Return to Sport After ACL Reconstruction: Strength and Functionality Testing

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Background: Functionality testing following anterior cruciate ligament (ACL) reconstruction can benefit clinicians and patients in determining readiness for return to sport. While a component of a multifactorial decision, inability to perform well on these tests predicts increased risk of reinjury. As of 2013, only 41% of orthopaedic surgeons report using strength or functionality testing in evaluating patients for return to sport (RTS).

Indications: In the intermediate to late stages of their rehabilitation program, patients may undergo these tests to determine readiness and safety to return to sport.

Technique Description: The tests described in this video include the single and triple hop for distance, triple crossover hop, single and double vertical leg jump tasks, drop jump landing task, and isokinetic and isometric strength testing.

Results: Clinicians who incorporate these tests into patient rehabilitation programs may reduce patient risk of ACL reinjury by 75% to 84%. The limb symmetry index (LSI) is a reliable calculated measure for these tests, with a strong reliability for the hop tests. The limb symmetry index can be calculated for each test and represents the ratio of measured performance of the involved, or post-ACL reconstruction, leg when compared against the uninvolved leg. The commonly used limb symmetry index threshold for passing each hop test is 90%. Patients who score 90% or greater on each of these tests are less likely to experience knee reinjury.

Discussion/Conclusion: The ability of knee strength and functionality tests in determining RTS following ACL reconstruction has been highlighted as a tool in potentially reducing risk of knee reinjury. Other isometric and isokinetic testing can be used in addition to the described functionality tests but may not be possible in certain practices due to equipment and funding limitations. Usage of these strength and functionality tests, in conjunction with clinician evaluation, may lead to more optimal outcomes for patients and lower rates of reinjury. Psychological assessment may aid in evaluating patient readiness for return to sport. Importantly, further sport-specific testing is still recommended and will optimize patient outcomes.

Keywords: hop test; ACL reconstruction; limb symmetry index; return to sport; ACLR tests

VIDEO TRANSCRIPT

In this video, we will be reviewing the strength and functionality tests used in assessing readiness for return to sport after anterior cruciate ligament (ACL) reconstruction. We will walk through the current use of these tests, discuss the rationale and indications for testing before return to sport, and perform several video demonstrations.

There are no relevant disclosures to this presentation.

Strength and functionality testing are commonly used techniques in evaluating knee stability and patient readiness in return to sport following ACL reconstruction. About 41% of orthopaedic surgeons utilize these tests as a component in a multifactorial decision in determining return to sport.[9] Poor performance on these tests increases risk of reinjury upon return to sport.

We will demonstrate and discuss the hop tests, including the single leg hop for distance, the triple leg hop for distance, and the triple crossover hop. We will demonstrate isokinetic and isometric strength testing using dynamometers. Finally, we will demonstrate single and double leg vertical jump tasks, followed by the drop jump landing task.

The goals of testing following ACL reconstruction are to determine the strength of the muscles surrounding the knee, primarily the quadriceps and hamstrings, and

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evaluate knee stability and functionality through comparing the involved leg with the noninvolved leg. These tests may be conducted during the intermediate and late stages of rehabilitation.[2] These tests, along with psychological readiness, and surgeon evaluation are components in a decision made with patients for return to sport. No single test has been shown to have predictive validity alone, so a battery of tests is recommended.[1,10]

We will now explain and demonstrate the hop tests. We will begin with the single leg hop for distance. Instruct the patient to begin standing on 1 leg.

You will ask the patient to jump as far as they can, while landing on the same leg used to jump off. Upon landing, measure from the jumping point to where the patient landed. This is then recorded in centimeters. