Lower Extremity Functional Testing: A Review of the Evidence and Implementation for RTS

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Disclosure

- We have nothing to disclose

Objectives

- Discuss lack of current consensus in return to sport decision making
- Review research that supports lower extremity functional testing for return to sport decision making
- Demonstrate how to administer and grade 4 lower extremity functional tests in clinic or on field to help guide return to play decisions

What is the most consistently reported risk factor for future injury?

- Previous Injury
- Multiple studies have shown a 2-19x greater risk of injury after previous injury[1]
- Numbers for ACL-R are worse with anywhere from 20-35% of patients suffering a second injury (re-tear or contralateral tear) in the first 2 years after surgery[2,3,4]

Is there anything we can do to improve these numbers?

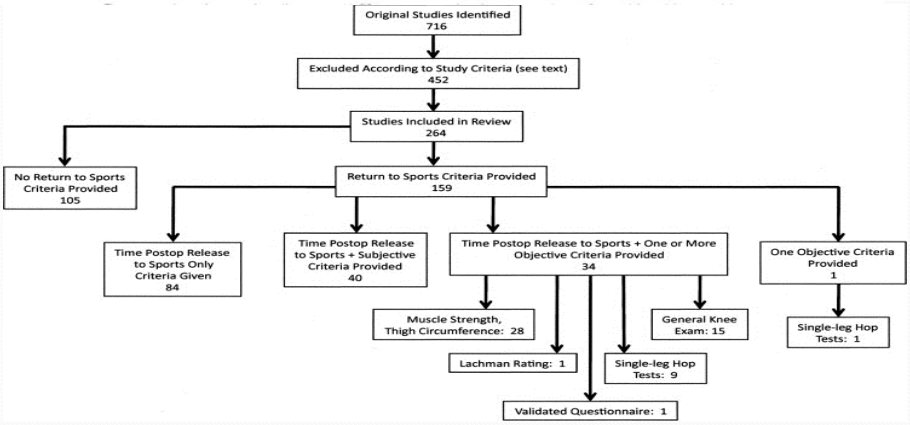
What We Know

- Injury/ pain change motor control/ proprioception
- These changes increase risk of injury
- Many patients/ athletes continue to have modifiable risk factors after rehab/ RTS
- Clinical testing can identify those changes
- Clinical return to activity/sport and discharge testing is occurring but it is highly variable and not standardized.

Systemic Review With Video Illustration

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.



Barber-Westin et al [5]

Systemic Review With Video Illustration

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

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TABLE 4. *Objective Criteria Provided for Release to Sports Activities*

Criteria Categories	No. of Studies
Time postoperatively, muscle strength	16
Time postoperatively, muscle strength, ROM/effusion	3
Time postoperatively, thigh circumference, single-leg hop test	3
Time postoperatively, ROM/effusion	4
Time postoperatively, muscle strength, single-leg hop test	2
Time postoperatively, muscle strength, ROM	2
Time postoperatively, Lachman rating, effusion	1
Time postoperatively, muscle strength/thigh circumference, single-leg hop test	1
Time postoperatively, muscle strength, single-leg hop test, ROM/effusion	1
Time postoperatively, muscle strength, 4 single-leg hop tests, ROM/effusion, validated questionnaires	1
Single-leg hop test	1

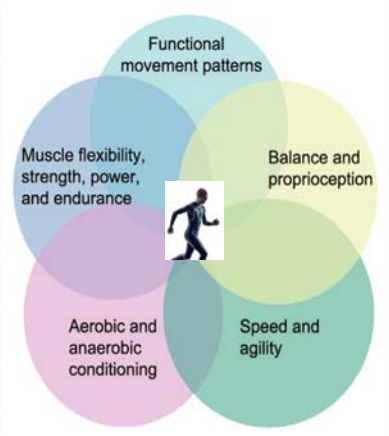
NOTE. Data are presented for 35 studies that provided objective criteria for return to sports.

- Lets go with a more basic injury- high school female soccer player with ankle sprain
  - Rest, Ice, does rehab with ATC for two weeks
  - Goes back to play - is she ready?
  - At that time she has full ROM, full strength (with MMT), and pain free
  - Still unable to balance on that ankle with good control, slight hesitation landing jump on that ankle
  - 3 months later has non-contact ACL tear, or another ankle sprain
  - Could the injury 3 months later been avoided?

Barber-Westin et al [5]

What to consider with RTS decision making

- Strength
- ROM
- Balance/ Static Stability
- Neuromuscular Control
- Functional Movement
- Psychological Readiness
- Functional Activity
  - Cutting, jumping, running, hopping, sport specific activity



Manske et al [6]

What do we want out of functional tests?

