

# 2019 Encore-Uhler Sports Medicine Symposium

ACL Rehabilitation: Revisiting the Early Stages of  
Recovery

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1. Historical research – one of the most published pathologies in history
  - Overall injury rate is approaching 300,000 annually
  - 2-8x higher in women than men participating in the same sport
  - Average cost of surgical repair of an ACL repair is approximately \$15,000-20,000
  - 30% of ACL individuals may incur a second ACL injury
2. Current published reports state
  - If 33% of athletes return to sports within one year and 37% never return to their prior level of sport participation
  - The question continues: What changes do we need to make?
  - What exercises should be recommended?
  - What needs to change due to:
    - A) Meniscus repair
    - B) Articular cartilage lesions
  - Is proprioception the key to recovery?

Ref: Greenberg EM, Greenberg ET. Et. Al. JOSPT 48(10) 2018.

# Concepts of Early Implementation of Current Evidence for ACL Outcomes

## What should we reconsider?

- Proper patient counseling- sometimes involves graft selection
- Managed care limitation: criteria for discharge should be based on function
  - Patients sometime base it on money
- Why the first two months of post-operative rehab may be the most important
- Functional testing
- Return to play
- Rate of re-injury

Reference: Fisberg, Grindem, Olestad JOSPT 2016

Miller CJ, Christenson JC 2015

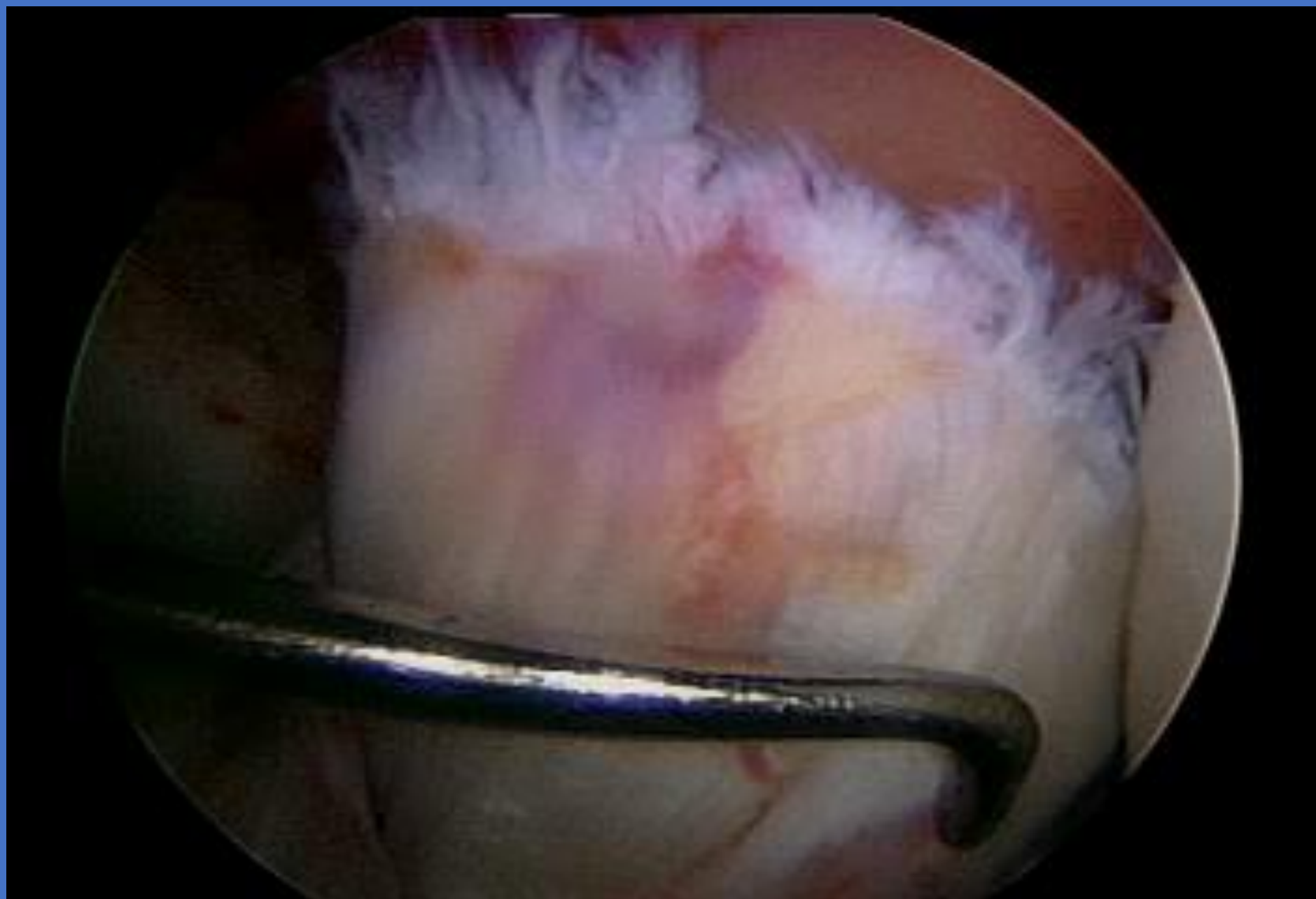
- Athletes who have had a ACL reconstruction are 6x more likely to go through it again within 2 years
- Female athletes are 4x more likely to be injured within 24 months
- Female athletes are twice as likely to suffer an injury to the opposite knee
- High school study – presented at CSM 2017: Female high school athletes were 3 times more likely to suffer loss of time compared to male athletes
- Dramatically increased rates of meniscus repairs and follow-up meniscus surgery in adolescence ages 13-17- greater percentage reported in males

Herzog MM, Marshall SW, et.al. Sports Health 10(8) 2018.

