THE HIP: Biomechanics, Pathology, and Diagnosis

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Ball and Socket Joint

- Joint Reaction Force
- 1/3 body weight in double stance
- 3-4x body weight in single leg stance
- 5x body weight during walking
- 10x body weight running

Bony Acetabulum/Femoral Head

- Inferior
- Lateral
- Anterior
Column and Angle

• Angle between Femoral/neck and shaft
• Length 3-5cm
• Ranges from 115-140˚
• Superior, Medial, Anterior

Column Angles

• Coxa Valga >125˚
• Coxa Vara < 115˚
• Normal 120˚

Coxa Valga

• Higher pelvis
• Hip Adduction
• Increased leg length
Coxa Vara

- Lower Pelvis
- Hip Abduction
- Decreased leg length
- Poor abductor length tension
- Limited abduction

Anterior Antetorsion angle

- Longitudinal Axis of the neck
- transverse axis
- distal femoral condyles
- Angle is 10-25°

Anteversion > 20°

- If Uncompensated:
  - Exposes anterior
  - Femoral head
- If Compensated:
  - Femoral IR
  - Toe-in-Gait
  - Pronation
Anteversion >20°

- If Uncompensated:
  - Exposes posterior
  - Femoral head

- If Compensated:
  - Femoral ER
  - toe-out-gait
  - Supination

Retroversion <12°

- If Uncompensated:
- If Compensated:

Anteversion and Retroversion
Acetabular Angle

- Mechanical Axis of the Acetabulum
- Transverse axis through center acetabulum through
- Femoral head
- Angle is 30-40°

Acetabular angle

Hip Congruency

- The Superior angle of the Femur (115-140°) is >
- Inferior angle of the acetabulum (22-42°)
What is the position of greatest Hip congruency?

- Hip Flexion
- Hip Abduction
- Hip ER
- Is this closed packed???

Only about 70-80% of femoral cartilage involved in weight bearing

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Hip joint positions

<table>
<thead>
<tr>
<th>Closed Packed Position</th>
<th>Open Pack Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Extension</td>
<td>30° flexion</td>
</tr>
<tr>
<td>Full IR</td>
<td>30° abduction</td>
</tr>
<tr>
<td>Full Abduction</td>
<td>20° ER</td>
</tr>
</tbody>
</table>

Capsular Pattern
IR>Extension>Abduction>Flexion>ER

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Arthrokinematics

<table>
<thead>
<tr>
<th>Movement</th>
<th>Neutral</th>
<th>90° Hip flexion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion/extension</td>
<td>All parts of capsule</td>
<td>same</td>
</tr>
<tr>
<td>Abduction</td>
<td>Inferior glide</td>
<td>Anterior glide</td>
</tr>
<tr>
<td>Adduction</td>
<td>Superior glide</td>
<td>Posterior glide</td>
</tr>
<tr>
<td>Internal Rotation</td>
<td>Posterior glide</td>
<td>Inferior glide</td>
</tr>
<tr>
<td>External Rotation</td>
<td>Anterior glide</td>
<td>Superior glide</td>
</tr>
</tbody>
</table>
Pulvinar Acetabulum

- The fat pad of the hip
- Provides communication between intracapsular and extracapsular tissues via the pad
- Assist with attenuation of compression forces during weight-bearing
- During gait, pad compressed and squeezed out of the joint allowing it to absorb the compression forces

Pulvinar Acetabulum

- Returns via a vacuum that occurs during non-weight-bearing
- During distraction, there is a pressure differential that is produced (400-600N) causing the fat pad to return to the cavity and commonly in the semitendinous iliac bursa
- During any pathology to the hip that causes tonic muscle guarding, will cause increased force/load into the joint and trap the fat pad, therefore force attenuation is disrupted

Capsuloligamentous Complex

- Telleria et al. 2011 Arthroscopy
- Shu et al. 2011 Sports Med Clinics
- Safran et al 2010 J Am Acad OrthoSurg
- Composed of longitudinal and circular fibers (zona orbicularis)
- Zona orbicularis is more reinforced posterior and inferior and eventually blend with the iliofemoral ligament
- Longitudinal fibers strong anteriorly and form all the distinct ligaments
Ligaments of the Hip

Capsuloligamentous Complex

- Anterosuperior capsule is more taut and hypertrophied and the inferoposterior capsule is thinner
- "Y" ligament of Bigelow (iliofemoral) is the thickest of the ligaments, limits anterior translation of hip, ER, and the lateral band is taut with flexion and adduction
- Pubofemoral - wraps around the femoral head superiorly and blends with the ishiofemoral ligament, limites ER in Extension

