


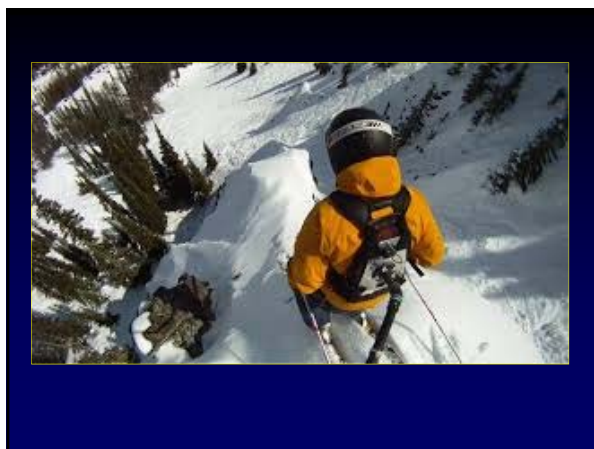
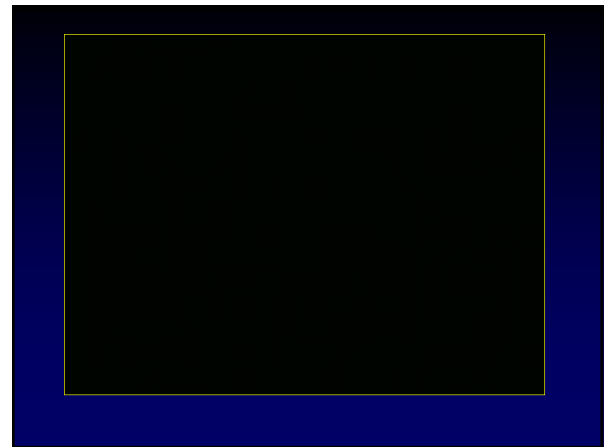
Proprioception & Neuromuscular Control
Drills for the ACL Patient
Kevin E. Wilk, PT, DPT, FAPTA



Proprioception & Neuromuscular Control
Drills for the ACL Patient
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"Bummer of a birthmark, Hal."



ACL INJURIES

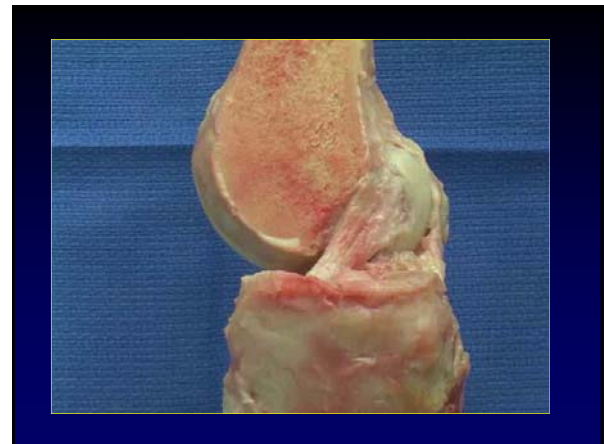
Introduction

- ACL injuries common in sports & strenuous work
 - » *So frequent that the seriousness is often forgotten*
- Totally disrupted more than any other knee ligament
- 200,000 ACL injuries annually
 - Fu: AJSM '99*
- ✓ 148,714 ACL surgeries in 2013
- ✓ 19 yrs; 58% increase in number ACL surgeries
 - Wilk: JOSPT '15*

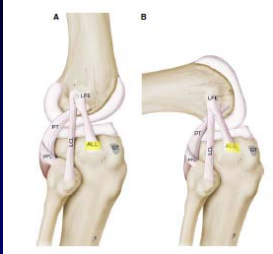

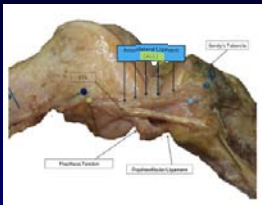




Evidence Based Rehab Return to Normal Function



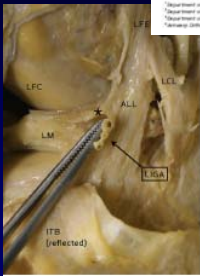
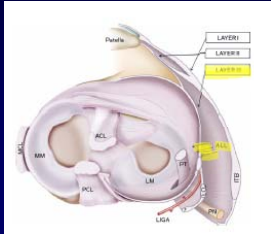
Claes et al: J Anat 2013

Claes et al: J Anat 2013

Journal of Anatomy

Anatomy of the anterolateral ligament of the knee

ACL Injuries

Introduction

- Over 200,000 ACL injuries annually
- 62-66% sports related, usually non-contact – **70%**
- Over 60% in males
- 67% occurs in individuals 15-29 yrs of age
- 26% occurs in 30-44 yrs
- 7% occurs in individuals above 45 yrs of age








ACL INJURIES

Introduction

- ✓ 1 in 3,500 people will sustain an ACL injury
 - ✓ *Baer, Harner: Clin Spts Med '07*
- ✓ Estimated 1 million ACL injuries worldwide
- Females are 4-6 times higher risk of ACL injury
- ✓ ACL outcomes (IKDC scores) 61-67 of 100
 - Biau et al: CORR '07*
- ✓ 61-74% of ACL patients exhibit radiographic knee OA 7-12 yrs following surgery
 - Pinczewski et al: AJSM '07* *Thompson: AJSM '15*
 - Liden et al: Arthroscopy '08* *Luc: JAT '14*
- ✓ 10x greater rate OA in ACL injured knee
 - Fleming et al: JOSPT '03*

Brophy, Gill, Lyman, et al: AJSM '09

- Effect of ACL Reconstruction &/or Meniscectomy on length of career in NFL
- 54 athletes with meniscectomy alone
- 29 ACL reconstruction
- 11 both ACL recon & partial meniscectomy
- *History of an isolated meniscectomy not isolated ACL reconstruction shortens career*
- *Combination (ACL & Meniscus) was most detrimental (~2yrs)*

Carey et al: AJSM '06

- Effects of ACL injury on running backs & wide receivers in the NFL players (N=33)
- ✓ *80% returned to NFL play*
- ✓ *Performance of those returning – performance was reduced by 1/3*



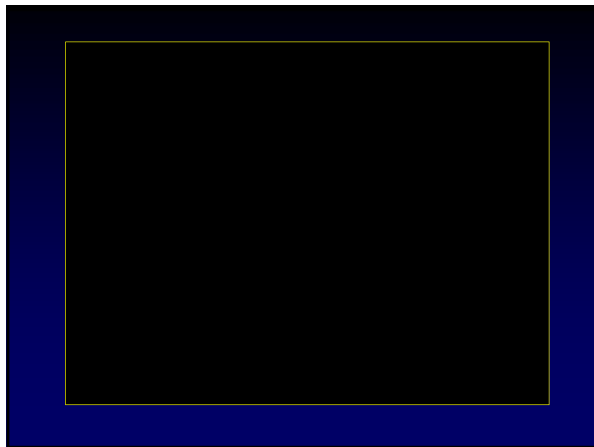
ACL Injuries

Return to Play


- ✓ *78% of NBA players returned to play following ACL surgery*
- ✓ *Of the players returning: 44% experienced a decrease in standard statistical categories & player efficiency ratings*

Busfield et al: Arthroscopy '09





Shah, Andrews, Fleisig: AJSM '10



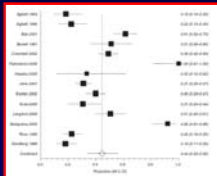
- 49 NFL players underwent ACL/PTG
- ✓ 63% returned to NFL play (31/49)
- ✓ Average length of time to return 10.8 mos
- Age, position & number of procedures not a factor in return rate
- Players who had more than 4 yrs of experience higher rate of return
- Players drafted in first 4 rounds – higher rate of return to play

Return to Sports

After ACL Reconstruction:

- Systematic review of 48 studies reporting return to sports of 5770 individuals after ACL reconstruction at mean follow-up of 41.5 months



Return to Some Form of Sports	82% (95% CI 73 to 90%)
Return to Pre-Injury Level of Sports	63% (95% CI 54 to 71%)
Return to Competitive Sports	44% (95% CI 34 to 56%)



Ardern CL et al. 2011

Return to Sports

- Reasons for reduced sports participation for those that did not return to prior level:
 - ✓ Fear of re-injury (19%)
 - ✓ Problems with structure/function of knee (13%)
 - ✓ Family commitments or lifestyle changes (11%)

Ardern, BJSM: 2011

Kinesiophobia

- ✓ Fear of movement/reinjury
 - "I'm afraid that I might injure myself if I play a sport or exercise"
 - Tampa scale for kinesiophobia
Woby et al: Pain '05
- Interventions which improve self efficacy may improve knee function short term
Chmielewski et al: JOSPT '08
Chmielewski et al: Phys Ther '11
Lentz et al: JOSPT '12

Why??

[RESEARCH REPORT]

The Association of Pain and Fear of Movement/Reinjury With Function During Anterior Cruciate Ligament Reconstruction Rehabilitation

[RESEARCH REPORT]

Return to Preinjury Sports Participation Following Anterior Cruciate Ligament Reconstruction: Contributions of Demographic, Knee Impairment, and Self-report Measures

Item	Response	Correct item-total correlation	Response mean (difference)
1	I'm afraid that I might re-injure myself if I exercise	0.62	0.42
2	If I were to continue to try pain-reducing measures	0.47	1.24
3	My knee is stiff and I have swelling, especially in the morning	0.58	0.76
4	My knee is stiff and I have swelling, especially in the evening	0.58	0.76
5	My knee is stiff and I have swelling, especially at night	0.58	0.76
6	My knee is stiff and I have swelling, especially during the day	0.58	0.76
7	My knee is stiff and I have swelling, especially when I'm walking	0.58	0.76
8	My knee is stiff and I have swelling, especially when I'm running	0.58	0.76
9	My knee is stiff and I have swelling, especially when I'm jumping	0.58	0.76
10	My knee is stiff and I have swelling, especially when I'm climbing stairs	0.58	0.76
11	My knee is stiff and I have swelling, especially when I'm sitting down	0.58	0.76
12	My knee is stiff and I have swelling, especially when I'm standing up	0.58	0.76
13	My knee is stiff and I have swelling, especially when I'm bending over	0.58	0.76
14	My knee is stiff and I have swelling, especially when I'm twisting my knee	0.58	0.76
15	My knee is stiff and I have swelling, especially when I'm leaning back	0.58	0.76
16	My knee is stiff and I have swelling, especially when I'm leaning forward	0.58	0.76
17	My knee is stiff and I have swelling, especially when I'm walking on uneven ground	0.58	0.76
18	My knee is stiff and I have swelling, especially when I'm walking on smooth ground	0.58	0.76
19	My knee is stiff and I have swelling, especially when I'm walking on a hard surface	0.58	0.76
20	My knee is stiff and I have swelling, especially when I'm walking on a soft surface	0.58	0.76

Return to Preinjury Sports Participation Following ACLR

Why Didn't They Return to Sports (n=42)

- ✓ Kinesiophobia* - more present in low level athletes – elite athletes
- ✓ Instability*
 - ✓ 31 patients responded they had instability (68%)
- ✓ Quad PT/BW ratio*
 - ✓ important test parameter
 - ✓ quads are shock absorbers
 - ✓ Wilk et al: JOSPT '94 correlation b/w QPT/BW
- ✓ IKDC scores (15 pts difference)*
- ✓ Knee effusion (present in 9 pts)* - 21%
- ✓ Pain scale difference*
- ✓ Tegner scale differences

[EDITORIAL]

We Can Do Better

JOSPT 2014

KEVIN E. WILK, PT, DPT, FAPTA
Champion Sports Medicine, Physiotherapy Associates, Birmingham, AL
American Sports Medicine Institute, Birmingham, AL
JOSPT Online First: doi:10.2519/jospt.2014.0101

Typically, the goal of any rehabilitation program is to return the patient/athlete to the preinjury level. This is the frequently used benchmark reported in the literature when determining rehabilitation goals or describing the outcomes following anterior cruciate ligament (ACL) injury or reconstruction.^{1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100} Additionally, it is often used in characterizing almost any other type of body functional ability. The rehabilitation program should identify, address, and correct all specific predisposing factors that may lead to another injury by addressing the physical, biomechanical, environmental, and psychological factors of the whole person during the rehabi-

[EDITORIAL]

Anterior Cruciate Ligament Injury Prevention and Rehabilitation: Let's Get It Right

JOSPT 2015

KEVIN E. WILK, DPT, FAPTA
Champion Sports Medicine, Physiotherapy Associates, Birmingham, AL
American Sports Medicine Institute, Birmingham, AL
JOSPT Online First: doi:10.2519/jospt.2015.0101

Anterior cruciate ligament (ACL) injuries are among the most common and functionally disabling conditions in orthopaedics and sports medicine. The incidence of ACL reconstruction (ACLR) in the United States has increased dramatically over the past 20 years. In 1994, an estimated 66,697 ACLR procedures were performed. By 2013, the yearly number of procedures had increased by 58% to 148,714.¹ Over this 20-year period, the fastest-rising

Anterior cruciate ligament injuries and ACLRs are extremely costly to patients and to the US health care system, which is transitioning toward value-based reimbursement for services rendered. With regard to ACLR specifically, the costs include surgeon and hospital/ surgery center fees plus the cost of rehabi-

ACL Reconstruction Overview

- ✓ ACL injuries are the most common ligamentous injuries of the knee requiring surgery
- ✓ 175,000 ACL R performed year 2000
- ✓ Total cost of over 2 billion dollars
Spindler: NEJM '08

Long Term Successful Outcome




ACL Rehabilitation *Limb Confidence*

!! Perturbation Training to Enhance Neuromuscular Control

- Various levels of dynamic stability

Stability → *Mobility*
Controlled Mobility → *Skill*
- ✓ Perturbation skill one of highest level
- ✓ Improves clinical outcomes

Wilk: J Athl Trn '99
Fitzgerald: Phys Ther '00

Must gradually progress to skill level drills !!

