**Biomechanics of Joints and Orthopaedic Implants**
**Professor Sanjay Gupta**
**Department of Mechanical Engineering**
**Indian Institute of Technology, Kharagpur**
**Lecture: 07**
**The Spine**

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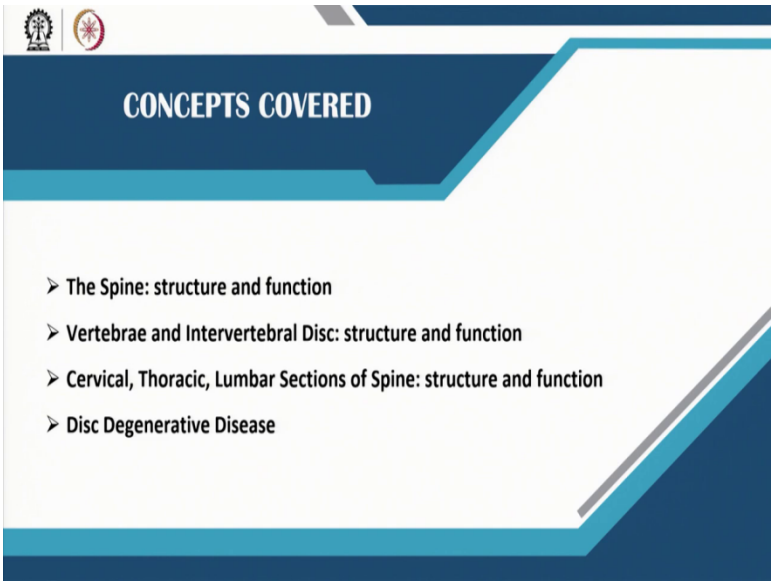


Good morning everybody. Welcome to the lecture on spine. This lecture will cover the following topics: the spine - structure and function, vertebrae and intervertebral disc - structure and

function. The cervical, thoracic, and lumbar spines will be discussed with regard to their structure and function. And the final topic would be the disc degenerative disease of the spine.

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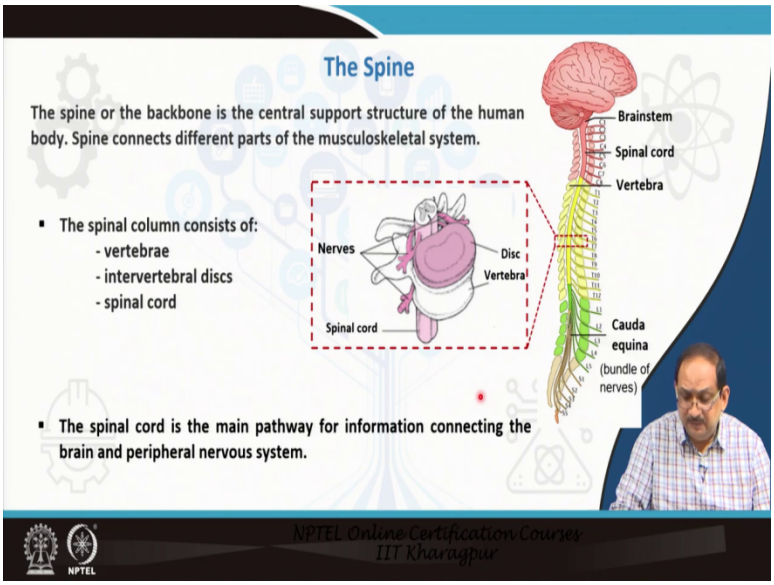


The spine or the backbone is the central support structure of the human body. The spine connects different parts of the musculoskeletal system. The spinal column consists of the vertebrae, the intervertebral discs, and the spinal cord. The vertebral column surrounds the spinal cord, which travels within the spinal canal formed from a central hole in each vertebra. The spinal cord is the main pathway of information connecting the brain and the peripheral nervous system. The spinal cord is part of the central nervous system that supplies nerves and receives information from the peripheral nervous system within the body.

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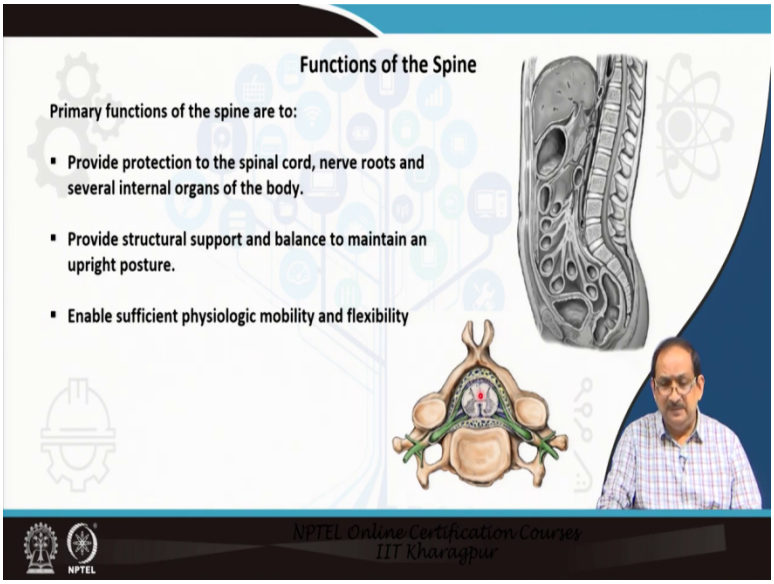


The primary functions of the spine are to provide protection to the spinal cord, the nerve roots, and several internal organs of the body. The next function is to provide support and balance to maintain an upright posture, and the third is to enable sufficient physiologic movement and flexibility.