MV Paterno PT PHD- American Orthopedic Society Annual Meeting 2013

Fox, Shanley, Chaaban, et. al – JOSPT 2017





# Pre-operative Goals

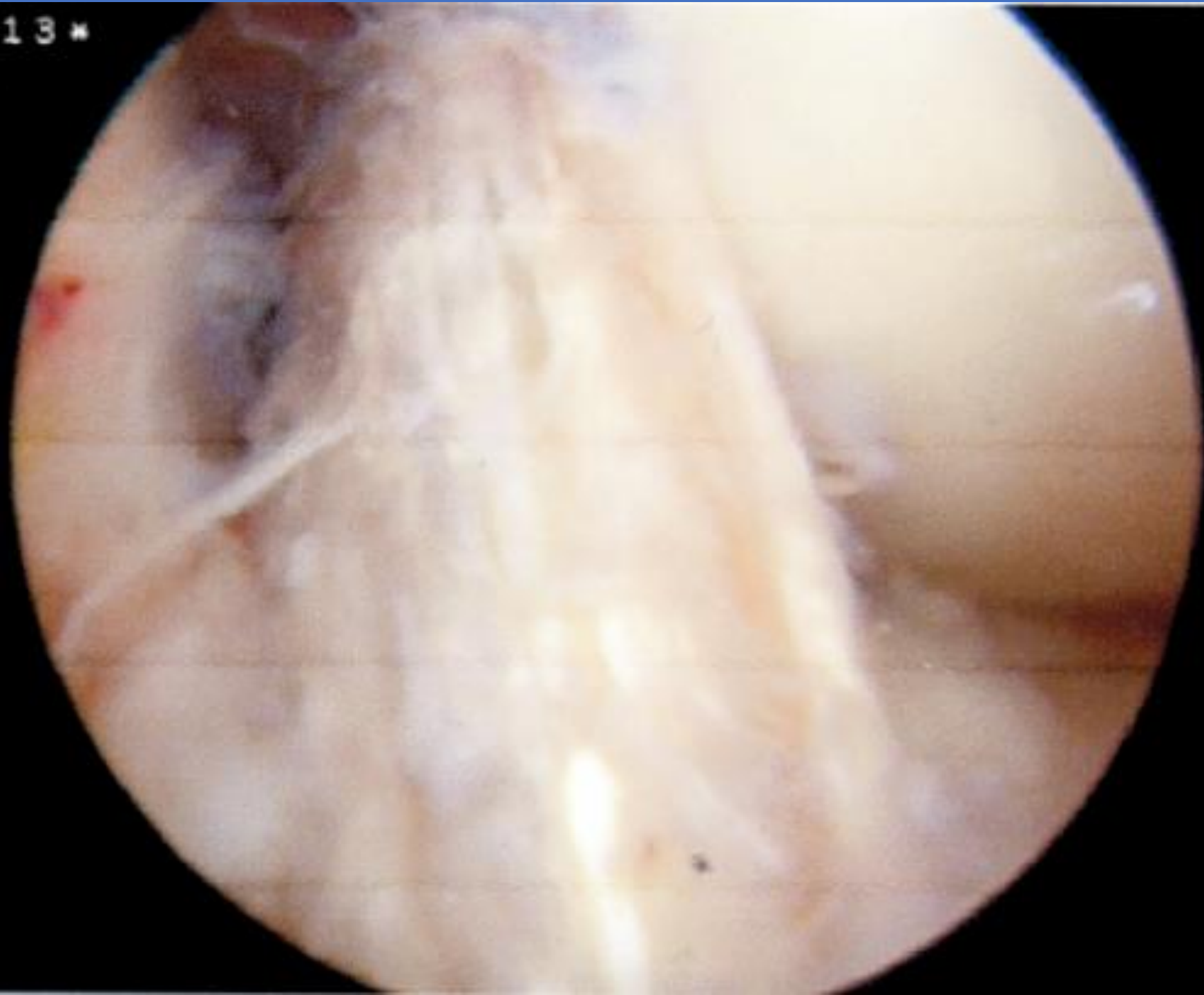
- Reduced or absent effusion
- Full terminal extension in comparison
- Normal flexion
- Normal gait
- Leg control – symmetrical quadriceps strength – 90% strength level
- Hamstrings strength compared to opposite knee
- Co-contraction and hip core strengthening







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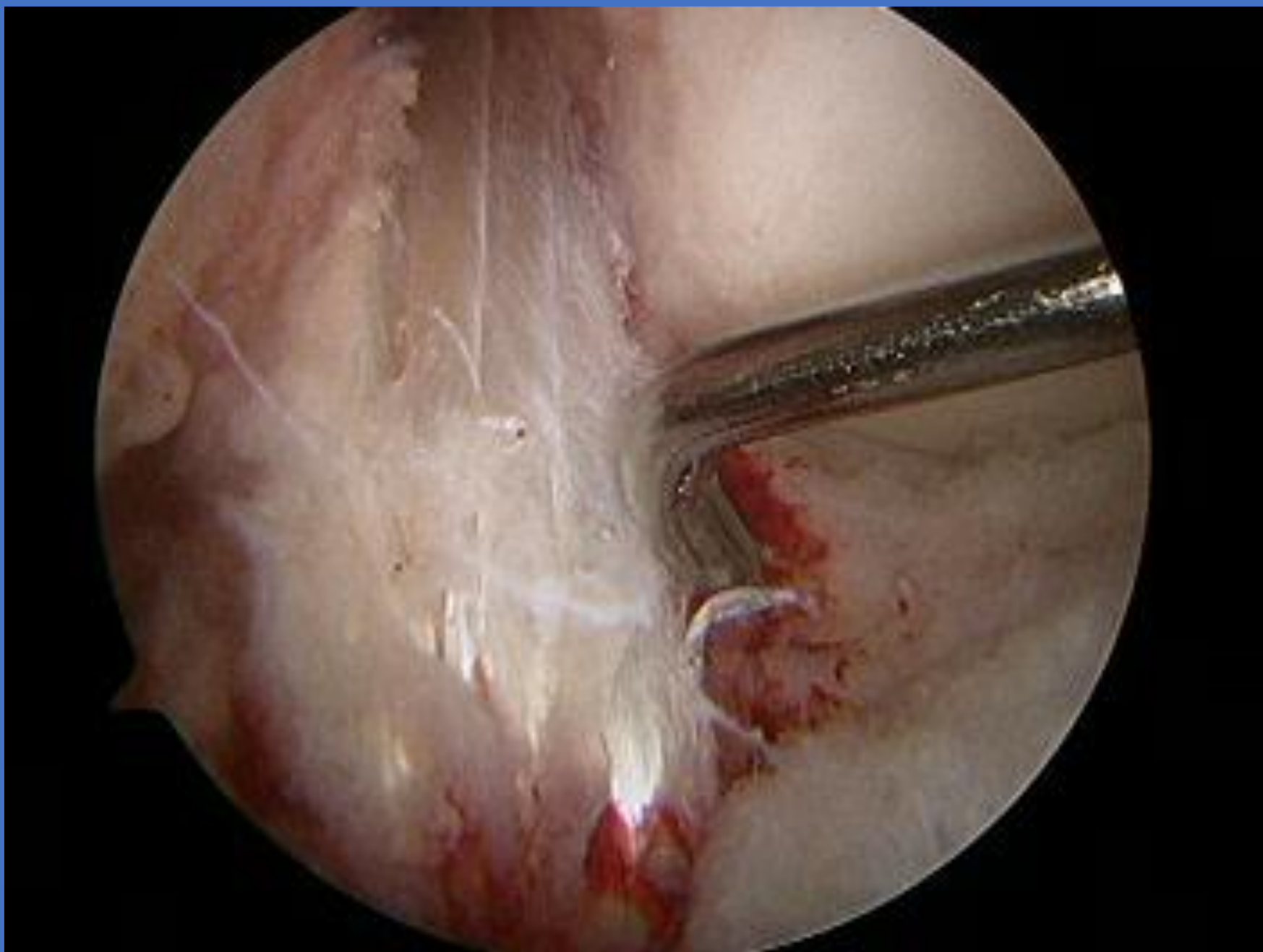