Fitzgerald, Axe, Snyder-Mackler: *Phys Ther : '00*

- Perturbation training ACL deficient knee patients (athletes)
- 26 patients isolated ACL rupture
- Randomly assigned to group:
 - » A standardized program
 - » Standardized program & perturbation training
- ✓ Results: **91%** perturbation group return to play (6 months)
- 50%** standardized group return to play (6 months)

Group Characteristics for Activity Level		
Activity	Standard Group	Perturbation Group
Collegiate football	1	2
Semiprofessional football		1
Collegiate lacrosse	1	
Collegiate field hockey		1
Collegiate track/hockey	1	
High school basketball	1	
High school field hockey		1
Semiprofessional baseball		1
Senior Olympic volleyball		1
Baseball	5*	
Hockey	1	1
Tennis	1	1
Soccer	1*	2
Volleyball		1

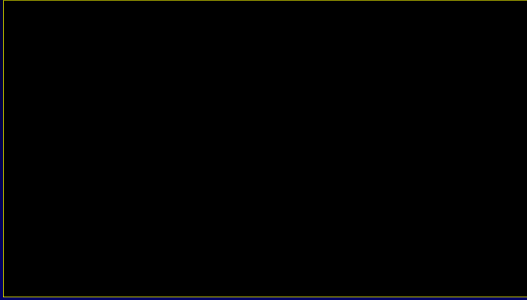
* Five subjects also worked as cross-country workers (level II recipients).
* Subjects may also be qualified for the level patient activity (level II recipients).

Perturbation Training to Enhance NM Control

Perturbation Training to Enhance NM Control

Linking Arms & Lower Extremity

Movements & Change of Planes



Lateral Slides

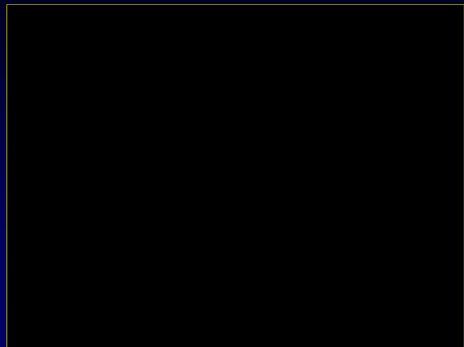
Reactive Lateral Slides

Reactive Lateral Slides on Verbal

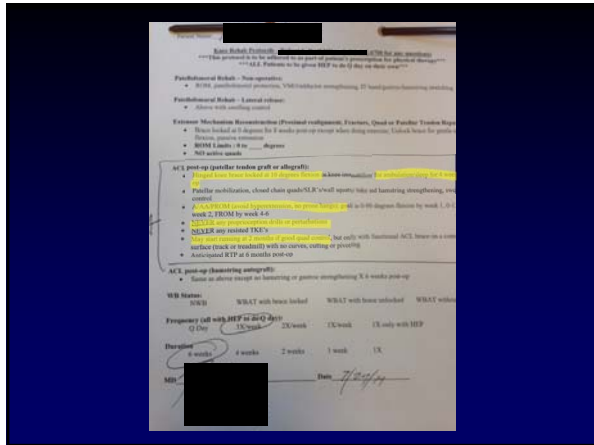
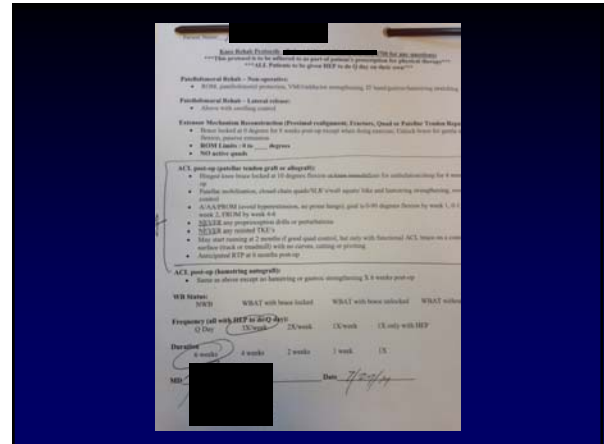
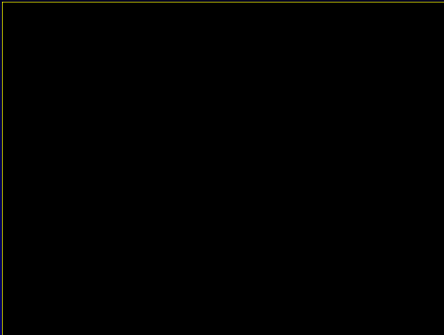
Movements with Stabilization



Movements with Stabilization

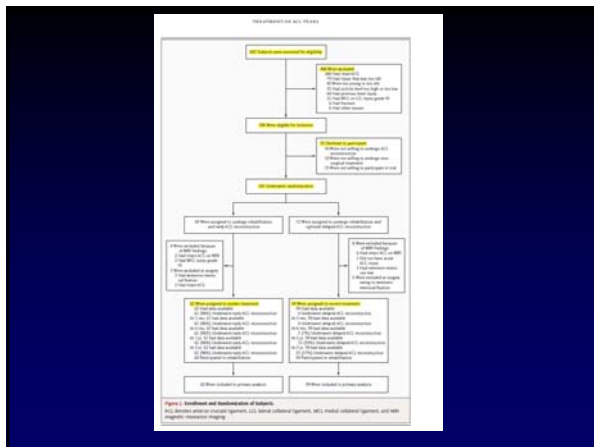


Movements with Stabilization



Frobell et al: NEJM '10

- Randomized trial of treatment for acute ACL tears
- 121 young adults, acute ACL injury
- Randomized into 2 groups:
 - » Structured rehab & early ACL reconstruction (n=62)
 - » Structured rehab & with option of delayed rehab (59)
- Of the 59 in delayed surgery, 23 underwent surgery & 36 Rx with rehabilitation no surgery
- Primary outcome: baseline to 2 yrs post-injury
- **Conclusion:** "a strategy of rehab plus early reconstruction was not superior to delayed surgery"



THE NEW ENGLAND JOURNAL OF MEDICINE

ORIGINAL ARTICLE

A Randomized Trial of Treatment for Acute ACL Reconstruction*

Table 2. Adverse Events.*

Adverse Event	Rehabilitation plus Early ACL reconstruction (N=62)	Rehabilitation plus Optional Delayed ACL reconstruction (N=59)	P Value
	number of events		
Serious events†			
Site other than index knee	10	11	0.74
Macrospondylitis‡	2	3	
Skin§	1	4	
Gastrointestinal¶	1	3	
Other	6	1	
Index knee	26	40	0.06
Subluxative or chronic instability**	12	19	
Medical signs and symptoms	14	21	
Pain, swelling, or both	6	3	
Decreased range of motion	4	1	
Extension deficit	1		
Arthrofibrosis	1		
Graft rupture	3	1	
Others	4	3	
All serious events	36	31	0.67
Nonserious events ††			
Site other than index knee	87	103	0.13
Index knee	37	44	<0.001
All nonserious events	124	147	0.29

Paterno, Rauh, et al: AJSM '14

- ACL reinjury rate following ACLR
- 78 subjects underwent ACLR – return to sports
- ✓ 15x greater 2nd ACL in subjects with ACLR if they return to sports during the first year
- ✓ 6x greater 2nd ACL injury in subjects returning to sports within 12-24 mos
- ✓ Females ACLR 4x greater rate of injury 24 mos.
- ✓ 2x more likely to tear opposite knee ACL
- ✓ 30% athletes sustained 2nd ACL inj – 21% on contralateral side 9% opposite side

Grindem, Snyder-Mackler, Engebretsen, et al: BJSM '16

- Can we reduce reinjury rates in ACLR pts
- Delaware-Oslo ACL Cohort Study
- 106 patients ACLR – 2yr FU
- ✓ 30% pts returning Level I sustained reinjury, 8% returning to a lower level (4x higher reinj rate)
- ✓ Every month delayed returned to sports until 9mos – rate of reinjury was reduced 51%
- ✓ More symmetrical quadriceps strength prior to return to sports sign. Reduced reinjury rate

Reduce Re-Injury Rate by 84% **Strict Criteria to Return to Sports**

Original article

Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Oslo ACL cohort study

Hege Grindem,¹ Lynn Snyder-Mackler,² Håvard Moksnes,³ Lars Engebretsen,^{3,4} May Anna Risberg^{1,4}

ABSTRACT Knee injury after ACL reconstruction is common and increases the risk of osteoarthritis. There is some evidence to guide return to sport (RTS) decisions in this population.

Objectives To assess the relationship between level of return after ACL reconstruction and (1) return to level I sports, (2) timing of RTS and (3) knee function prior to return.

Methods 106 patients who participated in pre-injury sports participated in this prospective 2-year cohort study. Sports participation and knee injury were recorded monthly. Knee function was assessed with the Knee Outcome Survey-Activities of Daily Living Scale, global rating scale of function, and quadriceps strength.

Results 57 patients returned to level I sports, 49 did not. 27 patients returned to level I sports within 12 months, 30 returned between 12 and 24 months, and 0 returned after 24 months. 10 patients did not return to level I sports. 10 patients returned to level I sports after ACL reconstruction. 10 patients returned to level I sports after ACL reconstruction. 10 patients returned to level I sports after ACL reconstruction.

Failla, Løgerstedt, Grindem et al: AJSM '16

- Does extended Pre-Op Rehab Influence Outcomes 2 years after ACLR
- MOON & Delaware-Oslo ACL Cohorts
- 150 patients in each group
- Criteria based when reconstruction is performed
- ✓ DOC group: strength training, ROM & NM drills
- ✓ The DOC group had significantly higher Return To Sports rate at 2 yrs
- ✓ 12-15% higher scores (IKDC, KOOS)
- ✓ DOC pre-op average



Neuroplasticity Following ACL Injury

[RESEARCH REPORT]

DIETRICH GRONING, PH.D. • STEPHEN J. LANG, PH.D. (C) • ROBERTA S. NICOLA, M.D. (C) • KATHY M. CHOLEWICKI, PH.D. • SEAN M. WATTS, PH.D. • JAMES S. UNDERWOOD, PH.D.

Neuroplasticity Associated With Anterior Cruciate Ligament Reconstruction

Individuals who experience a primary anterior cruciate ligament (ACL) injury are at substantially increased risk of experiencing a second ACL injury, despite surgical reconstruction and rehabilitation. Athletes who attempt to return to activity are at an exceptionally high risk of reinjury (30 to 60 times greater relative to those without injury history).^{1,2} The mechanisms for the heightened injury risk may extend beyond the physiological and biomechanical and physiologic needs of rehabilitation and post-injury may also require theoretical neuroplastic changes. Neuroplasticity, experience-dependent factors, including behavioral changes due to neuroplastic gain, modified the neuromuscular system, and subsequent changes in the neuromuscular system may be involved in the increased injury risk.

