

**Biomechanics of Joints and Orthopaedic Implants**  
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**Indian Institute of Technology, Kharagpur**  
**Lecture: 04**  
**The Hip Joint**

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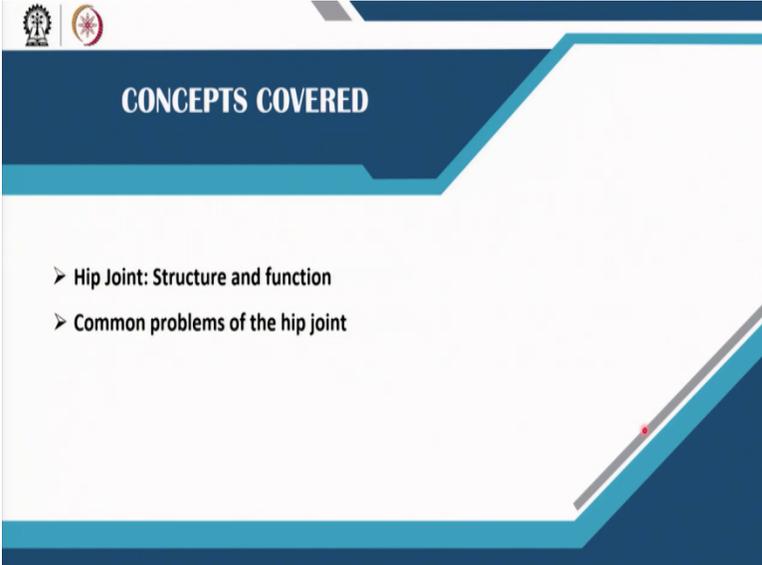


The banner features a blue and black geometric design at the top with two circular logos. Below this, a blue bar contains the text "NPTEL ONLINE CERTIFICATION COURSES". The main title "BIOMECHANICS OF JOINTS AND ORTHOPAEDIC IMPLANTS" is in bold blue, followed by "PROF. SANJAY GUPTA" and "DEPARTMENT OF MECHANICAL ENGINEERING, IIT KHARAGPUR" in smaller blue text. At the bottom, it specifies "Module 01:" and "Lecture 04 : THE HIP JOINT". A small red dot is visible on the right side of the slide.

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**BIOMECHANICS OF JOINTS AND ORTHOPAEDIC IMPLANTS**  
PROF. SANJAY GUPTA  
DEPARTMENT OF MECHANICAL ENGINEERING, IIT KHARAGPUR

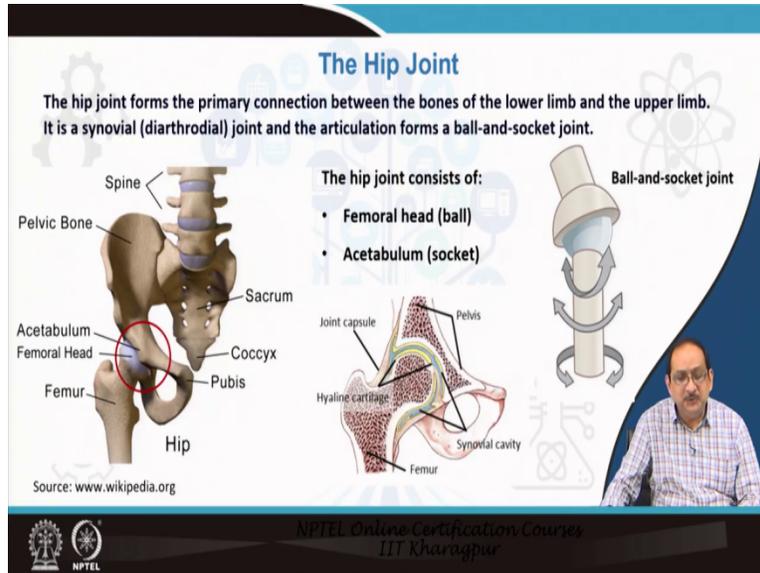
Module 01:  
Lecture 04 : THE HIP JOINT



The slide has a blue and white geometric design. At the top left, there are two small circular logos. The title "CONCEPTS COVERED" is in bold white text on a dark blue background. Below the title, there is a list of two items, each preceded by a right-pointing arrowhead. A small red dot is visible on the right side of the slide.

**CONCEPTS COVERED**

- Hip Joint: Structure and function
- Common problems of the hip joint



Good morning everybody. Welcome to the lecture on the hip joint.

In this lecture, we will be discussing the structure and function of the hip joint and the common problems of the hip joint. The hip joint forms the primary connection between the bones of the lower limb and the upper limb. It is a synovial joint and the articulation forms a ball and socket joint.

The hip joint consists of the femoral head which is the ball and the acetabulum which is part of the pelvic bone and is regarded as the socket. So, the hip joint basically is an articulation between the femoral head and the acetabulum.

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Now, I am showing you composite femur which is an artificial femur very similar in structure and geometry of the actual femur. The femur bone consists of the head, femur head, the neck, the greater trochanter and the lesser trochanter. We are moving towards the posterior view.

