Objectives

- Participant will review the relevant bony and soft tissue anatomy of the pelvic girdle
- Participant will review the normal biomechanics of the sacrum and innominate

Objectives

- Participant will review the systemic diseases and mechanical disorders which can affect the pelvic girdle
- Participant will review the mechanical impairments common to the pelvic girdle

ANATOMY REVIEW

Sacrum

- Fusion of five sacral vertebrae
  - S1-4 SPs/laminae fused at midline
  - S5 SP/lamina remains unfused at midline
  - S1-5 TPs fused laterally

Sacrum

- Articulating surface
  - L-shaped running between S1 and S3
  - Essentially concave
  - Hyaline cartilage
  - Propeller form
    - Change in orientation between S1/2 and S3
**Innominate**

- Fusion of ilium, ischium, and pubis
- Ilium articulating surface
  - L-shaped running just superior to PSIS and inferior to PIIS
  - Essentially convex
  - Fibrocartilage

**Innominate**

- Pubis articulating surface
  - Symphysis
  - Hyaline cartilage with fibrocartilage disk
  - Primary support from ligaments
    - Superior pubic ligament
    - Arcuate ligament
      - Insertion site for adductor longus and rectus abdominus

**Sacroiliac Joint Ligaments**

- Ventral sacroiliac
  - Weakest of SI ligaments
  - Thickening of anterior and inferior parts of joint capsule (Williams 1995)
  - Prevents out flare of the joint

**Sacroiliac Joint Ligaments**

- Interosseous
  - Strongest of SI ligaments
  - Completely fills the space between the lateral sacral crest and iliac tuberosity
  - Primary barrier to direct palpation of the joint

**Sacroiliac Joint Ligaments**

- Long dorsal
  - Lateral sacral crest of S3/4 to PSIS and iliac crest
  - Medial fibers blend with thoracolumbar fascia, erector spinae, multifidus, and sacrotuberous ligament
  - Frequent area of pain in patients with pelvic dysfunction (Fortin 1999)

**Sacroiliac Joint Ligaments**

- Long dorsal
  - Palpable just inferior to PSIS
  - Tension increased with counternutation, loading of sacrotuberous ligament, and contraction of erector spinae
  - Tension decreased with contraction of latissimus dorsi and gluteus maximus
  - Vleeming 1996 and 1997
Sacroiliac Joint Ligaments

- **Sacrotuberos**
  - S3-5 to PSIS and ischial tuberosity
  - Attachments with gluteus maximus, biceps femoris (some individuals), multifidus, and piriiformis
  - Fibers blend with long dorsal ligament

- **Sacrospinous**
  - Lateral aspect of sacrum and sacrum and coccyx to ischial spine
  - Blends with SI capsule proximally (Willard 1997)
  - Closely connected with coccygeus muscle

- **Iliolumbar**
  - 5 bands
  - Arise from TPs of L4 and L5 to SI ligaments and iliac crest
  - Blends with quadratus lumborum
  - Provides coronal and sagittal stability to Lumbosacral junction

**Muscles**

- **Transverse abdominus**
  - Attachments to inguinal ligament, iliac crest, thoracolumbar fascia, diaphragm
  - Blends with internal oblique
  - Local system
    - Tonic activity for 100% of gait cycle at speeds less than 3m/s (Saunders et al 2004)
    - Preparatory activation for rapid arm movement
  - Action: Increase intraabdominal pressure

- **Rectus abdominus**
  - Attachments from 5th-7th costal cartilages and xyphoid process to pubic crest and tubercle
  - Joins with transverse abdominus, internal oblique, pyramidalis, and adductor longus to stabilize pubic symphysis
  - Global system
  - Action: Trunk flexion

- **Internal oblique**
  - Attachments from lower three ribs to inguinal ligament, iliac crest, thoracolumbar fascia, abdominal aponeurosis
  - Global/local systems (O’Sullivan 2000)
  - Action: Trunk flexion and ipsilateral sidebend and rotation
Muscles

- **External oblique**
  - Attachments from lower eight ribs to iliac crest and abdominal aponeurosis
  - Blends with contralateral external and internal oblique
  - Global system
  - Action: Trunk flexion, ipsilateral sidebend and contralateral rotation

- **Iliopsoas**
  - Attachments from lumbar vertebrae and discs and upper 2/3 of iliac fossa to lesser trochanter of femur
  - Global system as a whole
  - Local system if taken separately
  - Decreased cross-sectional areas of psoas in subjects with HNP and radiculopathy (Dangaria & Naesh 1998)
  - Action: Hip flexion, Abduction, ER; increased lumbar lordosis

