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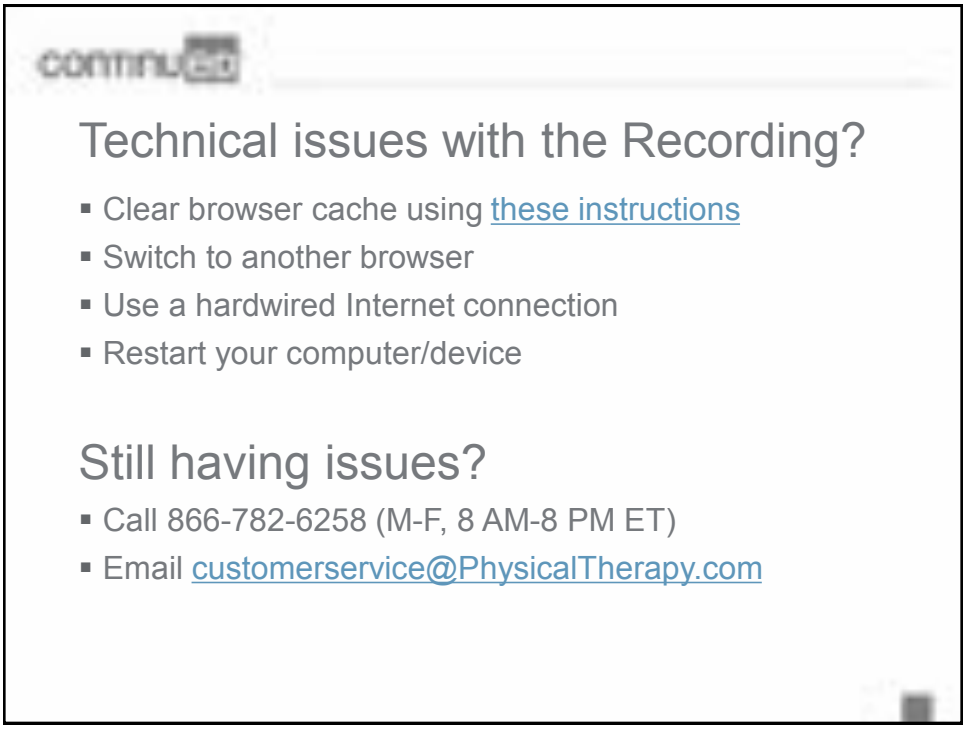
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Ortho & sports virtual conference: Lower Extremity Athletic Injuries

Guest Editor: David Nolan, PT, DPT, MS, OCS, SCS, CSCS

10/1: Comprehensive Care of the Hip
Peter Draovitch, PT, MS, ATC, CSCS, SCS

10/2: ACL: From Prehab to Return to Play
Kristina Fleming, PT, DPT, SCS

10/12: Bone Stress Injuries
Adam Tenforde, MD

10/13: Running Related Injuries
David Nolan, PT, DPT, MS, OCS, SCS, CSCS

10/14: The Foot Core: Let's Think Differently About the Foot
Irene Davis, PhD, PT, FACSM, FAPTA, FASB

CONTINUED

ACL: From Prehab to Return to Play

Kristina Fleming, PT, DPT, SCS
Board-Certified Sports Clinical Specialist

CONTINUED

CONTINUED

Learning Outcomes

Participants will be able to:

- Identify at least 2 objective characteristics and at least two movement patterns that place a patient at heightened risk for re-injury.
- Outline a post-operative rehabilitation program, including appropriate timelines and at least two methods for objective data collection.
- Describe at least 3 elements of return-to-sport readiness following ACL reconstruction.

CONTINUED

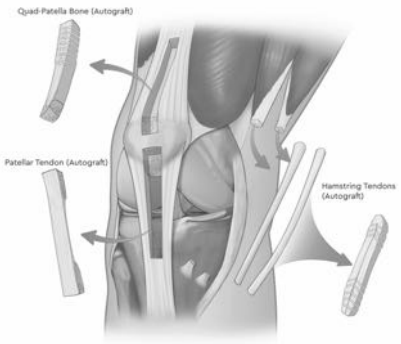
Relevance

- 350k ACL reconstructions in US annually
  - 1M worldwide
  - 1 in 3000 Americans each year
- Female athletes remain at 4-6x greater risk than their male counterparts
  - High school: 9-fold increase in risk
  - College: 5-fold increase in risk
- Most injuries are non-contact

Anatomy Review

- Extends from lateral femoral condyle to anterior medial tibial crest
- Prevents anterior translation and medial rotation of the tibia
- Increased risk of injury:
  - Narrow intercondylar notch
  - Posterior tibial slope
  - Depth and integrity of menisci
- ACL resists *more* rotation in *lower* knee flexion angles
- Greatest stress to the ACL: DL or SL landing with an extended knee, combined with abduction moment

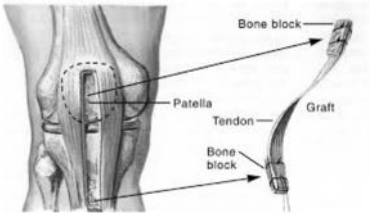
Graft Options



- Native ACL
  - 2160 N
- Autograft
  - Patellar tendon (BPTB)
    - 2977 N
  - Hamstring tendon
    - 4140 N
  - Quad tendon
    - 2353 N
- Allograft
  - 2000 – 4000 N

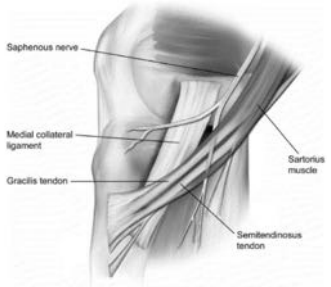
Patellar Tendon (BPTB)

- 6-8cm incision over central patellar tendon
  - Paratenon incised and closed
- Middle 1/3rd of tendon harvested with bone blocks at both ends
- Pros:
  - Bone-to-bone healing
  - Excellent pull-out strength
  - Excellent long-term results
- Cons:
  - Post-operative pain
  - Extensor mechanism disruption
  - Small incidence of anterior knee pain/tendinopathy
  - Difficulty kneeling



Hamstring Tendon

- Semitendinosus & Gracilis
  - 3cm oblique incision medial to the tibial tubercle
  - Sartorius is split to gain access
- Bundled 3/4/5 times (depending on tendon size)
- Pros:
  - Extensor mechanism intact
  - Excellent graft strength
  - Less post-operative pain
- Cons:
  - Soft tissue fixation
  - Hamstring weakness/cramping
  - Increased long-term laxity



Quad Tendon

- 1.5– 2 cm incision
  - 10 cm long, 7 mm wide
- Bone block on one end
- Pros:
  - Similar functional outcome to BPTB
  - Partial bone-to-bone healing
- Cons:
  - Limited research
  - Technical difficulty/novelty
  - Involves extensor mechanism