Rehab Implications:

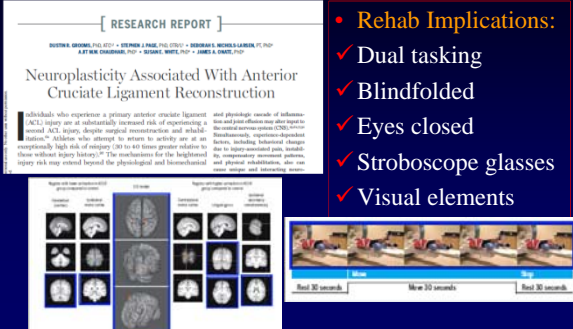
- ✓ Dual tasking
- ✓ Blindfolded
- ✓ Eyes closed
- ✓ Stroboscope glasses
- ✓ Visual elements

Neuroplasticity Following ACL Injury

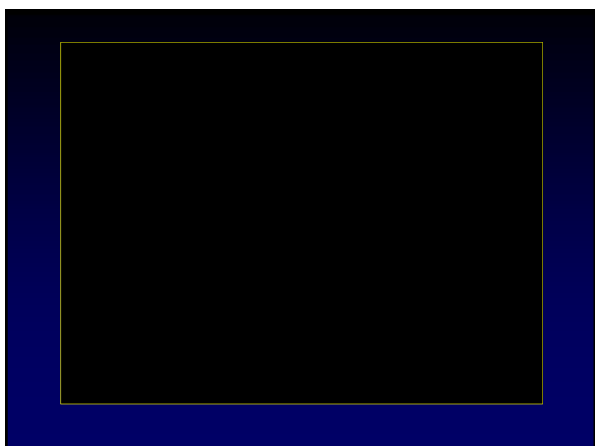
[RESEARCH REPORT]

NEUROPLASTICITY ASSOCIATED WITH ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

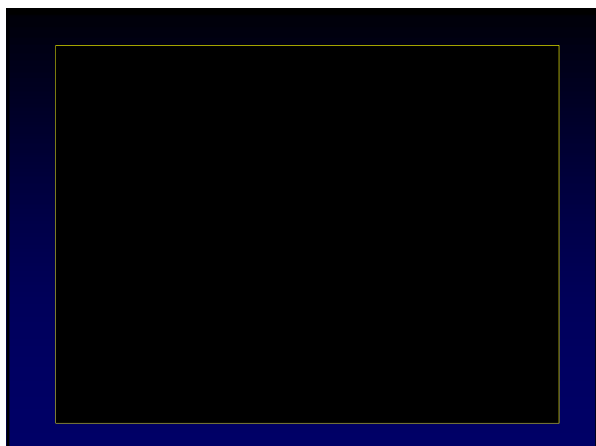
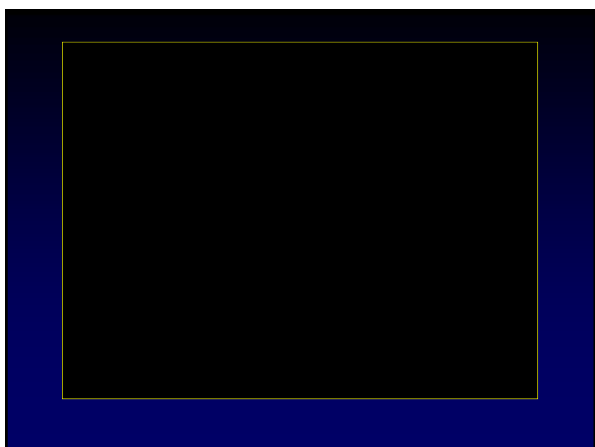
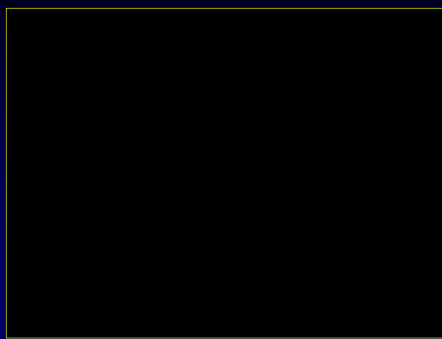
- Rehab Implications:
 - ✓ Dual tasking
 - ✓ Blindfolded
 - ✓ Eyes closed
 - ✓ Stroboscope glasses
 - ✓ Visual elements



The research report abstract discusses neuroplasticity associated with ACL injury and reconstruction. It mentions that individuals who experience a primary anterior cruciate ligament (ACL) injury are at a substantially increased risk of experiencing a second ACL injury, despite surgical reconstruction and rehabilitation. The abstract also notes that individuals who attempt to return to activity are at an exceptionally high risk of re-injury (20 to 40 times greater relative to those without injury history). The mechanisms for the heightened injury risk may extend beyond the anatomical and biomechanical and physiologic aspects of inflammation and joint effusion, but also include the central nervous system (CNS) response to injury, including proprioceptive deficits, including balance changes due to hyperextension pain, unstable ligamentous movement patterns, and proprioceptive movement patterns, and proprioceptive deficits, the same motor output and learning activities.



Unbalanced Bar Balance Drills



How Do You Know When Your ACL Patient is Ready to Run? Return to Sports?



How Do You Know When Your ACL Patient is Ready to Run? Return to Sports?

No Association of Time From Surgery With Functional Deficits in Athletes After Anterior Cruciate Ligament Reconstruction

AJSM '12

Evidence for Objective Return-to-Sport Criteria

Gregory D. Myer, ^{1,11} PhD, FACSM, CSCS[®], Larry Martin Jr, ^{1,11} PhD, Kevin R. Ford, ^{1,11} PhD, Mark V. Paoloni, ^{1,11} PT, PhD, SCS, ATC, Lakira C. Schmitt, ^{1,11} PT, MPT, PhD, Robert S. Hecht Jr, ¹ MD, FACS, Angelo Colosimo, ¹ MD, and Timothy E. Hewett, ^{1,11} PhD
Investigation performed at Cincinnati Children's Hospital Medical Center

Post-Op ACL Reconstruction

Where did the 80% of opposite side come from ?

Netter: Knee Surg Spts Traumatol Arthrosc '06

- ✓ Test battery Q?H strength & power (conc & ecc)
- ✓ ≥90%

Van Grinsven: Knee Surg Spts Traum Arth '10

- ✓ 85% or better in ACL patients

Barber-Westin, Noyes: Arthroscopy '11

- ✓ strength: <10% deficit
- ✓ Hop test: <15% deficit
- ✓ Vertical landing: >60% knee separation distance

Post-Op ACL Reconstruction *Functional Screening Test*

Return to Play Criteria



Non-Operative Rehab Shoulder Instability

The Weekend Warrior



Knee Injuries – ACL +

The Weekend Warrior



Movements with Poor Stabilization



Post-Op ACL Reconstruction *Return to Play Criteria*

- ✓ 3 P Program:
- ✓ Performance
- ✓ Practice
- ✓ Play

Post-Op ACL Reconstruction Return to Play Criteria

- ✓ 3 P Program:
- ✓ Performance Training:
 - ✓ performance training – sport specific drills
 - ✓ plyometrics
 - ✓ agility drills
 - ✓ speed drills
 - ✓ sport specific drills (cutting, deceleration, etc)

Post-Op ACL Reconstruction Return to Play Criteria

- ✓ 3 P Program:
- ✓ Practice situations:
 - ✓ control practice
 - ✓ gradual increase time, intensity, reps
 - ✓ lower intensity to begin gradually increase intensity
50-60% → 75% → 80-90% → 100%
 - ✓ return to practice game (game simulation)

Post-Op ACL Reconstruction Return to Play Criteria

- ✓ 3 P Program:
- ✓ Play:
 - ✓ return to competition
 - ✓ game situation
 - ✓ 100% effort

2016 Consensus statement on return to sport from the First World Congress in Sports Physical Therapy, Bern

Clare L Arden,^{1,2} Philip Glasgow,³ Anthony Schneider,⁴ Erik Whitroux,^{5,7} Benjamin Clancy,^{8,9} Ann Cook,² Boris Gajdosic,^{10,11} Stefan Griffin,¹² Karim M Khan,¹³ Howard Mokone,^{4,8} Stephen A Mutch,^{14,15} Nicola Philipp,¹⁶ Gustaf Reurink,¹⁷ Robin Sadler,¹⁸ Karin Grövae Silbernagel,¹⁹ Kristian Thorborg,^{20,21} Arntang Wangensteen,^{1,8} Krvin E. Wilk,²² Mario Bizzini²³

ABSTRACT
Deciding when to return to sport after injury is complex and multifactorial—an exercise in risk management. Return to sport decisions are made every day by clinicians, athletes and coaches, ideally in a collaborative way. The purpose of this consensus statement was to present and synthesize current evidence to make recommendations for return to sport decision-making, clinical practice and future research directions related to returning athletes to sport. A half day meeting was held in Bern, Switzerland, after the 19th World Congress in Sports Physical Therapy. 17 expert clinicians participated.

KEYWORDS
Return to sport, injury, risk management, consensus statement

Post-Op ACL Reconstruction Functional Screening Test

- ✓ Clearance for running
- ✓ Clearance for agility drills
- ✓ Clearance for jumping
- ✓ Clearance for hopping & cutting
- ✓ Proceed to the return to sport

Post-Op ACL Reconstruction Functional Screening Test

- Clearance for Running:
 - ✓ 30 Step & holds
 - ✓ 10 single leg squats
 - ✓ 1 rep max on leg press
 - ✓ 15 min of fast treadmill walk
 - ✓ KT testing
 - ✓ Isokinetic testing

- ✓ FMS test
- ✓ Y balance test
- ✓ Landing CoG
- ✓ Gait pattern (biomechanical)
- ✓ Vertical Jumping

Post-Op ACL Reconstruction *Functional Screening Test*

- **Clearance for Running:**
 - ✓ 30 Step & holds
 - ✓ 30 step & holds w/o loss of balance
 - ✓ 10 single leg squats
 - ✓ 10 consecutive squats to 45 deg
 - ✓ 1 rep max on leg press
 - ✓ $\geq 70\%$ 1 RM on leg press
 - ✓ 15 min of fast treadmill walking (normal gait)
 - ✓ KT testing (specific criteria)
 - ✓ Isokinetic testing (specific criteria)

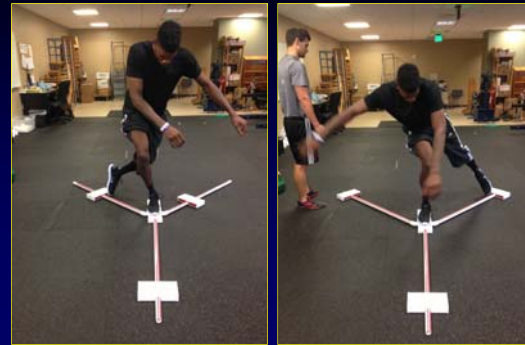
Functional Movement Screen FMS



Functional Movement Screen FMS



Y Balance Test



Post-Op ACL Reconstruction *Functional Screening Test*

- **Clearance for Agility Drills:**
 - ✓ 1 rep max on leg press
 - ✓ 10 single leg squats with weights
 - ✓ Run 1 mile on treadmill
 - ✓ KT testing
 - ✓ Isokinetic testing
 - ✓ Hop test

Post-Op ACL Reconstruction *Functional Screening Test*

- **Clearance for Agility Drills:**
 - ✓ 1 rep max on leg press
 - ✓ $\geq 85\%$ of uninvolved side
 - ✓ 10 single leg squats with weight to 45 deg
 - ✓ $\geq 75\%$ of uninvolved side
 - ✓ Run 1 mile on treadmill
 - ✓ normal gait pattern
 - ✓ KT testing (specific criteria)
 - ✓ Isokinetic testing (specific criteria)
 - ✓ Hop testing ($85\% >$ of uninvolved side)

Post-Op ACL Reconstruction Functional Screening Test

- Clearance for Return to Sport:
 - ✓ Strength achieves >90%
 - ✓ Displays normal running pattern – no pain
 - ✓ Has practiced & displays no hesitation or compensation strategies
 - ✓ Practiced full effort – no swelling or pain
 - ✓ KT test
 - ✓ Hop test (90% ≥ uninvolved side)

ACL Injury Return to Sports

- Levels of Sports (Based on Loading/Stress)
 - I: Basketball, Soccer, Volleyball, Gymnastics, Football, Skiing, Lacrosse
 - II: Baseball, Softball, Kickball, Nordic Skiing, Hiking, Bowling
 - III: Golf, Running, Biking, Swimming, Walking

ACL Injury Return to Sports

Current Concepts

Athletic Activity after Joint Replacement

William L. Healy, MD, Richard Iorio, MD, and Mark J. Lemos, MD
From the Department of Orthopaedic Surgery, Lahey Clinic, Burlington, Massachusetts

Activity after Total Hip Arthroplasty—1999 Hip Society Survey

Recommended/Allowed	Avoided with symptoms	Not recommended	No conclusion
Stationary bicycling	Low-impact aerobics	High-impact aerobics	Jazz dancing
Croquet	Road bicycling	Baseball/softball	Square dancing
Hallroom dancing	Bowling	Basketball	Pinning
Golf	Canoeing	Football	Ice skating
Horseback riding	Hiking	Gymnastics	Rollerblade skating
Shooting	Horseback riding	Handball	Rowing
Shuffleboard	Cross-country skiing	Hockey	Speed walking
Swimming		Jogging	Downhill skiing
Doubles tennis		Lacrosse	Stationary skiing*
Walking		Racquetball	Weight lifting
		Squash	Weight machines
		Rock climbing	
		Soccer	
		Singles tennis	
		Volleyball	

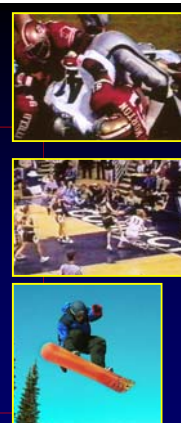
* NordicTrack, Logan, Utah.