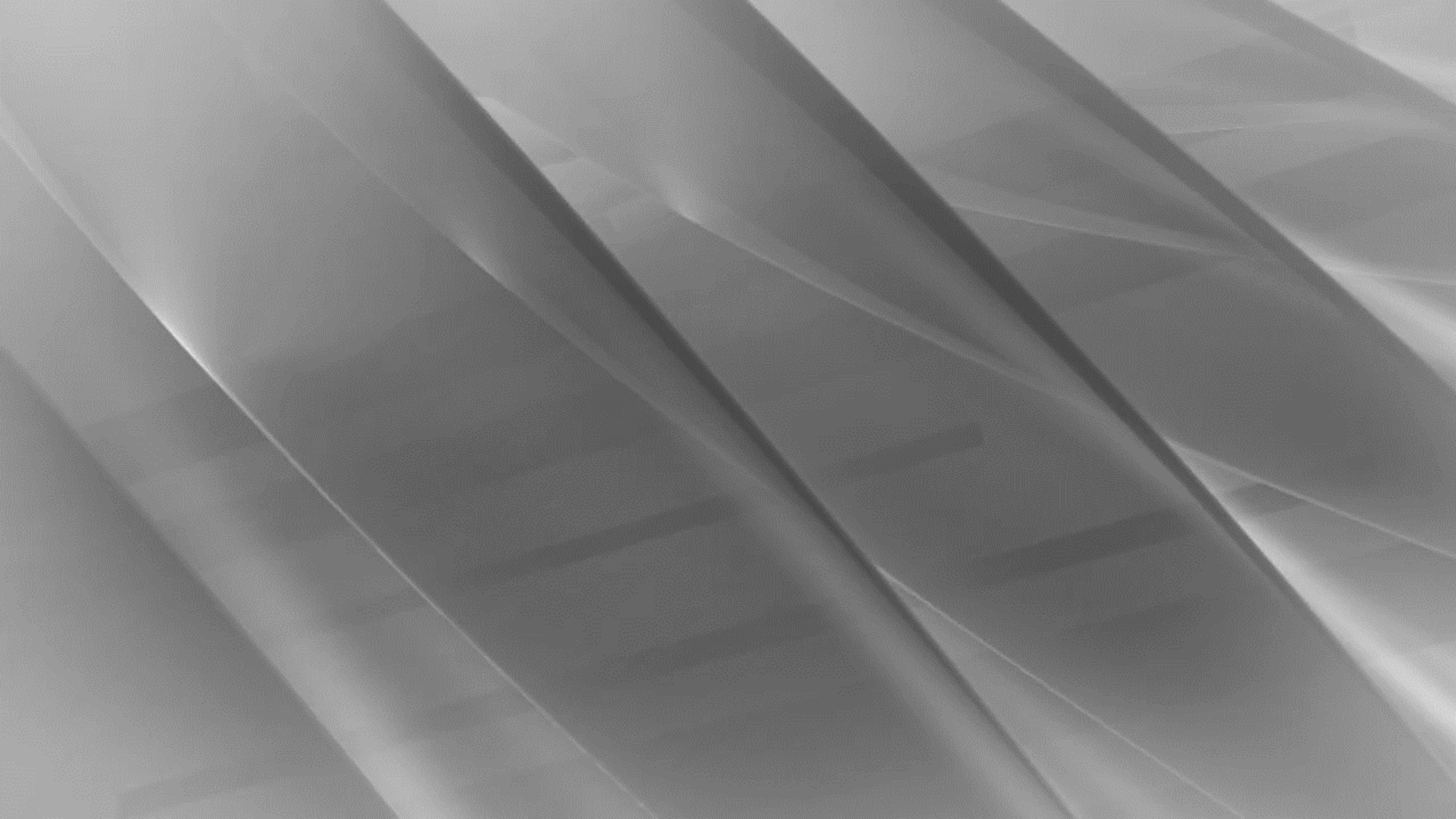




















# Three Phases of Rehabilitation

- I Pre-Functional
  - Immediate post-op early motion
  - Controlled Ambulation-early weight bearing if allowed
- II Return to Function
  - Muscle re-education – OKC/CKC progression
  - Early proprioception- neuromuscular training
- III Return to Activity
  - Advanced strengthening and sports-specific training

# Interactive Outcomes- Pre-functional Phase

- Pain report and reduction of swelling
- Mobility – ROM goals met
- Leg control – muscle recruitment
- Progressive ambulation (ADL Report)

# Functional Progression – ACL

## Pre-functional – phase one

- Mobility
  - Full normal extension
  - Flexion as tolerated – but not pushed
    - CPM is for extension not flexion
  - Patella mobility – all direction
  - Hip mobility to assist with core stabilization
  - Hamstrings re-lengthening
  - Heel cord re-lengthening
  - Manual over pressure mobility toward extension
- Phase one exercises focus on patella femoral protection?

Reference: Galvenor AG, Crosley KM JOSPT 2016

Clinical Practice Guidelines. (Multiple Authors). JOSPT 2018 48(9) A1-A42.

# Top Three Rehab Concerns of Early Interventions

1. Loss of Motion: loose flexion not extension
  - Reasons:
    - Notchplasty
    - Adhesions
    - Surgery performed too early
    - Graft position
    - Pain
  - Treatment:
    - Mobility – load with prolonged time
    - Extension stretch – re-lengthening
    - Prone hangs
    - CKC – STE
    - Splinting – JAS, Dynasplint extension board
    - Patella femoral joint mobilization





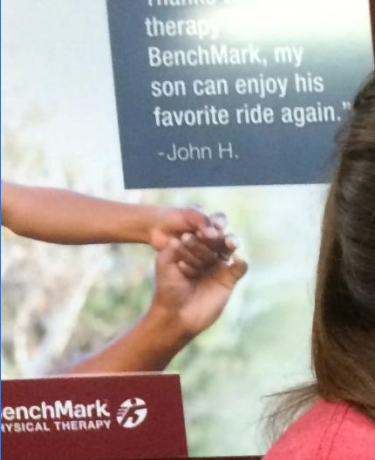
## 2. Patella-femoral protection

- Keeping the patella in the sulcus
- Short-arc quadriceps of 90-40 degrees
- Partial squats – CKC Activities
- Leg press

## 3. Effusion

- Modalities, infrared – electrical stimulation
- Back off too much quadriceps activities
- Emphasize co-activation, H/Q















# Functional Progression – ACL

## Pre-functional – phase one

- Recruitment
  - Core stabilization – swiss/plyo-ball exercises
  - Co-contraction hamstrings over the quadriceps
  - Leg control – standing SLR – Hip strengthening
  - Quadriceps isometrics
  - Quadriceps Activation Failure (QAF)
  - Sub-max eccentric quads manual application
  - Eccentric hamstrings control 30° → 90°

Reference: Lepley LK, Palmieri Smith RM, JOSPT 2015





























# Hamstrings - Revisited

- Hamstrings create a posterior directed force on the tibia when the flexion angle is  $30^{\circ}$  or greater
- Are the hamstrings the true core muscle group of the lower extremity?
- Is the best brace for the knee to develop eccentric powerful hamstrings and core strength?

Reference: Bourne MN, Williams MD et al. Br J Sports Med 2017

# Functional Progression – ACL

## Pre-functional – phase one

- Tri-plane stabilization – neuromuscular training
  - Mini squats – double leg – trunk tilted forward – BW only
  - Standing terminal extension (STE)
  - Balance weight shift exercises – balance board/BOSU
  - Leg press sub-max double leg
    - Co-contraction vs Closed Kinetic Chain
    - Terminal extension 0°-45° loading
  - Single leg balance

*References: Distasi, Myers, Hewett 2013  
Wilk et. al. 2012*

*Shultz R et. al. 2015*







# What is True Closed Kinetic Chain?

- Distal segment meets considerable external resistance that restrains free motion
- Original engineering definition involved fixtures of both the proximal and distal ends of the kinetic link system (*Steindler, 1955*)
- True closed kinetic chain movement patterns do not technically exist in the human body. Except in isometric exercises where no movement of the proximal or distal segments occurs.
- ***Clinical Definition: Exercise Remains Fixed distally***

Historical Reference: Ellenbecker TS, Davies ES (2001)



# Principles of Using Closed Kinetic Chain Loading

- Co-activation recruitment
- Tri-plane movement patterns
- Increased proprioception and joint stability
- Contributes to reduced shear-forces

*Reference: Begalle, etal. JAT 2012*











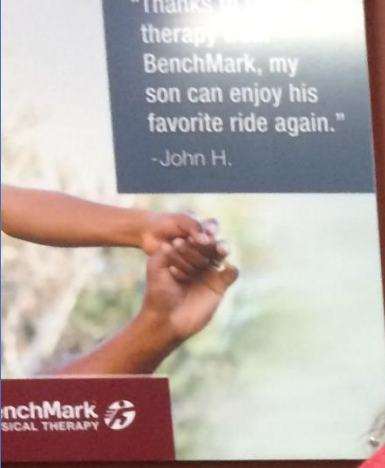


# Functional Progression – ACL

## Return to Function – Phase Two

- Mobility
  - Full ROM extension & flexion
  - Hamstrings – functional re-lengthening
- Recruitment - Strength
  - PRE – hamstrings  $30^{\circ} \rightarrow 90^{\circ}$
  - PRE – quadriceps  $45^{\circ} \rightarrow 90^{\circ}$
  - PRE – hip strengthening – all planes
  - Advanced core exercises – hamstrings – bridge row
  - High speed isokinetics
  - Quad Set Plus test/exercise
- Suggested Strength Goals based on body weight:
  - Males – 55%-60%
  - Females – 45%-50%



