CSM 2018 Outline

Educational Session Title:
Neuromuscular Training after ACLR to Decrease ACL Re-Injuries & Risk in Females

Speakers:
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1. Introduction
   a. Common sports injury
2. Anatomy
   a. ACL bundles
   b. Blood supply
3. Biomechanics
   a. Mechanism of Injury
4. Risk Factors
   a. Modifiable
      i. Preventative measures
      ii. Proper landing technique
   b. Non-modifiable
      i. Notch
      ii. Ligament laxity
      iii. Tibial plateau
      iv. Neuromuscular maturation
      v. Hormonal influence
5. Current Technique
   a. Endoscopic Interference Fixation Utilizing Bioabsorbable Screws
6. Pre-Operative Assessment
7. Graft Selection/harvest
8. Arthroscopic Approach
   a. Tunnel Selection
      i. Tibial
      ii. Femoral
   b. Implantation
9. Post-Surgery
   a. Rehabilitation
   b. Complications
Re-Establishing Proprioception and Neuromuscular Control in the ACL Reconstructed Knee

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I. Introduction

A. ACL injuries are common in sports.
   1. The ACL is totally disrupted more than any other ligament of the knee.
      a. Incidence in general population:
         1) approximately 200,000 ACL injuries annually
         2) approximately 174,684 ACL undergo reconstruction
      b. Incidence of ACL tears in football players
   2. Some sports have a higher injury rate
   3. Some individuals are at a higher risk of injury
      a. High school female athlete (16-19 yr old)
      b. Level I sports higher injury rate

B. Well Designed Rehab Program is Vital
   1. Must include proprioception & neuromuscular control exercises
   2. Strengthening exercises & drills
   3. Functional rehab program
   4. Gradually increase the rehab challenges
   5. Reduce kinesiophobia.

III. Terminology

A. Specific Terms and Definitions
   1. Proprioception - Conscious and unconscious appreciation of joint position
   2. Kinesthesia - The sensation of joint motion or acceleration
   3. Neuromuscular Control - The efferent response (motor) to sensory information
   4. Feed-forward neuromuscular control - involves planning movements based on sensory information from past experiences (motor learning)
   5. Feedback Process - Continuously regulates motor control through reflex pathways
      a. Feed-forward mechanism responsible for preparatory muscle activity
      b. Feed-back process associated with reactive muscle activity
V. Re-establishing Proprioception and Neuromuscular Control

A. The Rehabilitation Program
   1. Gradual and progressive
   2. Tasks gradually get more difficult
   3. Controlled tasks and activities
   4. Enhance neuromuscular control

B. Four Elements and Stage
   1. Proprioceptive and kinesthetic sensation & Static Joint Stability
   2. Dynamic joint stability
   3. Reactive neuromuscular control
   4. Functional motor patterns (Skill, Sports)

C. Specific Rehabilitation Techniques and Drills

1. **Proprioceptive and kinesthetic sensation & Static Joint Stability**
   
   Objective: Training to restore the neurosensory properties of the injured ligaments, enhance sensitivity of secondary peripheral afferents, and provide deafferentation of mechanoreceptors in the lower extremity.
   
   a. Specific techniques
      
      1) Joint repositioning (passive active joint repositioning)
      2) Functional range of motion
      3) Ability to perform AROM with static holds
      4) Weight distribution
      5) Weight shifts
      6) Mini-squats with static stabilization
      7) Weight shifts with static holds
      8) Functional range of motion with static holds
      9) Diagonal weight shifts
      10) Standing on foam (static holds)
      11) Pool activities
      12) Biodex stability system squats
      13) Stepping drills
      14) Train the core & hips
      15) Braces, neoprene sleeves, elastic wraps (provide feedback)

2. **Dynamic stabilization**
   
   Objective: To encourage preparatory agonist/antagonist coactivation during functional activities.
*Requires anticipating and reacting to joint loads.