Post-Op ACL Reconstruction Functional Screening Test

- Clearance to Return to Practice: (additional)
 - ✓ vertical drop jump
 - ✓ unilateral bridge for time
 - ✓ full prone plank
 - ✓ running & cutting (running making 90°)
 - ✓ running & deceleration (running straight at higher percentage and stop on a dime)

ACL Injuries Introduction

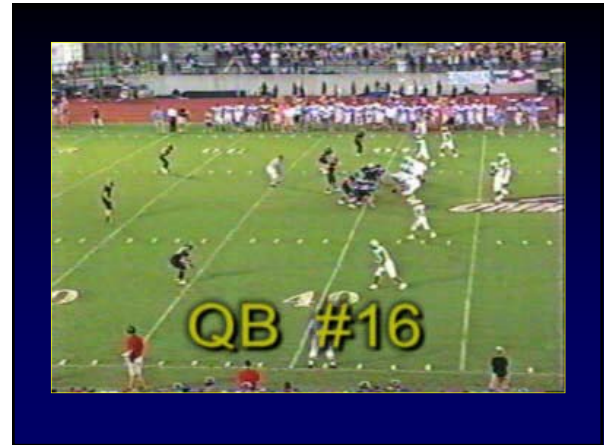
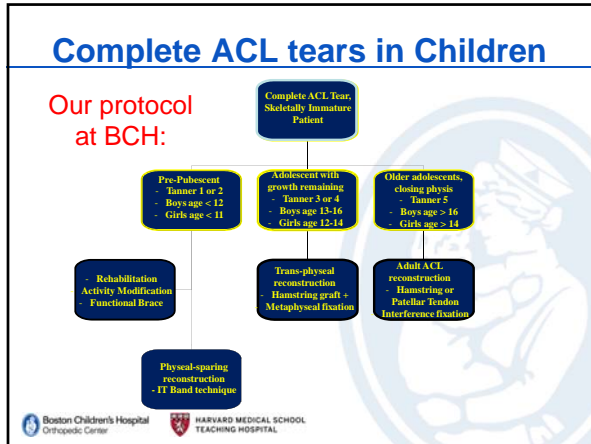
- Usually occurs in “high risk” sports
 - ✓ Football
 - ✓ Basketball
 - ✓ Volleyball
 - ✓ Soccer
 - ✓ Skiing
 - ✓ Team Handball



ACL Injuries Introduction

- ACL Age Distribution
 - Scandinavian Registry *Lind: Acta Orthop '09*
 - ✓ Female peak age – 15 yrs
 - ✓ Male peak age – 20 yrs
- Risk of Contralateral ACL Injury
 - ✓ Systematic review of 13 prospective studies
 - ✓ 2nd Inj Contralateral Risk > than First Time Risk
Sward et al: KSST '10





ACL Injuries


Dynamic Q Angle

- ✓ Proximal Components
 - ✓ Femoral adduction
 - ✓ Femoral internal rotation
- ✓ Distal Components
 - ✓ Hyperpronation
 - ✓ Tibial internal rotation

ACL Injuries

- ✓ **Not an isolated injury**
 - Injury affects mechanoreceptors
 - Within 24 hrs after injury
Lephart: AOSSM '97
 - Deficits may last 6 yrs or more
Denti: Knee Surg Spis Trauma '00
 - "Quadriceps avoidance gait"
Andriacchi: CORR '94
Berechuck: JBJS '90


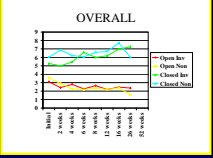
The Effects of ACL Injury on Lower Limb Proprioception



Unilateral ACL Injury Affects Both Lower Extremities
Wilk: CSM '04

ACL Injuries

- **Not an isolated injury**
 - ✓ Injury affects both extremities
 - ✓ For at least 3.6 mos
Wilk, et al: CSM '03
 - ✓ Alters firing mechanism
Wojtys, Huston: AJSM '94

Neuromuscular Performance Characteristics in Elite Female Athletes*
Lynn J. Huston, J. MS, and Edward W. Wojtys, MD
From MedSport, Section of Orthopaedic Surgery of the University of Michigan, Ann Arbor, Michigan

ACL Injuries


- **Not an isolated injury**
 - ✓ Injury affects both extremities
 - ✓ **Quadriceps weakness & activation failure following ACL injury &/or reconstruction bilaterally**
Hart et al: J Athletic Trn '10
Chmielewski: J Orthop Res '04
Farquhar: Muscle Nerve '05
Holder-Powell: Eur J Appl Physiol 01




Quadriceps Activation Following Knee Injuries: A Systematic Review
George M. Hart, PhD, FACSM, Brian R. Robinson, PhD, ATC, Jay Hester, PhD, ATC, PhD, FACSM, Christopher D. Impert, PhD, ATC, PhD, FACSM
*Presented at the American College of Sports Medicine National Meeting, 2010

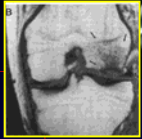

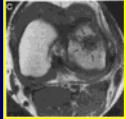

ACL Injuries

- **Deficits in Balance & Proprioception is Long Term**
 - ✓ Posture & balance deficits can be present up to 2-3 yrs
Clark: J Biomech '14 (6-18 mos)
Howells: Knee Surg Spts Trau '11
(systematic review 10 studies – impaired posture at 29 mos)



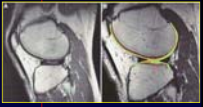
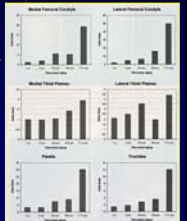
ACL Injuries

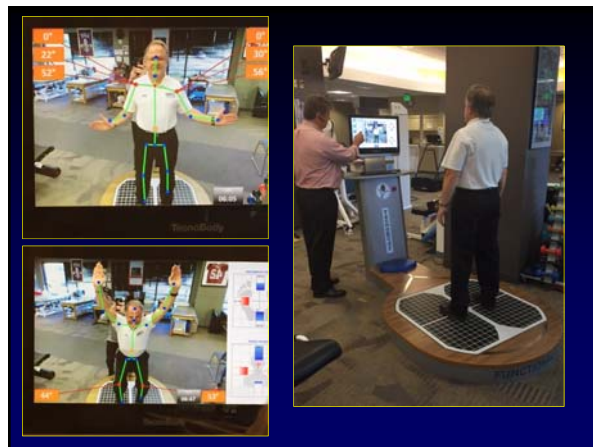
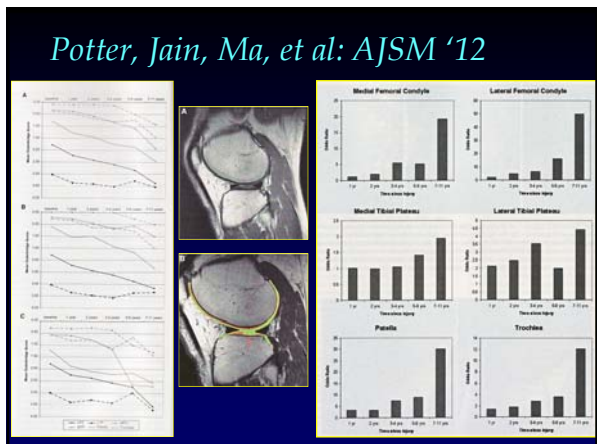
- **Not an isolated injury**
 - **Bone bruises present 71-100% patients**
Potter et al: AJSM '12
Spindler: AJSM '93
Rosen: Arthroscopy '91
Graf: AJSM '93
Johnson: AJSM '98
 - **65% exhibited marrow changes & cartilage thinning 6 yrs after ACL injury**
Faber: AJSM '99

Potter, Jain, Ma, et al: AJSM '12

- 42 knees in 40 patients (28 ACLR, 14 non-op)
- MRI at time of initial injury then annually for a maximum of 11 yrs
- **All patients sustained initial chondral injury 100% incidence**
- Risk of cartilage loss doubled from yr 1 for the lateral & medial compartment & 3x for patella
- By 7 to 11 years: LFC **50x**, MFC 19x, & patella 30x
- Size of the bone bruise associated to degeneration from yr 1 to yr 3



Treat The Osseous Lesion Bone Bruise

- **Rehabilitation Guidelines:**
 - Control wt. bearing forces (crutches)
 - No early running & jumping
 - Cryotherapy & compression
 - Train & restore proprioception
 - Emphasize unloading programs
 - Progress to gradual/progressive loading program
 - Pool exercises, bicycle, etc...
 - Muscle stimulation to quads
 - Motion, motion, motion ...
 - Delay compressive loading (running...)






PACE Yourself First – Before you can go FAST !!!




It's all about milestones !!!

Reduce Swelling & Pain





Proprioception & Neuromuscular Control Drills for the ACL Patient



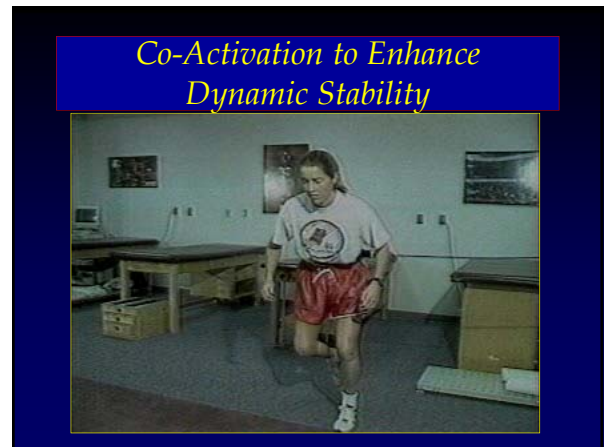
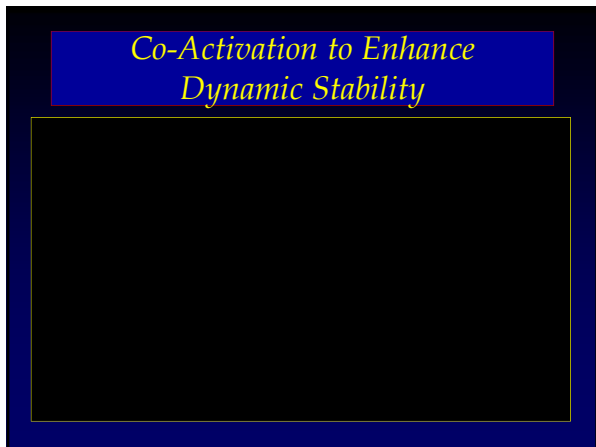
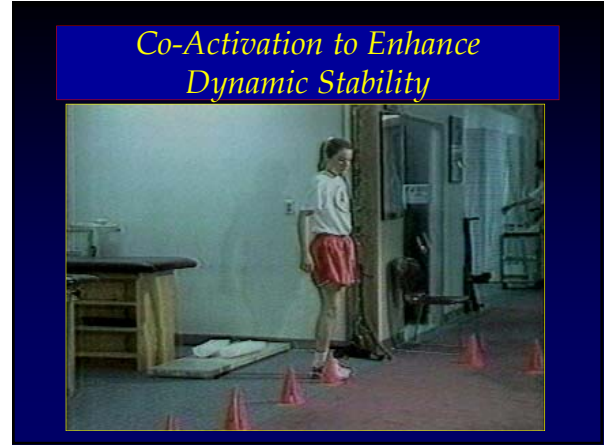
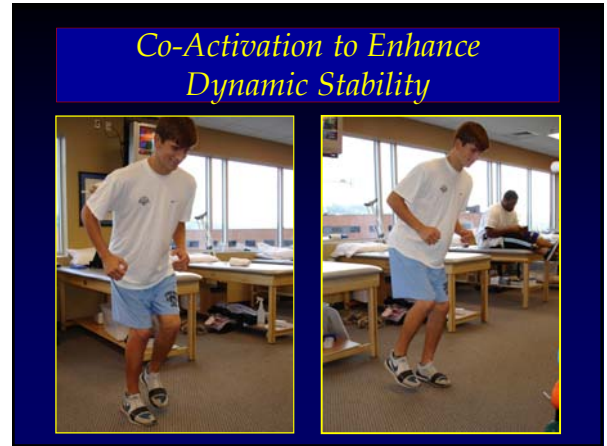
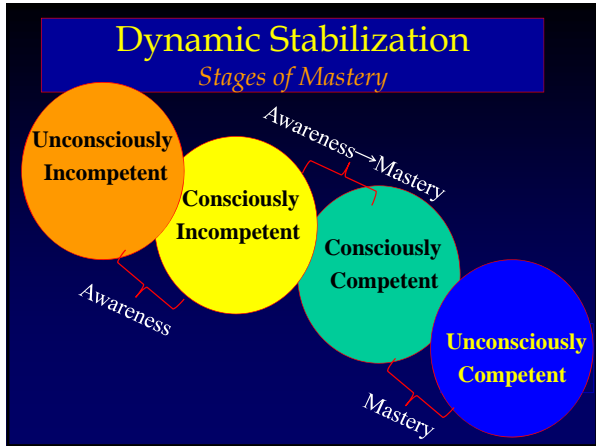