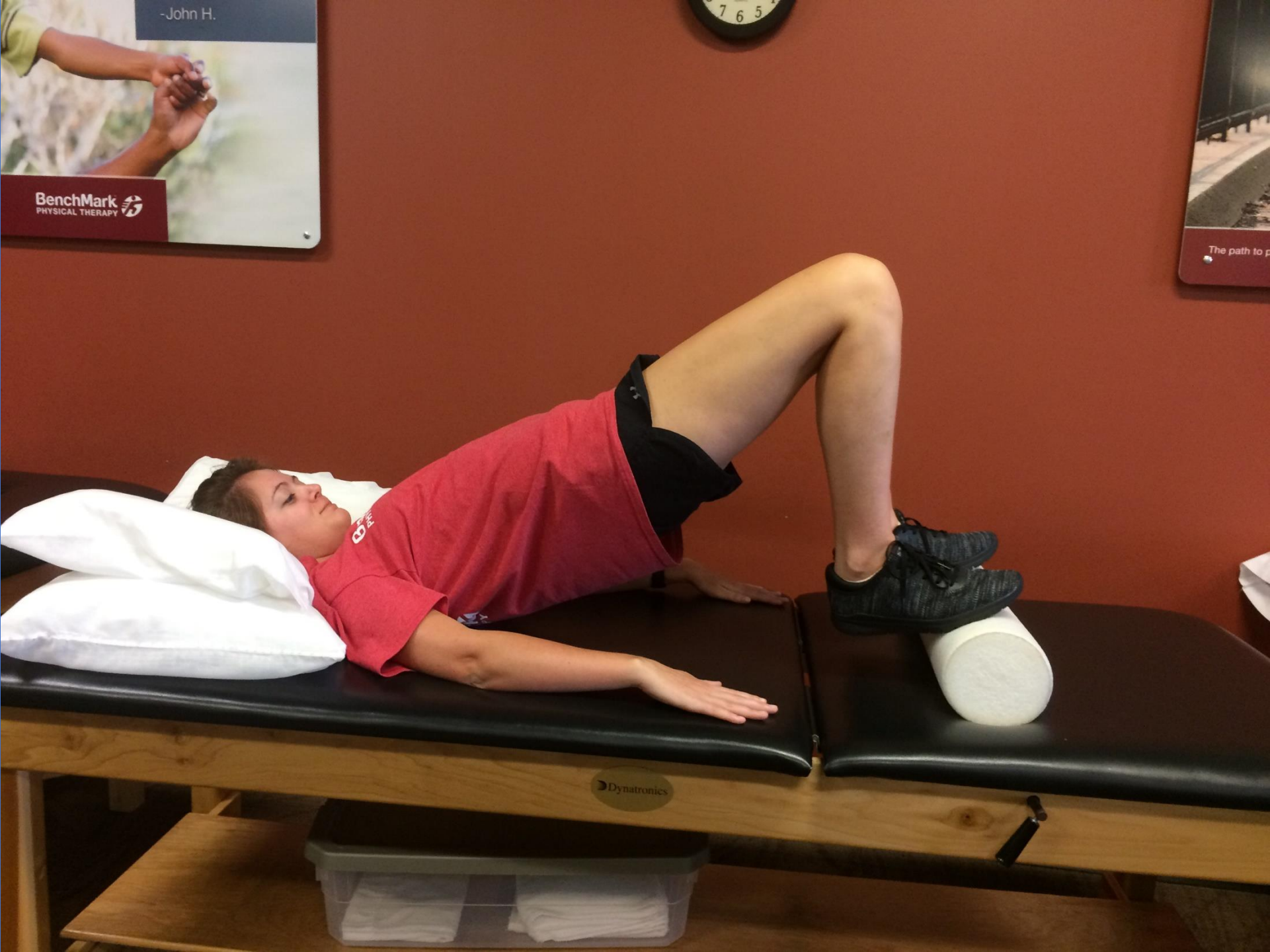












# Open- or Closed-Kinetic Chain Exercises After Anterior Cruciate Ligament Reconstruction?

- OKC and CKC Exercises both produce strains on the ACL in terminal extension
- OKC with increase of resistance does increase ACL strain-suggested arc of motion 90-40°
- CKC does not increase the ACL strain with increase load
  - Short flexion angle quadriceps exercise to protect the patella femoral joint and ACL strain

Reference: Luque-Seron, Medina-Purqueres, Sports Health 2016

Historical References:

Henning 1985

Beynnon 1997

# Functional Progression – ACL

## Return to Function – Phase Two

- Tri-plane stabilization
  - Balance activities – balance board – BOSU
  - Progress to single leg squat on uneven surfaces
  - Balance vector – 3 planes
  - Leg press total gym single leg – increase flexion angle
  - Lateral step-up, retro step-ups and front step downs
  - Slide board – FITTER
  - Plyo-toss with squat – progress to single leg
  - Sports cord exercises
  - Lateral and forward lunges
- Suggested Goals
  - Leg press test – 90% BW
  - Isokinetic testing – 85% work symmetry

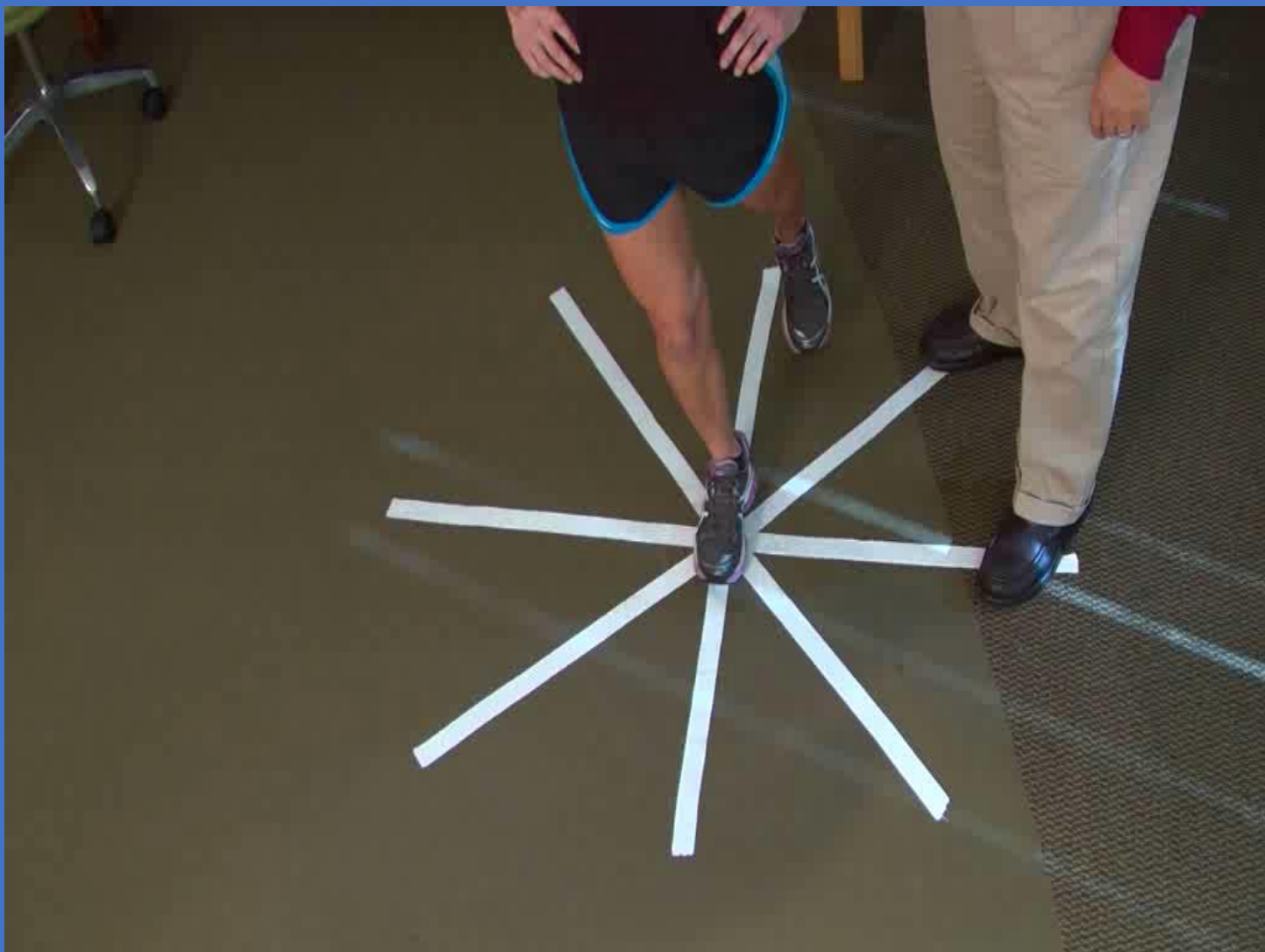
Reference: Sugimoto D, Myer GD, Barber Foss KD, Hewett TE Br J Sports Med 2015

