Sex Based Considerations in Caring for Common Sports Injuries

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The AAOS Women’s Health Issues Advisory Board (WHIAB) seeks to advocate, advance, and serve as a resource on sex and gender differences in musculoskeletal health.

Females suffer from injury/disease in different ways than males. Recognizing sex-related differences is critical to optimizing patient care.

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Patellofemoral Pain Syndrome

Definition
- Anterior or retropatellar knee pain with activities such as prolonged sitting, running, stair-climbing, squatting.10
- General term with broad definition, often used when other knee pathology has been ruled out.
- Common diagnosis, especially in young athletes.9

Sexual Dimorphism
- Female athletes are more at risk than males of experiencing patellofemoral pathology.1,3,7,10
- Proposed causes of this dimorphism include anatomic, hormonal, and neuromuscular factors:
  Anatomic
  - Differences in Q-Angles between the sexes is commonly referenced as a possible reason for differences in knee pathology.1,3
  - Directional pull of quadriceps muscle may be impacted by Q-angle
  - However, there is no evidence that increasing Q-angle leads to increased risk of patellofemoral pain or other knee issues
  - There are sex-specific differences in distal femoral shape, such as the trochlear groove, that may contribute to mal-tracking and pain.6

Hormonal
- Increased laxity of joints may put more stress on the knee, leading to pain.8

Neuromuscular
- Hip muscle strengthening has been shown to improve knee pain in females. Hip kinematic studies show females tend towards more internal rotation of the femur and greater hip adduction with running.2,4
- During a squat, those with patellofemoral pain also tend to have more femoral internal rotation.
- Knee kinematic studies have shown sexual dimorphism in muscle activation of both the kicking and the supporting lower extremities during a soccer kick.4

Treatment
- Mainstay of treatment remains physical therapy, with hip strengthening becoming a bigger focus.2,5,7,8
- Sometimes a role is found for surgery, but this is usually associated with more specific diagnoses such as patellar instability.

References:

Achilles Tendon Rupture

Prevalence and Incidence
- The prevalence of Achilles tendon rupture is 6-37/100,0001.
- Acute Achilles tendon rupture is more common in men.
- The incidence of Achilles tendon rupture has increased over all age groups over a 33 year period in both young male persons (most common) and elderly females.2
- The male: female ratio of 2.81:1.3

Etiology and Location
- Nonacute pathology for rupture is more common in women, with the age in women slightly higher.
- Whether degeneration or not, the requirement of eccentric contraction of sufficient force is still required.4
- The most common location is 3-6 cm above the calcaneal insertion.

Sexual Dimorphism
- Sex may affect outcomes after acute Achilles tendon rupture. Overall, male patients have better outcomes at 1 year compared to female patients, regardless of treatment method.5
- A study in rats found that female sex hormones had an inhibitory effect on muscle fiber diameter. This proposed a possible protection to risk of rupture in women.6
- Stiffness of tissue and lever arm length affects increase risk of injury in men. Men have higher joint stiffness and higher lever arm. This increases the strain on the tissues when stretched for a given change in joint angle.7
- Moderate evidence that decreased tendon fibral size also increases the risk in women.
- Limited evidence was found for other modifiable factors such as increased body weight, oral corticosteroid use.8
- One important non-modifiable risk factor for women is increasing age.

Future
More studies are needed to further identify and determine the racial differences and what preventative measures might prevent Achilles tendon rupture acutely in young males and elderly females.
**Epidemiology**

- **Highest Female:Male rate differences:** Basketball and Team Handball
  
- **Prevention and post ACLR rehab programs:** No sex differences
  
- **Mechanisms of Injury:** No sex difference in noncontact mechanisms; difference in weight bearing pivot shift

**Extrinsic Risk Factors**

- **Kinematics:** Valgus Collapse and increased knee abduction moment
  - 205 female athletes, 9 ACL tears: Greater abduction moment predicted ACL injury p<.001
- **Biomechanical/Neuromuscular:** Proximal Control
- **Mini Squat, Normal Subjects:**

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
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<tbody>
<tr>
<td>Pelvis</td>
<td>Level</td>
<td>Contralateral Drop</td>
</tr>
<tr>
<td>Hip</td>
<td>No Rotation</td>
<td>Internal Rotation and Adduction</td>
</tr>
<tr>
<td>Knee</td>
<td>0° Varus/Valgus</td>
<td>Valgus</td>
</tr>
<tr>
<td>Tibia</td>
<td>Neutral</td>
<td>External Rotation</td>
</tr>
<tr>
<td>Foot</td>
<td>Flat</td>
<td>Pronation</td>
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<tr>
<td>Back</td>
<td>Flat</td>
<td>Lordotic</td>
</tr>
<tr>
<td>Pelvis</td>
<td>Neutral</td>
<td>Anterior Tilt</td>
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</tbody>
</table>