Allograft

- Cadaveric tissue
  - Achilles
  - Hamstring
  - BPTB
- Variable sterilization tech.
- Pros:
  - Minimal pain
  - Shorter OR time
  - Cosmesis
- Cons:
  - High re-rupture rate
  - High cost
  - Disease transmission

Criterion-Based Rehab Following ACL Reconstruction

CONTINUED

[CLINICAL COMMENTARY]

KEVIN E. WILK, PT, DPT[1] • LEONARD C. MACRINA, MSPT, SCS, CSCS[2] • E. LYLE CAIN, MD[3]
JEFFREY R. DUGAS, MD[4] • JAMES R. ANDREWS, MD[5]

Recent Advances in the Rehabilitation of Anterior Cruciate Ligament Injuries

[CLINICAL COMMENTARY]

DOUGLAS ADAMS, PT, DPT, SCS, CSCS[1] • DAVID LOGERSTEDT, PT, PhD, MPT, SCS[2] • AIRELLE HUNTER-GIORDANO, PT, DPT, SCS, OCS, CSCS[3]
MICHAEL J. AXE, MD[4] • LYNN SNYDER-MACKLER, PT, ATC, ScD, SCS, FAPTA[5]

Current Concepts for Anterior Cruciate Ligament Reconstruction: A Criterion-Based Rehabilitation Progression

CONTINUED

Immediate Post-op Rehab (Week 0-2)

- Treatment goals
  - *Regain full extension*
  - Regain quad control
  - Normalize patellar mobility
  - Decrease pain/swelling

- Milestones to Progress
  - ROM 0-90°
  - Active quadriceps contraction with superior patellar glide

Early Extension

- More robust procedures can withstand more aggressive rehab
  - Early weight-bearing
  - Early range of motion
  - Surgery-modified rehab vs rehab-modified surgery
- Motion loss
  - 25.3% incidence at 4 weeks (>5°) *Mauro Arthroscopy 2008*
  - Leading cause of poor outcomes following ACLR *Wilk JOSPT 2012*
    - Abnormal joint kinematics
    - Decreased quadriceps strength
    - Scar tissue formation in anterior interval
    - Increase in PF joint pressures

Early Extension

- Loss of >5° results in poorer long-term outcomes *Shelbourne AJSM 2009*
  - Lower subjective scores
  - Higher incidence of osteoarthritis
- Achieve full extension (including hyperextension) by end of week 1
  - Low-load, long duration stretching *Wilk JOSPT 2012*
    - Heel prop/prone hang
    - 60 minutes total per day

Neuromuscular Electrical Stimulation

- Arthrogenic muscle inhibition (AMI) *Kim JOSPT 2010*
  - Main cause of weakness after knee surgery
  - Occurs in the setting of pain, trauma, or joint effusion
    - 20-30ml – vastus medialis
    - 50-60ml – rectus femoris/vastus lateralis
- NMES directly recruits motor neurons, bypasses AMI *Palmieri Clin Sports Med 2008*
- Compared with volitional exercise alone, NMES group demonstrated: *Snyder-Mackler JBJS 1991*
  - More normal gait patterns
  - Improved quadriceps strength
    - Exercise only: 46.7% LSI
    - Exercise with NMES: 70.1% LSI

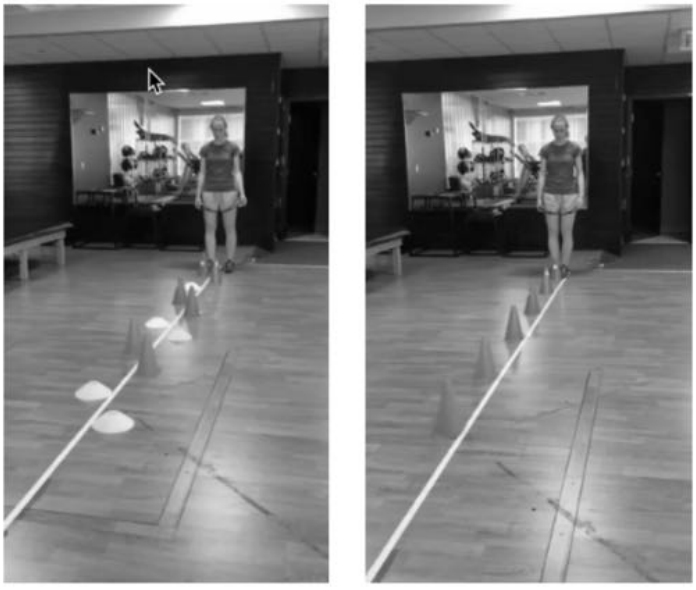
Early Rehab (Week 2-4)

- Treatment suggestions
  - Wall squats
  - Prone hangs as needed
  - Active terminal extension
    - Prone quad sets
    - Standing TKE
  - Step-ups (<30°)

- Milestones to Advance
  - >110° knee flexion
  - Straight leg raise *without lag*
  - Crutch-free ambulation
  - Ambulation with full knee extension
  - Reciprocal stair climbing
  - KOS-ADL >65%


60


60



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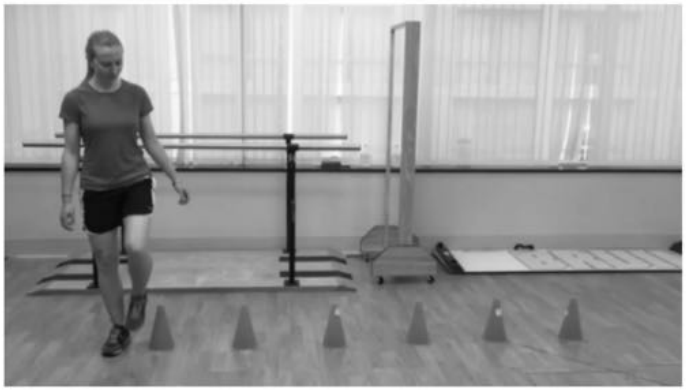

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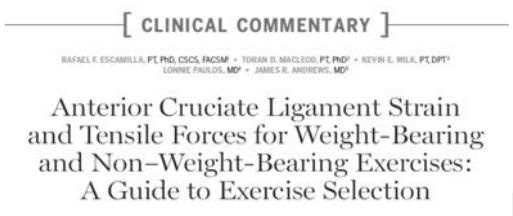
Intermediate Rehab (Weeks 4-6)

- Treatment Goals
  - Continued quad strengthening
  - Initiate balance/proprioception activities
  - Introduce core/upper body strengthening

- Milestones to Advance
  - Stable knee effusion
  - Knee flexion ROM to within 10° of uninvolved side
  - Quadriceps strength >60% of uninvolved side

OKC vs CKC Strengthening

- Quadriceps exert an anteriorly-directed force on the tibia from 0-60° of knee flexion in OKC
- Peak ACL strain of 3.2-4.4% (150-350 N) occurs between 10-30° OKC knee extension
- Minimal to no ACL loading with CKC bilateral squat (0-45°), *depending on technique*
  - Knees ahead of toes increases load
  - Forward trunk lean decreases load


[CLINICAL COMMENTARY]