- **Quadratus lumborum**
  - Attachments from iliolumbar ligament and iliac crest to 12th rib and TPs of L1-4
  - Global/local system (Gibbons et al 2002)
  - Action: Trunk sidebending and extension; Anchor 12th rib for inspiration

- **Deep Multifidus**
  - Attachments from lamina and zygapophyseal joint to mammillary process two levels below
  - Blends with sacrotuberous ligament in pelvis
  - Local system
    - Preparatory contraction for rapid arm movements into flexion/extension (Mac Donald et al 2009)
    - Phasic activity corresponding to time of increased vertical loading during gait (Saunders et al 2004)
  - Action: Intervertebral spinal compression and posterior shear

- **Superficial Multifidus**
  - Attachments from spinous process to lamina three levels below
  - Global system
  - Action: Extension and contralateral rotation

- **Erector spinae**
  - Attachments spanning posterior thoracic spine to pelvis
    - Longissimus thoracis
    - Iliocostalis lumborum
  - Local/Global systems (Bergmark 1989)
  - Action: Extension and ipsilateral sidebending
Muscles

- Piriformis
  - Attachments from anterior S2-4, anterior PIIS, and sacrotuberous ligament to greater trochanter
  - Global system
  - Action: ER, ABD at 90° flexion, IR at max flexion

Muscles

- Gluteals
  - Attachments from iliac crest, lateral sacrum, and coccyx to ITB and femur (Max)
  - Attachments from iliac crest to greater trochanter (Med/Min)
  - Global system
  - Action: Extension and ER (Max); Abduction and rotation (Med/Min)

Muscles

- Diaphragm
  - Attachments from xyphoid, lower six ribs to bodies and disks of L1-3 (right) and L1-2 (left)
  - Local system (Hodges & Gandevia 2000)
    - Maintains activity for respiration along with increased preparatory and tonic activation during rapid/sustained arm movement
    - Complementary, opposite activity pattern to TrA
    - Action: Inspiration, Increased intraabdominal pressure

Muscles

- Pelvic floor
  - Levator Ani Group
    - Pubococcygeus, puborectalis, and iliococcygeus
    - Blends with the endopelvic fascia above and obturator internus laterally
    - Ischiococcygeus
      - Ventral aspect of sacrospinous ligament and ischial spine to sacral apex S4 and S5

Muscles

- Pelvic floor
  - Local system
    - Tonic activation in standing and with rapid arm movements (Smith et al 2007)
    - Increased activation during quiet and resisted expiration/cough (Neumann & Gill 2002)
    - Significant increase in SIJ stiffness with contraction of group (Post-Goudswaard et al 2004)
    - Strong synergist with TrA (Hodges et al 2007)
  - Action (group): Provide support for urethra and vagina
  - Action (ischiococcygeus): Sacral counter-nutation

Muscles

- Adductors
  - Attachments from pubic ramus and ischial tuberosity to femur from lesser trochanter to knee
  - Global system
  - Action: Adduction, IR, and flexion, extension for 1/3 of Ad magnus
**Thoracolumbar Fascia**

- Attachment site for transverse abdominus, internal oblique, erector spinae, multifidus, biceps femoris, gluteus maximus, latissimus dorsi, lower trapezius, external oblique
- Connections to lumbar spine and pelvis are key for providing stabilization

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**BIOMECHANICS REVIEW**

**SI Joint Mobility**

- Small amounts of angular (1°- 4°) and translatory motion (1-3mm)
- Variable between individuals
- Symmetrical within an individual
  - Buyruk et al 1997, Damen et al 2002

**Naming SIJ Motion**

- Innominat motion
  - Anterior Rotation
  - Posterior Rotation

- Sacral motion
  - Flexion (Nutation)
  - Extension (Counternutation)

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**Anterior Rotation**

- Forward rotation of the innominate
- Occurs unilaterally with extension of the freely swinging leg
- Inferior/posterior glide of ilium on sacrum

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**Posterior Rotation**

- Backward rotation of the innominate
- Occurs unilaterally with hip flexion
  - Superior/anterior glide of ilium on sacrum
- Occurs unilaterally with single limb stance
  - Superior/posterior glide of ilium on sacrum