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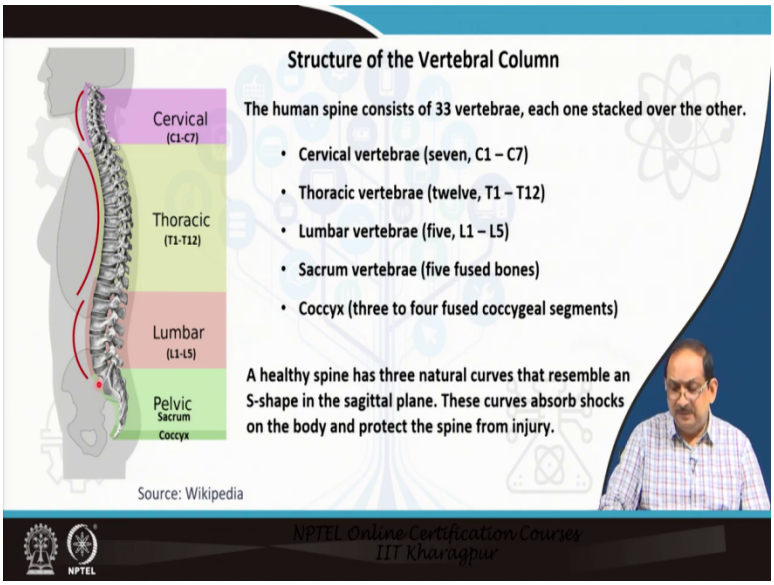


Let us come to the structure of the vertebral column. The figure presented on the left-hand side consists of the vertebral column wherein there are four regions, the cervical spine section, the thoracic spine section, the lumbar spine section, and finally, the sacrum and the Coccyx with the

pelvic bone. The main region of the spines or the sections of the spine consists of the cervical, thoracic, and the lumbar spine.

The human spine consists of 33 vertebrae, each one stacked over the other. The cervical vertebra or cervical spine section consists of seven units C1 to C7. The thoracic vertebrae consist of twelve vertebrae; they are numbered T1 to T12. The lumbar spine section consists of five broad vertebrae from L1 to L5. The sacrum section has five fused bones that are towards the end of the spine. And finally, the coccyx contains three to four fused coccygeal segments.

A healthy spine has three natural curves, as shown in the figure that resembles an S shape in the sagittal plane, and these curves help to absorb shocks on the body, and it protects the spine from injury.

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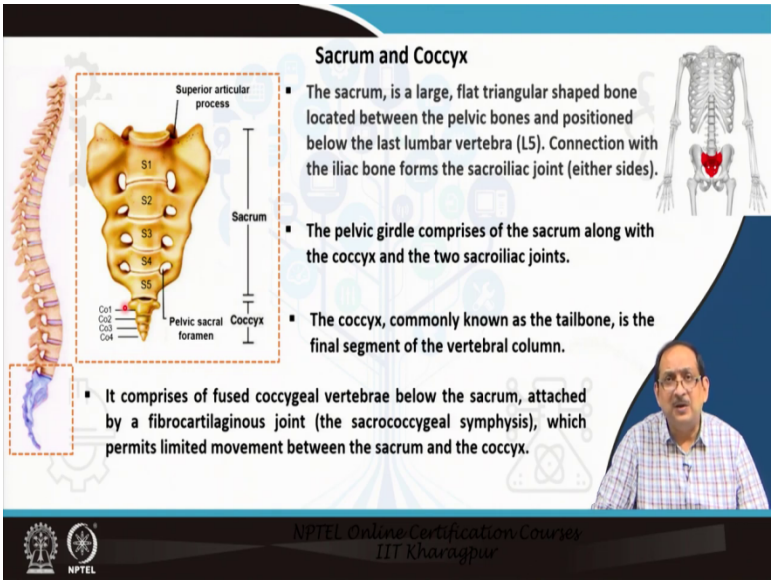


Let us come towards the end of the spinal cord on the vertebral column, wherein we have the sacrum and the coccyx. The sacrum is a large flat triangular-shaped bone nested within the two pelvic bones on either side and positioned below the last lumbar spine i.e., lumbar vertebra L5. Connection with the iliac bone somewhere here and here on either side forms the sacroiliac joint on both sides.

The pelvic girdle comprises the sacrum along with the coccyx and the two sacroiliac joints. The coccyx, commonly known as the tailbone, is the final segment of the vertebral column. It comprises fused coccygeal vertebrae below the sacrum. So, it is located below the sacrum attached by fibrocartilaginous joints, which permits very limited movement between the sacrum and the coccyx.

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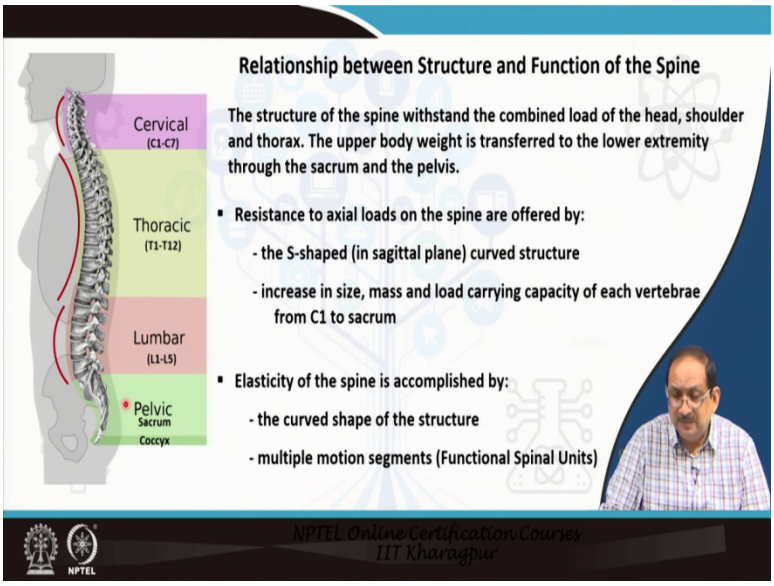


