Promoting Knee Joint Health Across the Lifespan
Complex Interactions and Innovative Solutions

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Non-Contact ACL Injury
Most Common in High Risk Sports Postures
Accounts for 70% of all ACL injuries
Precise Mechanism/s Remain Unclear

Long And The Short of It

Surgery and Extended Rehab
Osteoarthritis

Athletes Rarely return to pre-injury competitive levels
First radiologic signs appear approx. 10 years post injury (Lohmander et al., 2004)
Within the coming decades large number of relatively young individuals requiring total knee replacement - Particularly women

Why So Important?

Is This Inevitable?
 Contributing Factors

Non-Modifiable
- Anatomy
- Hormones

Modifiable
- Footwear
- Neuromuscular Control

ACL injury involves complex interaction of modifiable and non-modifiable factors.

Neuromuscular Training Programs

Early results are indeed promising (Gilchrist et al., 2008; Myer et al., 2006)

Despite increased number of quality of programs, ACL injury rates and the associated gender disparity remains (Agel et al., 2005)

Successful Prevention?

1. Extent of Injury
2. Injury Mechanisms
3. Introduce Prevention
4. Assess Effectiveness

Improved prevention limited by incomplete knowledge of injury mechanisms (Bahr and Krosshaug, 2005)

Which Factors are Important?

Can Research Cater to Individual Joint Vulnerabilities?

The ACL Injury Mechanism

Bridging the Gap Between the Lab and the Field

Assessing Integrative Morphologic and Mechanical Contributions to Knee Joint Health
1. Lab-based Injury Predictions

Does this ….. Help explain this ?

Bringing the Field to the Lab

Fatigue caused large increases in specific movements / forces during landings in both men and women.

McLean et al., 2007

Mechanisms and Prevention

May be possible to modify central processing and control behaviors.

Fatigue-Induced ACL Injury Risk Stems From a Degradation in Central Control

Performed sequential series of squats (n = 3) and random landing task.

Cumulative Fatigue Effects

McLean and Samorezov, 2009 (Med Sci Sports Exerc)
Fatigue and Decision Making

Limb Effects

Screening and Prevention

Central Versus Peripheral Control?

Are We Getting Closer?

- Increased reaction time = increased risk?
  - Movement specific or transferable tests?
- Train central control patterns to minimize response delay and maximize response success
- Maximum exposure to random movement environments and tasks
  - Expert versus novice (Abernathy et al., 1996)
  - Virtual training environments
Bringing the Lab to the Field

Body Worn Kinematic Sensors
Currently developing prototype lightweight BiOMEMS sensor system to quantify lower limb joint rotations in real-time

Potential Applications
- Wireless data transmission
  - joint injury risk can be examined in real-time during actual sports participation
- Real-time continuous feedback

Current Status
MEMS Device
Current Gold Standard
McLean and Perkins, 2009

Matching Models and Humans
Human Experiments
Model Simulations
McLean et al., 2003

Baseline NMC Perturbations
Monte Carlo Simulations
(5000 Simulated Trials)

Peak Loads
- Anterior Drawer (> 2000 N)
- Valgus (> 125 Nm)
Woo et al., 1991
Seering et al., 1980
Prescribed NMC Changes

- Bone position/velocity at heel strike
- Muscle coordination
- Random numbers \( n(0, SD) \)

6 MC series (3 conditions x 2 modifications)

McLean et al., Clin Biom, 2008

Injury Scenarios

Peak Loads

Same Injury Criteria

Training Against ACL Injury

Modification/alteration of hip NMC may reduce ACL injury risk

Assessing Integrative Morphologic and Mechanical Contributions to Knee Joint Health

Sensitivity to Hip Control

Male
Female

Females may need to land with more consistent hip motions to accommodate relative strength and neuromuscular deficiencies?

Training Implications

Must consider role of individual anatomy / laxity

Global modification strategies may be hazardous for some individuals.
Feasibility of a Homogeneous Training Strategy

Structural contributions to resultant joint and ACL loading profile

Model Predictions

RMS Prediction Error
M = 0.51 ± 0.10 %
F = 0.52 ± 0.10 %

Variance
Mal R² = 0.79 ± 0.02
Fem R² = 0.78 ± 0.04

RMS Validation Error
Mal = 0.65 ± 0.05 %
Fem = 0.66 ± 0.03 %

Gender Comparisons

Significant increases in ACL strain in female models compared to males between at each shear load level

Predicted ACL strain within 1% of measured data

Bringing Pieces of the Puzzle Together

Anatomy
Mechanics
Do key anatomical indices predict resultant knee joint mechanics?

DESIGN

Dominant limb anatomical and biomechanical measures
Increases in LTS were significantly associated with increased peak stance ATS.

Increases in MTS:LTS were significantly associated with decreased peak stance abduction.

Increases in MTS:LTS and TW:ICD were significantly associated with decreased peak stance internal rotation.

Examined potential for high-risk anterior tibial acceleration – ACL strain relations to be governed by posterior tibial slope.

Based on recent in vivo measurement techniques.

Plane film radiographs.
Mean (± SD) peak AMB strain was significantly (p = 0.004) correlated (r² = 0.62) with anterior tibial acceleration.

Peak impact-induced anterior tibial acceleration was significantly (p = 0.004) correlated with posterior tibial slope (r² = 0.67).

Peak AMB strain was significantly (p = 0.007) correlated with posterior tibial slope (r² = 0.58).

Combined acceleration and tibial slope factors explained 81.2% of the variation observed in peak AMB strain magnitudes.

Current Efforts and Directions

Quest For Subject Specificity

Screening for Patient Specific Risk

Specimen – Specific Modeling

Sensitivity of modeled ACL strain response to specimen specific tibial slope and ligament laxity profiles

Consideration of additional joint factors – e.g., laxity
Modeling Growth and Evolving Injury Risk

Examining combined hazardous pathways across maturation

Fluoroscopic-Driven Knee Models

Correlate anatomy with accurate bony motions during dynamic landings

Combating High Risk Biomechanics is Possible

First Need to Ask the Right Questions

THANK YOU

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