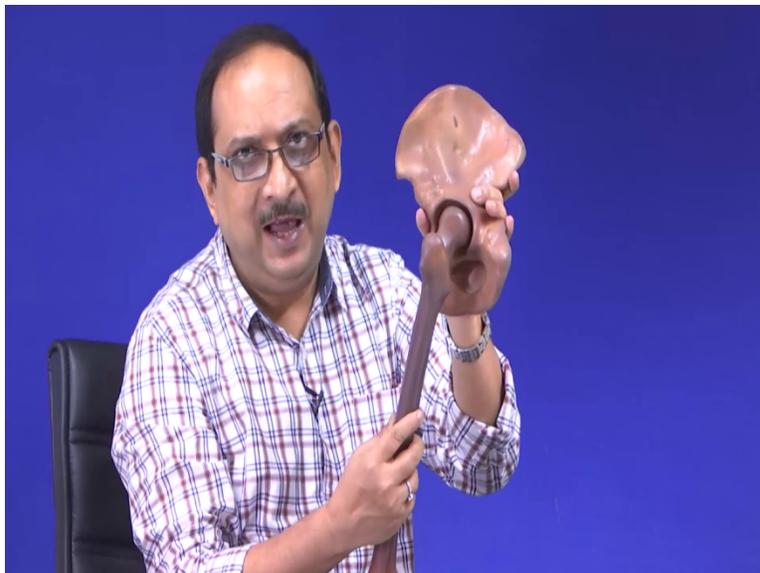
So, we have the condyles, the two condyles of the femur at the distal end. Now, this proximal part of the femur actually consists of the head neck and the trochanters. The main body of the femur is the femur shaft and it is connected to the distal part of the femur, the medial condyle and the lateral condyle.

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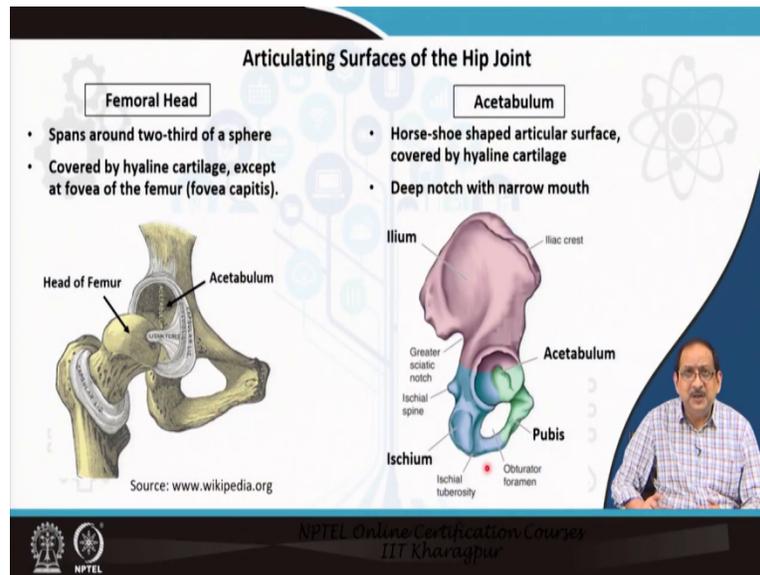
The femur head articulates with the pelvic bone within the acetabular cavity or the acetabulum. You can see the inside of the acetabulum here.

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This is where the femur head articulates within the hip joint and forms a ball and socket joint.

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The articulating surfaces of the hip joint consist of the femoral head and the acetabulum. The femoral head spans around two third of a sphere. It is covered by a hyaline cartilage except the fovea of the femur. The fovea capitis is a small depression. The figure on the left presents the head of the femur with the fovea capitis and the acetabulum.

The acetabulum is a horseshoe shaped articular surface covered by hyaline cartilage. It is a deep notch with a narrow mouth as shown in the figure. It is part of the pelvic bone.

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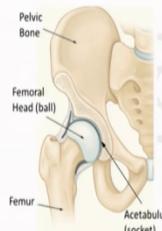
### Functions of the Hip Joint

The hip joint is a major load bearing joint

Primary functions of the hip joint are:

- to support to the body weight in both static (e.g. standing, sitting) and dynamic (e.g. walking, running) postures.
- to facilitate transfer of forces and moments (load transfer) from the upper part of the body (trunk) to the lower extremities.
- to enable a large range of movement and maintain stability during these movements.
- to retain balance and to maintain the pelvic inclination (tilt) angle

Source: www.wikipedia.org



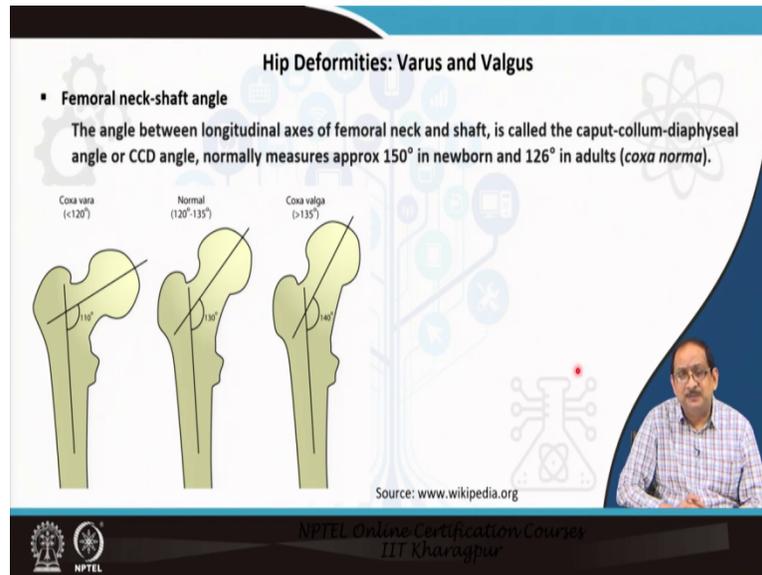
Comparison between a neutral and anterior pelvic tilt – effect on height

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Now, let us discuss about the functions of the hip joint. The hip joint is a major load bearing joint. The primary functions are to support the body weight in both static and dynamic postures. The other functions are as follows: to facilitate transfer of forces and moments, to enable a large range of movement and maintain stability during these movements, to retain balance and to maintain the pelvic inclination angle.