Let us come to the relationship between the structure and function of the spine. The structure of the spine can withstand the combined load of the head, shoulder and thorax that is the upper part of the body. So, the weight of the upper part of the body is transferred to the lower extremity through the sacrum and the pelvis.

The resistance offered to the axial loads by the spine is primarily due to the S-shaped curve structure and due to increase in mass size and load-carrying capacity as a whole of each vertebra, when we move from C1 the first cervical vertebrae to the last vertebrae L5 and further to the sacrum.

The increase in size, mass, and load-carrying capacity is responsible for offering more and more resistance to the axial load on the spine. The elasticity of the spine is accomplished by the curved shape of the structure and multiple motion segments, which are known as the functional spinal units.

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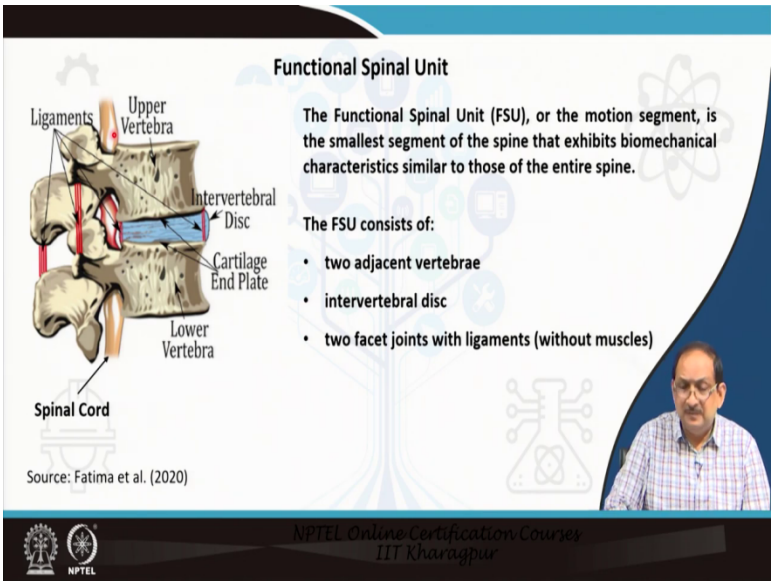


Now, what is this functional spinal unit? This functional spinal unit, or FSU, as we always call it, or the motion segment is the smallest segment of the spine that exhibits biomechanical characteristics similar to those of the entire spine. So, the FSU consists of two adjacent vertebrae and intervertebral disc located in between the two vertebrae and two facet joints with ligaments but without any muscles. You can see in the image presented in the slide on the left. The spinal cord is passing through the FSU basically through the spinal canal.

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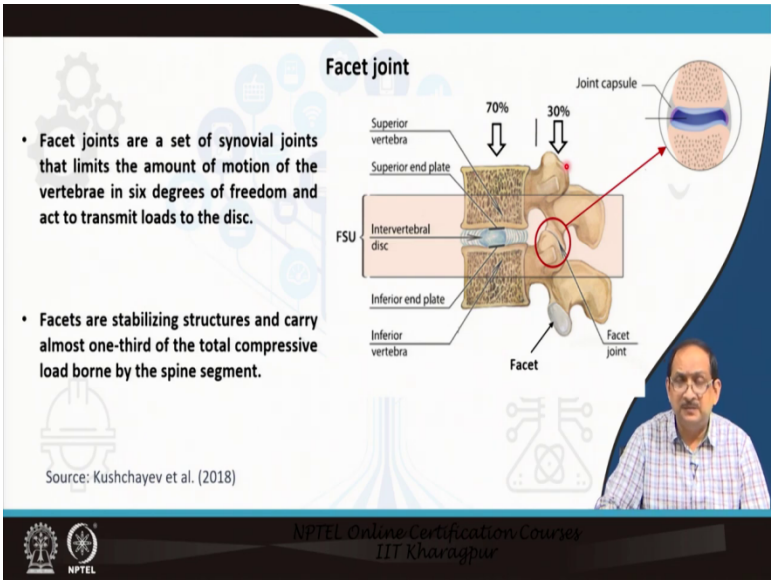


Let us now come to the facet joint. We mentioned facet joint in the functional spinal unit. What is this facet joint? Facet joints are a set of synovial joints. Now, this vertebra is generally considered as a fibrocartilaginous or cartilaginous joint with very limited movement. Within this vertebral column, the facet joints are a set of synovial joints that limits the amount of motion of the vertebrae in six degrees of freedom and act to transmit loads to the disc.

The different parts of the facet joint are presented in the image of the slide. And if we just enlarge one facet joint, which is formed by two facets or a combination of two facets. If we enlarge the joint capsule, we see the synovial cavity in the facet joint. The facets which formed the facet joints are stabilizing structures and carry almost one-third, almost one-third, of the total compressive load borne by the spine segment.