a. Specific techniques

1) Lateral step-overs (cone stepping)
2) Lateral lunges (straight plane and rotational movements)
3) Kickers
4) Stability stance on foam
5) “Step downs” Step downs on foam
6) “Balance beam activities”
7) Squats and weight shifts on foam
8) Squats on Bosu ball
8) Bilateral leg balance squats on wobble boards
9) Lunges onto unstable surface (tremor, foam, etc)
10) Single leg stability drills on foam
11) Single leg stability drills on wobble board
12) Initiation of Perturbation training

Stable surface → unstable platforms
Single plane → multi-plane movements
Single skill → multi-skill activities
2 legged drills → 1 legged drills

3. **Reactive neuromuscular control**

Objective: Focuses on stimulating the reflex pathway from articular and tenomuscular receptors to stabilizing muscles.

*Anticipated and unanticipated activities.

a. Specific techniques

1) Single legged drills
2) Single leg perturbations on wobble board
3) Single leg ball catches on foam
4) Single leg ball catches on bosu ball
5) Single leg star drill
6) Bilateral Plyometric jumps (leg press, squat machine, etc)
7) Plyometrics on boxes side to side
8) Plyometric jumps with rotation
9) Plyometric jumps (foam)
10) Lateral lunges (foam)
11) Balance reaction with perturbation
12) Balance reaction with perturbation and skill  
13) Lateral lungs with perturbation  
14) Plyometrics with perturbation  
15) Skill movement with explosive movement & stabilization

4. **Functional motor patterns**

Objective: Activities that simulate function sport activities and incorporate all available resources such as peripheral afferents, muscle co-activation, and reflex and preprogrammed motor control.

a. Specific techniques  
1) Pool activities  
2) Crossover walking  
3) Backward running  
4) Side slides  
5) Forward light jogging  
6) Figure eight  
7) Forward running – increase speed with stop & starts  
8) Yo-Yos  
9) Cutting drills  
10) Running & cutting  
    45 degree cuts & then 90 degree cuts  
11) Sports skills  
    (Catching a ball, dribbling a ball, fielding a ball, running and sliding, etc.)  
12) Gradual return to sport (interval program)

VI. **Summary**

A. **Key Points**

1. Disruption of the ACL may compromise static and dynamic restraining mechanisms of the knee.  
2. Dynamic stabilization is mediated by mechanoreceptors, muscle spindle and pathways.  
4. Feed-forward and feed-back neuromuscular control.  
5. Specific rehabilitation program  
   a. Gradual, progressive, sequential program  
   b. Challenging program (40-50% failure)  
   c. Prevent deafferentation

3. Integrate into your program, which must include range of motion, strengthening, endurance, etc.

4. **Progressive, Sequential and Challenging Program**
1 Re-Injury Rates of Post-Op ACL Reconstruction and Re-Injury Prevention Strategies

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2 ACL Primary Injury Rates  
Relatively Low Incidence all Sports

• Stanley et al, 2016  
  » 12,170 High School & College Female Athletes  
    • 1.84% prevalence of ACL Injuries  
  » 14,741 High School & College Male Athletes  
    • 0.77% prevalence of ACL Injuries  
  » 1.25% of High School & College Athletes Have Sustain an ACL Injury  
  » 24 Times Higher Re-Injury Rate in Those Returning to Division I Sports Following ACLR  

3 ACL INJURIES

• Annually there are 200,000 - 250,000 ACL injuries (40-50% are 15-19 yo) with over 100,000 reconstructions (Mather et al 2013)  
• Approximately:  
  » $38,000 per injury lifetime cost (Mather et al, 2013) & 3 billion annually  
  » 60-70% are sports-related and occur in individuals 14-29 yo  
    • Young (14-22 yo) active females have highest prevalence of injury  
  » 65-75% are non-contact injuries (Olsen et al, 2004)  
• Osteoarthritis is developed in 1 of 3 in 5 years and 90% in 10 years