The effect of the pelvic tilt angle on the height of a subject is shown here in this figure for the normal case, and for the anterior pelvic tilt. So, it is observed that for an anterior pelvic tilt, there is an effect on the height of the subject.

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Now, let us discuss about some hip deformities, the eminent among those are the varus and valgus. Before we discuss about varus and valgus. We should define what is the femoral neck shaft angle. The femoral neck shaft angle is the angle between the longitudinal axis of the femur neck and shaft, it is also called the CCD angle and normally measures for newborn child as 150 degrees and for adults, it is about 126 degrees. So, the neck shaft angle between 120 to 135 corresponds to a normal condition.

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### Hip Deformities: Varus and Valgus

- Femoral neck-shaft angle**  
 The angle between longitudinal axes of femoral neck and shaft, is called the caput-collum-diaphyseal angle or CCD angle, normally measures approx  $150^\circ$  in newborn and  $126^\circ$  in adults (*coxa norma*).

Coxa vara  
( $<120^\circ$ )



Normal  
( $120^\circ-135^\circ$ )



Coxa valga  
( $>135^\circ$ )



Coxa vara is a deformity, where the neck-shaft angle is reduced to less than 120 degrees. This results in shortening of leg and development of a limp (asymmetric abnormality of the gait).

Coxa valga is a deformity, where the neck-shaft angle is increased, usually greater than  $135^\circ$ .

Source: www.wikipedia.org



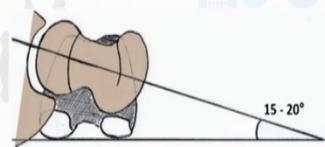
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Now, for a varus deformity the neck shaft angle is reduced to less than 120 degrees. This results in shortening of the leg and development of a limp acid asymmetric abnormality of the gait. On the other hand, the valgus is the condition where the neck shaft angle is increased. As you can see in this figure. It is usually greater than 135 degrees.

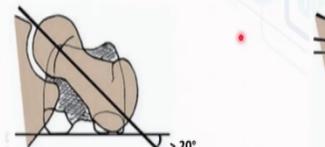
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### Hip Deformities: Anteversion and Retroversion

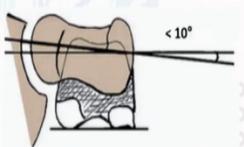
- Femoral Neck Anteversion:**  
 Angle between an imaginary transverse line oriented along medial-lateral direction through the knee joint and an imaginary transverse line oriented through the center of the femoral head and neck.



Femoral Neck Anteversion: Normal angle  $15 - 20^\circ$



Increased Femoral Neck Anteversion: angle  $> 20^\circ$



Femoral Neck Retroversion: angle  $< 10^\circ$



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The other hip deformities are anteversion and retroversion. Here also we need to look into the femoral neck anteversion angle. it is the angle between an imaginary transverse line oriented

along the medial lateral direction through the knee joint and an imaginary transverse line oriented through the center of the femoral head and the neck.

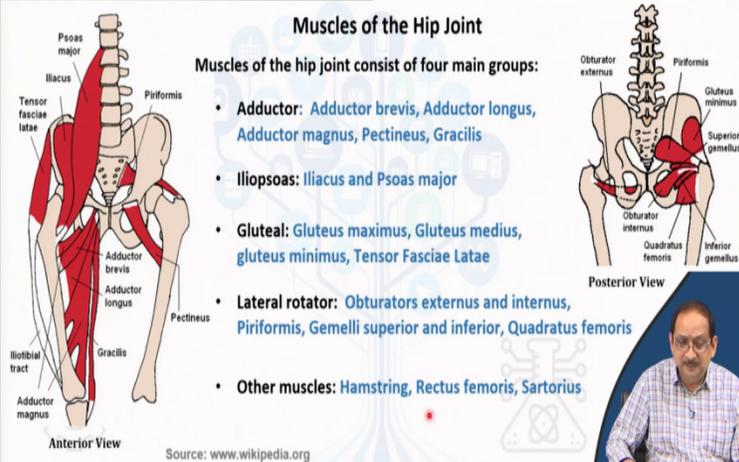
The angle between these two imaginary transverse lines is known as the femoral neck anteversion angle, the normal range is between 15 to 20 degrees. The opposite of anti-version is retroversion in which the angle is less than 10 degrees. So, you can observe the deformities very clearly with regard to the normal situation.