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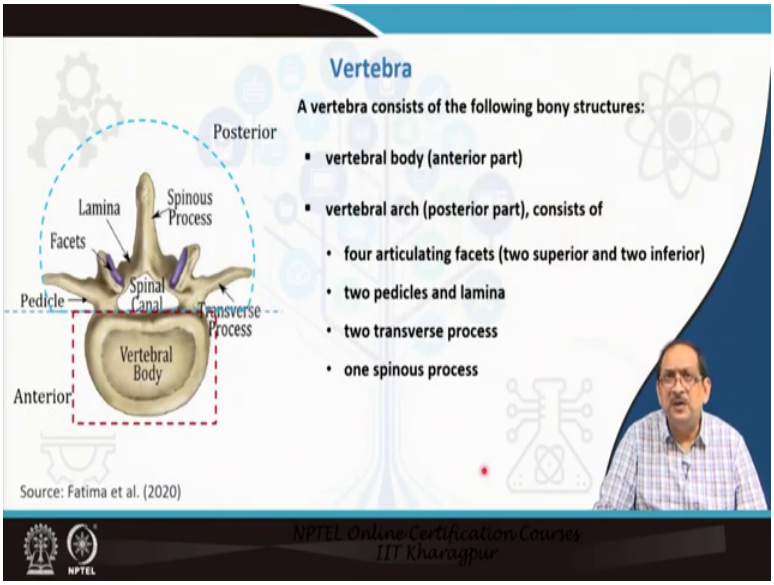


Let us now discuss more in detail the structure of the vertebrae. A vertebra consists of the following bony structure. The vertebral body is located on the anterior side of the vertebrae. Whereas the vertebral arch is located on the posterior portion of the vertebra. The vertebral arch in the posterior portion consists of four articulating facets, two superior and two inferior, two pedicle and lamina, two transverse processes, and one spinous process.

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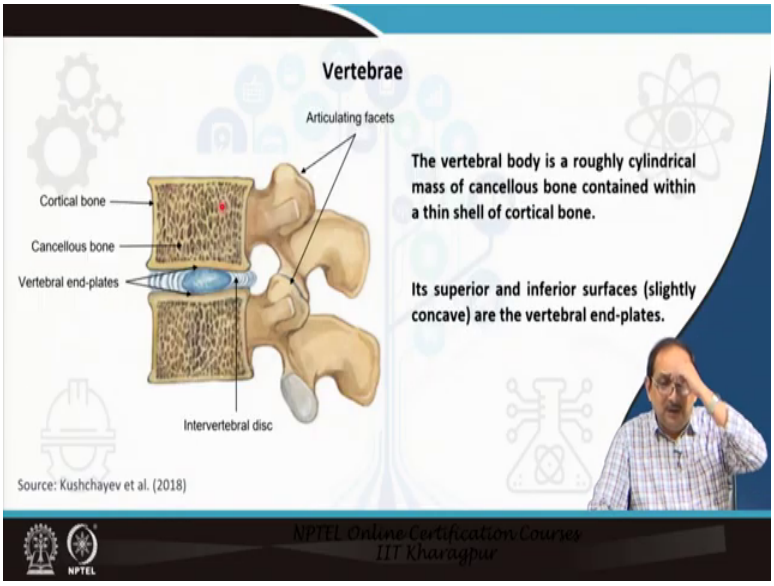


The vertebral body is a cylindrical mass consisting of a core cancellous bone contained within a thin shell of cortical bone. Now, it has an inferior surface and a superior surface that is slightly concave in shape, and they are known as vertebral endplates. Within these two vertebrae, there is the intervertebral disc, and we have the articulating facets that form the facet joints.

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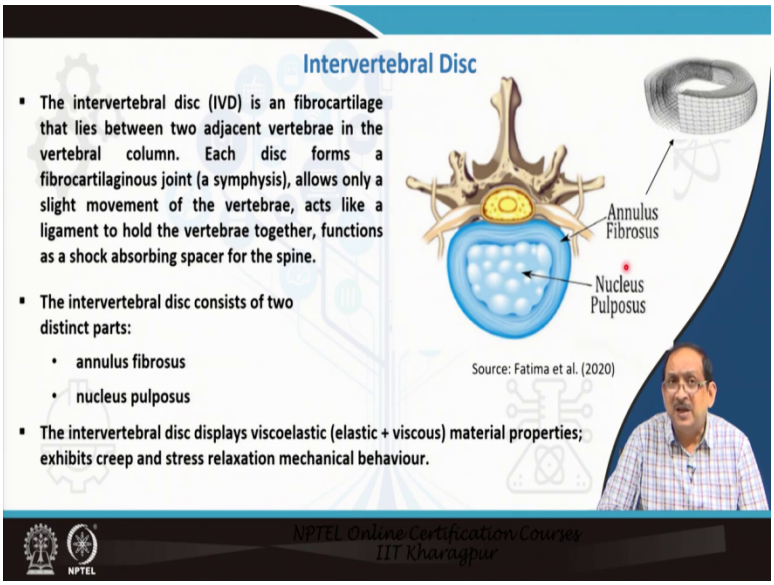

Now, let us discuss more in detail the intervertebral disc. The intervertebral disc, as shown in the figure, is also known as IVD in short, is a fibrocartilage that lies between the two vertebrae in the vertebral column that we have already observed in the slides presented earlier. Now, each disc forms a fibrocartilaginous joint (a symphysis) which allows only a slight movement of the vertebrae, and it acts like a ligament to hold the vertebrae together. It also functions as a shock-absorbing spacer within the spinal column.

