Noncontact ACL Injuries and Their (Possible) Prevention

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Epidemiology

- 1 injury in every 3000-3500 people
- 75,000 – 80,000 injuries in the US annually
- 70% involved with sports
- 70% considered “noncontact”
- 5% >45 or <16
- Between 15-25, 1 in every 1000 people
Epidemiology cont

- Total number of injuries greater in men
- Increased rates in women
  - 1985 Gray - 10X higher in basketball players
  - 1990 Ireland and Wall - 4X higher in Olympic basketball players
  - 1992 Ferretti - increased in female volleyball players
  - 1994 Lindenfeld - 3X higher in indoor soccer players
    - First prospective study
  - 1995 Arendt and Dick - 2.4X higher in NCAA soccer and 4.2X higher in NCAA basketball players
  - 1998 Myklebust - 5X higher in handball players
Title IX - 1972

1995 women comprise 37% of college student athletes

1996 2.4 million girls represent 39% of all high school athletes

1997 >100,000 women participate in intercollegiate athletics
Risk Factors for noncontact ACL injuries

- **Extrinsic**
  - Shoe/surface interaction

- **Intrinsic**
  - Hormonal
    - Estrogen and OCPs
  - Anatomic
    - Notch width index
  - Neuromuscular
Extrinsic Risk Factors

- Does the playing surface lead to more injuries?
  - Artificial turf
- What is the role of footwear?
- Shoe/surface interaction
  - Increase in performance at the expense of the knee
Extrinsic Risk Factors

- 1981 Stevenson and Anderson
  - 1.8 higher relative risk on artificial turf in collegiate intramural football teams

- 1988 Nicholas et al.
  - No difference in 20-year analysis of one NFL team

- 1992 Powell and Schootman
  - Significantly higher risk of knee sprains on artificial turf
Extrinsic Risk Factors cont

- More important is shoe/surface interaction
- “Release Coefficient”
  - Force-to-weight ratio of shoe/surface interaction
  - Torg 1974
- 1990 Strand et al.
  - Higher ACL injuries on synthetic floors
- 1997 Myklebust et al.
  - 55% of ACL injuries involved significant friction between shoe and floor
Extrinsic Risk Factors

- Many variables in the shoe/surface interaction
  - Cleat design
  - Different artificial turf designs
Extrinsic Risk Factors cont

- Weather factors
  - moisture, humidity
- Balance between performance and safety
Extrinsic Risk Factors cont

- Inconclusive

- Ideal shoe for the Ideal surface
  - sport and athlete specific
Hormonal Risk Factors
Hormonal Risk Factors cont

- Estrogen and progesterone receptors in ACL
  - 1996 Liu et al.
  - 1998 Sciore et al.

- Increase in estrogen decreases collagen synthesis and fibroblast proliferation
  - 1997 Liu et al.
  - 1999 Yu et al.
Hormonal Risk Factors cont
Hormonal Risk Factors

- 1998 Wojtys et al.
  - Increase in ACL injuries during ovulatory phase
  - Decrease in follicular phase

- 1998 Myklebust et al.
  - Fewer injuries in ovulatory phase
  - ½ subjects on OCP

- 1999 Arendt et al.
  - Injuries just before or after onset of menses, regardless of OCP use
Hormonal Risk Factors (cont)

- 2002 Slauterbeck et al.
  - ACL injuries greatest in luteal phase
Hormonal Risk Factors cont

- 2003 Strickland et al.
  - Estrogen at physiologic levels does not lead to decreased knee ligament strength

- 2003 Dragoo et al.
  - Relaxin receptors are present in the female ACL
Anatomic Risk Factors
Anatomic Risk Factors cont

- Ligamentous laxity
  - 2000 Boden et al
  - 2003 Uhorcak et al
  - 2005 Ramesh et al
Anatomic Risk Factors

- Increased femoral anteversion
- Genu valgus
- Greater Q angle
- Increased tibial external rotation
- Increased forefoot pronation
- Pes planus
Anatomic Risk Factors