Dynamic Stabilization


Stages of Motor Control Fitts & Posner

COGNITIVE STAGE	ASSOCIATIVE STAGE	AUTONOMOUS STAGE
<ul style="list-style-type: none"> • Identify Objectives • Self-talk/ Questioning • ↑ Errors/Variability • Instruction/ Feedback 	<ul style="list-style-type: none"> • Associate with environmental cues • Refining/Consistent • ↓ Errors/Variability • Identify/Correct Errors 	<ul style="list-style-type: none"> • Subconscious/ automatic • Multiple tasks • ↓↓ Errors/ variability • ↑↑ Identify/Correct • Perfection

Beginner
➔
Expert



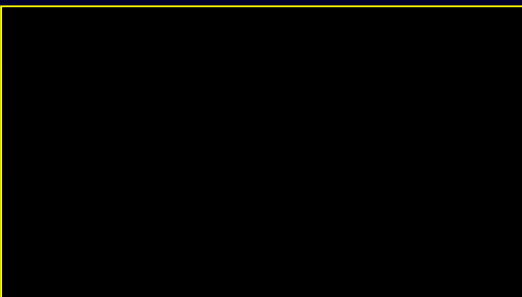
Co-Activation to Enhance Dynamic Stability




Dynamic Stabilization Co-Activation Drills



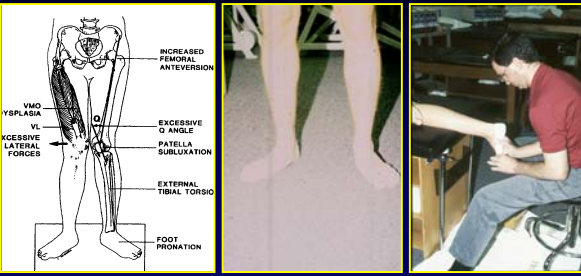
Co-Activation to Enhance Dynamic Stability



Stabilization From ABOVE & BELOW



Establish Proper Foot Position



- VMO
- YSPLASIA
- VL
- EXCESSIVE LATERAL FORCES
- INCREASED FEMORAL ANTEVERSION
- EXCESSIVE Q ANGLE
- PATELLA SUBLUXATION
- EXTERNAL TIBIAL TORSION
- FOOT PROMINATION



ACL Rehabilitation *Immediate Post-injury*

- Train uninjured extremity immediately
 - » Single leg balance Biodex
 - » Single leg bicycle Unicam
 - » Lateral step-down / front





Stimulation to Uninjured Extremity







Train the Uninjured Extremity Too!!




ACL Rehabilitation *Dynamic Stabilization Phase*





- Maintain knee motion
- ✓ *Normalize unilateral muscle ratio*
- ✓ *Enhance stabilization proximal & distal*
Wilk et al: JOSPT '12
- Improve proprioception & NM control





Dynamic Stabilization *Overview*


- Proprioception
- Kinesthesia
- Neuromuscular control
- Functional stability
- Dynamic stabilization


Step Down Test



Lower Extremity Assessment *Step Down Test*



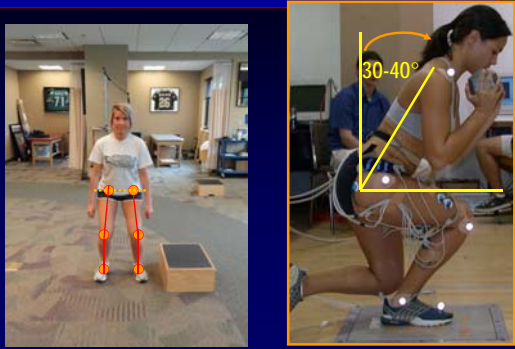
Drop Vertical Jump



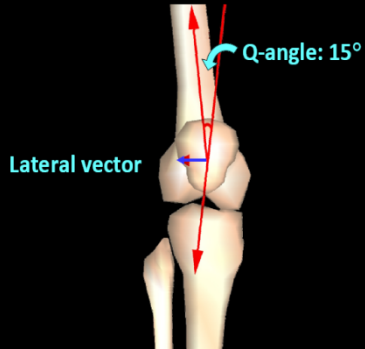
Drop Vertical Jump



Drop Vertical Jump




Lower limb alignment & lateral forces on the patella



ACL Injuries *Dynamic Q Angle*

- ✓ Proximal Components
 - ✓ Femoral adduction
 - ✓ Femoral internal rotation
- ✓ Distal Components
 - ✓ Hyperpronation
 - ✓ Tibial internal rotation





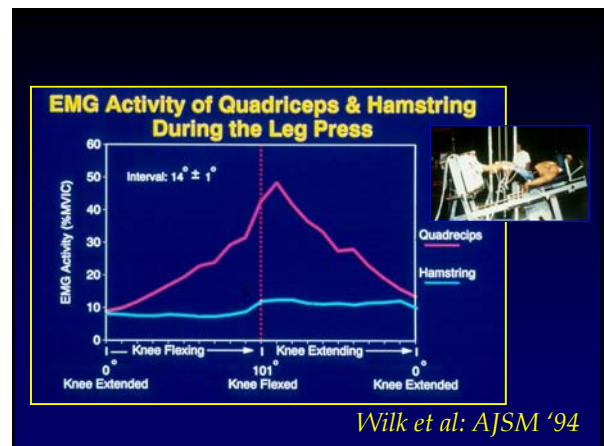
ACL Rehabilitation *Dynamic Stabilization Drills*

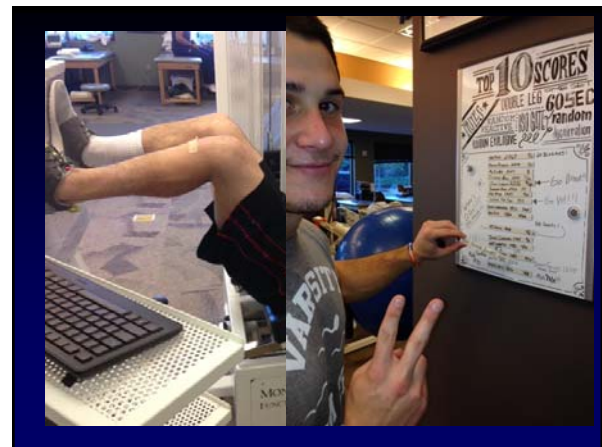
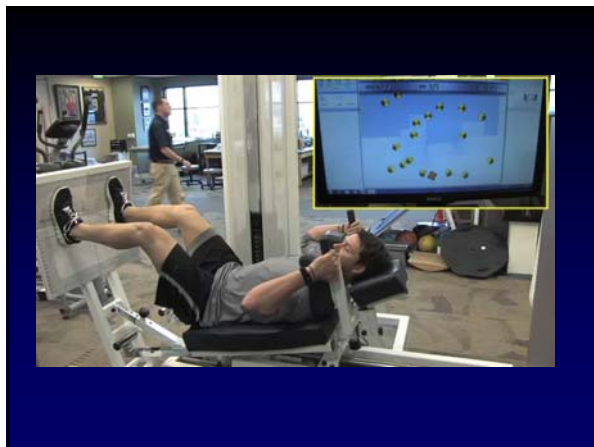
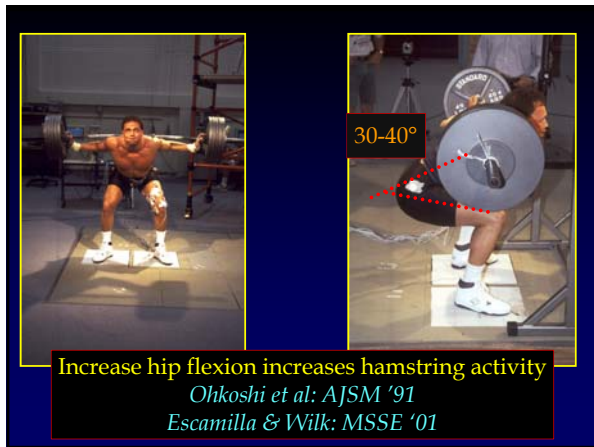
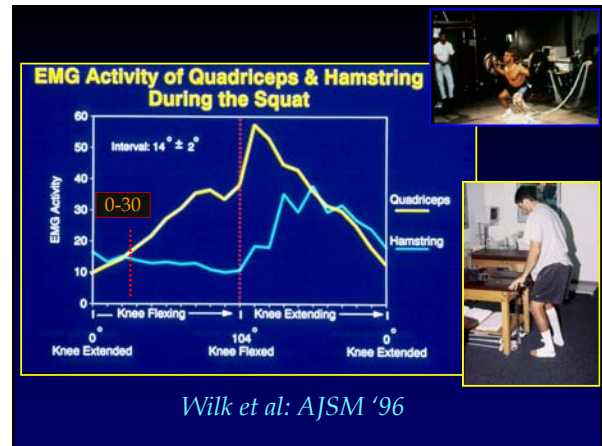
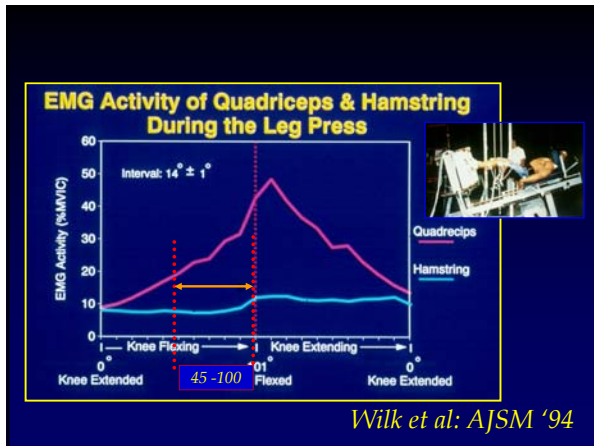
- Maintain full motion
 - » Supine LLD stretches
 - » Maintain knee flexion of 135°
 - » *associated MCL injuries – *extra motion!!*



ACL Rehabilitation *Dynamic Stabilization Drills*

- Progress strengthening program
 - ✓ Leg press 40-100 deg.
 - ✓ Wall squats 0-70 deg.
 - ✓ Decline squats
 - ✓ Lateral step-ups
 - ✓ Front step-downs
 - ✓ Knee extensions 90-40 deg
 - » Hip & hamstrings
 - » Calf muscles






ACL Rehabilitation Advanced Strengthening Phase

Strengthening Ex Days

- ✓ Leg press (45-100)



EMG Activity of Quadriceps & Hamstring During the Leg Press

ACL Rehabilitation Advanced Strengthening Phase

Strengthening Ex Days

- ✓ Leg press (45-100)
- ✓ Wall Slides (0-75)




