spinal instability. The pedicle and the facet carry only 20% of any vertical load.
The remaining 80% of this load is absorbed by the intervertebral discs.

The bodies of the lumbar vertebrae are typically wide and in the form of a kidney, the pedicles are inclined to the posterior, the laminae are thick, the vertebral foramina have triangular shapes, the transverse processes are thin and long, the spinous processes are short and wide extending to the posterior. Upper joint surfaces face the anterior, inferior joint surfaces face the lateral. The joints surfaces of the lumbar vertebra for the costae and the associated transverse processes do not have foramina.

**Intervertebral Discs**

The intervertebral discs are the remnants of the notochord and are found between the vertebral bodies consisting of fibrocartilagenous structures. They are thicker at areas where the vertebral column is more mobile like the cervical and the lumbar regions.

Nucleus pulposus is an ovoid structure having yellowish color and it consists of gelatinous mucoprotein. A fibrous structure called annulus fibrosus made up of collagen fibrils surround and strengthen the nucleus. Collagen bands extend in an oblique manner between the neighboring vertebral bodies. The inclinations of the fibers are opposite to each other on the neighboring lamellae. The fibers at the periphery attach tightly to the anterior and the posterior longitudinal ligaments of the spinal column.

Lumbar disc structures are thinner on the anterior contributing to the formation of the lumbar lordosis. In early decades of life, we see the entry and exit of thin blood vessels into the discs. In the coming three decades, these vascular structures obliterate. Following this event, the nutrition of the disc is maintained only by the lymphatics and the osmosis of the extracellular fluid. In young individuals, the water content of the disc is around 80-90%, with aging this decreases down to 65% and water is replaced by fibrous cartilage. Intervertebral discs are shock absorbers for the vertebrae and they constitute 20-25% of its length in young individuals; together with the decrease in water content due to aging, this percentage decreases as well. Aging also damages the collagen fibers of the annulus and the nucleus pulposus that is under pressure can no longer be protected. The discs get thinner as we age, their flexibility is decreased and it becomes difficult to distinguish the annulus from the nucleus.

**Ligaments**

The ligaments of the lumbar region resist to stretching and tensile forces. Their main responsibility is to prevent any excessive movement and to maintain stability. Furthermore, the capsule and the ligaments contain proprioceptive sensory receptors that are associated with the movement. Except for ligamentum flavum, most ligaments consist of collagen fibers. Ligamentum flavum on the other hand has high percentage of elastic fibers.

**PLL** extends from the skull to the sacrum on the anterior surface of the vertebral column like a continuous band; it attaches tightly to the lateral sides of the anterior surfaces of the vertebral bodies and has a wide surface. ALL is responsible for limiting the extension. As it has nociceptive and proprioceptive innervation, if extension injuries cause damage to the ALL, pain ensues. It is the most important ligament for the stabilization of the lumbar vertebra.

PLL is wider in the upper lumbar region while getting narrower and weaker in the lower lumbar region; at L5-S1 space, its thickness decreases by 50%. This ligament extends on the posterior surface of the vertebral column from the skull to the sacrum like a band and attaches to the posterior sides of the discs. It has two layers as the superficial and the deep. Superficial fibers are like bands on the midline. Deep fibers are shorter and they extend to the lateral part of the annulus fibrosus fibers of the intervertebral disc by getting wider. PLL receives its sensory innervation from the recurrent meningeal nerve. Neurotransmitters like substance P and neoromodulators like encephalins are contained within the terminal fibers of the sinovertebral nerve innervating PLL and they render PLL quite sensitive to pain.

Ligamentum flavum extends from the anterior inferior portion of an upper vertebral lamina to the posterior superior portion of a lower vertebral lamina. It is bilaterally located. It covers the posterior part of the vertebral canal. Its thickness increases as we proceed from cervical to lumbar. During anterior flexion and erect posture it protects the posterior elements and maintains stability. During the flexion of the vertebral column it prevents the vertebral bodies from separating from each other, its length increases during flexion and shortens during extension.