- Notch Width Index
  - Measurement made from a prone bent knee
  - Width of intercondylar notch to width of femoral condyle
- 1988 Souryal et al.
- Originally looked at in bilateral injuries
- More recently investigated toward gender differences
Anatomic Risk Factors

- Notch width
- Bicondylar width
- Popliteal Groove

Line along most inferior point of both condyles

20°
70°
Anatomic Risk Factors

- 1997 Teitz et al.
  - Female NWI smaller than male but not statistically significant
  - No difference between uninjured and injured knees

- 1998 Shelbourne et al.
  - Female notch widths less than males
  - May reflect smaller ACL
Anatomic Risk Factors

- **2001 Anderson et al.**
  - No difference in NWI
  - Women with smaller ACLs

- **2002 Charlton et al.**
  - Volume of femoral notch smaller in women
  - Smaller volume corresponded with smaller ACL
  - Related to difference in height and weight
Anatomic Risk Factors cont

- 2003 Uhorchak et al.
  - 4 risk factors
    - Narrow femoral notch width
    - Increased average body mass index
    - Generalized joint laxity
    - KT-2000 above 1 SD than normal
  - Risk factors were cumulative
Anatomic Risk Factors cont

- Posterior Tibial Slope
  - 2010 Todd et al
  - 2011 Mclean et al
Neuromuscular Risk Factors
Neuromuscular Risk Factors cont

- **Neuromuscular control**
  - Unconscious activation of the dynamic restraints surrounding a joint in response to sensory stimuli

- **Functional joint stability**
  - Joint stability required to perform a functional activity
Neuromuscular Risk Factors cont

- Mechanoreceptors
  - Muscle, articular tissues, skin
- Afferent neurons to spinal cord
- Spinocerebellar pathways
  - Cerebellum subconsciously plans and modifies motor activities
Neuromuscular Risk Factors cont

- **Muscle physiology**
  - Stronger the muscle, more protective
    - Men generally larger and stronger
    - Increased cross-sectional area
  - **Efficiency of contraction**
    - Fully activate motor units
    - Men more efficient
      - 1978 Komi and Karlsson
Neuromuscular Risk Factors

- **Muscle Reaction Time**
  - Interval between onset of stimulus and start of action potential
  - Muscles must react quick enough to defend against injury
  - No reported sex differences
  - Muscle fatigue affects muscle reaction time
Muscle Activation Patterns

1996 Huston and Wojtys
- Female athletes contracted quadriceps first in response to anterior tibial translation
- Male athletes and all nonathletes activated hamstrings first

2003 Fagenbaum and Darling
- Similar knee activation patterns in men and women
- Significant role of hamstrings in improving knee stability
Neuromuscular Risk Factors cont

- Muscle Stiffness
  - As knee spanning muscles contract, increase joint contact forces, decrease tibial-femoral displacements, dissipate ground-reaction forces
  - 1975 Such et al.
    - Women with significantly less stiff knee joints
  - 1988 Bryant and Cook
    - Women 35% less stiff
Neuromuscular Risk Factors cont

- Electromechanical Delay
  - Time lapse between neural activation of muscle and actual force generated
  - Shorter delay in men than women
    - 1978 Komi and Karlsson
    - 1986 Bell and Jacobs
    - 1991 Winter and Brookes
Neuromuscular Risk Factors cont

- **Ligament Dominance**
  - Imbalance leading to valgus collapse

- **Quadriceps Dominance**
  - Quads preferentially activated

- **Leg Dominance**
  - Muscular asymmetry

- **Trunk Dominance**
  - Core dysfunction
Neuromuscular Gender Differences

- Women have less absolute muscle mass than men
- Women contract their muscle less efficiently
- No difference in muscle reaction time
- Women contract their quadriceps first in response to anterior tibial translation
- Women have less stiff knees
- Women have a longer delay in activating their muscles
Noncontact Mechanism of Injury
Noncontact Mechanism of Injury cont

- 2000 Boden et al
- Injury occurred during landing or decelerating/pivoting
- Knee flexion 10-30 degrees
- Knee in valgus
Noncontact Mechanism of Injury