Figure 2. 90/90 deg knee flexion during exercise ascent

Wall Squat Long & Short




Nagura : J Appl Biomech '06
Nisell: AJSM '89

Escamilla & Wilk: MSSE'09





Escamilla & Wilk: JOSPT '08

ACL Rehabilitation Advanced Strengthening Phase

Strengthening Ex Days

- ✓ Leg press (45-100)
- ✓ Wall Slides (0-75)
- ✓ Step downs



Effect of decline squat

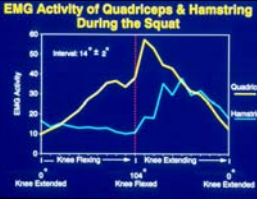


ACL Rehabilitation

Advanced Strengthening Phase


Strengthening Ex Days

- ✓ Leg press (45-100)
- ✓ Wall Slides (0-75)
- ✓ Step downs
- ✓ Squats



EMG Activity of Quadriceps & Hamstring During the Squat

Interval: 14° ± 2°



ACL Rehabilitation

Advanced Strengthening Phase

Strengthening Ex Days

- ✓ Leg press (45-100)
- ✓ Wall Slides (0-75)
- ✓ Step downs
- ✓ Squats
- ✓ Lunges

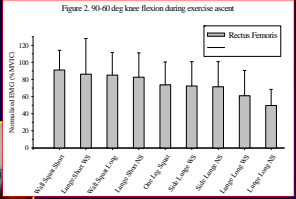



Figure 2. 90-60 deg knee flexion during exercise ascent

Legend: Rectus Femoris



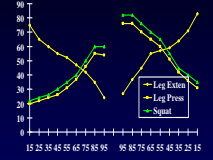

Escamilla & Wilk: JOSPT '08
Escamilla & Wilk: Clin Biomech '08

ACL Rehabilitation


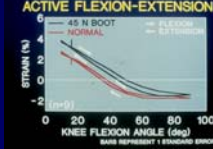

Advanced Strengthening Phase

Strengthening Ex Days

- ✓ Leg press (45-100)
- ✓ Wall Slides (0-75)
- ✓ Step downs
- ✓ Squats
- ✓ Lunges
- ✓ Leg Extensions 90-40



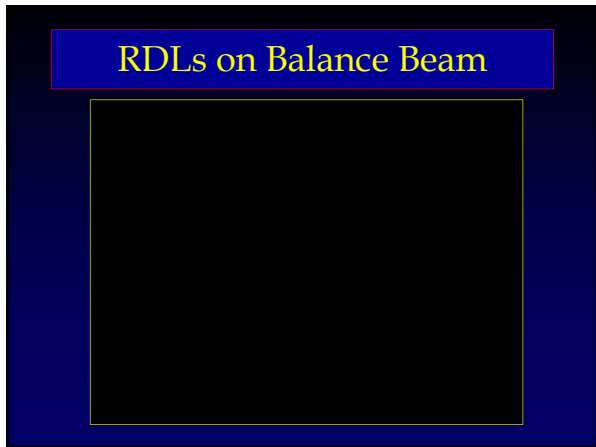
Legend: Leg Extension, Leg Press, Squat

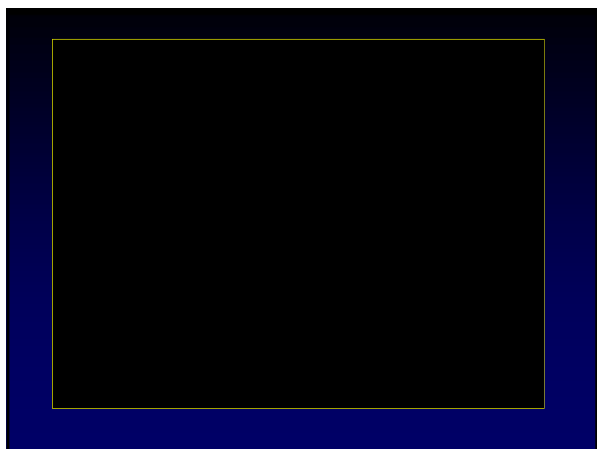
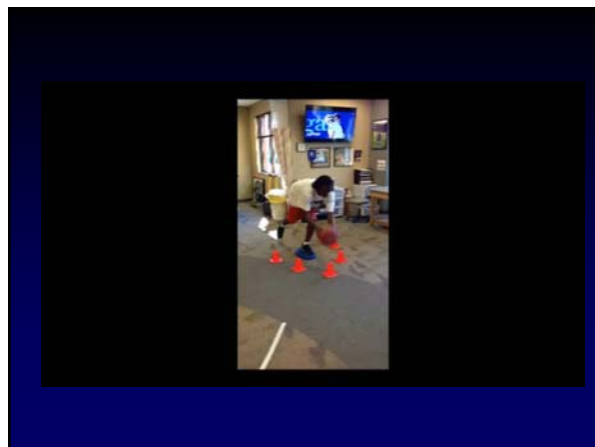
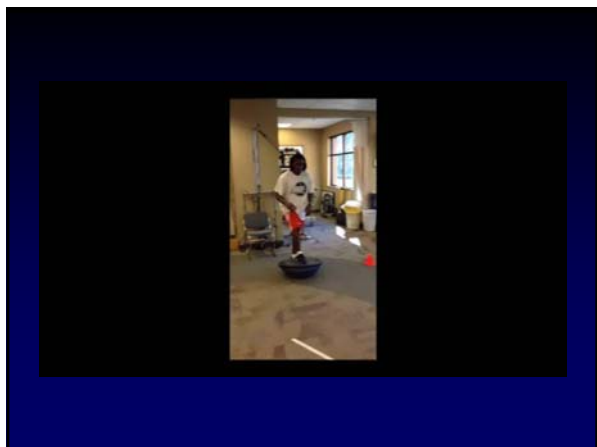
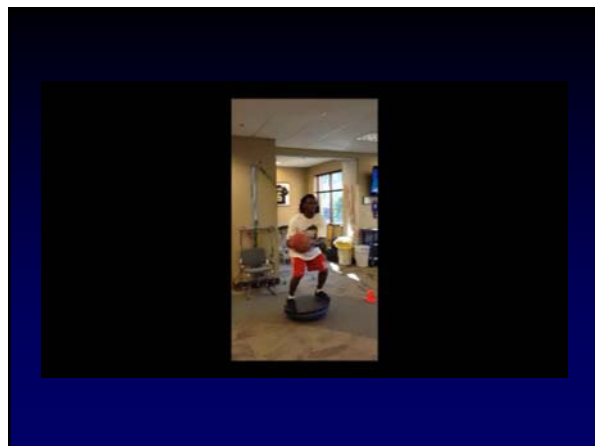




RDLs

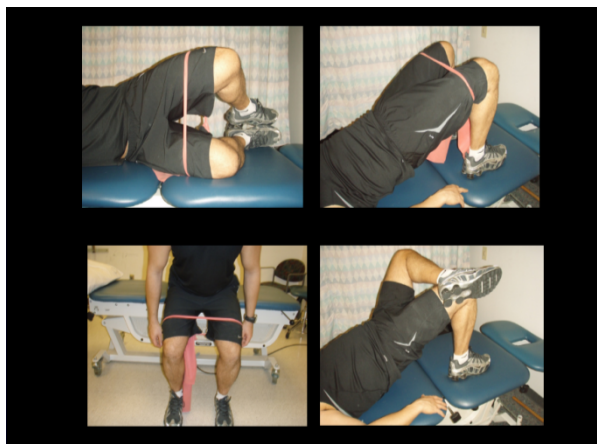


RDLs





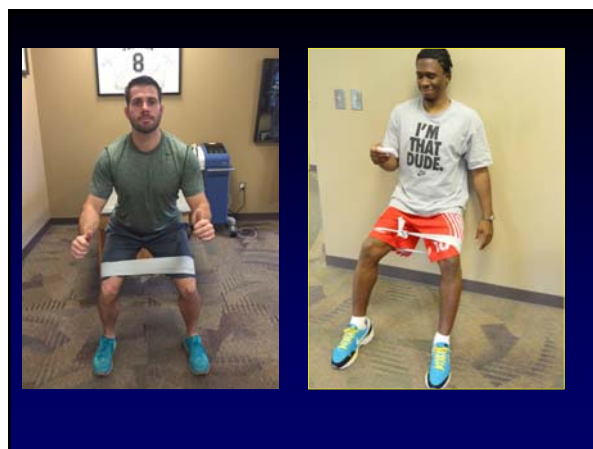




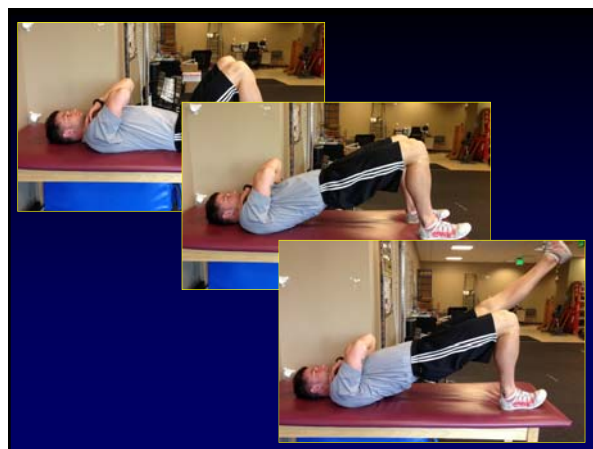


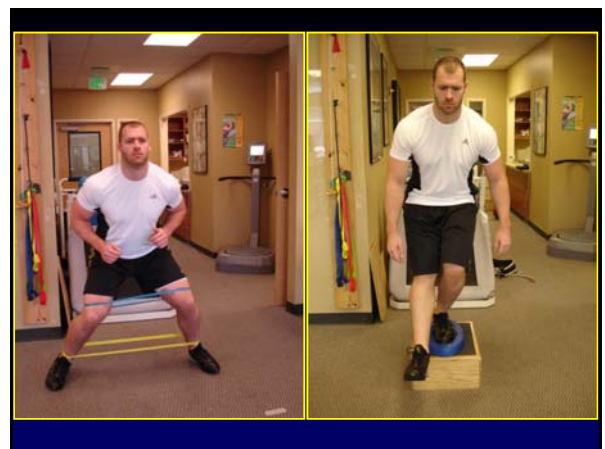
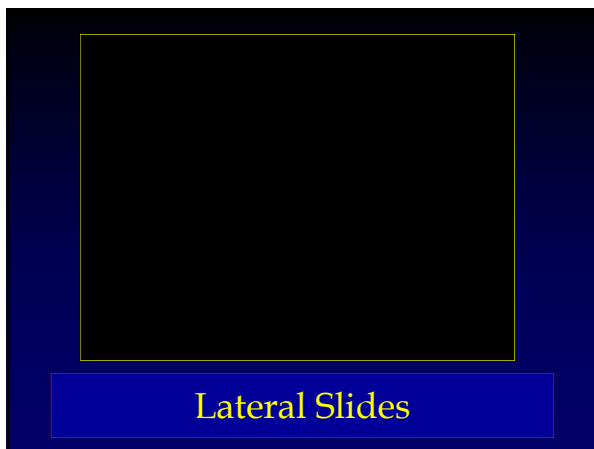
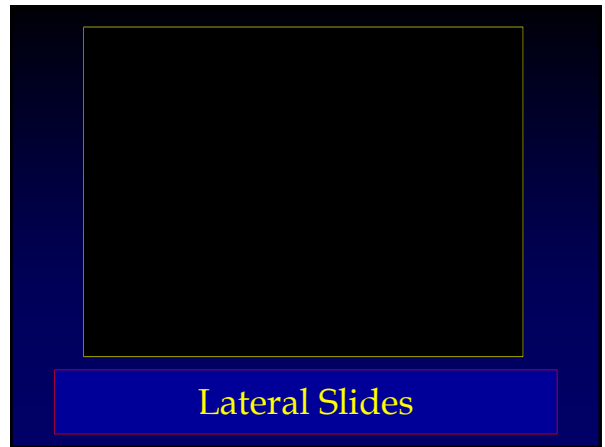
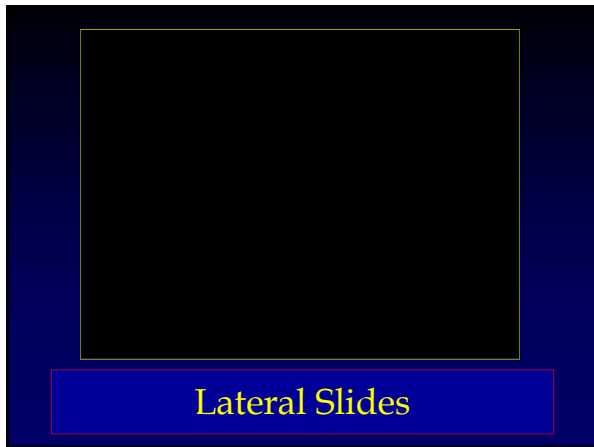
My Favorite Hip Exercises