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### Muscles of the Hip Joint

Muscles of the hip joint consist of four main groups:

- **Adductor:** Adductor brevis, Adductor longus, Adductor magnus, Pectineus, Gracilis
- **Iliopsoas:** Iliacus and Psoas major
- **Gluteal:** Gluteus maximus, Gluteus medius, gluteus minimus, Tensor Fasciae Latae
- **Lateral rotator:** Obturators externus and internus, Piriformis, Gemelli superior and inferior, Quadratus femoris
- **Other muscles:** Hamstring, Rectus femoris, Sartorius



The slide features two anatomical diagrams. The 'Anterior View' on the left shows the hip joint from the front, with muscles like the Psoas major, Iliacus, Tensor fasciae latae, Adductor brevis, Adductor longus, Pectineus, Gracilis, Adductor magnus, and Iliotibial tract labeled. The 'Posterior View' on the right shows the hip joint from the back, with muscles like the Obturator externus, Piriformis, Gluteus minimus, Superior gemellus, Obturator internus, Quadratus femoris, and Inferior gemellus labeled. A small inset video of a presenter is visible in the bottom right corner.

Source: www.wikipedia.org

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Let us now discuss about the muscles of the hip joint. The muscles of the hip joint consists mainly of four main groups. The four main groups are the abductor iliopsoas, gluteal and lateral rotator. Within the abductor muscles, we have the abductor group of muscles, the abductor brevis abductor longus, abductor magnus, pectineus and gracilis. These are the main four groups of muscle acting on the hip joint. The other muscles are hamstring, rectus femoris and Sartorius.

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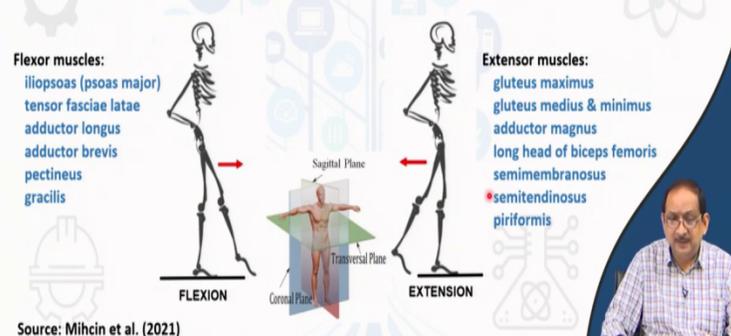
### Movements and Muscles of the Hip Joint

The movements in the hip joint along with the range of motions and the muscles are:

**Flexion (140°) and Extension (20°) around the transverse axis (left-right) in sagittal plane**

**Flexor muscles:**  
iliopsoas (psoas major)  
tensor fasciae latae  
adductor longus  
adductor brevis  
pectineus  
gracilis

**Extensor muscles:**  
gluteus maximus  
gluteus medius & minimus  
adductor magnus  
long head of biceps femoris  
semimembranosus  
semitendinosus  
piriformis



The diagram illustrates hip flexion and extension. On the left, a skeleton is shown in a flexed position with a red arrow pointing forward, labeled 'FLEXION'. On the right, a skeleton is shown in an extended position with a red arrow pointing backward, labeled 'EXTENSION'. In the center, a 3D model of a human torso is shown with three planes: Sagittal Plane, Transversal Plane, and Coronal Plane. A small inset video of a presenter is visible in the bottom right corner.

Source: Mihcin et al. (2021)

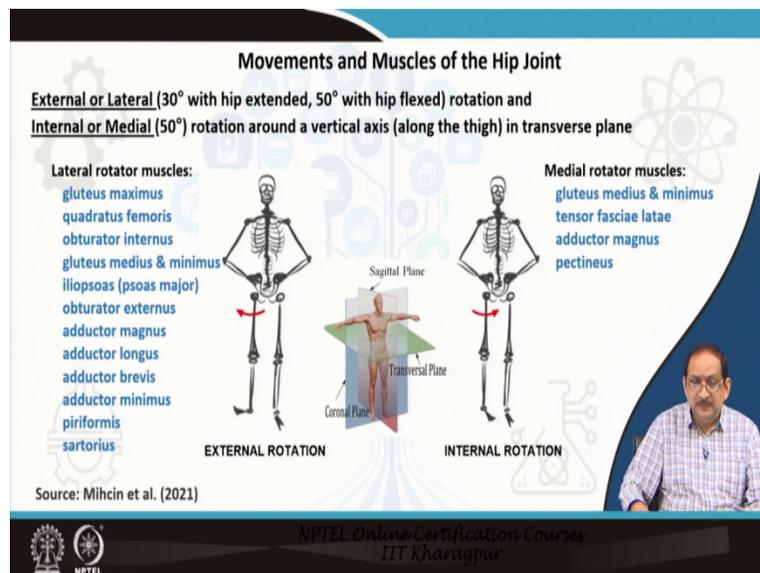
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Let us discuss about the movements offered by the hip joint and the muscles responsible for each movement. The movements in the hip joint along with the range of motions and the muscles responsible for the movements is indicated here. The maximum range of motion is indicated within brackets as shown here for flexion and extension and the muscles responsible for the movements are listed beside each figure that represents a particular movement.

Now, the hip joint offers quite a variety a large range of motion, the flexion and extension are two such movements. The maximum angle of flexion is 140 degrees and the maximum angle for extension is relatively less that is 20 degrees around the transverse axis in the sagittal plane. So, this is measured in the sagittal plane as shown in the figure.