- **1999 Malinzak**
  - Women land in more erect position
  - Less knee and hip flexion
  - More knee valgus

- **2000 Noonan et al.**
  - As knee flexion decreased, force vector increased
  - Forces exceed 2000N
Noncontact Mechanism of Injury

- 2002 Chappell
  - Female rec athlete with increased proximal tibial shear force
  - Females with greater knee extension and valgus
Noncontact Mechanism of Injury
Noncontact Mechanism of Injury cont
Prevention

- Bracing
- Oral Contraceptive Pills
- Neuromuscular Coordination
Bracing

- **Prophylactic brace**
  - Absorbs direct or indirect stress to prevent or reduce knee injury

- **Functional brace**
  - Originally designed to enhance knee stability in ACL-deficient knee
  - Now used prophylactically as well

- **Rehabilitative brace**
Bracing cont
Bracing cont
Bracing

- 1984 AAOS issued position statement

“AAOS believes that the routine use of prophylactic knee braces currently available has not been proven effective in reducing the number or severity of knee injuries. In some circumstances, such braces may even have the potential to be a contributing factor to injury.”
2003 AAOS issued a new position statement

“Prophylactic knee braces may provide limited protection against injuries to the MCL in football players. Scientific studies have not demonstrated similar protection to other knee ligaments, menisci, or articular cartilage.”

retired December 2008
Bracing

- Inconclusive studies
- Possible psychological effect
Oral Contraceptive Pills

- OCPs could potentially decrease ACL injuries
- Controversial
Neuromuscular Conditioning
Neuromuscular Conditioning cont
Neuromuscular Conditioning

- **Sportsmetric**
  - Dr. Frank Noyes-Cincinnati

- **Prevent Injury and Enhance Performance (PEP)**
  - Dr. Bert Mandelbaum-Santa Monica
  - FIFA 11+
Neuromuscular Conditioning cont

- Proprioceptive training
- Stretching
- Plyometrics
- Movement training
- Core strengthening
- Balance training
- Resistance training
- Speed training
Neuromuscular Conditioning

- 2006 Hewett et al
- 2006 Grindstaff et al
- 2010 Yoo et al
- 2012 Sadoghi et al
- 2013 Gagnier et al
2006 Hewett et al

- Examined 6 clinical studies
- Plyometrics, balance and strength training
  - Plyometrics
- Exercises done more than once a week
- Duration of training at least 6 weeks
Neuromuscular Conditioning cont

- 2006 Grindstaff et al
  - Examined 5 studies
  - 89 subjects needed to prevent 1 ACL injury in 1 season
  - 70% relative risk reduction
  - Verbal feedback
  - Preseason and inseason training
  - Performance enhancement
2010 Yoo et al

- Examined 7 studies
- Age < 18
- Soccer > handball
- Preseason and inseason > preseason or inseason
- Plyometrics and strengthening > balance
Neuromuscular Conditioning

- 2012 Sadoghi et al
  - Examined 8 studies
  - 52% risk reduction in females athletes
  - 85% risk reduction in male athletes
  - Unable to determine which program is best
Neuromuscular Conditioning

- 2013 Gagnier et al
  - Examined 14 studies
  - ACL incidence reduced by 50%
  - Unable to say what components of programs were effective
  - Unable to say what populations may be more amenable to interventions
Future Directions

- What is key?
- Screening
- Compliance
- Postop Protocols
Future Directions

What is the key component of these programs?

- Plyometrics
- Sport specific
Future Directions cont

- Screening
  - At risk population
  - Cost-effective
Future Directions cont

- Compliance
  - Performance vs protection
  - Sport specific
Future Directionscont

- Postop protocols
  - Should postop protocols employ more proprioceptive and plyometric exercises?
  - Should surgeons emphasize neuromuscular training when evaluating postop patients?
Future Directions

- 2001 Risberg et al.
  - Addition of balancing and plyometrics
- 2001 Tyler and McHugh
Summary

- Numerous risk factors associated with noncontact ACL injuries
- Modification of these risk factors can lead to prevention
THANK YOU