RAFAEL F. ESCAMILLA, PT, PhD, CSCS, FACSM[1] • TORAN D. MACLEOD, PT, PhD[2] • KEVIN E. WILK, PT, DPT[3]
LONNIE PAULOS, MD[4] • JAMES R. ANDREWS, MD[5]

Anterior Cruciate Ligament Strain and Tensile Forces for Weight-Bearing and Non–Weight-Bearing Exercises: A Guide to Exercise Selection

Non-Weight-Bearing Exercises			
Author	**Exercise**	**ACL Strain (%)***	**Knee Flexion Angle (°)**
Beynnon et al[2]	Isometric seated knee extension using a 27-Nm torque as resistance	3.2	30
	Isometric seated knee extension using a 27-Nm torque as resistance	−2.5	90
	150-N (34-lb) Lachman test	3.7	30
	Anterior drawer test, 150 N (34 lb)	1.8	90
Beynnon et al[4]	Dynamic seated knee extension (0°-90° of knee flexion) using a 45-N (10-lb) force as resistance	3.8†	10
	Dynamic seated knee extension (0°-90° of knee flexion) without external resistance	2.8†	10
	Isometric seated knee extension using a 30-Nm torque as resistance	4.4	15
	Isometric seated knee extension using a 30-Nm torque as resistance	2.0	30
	Isometric seated knee extension using a 30-Nm torque as resistance	−0.2	60
	Isometric seated knee extension using a 30-Nm torque as resistance	−0.5	90
Fleming et al[5]	100-N (22.5-lb) Lachman test	3.0	30
	150-N (34-lb) Lachman test	3.5	30

Strength Testing

- Maximum voluntary isometric contraction (MVIC)
  - Calculate at 60° knee flexion (quad neutral)
  - Compare to uninvolved side to calculate limb symmetry index (LSI)

"With no significant difference in the between-instrument measurements and fair inter-instrument reliability, the dynamometers appear to provide comparable results."

"... the HHD can be used with confidence as an instrument for assessing muscle performance (strength) and/or for monitoring changes due to rehabilitation interventions."

"The results showed a good correlation between the two dynamometer (HHD and Isokinetic Biodex)."

"For most muscle groups, moderate to strong correlations were observed between the strength values recorded by (HHD) myometer and isokinetic dynamometer."

"... there was no satistically significant difference between the reliability of Kin-Com and hand-held dynamometer-obtained data. ... HHD is a viable alternative to more costly modes ..."

Hand-held Dynamometry Correlation With the Gold Standard Isokinetic Dynamometry: A Systematic Review

Timothy Stark, BS, DC, Bruce Walker, DC, MPH, DrPH, Jacqueline K. Phillips, PhD, BVSc(Hons), René Fejer, BSc, MSc, PhD, Randy Beck, BSc, DC, PhD

The Reliability and Validity of a Luggage Scale for Gluteal Strength Measurements

Taylor Morris*, Tyler Nance, Molly Porter, Kayla Zerr
Faculty: BJ Lehecka
Department of Physical Therapy, College of Health Sciences

- Luggage scale exhibited similarly high inter- and intra-rater reliability to HHD
- Moderate correlation found between luggage scale and HHD for hip extension, and high correlation for hip abduction
- *"The luggage scale is a reliable, valid, and cost-efficient clinical tool..."*

Neuromuscular Control

- Neuromuscular deficits contribute to clinical impairments: *Ingersoll Clin Sports Med 2008*
  - Strength loss
  - Muscle atrophy
  - Impaired balance
  - Altered functional capacity
- Self-reported knee function measures improve with neuromuscular rehabilitation program *Risberg Phys Ther 2007*
- Use of balance and neuromuscular re-education activities has no adverse effects on laxity or strength *Cooper Res Sports Med 2005*

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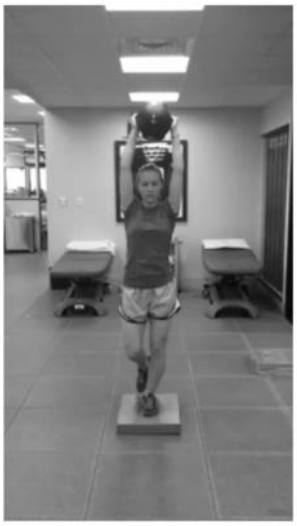

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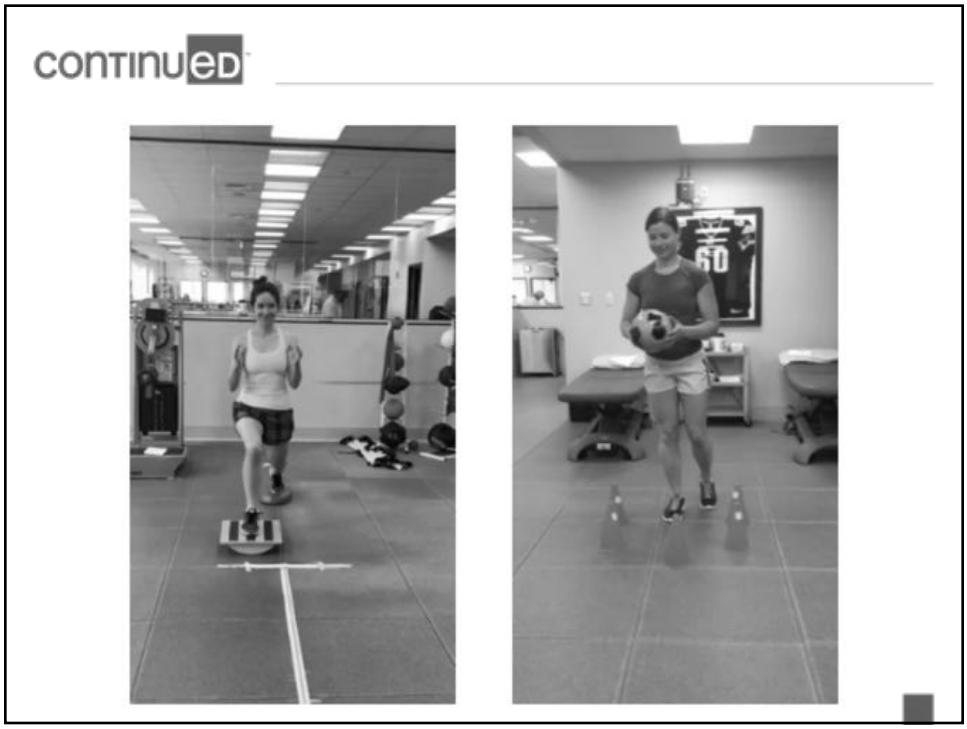
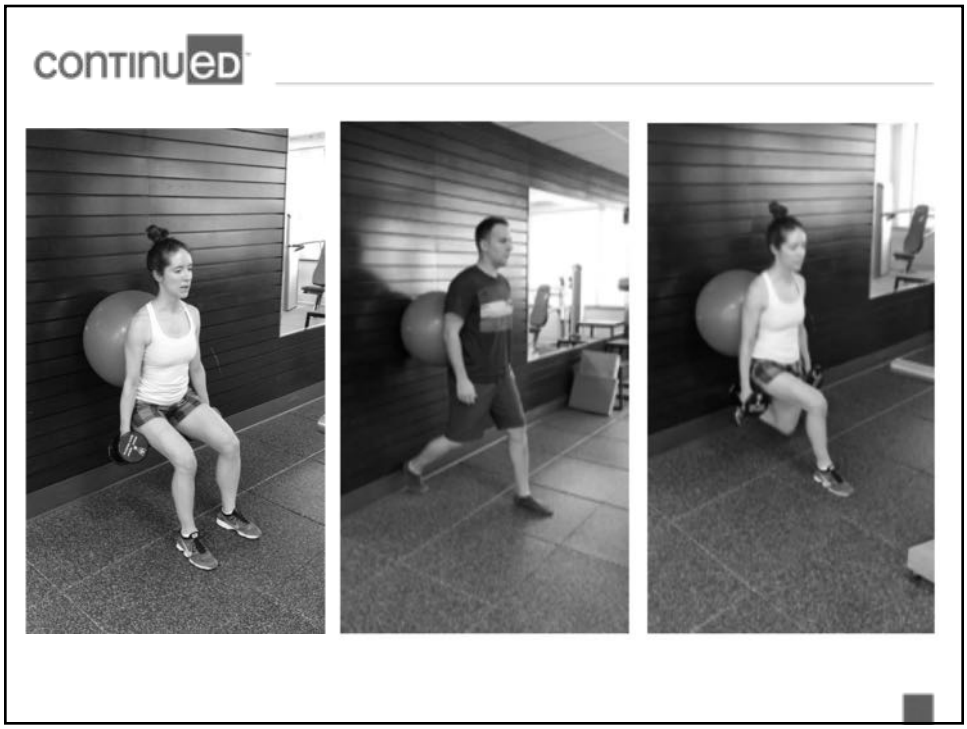
Advanced Rehab (Weeks 6-12)