4 ACL Injury Rates

• Higher incidence in “high risk” sports that involve running & hard cutting, deceleration, twisting, and jumping & landing  
• ACL Injuries relatively common in basketball, soccer, and volleyball, especially in young active females

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7 ACL INJURIES  
Female Athlete

• Females have a 4-8 times higher incidence of ACL injuries compared to males:  
  » Chandy (HS sports) 4.6 : 1  
  » Arendt (coll. sports) 4 : 1  
  » Malone (basketball) 8 : 1
Lindenfeld (soccer) 6 : 1
Ferratti (volleyball) 4 : 1

- Muscle strengthening of the hip abductors, extensors and external rotators, as well as the quadriceps, especially concomitant with plyometric training, has been shown to decrease ACL tears, especially in females (Hewett et al, AJSM, 2006)

8 □ Mechanical Model Linking Lateral Trunk Motion to Changes in GRF, Hip Add & Knee Abd Moments, & ACL Loading During Cutting & Landing

9 □ Deficits in Neuromuscular Control of the Trunk (primarily Coronal Plane Lateral Flexion) Predict Knee Injury Risk

10 □ Deficits in Neuromuscular Control of the Trunk (Coronal Plane Lateral Flexion) Predict ACL Injury Risk in Females

11 □ Knee Abduction & Hip Adduction Moments, GRF, & Landing Contact Time (less in ACL Injured) Predict ACL Injury Risk In Female Athletes

12 □ Biomechanical & Neuromuscular Factors That May Increase ACL Injury Risk in Females

13 □ Neuromuscular Factors That May Increase ACL Injury Risk in Females

14 □ ACL RE-INJURY RATES IN YOUNG FEMALES AND ACL INJURY PREVENTION PROGRAMS

15 □ Current Return to Sport (RTS) Criteria after ACLR from Recent Meta Analysis (Abrams et al, 2014)
- 88 Studies Reviewed
- Athletes RTS 6-9 months after ACLR
- 6 Months Post ACLR Most Common Time for RTS Testing
- Hop Tests most Common Tests for RTS Readiness
- Quadriceps and Hamstrings Strength Also Very Common for RTS Readiness
  » ≥90% Strength and Performance of Involved Side Compared to Non-Involved Side Most Common

16 □ High Incidence of 2nd Injury Following Return to Sport (RTS)
- Paterno et al, 2014
  » 29.5% sustained 2nd ACL Injury
- Kamath et al, 2014
  » 37.1% sustained 2nd ACL Injury
- Webster et al, 2016
  » 30.0% sustained 2nd ACL Injury
- Grindem et al, 2016
  » 34.6% sustained 2nd ACL Injury
ACL Re-Injury Rates in Young Females

- In the first 1-5 years post ACL reconstruction ACL re-injury rates have been reported to be 12-35% in young active females (especially females 14-22 year old) who participate in sports that have high ACL re-injury rates, and the top three are basketball, football (soccer), and volleyball
- Contralateral ACL injuries (non-involved side) are also relatively common after an ipsilateral ACL injury and reconstruction, and have been shown to occur at a similar rate as an ipsilateral ACL re-injury

ACL Re-Injury Rates

Time Dependent Relative to RTS

- Grindem et al, 2016
  » 100% of Athletes who Returned to Sport (RTS) in < 5 Months Sustained ACL Re-Injury
  » 39.9% of Athletes of ACL Injuries who RTS in ≤9 Months Sustained ACL Re-Injury
  » 19.4% of Athletes of ACL Injuries who RTS in ≥9 Months Sustained ACL Re-Injury
  » 51% Decrease in Re-Injury Rate for Each Month Delay in RTS Up to 9 Months
  » Current 6-9 Months RTS may be Inadequate for Minimizing Reinjury Rates