The flexion is moving your leg forward and extension is moving your leg backwards. The flexor muscles responsible for the movement flexion is indicated on the left-hand side of the slide. The extensor muscles that is responsible for the movement extension is also indicated here in the slide on the right-hand side.

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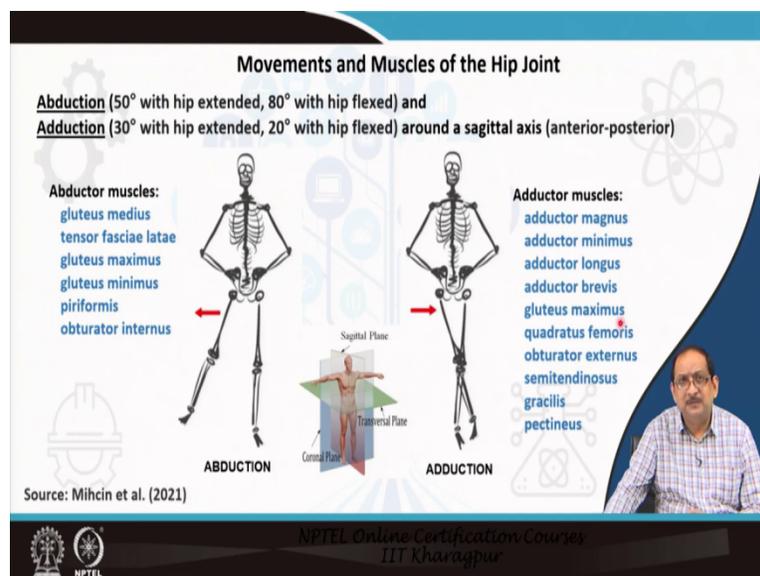


The other movements are external or internal rotation. External rotation is also referred to as lateral rotation. The maximum angle of rotation is 30 degrees with hip extended and 50 degrees

with hip flexed. The external or lateral rotation is indicated in the figure here as you can see. It is a rotation which is away from the midline of the body. Therefore, it is lateral rotation.

The medial rotation is a rotation of the hip towards the midline of the body and it is called internal or medial rotation. The maximum angle is 50-degree rotation around the vertical axis in the coronal plane. The muscles responsible for the lateral or external rotations are listed on the left-hand side beside the figure. About five muscles are responsible for internal rotations. These are also listed here in this slide.

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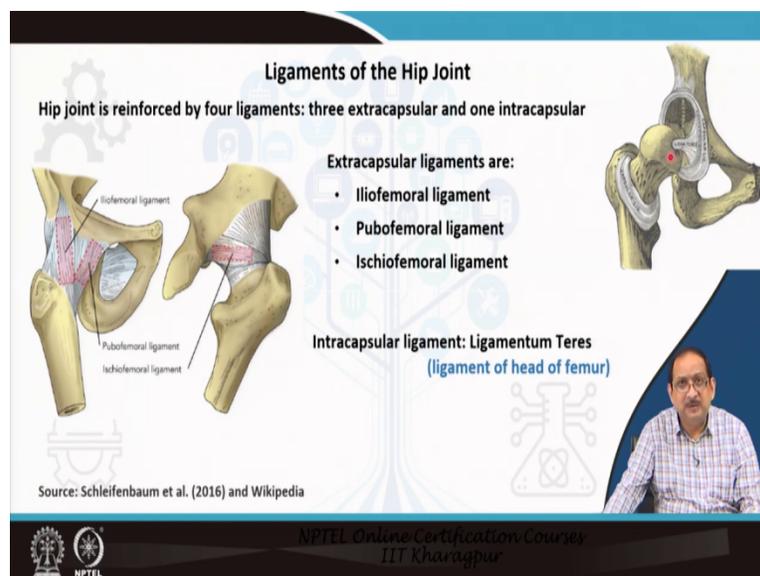
The other movements are abduction and adduction. So, abduction is raising the leg away from the midline of the body whereas, adduction is moving the leg inwards towards the midline of the body. For hip we can have a maximum of 50-degree abduction with hip extended and 80-degree abduction when the hip is flexed.

The angle for adduction is 30 degrees with hip extended and 20 degrees with hip flexed around the sagittal axis in the anterior posterior direction. The abductor muscles, the muscles responsible for the movement abduction is listed here in this slide. There is host of muscles responsible for the movement adduction and it is called the adductor muscles are also listed here in this slide.

The hip joint also provides the movement: abduction and adduction. Abduction is rotating away from the midline and adduction is rotating towards the midline. Now, the maximum angle of during abduction is 50 degrees with hip extended and 80 degrees with hip flexed.

For adduction, it is 30 degrees with hip extended and 20 degrees with hip flexed. So these angles can be measured around the sagittal axis which runs along the anterior and to posterior direction. The abductor muscles are listed here. And the adductor muscles are also given presented here in this slide.

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The ligaments of the hip joint play an important role in stabilizing the joint. The hip joint is reinforced by four ligaments out of which three are extracapsular and one intracapsular. The extracapsular ligaments are the iliofemoral ligament, pubofemoral ligament and ischiofemoral ligament whereas the intracapsular ligament is known as the ligamentum teres or the ligament of the head of the femur.

