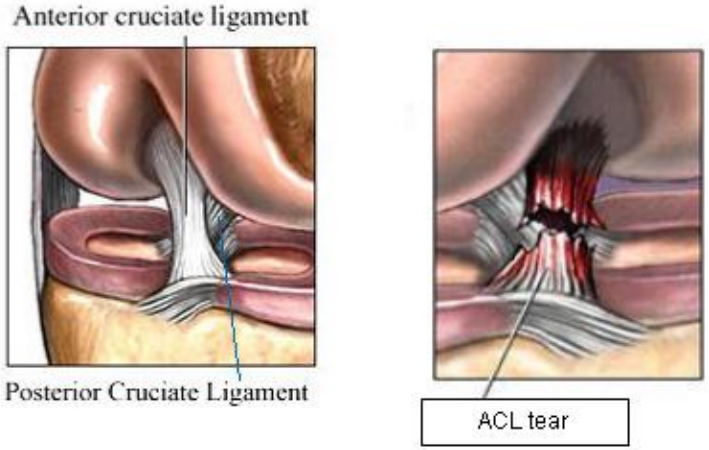
# ACL Injury
# Non-Operative Rehabilitation

Amy S. Bencic, PT,DPT,OCS
Indiana Total Therapy
Human Motion Institute




- The ACL provides 85% of the total restraining force to anterior translation of the tibia.
- An ACL tear is a common injury that occurs in all types of sports. It typically occurs during a sudden cut, twist, deceleration, or landing from a jump, as it typically is a noncontact injury. (60% to 70%)
- It is the most common severe ligamentous injury incurred by athletes.

- The ACL contains mechanoreceptors and free nerve endings that are hypothesized to aid in stabilizing the knee joint.
- ACL injury is isolated in 25% of cases. Combined injuries may involve meniscus (60%), articular cartilage (30%), or collateral ligaments (30%), joint capsule, or combination of such injuries.
- ACL injuries occur most commonly in individuals aged 14–29 years. These years correspond to a high degree of athletic activity

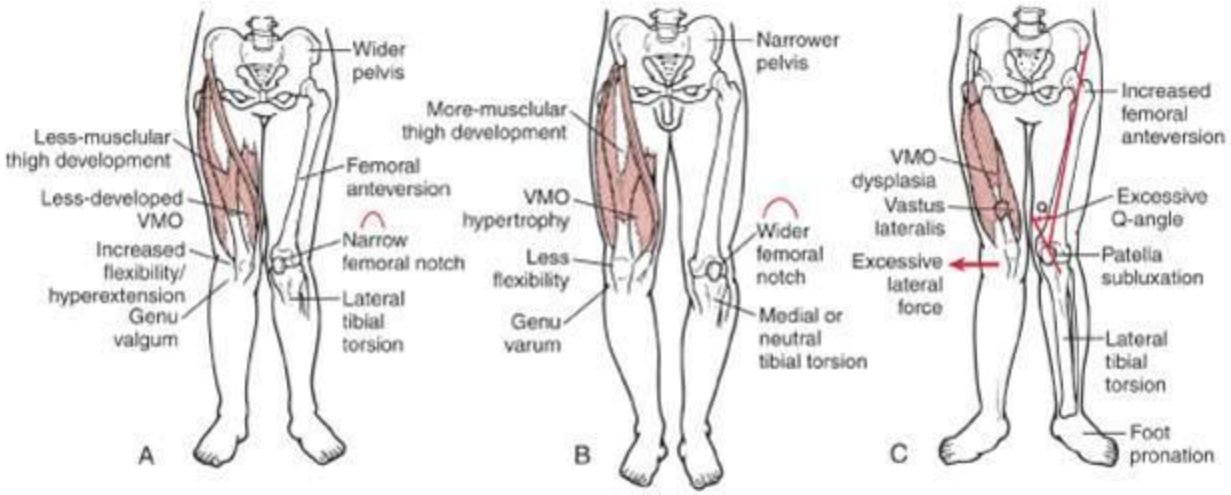
- In the months following ACL injury, “functional impairment” becomes the primary concern. The development of symptoms of knee instability is unpredictable. Instability ranges from 16% to almost 100% of cases. Functional instability is more likely to occur with combined damage to the meniscus, articular cartilage, and other ligaments.

  According to numerous studies, female athletes sustain a greater number of ACL injuries than male athletes. These results are well supported.

# Female Athletes vs. Male Athletes

# Unique Characteristics of the Female vs. Male Athlete
# Anatomical Differences

- Wider pelvis
- Increased flexibility
- Less-developed thigh musculature
- Narrower femoral notch
- Smaller ACL
- Increased genu valgus
- Increased external tibial torsion




From Griffin, L.Y. [ed.]: Rehabilitation of the Injured Knee. St. Louis, C.V. Mosby Co., 1995, pp. 298–299.

# Female vs. Male Athlete Laxity and ROM

- Greater ROM
- Genu recurvatum
- Increased knee laxity
- Increased hip rotation

## Muscular and Neuromuscular

- Diminished muscular force
- Dependence on quadriceps muscle for stability
- Longer time to develop force
- Longer electromechanical response time

# Neuromuscular Control Imbalances The Evidence

- Hewett et al describe 3 neuromuscular control imbalances common to female athletes which are believed to place them at risk for ACL injury.

- 1) LIGAMENT DOMINANCE
- 2) QUADRICEPS DOMINANCE
- 3) LEG DOMINANCE

# LIGAMENT DOMINANCE

- Occurs when the NM control strategy employed by the athlete provides insufficient dynamic restraint of the knee, thus allowing an excessive amount of ground reaction force (GRF) associated with sport maneuvers to be absorbed by knee ligaments. Females allow the GRF to control the motion of the LE. ( Inc. valgus)

# Ligament Dominance

Bendjaballah et al found that a 5 degree valgus at the knee could inc. load on ACL 6-fold.

# Ligament Dominance

- Hewett et al found that females who injured ACL's, have significantly greater valgus knee angles at initial contact, greater maximum valgus angles, and greater peak abduction moment at the knee when landing from a jump than compared to uninjured females. This position is found to be a significant predictor of ACL injury.

