Female Athlete Knee Injury

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Outline

• Historical Perspective
• Gender-specific movement patterns
• Knee Injury
  – Anterior Cruciate Ligament Injury
  – Patellofemoral Pain
• Prevention Programs
• Future Directions

Participation in Sport

Title IX
Equal Opportunity in Education Act
Benefits of Sport

- Higher graduation rates
- Fewer unwanted pregnancies
- Greater self esteem
- Team, leadership
- Decrease risk of chronic illness
  - Heart disease
  - Diabetes
  - Osteoporosis

Gender Differences

- Cardiovascular
  - Smaller heart
  - Cardiac output 30% less than equally trained male
  - 10-15% less hemoglobin, 6% less rbc's
- Pulmonary
  - Smaller chest wall
  - Less vital capacity
  - Dec VO2 max
- MSK
  - Growth spurt earlier
  - Less lean body mass, dec strength, power, speed
- Endocrine

Anatomic Differences

- Limb length
- Articular surface
- Flexibility / ligament laxity
- % Muscle / % Fat
  - Thigh mm development
- Static alignment
  - Wider pelvis
  - Femoral anteversion
  - Genu valgum
  - Narrow notch
  - External tibial rotation
  - Foot pronation
  - Narrower shoulders
  - Lower COG
Dynamic Alignment

Landing Mechanics

Step Down

Courtesy of Luke Oh, MD, MGH Sports Medicine
Single Leg Squat

Drop Jump

Dominant Movement Pattern

- Core instability
- Hip adduction / internal rotation
- Tibial external rotation
- Navicular Drop / Foot pronation
- In toe or Out toe
- ‘Apparent’ knee valgus
Female Athlete Injuries

- **Acute**
  - Anterior Cruciate Ligament Injury
  - Patellar subluxation / dislocation
- **Overuse**
  - Patellofemoral Pain
  - Greater Trochanteric Pain Syndrome
  - Iliotibial Band Syndrome
  - Medial Tibial Stress Syndrome
  - Stress Fracture

Knee Injury Rates


Anterior Cruciate Ligament Injury

- 80,000 – 250,000 annual incidence
- 70% noncontact
- 50% age 15-25 yo
- Females 2-8:1
- Sport-specific
  - Soccer, basketball
Impact of ACL Injury

- Cost
  - 100,000 reconstructions annually
- Time lost from work, school, sports
- Natural history
  - Post-traumatic degenerative disease
- 1/10 re-injury rate

Mechanism of Injury

- Landing
  - Straight knee 28%
- Deceleration
  - Planting and cutting 29%
  - One-step stop w/ knee hyperext 26%
- Unexpected perturbation
- Relative knee / hip extension, knee abduction w/ foot pronation
- Axial load
In Vivo ACL Biomechanics

- High strain
  - Near full extension
  - Quadricep ctx or isometric hamstring ctx

- Low strain
  - < 50 deg KF
  - Hamstring or isometric quadricep ctx

Female ACL Injury
What Gives?
- Multifactorial
  - Environmental
  - Anatomic
  - Hormonal
  - Neuromuscular

Anatomic Factors
- Knee valgus
- Foot pronation
- BMI
- Femoral notch properties
  - Notch width
  - Notch shape
- ACL mechanical quality

Joint Laxity
- Hypermobility
- Musculotendinous flexibility
- Genu recurvatum can delay hamstring activation
- Posterior tibial slope
- Anterior tibial translation
- Mixed studies for injury risk
Hormonal Factors

- Estrogen, progesterone, relaxin receptors on ACL fibroblasts
- Estrogen reduces collagen synthesis
- High levels
  - ligament laxity
  - muscle fatigability
- Estrogen highest in pre-ovulatory phase

Yu et al. CORR. 2001.

Hormonal Factors

Wojtys et al. AJSM. 2002.

Hormonal Factors

Hewett et al. AJSM. 2007.

Effects of the Menstrual Cycle on Anterior Cruciate Ligament Injury Risk

A Systematic Review

Hewett et al. AJSM. 2007.
Oral Contraceptives

- 42-70% collegiate female athletes
- Blunt cyclic hormonal fluctuations
  - May increase passive and dynamic knee stability
  - May lower injury risk
- Mixed studies

Conclusion
Hormonal differences likely contribute to risk for ACL injury
No direct relationship b/t specific hormone fluctuation and injury

Neuromuscular Factors

- Movement Patterns
  - Landing mechanics
    - Core instability
    - Hip: Less HF, Dec gluteal firing
    - Knee: Less KF, valgus
    - Foot: pronation velocity, less PF
    - Increase ground reaction force
Weak Link in Kinetic Chain

Neuromuscular Factors

- Movement Patterns
  - Leg dominance
  - Balance, proprioception
  - Fatigue
    - Exaggerates pattern
    - Male and female
    - Increased proximal tibial anterior shear force

Quadriceps Dominance

- Quadriceps dominant ctx
  - In vivo analysis higher ACL strain
  - Eccentric ctx, anterior translation of tibia
  - Hamstring activation during landing / pivoting may be protective
- Medial quadriceps relative weakness
Bottom Line
Posterior Kinetic Chain Weakness

• Shorter activation of muscles that maintain knee stiffness
  – Gastrocnemius
  – Gluteus maximus, medius, minimus
  -- Hamstring
  – Single leg stance, squat

ACL Injury Prevention Programs
Do They Really Work?

Prevention Premise

• Epidemiology
  – Target young female
• Understand Mechanism of Injury
• Identify Risk Factors
• Implementation
• Compliance
Understanding and Preventing Noncontact Anterior Cruciate Ligament Injuries

A Review of the Hunt Valley II Meeting, January 2005
AJSM. 2006.