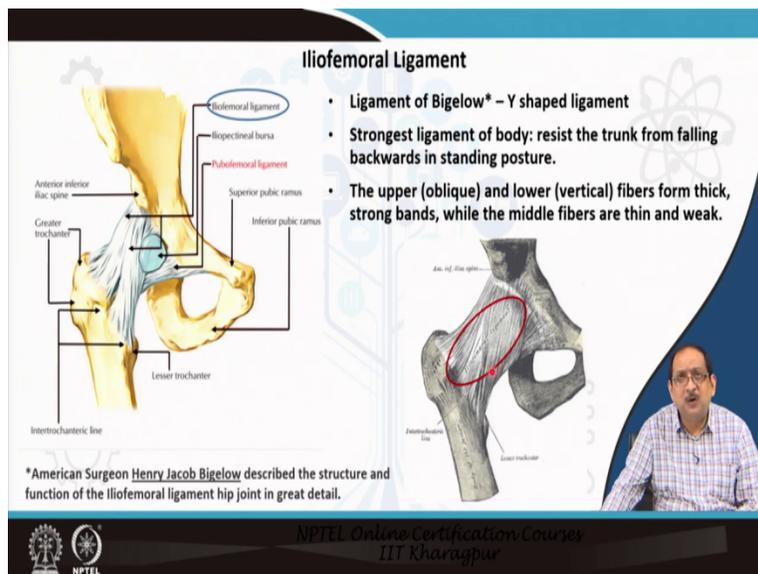
This intracapsular ligament is attached to a depression in the acetabulum acetabular notch and a depression on the femoral head. It is a relatively small structure, which runs from the acetabular fossa to the head of the femur.

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Let me show you the model of a hip joint. You can see the pelvic bone and the femur bone and the femoral head of the femur inside the cavity the acetabulum. The arrangements of the ligaments are shown clearly that is holding the hip joint to offer stability to the joint.

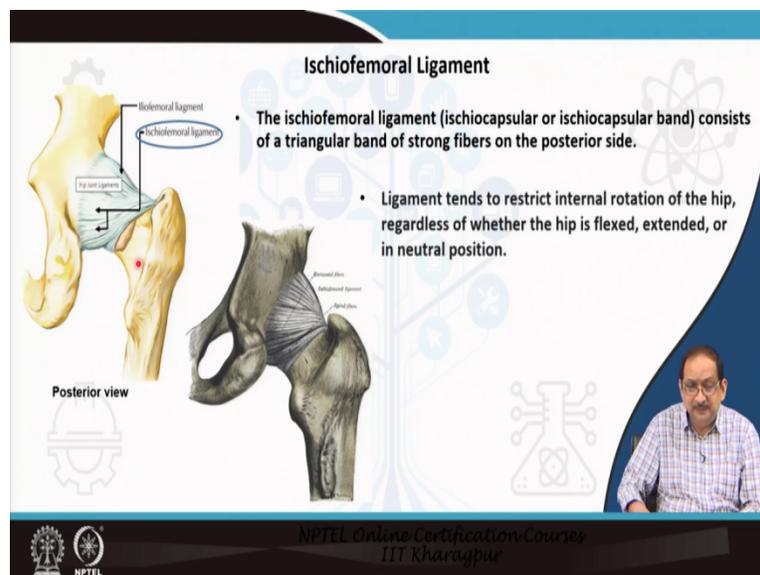
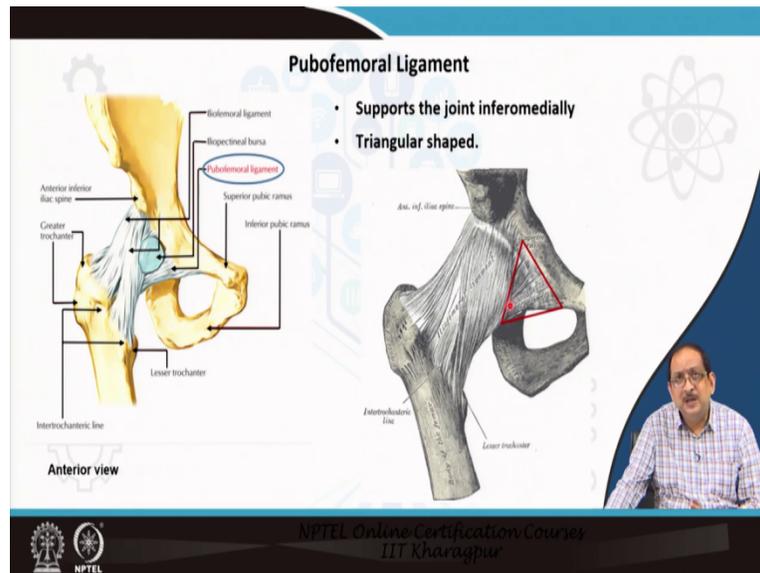
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The iliofermoral ligament is also known as the ligament of big yellow. It is basically a Y shaped ligament. As you can see here in the anterior view. It is quite a thick band of ligament. It is the

strongest ligament of the body and it resists the trunk from falling backwards in the standing posture. The upper and lower fibers form thick strong bands while the middle fibers are relatively thin and weak.