ACL Re-Injury Rates

Criteria Dependent Relative to RTS

- Grindem et al, 2016
  » 38% who Failed RTS Criteria Sustained ACL Re-Injury
  » 5.6% who Passed RTS Criteria Sustained ACL Re-Injury
    • 84% lower ACL Re-Injury in Those Who passed RTS Criteria Compared to Those Who Failed RTP Criteria
  » An Important RTS Criteria is Quadriceps Strength Limb Symmetry Index (LSI)
    • 33.3% Re-Injury Rate in Those with LSI < 90%
    • 12.5% Re-Injury Rate in Those with LSI ≥ 90%
  » Hop Test Not Associated with ACL Re-Injury
  » No Single Criteria/Test Was Adequate to Determine Readiness to Safely RTS

ACL Re-Injury Risk Rate Following RTS

- 2-4 times more likely to re-injury ACL with:
  » Increased knee valgus and hip adduction angles (Paterno et al, 2013)
  » Increased knee extension moment asymmetry (Paterno et al, 2013; Grindem et al, 2016)
  » Quadriceps strength LSI <90% (Grindem et al, 2016)
  » A score < 56 points on the Anterior Cruciate Ligament-Return to Sport after Injury scale (ACL-RSI), which indicates psychological readiness to return to sports participation, may indicate an increased risk of not returning to their preinjury level of function (Ardern et al,
Single leg balance deficit (Paterno et al, 2013)

Step Down Test

ROM, Strength, Power, and Biomechanical Deficits Following RTS

- **Range of Motion**
  - ↓ 3-5° knee extension compared to uninvolved side (Shelbourne & Grey, 2009)
  - ↓ hip rotation ROM (Gomes et al, 2008)
  - ↓ ankle dorsiflexion ROM (Wahlstedt et al, 2015)

- **Strength**
  - Quadricep strength deficits continues 5 years post ACLR (Lautamies et al, 2008)

- **Power**
  - ↓ performance in hop test (Hegedus et al, 2014)

- Altered Biomechanics and Poor Movement Quality (Hart et al, 2009, 2015; Bell et al, 2014)

Multi-Dimensional RTS Norm Criteria for HS and College Age Athletes

Load Management & Progression after RTS

Acute to Chronic WorkLoad Ratios and Re-Injury Risk (Blanch & Gabbett, 2015)

Training Loads in Football (Soccer) (Malone et al, 2015)

In-season 1 Week Microcycle

Case Example: Training Loads During ACLR Rehabilitation Until RTS (Padua, 2017)


Select ACL Injury Prevention Programs

Newer ACL Injury Prevention Programs

Key Components of Neuromuscular Training

- Single Limb Balance - strength, proprioception (Caraffa, 1996)
- Perturbations - anticipated & unanticipated (proprioception & balance) (Olsen et al, 2005)
- Strength Training (protects from ACL injury; helps build solid strength base for higher intensity plyometric training) (Hewett et al, 1999; Olsen et al, 2005)
  - Core, hip, thigh musculature
• Plyometrics (Start with lower intensity and progress to higher intensity – most important variable in reducing ACL injury risk) (Hewett et al, 1999; Olsen et al, 2005; Petersen et al, 2005)
  » Stretch reflex can increase muscle stiffness by one to three times (Hagood et al, AJSM 1990; Lieber & Friden, 1992)
• Agility (muscle coordination and specificity of training)
  » (Mandelbaum et al, 2005; Olsen et al, 2005)

35 **Key Results of Neuromuscular Training**

• Rate of non-contact ACL Injuries decreased 70-80% in female athletes (Hewett et al, 2006; Mandelbaum et al, 2005; Myklebust et al, 2013)
• Jumping and landing biomechanics improved (↓ valgus moment and ↑ knee flexion) with ↓ ACL injury risk (Chappell & Limpisvasti, 2008)
• Peak landing forces ↓ 22%, knee valgus moments ↓ 50%, ham:quad peak torque ratio ↑ 15-25%, hamstring muscle power ↑ 20-45%, vertical jump Ht ↑ 10%, max hip adduction & ankle eversion angles ↓, & max knee flexion angle ↑ (Hewett et al, 1996; Myer et al, 2006; Chappell et al, 2008)
• ↓ hip IR and ↓ hip adduction (Pollard et al, 2006)