<table>
<thead>
<tr>
<th>Risk</th>
<th>Strategy</th>
<th>How?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extended knee</td>
<td>Flexed knee</td>
<td>Soft landing</td>
</tr>
<tr>
<td>Extended hip</td>
<td>Flexed hip</td>
<td>Soft landing</td>
</tr>
<tr>
<td>Knee varus</td>
<td>Minimal varus</td>
<td>Control in landing</td>
</tr>
<tr>
<td>Loss of balance</td>
<td>Improve balance</td>
<td>Dynamic balance training</td>
</tr>
<tr>
<td>Poor skill</td>
<td>Improve agility</td>
<td>Agility skills</td>
</tr>
</tbody>
</table>

ACL Prevention Programs

- Several neuromuscular programs proposed
  - Preseason vs In season
  - Frequency and duration of training
  - Various sports
    - Soccer, handball, volleyball, basketball
  - Most prospective, non-randomized
  - Athlete compliance
  - Encouraging results
Anterior Cruciate Ligament Injuries in Female Athletes

<table>
<thead>
<tr>
<th>Studies</th>
<th>OR (fixed) 95% CI</th>
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<tr>
<td>Hewett et al. (1999)</td>
<td>0.52 [0.36, 0.73]</td>
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<tr>
<td>Hewitt et al. (1999)</td>
<td>0.72 [0.40, 0.98]</td>
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<tr>
<td>Soderman et al. (2002)</td>
<td>0.63 [0.46, 0.88]</td>
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<tr>
<td>Wulff et al. (2002)</td>
<td>0.64 [0.35, 1.18]</td>
<td>0.64 [0.35, 1.18]</td>
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<tr>
<td>Mandersbaum et al. (2005)</td>
<td>0.51 [0.36, 0.71]</td>
<td>0.51 [0.36, 0.71]</td>
</tr>
<tr>
<td>Peterson et al. (in press)</td>
<td>0.21 [0.02, 1.79]</td>
<td>0.21 [0.02, 1.79]</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>0.43 [0.30, 0.61]</td>
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</tr>
</tbody>
</table>

Test for overall effect $Z^2=4.31 (P<0.001)$

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A Randomized Controlled Trial to Prevent Noncontact Anterior Cruciate Ligament Injury In Female Collegiate Soccer Players
Julie Girardot,*, MD, Erin R. Mandersbaum,† MD, Heidi Mellerowicz,‡ MPH
AJSM. 2008.

- **Study Design**
  - 61 NCAA Div 1 soccer teams, 1435 athletes
  - Intervention group: PEP 3Xwk during 2002 season
  - Control group: own customary warm up

- **Results**
  - Overall 41% reduction in ACL 18:7
  - Noncontact 70% reduction 10:2
  - Significance: decrease in reinjury, late season injury

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PEP Program Prevent injury and Enhance Performance Field Set-Up

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Decrease Risk of ACL Injury

• Numbers Needed to Treat = 89 to Prevent 1 ACL Injury
• Risk Reduction of other Injuries?
  – Patellofemoral Pain
  – Peritrochanteric Pain
  – LE Stress Fracture
• Performance Enhancement

Patellofemoral Pain

• Females 2:1
• Overuse Injury
• Pain generator controversial
• Imbalanced forces controlling patellar tracking, jt overload
  • Static stabilizers
  • Dynamic stabilizers
• Peripatellar pain; down stairs, prolonged sitting

Patellofemoral Pain Risk Factors

• Training errors
• Increased Q angle / valgus
  • Normal Q angle < 20°
• Ligamentous laxity
• Patellar hypermobility
• Genu recurvatum
• Foot pronation
A prospective investigation of biomechanical risk factors for patellofemoral pain syndrome.
Boling MC et al. AJSM. 2009.

- Decreased KF angle
- Decreased vertical ground reaction force
- Increased hip internal rotation angle
- Decreased quad and hamstring strength
- Increased navicular drop

No single biomechanical factor has been consistently shown to reliably predict the presence or outcome of PFS

Patellofemoral Pain

- Evaluate entire kinetic chain
- Dynamic alignment
  - Single-leg squat
  - Lateral cutting
  - Jumping
  - Running
- Strength / Flexibility
  - Hip Adb / ER
  - Core
  - Quad, hamstring, ITB
  - Foot/Ankle

Dynamic Testing
Treatment: Table Out

- **Individualized Program**
  - Activity modification
  - NSAID, brace, tape, orthotics
  - Physical Therapy
  - Correct dynamic imbalances
    - Quad strengthening
    - Core, hip stabilization
    - Stretching
  - Motor retraining
  - Skill acquisition

- **Surgical**

Myth of the VMO

- Can vastus medialis oblique be preferentially activated?
  - Limb-joint orientation
  - Muscular co-contraction
  - EMG studies reveal insufficient data
- Do the VMO and VML really exist?
  - Insufficient evidence to suggest 2 separate components of VM exist
Summary
- Female athletes are target
- Dominant movement patterns
- Importance of kinetic chain
- Neuromuscular control, motor retraining
- Prevention may be best treatment

Future Directions
- Neuroplasticity
  - Transcranial magnetic stimulation, fMRI
- Landing Error Scoring System
  - Identify female high risk pattern
- Individualized programs
- Prevention / postoperative PT training
- Preparticipation examination
- Dissemination / Compliance

Thank You
### Anterior Cruciate Ligament Deficiency Causes Brain Plasticity

**A Functional MRI Study**

- 17 ACL def > 6 mo, 18 ACL intact dominant legs
- Brain activation patterns using fMRI
- **Results ACL def**
  - Decreased activation in several sensorimotor cortical areas, increased activation in 3 areas
- **Conclusion**
  - ACL def can cause reorganization in CNS
  - Neurophysiologic dysfunction not just periph msk
  - New standards in rehab and motor relearning