Ligaments continued

- Ishiofemoral ligament - triangular in shape with an extended apex to the acetabular margin. Spirals superolaterally to the greater trochanter. Fibers of the pubofemoral blend with it proximally.
- IR in both flexion and extension and posterior translation
- Zona orbicularis - surrounds femoral neck, intra-capsular, predominantly longitudinal fiber orientation
Ligaments

- Zona orbicularis resists axial distraction and has been demonstrated to have a screw-home effect during hip extension
- The ischiofemoral ligament is also taut in extension and with zona orbicularis provide a closed packed position for the hip
- As the hip moves into flexion and ER the capsuloligamentous complex unwinds
- Ligamentum Teres- blends with transverse ligament of the hip and inserts into forvea femoris- area without cartilage
- Tight in adduction, ER, and flexion

Pulvinar Acetabulum


Neurophysiology

- Wyke 1985 and Warmerdam 1999
- Joint capsule mechanoreceptors have reflexogenic influences, both facilitory and inhibitory
- Wyke 1985
- Effects motor unit activity in muscles over the same joint along with distal muscle groups, even on the contralateral side
Neurophysiology

- Yerys et al. 2002 J Man Manip Therapy
- Increased Glute max strength after hip P-A mobilizations
- Makofsky et al. 2007
- Increased hip abductor torque after inferior hip mobilizations
- Beckman 1995, Friel et al. 2006 J Athletic Training
- Reduced hip abduction firing and strength associated with injuries to the foot/ankle

Neurophysiology

- Cibulka et al. 1986
- Mobilization to the sacroiliac joint restored length-tension and peak torque to the hamstrings
- Sutter et al. 1999
- Sacroiliac manipulation has been shown to increase peak torque of the quadriceps and reduce anterior knee pain

Clinical Diagnosis

- Plante et al 2011 Clinical Sports Medicine
- History critical
- Delineate intra-articular from Extra-articular(location of pain)
- Intra-articular typically groin pain
- Extra-articular lower and may be in adductors, or lateral with snapping or greater trochanter
Plante Et Al 2011

- Suggest use of SLS, leg length(functional/structural), observe pelvic obliquities
- C-Sign
- Palpation
  ASIS medially lateral femoral cutaneous
  ASIS origin Sartorius/AIIS origin Rectus Femoris-apophyseal avulsions
  Iliac Crest-Hip pointer
  Pubic symphysis pain-adductors
  Posterior Greater trochanter-piriformis
  Special Test

Differential diagnosis

- Articular cartilage possible chondral or OA
- Bursitis-trochanteric/Psoas
- Inflammatory-Synovitis, tendonitis
- Labral tears, muscle strains, overuse, stress fractures
- SCFE, Dysplasia, Legg-Calve Perthes
- Systemic conditions- Lupus, RA,
- Avascular necrosis
- Traumatic conditions-dislocations, avulsions, fractures, contusions
- Referred pain from lumbar, SIJ, pubic pain, or surrounding muscles of hip

Avascular Necrosis

- Common Complication of SCFE
- Often occurs in acute slips or unstable slips-abrupt slip/displacement of the epiphysis can cause disruption to the retinacular vessels
- Aseptic necrosis can occur in with treatment to chronic stable slips, during reduction od stable or chronic slips, improper pin placement, and possible with femoral osteotomies
Avascular Necrosis

- du Sart et al. Open J of Orthopedics 2014
- Parsch et al. 2009 J of Ped Orthopedics
- Found significant decreased chance of AVN in stable versus unstable
- Stuttgart, Germany limited AVN to 0% when performing open reduction/decompression and Kirschner wiring

Blood Supply femoral Head

- Provided by the medial and lateral circumflex arteries distally and from the forveal artery in the ligamentum teres proximally
- Any displacement or shift of the femoral head in relation to the femoral neck can shear and disrupt the circumflex arteries
- Slip or dislocation of the femoral head from within the acetabulum and tear the ligamentum teres

Slipped Capital Femoral Epiphysis

- Most commonly affects boys than girls
- Both active and also common in obese children
- Children with skeletal and sexual immaturity
- Ages 10-16 most common range due to increased participation in sports and activity levels
- Etiology is unknown
Incidence and Etiology

- Loder et al. J. Ortho Pediatrics 2013
- Capital femoral epiphysis displaces post/inf in relation to femoral metaphysis
- Suspected biomechanical and biochemical factors
- Possible imbalance between growth and sex hormones
- Hypothyroidism, hypopituitarism, hypogonadism
- Weakens epiphysis/failure to unite
- Obesity, femoral retroversion
- Increased physeal obliquity, Increased chondrocyte proliferation

SCFE signs and symptoms

- Lehman et al. JAMA 2013
- Pain in the hip, groin, or medial thigh and knee
- Antalgic and/or Trendelenburg
- Unable to bear full weight
- Limited flexion, abduction, and IR
- Affected leg in IR and may be leg length discrepancy
- Passive hip flexion results in abduction and ER