- Treatment Goals
  - Continue quad strengthening
  - Progress neuromuscular control, proprioception, and balance activities
  - Single leg strengthening
  - Progress loaded strengthening

- Milestones to Advance
  - Quadriceps strength >80% of uninvolved side
  - Normal gait pattern
  - Full knee range of motion
  - Trace or less knee effusion





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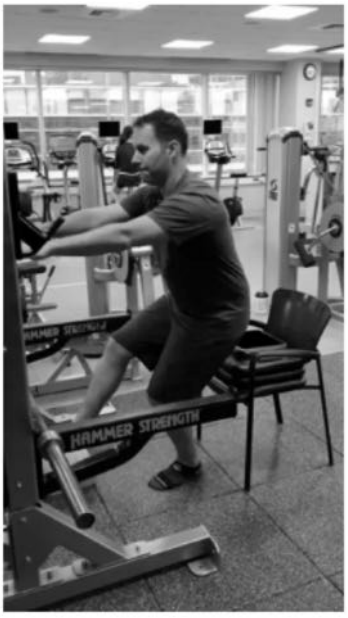


TABLE 3 GRADUATED RUNNING PROGRAM TO RETURN A RUNNER TO 30 MINUTES OF PAIN-FREE RUNNING

Stage/Level	Description
0	Pre-entry to graduated running program
	Pain during walking in normal activities of daily living
1	Initial loading and jogging (50% normal pace) with increasing duration
A	Walk 30 minutes
B	Rest
C	Walk 9 minutes and jog 1 minute (3 repetitions)
D	Rest
E	Walk 8 minutes and jog 2 minutes (3 repetitions)
F	Rest
G	Walk 7 minutes and jog 3 minutes (3 repetitions)
H	Rest
I	Walk 6 minutes and jog 4 minutes (3 repetitions)
J	Rest
K	Walk 4 minutes and jog 6 minutes (3 repetitions)
L	Rest
M	Walk 2 minutes and jog 8 minutes (3 repetitions)
N	Rest

Warden SJ, Davis IS, Fredericson M. Management and prevention of bone stress injuries in long distance runners. *J Orthop Sporst Phys Ther*. 2014;44:749-765.

Transitional Rehab (Weeks 12+)

- Treatment
  - Introduce *speed* during strengthening
  - Progress plyometrics/agility exercises
  - Sport-specific activities
  - Functional testing
- Milestones to Advance
  - Quadriceps/hamstring strength >95% of uninvolved side
  - Symmetrical hop testing
  - Sufficient NM control
  - Completion of RTS progression

Add higher-level strengthening videos

- Regain explosiveness
  - Reactive plyos with perturbations
  - Split squats with hop
  - Sustained BOSU squats
  - Ski/snowboard specific NM control

Return-to-Sport Decision-Making Following ACLR

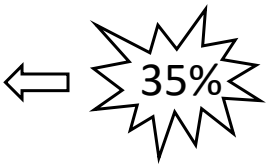
Return-to-Sport after ACLR

Ardern et al BJSM 2016

- Primary ACLR
  - 82% return to sport
  - 63% return to pre-injury level
    - Level 1 sports: 61.9%
    - Level 2 sports: 77.8%
  - 55% return to competitive sport
- Elite Athletes
  - 83% return to pre-injury level at 6-13 months
    - No significant deterioration in performance

Re-Injury Risk

- Wiggins et al AJSM 2016
  - Overall ACL re-injury: 15%
    - Ipsilateral graft failure: 7%
    - Contralateral injury: 8%
  - Patients who RTS: 20%
  - Patients <25 yo: 21%
- Webster et al AJSM 2016
  - Overall graft rupture: 18%
    - Males <18: 28.3%
    - Females <18: 12.9%
  - Contralateral ACL rupture: 17.7%



