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

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Sara Stites, PT, DPT, ATC

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 injury¹
- 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 surgery²³⁴

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.

Original studies identified: 714
Excluded according to study criteria (see text): 453
Studies included in review: 261

Return to sports criteria provided: 159

Time postop release to sports only + subjective criteria provided: 84
Time postop release to sports + one or more objective criteria provided: 46

Muscle strength, thigh circumference: 28
Lachman + knee flex: 1
Valgus + flexion: 1
Lachman: 2
Single leg hop tests: 5
Single leg hop tests / strength: 1

Barber-Westin et al 5
• Let's 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?

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

Barber-Westin et al 5

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

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.](image)

**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**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Cleared</th>
<th>Not cleared</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMS composite score</td>
<td>12.7 ± 1.1</td>
<td>14.9 ± 1.3</td>
<td>.873</td>
</tr>
<tr>
<td>Net score</td>
<td>12.4 ± 1.2</td>
<td>14.2 ± 1.2</td>
<td></td>
</tr>
<tr>
<td>Number of FMS asymmetries</td>
<td>1.5 ± 0.4</td>
<td>0.8 ± 0.2</td>
<td>.740</td>
</tr>
</tbody>
</table>

![Mayer et al.](image)
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
### Y-Balance/ SEBT Scoring

<table>
<thead>
<tr>
<th></th>
<th>Right (cm)</th>
<th>Left (cm)</th>
<th>Difference (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>56</td>
<td>54</td>
<td>2.0</td>
</tr>
<tr>
<td>Posteromedial</td>
<td>87</td>
<td>87</td>
<td>2</td>
</tr>
<tr>
<td>Posterolateral</td>
<td>87</td>
<td>83.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Norm is less than 4 cm difference for anterior reach

Composite Score = \( \frac{(\text{Anterior} + \text{Posteromedial} + \text{Posterolateral}) \times 100}{3 \times \text{limb length}} \)

<table>
<thead>
<tr>
<th></th>
<th>Leg length 74cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composite</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>103.6%</td>
</tr>
<tr>
<td>Left</td>
<td>101.1%</td>
</tr>
</tbody>
</table>

### 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
### 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

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**Composite Leg length 74cm**

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample Description</th>
<th>Composite Score (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butler et al. 2013</td>
<td>Rwandan male adolescent soccer athletes</td>
<td>105.6 ± 6.8</td>
</tr>
<tr>
<td>Butler et al. 2013</td>
<td>American male adolescent soccer athletes</td>
<td>97.8 ± 6.2</td>
</tr>
<tr>
<td>Butler et al. 2012</td>
<td>High school soccer athletes</td>
<td>98.4 ± 1.1</td>
</tr>
<tr>
<td>Butler et al. 2012</td>
<td>College soccer athletes</td>
<td>100.9 ± 0.9</td>
</tr>
<tr>
<td>Butler et al. 2012</td>
<td>Professional soccer athletes</td>
<td>101.8 ± 1.2</td>
</tr>
<tr>
<td>Garrison et al. 2013</td>
<td>Baseball players with ulnar collateral ligament (UCL) tear</td>
<td>89.1 ± 6.7</td>
</tr>
<tr>
<td>Garrison et al. 2013</td>
<td>Baseball players without UCL injury</td>
<td>95.8 ± 6.1</td>
</tr>
<tr>
<td>Gorman et al. 2012</td>
<td>Single sport athletes in high school</td>
<td>97.1 ± 8.2</td>
</tr>
<tr>
<td>Gorman et al. 2012</td>
<td>Multisport athletes in high school</td>
<td>97.1 ± 6.4</td>
</tr>
<tr>
<td>Hannon et al. 2014</td>
<td>Baseball players three months postsurgery for UCL tear</td>
<td>94.9 ± 9.5</td>
</tr>
<tr>
<td>Shaffer et al. 2013</td>
<td>Male and female service members</td>
<td>90.6 ± 7.5</td>
</tr>
<tr>
<td>Smith et al. 2014</td>
<td>Athletes injured during sporting season</td>
<td>101.3 ± 7.8</td>
</tr>
<tr>
<td>Smith et al. 2014</td>
<td>Athletes uninjured during sporting season</td>
<td>101.2 ± 7.1</td>
</tr>
<tr>
<td>Teyhen et al. 2014</td>
<td>Male military service members</td>
<td>98.3 ± 8.9</td>
</tr>
<tr>
<td>Teyhen et al. 2014</td>
<td>Female military service members</td>
<td>95.1 ± 7.8</td>
</tr>
<tr>
<td>Teyhen et al. 2014</td>
<td>Military service members 30 years and older</td>
<td>95.2 ± 8.8</td>
</tr>
<tr>
<td>Teyhen et al. 2014</td>
<td>Military service members younger than 30 years</td>
<td>98.1 ± 8.3</td>
</tr>
</tbody>
</table>

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

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
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.

\[
\begin{array}{|c|c|c|}
\hline
\text{LSI} & \geq 85 & \geq 90 & \geq 95 \\
\hline
\text{SH} & 100 & 100 & 73 \\
\text{TH} & 100 & 100 & 68 \\
\text{CH} & 100 & 100 & 64 \\
\text{TH} & 100 & 100 & 86 \\
\text{All Tests} & 100 & 100 & 40 \\
\hline
\end{array}
\]

Munro et al. 16

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
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

Department of Sport, Exercise, and Physiotherapy, The University of Salford, Salford, United Kingdom

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.

**RELATIVE AND ABSOLUTE RELIABILITY OF A MODIFIED AGILITY T-TEST AND ITS RELATIONSHIP WITH VERTICAL JUMP AND STRAIGHT SPRINT**

Radiouane Haj Sassi,1 Wadh Dardourl,1 Mohamed Haj Yahmed,2 Nabil Gmada,3 Mohamed Elieedh Mahfoudhi,3 and Zied Ghribi1

1Research Unit, School and University Sports Practice and Performance, Higher Institute of Sports and Physical Education, Ker, Tunisia; and 2Research Unit, Analysis and Evaluation of Factors Affecting the Sports Performance, High Institute of Sports and Physical Education, Ker Said, Tunis

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.
Questions?

Demonstrations and Practice
References


References