Functional Testing & Return to Sport

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**OBJECTIVES**

1. Provide a review of tests most commonly seen in the literature and used in clinical settings  
2. Discuss proper testing procedures to improve safety, reliability, sensitivity and specificity  
3. Highlight current research trends to improve functional testing

**ENTRANCE CRITERIA**

1. >= 12 weeks post-op  
2. <=1+ knee effusion  
3. >= 80% quadriceps strength index  
4. Full knee ROM  
5. Pain-free hopping  
6. Normal gait

**Additional Considerations**

- Knee extension peak torque/body weight ratio: 300 degrees/sec: 40% for males, 30% for females  
- 180 degrees/sec: 60% for males and 50% for females  
- No post-surgical history of giving way, or a negative pivot shift  
- KT 1000 testing: no R:L difference greater than 3mm

**Additional Considerations**

The athlete must be able to demonstrate safe and proper form with…  
- vertical jumps  
- broad jumps  
- hops  
- direction changes at slower speeds

**HOP TESTING**

1. Single Hop for Distance (2)  
2. Timed Hop (2)  
3. Triple Hop for Distance (16)  
4. Cross-over Hop for Distance (16)
**Single Hop for Distance**

1. The athlete stands on one leg, with his or her toes on the starting line, and performs a maximal hop horizontally, landing on the same leg.
2. Arms may swing freely to assist, be held on hips or behind the back – must remain consistent.
3. The distance is measured from the starting line to where the posterior heel lands.
4. Landing position must be held for 2 seconds with no loss of balance or extra steps.

**Timed Hop**

1. 6 meter distance is marked off using athletic tape.
2. Athlete stands on one leg with toes on the starting line.
3. The athlete is instructed to perform repeated, forceful single leg hops across the finish line. These should be done as quickly as possible, while maintaining proper form.
4. The test ends once the back of the heel crosses the finish line, and time is measured to the nearest 1/100 of a second.

**Triple Hop for Distance**

1. A strip of athletic tape, 15 cm in width and 6 meters long is placed perpendicular to the start line.
2. The athlete stands on one leg with toes behind the start line.
3. The athlete is instructed to perform 3 maximal effort hops in a straight line.
4. End distance is measured from where the posterior heel of the last hop lands.
5. Triple hop distance has been shown to be a strong predictor of lower extremity strength and power.

**Cross-over Hop for Distance**

1. A strip of athletic tape, 15 cm wide and 6 meters long is placed perpendicular to a starting line.
2. The athlete is instructed to make 3 consecutive hops on one leg, crossing over the center line each time.
3. The athlete is not allowed to pause to control him or herself between hops and the landing must be controlled on the last hop.
4. Maximum distance is measured from the posterior heel of the last hop.

**LSI: Limb Symmetry Index**

- For single, triple, crossover hop:
  \[ \text{LSI} = \left( \frac{\text{mean distance for the involved limb}}{\text{mean distance for the uninvolved limb}} \right) \times 100 \]

- For timed hop:
  \[ \text{LSI} = \left( \frac{\text{mean time on the uninvolved limb}}{\text{mean time on the involved limb}} \right) \times 100 \]

- 85% or greater is considered normal regardless of leg dominance, gender, or sport activity level.

- Uninvolved leg can be used as a reference guide regardless of leg dominance.

- **Caution**: if other injury or past surgery has occurred on the "uninvolved side" - use body weight comparisons (torque or total work to body weight ratios) on isokinetic testing to provide additional data.
STATISTICAL REVIEW of HOP TESTS

- Reliability
- Sensitivity
- Specificity

RELIABILITY

- "The extent to which measurements are consistent, dependable, and free from error" (3)
- As measured by ICC -intraclass correlation coefficient (19)
  - <.75 poor to moderate reliability
  - >.75 good reliability
  - >.90 excellent reliability for clinical measure

RELIABILITY of HOP TESTS

Hop tests have demonstrated high test-retest reliability in normal, young adults
- Single Hop for Distance = 0.92 to 0.96
- Timed Hop = 0.66 to 0.92
- Triple Hop for Distance = 0.95 to 0.97
- Cross-over Hop for Distance = 0.93-0.96

Logerstedt et al. JOSPT 2010 (12)

RELIABILITY of HOP TESTS

High reliability for ACL reconstructed patients has been demonstrated as well
- Single Hop for Distance = 0.76-0.96 (11,20)
- Timed Hop = 0.82-0.96 (9,20)
- Triple Hop for Distance = 0.88 (20)
- Cross-over Hop for Distance = 0.84-0.94 (9,20)

SENSITIVITY and SPECIFICITY

- Sensitivity: percent probability that the tests would demonstrate abnormal lower limb symmetry values in ACL deficient patients (10)

SENSITIVITY and SPECIFICITY

- Specificity: percent probability that the tests would demonstrate normal lower limb symmetry values in normal patients (10)