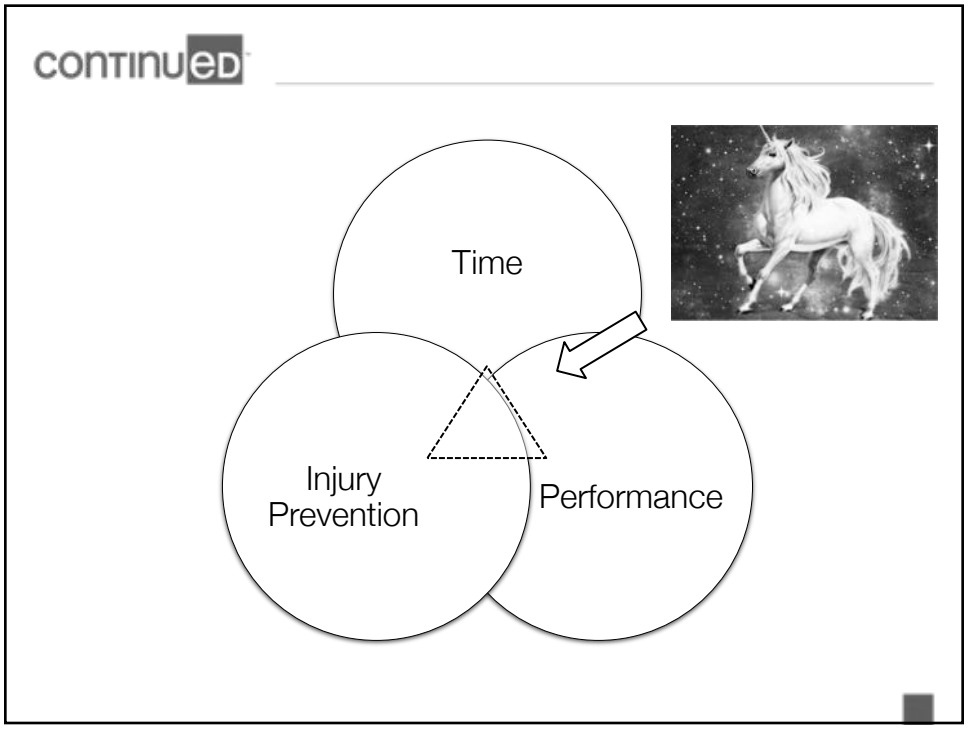
- Non-Modifiable Risk Factors
  - Bony morphology
  - Gender
  - Joint laxity
  - Hormonal changes

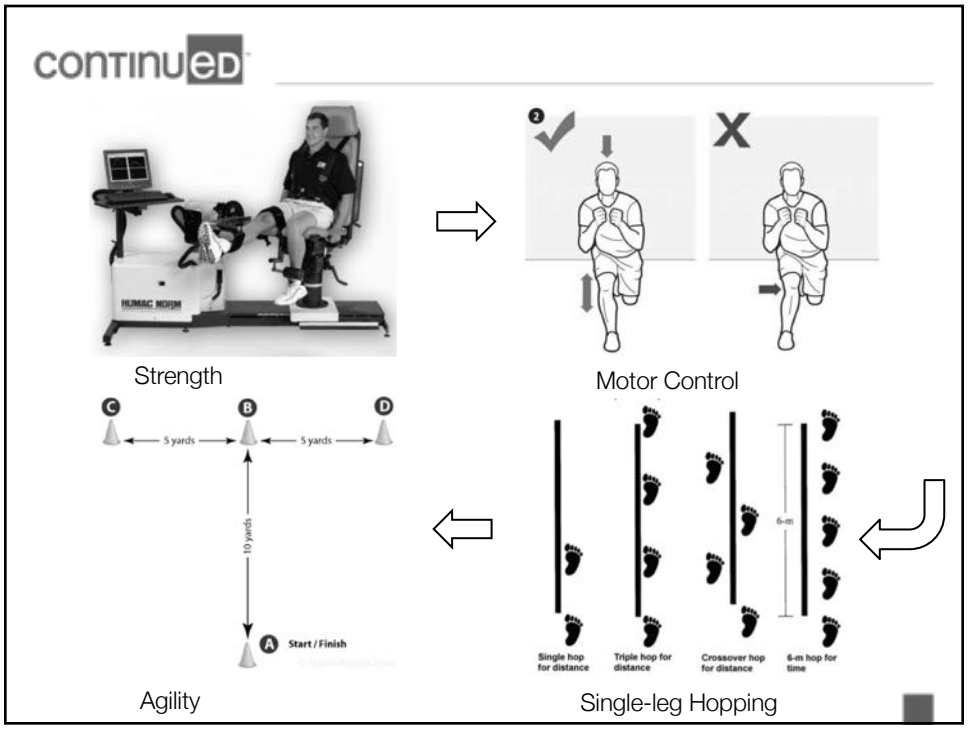
- Modifiable Risk Factors
  - Strength
  - Neuromuscular Control
  - Fatigue/Fitness
  - Intelligence?

- 264 studies included
  - 32% provided only time from surgery (6 months) as RTS criteria
  - 15% provided time from surgery, as well as one subjective measure
- 13% included at least 1 objective measure
  - Thigh circumference
  - "General knee exam"
  - Single-leg hop testing (4%)

Factors Used to Determine Return to Unrestricted Sports Activities After Anterior Cruciate Ligament Reconstruction

Sue D. Barber-Westin, B.S., and Frank R. Noyes, M.D.


Time
Injury Prevention
Performance


Strength
Motor Control
Agility
Single-leg Hopping
5 yards
5 yards
10 yards
Start / Finish
Single hop for distance
Triple hop for distance
Crossover hop for distance
6-m hop for time
6-m

Clearance for Testing

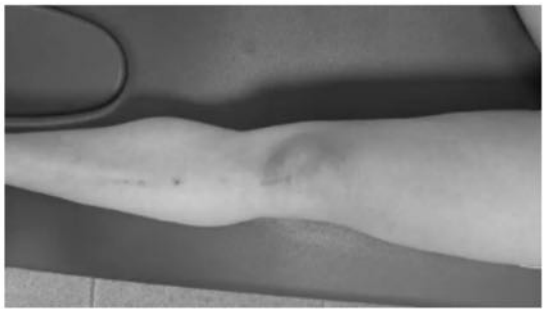


TABLE 2 — Effusion Grading Scale of the Knee Joint Based on the Stroke Test

Grade	Test Result
Zero	No wave produced on downstroke
Trace	Small wave on medial side with downstroke
1+	Larger bulge on medial side with downstroke
2+	Effusion spontaneously returns to medial side after upstroke (no downstroke necessary)
3+	So much fluid that it is not possible to move the effusion out of the medial aspect of the knee

Reproduced from Sturgill et al.[39]

0-1 (stable) knee pain
≤ trace joint effusion
Full, pain-free ROM
>80% quad LSI

Motor Control

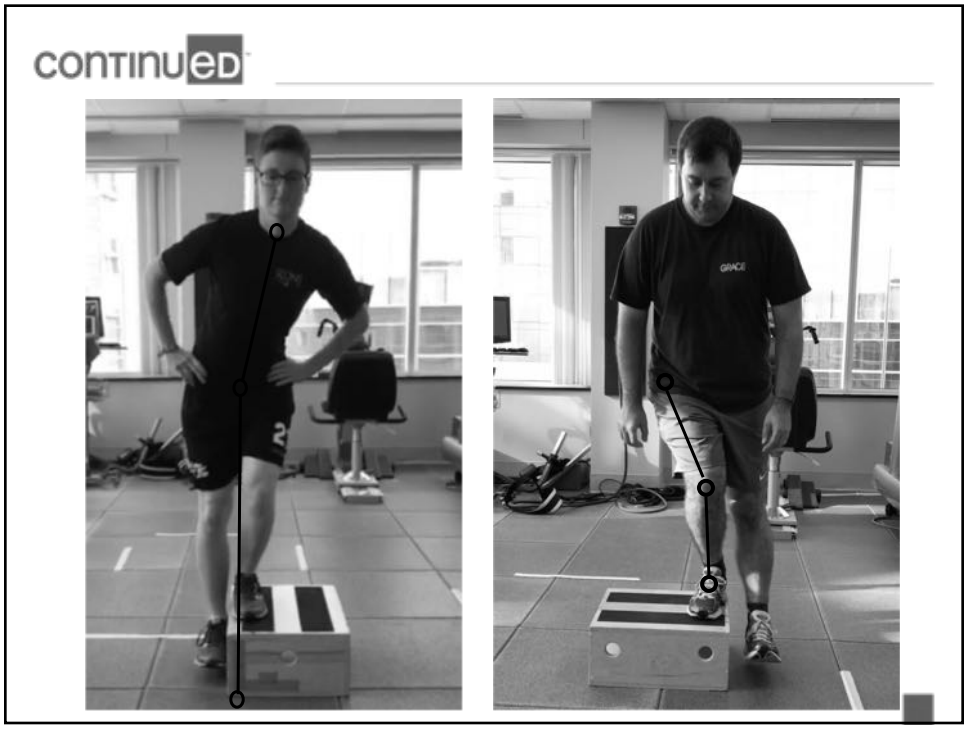
[RESEARCH REPORT]