- Be Reliable- produce stable and consistent results
- Be predictive or injury or asymmetry
- Be Valid- measures what it is supposed to measure
- Address deficits that can be modified

There are a lot of different tests that are being used, we are going to review 4 different tests that meet the above criteria that can be used for LE functional testing.

Functional Movement Screen

The FMS consists of 7 tests which include the deep overhead squat, hurdle step, in-line lunge, active straight leg raise, shoulder mobility, trunk stability push-up, and rotary stability test. These tests assess general overall functional movement and is scored using a 0-3 system for each test. Cumulative scores below 14 are considered at risk for injury. Scores below 2/3 on individual tests can be considered unsatisfactory in that movement pattern.

Utilizing the OHS for RTS criteria can be a useful clinical tool that tests neuromuscular control throughout the body while moving as a single unit. Using a good clinical eye one could potentially identify limitations in shoulder mobility/ stability, trunk stability, hip strength and stability, as well as knee mechanics, and finally ankle ROM.

Overhead squat FMS scoring

View	Checkpoints	Compensation	Probable Overactive Muscles	Probable Underactive Muscles	Possible Injuries
Anterior	Feet	Turn out	Soleus, Lateral gastroc, Biceps Femoris (short head), TFL	Med. Gastroc, Med. HS, Gluteus medius and maximus, Gracilis, Popliteus, Sartorius	Plantar fasciitis, Achilles tendinopathy, medial tibial stress syndrome, ankle sprains, patellar tendinopathy
		Flatten	Peroneal's, lateral gastroc, biceps femoris, TFL	Anterior and posterior tib., med. Gastroc, gluteus medius	
	Knees	Valgus	Adductors, biceps femoris (short head), TFL, lat. Gastroc, vastus lateralis	Med. HS, Med. Gastroc, glute med and max, VMO, Ant. And post. Tib.	Patellar tendinopathy, PFPS, ACL injury, IT band tendonitis
		Move outward	Piriformis, biceps femoris, TFL, glute min.	Adductor complex, med. HS, glute max.	
Lateral	LPHC	Excessive Forward Lean	Soleus, gastroc, hip flexors, piriformis, rectus ab., ext. oblique	Ant. Tib, glute max, erector spinae, intrinsic core stabilizers (trans. Ab., multifidus, transversiospinalis, internal oblique, pelvic floor)	HS, quad, and groin strain, LBP
		Low back arches	Hip flexors, erector spinae, lats.	Glute max, HS, intrinsic core stabilizers	
		Low back rounds	HS, adductor magnus, rectus ab., ext. obliques	Glute max, erector spinae, intrinsic core stabilizers, hip flexors, lats	
	Shoulders	Arms fall forward	Lats, pec minor & major, coracobrachialis, teres maj.	Mid/Lower trap, rhomboids, posterior deltoid, RC	Headaches, Biceps tendonitis, shoulder injuries.

View	Checkpoints	Compensation	Probable Overactive Muscles	Probable Underactive Muscles	Possible Injuries
Posterior	Foot	Flattens	Peroneal's, lateral gastroc, biceps femoris (short head), TFL	Anterior and posterior tib., med. Gastroc, gluteus medius	Plantar fasciitis, Achilles tendinopathy, medial tibial stress syndrome, ankle sprains, patellar tendinopathy, HS, quad, and groin strain, LBP, SI joint pain
		Heel of foot rises	Soleus	Anterior tib.	
	LPHC	Asymmetric weight shift	Adductor complex, TFL (Same side of shift) gastroc, soleus, piriformis, biceps femoris, glue med. (opposite side of weight shift)	Glute med. (same side of shift) anterior tib, adductor complex (opposite side of shift)	

Clark et al [7]

Functional Movement Competency and Dynamic Balance After Anterior Cruciate Ligament Reconstruction in Adolescent Patients

Matthew J. Boyle, BSc, MBChB, FRACS, Robert J. Butler, DPT, PhD, and Robin M. Queen, MS, PhD

1. Researchers performed FMS on groups of skeletally mature and immature athletes, and a group of adults 9 months post-op to determine readiness for RTS and assess functional movement.
2. All three groups had composite scores below 14, showing all groups are not functionally ready for RTS.
3. Key take away- Most patients are not ready to RTS 9 months post-op. FMS is a reliable way to assess functional movement to help determine readiness for RTS.