Ideal test should be:
- sensitive enough to detect a deficiency if it is present (avoid too many false negatives).
- specific enough not to over-report deficiencies that are not there (avoid too many false positives)

We would like both to be as close to 100% as possible but there is generally some trade off.
SENSITIVITY and SPECIFICITY

In general, hop testing has shown:

- **High specificity** 94-97% (16)
- **But lower sensitivity** 38-58% (16,22)
  
i.e. too many ACL deficient knees could be identified as normal

Improving Sensitivity of Hop Tests

Perform tests as a battery:

- Noyes and colleagues (16) found sensitivity improved to 62% when the results of the single leg hop and timed hop were combined
- Itoh and colleagues (10) found the percentage of ACL-deficient patients with functional asymmetry in at least one of four tests was 82% (figure 8 hop, up down hop, side hop, single hop)

Functional Ability Test (10)

Testing when the athlete is fatigued:

- Augustsson 2004 (1)
  
  • Examined a pre-exhaustion protocol to determine functional deficits
  • Improved sensitivity of single-leg hop test to 68% when the subject was fatigued, and 84% when a one rep max strength test was considered

LATE STAGE TESTING

Once the athlete has demonstrated proficiency on the more basic functional tests, higher level testing can be considered. This will place a higher functional demand on the knee, and come closer to approximating the stresses of sport. This will lead to improved sensitivity rates, as fewer deficient knees will be able to “sneak by.”

- **Single Limb Vertical Hop**
- **Modified Agility T-test**

Single Limb Vertical Hop

- **Chalk mark on the wall**

Pros: inexpensive, commonly available in clinics, training rooms
Cons: arm swing has been shown to influence vertical jump height performance and therefore makes it an invalid assessment of lower extremity function (23)
Single Limb Vertical Hop

- **Contact Mat/Force Platform**

  **Pros:**
  1. Eliminates the need to use the arms
  2. Allows the recording of other data in addition to jump height: ground reaction force, time on the ground, power, counter movement depth

  **Cons:**
  1. Cost/availability

Contact Mat/Force Platform – Examples

1. Accupower AMTI - Hickey 2009 (8)
2. Swift Performance - Meylan 2009 (13)
5. Just Jump System by Probotics - Burr 2007(4)

Just Jump System by Probotics

- Portable
- Moderate cost
- Excellent reliability
  ICC=.997 Burr 2007 (4)
- Multiple Test Options:
  - 1 jump
  - 4 jumps
  - sprint timer

1 Jump Mode:

- Left display is hang time in seconds and Right display is jump height in inches
- Do not allow the athlete to land knees in the “tuck position”

4 Jump Mode:

- Display shows ground time, ELPF (explosive leg power factor: air time divided by ground time), average jump height in inches

Just Jump System by Probotics

Single Leg Vertical Hop in the Literature

Gustavsson 2006 (5) showed a battery of 3 tests revealed a high level of sensitivity (when at least one was abnormal)

- one leg vertical hop, side hop, single leg hop

- 87% sensitivity in patients with an ACL injury
- 91% in patients who had undergone ACL reconstruction
Single Leg Vertical Hop in the Literature

- Petshnig 1998 - “one-legged vertical jump test is capable of detecting functional limitations of the lower limb following knee ligament reconstruction up to 54 weeks post-operatively” (18)

Modified Agility T-test

- Involves cutting and side shuffling to only one side per trial, so right to left comparison is possible (8,15)
- Hickey et al. 2009 showed good reliability between testing days (ICC=0.825) (8)
- Goal is 10 % symmetry (15)

Modified Agility T-test Performance (8)

1. Run 15 feet
2. Cut laterally and shuffle 15 feet- no cross over allowed
3. Backpedal 15 feet
4. Run forward 15 feet
5. Cut laterally and shuffle 15 feet
6. Backpedal 15 feet across finish line

IMPROVING FUNCTIONAL TESTING

Summary:

- Ensure the athlete can demonstrate symmetry on the more basic tests before advancing to higher level testing
- Consider the demands of the sport and level of the athlete when choosing tests. Not all of the higher level tests may be appropriate- look at your risk to benefit ratio.
- Use a test battery or group of tests to maximize sensitivity and ensure that deficient athletes are not cleared for sport

- Ensure that the same tester performs the tests at different points in the rehab process
- Standardize warm-up and testing procedures, including hand placement to minimize compensation from the arms that could alter tests results
- Ensure that the athlete wears the same shoes for all test dates
- Consider testing when the athlete is fatigued for later stage testing
TAKE HOME POINTS

- There is no consensus on timeframe for return to sports s/p ACL reconstruction
- Do not rely solely on one test, or looking at the calendar to make return to sport decisions
- Keep abreast of new research on improving current testing protocols, and criteria based late stage rehab (15)
- Allow a gradual transition- drills in practice, unopposed practice, opposed practice, scrimmage, game situation
- Continue to re-assess over the long term

Good Teamwork=Success

- Accept input from all members of the rehab team

REFERENCES


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