**Intrinsic Risk Factors**

- **Hormonal / Joint Laxity:** Data are insufficient to make any conclusive statement regarding menstrual cycle of knee laxity and on the rate of ACL injury in females
- **The COL5A1 Gene Is Associated With Increased Risk of ACL Tears in Females:** Gene that encodes alpha1 chain of type 1 collagen ACL tears type 5 collagen Achilles tendon injuries. Hypermobility (excessive joint laxity) associated with increased incidents of musculoskeletal injury
- **Notch Size:** No Sex Differences; Smaller Notch and Ratios = Greater ACL Tear Rate
- **Tibial Plateau Geometry:**
  - No Sex Difference
  - Tibial Plateau Risk Model: Medial and Lateral Slope and Medial Tibial Depth
  - Odds Ratio (Hashemi/Gibson): 1 mm ↓ MTP and 1° ↑ Posterior Slope: Females: 3.58 / Males: 4.18

**Surgical Management**

- **Graft Choice:** No sex difference; do not change based on cosmetic concerns
- **Pearls:** For the smaller, shorter patient: Adjust femoral fixation; Use suspension or bioabsorbable devices; Avoid iatrogenic ITB Syndrome

**Outcomes**

- **Graft Failure/Future Surgeries:** Meta Analysis 13 studies – no sex differences in Graft Failure (8); Contralateral ACL Rate (3); Laxity Post OP (6)
- **Return to Play/Activity Level:** Moon Study
  - 100 Soccer Athletes (55) Male (45) Female
  - Average age 24.2 years
  - 7 year follow up 30% still playing
  - Females more likely to have ACL Surgery (%20 vs %5 p=.03)
  - Older athletes and females less likely to RTP p=0.37
  - 2 Year F/U Females Lower Activity (OR=0.60)3
- **Development of Osteoarthritis:**
  - Longer term Registry follow up needed
- **Swedish ACL Registry:**
  - 100 Soccer Athletes (55) Male (45) Female
  - Average age 24.2 years
  - 7 year follow up 30% still playing
  - Females more likely to have ACL Surgery (%20 vs %5 p=.03)
  - Older athletes and females less likely to RTP p=0.37
  - 2 Year F/U Females Lower Activity (OR=0.60)3

**References:**

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- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2738443/
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- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2738443/
Shoulder Instability and Ligamentous Laxity

Is There Sex Difference in Shoulder Instability?

- NIH Revitalization Act of 1993: Requires all NIH-supported human subjects research include and analyze the impact on women & minorities
- Multi-Directional Shoulder Instability (MDI) is thought to be more common in females: Females comprise <50% of the population reported in clinical series on MDI
- Traumatic Shoulder Dislocation data mixed results: Question whether females have inferior outcomes with arthroscopic Bankart stabilization

Epidemiology of Shoulder Dislocation

Incidence in Shoulder Dislocations
- Overall: 0.08-0.24/1000 person-years
- Military: 1.69/1000 person-years (Cadets: 4.35/1000 person-years)
- Male: 1.82 vs. Female 0.90
- Males 2.6 times more likely to present to emergency department for shoulder dislocation relative to males
- White 1.78 > Other 1.59 > Black 1.41
- Inverse relationship with age vs. direct relationship with activity level
- Subluxation events >> dislocation events

Return to Play
- Approximately 3:4 athletes will return and complete season after in-season anterior shoulder instability
- Subluxation events 5.3x more likely to return to sport vs. dislocation events
- Did not look at sex based differences

Sex-Based Differences in Anatomy

Glenoid Morphology Associated with Instability
- Tall and Thin less stable than Short and Wide
- Increasing coraco-humeral distance proportional to instability risk

Glenoid Dimensions Vary by Race and Sex
- Females have significantly small glenoids (height and width) vs. males
- Females have significantly higher inclination angles vs. males
- Glenoid retroversion increased for Whites vs. Blacks
  - No significant difference for sex

Sex Differences in Range of Motion
- Variations on study population size, design, and measuring techniques contribute to confusion and variation on body knowledge
- Females have greater ROM vs. Males in all planes of motion
  - True in PROM & AROM (PROM > AROM)
  - Race, Occupation, Sports Participation no effect on shoulder ROM
  - Motions with greatest difference was abduction & external rotation
- Dominant vs. Non-Dominant extremity range of motion
  - Sufficient magnitude to call into question of contra-lateral limb as internal reference point
- Questions of statistical vs. clinical significance
  - Especially for abduction-external rotation for the dominant shoulder in athletic populations