**Supraspinous ligament** covers the surfaces of the spinous processes. It is the only segmental ligament
pertaining to the posterior column. Its function is to prevent extreme flexion. It generally ends at the level of L4. This ligament is then replaced by erector spina and thoracolumbar fascia.

*Interspinous ligament* lies between the two spinous processes. It consists of anterior, middle and posterior portions. This ligament also prevents the extreme flexion of the spinal column. Its sensory innervation is through mechanoreceptors and nociceptive nerve endings; that is why it causes back pain when injured.

*Intertransverse ligament* extends in between the transverse processes of neighboring vertebrae. It controls the lateral flexion.

*Capsular ligament* consists of fibers that are perpendicular to the sides of the facet joint processes and the joint surface. It is shorter and tighter in the thoracic and lumbar regions. It allows the facets to slide during all the movements of the spine.

*Iliolumbar ligament* extends from the tip of the transverse processes of the right and the left L5 vertebrae to the iliac crest. It stabilizes the pelvis on the lumbosacral spine.

**Muscles**

**Muscles Originating from the Lumbar Vertebra**

These are the most important elements of the dynamic stability of the vertebral column and its movement control. Anatomically they can be divided into two as the anterior and the posterior.

* Superficial posterior muscles

They are collectively called as erector spina. They originate from the last two thoracic vertebrae, all the lumbar vertebrae, the sacrum, the sacroiliac ligament and the medial portion of the iliac crest; they extend upwards and divide into three columns under the 12th costa. (Figures 1 and 2)

*Iliocostalis (lateral band)* attaches to costal angles and extends to the level of C4-C6. It has lumbarum, thoracis and cervicis portions.

*Longissimus (intermedial band)* is placed in the middle. It has thoracis, cervicis and capitis portions. Extending upwards from T1, it attaches to the transverse processes of all the vertebrae.

*Spinalis (medial band)* is the most inwardly located. While its medial border attaches to the posterior processes of the thoracic vertebrae, its lateral border is free.

* Deep posterior muscles

These muscles are shorter and are involved in the axial rotation of the vertebra.

*Multifidus* generates form the multipennate muscle series that covers the laminae of the vertebral column between C2-L5. Three to four fascicles attach

![Figure 1: Erector spinales muscles (1)](The figure is obtained from reference number 17)
to each spinous process, the other ends of the fascicles attach to the articular process at the cervical level, to the transverse process at the thoracic level and to the mamillary process and the posterior portion of the sacrum at the lumbar level.\textsuperscript{15}

Rotators lie under the multifidus muscle and are found only in the thoracic region. There are twelve of these on each side. The first one is in between the first and the second vertebra, while the last one is between the eleventh and the twelfth. It extends from the transverse process of one vertebra to the spinous process of the neighboring vertebra.\textsuperscript{5,14}

Interspinalis has short muscle fascicles. They extend in between the spinous processes of consecutive lumbar vertebrae. There are usually four pairs within the five lumbar vertebrae. Rarely there can be one more pair between the last thoracic vertebra and the first lumbar vertebra or between the fifth lumbar vertebra and the sacrum.\textsuperscript{14}

Intertransversaris is the small muscle group extending between the transverse processes of the vertebrae. In the lumbar region we see them as one pair on each side of the vertebral column.\textsuperscript{14}

Anterior muscles of the lumbar vertebra are psoas and quadratus lumborum.

Iliopsoas; psoas major is a long and fusiform muscle; it starts from the lumbar portion of the vertebral column. It extends downwards and from underneath the inguinal ligament it passes through the anterior portion of the hip joint capsule and attaches to the minor tubercle of the femur. Iliacus is a muscle having a triangular shape and it fills the iliac fossa.\textsuperscript{16,17}

Quadratus lumborum is located behind the abdominal cavity and next to the lumbar spine. It extends from the iliac crest to the lower lumbar vertebra.\textsuperscript{16,17}

Abdominal muscles

The superficial layer consists of rectus abdominis and external oblique muscles, while the deep layer harbors internal oblique and transversus abdominis muscles.\textsuperscript{13}