Hungerford 2002
Posterior Rotation

- Conjunct motion in weight bearing and non-weight bearing innominates
- Combination of rotation and sidebending usually opposite
  Hungerford 2002

Sacral Flexion

- Forward motion of the sacral base
- Occurs in sitting or standing (Sturesson et al 2000)
- Increases during initial stages of forward and backward bending (Levin 1997)
- Inferior/posterior glide of sacrum on ilium

Sacral Extension

- Backward motion of the sacral base
- Occurs in supine lying
- Occurs in fully slouched position
- Anterior/superior glide of sacrum on ilium

Open Pack Positioning

- Sacral extension and anterior innominate rotation share complimentary arthrokinematics
- Limited ligamentous tension and joint congruency
- Often a position of fixation in patients with dysfunction

Close Pack Positioning

- Sacral flexion and posterior innominate rotation share complimentary arthrokinematics
- Maximum ligamentous tension and joint congruency
- Facilitates maximum load bearing

Mechanisms of Load Bearing

- Form closure
  - Stability created by the joint surfaces, shape of the bone, and ligamentous integrity
- Force closure
  - Stability created by the myofascial system
  - A component of inner and outer muscles working together

The combination of form/force closure creates a self locking mechanism that stabilizes the SI joint during loading.
Form Closure

- Ligaments that tighten with nutation
  - Interosseous
  - Sacrotuberosus
  - Sacrospinous
- Ligaments that tighten with counternutation
  - Long dorsal

Force Closure

- Anterior oblique system
  - Internal/external oblique
  - Abdominal fascia
  - Contralateral adductors

- Superficial posterior oblique system
  - Latissimus dorsi
  - Gluteus maximus
  - TLF

- Deep longitudinal muscle system
  - Erector spinæ
  - TLF
  - Biceps femoris

- Inner muscle unit
  - Multifidus
  - Diaphragm
  - TA
  - Pelvic floor
Roles of Local Muscle System

- Increase intraabdominal pressure
  - Achieved through contraction of the diaphragm and transverse abdominus (Hodges et al 2003)
  - Provides resistance to flexion

- Increase tension in thoracolumbar fascia
  - Transverse abdominus has direct pull on deep lamina of thoracolumbar fascia (Barker and Briggs 1999)
  - Multifidus contraction "pumps up" TLF (Vleeming et al 1995)
  - Recruitment of myofibroblasts in TLF (Schleip et al 2005)

- Increase articular stiffness
  - Transverse abdominus contraction approximates the ilia anteriorly
  - Multifidus and levator ani force couple controls nutation/counternutation
  - Snijders et al 1997

PATHOLOGY REVIEW

Systemic Diseases

- Inflammatory disorders
  - Ankylosing spondylitis
    - Bilateral, chronic, nontraumatic, young males
  - Reiter's syndrome
    - Urethritis and episodic conjunctivitis
  - Rheumatoid arthritis
    - Bilateral, chronic, nontraumatic, nodules
  - Psoriatic spondylitis
    - Skin lesions

- Infectious disorders
  - Pyogenic arthritis
    - Joint pain with constitutional symptoms
  - Increased risk in post-ops, chronic RA, diabetics, lupus, and sickle cell anemia
  - Tuberculosis
    - Cough with constitutional symptoms
  - Increased risk in low socioeconomic status and healthcare workers
Systemic Diseases

- Metabolic disorders
  - Gout
    - Inflamed first MTP, kidney stones
  - Hyperparathyroidism
    - Generalized weakness
    - Depression
    - Confusion
    - Nausea

- Miscellaneous
  - Paget’s disease
    - Abnormal bone remodeling
    - Bone is enlarged, brittle, and prone to breakage
    - No distinctive symptoms or signs
  - Gaucher’s disease
    - Osteopenia
    - Anemia
    - Excessive fatigue
    - Thrombocytopenia
    - Yellow spots in the eyes
    - Nosebleeds

Mechanical Disorder Prevalence

- About 13-30% in patients with low back pain
  - Schwarzer et al. 1995
- About 20% in patients with CLBP below L5-S1
  - Maigne et al. 1996

Mechanical Disorder Etiology

- Effects on form closure
  - Trauma
  - Aging
  - Pregnancy
- Effects on force closure
  - Postural strain

Trauma

- Macrotrauma
  - Sprain/displacement
    - Fall on buttock
    - Stepping off a curb
    - Lift and twist
    - Overzealous kick