# QUADRICEPS DOMINANCE

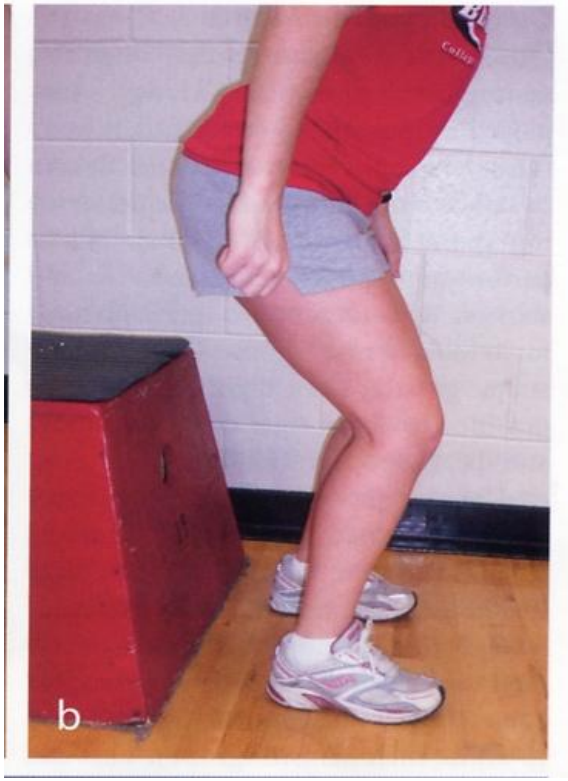
- A NM control strategy when the athlete preferably activates the quads over the knee flexors to stabilize during sporting maneuvers. When the tibia begins to shift forward, females tend to activate quads to stabilize the knee whereas males utilize the hamstrings.
- Supported by studies (Chappell et al) quad force will draw the tibia forward with the knee flexed 45 degrees or less stressing the ACL, while the hamstrings will pull it back.

# Quadriceps Dominance

- Limited strength of the hamstrings in relation to the quads may be a factor as the female athletes have been shown to have significantly lower peak hamstring-to-quad strength and take significantly longer to reach hamstring peak torque compared to male athletes.

# LEG DOMINANCE

- Describes the differing NM control between the right and left LE's.
- Demonstrated by asymmetrical foot position with landing often with the weaker ND leg forward.
- Females demonstrate decreased hamstring torque ND vs. Dom LE.
- A 15% difference with side-to-side comparisons LE strength or power puts at risk.
- Studies suggest this can affect both limbs.



# Additional Extrinsic Factors that affect NM control

- 1) Joint Position and ROM
- 2) Core stability
- 3) Neuromuscular fatigue

# Joint Position and ROM

- Females tend to land with less knee and hip flexion.  When the knee is flexed to 45 or less the quads draw the tibia forward, however, if flexed greater than 45, the pull of the quads changes and will act to pull the tibia posterior
- Also with the knee flexed past 20, the hams will become more effective in drawing the tibia posterior on the femur.
- The position of the hip is important, because quad activity tends to decrease with increased hip flexion.

# Core Stability

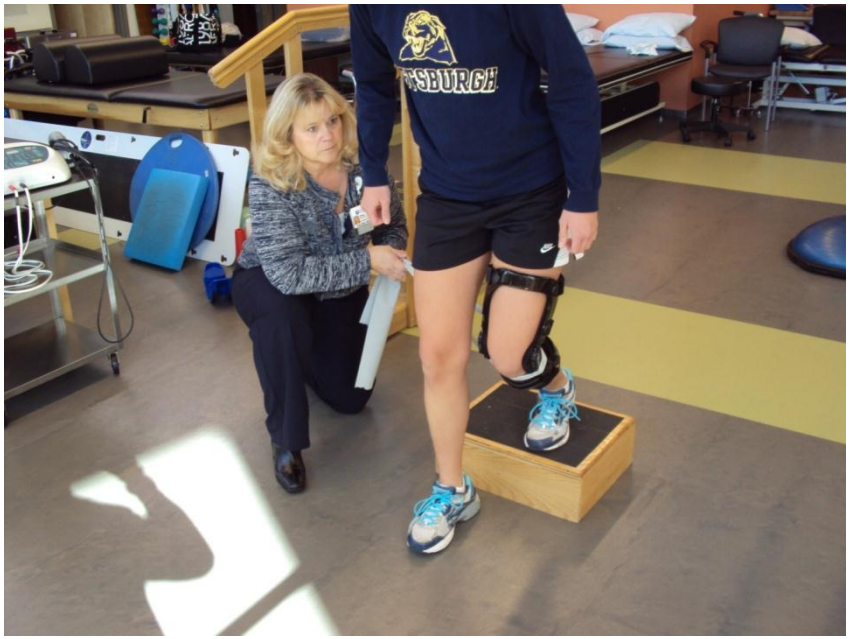
- Defined as the ability to maintain proper alignment of the lumbopelvic-hip complex in various postures and loading positions.
- Both static and dynamic forces contribute.
- Passive forces include bony alignment and soft tissue compliance.  Dynamic forces include mm. of the lumbopelvic-hip complex  (hip ER's, gluts, hams, abdominals, quadratus lumborum, erector spinae, and multifidus)
- Weakness of these mm. can lead to inc.valgus movement at the knee with rep. jumping.

# Neuromuscular Fatigue

- Research suggests exercise near exhaustion may inc. joint ligament laxity and provide inadequate feedback from jt. mechanoreceptors, thus compromising the ability of knee reflexes to stabilize the joint.
- Fatigue affects the mm spindle and GTO's, potentially leading to dec. proprioceptive feedback to the CNS and dec. NM control.
- (Chappell et al) studies show with fatigue inc. peak proximal anterior shear force at the knee and dec. knee flex. angles, and females inc. external abduction moment at knee.

# Factors to Consider in ACL Rehabilitation of the Female Athlete

1. Females exhibit a wider pelvis and increased genu valgus- Dynamic control of valgus moment at the knee joint needs to be addressed.