Cobian DG, Robbins D, Yack HS, Williams GN JOSPT (CSM) 2017

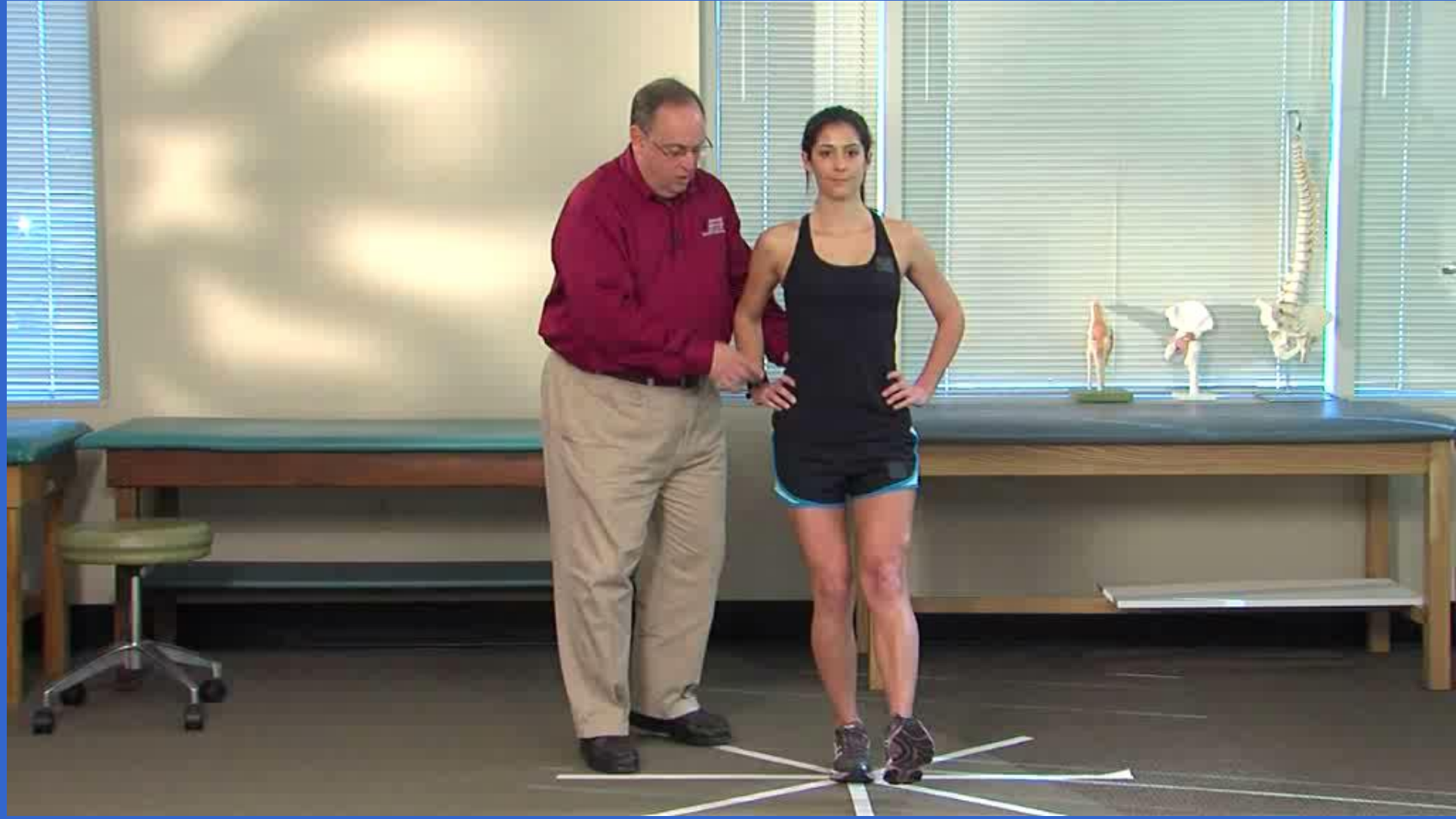
Reinking SF, Schmitt LC, Thomas S, Paterno MV JOSPT (CSM) 2017











