Musculoskeletal Biomechanics

BIOEN 520 | ME 527

Session 14A1

Biomechanics of the Hip
Session 13 Review...

- Gait lab tour and demo
- Biomechanical testing lab tour and demo
- Lab 2 assignment
Session 14A1 Overview...

- Hip
- Anatomy
- General function
- Pathology
Hip: Anatomy

- **type of joint:**
  - synovial (diarthrodial)
  - ball and socket
Hip: Anatomy

- synovial joint:
  - ends of bones lined with articular cartilage
  - encapsulated with a fibrous capsule
  - capsule lined with synovium
  - stabilized with ligaments and tendons
Hip: Anatomy

- **bones:**
  - femur
  - pelvis (ilium, ischium, pubis)
Hip: Anatomy

- **femur:**
  - femoral head is spherical
    - superior and medial (125°)
    - anteversion (transverse, 15° to 20°)
  - femoral neck is obliquely orientated
Hip: Anatomy

- **femur:**
  - Q-angle
    - ASIS to patella, subtract from 180°
  - male (12°)
  - female (16°)
Hip: Anatomy

- **femur:**
  - longest, heaviest, strongest
  - 26% of person’s height
  - useful for estimating heights
  - greater and lesser trocanter
Hip: Anatomy

- **pelvis:**
  - largest bone in the body (6 bones)
  - acetabulum is a concave structure
    - anterior, lateral and inferior
  - ossification center in middle
Hip: Anatomy

- capsule: two directions of fibers
  - distal and lateral from pelvis to femur
  - annular fibers (zona orbicularis)
Hip: Anatomy

• ligaments:
  ▪ iliofemoral and pubofemoral
    ▪ iliofemoral: strongest ligament = 350 tensile strength
  ▪ ischiofemoral
  ▪ limit joint motion
Hip: Anatomy

- ligaments:
  - ligamentum teres
    - protects artery
  - zona orbicularis
    - button hole – little stability?
    - stability in distraction?
    - not well understood
Hip: Anatomy

- cartilage:
  - thickest on anterosuperior acetabulum and anterolateral femoral head
  - labrum – fibrocartilage ring, stabilizing all but inferior rim
Hip: Anatomy

- muscles:
  - 22 acting around hip joint
  - sagittal plane - flexion and extension
  - frontal plane – abduction and adduction
  - transverse plane – internal and external rotation
Hip: Function – Range of Motion

- flexion: 120°
- extension: 20°
- internal rotation: 30°
- external rotation: 60°
- abduction: 45°
- adduction: 30°
Hip: Function – General

- transfers load from trunk to lower extremity (and vice versa)
- maintains balance (M/L)
- permits stable rotational movement in 3 planes (circumduction)
- absorbs shock
Hip: Pathology - Fractures

• primarily caused by:
  ▪ high energy impacts
    • fall from height
    • automobile crashes

• osteoporosis
  ▪ chicken v. egg
  ▪ fall then fracture, not fracture then fall
Hip: Pathology - Fractures

**Garden I fracture**
incomplete and minimally displaced.

**Garden II fracture**
complete, nondisplaced.

**Garden III fracture**
complete fracture and partially displaced.

**Garden IV fracture**
completely displaced, with no engagement of the 2 principal fragments.
Hip: Pathology - Fractures

AO Classification of Intertrochanteric Fractures

A1: Simple (2-fragment) fractures
A1.1 Fractures along the intertrochanteric line
A1.2 Fractures through the greater trochanter
A1.3 Fractures below the lesser trochanter

A2: Multifragmentary fractures
A2.1 With one intermediate fragment
A2.2 With 2 intermediate fragments
A2.3 With more than 2 intermediate fragments

A3: Intertrochanteric fractures
A3.1 Simple, oblique
A3.2 Simple, transverse
A3.3 With a medial fragment
Hip: Pathology – Fracture Treatment

- Cannulated Bone Screws
- Compression screw and side plate
Hip: Pathology – Arthroplasty

- **indications:**
  - end stage osteoarthritis (vast majority)
  - hip fracture with interrupted vasculature
  - rheumatoid arthritis
  - congenital deformities

- **332,000 per year in US** (National Hospital Discharge Survey: 2010)

- **forces in hip:**
  - 3x to 4x BW in walking
  - 5x jogging or on stairs
  - 8x stumbling
Hip: Pathology – Arthroplasty
Hip: Pathology – Arthroplasty

- Components:
  - femoral component (stem/ball)
  - acetabular component (cup: shell /liner)
Hip: Pathology – Arthroplasty

- materials:
  - metal and polyethylene
  - ceramic and ceramic, metal and metal
Hip: Pathology – Arthroplasty

- metal and metal – submicron metallic debris
  - hip and articular surface replacement (ASR)
- 11/2013 – J&J agreed to a ~$4B settlement
- http://tinyurl.com/kzlkxm7
Hip: Pathology – Arthroplasty

- increase ion levels (chromium and cobalt)
- metallosis (build up of metals)
- hypersensitivity to metal
- osteolysis and early implant failure
Hip: Pathology – Arthroplasty

- component attachment
Hip: Pathology – Arthroplasty

- cemented advantages:
  - used osteoporotic bone
  - add antibiotic, reduced risk of post-surgical infection
  - dries within 10 minutes, confident it is firmly in place
Hip: Pathology – Arthroplasty

- cemented disadvantages:
  - cement breakdown can lead to loosening, revision
  - cement debris can irritate surrounding tissue
  - rare, but cement can enter blood stream and end up in the lungs – life threatening
Hip: Pathology – Arthroplasty

- cementless advantages:
  - better long-term bond between bone and prosthesis
  - no worry about potential breakdown of cement
Hip: Pathology – Arthroplasty

- cementless disadvantages:
  - require healthy bones
  - patients with low density (osteoporotic) are ineligible
  - up to 3 months for bone to grow into joint component
Hip Function

- motion data
Hip Function

- motion data
Musculoskeletal Biomechanics

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Session 14A2

Biomechanics of the Knee
Session 14A1 Review...