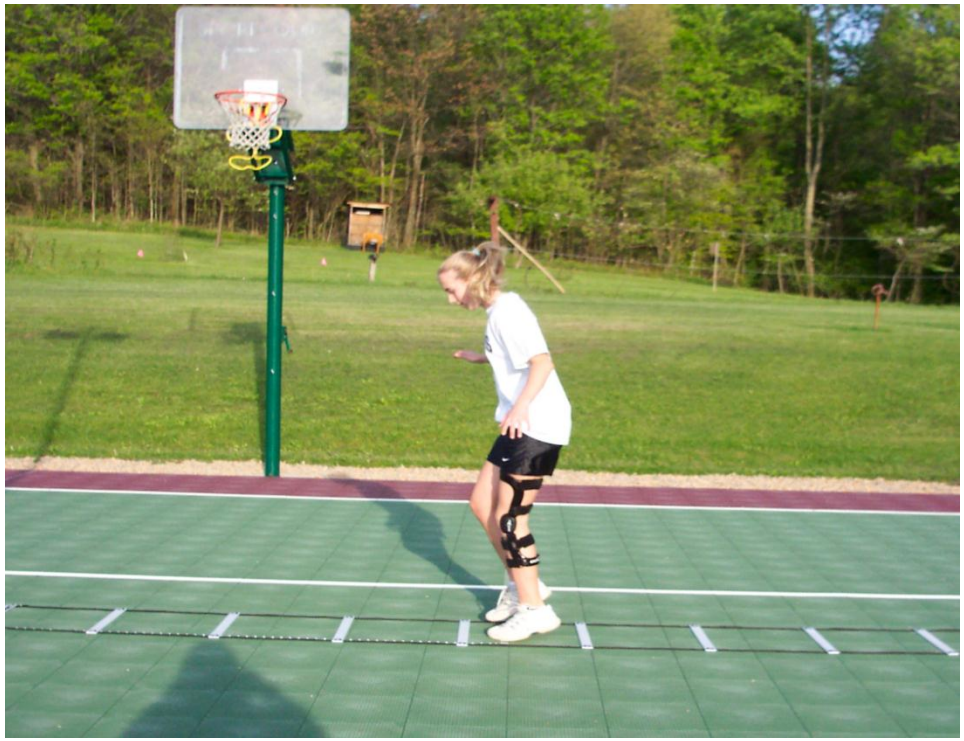


# Factors to Consider in ACL Rehabilitation of the Female Athlete

2. Female athletes recruit quadriceps muscle to stabilize the knee- Retrain the neuromuscular pattern to also include the hamstrings

# Factors to Consider in ACL Rehabilitation of the Female Athlete

3. Females generate muscular force more slowly than males- Train for fast speeds and reaction timing. (hamstrings, core trunk, interval speed training, plyometrics)



# Factors to Consider in ACL Rehabilitation of the Female Athlete

4. Jumping athletes lose hip control upon landing- Train for hip and trunk control for proper landing. ( Plyometrics, postural retr. Core)

5. Less-developed thigh musculature- Train the lumbopelvic-hip musculature to assist in stabilization.
6. Genu recurvatum and increased joint laxity- Train the athlete to control knee extension.
7. Exhibit less-effective dynamic stabilization- Enhance neuromuscular control and protective pattern reflexes. (plyometrics, balance, perturbation)
8. Poor muscular endurance rates- Train to enhance endurance.

# Examination ( H&P) Mechanism of Injury

# Examination
# History and Physical

- Mechanism of injury- sports, contact vs noncontact
- History of previous knee injury
- Pain- Visual Analog or Numeric Scale
- Feeling/hearing a “pop” and “giving out” (50%)
- Ability to continue playing sport
- Swelling- midpatellar girth, stroking test
- Palpation
- Loss of knee ROM- Goniometer is standard measurement tool. The standard error is 3 deg.
- Loss of strength- MMT or dynamometer
- Clinical tests- Anterior Drawer, Lachman Test, Pivot-Shift Test

B

B

B

# Functional Tests

- Used for progression and discharge criteria. Functional tests are being developed and tested continuously.
- The most commonly used and tested are a series of one-legged hops as described by Noyes et al, relating involved knee hopping distance and time to that of the uninvolved leg. These tests include measurements of single hop for distance, triple hop for distance, crossover triple hop for distance, and a timed 6-meter hop.
- The sensitivity of the single (49%), triple (50%), crossover (58%), and timed (52%) were reported by Noyes et al. The specificity was 97% and 94% for the timed and single hops, respectively