Classification SCFE

- Loder et al JBJS 1993
- Established classification and still used today
- Measured by amount of slippage
- Pre-slip shows changes in epiphyseal plate without movement
- Grade 1 - head displaced 1/3 width of neck
- Grade 2 - head displaced up to ½ of neck width
- Grade 3 - head displaced greater than 1/2 neck width
Diagnosis SCFe

- Wright et al. J of Ped. Orthopedics 2012
- Du Sart et al. Open J of Orthopedics 2014
- Plain radiographs pelvic A/P and lateral frog leg position
- A/P radiographs show physis widened and increased opacity metaphysis and epiphysis may seem smaller
- Lateral Radiographs demonstrate slippage sooner
- T2 weighted MRI- show marrow edema and slippage, often ordered when suspect SCFE

Imaging SCFE

SCFE Imaging Cont

- Two Main Methods
- Southwick-create an axis for the femoral neck and then determining if the epiphysis is misaligned/tilted
- Klein Line- A line is drawn along the lateral aspect of the femoral neck on the A/P view. There will not be intersection on any portion of the head in SCFE
SCFE Kleine Line

![Image of SCFE Kleine Line](image)

Figure S: Normal Kleine Line: The line is drawn along the lateral aspect of the femoral neck and transsects a portion of the femoral epiphysis base (white arrow).

Imaging SCFE

![Image of Imaging SCFE](image)

Treatment for SCFE

- Parsch et al. 2009 J Ped Orthopedics
- Jacoby et al. 2010 Clin Sports Med
- Loder et al. 2013 J Ped Orthopedics
- Stable SCFE without surgical dislocation: Situ single screw fixation over multiple pin fixation and potential osteotomy or spica cast
- Unstable SCFE without surgical dislocation: reduction with decompression and internal fixation
SCFE Radiograph of Pinning

Complications SCFE
- Loder et al 2012 and 2013 J Ped Orthopedics
- Benjamin et al 2007 JBJS
- Early DJD, Abnormal biomechanics, retroversion femoral head, Avascular necrosis

Hip Dysplasia
Hip dysplasia

- Acetabulum-shallow with deficient bone anterior and lateral
- Normally oval shaped with narrow A/P diameter
- Increased anteversion with center of rotation shifted lateral
- Femur-straight and more narrow with metaphyseal change
- More narrow medial to lateral than A/P with increased anteversion proximally
- Shorter neck with more valgus with posterior positioned greater trochanter

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Hip Dysplasia

- Wenger and Lee et al. 2013 J Pediatric Orthopedics
- Cooperman et al. 2013 J Pediatric Orthopedics
- Acetabular dysplasia is identified by radiographs and is observed as a shallow acetabulum and narrow rim that does not fully cover/surround the femoral head
- This leads to abnormal biomechanics and shear that further creates instability and stress to the labrum and capsuloligamentous system

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Hip dysplasia

- Infantile dysplasia or Developmental Dysplasia is often identified by clinical exam and plain radiographs
- Normally associated with dislocation, subluxation or being unstable
- Newer evidence and review of literature does not support Adult Dysplasia directly leading to OA (Cooper et al. 2013)
Femoral Acetabular Impingement/Labral Tears

- FAI has 2 main causes that result in repetitive stress to the anterior/superior labrum during terminal ranges of hip motion
- Results in damage to the labrum and acetabular cartilage
- Advanced can have chondral lesions on femur or within the acetabulum
- Combined impingement is combination of Cam and Pincer and most common. Beck et al. 2006 J Bone Joint Surg

Clinical Presentation

- Ejnisman et al. 2011, Anderson et al. 2013 Sports Med Clinics
- Can be insidious onset in 55-85% FAI
- Pain can be present post-trauma or without trauma
- Groin pain most common complaint, but patient can report pain in the lateral, buttock, and thigh
- Some reports of mechanical symptoms and instability
- Often symptoms worsen with activity

Types of FAI

- Normal
- Cam
- Mixed
- Pincer
Diagnosis

• Anderson et al. 2013 Sports Med Clinics
• Kakic et al 2014 British J Sports Med
• Tesla 1.5 or 3.0 offers higher signal ratio sensitive for hip labrum
• Normally 3 planes
• Intra-articular Arthrography can delineate the soft tissue and assist with increased contrast and with resolution
• All areas-the femoral neck junction, acetabulum, cartilage, and labrum must all be reviewed carefully for accurate diagnosis

Positive Imaging findings

• Cam-Impingement demonstrates decreased femoral head-neck alignment/contour, chondrolabral separation, chondral loss around the acetabulum
• Pincer-Impingement demonstrates clear overcoverage at the superior/anterior acetabular rim
• Anterior overcoverage-acetabular retroversion
• Global overcoverage