Aging

- 2nd & 3rd decade
  - Development of convex & concave relationship and ridges/depressions
- 4th & 5th decade
  - Irregular joint surfaces & cartilage fibrillation
  - Osteophyte formation
  - Capsular thickening
- 6th & 7th decade
  - Fibrous interconnections between articular surfaces
  - Exposed subchondral bone
**Pregnancy**
- Relaxin release primarily between 4th and 7th month
- 3rd trimester
  - Hypermobile counternutated position of the sacrum needed to open the pelvic inlet
- Hypermobile state can persist post delivery leading to post partum back pain
  - Pain 7/10 with asymmetric laxity of SIJ predictive of post-partum pain (8 weeks)
  - Damen et al 2002

**Postural Strain**
- Repetitive microtrauma or maintenance of sustained postures
  - Fatigue susceptibility in contractile system
  - Increased incidence of symptoms if form closure system has been previously compromised

**Mechanical Impairments**
- Stiffness from joint fibrosis
- Stiffness from muscle hypertonicity
- Stiffness from underlying instability and lock
- Instability/weakness

**Assessment of Stiffness**
- History and Observation
- ROM/Flexibility Testing
  - Fibrosis: Limited ipsilateral rotation and contralateral sidebend
- Special Testing
  - Palpation for position/condition
    - Iliac crest
    - ASIS
    - PSIS
    - Pubic tubercle
    - “Butt gripper” identification

**Stiffness—History and Observation**
- Joint fibrosis
  - Systemic inflammatory or traumatic
  - Patient usually presents several months after onset with pain in opposite SIJ (non-fibrotic joint)
- Hypertonicity
  - Insidious, pregnancy, or sport-related
    - MOI repetitive ER or asymmetrical vertical loading
  - Out-toed stance and gait
- Lock
  - Traumatic with immediate pain
    - Fall on buttocks, BT with heald, or extremity compressive load
  - May walk in forward flexion, lateral shift
  - Limited weight bearing or forward bending
Stiffness–Palpation for Position

- Upslip/Downslip of Innominate
  - Pure vertical displacement
  - All landmarks appear high or low
  - Associated with distractive or compressive force applied vertically through the leg or ischial tuberosity

- Inflare/Outflare of Innominate
  - Pure transverse plane displacement
  - ASIS positioned closer or away from midline/greater trochanter
  - ASIS/Pubic tubercle prominent or deep
  - Associated with hip tightness (myofascial) or fall directly onto ASIS or PSIS

- Anterior/Posterior Rotation of Innominate
  - Sagittal plane displacement
  - PSIS elevated or depressed
  - ASIS and Pubic tubercle opposite PSIS
  - Associated with trunk/hip myofascial tightness or fall directly onto ischial tuberosity

- Sacral torsion
  - Combined frontal and transverse plane displacement
  - Sacrum is sidebent and rotated to the same side
  - Associated with trunk/hip myofascial tightness and trauma via twisting or hip hyperflexion/extension

- Sacral unilateral flexion/extension
  - Combined frontal and transverse plane displacement
  - Sacrum is sidebent and rotated to the opposite side
  - Associated with trunk/hip myofascial tightness and trauma via twisting or hip hyperflexion/extension

Stiffness–Palpation for Condition

- “Butt gripper” (Lee 2004)
  - Overactivation of the deep external rotators
  - Palpable large divot posterior to greater trochanter
  - Limited hip flexion, adduction, IR
  - Subject to posterior innominate rotation positional fault
Assessment of Instability

- History
  - 17-35 years at initial onset
  - Unilateral sx
  - Mechanism of injury consistent with direction of instability
  - Aggravating factors consistent with direction of instability
- ROM/flexibility
- Strength Testing
- Special Testing
- Palpation

Craniocaudal Instability

- Onset
  - Sudden or repetitive vertical loading through lower extremity or ischial tuberosity
- Aggravating
  - Sustained vertical loading in sitting, walking, standing

May have pubic symphysis pain, especially if related to pregnancy

Additional aggravating factors
- Abduction/ER of hip
- Rolling over in bed
- Getting out of car

Anteroposterior Instability

- Onset
  - Traumatic via lifting/twisting
- Aggravating
  - Sustained forward bending
  - Gower’s sign upon return to standing
- Palpation
  - Accompanied with deep ER hypertonicity

Final thoughts...

- Stress relieving joint
- Pain generator in about 20% of patients
- History of trauma or pregnancy
- Stiffness/weakness impairments often co-exist

Thank You