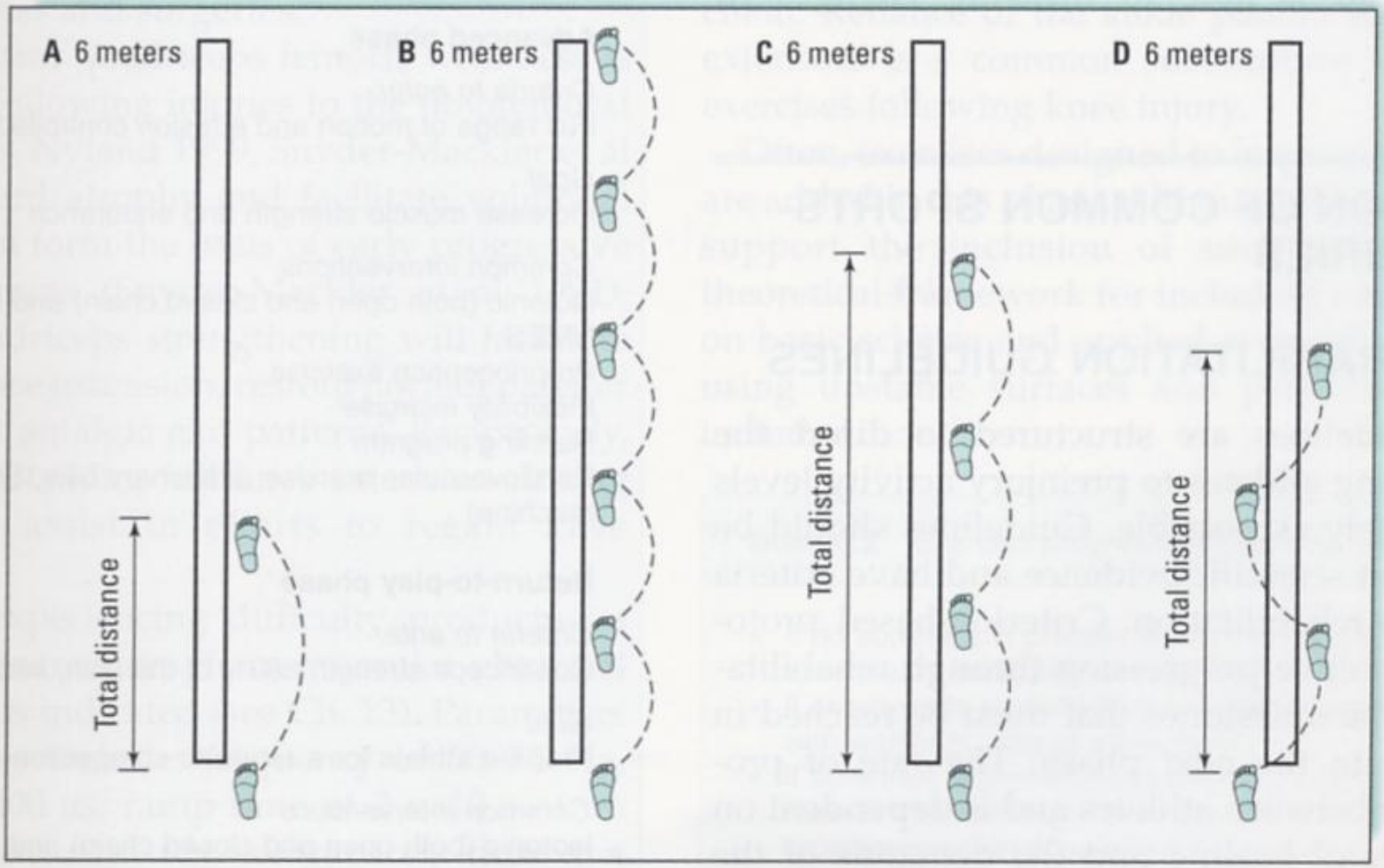



**Figure 20.9** Hop tests for the knee. **A**: Single hop for distance. **B**: Timed hop. **C**: Triple hop for distance. **D**: Cross-over hop for distance.

# Functional Tests

- A limb symmetry index (LSI) is used to assess whether a hop test is normal or abnormal. The LSI is a percentage of distance hopped expressed as involved/uninvolved x 100. Normal LSI is considered 80% to 85% based on the finding that 90% of subjects without ACL injury had an LSI of 80% to 85%.
- It is unknown how accurately a hop test can predict when a patient is ready to return to full activity.
- The best predictor for patient outcome is probably a combination of strength, self report, and functional testing. Each of these tap into a different component of the overall patient profile.

# Non-Operative Rehabilitation


# Non-Operative Rehabilitation

- Although an estimated 200,000 ACL injuries occur in the U.S. annually, only approximately 60,000 to 100,000 individuals with ACL deficiency undergo reconstructive surgery.

- Some individuals can stabilize their knees following ACL rupture, even during activities involving cutting and pivoting, but most experience instability with daily activities.

# Evidence

- Data by Chmielewski et al (PHYS THER, 8/05) suggest that physiological responses and motor control strategies of people who successfully compensate for the absence of the ACL (“copers”) are different from those of people who do not compensate well for the injury (“non-copers”)

- *Copers,* are defined as people who have returned to full activity without symptoms of instability for at least 1 year, use strategies involving more coordinated muscle activation that stabilize the knee without compromising knee motion.

# Copers vs. Non-copers

- There is no single pattern adopted by copers
- Individually adopt compensation patterns that are related to rate of muscle activation and unrelated to quadriceps femoris muscle force.
- Conversely, *Non-copers* adopt a remarkably limited strategy to stabilize their knees across activities with widely differing demands on the knee.
- Non-copers use a *Joint-Stiffening Strategy.* This includes decreased ROM (freezing the degrees of freedom), slower mm activation, generalized co-contraction of mm across the knee. This demonstrates an unsophisticated adaptation to the ACL injury.

Copers

Non-Copers

- Non-operative rehabilitation of ACL injury has not been a successful option for those that participate in high-level physical activity. However, there may be instances when pts may want to return to high-level activities with non-operative rehab.

- Examples:
- Skeletally immature athlete
- Athlete with pre-season or early season ACL injury who has exhausted eligibility and needs to establish worthiness for scholarship/all-star teams.
- Construction workers/seasonal workers who wish to postpone surgery until busy season is done.

- There are guidelines based on two clinical studies that improved the overall success of non-operative management of physically active individuals with ACL injuries.  Certain criteria are met to select appropriate candidates.

- A decision-making process for selecting appropriate candidates ("*Potential Copers")* as described by Fitzgerald et al.

- Individuals are classified as rehabilitation candidates if they have no concomitant ligament or meniscal damage associated with the ACL injury, have a unilateral ACL injury, and meet all four of the following criteria:

  1) Timed hop test score of 80% or more of the uninjured limb.
  2) Knee Outcome Survey Activities of Daily Living Score of 80% or more.
  3) Global Rating of Knee Function of 60% or more.
  4) No more than 1 episode of giving way since the incident injury to the time of testing.

- The individuals that meet the criteria participate in a rehabilitation program which consists of lower extremity musculature training, cardiovascular endurance training, agility and sport-specific training, and a program using balance perturbations prior to return to high-level activity.