KARYN HAITZ, BA[1] • REBECCA SHULTZ, PhD[2] • MELISSA HODGINS, MSPT, SCS, ATC[3] • GORDON O. MATHESON, MD, PhD[4]

Test-Retest and Interrater Reliability of the Functional Lower Extremity Evaluation

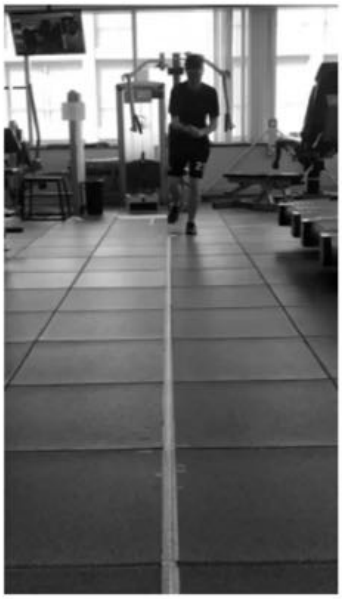
Timed Lateral Step-Down
Height: 60° knee flexion
Speed: 80 bpm

Lateral Leap and Catch
Distance: 60% height
Speed: 60 bpm



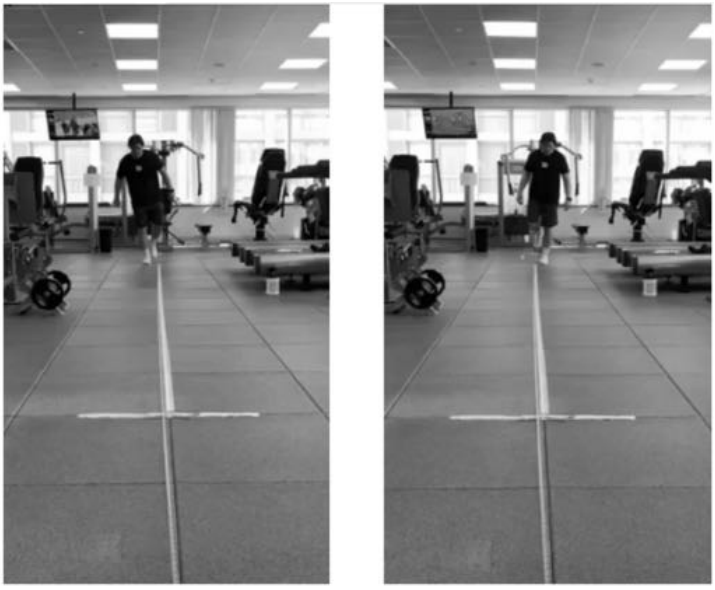
Hop Testing - SLHFD

Hop Testing - THFD

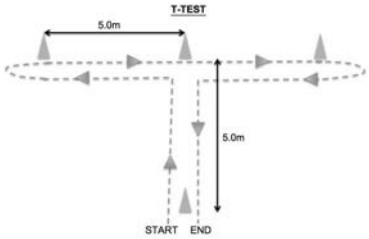


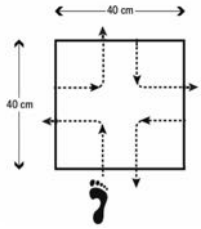
Hop Testing - COHFD

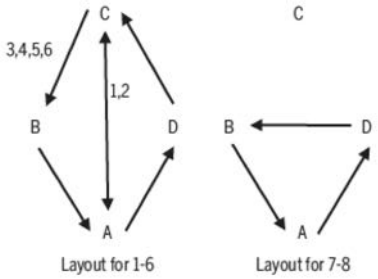
Hop Testing – 6m Timed Hop



Agility Testing

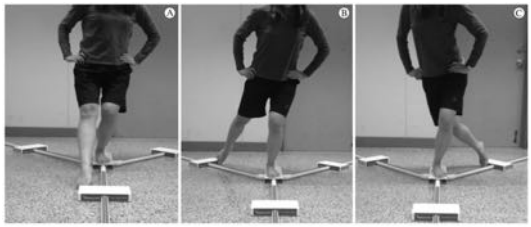






Additional Testing

Strength	Power	Balance/Control
Calculated single-leg 1RM	Single-leg vertical jump	Y-balance test



- Calculated single-leg 1 repetition maximum
  - As many repetitions as possible, to failure, on each leg
    - Start with unaffected leg
  - Between 5-10 repetitions improves validity
    - Start with 80-120% BW, depending on strength
  - Goals:
    - Symmetry
    - 150% BW on *each leg*

- Y-balance test
  - Reach as far as possible in 3 directions
    - Anterior
    - Posterolateral
    - Posteromedial
  - Adapted from SEBT
  - Goals:
    - Symmetry (<5cm difference side-to-side)
    - Composite score <94%

Psychological Readiness

- Psychological readiness is most closely associated with successful return to sport
  - Age, sex, and activity level not correlated
- Internal locus of control = lower perceived functional deficits post-operatively

The impact of psychological readiness to return to sport and recreational activities after anterior cruciate ligament reconstruction