Boyle et al [8]

Functional Testing Differences in Anterior Cruciate Ligament Reconstruction Patients Released Versus Not Released to Return to Sport

Stephanie W. Mayer,* MD, Robin M. Queen,*†‡ PhD, Dean Taylor,* MD, Claude T. Moorman III,* MD, Allison P. Toth,* MD, William E. Garrett Jr,* MD, PhD, and Robert J. Butler,*† DPT, PhD
Investigation performed at Duke University Medical Center, Durham, North Carolina, USA

1. Researchers compared FMS scores between ACL patients that were cleared or not cleared by their surgeons based on the following criteria:
   - Joint laxity
   - Strength
   - Effusion
   - ROM
2. Despite being deemed "appropriate" for RTS based on the above criteria the patients approved for RTS had no statistically significant better FMS scores than the patients deemed "not ready" for RTS.
3. Take away: A multi-factored approach should be used when determining readiness for RTS, some form of functional movement assessment should be one of these factors.

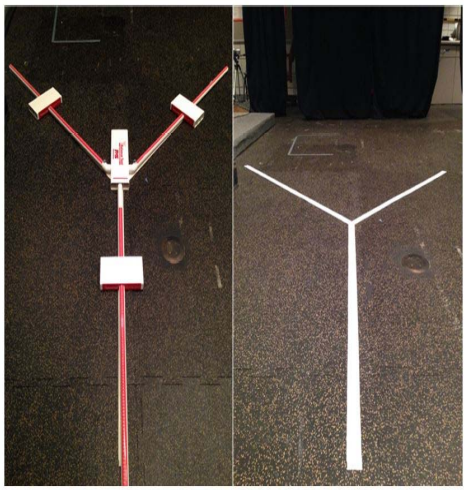
TABLE 3
Functional Movement Screen (FMS) Data for Cleared Versus Not-Cleared Groups

	Mean ± SD	*P* Value
FMS composite score		.873
Cleared	12.7250 ± 2.87329	
Not cleared	12.8222 ± 2.71602	
Number of FMS asymmetries		.740
Cleared	1.0263 ± 0.94402	
Not cleared	0.9524 ± 1.03482	

Mayer et al [9]

Y- Balance Test- Lower Quarter/ Star Excursion Balance Test

- Measures dynamic end limit stability
- Requires neuromuscular control, proprioception, ROM/flexibility, strength/ stability
- Tests anterior, posteromedial, and posterolateral reach
- Look at directional reach and composite score



Y-Balance/ SEBT

- Shoes off preferred
- Known learning effect so 4-6 practice trials in each direction-
- Standard testing order- (R) anterior, (L) anterior, (R) posteromedial, (L) posteromedial, (R) posterolateral, (L) posterolateral
- 4-6 trials (until normalizes)- take best score for each direction
- Body movement is allowed as long as returns to starting position under control
- Composite score is normalized to limb length- measure (R) most distal ASIS to (R) most distal medial malleolus

Lee et al [10]

Y-Balance/ SEBT Scoring

	Right (cm)	Left (cm)	Difference (cm)
Anterior	56	54	2.0
Posteromedial	87	87	2
Posterolateral	87	83.5	3.5

Norm is less than 4 cm difference for anterior reach

Composite Score = $\frac{\text{(Anterior + Posteromedial+ Posterolateral)}}{\text{3x limb length}}$ x100

Composite	Leg length 74cm
Right	103.6%
Left	101.1%

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www.nata.org/journal-of-athletic-training

original research

A Comparison Between Performance on Selected Directions of the Star Excursion Balance Test and the Y Balance Test

Garrett F. Coughlan, PhD, BSc Physio*†§; Karl Fullam, BSc Physio*; Eamonn Delahunt, PhD, BSc Physio*†; Conor Gissane, PhD, MS, BHum‡; Brian M. Caulfield, PhD, MSc Med Sci, BSc Physio*†

Y-Balance

- Coughlan et al[10] found interrater (0.99–1.00) and intrarater reliability (0.85–0.91)
- Faster to perform, easier to measure, does require equipment
- Research show increased injury rate with anterior reach symmetry greater than 4 cm
- Some protocols use some composite score cut off defined for MSEBT of below 94%, other studies show different composite score cut offs based on sport/age/injury (see next slide)

SEBT

- Test-retest reliability and response stability (.89-.93) [11]
- Slower to perform-Modified version has been validated[12], requires less equipment
- Plisky et al [13]
  - Injury risk was associated composite score below 94% and anterior reach asymmetry greater than 4cm
- Coughlan et al[10] found there were differences in anterior reach between the two tests- tests are not interchangeable

Table 1. Composite score comparison among different samples across multiple studies.