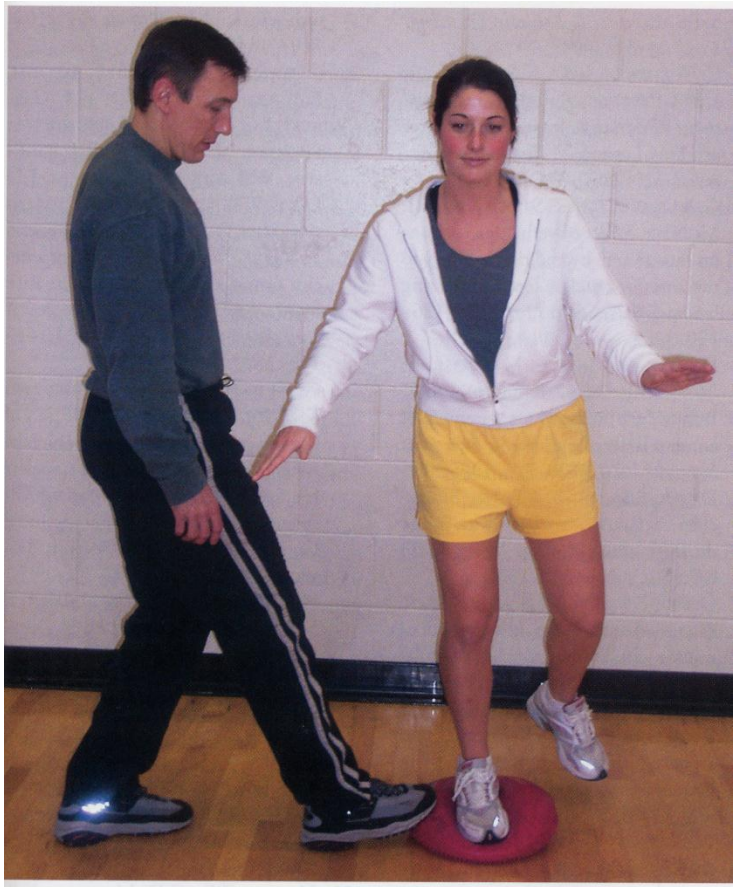


**Figure 4.** Perturbation applied to the support surface on which the athlete stands.

- During a 2 year period, 93 patients with ACL or graft ruptures without concomitant multiple ligament injury or repairable meniscal damage were tested. 39/93 (42%) of patients tested were candidates based on test scores. 28/39 patients (79%) were able to return to premorbid levels of activity and completed the season successfully.  None suffered further injury.
- Success was defined as the ability to complete the season without an episode of giving way.

- Previous studies where patients self-elected non-operative management for ACL injury, success rates for returning patients to high-level physical activity were 23% (9/39), 30% (12/40), and 39% (12/31).

  It appears that this decision-making criteria shows promise as an alternative way of selecting appropriate candidates (“Potential Copers”) over a self-elected basis for non-operative treatment.

- The second area of study was directed at improving the quality of non-operative rehabilitation strategies.

- Traditionally, non-operative ACL rehabilitation has been primarily impairment-based, emphasizing LE muscle strength and endurance, restoring knee joint mobility, agility training, activity modification, and bracing.

- There is evidence that treatment techniques , involving perturbations of support surfaces, can be used to induce compensatory alterations in muscle activity patterns in patients who are ACL deficient. This resulted in returning pts to a higher level of activity.


EXIT

# Neuromuscular Control ( Proprioception)

- Several types of sensory information contribute to NM control- visual, vestibular, and proprioceptive info are integrated by the CNS.
- Proprioception is well suited to mediate the unconscious activation of the dynamic restraints at the knee and other joints.
- Proprioception is defined as the sensory modality that encompasses the sensation of joint position and motion. Within the CNS, proprioceptive input is processed at three levels:1) spinal cord 2) brain stem 3) motor cortex/basal ganglia/ and cerebellum level

- Some authors suggest that NM training to enhance joint stability should incorporate all 3 levels of CNS.
- Spinal Cord Level- double leg or single leg balancing on an unlevel surface (perturbations) and plyometrics
- Brain Stem Level- Improve balance reactions and postural stability ( balance ex. Progressing from solid to unstable, double leg to single leg, eyes open to eyes closed)
- Conscious Level- awareness of body positions and movements prior to the initiation of a motor command and conscious awareness of the consequences after it has been initiated ( through repeated practice with attention to intrinsic and extrinsic feedback. Improves feed-forward NM control) Plyometrics, balance and perturbation


a
b
c


Balance Index
BIODEX

# Neuromuscular Control Perturbation Training

- The key principle is that patients with ACL deficiencies should be exposed to carefully controlled forces that destabilize the knee joint enough to elicit appropriate responses without putting the knee joint at risk for further injury. Gradually adding more challenging forces allows them to learn more appropriate muscle responses to unexpected forces that release the tight control of the knee that manifests in reduced knee flexion.
- Elimination of the joint stiffening strategy is important as this strategy is detrimental over time. After perturbation, the "potential coper" flexed more during weight acceptance, and degree of co-contraction was reduced, similar to control subjects.