The intervertebral disc consists of two distinct parts—the annulus fibrosus, as shown in the figure, and a nucleus pulposus. So, the nucleus pulposus is enclosed within the annulus fibrosus. The intervertebral disc displays viscoelastic material behavior, and in particular, they exhibit creep and stress relaxation mechanical behavior.

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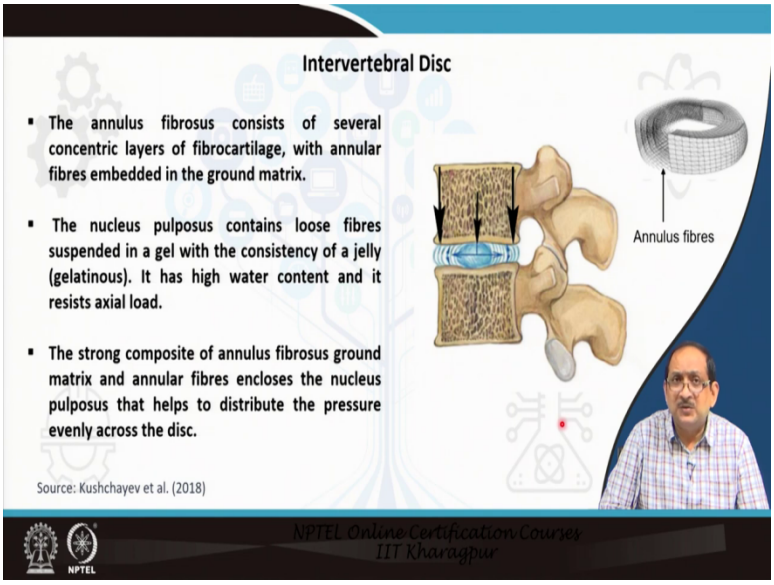

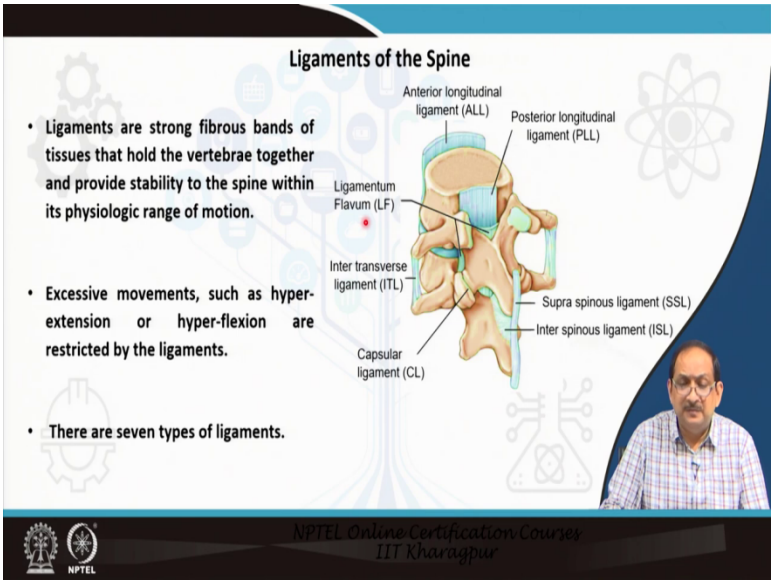


The annulus fibrosus, as shown in the figure, consists of several concentric layers of fibrocartilage with annular fibers embedded in the ground matrix. So, it is a composite structure in which we have concentric layers of fibrocartilage with annular fibers embedded in the ground matrix. The nucleus pulposus contains loose fibers suspended in a gel with the consistency of a jelly. It has high water content, and it resists axial loads.

The strong composite of the annulus fibrosus ground matrix and the annular fibers encloses the nucleus pulposus that helps to distribute the pressure evenly throughout the disk. Let us now discuss about the ligaments of the spine. The ligaments are strong fibrous bands of connective tissue that hold the vertebrae together and provides stability to the spine within its physiologic range of motion.

So, the ligaments provide stability to the spine. Excessive movements such as hyper-extension or hyper-flexion are restricted by the ligaments. There are seven types of ligaments which are shown in the figure. Anterior longitudinal ligament, posterior longitudinal ligament, supra spinous ligament, inter spinous ligament, capsular ligament, inter transverse ligament, and ligamentum flavum are the seven ligaments in the spine.

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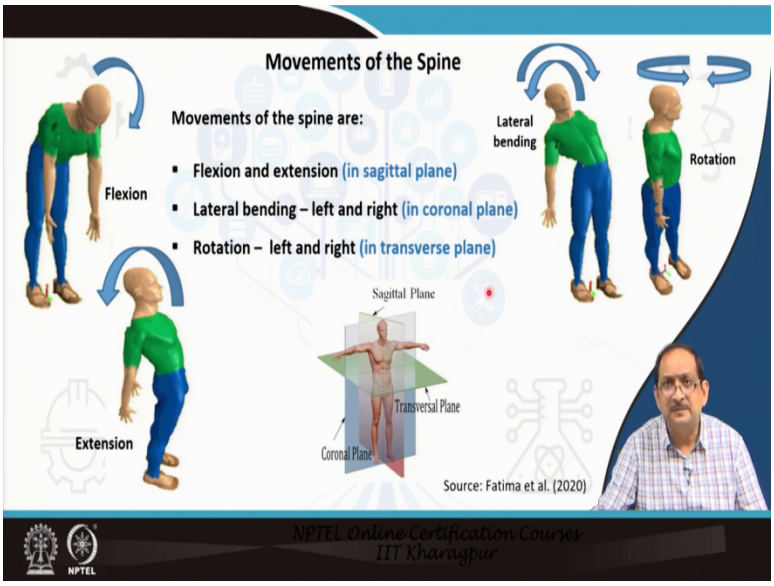


The movements of the spine need to be discussed. The movements offered by the spine are flexion and extension in the sagittal plane. So, front and back is extension, bending front and bending back is flexion and extension in this sagittal plane. Lateral bending to the left or to the right in the coronal plane is a movement offered by the spine, and the third movement is the rotation of the spine towards the left or towards the right in the transverse plane.