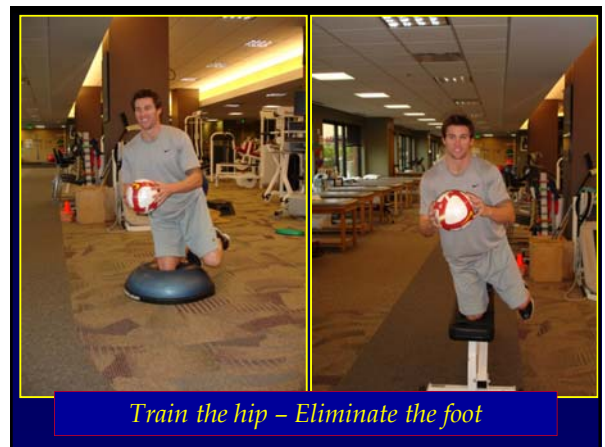
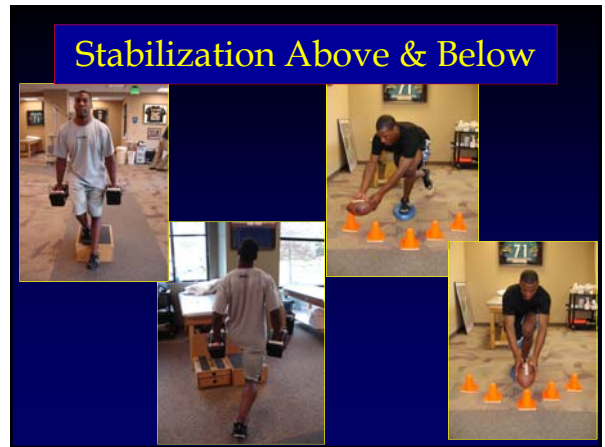
- ✓ Sidelying clams with manual resistance
- ✓ Seated theraband ER
- ✓ RDLs
- ✓ Single leg front step downs
- ✓ Star drill
- ✓ Instant Replay
- ✓ Single leg bosu ball catches
- ✓ Planks with hip abduction & ext

Bridging Exercises









ACL Deficient Knee Rehab

II: Dynamic Stabilization Phase (weeks 4-7)

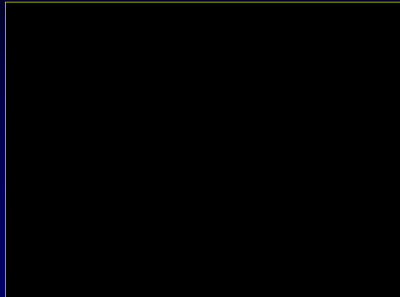
- Enhance stabilization proximal & distal
 - » Lateral lunges
 - » Lateral / front step downs
 - » Hip strengthening
 - » Lunges on foam
 - » Balance beam
 - » Strengthening ankle /foot



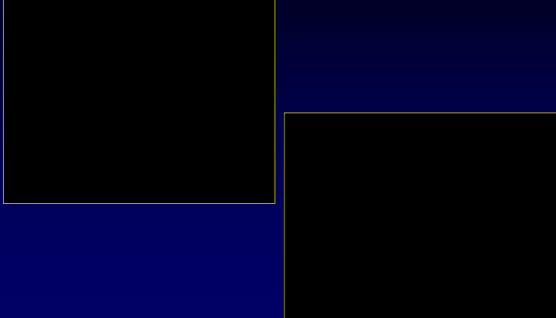
Establish Core Stability



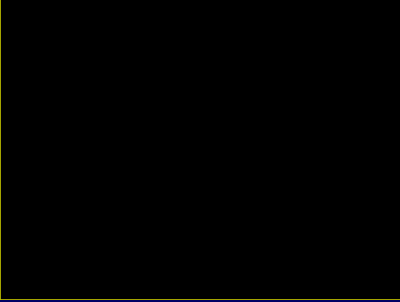
Hamstring/Core Muscle Training



Hamstring/Core Muscle Training



Hamstring/Core Muscle Training



Hamstring/Core Muscle Training



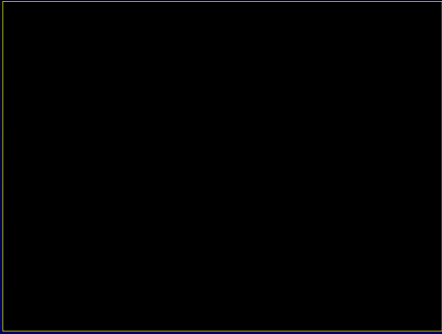

ACL Rehabilitation

What You Need to Know

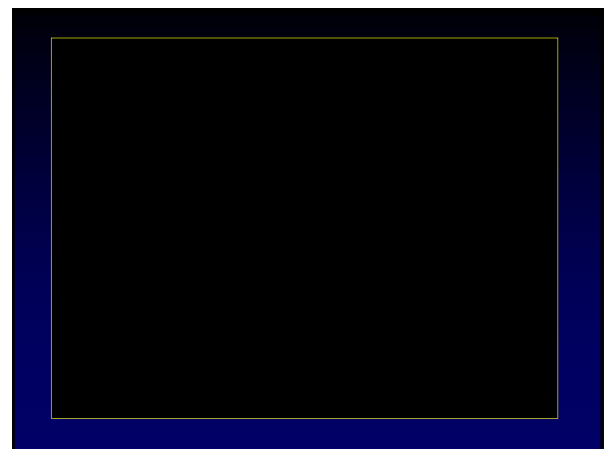
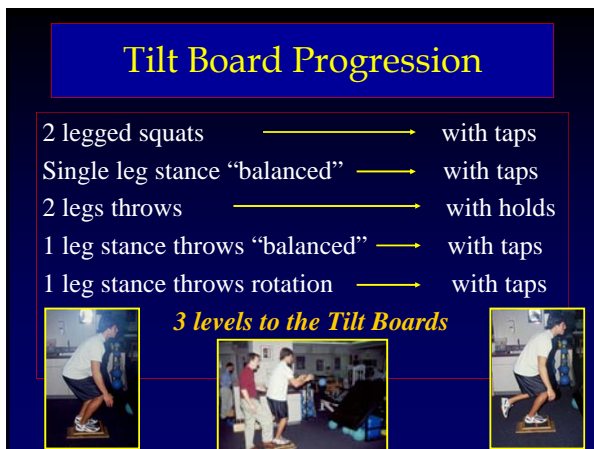
 Hamstrings, Hamstrings & Hamstring Control

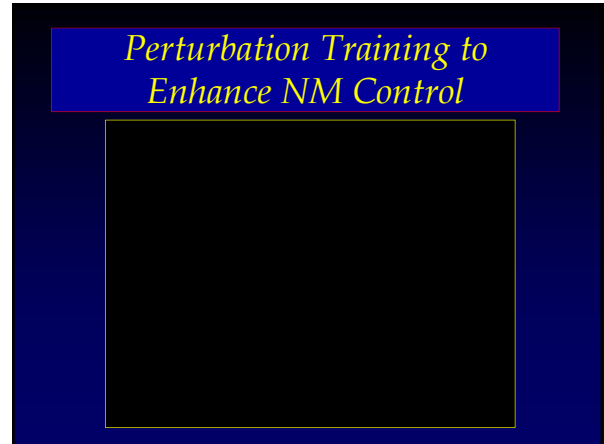


Crazy Hamstring Exercises



Soft Tissue Mobilization





Scand J Med Sci Spts '13

Review
Does pre-exercise static stretching inhibit maximal muscular performance? A meta-analytical review

L. Nishi, N. Saitoh, K. Maruyama

Motor Control and Human Performance Laboratory, School of Knowledge, University of Japan, Japan; Center for Knowledge Research, University of Forestry, Science and Research Center, Japan; Science

Corresponding author: Hiroe Maruyama, Motor Control and Human Performance Laboratory, School of Knowledge, University of Japan, Hongo 8-1, 113-8670 Japan. Email: maruyama@k.uj.ac.jp

Received for publication 7 January 2012

The results clearly show that SS before exercise has significant and practically relevant negative acute effects on maximal muscle strength and explosive muscular performance, while the corresponding acute effects on muscle power remain unclear. These findings are universal, regardless of the subject's age, gender, or training status. However, the magnitude of the static stretch-induced negative acute changes in performance was more pronounced in maximal isometric tests compared with maximal dynamic tests. Finally, the observed stretch-induced negative acute changes in selected muscular performance tests were related to the total duration of stretch, with the smallest negative acute effects being observed with stretch duration of 30-45 s, respectively. Based on the evidence from this study, we recommend that the range of SS in the side activity during warm-up routine should generally be avoided. Given the potential positive effect of pre-exercise SS on the reduction of incidence of muscle strains, further studies should examine the acute effects of SS of shorter duration (e.g., 15-30 s per muscle group), incorporated into a comprehensive pre-exercise warm-up routine, on maximal muscular performance.

- Meta-analysis of 144 articles
- Overwhelming evidence
- Static stretching before exercise has a pronounced effect on muscle performance, explosive and strength values (isometric)
- Regardless of age, gender or status
- Static stretch 30-45s

Challenge the Neuromuscular System



Challenge the Neuromuscular System



Phase I

STRENGTH TRAINING
3 sets of 10 repetitions with 48 hr rest.

- Side Plank - 10 minutes
- Sit-ups - 10 minutes
- Squats - 10 minutes
- Lunges - 10 minutes
- Heel Raises - 10 minutes
- Leg Press - 1000-1200 lbs. x 10
- Leg Press - 1000-1200 lbs. x 10
- Hip Flexion - 10 minutes
- Single Leg Squat - 10 x 10 seconds
- Heel raises - 10 x 10
- Hip Flexion - 10 minutes
- Side Plank - 10 minutes
- Sit-ups - 10 minutes
- Squats - 10 minutes
- Lunges - 10 minutes
- Heel Raises - 10 minutes
- Leg Press - 1000-1200 lbs. x 10
- Leg Press - 1000-1200 lbs. x 10
- Hip Flexion - 10 minutes
- Single Leg Squat - 10 x 10 seconds
- Heel raises - 10 x 10

Phase II I.F. Rehabilitation Program

STRENGTH DAYS	AGILITY
<ul style="list-style-type: none"> • Side Plank - 10 minutes • Sit-ups - 10 minutes • Squats - 10 minutes • Lunges - 10 minutes • Heel Raises - 10 minutes • Leg Press - 1000-1200 lbs. x 10 • Leg Press - 1000-1200 lbs. x 10 • Hip Flexion - 10 minutes • Single Leg Squat - 10 x 10 seconds • Heel raises - 10 x 10 	<ul style="list-style-type: none"> • Side Plank - 10 minutes • Sit-ups - 10 minutes • Squats - 10 minutes • Lunges - 10 minutes • Heel Raises - 10 minutes • Leg Press - 1000-1200 lbs. x 10 • Leg Press - 1000-1200 lbs. x 10 • Hip Flexion - 10 minutes • Single Leg Squat - 10 x 10 seconds • Heel raises - 10 x 10

Phase III I.F. Rehabilitation Program

STRENGTH TRAINING	AGILITY
<ul style="list-style-type: none"> • Side Plank - 10 minutes • Sit-ups - 10 minutes • Squats - 10 minutes • Lunges - 10 minutes • Heel Raises - 10 minutes • Leg Press - 1000-1200 lbs. x 10 • Leg Press - 1000-1200 lbs. x 10 • Hip Flexion - 10 minutes • Single Leg Squat - 10 x 10 seconds • Heel raises - 10 x 10 	<ul style="list-style-type: none"> • Side Plank - 10 minutes • Sit-ups - 10 minutes • Squats - 10 minutes • Lunges - 10 minutes • Heel Raises - 10 minutes • Leg Press - 1000-1200 lbs. x 10 • Leg Press - 1000-1200 lbs. x 10 • Hip Flexion - 10 minutes • Single Leg Squat - 10 x 10 seconds • Heel raises - 10 x 10

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Gradually Increase the Neuromuscular Challenges



ACL Rehabilitation

Return to Activity Phase

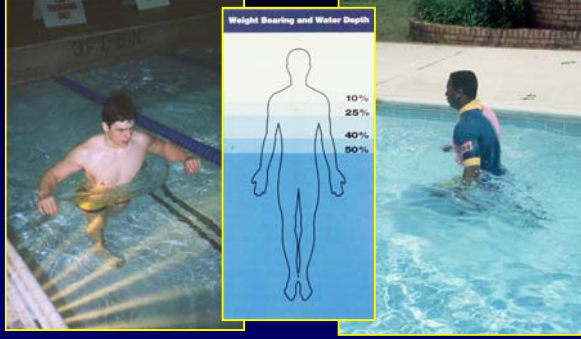
- **Running & agility program:**
 - backward run → lateral movements
 - lateral movements → forward running
 - jogging → jog / stops
 - jogging → run / stops
 - running → yo-yos
 - cutting drills → 45 deg. → 90 deg.