Sex Differences in Ligamentous Laxity

- Prevalence of generalized joint laxity between 8.8% and 64.6%
- 45% of girls and 29% of boys have hypermobile fingers
  - Suggestion of a association between hypermobility in girls and physical activity and body mass index
- Association extends after puberty
- No associations were seen in boys

Recurrent Shoulder Instability

Variety of injury and patient related factors may contribute to risk of recurrent shoulder instability

Sex Bias in Scoring Instruments

Overall health assessment + disease & site specific outcomes measures necessary
- Instruments also need to measure patients’ perception of health status
- Instrument Bias
  - Outcomes may vary due to factors other than shoulder pain, impairement, or disability
  - Effect of demographics in scoring instruments TJA
  - Evaluation of Constant-Murely, UCLA, ASES, SPADI, Oxford
  - Significantly higher total normalized scores for men
  - Constant-Murely most susceptible to gender bias, especially on the strength subscale
    - Men scored 8.3 points higher than women (out of 25)
  - UCLA susceptible to gender bias for range of motion
  - Oxford susceptible to gender bias for pain subscale
  - Hand dominance had no significant effect (Role of Confirmation bias?)

Conclusions

- Based on currently available literature, females seem to have lower rates of traumatic instability and recurrent instability
- Females have higher rates of generalized ligamentous laxity
- Few studies methodologically based to look for sex-based differences in shoulder instability
- Few studies sufficiently powered to look for sex-based differences in shoulder instability
- Gender bias in current outcomes measures identified
- Role of confirmation bias unknown

References:
Concussion

Overview

- **Concussion**: a complex pathophysiological process affecting the brain, induced by biomechanical forces.\(^1\)
- Incidence in US increasing. Approx. 1.6 - 3.8 million concussions each year.\(^2\)
- 5 percent of high school athletes will sustain a concussion each year.

Why look at sex?

- Recent literature suggests a sex-related difference
- Several studies indicate that in sports like soccer and basketball, females report more concussions than males.\(^3,4,5,6\)
- Female athletes may sustain more severe concussions with greater cognitive deficits and a longer recovery period.\(^7,8,9\)

Why the differences?

- **Biomechanical differences**: Women have less head/neck mass, resulting in greater reactive forces and 50% more acceleration during head trauma.\(^10,11\)
- **Hormonal differences**: Several studies have looked at adverse effects of estrogen on the brain after mTBI (mild traumatic brain injury).\(^12\)
- Patients with high levels of progesterone had worse outcomes after a mTBI.

Conclusions

- Literature suggests potential sex differences, but there is conflicting data.\(^13,14\)
- The disparity can be attributed to:
  - Different populations
  - Reporting bias (retrospective studies)
  - Male athletes may be more likely not to report a concussion\(^15\)
- Team physicians should have a high index of suspicion for concussion with any head trauma sustained, regardless of sex.
- Further research on concussions to determine the differences in incidence, symptom presentation and return to play criteria in men and women is still necessary.

References:


Table 1. Studies that found a sex-related difference in concussion incidence

<table>
<thead>
<tr>
<th>Primary Author</th>
<th>Year of Publication</th>
<th>Study Design</th>
<th>Patients studied</th>
<th>Evaluation tools</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marar</td>
<td>2012</td>
<td>Descriptive epidemiologic</td>
<td>1,936 high school athletes</td>
<td>Reported concussions</td>
<td>Females sustained twice as many concussions than males in soccer, females sustained 30% more concussions in volleyball</td>
</tr>
<tr>
<td>Lincoln</td>
<td>2011</td>
<td>Descriptive epidemiologic</td>
<td>158,430 high school athletes</td>
<td>Electronic medical record keeping</td>
<td>Females had double the risk of concussions than male athletes</td>
</tr>
<tr>
<td>Gessel</td>
<td>2007</td>
<td>Descriptive epidemiologic</td>
<td>100 high schools, 180 colleges</td>
<td>Reported concussions, electronic medical record keeping</td>
<td>In high school sports played by both sexes, females sustained a higher rate of concussions</td>
</tr>
<tr>
<td>Covassin</td>
<td>2003</td>
<td>Cohort study</td>
<td>882 collegiate athletes reporting a concussion</td>
<td>NCAA Injury Surveillance System</td>
<td>Female basketball players had an increased risk for concussion. Females sustained a higher percentage of concussions than male athletes in games</td>
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Stress Fracture Risk in Athletes