# Non-Operative Rehabilitation Protocol and Considerations

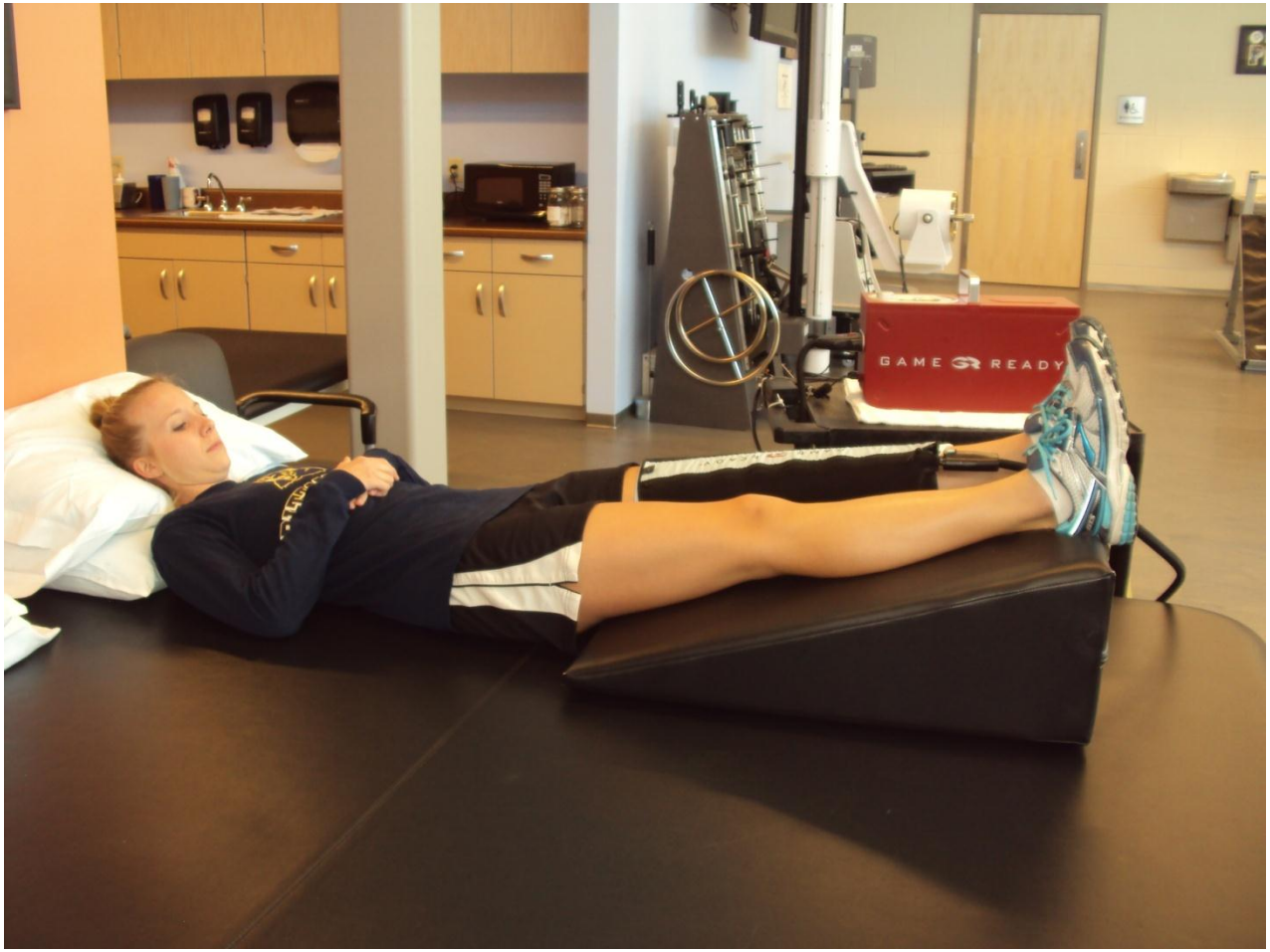
# Non-Operative
# Pre-Testing Rehabilitation

- PHASE I  (Motion and Protection)
- Impairments- Pain, edema, limited ROM, limited WB, gait with crutches, poor thigh muscle recruitment, instability
- Considerations
  - -PT 3x per week and HEP
  - -Avoid signs of inflammation
  - -Full extension
  - -WBAT: wean from assistive devices
  - -Emphasize heel-toe gait

- Goals:
- Painfree at rest
- Full ROM
- Fair quad isometric
- No lag with SLR
- Good patella mobility
- Ambulates independently
- Pain and edema control
- Initiation of muscle control/ proprioception

- Treatment:
- PROM/AROM, patella mobilization
- Quad NMES (as needed) at 0 deg- ES elicited muscle contraction is more effective
- Isometrics (quad, hams, add., gluts. abd., abdominals, QL) to improve muscle recruitment in preparation for functional activities.

- 4-direction leg raises, use surface EMG to VMO
- Weight-shifts and gait training. (Stimulates mechanoreceptor firing)
- Light CKC ex. (BAPS, wobble board, minisquats, calf raises, 1-leg balance) initiates neuromuscular control, proprioception
- Hip, ankle, and core strengthening
- Ankle pumps, elevation, ice/ES as needed, ace wrap, brace. ( RICE- The swollen knee should not be subjected to large stresses involving the tissue during the acute stage. ES has some evidence for use in resolving edema with muscle pumping action and some evidence for edema prevention at a sensory level high volt pulsed current.)
- Quad, hamstring, hip flexor, ITB, gastroc stretches
- Aquatics (ambulation, CKC exercises)
- Cardiovascular conditioning (UBE, bike, aqua)


GAME READY

- Phase II (Motion and Control)
- Considerations
  -PT 3x per week and HEP
  -Increase resistance and challenges
  -Gradually increase ROM
  -Wear brace for functional activities (the brace provides additional proprioceptive input and knee stability.) Wojtys et al demonstrated that knee braces were able to control anterior tibial translation in ACL-deficient knees by between 69.8% and 84.9% when combined with the stabilizing effects of the LE muscle contraction, but they interfered with the activation of the muscles contributing to the knee joint stability. Beynnon et al showed that bracing can reduce the strain on the ACL in WB and NWB situations, indicating that it may be helpful during dynamic activities. The use of braces remains theoretical and continues to be controversial.

- Goals:
- Full AROM, normal MMT
- Independent gait
- No lag with SLR
- Good VMO tone with quad set
- Good patella mobility
- Pain and edema controlled

- Treatment:
- Progress with ex. in phase I
- Stationary bike( high seat)
- Hamstring curls (standing, supine, prone)
- Isotonic quad strengthening (90deg-45deg) Evidence suggests that resisted leg ex can be performed in this range without inducing significant ant. shear forces in the TF joint