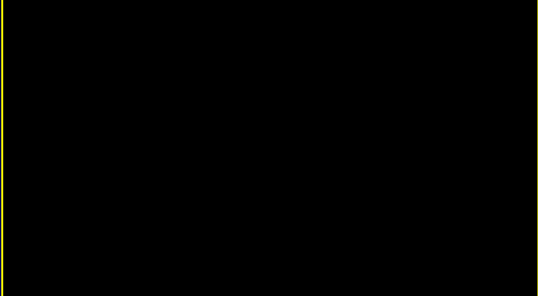
Proprioception & NM Control

Progressive WB Loading

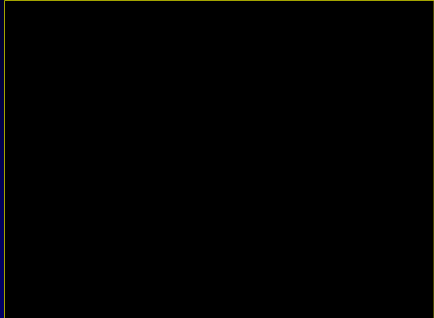





Agility Drills



Agility Drills



ACL Rehabilitation

Running & Functional Drills

- ✓ Running straight line first
- ✓ Running – deceleration – stop – go again
- ✓ Then progress to 45 deg. cutting
- ✓ Then progress to 90 deg. cutting
- ✓ Initiate drills at 50-60% then progress to 60-75% then to 75-90% then lastly 100%



Progression is based on signs & symptoms

ACL Rehabilitation

Initiation of the Running Program

- ✓ Reduced body weight running:
- ✓ 50-60% BW depends on condition articular surfaces & associated pathologies
- ✓ Interval running
 - ✓ Gradually increase WB forces:
 - ✓ 60-75%
 - ✓ 75-90%
 - ✓ 100%



Running progression designed to advance without pain/set backs




ACL Rehabilitation

Agility Drills – Running Drills

- ✓ Backward Running
- ✓ Forward Run
- ✓ Side slides (low)
- ✓ Cariocas
- ✓ Start/stops
- ✓ Acceleration ladders
- ✓ Reaction drills
- ✓ Combinations



Running Drills – (Hallway)





ACL Rehabilitation

Agility Drills – Run/Cutting Drills

- ✓ Forward running
- ✓ 45 deg zig zag
- ✓ Shuttle run
- ✓ 90 deg hard cuts
- ✓ Backward run turn & go (run)
- ✓ Sport specific drills

ACL Rehabilitation

Agility Drills – Ladder Drills

Forward & Backward Drill

ACL Rehabilitation

Agility Drills – Ladder Drills

Side to side Drills

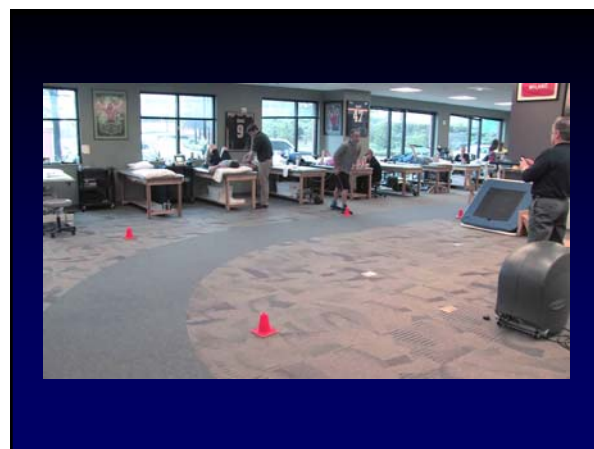
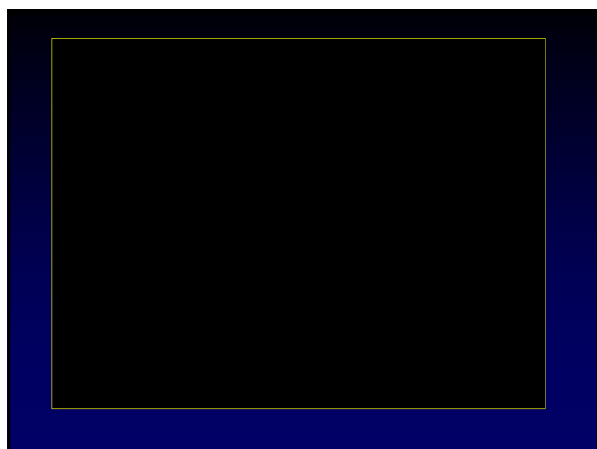
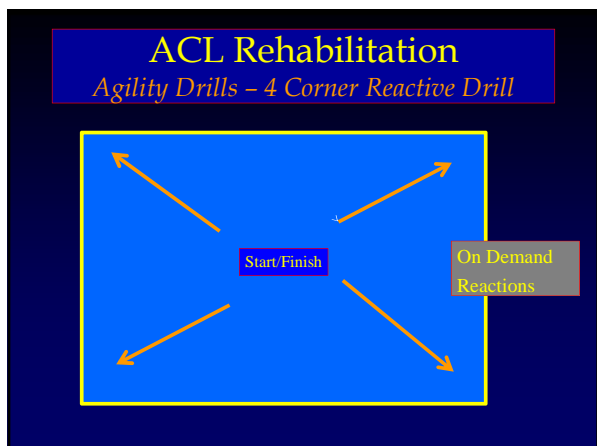
ACL Rehabilitation

Agility Drills – Ladder Drills

Quick Feet Drill

ACL Rehabilitation

Agility Drills – 4 Corner Drill



ACL Deficient Knee Rehab

IV: Return to Activity Phase (weeks 12? 16 weeks?)

- Plyometric program
floor → boxes
side to side → diagonal
2 legged → 1 legged
straight → rotational
"Sportmetrics Program"

Gradually increase box height

The slide contains a list of plyometric program components: floor to boxes, side to side to diagonal, 2 legged to 1 legged, and straight to rotational. It also mentions the 'Sportmetrics Program' and the instruction to 'Gradually increase box height'. Two small inset photos show a person performing a box jump.



Pool Plyos

A woman with long dark hair, wearing a dark jacket, is looking down. The background is blurred, suggesting an indoor setting.

ACL Rehabilitation Summary

- Similar rehab as for the reconstructed ACL patient
- *Emphasize proprioception & NM control training*
 - Building blocks – one step at a time
 - Perturbation training
 - Enhance NM control
- Promote unilateral muscle ratios
- Prevent negative effects to mechanoreceptors
- Train contralateral extremity immediately
- Requires 10-12 weeks before sports
- Is it effective for the ACL deficient patient ??
- *Depends on type of patient*
Competitive Athlete--- Recreational Athlete--- Non-athlete

A small inset image shows a person performing an exercise on a piece of equipment. Another inset image shows a person performing a different exercise.

Knee Lab
Proprioception & NM Control

- ✓ Stability Position (30-45°)
 - ✓ standing on floor
 - ✓ standing on floor (eyes closed)
 - ✓ standing catching a ball
 - ✓ standing with ball up & down
 - ✓ standing on foam
 - ✓ standing on floor then foam side to side overhead
 - ✓ standing on floor cross drill
 - ✓ standing on foam cross drill

1

Knee Lab
Proprioception & NM Control

- ✓ Lateral Lunges (30-45°)
 - ✓ straight no cord
 - ✓ straight with cord straight
 - ✓ diagonal (30° angles)
 - ✓ diagonal with rotation
 - ✓ lateral straight foam
 - ✓ lateral straight on foam fast
 - ✓ ball catches/throws
 - ✓ lunges onto rocker board

2

Knee Lab
Proprioception & NM Control

- ✓ Stepping Drills (Cones or Cups)
 - ✓ forward/backward
 - ✓ side to side
 - ✓ speed --- slow, fast & slow
 - ✓ stepping with ball drills
 - ✓ stepping with foam
 - ✓ step over huddle with rotation

3

Knee Lab
Proprioception & NM Control

- ✓ RDLs
 - ✓ unweighted
 - ✓ weighted
 - ✓ weighted with shoulder flexion & trunk ext
 - ✓ CLX RDL
 - ✓ star drill
 - ✓ cones/cups
 - ✓ tape on floor
 - ✓ standing on box
 - ✓ RDL into knee to chest

4

Knee Lab
Proprioception & NM Control

- ✓ Hip Abduction & ER Strengthening
 - ✓ clams
 - ✓ RDLs
 - ✓ Star
 - ✓ Side plank
 - ✓ Side plank with hip abduction
 - ✓ side plank with hip abduction against wall
 - ✓ side plank w/ hip abd against wall with Tband
 - ✓ side plank hip abduction wall with IR

5

Knee Lab
Proprioception & NM Control

- ✓ Hamstring Training Drills
 - ✓ stability ball bilateral
 - ✓ stability ball unilateral
 - ✓ stability ball bilateral **ECCENTRICS**
 - ✓ stability ball theraband
 - ✓ TRX bands
 - ✓ Norwegian eccentric hamstrings
 - ✓ with manual resistance
 - ✓ Fast speed hamstrings standing w/ theraband

6

Knee Lab

Proprioception & NM Control

- ✓ Perturbations
 - ✓ tilt board squats
 - ✓ tilt board squats with ball catches
 - ✓ tilt board ball catches with perturbations
 - ✓ single leg stability position w/ ball catches
 - ✓ single leg stab position w/ ball & perturbat
 - ✓ bosu ball ball catches
 - ✓ tremor board (?)
 - ✓ foam with theraband perturbations

7

Knee Lab

Proprioception & NM Control

- ✓ Step downs
 - ✓ box
 - ✓ box with theraband
 - ✓ box with ball catches
 - ✓ box with ball catches with theraband
 - ✓ box with perturbations of therabnd
 - ✓ box with foam with ball & theraband
 - ✓ **Front Step Downs vs. Lateral Step Downs**

8

Knee Lab

Proprioception & NM Control

- ✓ Bridging
 - ✓ bilateral bridging
 - ✓ unilateral bridging
 - ✓ bridging on stability ball
 - ✓ stability ball with theraband
 - ✓ floor bridging with hip abduction
 - ✓ floor bridging w/ manual resistance

9

Knee Lab

Proprioception & NM Control

- ✓ Lateral Slides
 - ✓ without resistance band
 - ✓ with resistance band (thighs)
 - ✓ with resistance bands (ankles)
 - ✓ with CLX
 - ✓ with CLX with ball catches
 - ✓ with CLX & reactive drills with ball catch
 - ✓ with CLX four corners

10

Knee Lab

Proprioception & NM Control

- ✓ Clams
 - ✓ movement
 - ✓ with resistance band
 - ✓ with manual resistance
 - ✓ concentric
 - ✓ concentric/eccentric
 - ✓ conc/ecc with RS
 - ✓ side plank with clams

11

Knee Lab

Proprioception & NM Control

- ✓ Functional Drills - Running
 - ✓ backward running
 - ✓ lateral slides
 - ✓ forward
 - ✓ run fwd – deceleration - starts
 - ✓ cutting
 - ✓ zig zags
 - ✓ functional drills

12

Knee Lab
Proprioception & NM Control

- ✓ Ladder Agility Drills
 - ✓ 2 feet forward
 - ✓ 2 feet sideways
 - ✓ front foot in lateral
 - ✓ back foot out lateral
 - ✓ Ickey shuffle
 - ✓ combination drills
 - ✓ reverse drills
 - ✓ combination & reverse drills
 - ✓ ladders with CLX

13

Knee Lab
Proprioception & NM Control

- ✓ **Vertical Drop Jump**
 - ✓ 2 legged jump
 - ✓ 1 leg jump
 - ✓ 2 leeged jump onto foam

13

Knee Lab
Proprioception & NM Control

- ✓ Functional Drills - Sports
 - ✓ QB drills
 - ✓ lateral slides with CLX & FB
 - ✓ lateral slider with CLX & FB w/ reactions
 - ✓ Volleyball Drills
 - ✓ CLX jumps
 - ✓ CLX jumps into push ups

14

Knee Lab
Proprioception & NM Control

- ✓ Functional Drills - Sports
 - ✓ Windmill Softball Pitching Drills
 - ✓ CLX resistance windmill motion
 - ✓ CLX resistance for shoulder flexion
 - ✓ Golfer's Drills
 - ✓ Back shoulder ER w/ lead leg abd (CLX)
 - ✓ Lead shoulder acceleration phase with back leg

15