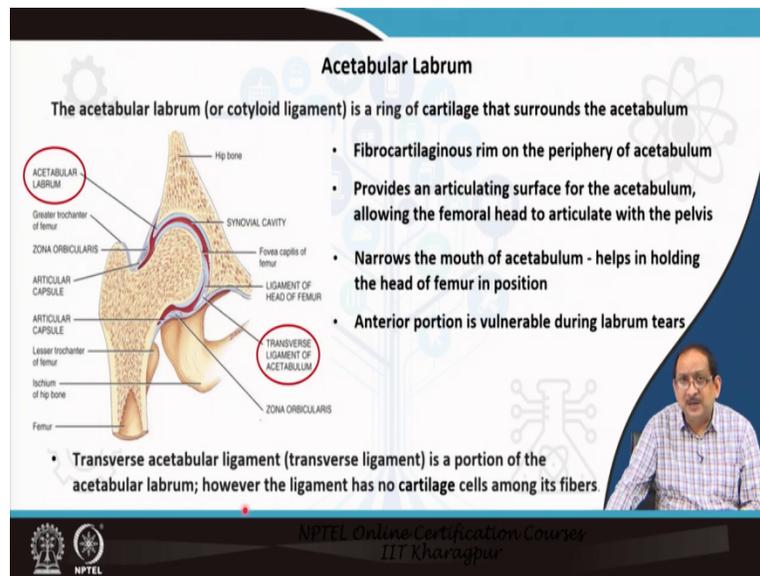
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The pubofemoral ligament supports the joint inferomedially. It is a triangular shaped ligament adjacent to the iliofemoral ligament. The ischiofemoral ligament is located on the posterior side of the joint. The ischiofemoral ligament consists of a triangular band of strong fibers towards the posterior side. The ligament tends to restrict internal rotation of the hip regardless of whether the

hip is flexed, extended or in a neutral position. The ischiofemoral ligament is clearly shown here in the figure.

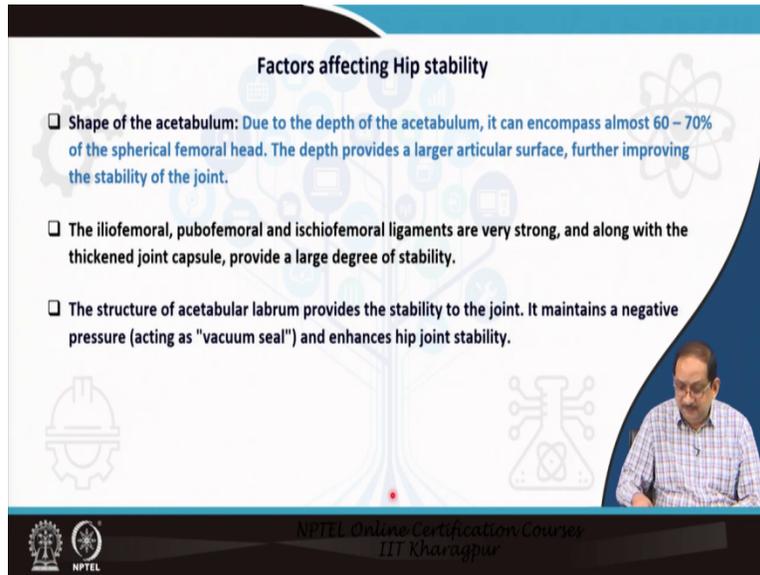
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Now, an important structure in the acetabulum is the acetabular labrum which is a ring of cartilage that surrounds the acetabulum. This is clearly shown here in the figure. It is a fibrocartilaginous rim on the periphery of the acetabulum. It provides an articulating surface for the acetabulum allowing the femoral head to articulate within the pelvis.

It narrows the mouth of the acetabulum and it helps in holding the head of the femur in position within the acetabular cavity. The anterior portion of the acetabular labrum is vulnerable during labrum tears. Now, there is another ligament known as the transverse ligament of the acetabulum or transverse acetabular ligament. It is a portion of the acetabular labrum but the ligament has no cartilage cells among its fibers.

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**Factors affecting Hip stability**

- ❑ **Shape of the acetabulum:** Due to the depth of the acetabulum, it can encompass almost 60 – 70% of the spherical femoral head. The depth provides a larger articular surface, further improving the stability of the joint.
- ❑ The iliofemoral, pubofemoral and ischiofemoral ligaments are very strong, and along with the thickened joint capsule, provide a large degree of stability.
- ❑ The structure of acetabular labrum provides the stability to the joint. It maintains a negative pressure (acting as "vacuum seal") and enhances hip joint stability.

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Now, let us summarize the factors that affect hip stability. The most important factor that affecting hip stability is the shape of the acetabulum. Due to the depth of the acetabulum, it can encompass almost 60 to 70 percent of the spherical femoral head. So, the depth provides a larger articular surface further improving the stability of the joint.

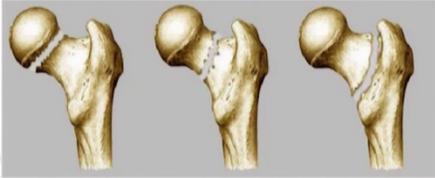
The iliofemoral, pubofemoral and ischiofemoral ligaments are the three most important ligaments which provides a large degree of stability to the hip joint. The structure of the acetabular labrum provides the stability to the joint. It maintains a negative pressure acting like a vacuum seal and it enhances the joint stability.

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**Common Problems of the Hip Joint**

**Intracapsular Fracture**

- It may be subcapital (near the head), cervical (in the middle) or basicervical (near trochanters).
- Such a damage is maximum in subcapital and least in basicervical fractures.
- These fractures are common in old age, between 60 and 80 years.