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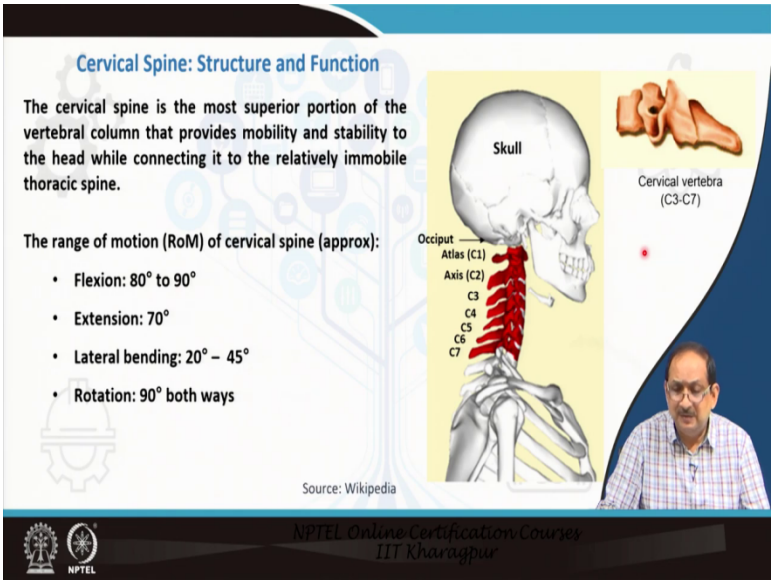

Now, we will discuss about each section of the vertebral column on the spine, starting from the cervical spine, its structure and function. The cervical spine is the most superior portion of the vertebral column that provides mobility and stability to the head while connecting it to the relatively immobile thoracic spine. So, the cervical spine consists of the vertebrae C1 to C7, and it is the topmost part of the vertebral column.

So, one of the cervical spine vertebra between C3 to C7 is shape is shown here on the right. The range of motion in the cervical spine is flexion 80 to 90 degrees, extension about 70 degrees, lateral bending 20 to 45 degrees, and rotation 90 degrees both ways towards left towards right.

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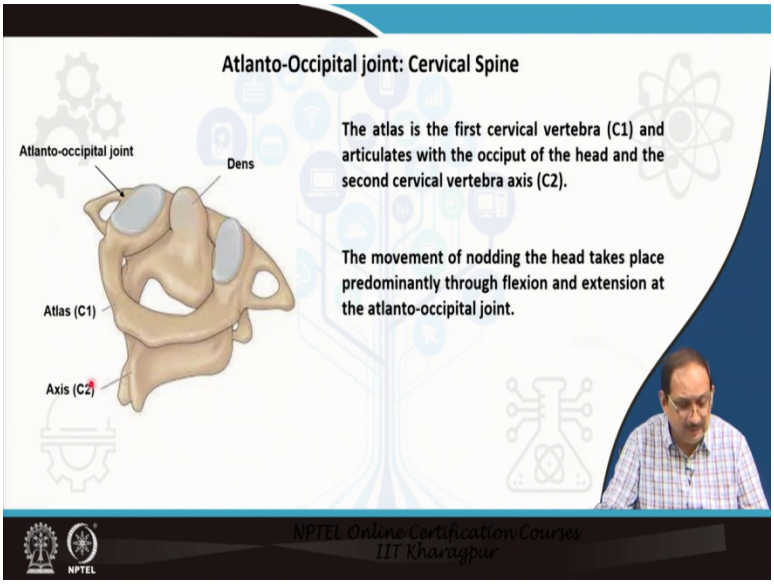

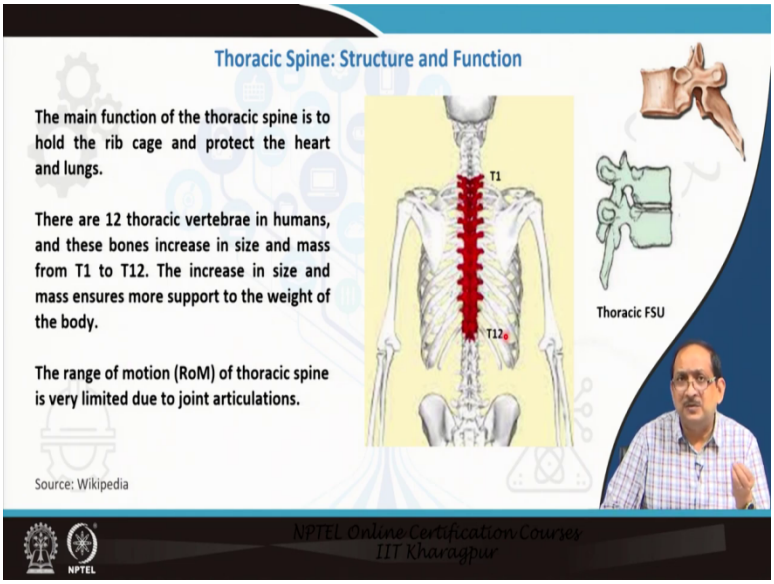


Let us now discuss more in detail about the atlanto-occipital joint in the cervical spine. The Atlas C1 is the first cervical vertebrae that articulates with the occiput (the lower portion of the head or the skull) on the one hand and the second cervical vertebra axis C2 on the other. Let us now discuss more about the thoracic spine it structure and function. As shown in the figure, we see the thoracic spine consists of vertebra T1 to T12.

