Knee Pain in the Adolescent Athlete

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Faculty Disclosure

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Dr. Grindstaff has listed no financial interest/arrangement that would be considered a conflict of interest.
Objectives

• Understand factors for and treatment of adolescents with knee pain
Summary

• Knee injuries may have common mechanism
  – Injury risk reduction programs
• Address underlying impairments
  – Rate limiting factors are quadriceps inhibition and exercise intensity that is too low
• Greater reliance on vision after injury
  – Limited somatosensory
• External focus
  – Reduces need for conscious (internal) control during movement
Are these injuries related?

- Patellofemoral Joint Pain
- Iliotibial Band Syndrome
- Non-Contact ACL Tear
Common Mechanism of Injury

- Hip adduction and internal rotation → knee valgus and tibial external rotation
- High knee abduction moments

Leetun et al, 2004; Myer et al, 2015; Aderem and Louw, 2015
Injury Risk Reduction

- Lower extremity injury (RRR= 36%)
- Knee injury (RRR= 26%)
- Non-contact ACL injury (RRR= 64-73%)
- Ankle-sprain risk (RRR= 65%)

Grindstaff et al., 2006; Foss et al., 2018; Emery et al., 2015; Sugiomoto et al., 2012; Schiftan et al., 2015; Padua et al., 2018
Neuromuscular Training Impact Example

- **250,000** ACL injuries per year
  - 70% non-contact (175,000)
- Potential to prevent about **120,000** ACL injuries
  - Assumes 70% risk reduction
- Potential to prevent approximately **45,000** cases of knee PTOA per year
  - 36% develop PTOA within 10 years
Optimal Program Design
Key References

• ACL Prevention- NATA Position Statement

• 2018 IOC Consensus Statement
PAEDIATRIC ACL INJURIES
Prevention, Diagnosis & Management
Reference: Ardern et al. BJSM 2018 (IOC Consensus Statement) Designed by eVMSportScience

The number of ACL injuries in children is rising...
... and the long-term outcomes after ACL injury in childhood, including development of osteoarthritis, is unknown

ADVICES

1. Completing the FIFA 11+ for Kids can reduce football-related lower limb injuries by over half
2. Combine history, examination findings and imaging to inform diagnosis and treatment decision-making
3. High-quality rehabilitation alone or ACL reconstruction + high-quality rehabilitation are both reasonable treatment options

4. Consider skeletal maturity, injuries to other knee structures and potential adverse events following treatment when advising children and their parent(s)/guardian(s)
5. Use a generic health-related quality of life measure, a self-reported knee function measure and an activity level measure to monitor outcomes
6. Encourage coaches, teams, clubs and federations to prioritise injury prevention
Not every sport has their FIFA 11+. And that's ok. Just make sure your IPP includes strengthening, proximal control ex's & plyometrics & goes for at least 10mins before each training session & game - Sugimoto et al (2014 & 2015)

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3969416/
http://bjsm.bmj.com/content/49/5/282.long
Neuromuscular Training

- Multicomponent training programs
  - Strength, plyometric, agility, flexibility, and balance
  - Sport specific and minimal equipment
- 2-3x per week, 10-20 min
  - Preseason and in-season
  - Ongoing/Multiple years
- Feedback on movement technique
- Implement at early age (e.g. < 15 years old)
  - Optimize motor-learning and ensure retention of improved neuromuscular control

Herman et al., 2012; OAAA 2016; Lauersen et al., 2014; Bizzini et al., 2013; Padua et al., 2012; DiStefano et al., 2016
Compliance

• Higher rate of compliance $\rightarrow$ lower rate of ACL injury
  – 2-3x/week $>$ 1x/week
• Ongoing, multiple years
  – Better movement retention

Sugimoto et al., 2012; Steffen et al., 2013; Soligard et al., 2008; Padua et al., 2012; Silvers-Granelli et al., 2018
Implementation Challenges

- Low implementation
  - More experience $\rightarrow$ less likely to implement
- Coach and player beliefs
  - Poor understanding of injury and risk
  - May not fully appreciate program benefit
  - Stretching $\neq$ injury prevention
- In person workshop more helpful