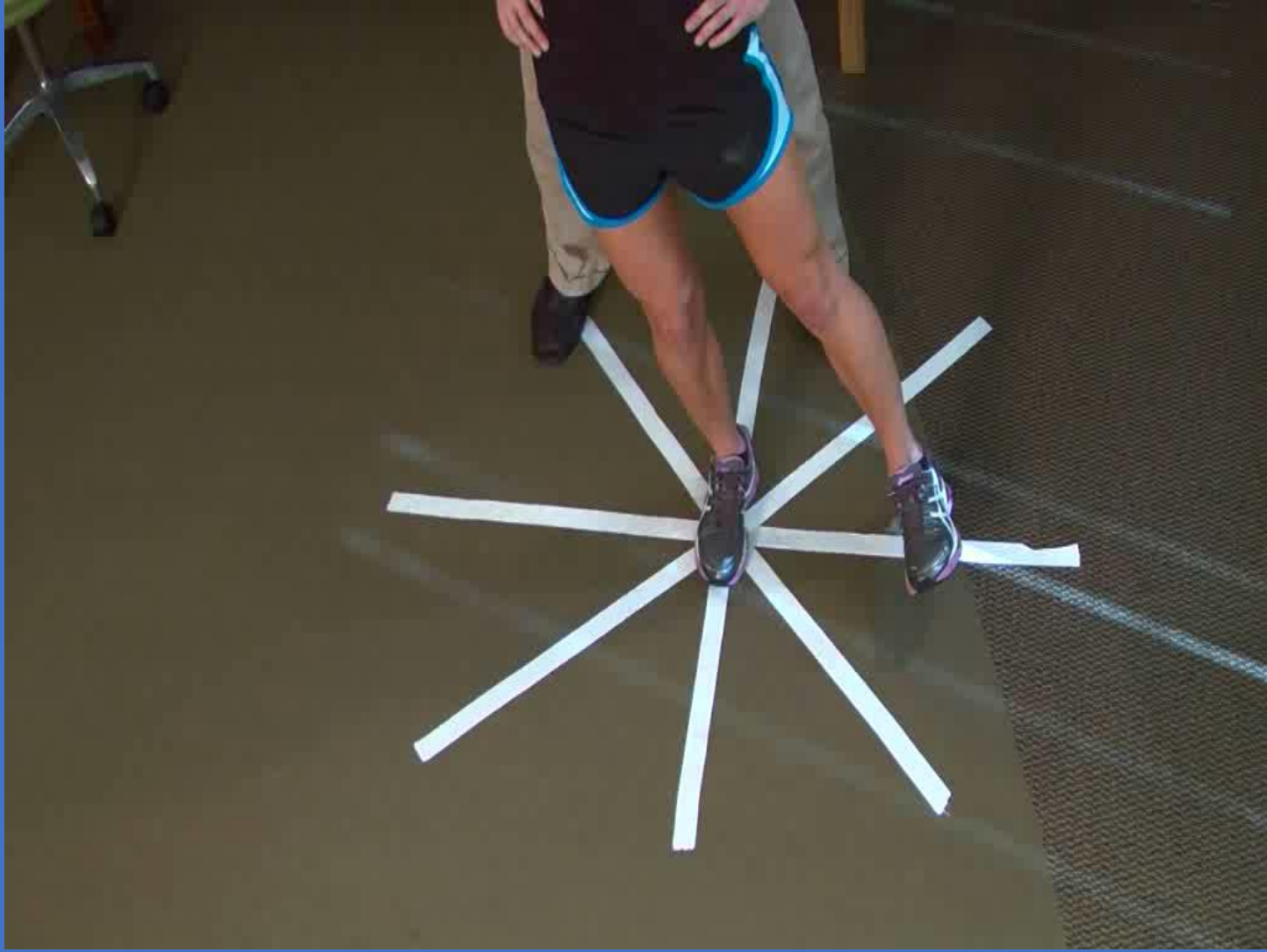




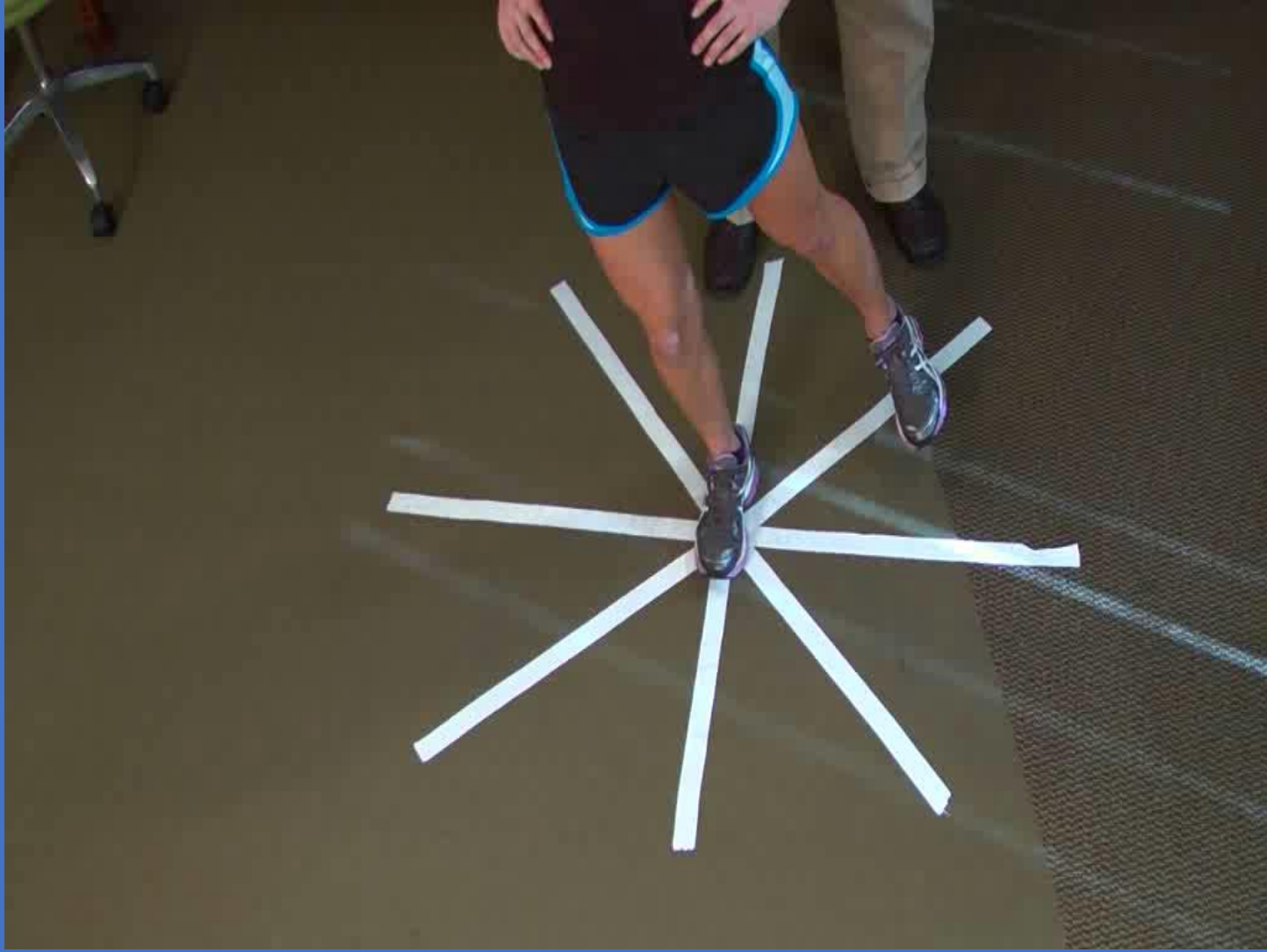












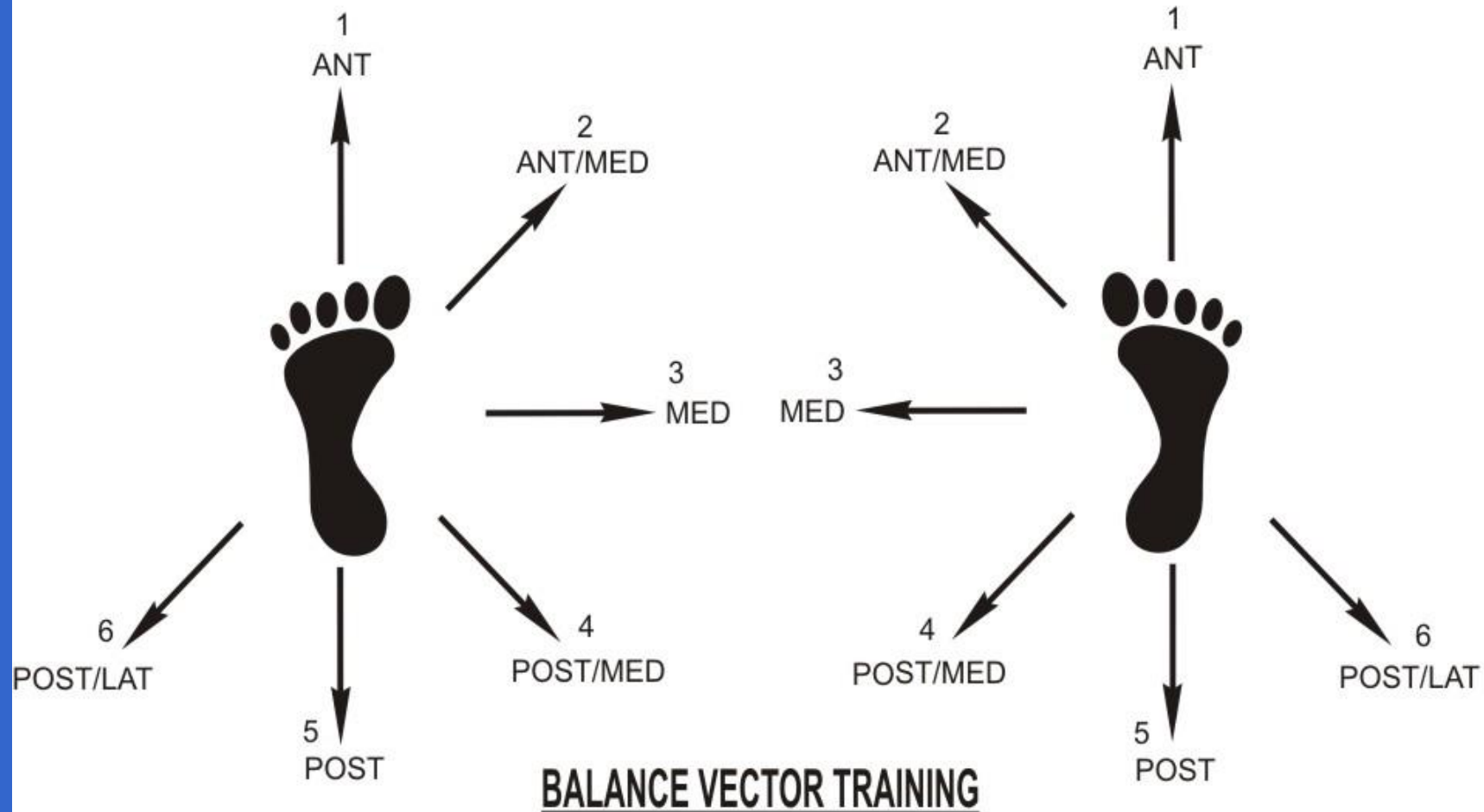


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## Heel to Toe Mini Squat

Sagittal Plane 1-5  
Transverse Plane 2-4-6  
Frontal Plane 3

5 seconds  
5 reps  
3 planes

















# Vital Five Program – CKC Function

- Mini squats – single plane → Co-contraction
- Balance vectors – tri-plane → proprioception
- Leg press – double to single leg → recruitment
- Lateral step-ups → quadriceps dominant
- Squats on uneven surface

# Functional Progression – ACL

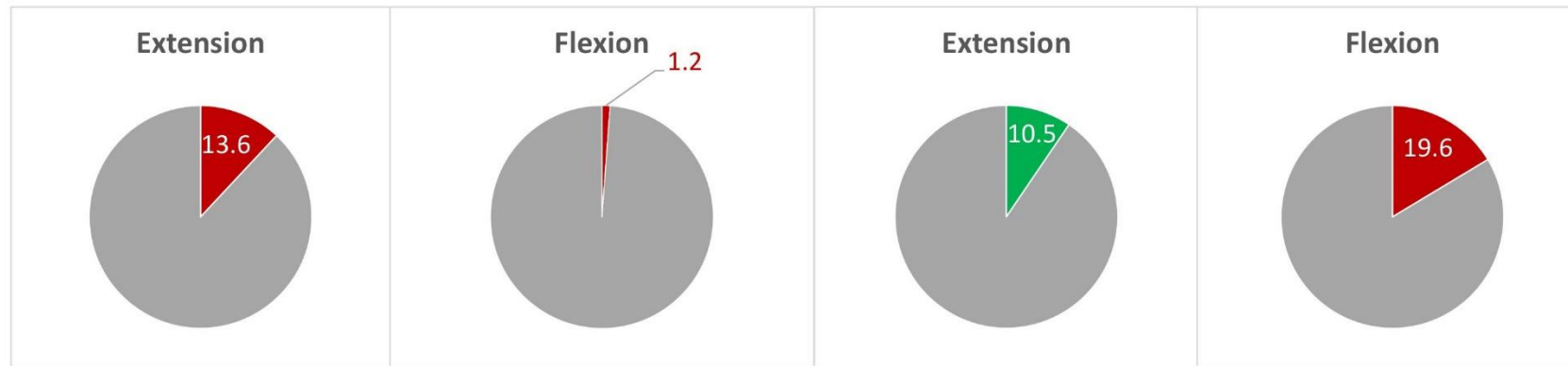
## Return to Activity Phase three

- Mobility
  - Any incomplete motion concerns mobilization as needed
  - Advanced functional LE re-lengthening
- Recruitment
  - Advanced quadriceps strengthening
    - Wall squats with ball single leg
  - Open kinetic chain progression
  - Isokinetic testing- total work
- Suggested goals
  - Quadriceps and hamstrings isotonic strength goals are 100% symmetry

Reference: Lepley LK Sports Health 2015

## Isokinetic Evalutaion

DOB:	7/2/1998	Joint:	Knee										
Hi:	65 in.	Protocol:	Isokinetic Bilateral										