EAGLE

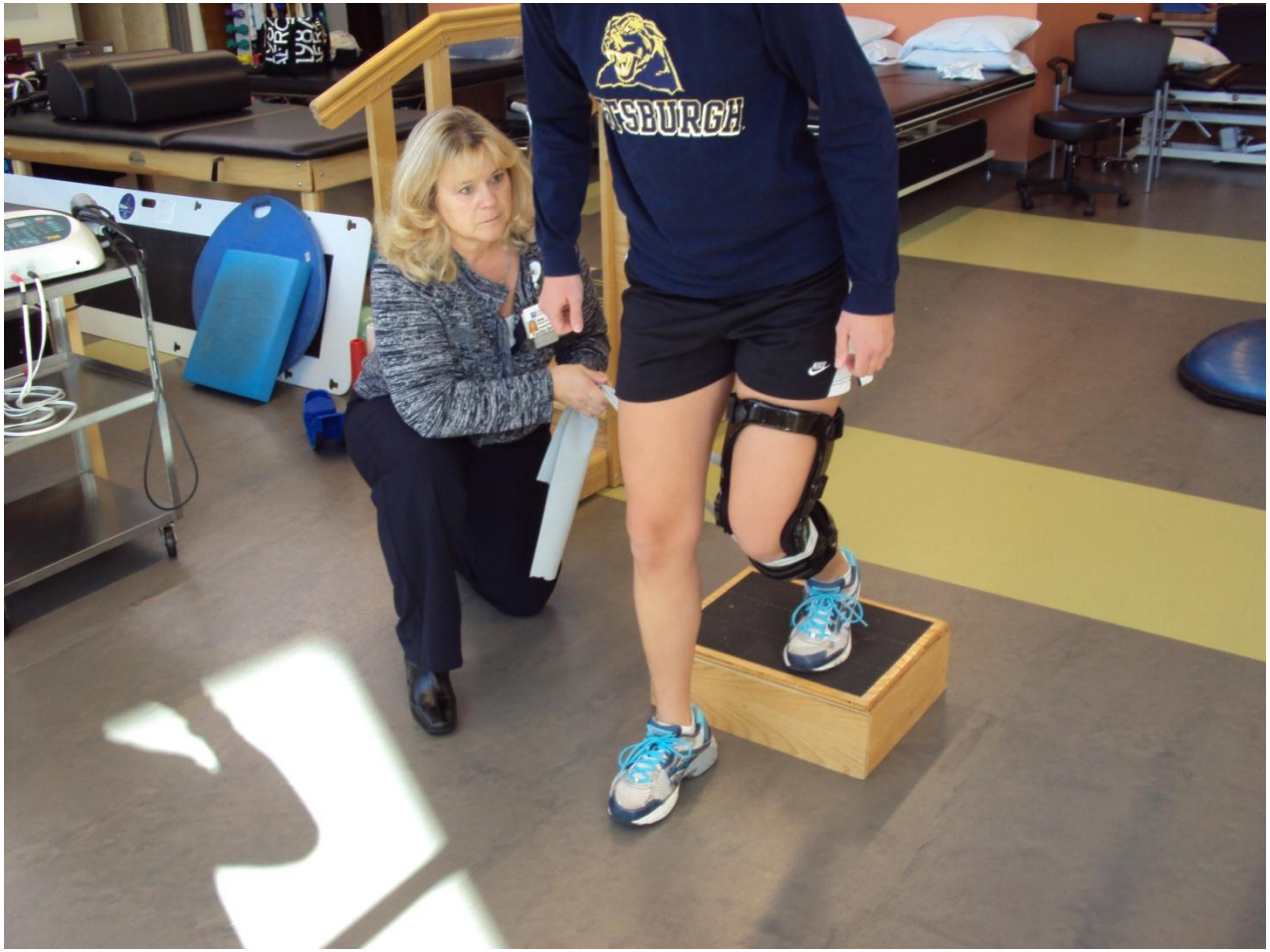
- Evidence also suggest that CKC ex. alone is insufficient to train the quad mm.  A progressive program aimed at restoration of quad muscle strength should include both OKC and CKC training positions.
- Increase CKC exercises:  Step-ups, leg press, plyotoss, Stairmaster, theraband kicks/ minisquats
- PNF techniques.

Phase III ( Strength and Proprioception) Considerations:

- PT 2-3x per week and HEP
- Progress CKC exercises
- Avoid patellar pain

- Goals:
- Full, painfree AROM
- Normal VMO tone: 5/5 MMT
- <20% quad deficit
- No effusion
- Ready patient for sport specific exercise.

- Treatment:
- Begin quad/ham isokinetics (CON/CON, 300-180) 90-45 deg pain & crepitus free
- Hamstring eccentrics 30-0 deg
- Calf strengthening
- Eccentric quad work (Step-downs, lunges) Control knee valgus and emphasize proper form



- Increase proprioceptive challenges, balance exercises (foam, BOSU, BAPS, cable column)
- Squats unstable platform
- Lateral activities (slideboard), step-ups, step-overs, lunges
- Dynamic neuromuscular patterns for hamstring control

- Phase IV  (Strength, Function, and Endurance)
- Considerations:
  - PT 2x per week and gym program
  - Emphasize dynamic control
  - Reinforce position of stability

- Goals:
- <10% strength deficit and proper H/Q ratio
- Satisfactory clinical exam

- Treatment:
- Progress with Phase III ex., increase resistance and challenges
- Light plyometrics( bilateral hops) correct posture
- Cardiovascular endurance (aquatics, treadmill, bike, slideboard, walk-jog program)
- Forward/ backward step-over
- Multidirectional movements
- Perform Test to progress with agility and perturbation

- When implementing a plyometric program, emphasis must be placed on perfect technique
- Key elements:
- 1) Correct posture with chest over knees
- 2) Jumping vertically with minimal forward/ backward/ or side to side movements
- 3) Landing softly on the balls of the feet with ankle, knee, and hip flexion to absorb the force
- 4) Recoiling immediately in preparation for the next jump
- 5) Maintaining Knee-over-toe position ( avoiding valgus position at the knee)
- 6) Landing with knee flexion to at least 45 degrees.
- 7) Landing from a jump with feet parallel, avoiding landing with 1 foot placed in front of the other.


**Figure 2.** Good landing technique with knees over toes, knees flexed past 45 degrees, and symmetrical foot position. (a) Frontal view. (b) Side view.

# Criteria used to determine readiness for testing.

- 1) No evidence of joint effusion
- 2) Full passive knee joint mobility
- 3) Full knee extension during a SLR on the involved limb
- 4) A quadriceps maximum voluntary contraction force on the involved limb equivalent to 75% of that on the uninvolved limb.
- 5) Tolerance for single-leg hopping on the involved limb without pain.