The structure of a thoracic functional spinal unit, as well as one vertebra, is shown on the right-hand side. The main function of the thoracic spine is to hold the rib cage and protect vital organs like the heart and the lungs. There are 12 thoracic vertebrae in humans, and these bones increase in size and mass as we move from T1 down to T12. The increasing size and mass ensure more support to the weight of the body. The range of motion of the thoracic spine is very restricted due to joint articulations.

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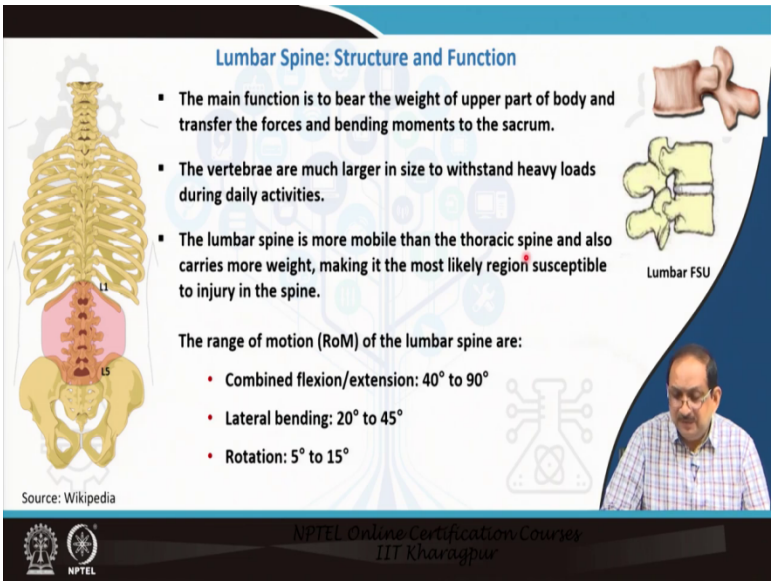


Let us now discuss about the lumbar spine and its structure and function. The lumbar spine is located towards the lower portion of the vertebral column, as shown in the figure, and the main function of the lumbar spine is to bear the weight of the upper part of the body and transfer the forces and bending moments to the sacrum and further to the pelvic bone. A typical structure of the lumber functional spinal unit and the structure of the lumbar vertebrae is shown on the right.

The vertebrae in the lumbar spine are much larger in size in order to withstand heavy loads during various physiological activities. The lumbar spine is more mobile than the thoracic spine and also carries more weight, making it the most likely region susceptible to injury in the spinal column. The range of motions offered by the lumbar spine is combined flexion and extension 40 to 90 degrees, lateral bending towards left or towards right 20 to 45 degrees, and rotation both ways 5 to 15 degrees.

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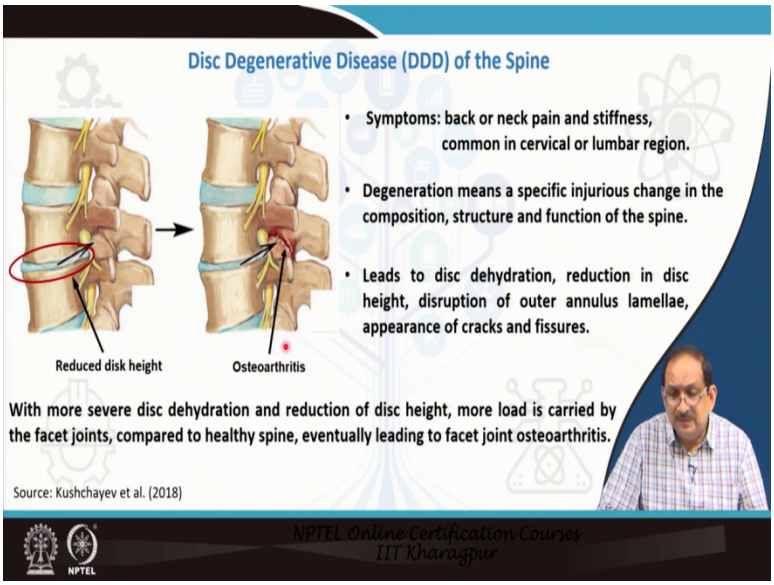


Let us come to the final topic, the disc degenerative disease of the spine. On the left, we can see the image where reduced disc height has been presented, and on the right, it proceeds towards osteoarthritis in the facet joints. The symptom of disc degenerative disease is back pain or neck pain, and it is also associated with stiffness in the spine. This is common in the cervical and lumbar regions of the spine.

Degeneration means a specific injurious change in the composition, structure, and function of the spine. This degeneration leads to disc dehydration, reduction in disc height, as indicated in the figure, and disruption of outer annulus lamellae, as well as the appearance of crack and fissures. With more severe disk dehydration and reduction in disc height, more load is carried by the facet joints as compared to the healthy spine, eventually leading to facet joint osteoarthritis.