Steffen et al., 2013; McKay et al., 2014; Read et al., 2017
Jumping Mechanics

• Knees over toes
  – Knee in line with 2\textsuperscript{nd} and 3\textsuperscript{rd} toes
  – Avoid valgus

• Land SOFTLY
  – Adequate hip and knee flexion
Improper Landing Mechanics
External Focus

- Land on the markers
  - Feet shoulder width
- Point your knees toward the cones
  - Knees over toes
- Touch cones when landing
  - Increased hip, knee, trunk flexion

Gokeler et al., 2013. Figure 1.
Program Examples
Neuromuscular Training Programs

- FIFA-11+
- Sportsmetrics
- Prevent Injury and Enhance Performance (PEP)
- Footy First
FIFA 11+ Injury Prevention Program

- 10-15 min warm-up
  - Can be abbreviated
- Running
- Strength, Plyometrics, Balance
- Running
**PART 1 RUNNING EXERCISES · 8 MINUTES**

1. **RUNNING STRAIGHT AHEAD**
   - Stand at the start of a marked lane on the playing field, or approx. 50 m apart.
   - Run as far as possible in a straight line without breaking stride.
   - Keep your knees high, your arms swinging naturally, and your head up to avoid injury.

2. **RUNNING HOP OUT**
   - Begin by facing the end of the lane, and then hop forward, alternating your hop to the right and left.
   - Perform for 30 seconds, then reverse direction.

3. **RUNNING HIP IN**
   - Stand facing a wall, with your feet shoulder-width apart and your knees bent.
   - Slowly rotate your hips in and out, trying to maintain a straight back.
   - Repeat for a total of 3 rotations, then reverse direction.

4. **RUNNING CIRCULATING PARTNER**
   - Run forward to the left of your partner, then shuffle to the right, and repeat.
   - Keep your body aligned with your partner's.

5. **RUNNING SHOULDER CONTACT**
   - Run forward to the left of your partner, then shuffle to the right, and repeat.
   - Keep your body aligned with your partner's.

6. **RUNNING QUICK FORWARDS & BACKWARDS**
   - As a group, try to shuffle your feet in a forward and backward motion, visiting each starting position.
   - Keep your body stable and your feet moving.

7. **RUNNING ACROSS THE PITCH**
   - Begin by facing one side of the pitch, and then run across it.
   - Keep your body aligned with your partner's.

**PART 2 STRENGTH · PLYOMETRICS · BALANCE · 10 MINUTES**

**LEVEL 1**

7. **THE BENCH**
   - **BEGINNER**
     - Stand on the bench, and swing your legs to work your hamstrings.

8. **SINGLE-LEG STANCE**
   - **BEGINNER**
     - Stand on one leg, keeping your body weight on the ball of your foot.

9. **SQUATS WITH TOE RAISE**
   - **BEGINNER**
     - Stand with your feet shoulder-width apart.
   - **INTERMEDIATE**
     - Add a toe raise to your squats.

10. **JUMPING VERTICAL JUMPS**
    - **BEGINNER**
      - Begin by jumping off both feet, then repeat.
    - **INTERMEDIATE**
      - Add a single-leg jump to your vertical jumps.

**LEVEL 2**

7. **THE BENCH ALTERNATE LEGS**
   - **BEGINNER**
     - Stand on one leg, and swing your other leg to work your hamstrings.
   - **INTERMEDIATE**
     - Add a toe raise to your squats.

8. **SINGLE-LEG STANCE HOLD THE BALL**
   - **BEGINNER**
     - Stand on one leg, and hold a ball in your hand.

9. **SQUATS LATERAL JUMPS**
   - **BEGINNER**
     - Jump sideways, keeping your body weight on the ball of your foot.
   - **INTERMEDIATE**
     - Add a toe raise to your lateral jumps.

**LEVEL 3**

7. **THE BENCH ONE LEG LIFT AND HOLD**
   - **BEGINNER**
     - Stand on one leg, and lift your other leg to work your hamstrings.
   - **INTERMEDIATE**
     - Add a toe raise to your squats.

8. **SINGLE-LEG STANCE TEST YOUR PARTNER**
   - **BEGINNER**
     - Stand on one leg, and hold your partner's leg to work your hamstrings.
   - **INTERMEDIATE**
     - Add a toe raise to your squats.