36 **Improvements in Performance from Neuromuscular Training**

• Increased strength and power (Yamaguchi, 2005)
• Sprinting speed (Goodwin, 2002; Fletcher, 2007, Faigenbaum, 2006; Barber-Wesin, 2010; Kilding, 2008)
• Vertical jump (Faigenbaum, 2006, Thompsen, 2007; Chappell, 2008; DiSteffano, 2012; Kilding, 2008; Hewett, 1996; Noyes, 2005)
• Agility (McMillan, 2007)
• Hop Distance (Barber-Wesin, 2010; Herrington, 2010)
• Hop Speed (Chappell, 2008)

37 **Neuromuscular Training Best Started Early**

38 **Neuromuscular Training and ACL Injury Prevention**

39 **Compliance of ACL Injury Prevention Programs by Coaches**

40 **Thank You!**
Let's put the science into practice:
Research now substantiates longer ACL post op programs to decrease the risk of a reinjury to the postoperative reconstructed ACL knee or to the contralateral knee, but is it practical to run a program with the obstacles of insurance? Professional sports and some collegiate programs have the ability to appropriately rehab the athlete to return to competition. However, are postoperative ACL programs practical in the hospital or private practice setting?

Obstacles:
1. Clearance or return to play based on a timeline
2. Test, give a home or gym program, return to test and clear
3. Insurance limitations (visits, re-imbursement, HMO's)
4. Staff and facility limitations
5. Cost prohibitive
6. Low compliance with home and gym program

How can we make this a win–win situation?

Our post op ACL program 3-phase program 4-10 month post op

Initial Assessment:
1. Evidenced-based evaluation
2. Full ROM
3. Strength test: isometric hip abd, quad and hamstrings
4. Hip / femoral angle retroversion
5. Foot arch assessment (pronation supination)
6. Hop Test
7. Y-Balance
8. Computer Assessment: Tibial angle and total excursion, weight bearing comparison
   a) Squat Test
   b) Single leg squat
   c) Jump Test
   d) Acceleration and deceleration
   e) Trunk Plank Test
9. Max V02 step test
   a) Phase I Step test
   b) Phase II
   c) Phase III Beep Test
Our program: Three-phase
4 to 5 months:

Mobility:
- Dynamic Warm-up
- Neuromuscular preparation
- Form run
- Balance training
- Coordination and fast twitch

Agility: linear, multidirectional
a) Phase 1: low intensity
b) Phase 2: medium intensity
c) Phase 3: High intensity + Reactive

Power:
- Keiser
- Hip work
- Gluts
- Core

Strength:
- Squats
- Lunge
- Dead lifts
- Posterior Chain
- Glut/Ham raise

Fitness Max VO2: and Overall Load.
- Cardio at home/gym
  - Phase I: Bike and elliptical
  - Phase II: Elliptical and Treadmill
  - Phase III: Return to practice...increase load off to the side
          Preparing to practice and load volume

Flexibility:
- Stretch: LE’s, Core
- Recommend Yoga strength stabilization and mobility

Class: Two days/week
- 200.00 / month includes 1 assessment
- 5:00 pm to 6:30 pm

Staff:
- Physical Therapist:
  - 4:30 to 5:00 Conducts 2 assessments
  - 5:00 to 5:30 Movement
- Strength Coach, CSCS
  - 5:00 to 5:30 Movement
  - 5:30 to 6:30 Weight room for power, Weights and Flexibility

Total number of students:
$200.00 student for 8 sessions / month = 25.00 session
$200 \times 12 \text{ students} \times 8 \text{ sessions} = $2,400
$300.00 \text{ per session}