Mechanisms of ACL Injury: Implications for Rehabilitation, Injury Prevention & Return to Sport Decisions

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Overarching research theme:

Identification and understanding of injury mechanisms will lead to the development of more effective and efficient clinical interventions

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Movement Behavior Associated With ACL Injury

How do ACL injuries occur?

- 70% of injuries are non-contact
  - Running & cutting
  - Landing from a jump
- 30% are contact – fouls, tackling from behind
- ACL injured athletes often recall unanticipated event, perturbation, or loss of concentration

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Mechanism of Injury
(Kirkendall and Garrett, 2000)

- Deceleration/Change in direction
- Knee flexion 0-30 degrees
- Tibial rotation and varus/valgus forces

Gender Bias

- Incidence of ACL injury in females is 4-8 times that of males.
  - Arendt et al., 1995
  - Hutchinson et al., 1995
  - Malone et al., 1993

- High risk group: females 15-20 years.
- Each year, one out of 100 high school female athletes and one of 10 college female athletes experiences an ACL injury
  - Adams et al., 2002

Non-contact ACL Injury: Categorical Risk Factors

I. Structural
II. Hormonal
III. Biomechanical
IV. Neuromuscular

Normal Function

Injury threshold

Biomechanical Risk Factors

- Kinematics
  - ↓ hip and knee flexion
  - ↑ knee valgus
  - ↑ hip internal rotation

- Kinetics
  - ↑ knee valgus moments
  - ↑ knee extensor moments
  - ↓ hip extensor moments

- Muscle activation patterns
  - ↑ quadriceps activity
  - ↓ gluteus max activity

Neuromuscular Control and Valgus Loading of the Knee Predict ACL Injury Risk in Female Athletes

- Prospective study of 205 female athletes
- Those who tore their ACL during the course of a season demonstrated knee valgus moments that were 2.5 times greater than those who did not tear their ACL

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Biomechanical Assessment: Drop-Jump

Females: “Knee Strategy”

- Increased Knee Extensor Moments
- Increased Quadriceps Activation
- Decreased Hip Extensor Moments
- Decreased Glut Max EMG
- Increased valgus loading at the knee

“Knee Strategy”

Pollard et al, Clin Biomech, 2010

Males: “Hip Strategy”

- Decreased Knee Extensor Moments
- Decreased Quadriceps Activation
- Increased Hip Extensor Moments
- Increased Glut Max EMG
- Decreased valgus loading at the knee

“Hip Strategy”

Greater Utilization of the Hip Extensors is Associated with Decreased Valgus Moments & Angles

Pollard et al, Clin Biomech, 2010

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**Hip-Knee ratios**

**Moments & Energy Absorption**

**Males vs. Females**


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**Abnormal Distribution of the**

**Hip and Knee Moments in Females**

**Why?**

- Hip extensor weakness relative to quadriceps
- Quadriceps overuse
- Increased ACL loading (anterior shear)

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**Biomechanical Assessment:**

**Side-Step Cut**

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**Causes of Valgus Loading at the Knee**

- Ground reaction force vector moves lateral
  - Shifting of COM lateral
- Medial movement of the knee joint center
  - Hip adduction & internal rotation
- Combination of both

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• Extensor
• Abductor
• External Rotator

Gluteus Maximus: “The Tri-planar Muscle”

Impaired Gluteus Maximus Muscle Performance & ACL Injury

Sagittal Plane
- Gluteus Maximus Activity
- Quadriceps Activity
- Knee Joint Anterior Shear

Frontal/Transverse Plane
- Hip Abduction & Int. Rotation
- Knee Valgus Angle
- External Knee Valgus Moment

Risk of ACL injury?

Behavioral Changes Following ACL Injury Prevention Training

PEP Program
Prevent injury and Enhance Performance
http://pt.usc.edu/aclprojectprevent

1. Agilities
2. Flexibility
3. Strengthening
4. Plyometrics
5. Technique

Results: Year 1

- Control: 32 ACL’s in 1901 athletes
- Enrolled: 2 ACL’s in 1041 athletes
- 88% reduction in ACL tears

Results: Year 2

- Control: 35 ACL’s in 1913 athletes
- Enrolled: 4 ACL’s in 844 athletes
- 74% reduction in ACL tears

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Pre-training biomechanical analysis

ACL injury prevention program

Post-training biomechanical analysis

Improved Hip Kinematics Following PEP Training

– Decreased hip internal rotation
– Decreased hip adduction


Knee/Hip Extensor Moment Ratio

Drop-Jump

*Decreased knee extensor moment

ACL Injury Prevention:
Less Dependence on a Knee Strategy

Ready to Return to Sport??

Implications for Rehabilitation and Return to Sport Decisions:

Evaluating & Changing Movement Behavior

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Ready to Return to Sport??

On average, soccer athletes perform 726 cutting maneuvers in a game


Functional Return to Sport Scoring

<table>
<thead>
<tr>
<th>Hip Stability</th>
<th>Shock Absorption</th>
<th>Hip Strategy</th>
<th>Total Score</th>
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<td>2 out of 6 total</td>
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Adequate = 2; Borderline = 1 Inadequate = 0

Movement Training to Minimize Re-Injury Risk

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<th>Shock Absorption</th>
<th>Hip Strategy</th>
<th>Pelvis Stability</th>
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</tbody>
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Adequate = 2; Borderline = 1 Inadequate = 0

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Concurrent Feedback

Concurrent Feedback

Concurrent Feedback

Concurrent Feedback

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Post-Response Feedback
*Knowledge of Results*

Variability in Practice

Variability in Practice

External Focus of Attention
*“Put your shoe between the lines”*

External Focus of Attention
*“Keep the light pointed straight ahead”*

External Focus of Attention
*“Stretch the hand”*

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**Contextual Interference**

**General Impressions Regarding Current ACLR Protocols**
- Focused primarily on strength impairments at the knee
  - Quadriceps
  - Hamstrings
- Little attention paid to high level hip strengthening or functional movement training (ie. lack of hip strategy)
- 6 months is too early to return to full contact sport

**Are current ACL rehabilitation protocols promoting a knee strategy?**

**Key Points**
- Altered movement behavior is an important contributor to ACL injury risk.
- Poor hip control appears to underlie altered movement behavior associated with ACL injury risk
- Motor skill learning that emphasizes hip control and a “hip strategy” appears to protect against ACL injury risk.
- Adequate hip strength and movement mechanics should be restored prior to returning an athlete to sport.

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