# Test Procedures and Criteria for Patient Selection

- The patient selection process includes 4 tests administered in the following order:

- 1) Single, crossover, triple, and timed hop tests.
- ( All pts wear a functional brace.)
  - -Protocol described by Noyes et al
  - -Score 80% or more

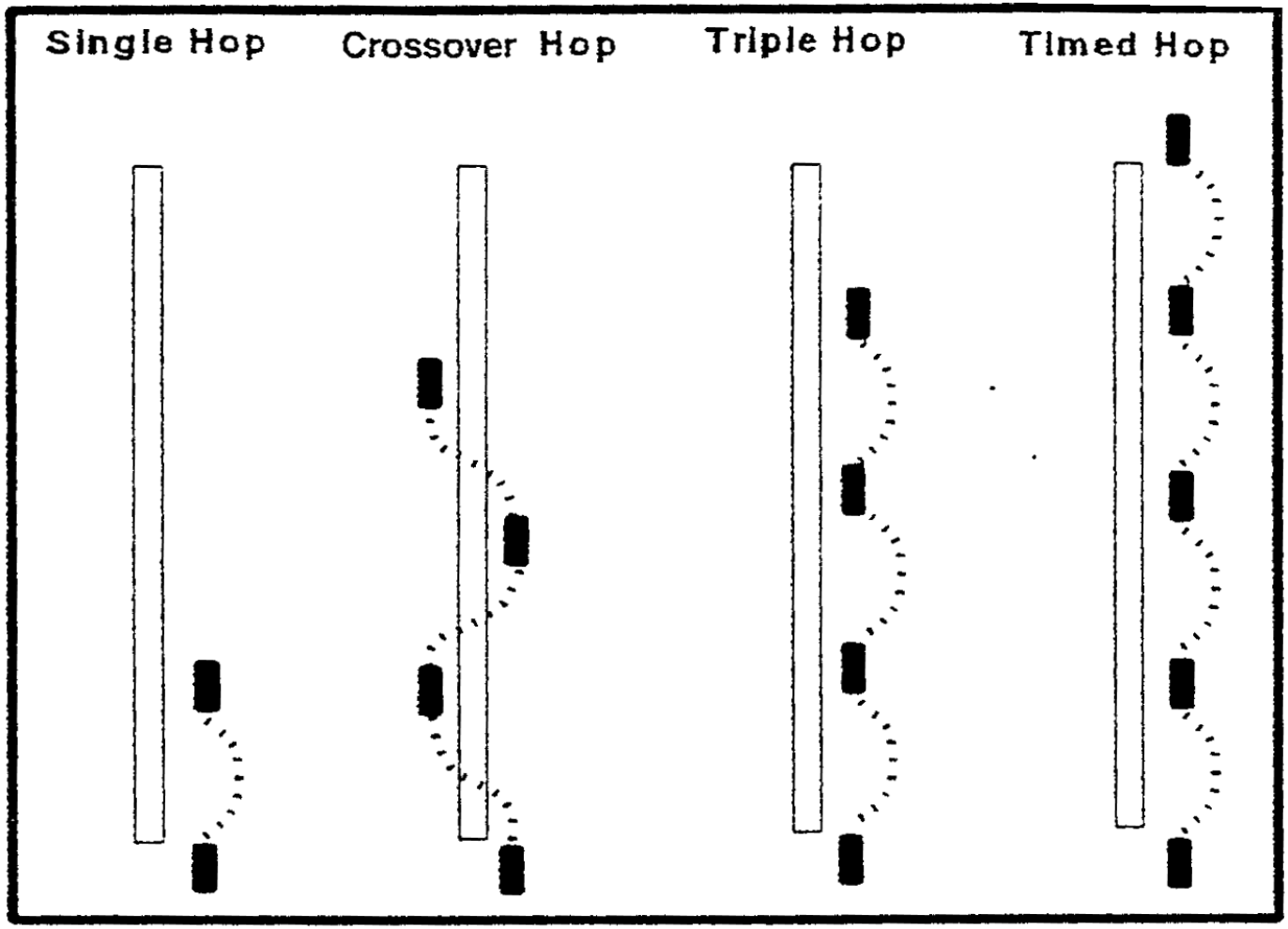



**Figure 4.**
Diagram of single-limb hop test series. Redrawn with permission from Noyes et al.[21]

- 2) Reported number of giving way episodes from the time of injury to the time of testing.
  - No more than one
- 3) Knee Outcome Survey of Activities of Daily Living Scale
  - Score 80% or more
- 4) Global Rating of Knee Function. ( Rate current level of Knee function on a scale of 0% t0 100%.)
  - Score 60% or more

# Rehabilitation

- Phase V  (Agility, Endurance, Perturbation)

- Goals:
- <10% deficit functional hop test, strength test and Functional Sport Performance Drill
- Return to full activity including high-level sports

- Treatment:
- Progress with Phase IV exercises
- Plyometric progression
- Progressive running, bicycling, skating program
- Sport-Specific training/ Re-entry program
- Perturbation Training

- Cardiovascular training- There is evidence that endurance capacity is specific to the type of training that is performed, therefore, the type selected should be sport specific.
- Agility training- Should also be sport specific. It is designed to allow the patient to adapt to quick changes in direction, quick starting and stopping, and cutting activities. It is recommended the pt. wear a functional brace during these activities. (Forward, Backward, lateral carioca, corner turn/pivot, on command drill, hop/skip, sport cord)
- Half-speed to Full-speed
- Increased distance, unexpected direction change
- Unopposed-- one-on-one opposed-- full practice with team

# Perturbation Training

- Roller board translation

  –Double limb

  –Single limb with support,

  –Single limb without support

- Tilt board perturbations
- Double limb
- Single limb
- Functional task

- Roller board and stationary platform perturbations
- Straddle stance
- Diagonal stance
- Functional Task


Bercic
30

# Return to Play

- Patients are to begin a partial return to sport by the 8th treatment of perturbation training.
- A partial return is defined as the ability to participate in practice-type drills, but not competition.
- Patients are discharged by the 10th perturbation treatment to full competition.


30
23


4

# Conclusion

- ACL injuries affect females more than males.
- We need to incorporate neuromuscular training such as plyometrics, balance, and perturbation training with emphasis on proper techniques and alignment to traditional strength, speed and agility programs.
- This has shown to improve kinetic and kinematic factors that are believed to place the female athlete at risk for ACL injury and improve the athlete's strength and functional skills.

Thank you!

Amy S. Bencic, PT,DPT,OCS
Indiana Total Therapy
abencic@indianarmc.org