Rectus abdominis is a long and smooth muscle extending alongside the abdominal wall. Linea alba divides it into two parts as the right and the left. The lateral border of the rectus abdominis can be seen as the external surface of the abdominal wall.
and is called as linea semilunaris. This muscle attaches to the pubic crest inferiorly and to the fifth and seventh costal cartilages and the xiphoid process superiorly.18

External oblique is the most superficial and the widest of all the muscles. Its muscular layer starts with the outer surfaces of the lower eight costae. It extends by opening like a fan and attaches to the xiphoid process, linea alba, pubic tubercle and the anterior half of the iliac crest. Most of the fibers end with a large aponeurosis. The lower end of the aponeurosis that is between the superior iliac spine and the pubic tubercle folds on itself to form the inguinal ligament.18

Internal oblique is a wide and thin muscular layer located underneath the external oblique muscle with fibers extending in a direction perpendicular to those of the external oblique muscle. It starts at the thoracolumbar fascia, 2/3 anterior portion of the iliac crest and 2/3 lateral part of the inguinal ligament. The fibers extend upwards and to the anterior. It attaches to the lower borders of the last three costae and their cartilage parts, the xiphoid process, linea alba and the pubic symphysis.14,18

Transversus abdominis lies underneath the internal oblique muscle. It is a thin muscle with a horizontal course. It starts from the inner surfaces of the last six cartilage vertebrae, 2/3 anterior surface of the iliac crest and 1/3 outer surface of the inguinal ligament. It attaches to the xiphoid process, linea alba and the pubic symphysis. The lower tendinous fibers mingle with the similar fibers of the internal oblique muscle and form the conjunctivus tendon that attaches to the pubic crista and linea pectinea.14,18

The functions of the lumbar region muscles and their innervations are shown on table 1.

Thoracolumbar Fascia

As the thoracolumbar fascia is attached to transversus abdominis and internal abdominal muscles, it acts like an abdominal and lumbar belt.13 The thoracolumbar fascia consists of 3 layers. Its anterior and middle layers cover the psoas and quadratus lumborum muscles. The posterior layer is the one with critical functions. This layer covers the erector spina and multifidus and joins with the middle layer alongside the lateral border of the erector spina.15

Posterior layer consists of the tendon of the latisimus dorsi aponeurosis. These tendons cover the ipsilateral lumbar muscles and on the midline they approach the lumbar and sacral spinous processes whereby meeting with the fibers coming from the opposite side. This layer is not only a retinaculum of lumbar muscles but also an extension of the posterior ligament of the lumbar spine due to its attachment.15

The part called the core originates from the thoracolumbar fascia namely “the lumbar belt of creation”. This fascia covers the body like a rim and creates a connection between the upper and the lower body. When it contracts together with the muscle groups the thoracolumbar fascia acts as a proprioceptor providing information about the position of the body.19

Core muscles consist of two different types of muscle fibers: slow and fast twitching fibers. Slow twitching fibers are found in the deep layer muscles and they belong to the local muscle system. They are short and they control the intersegmental movements, they respond to the changes in posture and extrinsic loading. The muscles included in this group are lumbar multifidus muscles, internal oblique muscle, transversus abdominis, intertransversaris, interspinalis and posterior fibers of the psoas. The posterior portion of the longissimus attach to the lumbar vertebra and due to its certain features, it is regarded as a member of the local muscles. Fast twitching fibers belong to the global system muscles that lie superficially. These muscles are rectus abdominis, external oblique muscle, and erector spina and quadratus lumborum. By forming a long momentum arm it contributes to the torque and movements of the vertebral column.19,20

Abdominal muscles are vital components of the core structure. Transversus abdominis is of utmost importance because of its stabilizing effect. Except for its lower fibers it follows a horizontal course and forms a belt around the abdomen. The rim structure formed by the internal oblique and the transversus abdominis muscles through thoracolumbar fascia plays a role in increasing the intraabdominal pressure.19,20 The most superficial and the most oblique muscle is the external oblique and it is influential in the control of the pelvic tilt.20 The superficial components of the multifidus muscles take part in rotation and the control of lumbar lordosis whereas
the deep ones control the movements performed by other spinal muscles via their limited momentum arms. Transversus abdominis and multifidus muscles are shown to contract 30 ms before the shoulder movements and 110 ms before the leg movements in healthy individuals. In individuals suffering from back pain, the movements in these muscles were shown to have delays before the extremity movements. 16-21

The functions and innervations of lumbar region muscles are shown on tables 1 and figure 3.