9. **JUMPING BOX JUMPS**
   - **BEGINNER**
     - Jump your feet off the ground, keeping your body weight on the ball of your foot.
   - **INTERMEDIATE**
     - Add a toe raise to your box jumps.

**PART 3 RUNNING EXERCISES · 2 MINUTES**

13. **RUNNING ACROSS THE PITCH**
    - Begin by facing one side of the pitch, and then run across it.
    - Keep your body aligned with your partner's.

14. **RUNNING BOUNDING**
    - Begin by running in a straight line, then jump onto one leg and repeat.

15. **RUNNING PLANT & CUT**
    - Begin by running in a straight line, then plant your feet and cut in the opposite direction.

**THE 11+**

- The 11+ exercises are designed to improve running, jumping, and coordination skills.
- Perform each exercise for a specified duration, and repeat as necessary.
- Emphasize proper form and technique to reduce injury risk.
- Gradually increase the duration and intensity of the exercises over time.

- **KNEE POSITION CORRECT**
- **KNEE POSITION INCORRECT**

- **FIFA RECOMMENDATIONS**
  - Warm-up: 5-10 minutes of gentle stretching and light jogging.
  - Stretching: Focus on major muscle groups and joints before and after exercise.
  - Rehydration: Drink water before, during, and after exercise.
  - Cool-down: 5-10 minutes of gentle stretching and light jogging.
  - Nutrition: Consume a balanced diet with adequate protein, carbohydrates, and fats.
Interventions
Good Outcomes

• “We like to think that we are successful in the treatment of individuals with ACL injury”
  – About 60% make a full recovery
  – < 60% return to sport
  – > 50% develop knee osteoarthritis (OA) by middle age

Risberg et al, 2016 JOSPT
Uncomplicated Recovery

• Despite surgical **intervention and rehabilitation** 30-50% continue to have
  – Joint effusion
  – Weakness
  – Altered biomechanics
  – Decreased physical function
• 20-30% have reinjury within 2 years

Omaha Data

- Thirty-eight unilateral ACL-R
- 84% not ready to return to sport
  - 13 participants failed all 3 tests (<90%)
  - Six participants passed all 3 tests (>90%)
- Hop test ≠ quadriceps strength
  - 61% met hop test criteria
  - 39% met quadriceps strength
Quadriceps Weakness

• Common impairment after knee injury
  – Rapid onset
  – Protective mechanism
• Contributes to knee joint loading
• Can persist 15-20 years after injury

DeAndrae et al., 1965; Shakespeare et al., 1985; Stokes et al., 1984; Palmieri-Smith et al., 2007; Urbach et al, 2001; Svantesson et al, 2005; Krishnan and Williams, 2001
Other Muscles

• Initial weakness → recovery
  – Hip Extensor, ER, Abd, Add
  – Ankle PF

• Graft type impacts strength
  – Quadriceps > Hamstring

Quadriiceps Strength

- Early measures predict later
  - Presurgical
  - Early rehab
- Better strength → Better function

Hartigan et al., 2012; Logerstedt et al., 2013; Schmitt et al, 2012
Sample Case
Interventions

• “Can’t we just make the muscle stronger?”

• Traditional strengthening may not address inhibition
  – Inhibition limits strength gains

Knowledge Gap

- Causes of quadriceps weakness are not well understood
  - Intervention efficacy is mixed
Causes

- Peripheral muscle
  - Atrophy
- Neurological
  - Motor unit firing rate
  - Spinal reflex excitability
  - Corticospinal excitability
Quadriiceps Atrophy

- Muscle cross-sectional area and fiber type contribute to quadriiceps strength
  - Thigh circumference
  - Ultrasound imaging
  - MRI
- Type II > Type I

Quadriceps Inhibition

- Knee joint effusion (experimental)
- Patellofemoral joint pain
- Meniscectomy
- ACL injury/reconstruction
- Osteoarthritis

Quadriceps Inhibition

• Most severe immediately following injury or surgery
  – May persist despite return to function
• Limits strength gains