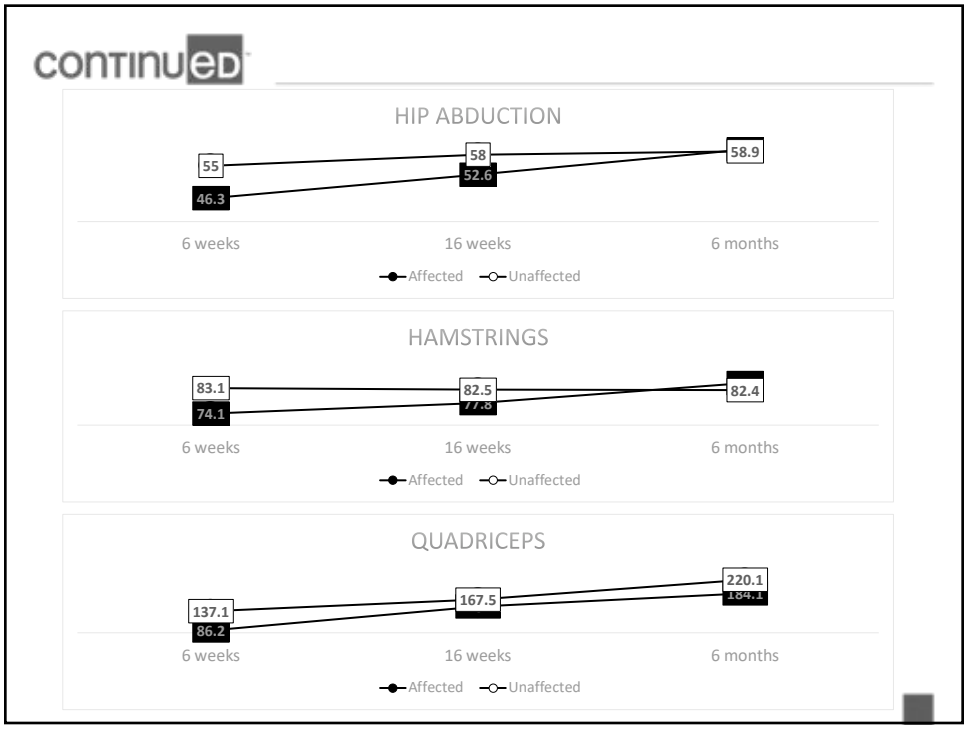
Clare L Ardern,[1,2] Annika Österberg,[2,3] Sofi Tagesson,[2] Håkan Gauffin,[4] Kate E Webster,[1] Joanna Kvist[2]

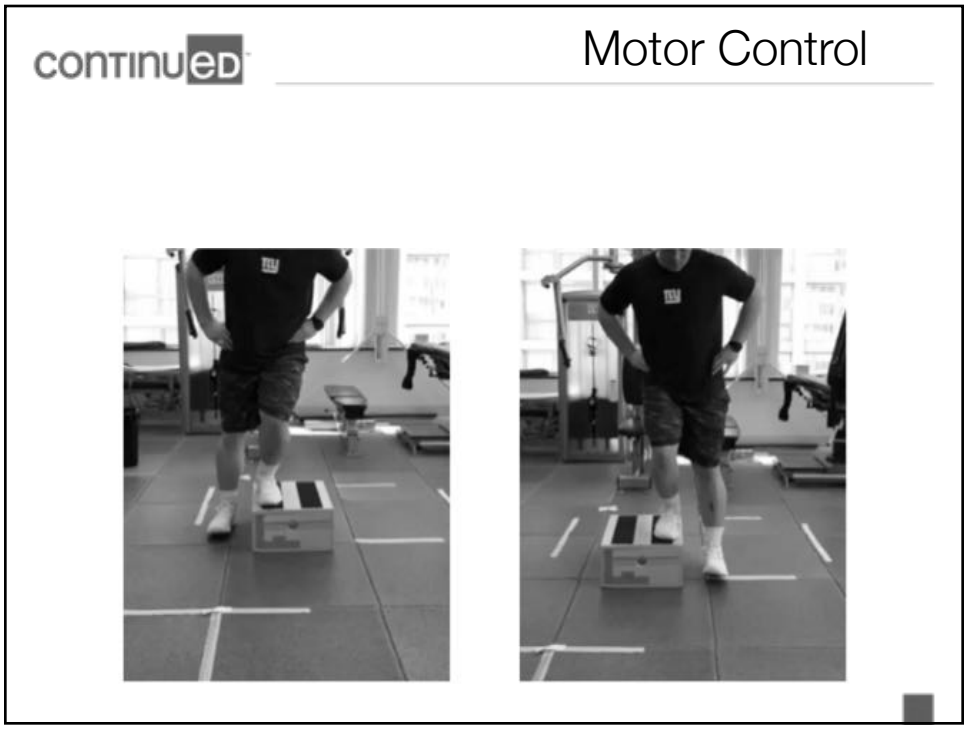
Case Study

- 19 y/o male football player (TE)
- DOI 9/20/17
- DOS 9/28/17
- ACLR with BPTB autograft
  - No concomitant injuries

Strength Testing

- Initial strength measurements @ 6 weeks
  - Hamstring: R 74.1, L 83.1; *LSI 89%*
  - Quad: R 86.2, L 137.1; *LSI 63%*
  - Hip abduction: R 46.3, L 55.0; *LSI 86%*
- Follow-up strength measurements @ 16 weeks
  - Hamstring: R 77.8, L 82.5; *LSI 94%*
  - Quad: R 149.7, L 167.5; *LSI 89%*
  - Hip abduction: R 52.6, L 58; *LSI 91%*
  - ** cleared to return to team lifts and initiate jogging progression*
- Follow-up strength measurements @ 6 months
  - Hamstring: R 84.9, L 82.4; *LSI 103%*
  - Quad: R 184.1, L 220.1; *LSI 84%*
  - Hip abduction: R 59.4; L 58.9; *LSI 101%*
  - ** cleared for hop testing and to resume speed/agility training with team*


HIP ABDUCTION
55
58
58.9
46.3
52.6
6 weeks
16 weeks
6 months
Affected
Unaffected
HAMSTRINGS
83.1
82.5
82.4
74.1
6 weeks
16 weeks
6 months
Affected
Unaffected
QUADRICEPS
137.1
167.5
220.1
86.2
6 weeks
16 weeks
6 months
Affected
Unaffected


Motor Control

Motor Control

Hop Testing

R 82”

L 83”

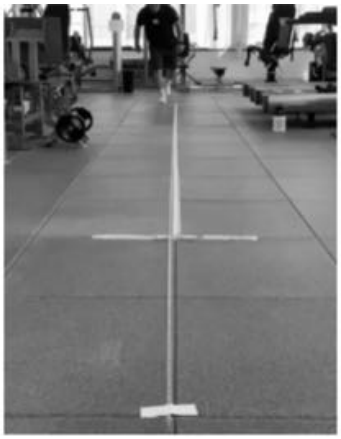
LSI 99%

Hop Testing

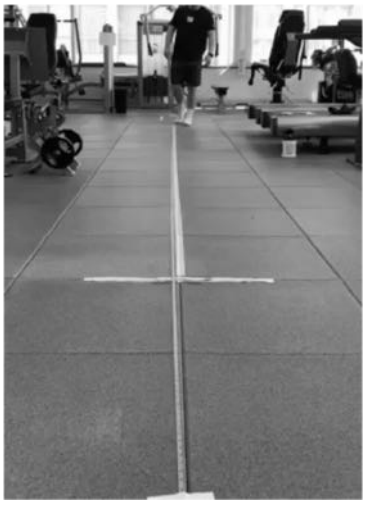
R 237”

L 241”