Clinical Diagnostic test

• Burnett et al. 2006 found 95% sensitivity for Impingement test and 92% sensitivity for c/o groin pain
• Leunig et al. 2005 Orthopedics 90-95% specificity for impingement testing
• Troelsen et al. 2009 Acta Orthopaedica found the Impingement test to have 100% specificity
• Martin et al. 2010 Sports Med Arthroscopy and Arthroscopy
• Recommends using Impingement, Quadrant, and FADIR tests
Clinical Testing

- Shu and Safran et al. 2011 Sports Med Clinics Recommend Apprehension testing
- Anterior-extension and ER
- Posterior- Flex-add IR hip and knee then posterior force
- Lateral- side lying with leg brought into and allowed to hang into adduction

- Philippon and Ejnisman et al. Sports Med Clinics Recommend the Impingement Test
- Flex, ADD, IR with positive anterior pain
- Good for FAI
- Still need thorough history and may need imaging

Labral Tears

Labral Tears
Labral Tears Classifications

- Morphological Alterations
  - FAI/Cam: abnormal femoral head-neck offset-leading to shear at chondrolabral junction, will normally cause detachment of labrum from articular cartilage (Cross et al. 2011 Sport Med Clinics)
  - Pincer/Rim: overcoverage of the acetabulum, labrum compressed between acetabular rib/neck/ coxa profunda and acetabular protrusion considered more global coverage of the femoral head

Adopted from Ejnisman 2011

Labral Tears Classifications

Mixed-Type: combination of both Cam and pincer/rim lesions

- Dysplasia:
  - Functional alterations
  - Instability: ilioptosim impingement-tight, causing compression anterior capsulolabral complex-tear
  - Trauma: Dislocation, crushing/impact injuries bruising and flattening of labrum
  - Degeneration

Shu and Safran 2011

- Tested Compressive and Tensile strength Cadaveric labrums
- Anterior/superior region lower compressive and tensile strength
- Concluded this area may be contributing factor to tears
Smith and Masouros et al 2009

- Suggest 4 primary causes
  - Trauma/laxity anterior capsule
  - Hypermobility
  - Bony impingement-decreased femoral head-neck junction
  - Overhang acetabular rim/retroversion
- Dysplasia

Shu and Safran 2011

- Hip Instability is uncommon due to the design of the hip femoral head to the acetabulum
- Looked at anatomical dissections of the hip capsular ligaments
- Surface area and path origin-insertion
- Instability from repetitive microtrauma identified by sport involving repetitive rotation and loading

Lumbar Root Pathologies

- L2
- Root Syndrome  Segmental Syndrome
- Anterior thigh pain Trigger Points: pectineus,
- DTRS none Sartorius, adductor longus
- Motor deficits-iliopsoas Cellulagic Zone-lateral upper thigh
  - Adductors
  - Sensory- upper anterior thigh
Lumbar Nerve root Pathologies

- **L3**
  - Root Syndrome
  - Segmental Syndrome
  - Pain: Anterior thigh/knee pain
  - Trigger point: Quadriceps
  - DTRs: Patellar
  - Cellulagic zone: Medial thigh
  - Motor: Quadriceps
  - Sensory: Anterior thigh/knee
  - Tension Test: Femoral nerve
  - Femoral nerve palsy: Sensory deficits with medial thigh (Saphenous)
  - Meralgia paresthetica: Result of entrapment lateral femoral cutaneous nerve at inguinal ligament

- **L4**
  - Root Syndrome
  - Segmental Syndrome
  - Pain: Lateral thigh/medial calf
  - Trigger Points: Anterior Tibialis, ITB
  - Motor deficit: Anterior Tibialis
  - Sensory Deficits: Lateral thigh
  - Cellulagic Zone: Medial leg/ankle, anterior knee
  - Tenoperiosteal zone: Medial
  - Tension Test: Femoral nerve/Sciatic

- **L5**
  - Root Syndrome
  - Segmental Syndrome
  - Pain: Buttock, posterior thigh
  - Glute Med, medial hamstrings
  - Lateral thigh/calf, medial foot
  - Cellulagic Zone: Lateral prox thigh
  - DTRs: Proximal Hamstring
  - Motor Deficits: Extensor Hallucis Longus, EDB
  - Sensory Deficits: Lateral calf/medial foot (dorsal/Plantar)
  - Decreased vibration: Lateral malleolus
Lumbar Nerve root Pathologies

- S1
- Root Syndrome
- Pain: Posterior thigh, calf, heal
- Lateral foot/toes
- DTRs: Achilles
- Motor Deficits