- Hip
- Anatomy
- General function
- Pathology
Session 14A2 Overview...

- Knee
- Anatomy
- General function
- Pathology
Knee: Anatomy

- type of joint:
  - synovial (diarthrodial)
  - hinge
  - 2 joints
    - tibiofemoral
    - patellofemoral
Knee: Anatomy

- bones:
  - femur, tibia, patella, fibula*
Knee: Anatomy

- femur:
  - distal femur - medial and lateral condyle, anterior patellar groove
Knee: Anatomy

- tibia:
  - proximal tibia - medial and lateral condyle, or tibia plateau
  - intercondylar eminence
Knee: Anatomy

- **tibia:**
  - second longest bone in body
  - stronger than fibula, about 85% of BW
Knee: Anatomy

- **patella:**
  - posterior face articulates, two facets
Knee: Anatomy

- patella:
  - largest sesamoid in the body
Knee: Anatomy

- ligaments:
  - anterior and posterior cruciate (ACL and PCL)
  - limits anterior and posterior tibial displacement
  - limits internal/external tibial rotation
Knee: Anatomy

- ligaments:
  - medial and lateral collateral (MCL and LCL)
  - limits varus/valgus knee motion
Knee: Anatomy

- capsule: not as fibrous as the hip
  - anatomy is quite complex (Fig 5, 6, 7, 8, 9)
Knee: Anatomy

- patellar tendon
  - ligament vs. tendon
Knee: Anatomy

- infrapatellar fat pad (Hoffa’s fat pad)
  - cushions patella
  - can become impinged
Knee: Anatomy

- cartilage:
  - all articular surfaces femur, tibia, patella
Knee: Anatomy

- cartilage:
  - medial and lateral meniscus
  - fibrocartilage, cushioning
Knee: Anatomy

- cartilage:
  - medial and lateral meniscus
  - fibrocartilage, cushioning
Knee: Anatomy

Superior (top) view of right knee

- Fibula
- Medial meniscus
- Lateral meniscus
- Tibia (shinbone)
- Front of knee
- Back of knee
Knee: Anatomy

- muscles: extensors
  - quadriceps
Knee: Anatomy

- muscles: flexors
  - hamstrings
Knee: Anatomy

anterior cruciate ligament
lateral condyle of femur (articular surface)
popliteus tendon
fibular collateral ligament
lateral meniscus
transverse ligament of knee
head of fibula
Gerdy's tubercle
posterior cruciate ligament
medial condyle of femur (articular surface)
medial meniscus
tibial collateral ligament
medial condyle of tibia
tibial tuberosity
adductor tubercle (medial epicondyle of femur)
medial condyle of femur (articular surface)
medial meniscus
tibial collateral ligament
medial condyle of tibia
posterior cruciate ligament
anterior cruciate ligament
posterior meniscofemoral ligament
lateral condyle of femur (articular surface)
popliteus tendon
fibular collateral ligament
lateral meniscus
head of fibula
Knee: Function – Range of Motion

• flexion: 160°
• extension: 0°
• internal rotation: 0° or 30° with knee flexed
• external rotation: 0° or 45° with knee flexed
• abduction: 0°
• adduction: 0°
Knee: Function – General

- transfers load from thigh to lower leg
- allows distance between trunk and ground to be varied; works essentially by axial compression under gravity
- allows long axis rotation when knee is flexed
- great stability in full extension
  - injuries are fractures of articular surface or ligament rupture
- great mobility after some flexion
  - knee unstable - ligaments and menisci at risk
Knee: Function – General

- knee loads during walking (female)
- 3.9x BW level, 8x BW downhill

Kuster, JBJS 1997
Knee: Function – General

- hinge joint – but axis changes, so femur slides on tibia
- screw home mechanism
  - external tibial rotation - knee extends (stance)
  - internal tibial rotation - knee flexes (swing)
  - caused by tibial and femoral epicondyles
Knee: Pathology - Osteoarthritis

- 4\textsuperscript{th} most common part of body (0.9%), after hands (7.3%), feet (2.3%) and hip (1.5%)
- 94-97% of all TKR due to OA
Knee: Pathology - Arthroplasty

- 719,000 per year in US (National Hospital Discharge Survey: 2010)
Knee: Pathology - Arthroplasty

- fixed bearing v. mobile bearing
Knee: Pathology - Arthroplasty

- mobile bearing unicompartmental knee replacement
Knee: Pathology - Arthroplasty

- Revision surgery
  - aseptic loosening (30%)
  - infection (20%)
  - pain, instability, stiffness (30-40%)
  - other factors (10-20%)
Knee: Pathology – ACL tear

- internal rotation of tibia
- anterior displacement of tibia
Knee: Pathology – ACL tear
Knee: Pathology – ACL reconstruction

- strengthen knee muscles
  - quads = PCL
  - hamstrings = ACL
- bracing the knee
Knee: Pathology – ACL reconstruction

- types of surgery: patellar tendon graft
  - gold standard, 90-95% success
  - donor site pain is main limitation
Knee: Pathology – ACL reconstruction

- types of surgery: hamstring tendon graft
  - interference screw (bioreabsorbable)
  - longer to heal, harvest is complex, hamstring weakness
Knee: Pathology – ACL reconstruction

- types of surgery: others?
  - quadriceps tendon graft
    - similar issue to hamstring tendon
  - allograft
    - blood borne disease
Knee Function

- motion data
Knee Function

- motion data