Study	Sample Description	Composite Score (%)
Butler et al. 2013	Rwandan male adolescent soccer athletes	105.6 ± 6.8
Butler et al. 2013	American male adolescent soccer athletes	97.8 ± 6.2
Butler et al. 2012	High school soccer athletes	98.4 ± 1.1
Butler et al. 2012	College soccer athletes	100.9 ± 0.9
Butler et al. 2012	Professional soccer athletes	101.8 ± 1.2
Garrison et al. 2013	Baseball players with ulnar collateral ligament (UCL) tear	89.1 ± 6.7
Garrison et al. 2013	Baseball players without UCL injury	95.8 ± 6.1
Gorman et al. 2012	Single sport athletes in high school	97.1 ± 8.2
Gorman et al. 2012	Multisport athletes in high school	97.1 ± 8.4
Hannon et al. 2014	Baseball players three months postsurgery for UCL tear	94.9 ± 9.5
Shaffer et al. 2013	Male and female service members	90.6 ± 7.5
Smith et al. 2014	Athletes injured during sporting season	101.3 ± 7.8
Smith et al. 2014	Athletes uninjured during sporting season	101.2 ± 7.1
Teyhen et al. 2014	Male military service members	98.3 ± 8.9
Teyhen et al. 2014	Female military service members	95.1 ± 7.8
Teyhen et al. 2014	Military service members 30 years and older	95.2 ± 8.8
Teyhen et al. 2014	Military service members younger than 30 years	98.1 ± 8.3

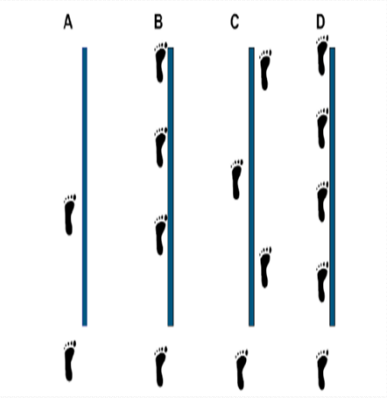
Values represent mean ± standard deviation. Composite score is reported as percentage of limb length.

Composite	Leg length 74cm
Right	103.6%
Left	101.1%

Smith [14]

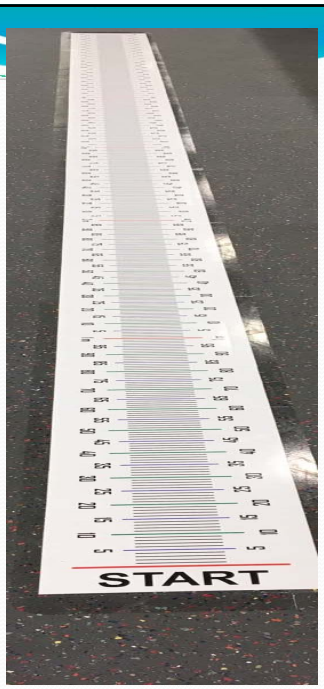
Hop Tests

- Provide valuable information about strength, power, and neuromuscular control of the LE
- Provide eccentric load to the LE
- Provide a LSI (limb symmetry index) that compares (R) to (L) LE
- 4 core hop tests most supported in the research are:
  - Single leg hop
  - Timed 6 meter hop
  - Triple hop
  - Triple crossover hop for



Hop Tests

- Requires 6 meter tape measure on the floor
  - Stop watch required for timed 6 meter hop test
- Should be 15cm wide
- 3-4 practice trials for each test
- Measurement from toe to heel
- Must stick and hold landing 3 seconds
- Two to three recorded trial then average them
- From average you can obtain LSI
- Also look at quality of movement with hop tests



Original article

A critical analysis of limb symmetry indices of hop tests in athletes after anterior cruciate ligament reconstruction: A case control study

A. Gokeler [a,*], W. Welling [a,b], A. Benjaminse [a,c], K. Lemmink [a], R. Seil [d], S. Zaffagnini [e]

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[b] Medisch Centrum Zuid, Groningen, The Netherlands
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[d] Département de l'Appareil Locomoteur, Centre Hospitalier de Luxembourg, Luxembourg, Luxembourg
[e] Rizzoli Orthopaedic Institute, University of Bologna, Bologna, Italy

- 52 patients who had undergone ACLR mean time out from surgery 7 months
- 188 healthy athletes
- Hop distance and LSI were compared between the two groups
- ACLR demonstrated (B) deficits compared to healthy comparisons
- ACLR patients all achieved above 85-90% which is criteria for most protocols
- Despite meeting these criteria they showed significant decrease in hop distance compared to healthy age/sex/ sport matched individuals
- Shows 85-90 LSI cut off post op ACLR may underestimate performance deficits

Gokeler et al [15]