Wt:	145.0 lbs	Pattern:	Extension/Flexion										
Gender:	Female	Mode:	Isokinetic										
Diagnosis:	ACL Reconstruction Quad. Tendon (Left)	Contraction:	CON/CON										
		Extension 60 deg/sec			Flexion 60 deg/sec			Extension 180 deg/sec			Flexion 180 deg/sec		
# of Reps (60/60): 5		Uninvol	Involved	Deficit	Uninvol	Involved	Deficit	Uninvol	Involved	Deficit	Uninvol	Involved	Deficit
# of Reps (60/60): 10		Right	Left		Right	Left		Right	Left		Right	Left	
Peak Tourqe	ft-lbs	108.5	93.8	13.6	78.7	77.7	1.2	54.9	60.7	-10.5	49.4	39.7	19.6
peak TQ/BW	%	74.8	64.7		54.2	53.6		37.9	41.9		34.1	27.4	
Max Rep Tot. Work	ft-lbs	113.3	118.3	-4.4	81.2	83.7	-3	67.4	80.8	-19.9	61.1	46.2	24.4
Coeff. Of Var.	%	11.2	8.7		3.7	4.1		25.0	15.8		16.5	11.5	
AVG. Power	Watts	89.8	92.4	-2.8	74	67.8	8.5	114.0	143.9	-26.3	107.8	80.1	25.7
Total Work	ft-lbs	469.6	563.8	-14.3	390.9	405.3	-3.7	553.0	692.9	-25.3	542.3	405.6	25.2
Aceeleration Time	msec	20.0	30.0		40	50.0		60.0	50.0		90	100	
Deceleration Time	msec	80.0	70.0		40	80.0		150.0	140.0		120	120	
ROM	deg	87.8	96.3		87.8	96.3		95.1	96.8		95.1	96.8	
AVG. Peak TQ	ft-lbs	93.4	89.3		75.7	73.3		44.3	52.4		43.7	34.7	
Agon/Avantag ratio	%	72.5	82.9	G: 62.0				90.0	65.4	G: 76.0			