**Definition**

Stress fractures are overuse injuries that occur with submaximal repetitive impact, usually in weight-bearing bones. Stress fractures are common and may represent up to 10% of all sports injuries. Stress fractures can develop when muscle fatigue does not allow normal dissipation of energy at impact, causing excess forces on bone. Typically, bone is able to remodel and adapt to gradual increasing loads. If the repetitive load is increased more rapidly than bone is capable of responding, areas of bony resorption may lead to micro-damage. If overuse continues without interval healing, a stress fracture occurs. In addition, if bone is not normal (low bone mineral density or osteopenia is present) stress fractures can occur at a lower threshold.

**Incidence**

Female athletes, dancers, and military recruits are at increased risk for developing stress fractures. Compared to their male counterparts, females’ risk for stress fracture may be increased by as much as 1.5-12 times.

**Multifactorial Etiology**

Stress fractures can occur in normal bone that is subject to increased repetitive loading without adequate time for repair and remodeling.

- **Change in Training /Change in Shoes:** An increase in the time or distance of training, or change in running training (running on hard surfaces ≥2/3 of the time), increases occurrences of stress fractures.
- **Biomechanical Factors:** Female pelvis are typically wider, with increased valgus at the femoral neck and knees.
- **Estrogen:** When females develop amenorrhea or oligomenorrhea, decreased estrogen leads to decreased bone mass, predisposing stress fractures.
- **Disordered Eating:** Females involved in appearance sports/activities that are judged subjectively (gymnastics, dancers, cheerleaders, figure skaters) have a high incidence of disordered eating.
- **Energy Deficit:** Endurance runners and triathletes may strictly limit caloric and nutritional intake, leading to a relative energy deficit.
  - The interrelationship of disordered eating/energy deficit plus menstrual abnormalities plus bone loss is called the Female Athlete Triad. The Triad is a major risk factor for stress fractures, including recurrent and non-healing stress fractures.

**Clinical Presentation**

- **History:** Runners account for the majority of stress fracture cases, presenting with a sudden increase in running distance, intensity, duration, speed, a change in running surface, or change in shoe wear with weeks to months of pain described as a deep ache. It is not associated with night or rest pain. A unicortical incomplete stress fracture may become complete if the patient tries to “run through the pain.”
  - This scenario is often seen with stress fractures of the anterior tibia, tarsal navicular, base of the fifth metatarsal, and on the superior tension side of the femoral neck.
  - Taking a careful history of any training change as above, as well as a thorough history of menstrual and nutritional status is critical. Females with disordered eating may not be particularly forthcoming about these behaviors, so gaining the confidence of the athlete along with her parents, coaches and trainers can be helpful.
- **Physical Exam:** Examination should include stance, gait, and mechanical bony alignment. The “Hop Test” may reproduce pain at the stress fracture site. Point tenderness and local swelling and/or periosteal thickening may be palpable. Bone percussion may reproduce pain at the fracture site. Height, weight, and BMI should be documented. Low BMI has been correlated with low bone mineral density and relative caloric deficit.
- **Labs:** Standard work-up should include a serum vitamin D level. Frequently, athletes in the northern hemisphere do not get adequate UV exposure to produce endogenous vitamin D, and are often nutritionally deficient. More detailed lab analysis may be required to workup endocrine abnormalities in athletes with amenorrhea/oligomenorrhea.

**Imaging**

- **Radiographs:** Plain radiographs should be obtained, but are frequently negative especially in the first few weeks after stress fracture. After 3 or more weeks, faint endosteal bone formation may be present. A lucent line is relatively uncommon, but is of concern especially in the anterior tibial cortex where it may be a harbinger of impending complete fracture.
- **Nuclear Medicine:** Technetium-99 triple phase bone scan is very sensitive for early detection of stress fracture. All 3 phases of the bone scan will show increased uptake. In pediatric patients with open physes, bone scan may not be as helpful since the physes will also show areas of increased uptake.
- **CT:** For potential stress fractures of the tarsal navicular, calcaneus, or femoral neck, CT can be the most helpful imaging modality. CT can delineate stress fractures which have gone on to delayed or nonunion.
- **MRI:** MRI is useful for early detection of stress fractures at all sites, with the added benefit of no ionizing radiation. A very early stress fracture may be noted as a finite area of bony edema.
- **DXA:** Indicated for athletes who have sustained multiple stress fractures, and in those with a history of amenorrhea for 6 or more months, and for athletes with disordered eating.