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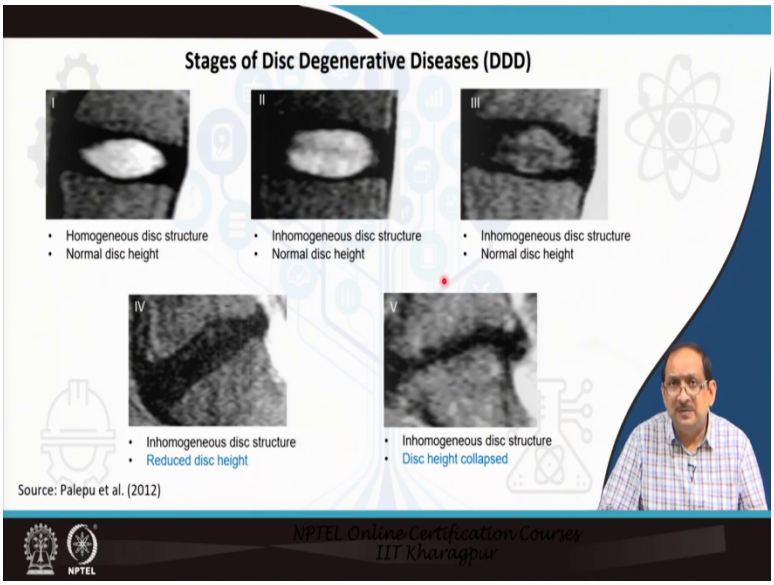


The different stages of disc degenerative diseases are plotted one by one. We start with stage one, where we see a homogeneous structure of the intervertebral disc and the height; the disc height is normal at the first stage. In the second stage, inhomogeneous disc structure is visible i.e. the inhomogeneity sets in within the intervertebral disc. However, still, the disc height is within normal limits.

In the third stage, we see a complete inhomogeneous disc structure. Still, the disc height is within the normal limit. In the fourth stage, we see, with the inhomogeneous disc structure, the disc height has started to reduce. So there is a reduction in the disc height that sets in at the fourth stage. Finally, the inhomogeneous disc structure, the disc has collapsed.

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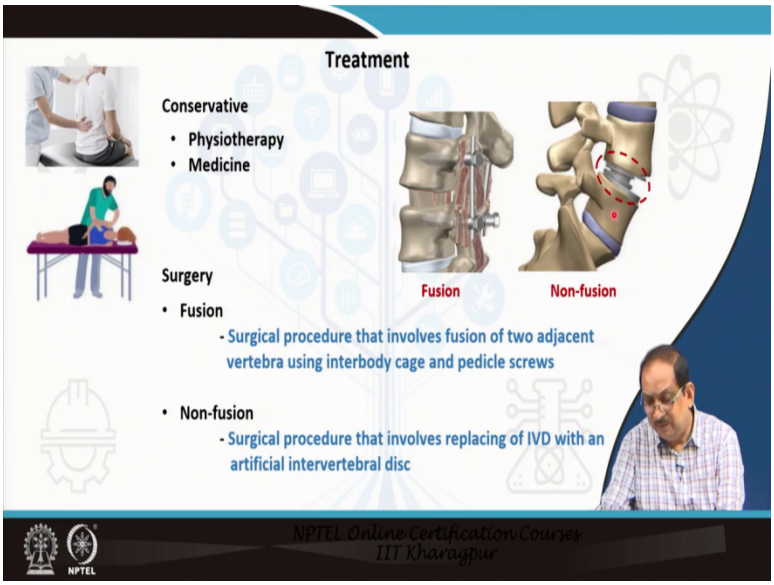


The treatments can be two types for the disc degenerative diseases. The first type is the conservative type of treatment, which includes physiotherapy and medicine, a combination of physiotherapy and medicine. But there is also a surgical treatment. There are two types of surgical procedures, one is fusion, and another is non-fusion as shown in the figure as well. In fusion surgery, the surgical procedure involves fusion of two adjacent vertebrae.

So, from the word itself, it involves the fusion of two adjacent vertebra using interbody cages and pedicle screws. Whereas the non-fusion type of surgery, the surgical procedure involves replacing the intervertebral disc with an artificial intervertebral disc, as shown in the figure.

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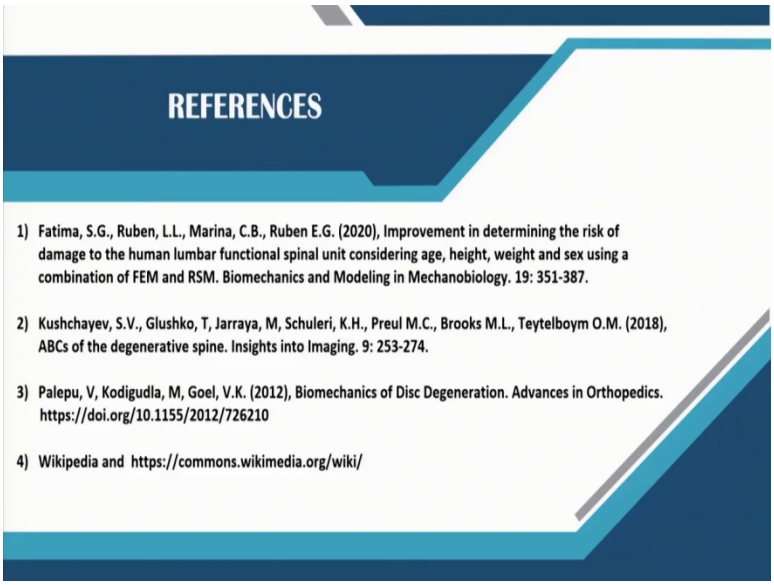


The lecture is based on few references, as shown here. Thank you for your listening.