LSI 98%



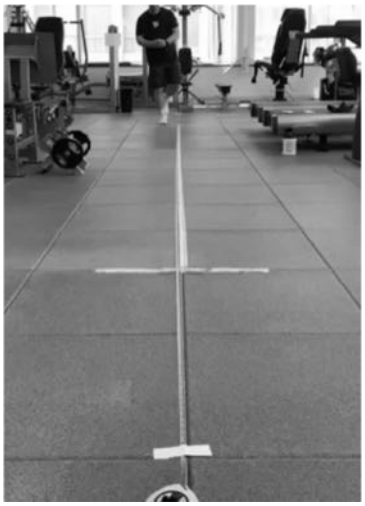
Hop Testing



R 224”

L 236”

LSI 95%



Agility Testing

Agility Testing

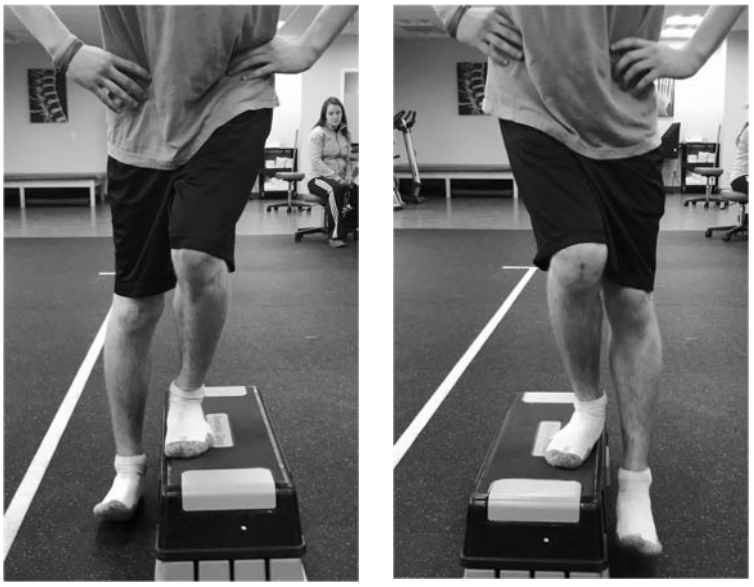
Case Study

- 19 y/o professional freestyle skier (halfpipe and slopestyle)
- R ACL rupture, MCL rupture, patellar tendon rupture, medial meniscus tear

- Staged procedures
  - 4/7/17: patellar tendon repair
  - 7/20/17: ACL reconstruction (hamstring autograft), MCL repair, medial meniscus repair

Case Study Metrics

- ROM
  - R knee: 3-0-128
  - L knee: 8-0-139
- Strength
  - Hip abduction: R 48.5 lbs, L 46.1 lbs; *LSI 105%*
  - Hamstrings: R 37.5 lbs, L 58.2 lbs; *LSI 64%*
  - Quads: R 86.5 lbs, L 77.5 lbs; *LSI 112%*
- Y-balance Test
  - Composite score: R 98, L 97
- Hop Testing
  - SLHFD: R 75”, L 83.5”; *LSI 90%*
  - THFD: R 249.5”, L 243”; *LSI 103%*
  - COHFD: R 246”, L 246.5”; *LSI 99%*



Case Study

- 23 y/o elite female skier, mountain biker, surfer
- R knee injury
  - ACL rupture
  - Medial meniscus tear
- R knee ACLR with hamstring autograft, medial meniscus repair
- Born with PFFD (proximal femoral focus deficiency)
  - Transfemoral amputation with osteointegration implant at age 11

Case Study Metrics

- ROM
  - R knee: 5-0-135
- Strength
  - Hip abduction: R 29.1 lbs
  - Hamstrings: R 29.3 lbs
  - Quads: R 67.6 lbs
- Calculated SL 1 RM
  - R leg: 208 lbs
- Y-balance Test
  - Composite score: R 116
- Hop Testing
  - SLHFD: R 53” (norm. 58”)
  - THFD: R 149” (norm. 185”)
  - COHFD: R 130” (norm. 160”)

CONTINUED

Research Report

Normative Values for Isometric Muscle Force Measurements Obtained With Hand-held Dynamometers

Knee flexion	N (153)	y=114.508−40.473S+0.206W−0.804A
	D (155)	y=142.244−52.112S+0.189W−0.892A
Knee extension	N (150)	y=344.343−98.409S+0.286W−2.717A
	D (154)	y=358.455−87.581S+0.297W−3.136A

$$358.455 - 87.581(1) + 0.279(578N) + 3.136(23) =$$
574 N (115 lbs)

CONTINUED

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BRIEF REPORT

REFERENCE VALUES FOR KNEE EXTENSION STRENGTH OBTAINED BY HAND-HELD DYNAMOMETRY FROM APPARENTLY HEALTHY OLDER ADULTS: A META-ANALYSIS

R.W. BOHANNON

Table 1
Reference Values for Knee Extension Force Normalized Against Body Weight

Age (y)	Gender	Side (n)	Mean (SE)%	I squared
60-69	Male	Nondominant (44)	48.8 (1.3)	0.0
		Dominant (46)	48.0 (1.4)	0.0
	Female	Nondominant (49)	38.9 (1.3)	12.5
		Dominant (50)	41.0 (1.3)	13.1
70-79	Male	Nondominant (50)	48.1 (1.2)	24.4
		Dominant (51)	46.1 (1.9)	10.9
	Female	Nondominant (47)	35.6 (1.4)	0.0
		Dominant (47)	37.7 (1.1)	0.0

CONTINUED

IJSPT

ORIGINAL RESEARCH

NORMATIVE DATA FOR HOP TESTS IN HIGH SCHOOL AND COLLEGIATE BASKETBALL AND SOCCER PLAYERS

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Table 4. *Proposed Normative Values*

Test	Male College	Female College
Single hop (cm)	192±20	149±17
6-m timed hop (sec)	1.74±0.21	2.13±0.20
Triple hop (cm)	632±72	470±53
Crossover hop (cm)	570±75	406±54
Test	**Male High School**	**Female High School**
Single hop (cm)	181±20	129±18
6-m timed hop (sec)	1.91±0.23	2.25±0.24
Triple hop (cm)	583±72	428±54
Crossover hop (cm)	522±77	375±60

CONTINUED

Kira Photos/Videos

Rehab Summary

- Normalize patellar mobility and ***extension ROM*** as early as possible
- Maximize quad activation and ***minimize AMI***
- Incorporate neuromuscular control as early and often as possible
- Exercise in safe ranges to minimize ACL strain
  - OKC 45 – 90
  - CKC 0 – 45
- Objectively monitor strength regularly to guide decision-making
  - Jogging: 80% strength symmetry
  - RTS: 95% strength symmetry

RTS Evaluation Summary

- Systematically perform clearance exam prior to functional testing
  - Pain → Effusion → ROM → Strength → Motor control
- Gather as much objective data as possible to re-create the demands of the sport
- Analyze *movement* patterns, not just *data*
- Consider the psychological impact of injury, refer appropriately

THANK YOU!

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