BETWEEN-SESSION RELIABILITY OF FOUR HOP TESTS AND THE AGILITY T-TEST

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ABSTRACT

Munro, AG and Herrington, LC. Between-session reliability of four hop tests and the agility T-test. *J Strength Cond Res* 25(5): 1470–1477, 2011—The purpose of this study were firstly to investigate whether learning affects were present in the administration of 4 hop tests and the Agility T-test and secondly

INTRODUCTION

Outcome measurement is an important tool in sports exercise science and medicine. It can be used to assess, evaluate, and justify training methods, treatment, and rehabilitation interventions through the identification of an athlete's ability to cope

- 4 hop tests have been shown to detect differences between injuries and uninjured limbs
- Reports that LSI of 85% is most commonly accepted
- Learning affect of 3 practice trials was enough for single leg and triple hop
- 4 trials were needed during crossover hop
- Shows that LSI in healthy individuals is typically above 90%, so 90% should be used as minimum RTS criteria after ACLR

LSI	≥85	≥90	≥95
SH	100	100	73
TH	100	100	68
CH	100	100	64
TH	100	100	86
All Tests	100	100	40

Munro et al [16]

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 Arna Risberg[1,4]

- Looked at Return to level 1 sports, timing of RTS, and knee function prior to RTS
- 106 patients in pivoting sports
- Function as assessed by Knee outcome survey, global rating scale of function, quad strength, and hop tests. Pass RTS criteria was >90 % on all tests
- For every month that RTS was delayed, until 9 months after ACL-R, the rate of knee re-injury was reduced by 51%
- While we don't know what perfect RTS test battery should be, quad strength is noted with asymmetrical knee biomechanics during hopping which has been found to help predict second ACL injury.

Grindem et al [17]

Original article

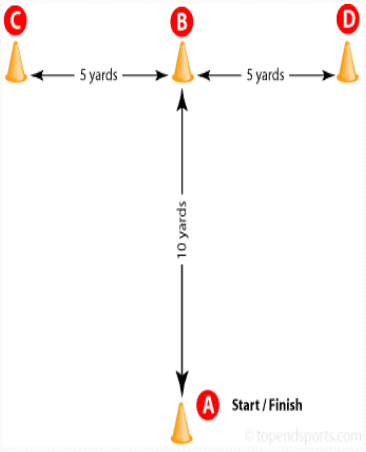
Likelihood of ACL graft rupture: not meeting six clinical discharge criteria before return to sport is associated with a four times greater risk of rupture

- Purpose- evaluate whether set of objective discharge criteria for RTS after ACL-R
- 158 male professional athletes who underwent ACL-R
- RTS Battery: isokinetic strength at 60°/180°/300°, T-Test, single hop, triple hop, triple crossover hop- passing considered greater than 90% for all tests and T- Test >11 seconds.
- 158 athletes- 26 (16.5%) ACL graft rupture average 105 days after RTS.
- Factors associated with re-tear
  - Not meeting all six criteria before returning to team training
  - Decreased quad/HS ratio at 60°/sec

Kyritis et al [18] Arden et al [19]

T-test

- Tests the ability to move quickly in 4 different directions within two of the primary movement planes.
- Large pool of normative data available.
- Common usage in the literature
- https://youtu.be/1UOP7hoeH_8



Between-Session Reliability of Four Hop Tests and the Agility *T*-Test

Allan G. Munro and Lee C. Herrington

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1. Test is easy to set up
2. The T-test was shown to only need 1 warm up trial for scores to neutralize and participants to have familiarization with the test, making this much faster to administer than other tests.
3. Test was shown to be reliable.
4. Determined best testing procedure is one practice trial and three scored trials. Take the best score as the final score.

Munro et al [16]

Relative and Absolute Reliability of a Modified Agility T-Test and Its Relationship With Vertical Jump and Straight Sprint

Radhouane Haj Sassi,[1] Wajdi Dardouri,[1] Mohamed Haj Yahmed,[2] Nabil Gmada,[1] Mohamed Elhedi Mahfoudhi,[2] and Zied Gharbi[1]

[1]Research Unit, School and University Sportive Practices and Performance, Higher Institute of Sports and Physical Education, Kef, Tunisia; and [2]Research Unit, Analysis and Evaluation of Factors Affecting the Sports Performance, High Institute of Sports and Physical Education, Ksar Said, Tunisia

1. Tested reliability of a modified T-Test that consisted of less total distance traveled.
2. Modified test was as reliable as the normal T-test
3. Key takeaway from findings:
   - Can utilize modified test in clinics with less space available.
   - May have higher specificity to a multitude of sports that require speed and agility in short intervals rather than over a prolonged distance.

Sassi et al [20]

Questions?

Demonstrations and Practice

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