The Innervation of the Lumbar Region

Conus medullaris ends at the level of L2 vertebra. It continues as the cauda equina in the lower segments. Cauda equina consists of anterior and posterior roots that come together at the neural foramen to form the spinal nerves. 13 After separating from the spinal cord, the anterior and the posterior roots join within the neural foramen and form the mixed spinal nerve. Spinal nerve divides into anterior and posterior branches. The primary anterior branch comes together with other anterior branches to form the lumbar and sacralplexuses. The primary posterior branches of the spinal nerves distribute into the posterior elements of the vertebral column and the postvertebral muscles. The medial branch provides for the motor innervation of the multifidus muscle after performing the sensory innervation of the facet joint. For example, the medial branch of the L3 primary posterior nerve first innervates the multifidus that attaches to the spinous process and then it continues to innervate the rotator and interspinalis muscles; this is followed by the sensory innervations of the interspinous ligament, the supraspinous ligament, ligamentum flavum, posterior part of the spinous process and the periosteum of the posterior arch. Because of this course, it makes anatomizes with the medial branches of the neighboring level nerves and sends an inferior branch to the lower facet joint and an ascending branch to the upper facet joint. That is why the facet joint is innervated by the medial branches of three primary posterior branches. 1,15 The lateral branch innervates the erecter spina muscle. 1

A branch coming out of the mixed spinal nerves within the intervertebral foramen combines with a sympathetic branch coming out of the deep ones control the movements performed by other spinal muscles via their limited momentum arms. Transversus abdominis and multifidus muscles are shown to contract 30 ms before the shoulder movements and 110 ms before the leg movements in healthy individuals. In individuals suffering from back pain, the movements in these muscles were shown to have delays before the extremity movements. 16-21

The functions and innervations of lumbar region muscles are shown on tables 1 and figure 3.

The Innervation of the Lumbar Region

Conus medullaris ends at the level of L2 vertebra. It continues as the cauda equina in the lower segments. Cauda equina consists of anterior and posterior roots that come together at the neural foramen to form the spinal nerves. 13 After separating from the spinal cord, the anterior and the posterior roots join within the neural foramen and form the mixed spinal nerve. Spinal nerve divides into anterior and posterior branches. The primary anterior branch comes together with other anterior branches to form the lumbar and sacralplexuses. The primary posterior branches of the spinal nerves distribute into the posterior elements of the vertebral column and the postvertebral muscles. The medial branch provides for the motor innervation of the multifidus muscle after performing the sensory innervation of the facet joint. For example, the medial branch of the L3 primary posterior nerve first innervates the multifidus that attaches to the spinous process and then it continues to innervate the rotator and interspinalis muscles; this is followed by the sensory innervations of the interspinous ligament, the supraspinous ligament, ligamentum flavum, posterior part of the spinous process and the periosteum of the posterior arch. Because of this course, it makes anatomizes with the medial branches of the neighboring level nerves and sends an inferior branch to the lower facet joint and an ascending branch to the upper facet joint. That is why the facet joint is innervated by the medial branches of three primary posterior branches. 1,15 The lateral branch innervates the erecter spina muscle. 1

A branch coming out of the mixed spinal nerves within the intervertebral foramen combines with a sympathetic branch coming out of