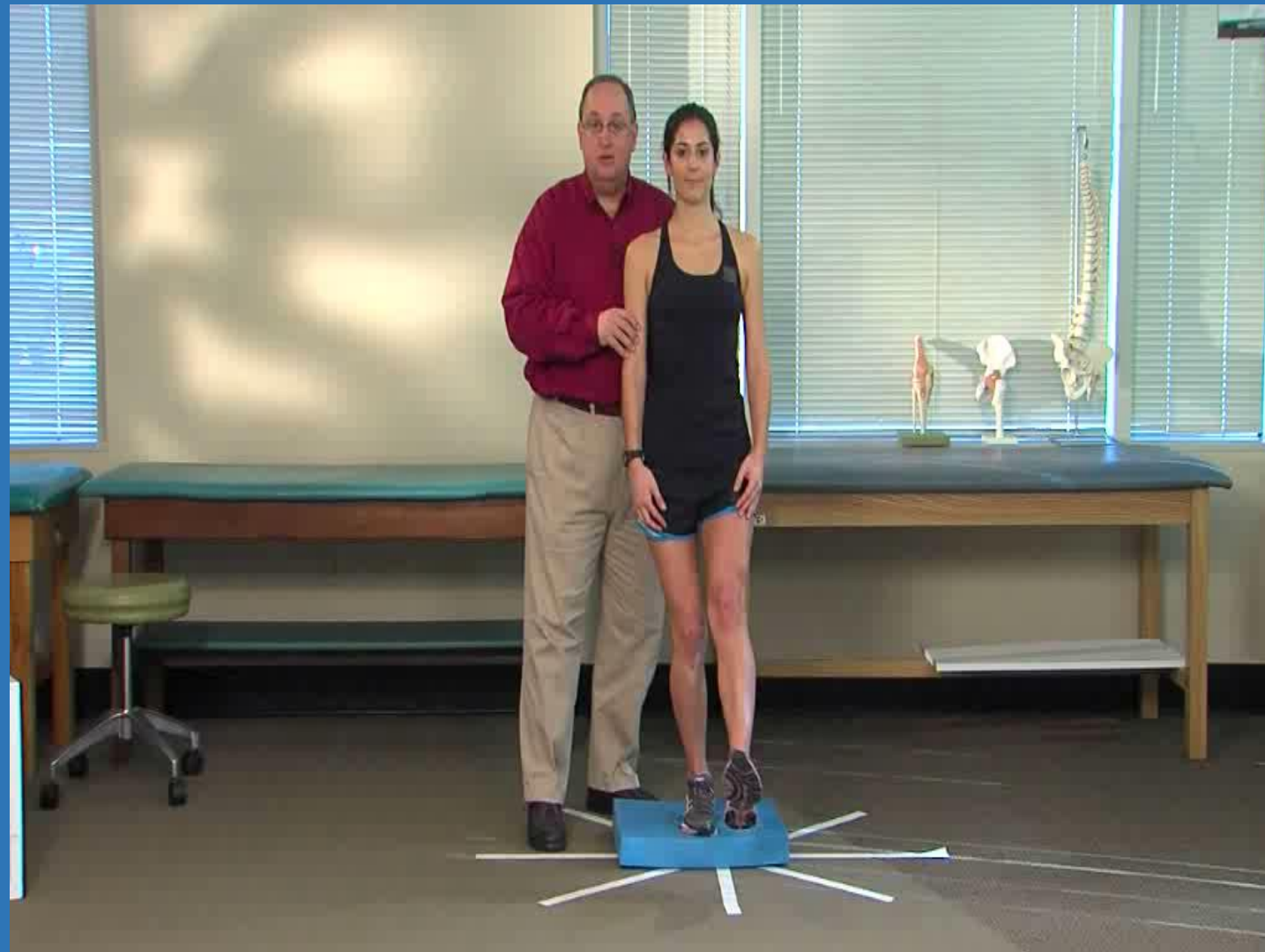
# Functional Progression – ACL

## Return to Activity Phase three

- Tri-plane stabilization
  - Advanced plyo-toss on uneven surfaces – BOSU
  - Neuro-reaction training
  - Advanced balance vector training – eyes closed
  - Step-jump balance hold on balance pad
  - Plyometric jumps – double to single leg
  - Lunges with weights – lateral lunges with bands/tubing
  - Sports Specific Training
    - Box Runs, Lateral Running, Retro sprinting, Vertical Jumps, Figure 8 run/cuts, running program.
  - Are we allowing patients to go back to sports too soon?
    - Some studies state that it may take 2-2.5 years of neuromuscular training for dynamic stability (JAT 2010)

Reference: Elias ARC, Hammill CD, Mizner RL JOSPT 2015  
Chaaban C, Thigpen SA et al. JOSPT (CSM) 2017  
Grooms DR, Onate JA Sports Health 2015



































# Plyometric Training

Progressive in nature

- Increase repetitions and sets/decrease rest period
- Decrease rest periods
  - Straight jumps -> Sagittal
  - Lateral jumps -> Frontal
  - Combination -> Transverse
- Frequency – three times a week
- Intensity – double leg jumps to single leg jumps
- Low intensity – 200 fast contacts
- Moderate intensity – 200 - 400 fast contacts
- High intensity – 400 – 600 fast contacts
- Sports specific training
  - Progressive running
  - Agility drills
  - Sudden starts and stops
    - 45° cutting then 90° cutting











# Objective Criteria for Discharge and Return to Sports

- Functional return-to-sport battery:
  - Early return to pivoting sports
  - The re-injury rate drops for each additional month after post-op month 9
  - 38% of those who failed a functional test battery sustained re-injury
  - Only 6% who passed sustained re-injury
- Testing may include but not limited to:
  - 90% strength comparison
  - Hop test symmetry
  - Outcome data survey based on ADL's (LEFS)
  - Functional movement screening
- Limb symmetry test may overestimate knee function
  - What is the future in return to sports function?

Reference: Br J Sports Med 2016

Wellsandt E, Failla MS, Synder-Mackler L JOSPT (2017)

## Level One Sports Involving: Jumping, pivoting and hard cutting

- Patients who return to level one sports have a 4.32x higher re-injury ratio
- Re-injury rate was reduced by delaying RTS until 9 months
- 38% of patients who failed RTS criteria suffered re-injury versus 5.6% of those who passed
- Symmetrical quadriceps strengthening reduced re-injury

References: Grindem H, Synder-Mackler, Moksnes H, et al. BR J. Sports Med 2016.



# FUNCTIONAL LOWER EXTREMITY TESTING

- Balance vector testing
- Leg press test – 100% body weight
- Isolated strength assessment (Isotonic vs. Isokinetic)
- Return to Sports – Functional Testing
  - Hop test – Time and distance – Single leg
  - Lower limb symmetry index-triple/crossover/distance hops
  - Functional movement screen
  - Agility (T Test)

*Reference: Culverner AG et. al. JOSPT 2016*

*Hegedus EJ et. al. BR J Sports Med 2015*

*Lepley LK, Palmieri-Smith RM JOSPT 2015*

*Reinking, Schmitt, Thomas, Paterno CSM Presentation 2017*

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# ACL Surgery: 10 Years Later

- American Journal for Sports Medicine - Washington University – St. Louis
- 100 soccer players (55 male, 45 female, age 11-53)
  1. 72 of the athletes returned to play within one year and are still playing after 7 years
  2. Male players are more likely to return to play if they had surgery when they were young
  3. Male players didn't cite ACL injury as a reason to discontinue playing
  4. More female players did cite ACL injury as the reason to stop playing
  5. 12 out of 100 (9 female, 3 male) underwent a second ACL surgery within 10 years



# What have we heard from recent publications?

- Less than 60% return to sport (Br J Sports Med 2014)
- More than 50% develop OA by middle-age (Am J Sports Med 2016)
- Young Athletes with ACL Injuries
  - 30% of younger/active patients suffer 2<sup>nd</sup> ACL rupture in the first few years (Clin J Sport Med 2012)
- 50% of patients may undergo meniscus surgery within 5 years
- Increase post-traumatic knee OA of 21-48% (Am J Sports Med 2009)
- Incidence of ACL tears are higher in girls through age 16 (Medscape, Feb 23, 2017)
- Return to sports before 7 months post-operative is associated with decreased likelihood of completing the next scholastic season (CSM Presentation 2017)
- Passing RTS criteria did not show a statistically significant association with risk of a second ACL injury

Reference: Ardern CL Sports Health 2015

Losciale JM et al. JOSPT 2019

# What to Consider Going Forward

- If 63% of post-operative ACL patients return to sports of their choice, what needs to be done to increase this percentage?
  - Early focus on quadriceps control without emphasizing over-training
- Will blood flow restriction training (BFR) be a recommended training application in the early months of rehabilitation?
- Will return to sports functional testing need to be reconsidered?
- What role will neuroplasticity changes play in the recovery?
- Future of Orthobiologics in ACL surgery
- Will there be renewed interest in prehabilitation which promotes neuromuscular control? Are you willing to see patients for free?

References: Grooms DR, Page SJ, et al. – JOSPT 2017

Webinar: JBJS – April 4, 2017

Scott BR. Loenneke JP et al – J Sci Med Sports 2016 and Sports Med 2015

Wellsandt E. Failla MJ, Snyder0Mackler L – JOSPT 2017

Hewett TE – JOSPT 2017

Mandelbaum BR. Medscape. 2019

# Questions