Subcapital      Transcervical      Basicervical

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Let us come to the second part of the lecture which is on the common problems of the hip joint. The common problems of the hip joint are fractures. So, let us discuss first about the intracapsular fracture. As shown in the figure the intracapsular fracture may be sub capital near the femoral head, the cervical or transcervical which is located in the middle part through the neck of the femur.

And the basis cervical fracture which runs through the lesser trochanter to the greater trochanter. So, it is near the trochanters. Such a damage is maximum when it is sub capital and least when it is a basicervical fracture. So, these fractures are common in old age patients between 60 to 80 years.

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**Extracapsular Fracture**

- Intertrochanteric (between the trochanters)
- Peritrochanteric (along the trochanters)
- Subtrochanteric (below the trochanters)
- These fractures occur in young adult subjects owing to severe traumatic injuries.

} Trochanteric fractures



Intertrochanteric      Peritrochanteric      Subtrochanteric

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The other type of fracture is extracapsular fracture as shown in the figure. It may be intertrochanteric, between the trochanters and peritrochanteric. Intertrochanteric is between the trochanters and peritrochanteric is along the trochanters. Now, these two can be classified under trochanteric fracture. The other type is subtrochanteric fractures which occurs below the trochanters. These fractures generally occurs in young adult subjects owing to severe traumatic injuries.

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### Arthritis: Osteoarthritis

Bone degenerative disease, **Osteoarthritis** is the most common form of arthritis in the hip joint.

- In osteoarthritis, the cartilage gradually wears away
- Results in bone-to-bone contact, producing **bone spurs**, causes pain and stiffness, restricts movements.

Osteoarthritis

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Arthritis is bone degenerative disease and osteoarthritis is the most common form of arthritis that is observed in the hip joint. As you can see in the figure that the cartilage gradually wears away in case of an osteoarthritis joint. In this figure as well we can see the cartilage is bone away as compared to the normal situation as indicated in this slide. Now, once it wears away, it results in bone-to-bone contact producing bone spurs eventually causing pain and stiffness and restricted movements.

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### Rheumatoid Arthritis

In **rheumatoid arthritis**, inflammation (swelling) of the synovial membrane that covers the synovial joint, results in pain and stiffness.

- Rheumatoid arthritis, an autoimmune disorder, occurs when the immune system mistakenly attacks the own body's tissues.
- The immune system damages normal tissue (such as cartilage and ligaments) and softens the bone.

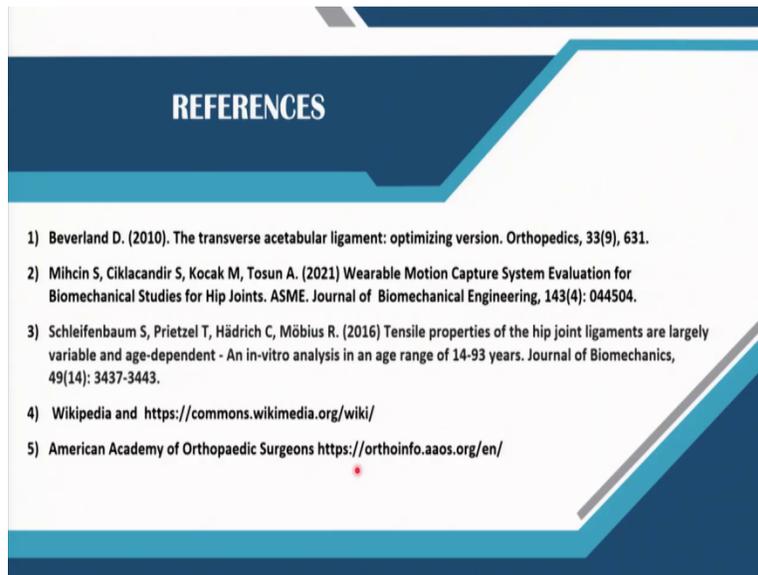
Rheumatoid arthritis

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The other common form of arthritis is the rheumatoid arthritis. In rheumatoid arthritis inflammation or swelling of the synovial membrane occurs. This synovial membrane covers the synovial joint. Rheumatoid arthritis results in pain in the joint and as well as stiffness. It may be noted that rheumatoid arthritis is an auto immune disorder disease.

It occurs when the immune system mistakenly attacks the own body's tissues. The immune system damages the normal tissue, such as cartilage and ligaments and softens the bone. Rheumatoid arthritis also affects the synovial fluid within the synovial joint.

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## REFERENCES

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- 2) Mihcin S, Ciklacandir S, Kocak M, Tosun A. (2021) Wearable Motion Capture System Evaluation for Biomechanical Studies for Hip Joints. *ASME. Journal of Biomechanical Engineering*, 143(4): 044504.
- 3) Schleifenbaum S, Prietzel T, Hädrich C, Möbius R. (2016) Tensile properties of the hip joint ligaments are largely variable and age-dependent - An in-vitro analysis in an age range of 14-93 years. *Journal of Biomechanics*, 49(14): 3437-3443.
- 4) Wikipedia and <https://commons.wikimedia.org/wiki/>
- 5) American Academy of Orthopaedic Surgeons <https://orthoinfo.aaos.org/en/>

The list of references is mentioned here based on which the lecture has been prepared. Thank you for listening.