<table>
<thead>
<tr>
<th>Movement</th>
<th>Muscle</th>
<th>Nerve root innervation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior flexion</td>
<td>1. Psoas major</td>
<td>L1-L3</td>
</tr>
<tr>
<td></td>
<td>2. Rectus abdominis</td>
<td>T6-T12</td>
</tr>
<tr>
<td></td>
<td>3. External abdominal oblique</td>
<td>T7-T12</td>
</tr>
<tr>
<td></td>
<td>4. Internal abdominal oblique</td>
<td>T7-T12, L1</td>
</tr>
<tr>
<td></td>
<td>5. Transversus abdominis</td>
<td>T7-T12, L1</td>
</tr>
<tr>
<td></td>
<td>6. Intertransversarisl</td>
<td>L1-L5</td>
</tr>
<tr>
<td>Extension</td>
<td>1. Latissimus dorsi</td>
<td>Thoracodorsal (C6-C8)</td>
</tr>
<tr>
<td></td>
<td>2. Erector spina</td>
<td>L1-L3</td>
</tr>
<tr>
<td></td>
<td>iliocostalis</td>
<td>L1-L3</td>
</tr>
<tr>
<td></td>
<td>lumborum</td>
<td>L1-L3</td>
</tr>
<tr>
<td></td>
<td>longissimus</td>
<td>L1-L5</td>
</tr>
<tr>
<td></td>
<td>thoracis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Transversospinalis</td>
<td>L1-L5</td>
</tr>
<tr>
<td></td>
<td>4. Interspinalis</td>
<td>L1-L5</td>
</tr>
<tr>
<td></td>
<td>5. Quadratus lumborum</td>
<td>T12, L1-L4</td>
</tr>
<tr>
<td></td>
<td>6. Multifidus</td>
<td>L1-L5</td>
</tr>
<tr>
<td></td>
<td>7. Rotators</td>
<td>L1-L5</td>
</tr>
<tr>
<td></td>
<td>8. Gluteus maximus</td>
<td>L1-L5</td>
</tr>
<tr>
<td>Lateral flexion</td>
<td>1. Latissimus dorsi</td>
<td>Thoracodorsalis (C6-C8)</td>
</tr>
<tr>
<td></td>
<td>iliocostalis</td>
<td>L1-L3</td>
</tr>
<tr>
<td></td>
<td>lumborum</td>
<td>L1-L3</td>
</tr>
<tr>
<td></td>
<td>longissimus</td>
<td>L1-L5</td>
</tr>
<tr>
<td></td>
<td>thoracis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Transversalis</td>
<td>L1-L5</td>
</tr>
<tr>
<td></td>
<td>4. Intertransversarisl</td>
<td>L1-L5</td>
</tr>
<tr>
<td></td>
<td>5. Quadratus lumborum</td>
<td>T12, L1-L4</td>
</tr>
<tr>
<td></td>
<td>6. Psoas major</td>
<td>L1-L3</td>
</tr>
<tr>
<td></td>
<td>7. External abdominal oblique</td>
<td>T7-T12</td>
</tr>
<tr>
<td>Rotation</td>
<td>1. Transversalis</td>
<td>L1-L5</td>
</tr>
<tr>
<td></td>
<td>2. Rotators</td>
<td>L1-L5</td>
</tr>
<tr>
<td></td>
<td>3. Multifidus</td>
<td>L1-L5</td>
</tr>
</tbody>
</table>

Table 1: The movements of the lumbar vertebral column muscles and their innervations
The role of the muscles in functional stability of the lumbar spine

The Blood Supply of the Lumbar Region

Arteries originating from the aorta supply the blood to the first four lumbar vertebrae, while the blood supplies of the fifth lumbar vertebra; the sacrum and the coccyx come from the small segmentary arteries originating from the medial sacral artery.

The venous blood coming out of the last plaques drains into the internal vertebral plexus found in between the duramater and the vertebrae. Internal venous plexus makes an anastomosis with the external venous plexus. These plexuses do not have valve systems. Plexuses drain into the intervertebral veins and these drain into the vena cava. The absence of a valve system provides for the close relationship in the venous circulation between the pelvis and the lumbosacral region thereby easing the metastases to the lumbosacral region from the pelvic region.
References