**Treatment**

- **Rest:** The mainstay of treatment is allowing rest for adequate bony healing, then gradually resume activity after pain has abated.
- **Rehabilitation:** Muscle strengthening and maintenance of aerobic conditioning is an important adjunct. Cross-training to a nonimpact activity such as swimming, biking, or rowing may be helpful.
  - Correct any caloric or nutritional deficit, especially with associated menstrual abnormalities. Oral contraceptives are not a first line treatment in cases of amenorrhea, since OCPs do not correct the underlying nutritional/caloric deficit. Most stress fractures will heal with standard nonoperative treatment. Due to some data on impaired fracture healing, avoiding NSAIDs is prudent.
- **Surgical Treatment:** May be indicated for stress fractures including the superior femoral neck, tarsal navicular, base of the fifth metatarsal, and the anterior tibia.
  - In elite or professional athletes, semi-elective early surgical intervention for these problem fractures may be considered rather than lengthier nonoperative treatment regimens. For patients with Female Athlete Triad, a multidisciplinary team approach is critically important. This should include a diettitian, psychologist, athletes trainer, primary care physician, trainer, coaches, and family.

**References**

Overview

- **Femoroacetabular Impingement (FAI) results from abnormal physical contact between the acetabulum and proximal femur and commonly presents as activity-related groin pain in adolescents and young adults.**

- On physical examination, patients with symptomatic FAI demonstrate:
  - Decreased passive hip flexion and internal rotation
  - Pain with hip flexion, internal rotation and adduction

- **FAI is typically characterized by the location of the predominant morphologic abnormality. There are three major types of FAI:***

- **Cam impingement (femoral-sided):** Apophysial extension of the articular surface at the anterosuperior head-neck junction of the proximal femur results in loss of the normal offset. Direct contact between this “bump” and the anterosuperior acetabulum during repeated motion results in cartilage injury and labral tearing (Figure 1)

- **Pincer impingement (acetabular-sided):** Overcoverage of the femoral head results from acetabular retroversion and/or coxa profunda; physiologic hip motion may over time result in repetitive contact between the acetabulum and proximal femur and ultimately in chondralabral injury

- **Mixed impingement:** Aspects of both cam and pincer lesions

Radiographic Incidence of FAI

Traditionally, cam-type impingement was associated with young athletic males and pincer impingement with females in their fourth decade of life. However, recent population-based studies have shown that:

- Cam lesions are more common in males than females
- In one study, 19.6% of males and only 5.2% of females had radiographic cam deformity
- Radiographic pincer lesions are common in both males and females, occurring in more than 15% of all patients
- Bilateral findings of FAI are more common in males than females

- **Cam:** M 24.7% versus F 6.3%
- **Pincer:** M 21.7% versus F 9.7%

Clinical Presentation

- At time of presentation, males and females report similar symptomatology, however, symptomatic males with cam-type impingement have higher alpha angles than symptomatic females (Figure 2).  

- Beaulé et al, J Orthop Res 2005
- 3D CT
- M 73.3° versus F 58.7°
- Hetsroni et al, Arthroscopy 2013
- CT
- M 63.6° versus F 47.8°

- Symptomatic females have increased femoral and acetabular anteversion than symptomatic males
- Hetsroni et al, Arthroscopy 2013
- Acetabular version (M 13.9° versus F 17.3° P < .001)
- Femoral anteversion (M12.1° versus F 14.4° P = .05)

- Males are more likely than females to have symptomatic bilateral FAI requiring surgery
- Klingenstein et al, AJSM 2013
- Odds Ratio M:F = 1.7 (95% CI 1.16-2.54)

- Females have lower preoperative hip function scores than males
- Malviya et al, JBJS-Br 2012
- Females with significantly lower modified Harris Hip Score
- Females with significantly lower Hip Outcome Score
- ADLs, sports domains

Treatment and Outcomes

- There is conflicting evidence for whether males or females are more likely to have surgery for FAI:
  - Ng et al, AJSM 2010
  - FAI surgical patients: 62.7% M versus 37.3% F
  - Clohisy et al, Clin Orthop 2010
  - FAI surgical patients: 62.7% M versus 37.3% F
  - Odds Ratio M:F = 1.7 (95% CI 1.16-2.54)

- There are no studies to date describing and/or examining sex-based surgical techniques

- Females demonstrate equal or greater improvements in clinical outcomes scores (e.g., modified HHS) 1 year following surgery, although their scores remain lower than those of males.