Shakespeare et al., 1985; Mizner et al., 2005; Petterson et al., 2011; Ingersoll et al, 2008; Hart et al, 2010; Harkey et al, 2016
Target Specific Cause

- Inhibition (neurological)
- Atrophy (peripheral)
Afferent Pathways

- Cryotherapy
- TENS
- Vibration
- Joint Mobilization

Fig 2. Pickar, 2002
Efferent Pathways

- NMES
- Biofeedback
- Transcranial direct current stimulation (tDCS)
- Repetitive TMS
Cryotherapy

- Facilitate quadriceps function
  - Spinal reflex excitability
  - Voluntary activation
- Consider use **prior to exercise**
  - Applied to knee joint

Hopkins et al, 2002; Pietrosimone et al, 2009
Sensory TENS

• Increase strength, voluntary activation, and function
  – Effective during treatment
  – Better effects with extended wear

Sensory TENS

- History of partial meniscectomy (n=23)
  - Voluntary activation increased 6% (P= .01)
  - Effect greater when inhibition present (10%; d= .71)

Grindstaff et al, In Review
Sensory TENS Parameters

- Electrodes surround knee joint
- **Strong, comfortable sensation** without muscle contraction (150 Hz, 150 µs)
- > 8 hours per day during activity

Vibration

• Improves balance, strength, hop performance
  – Reduces quadriceps inhibition (~5%)
• Mixed findings for joint reposition sense

Fu et al, 2013; Moezy et al, 2008; Berschin et al, 2014; Blackburn et al, 2014; Pamukoff et al, 2016; 2017
NMES

- Augments quadriceps strength, reduces inhibition
- Better patient reported outcomes
- Incorporate early and often
  - Weeks 1-4 post-op
  - 6 weeks duration

Kim et al., 2010; Lepley et al, 2015; Dantas et al, 2015
NMES Parameters

- Large electrodes
- Secure limb 60° or 90°
- Maximum tolerable level
- 1:5 $\rightarrow$ 1:3 $\rightarrow$ 1:1
Biofeedback

• Measures electrical activity (amplitude)  
  – Not force
• External cue used to improve retention
• Increases corticomotor excitability

Lepley et al, 2012; Pietosimone et al, 2015
Biofeedback Parameters

- Prep skin
- Secure electrodes
  - Recording
  - Reference (ground)
- Determine threshold
  - MVIC
- Set target threshold above
  - Auditory or visual cue when EMG signal above target

Lepley et al, 2012; Pietosimone et al, 2015
Visual-Motor Training

- Address greater reliance on visual system and loss of sensory input
- Eyes closed conditions most common method
  - Limited to static exercises (e.g. balance)
  - Most sports performed with eyes open, but visual input may be disrupted

Grooms et al, 2015 JOSPT
Visual-Motor Training

- Strobe glasses offers ability to manipulate visual input while performing activity (e.g. jump landing)
  - Greater emphasis on vestibular and proprioceptive systems
- May also be used to train visual system in isolation

Grooms et al, 2015 JOSPT
tDCS

• Healthy
  – Acute increase (10%) quadriceps peak torque (d= 0.6-0.95)
  – Did not augment 3 week exercise program

• Knee OA
  – Augments exercise with decreased pain (4/10), improved function (10 points WOMAC)

Vargas et al, 2017; Maeda et al, 2017; Ahn et al, 2017; Chang et al, 2017
Exercise Dosing

- Exercise intensity too low to elicit substantial gains in strength

Angelozzi et al., 2012; Augustssson, 2013
Resistance Training

- Healthy individuals (3x/week; 3-4 weeks)
  - Decreased AMT
  - Increased MEP/Mmax ratio
- Knee OA case study with 8 weeks of rehabilitation
  - Increased MEP/Mmax ratio

Rate Limiting Factors

- Quadriceps inhibition
- Exercise intensity that is *too low*
Summary

- Knee injuries may have common mechanism
  - Injury risk reduction programs
- Address underlying impairments
  - Rate limiting factors are quadriceps inhibition and exercise intensity that is too low
- Greater reliance on vision after injury
  - Limited somatosensory
- External focus
  - Reduces need for conscious (internal) control during movement
Thank You

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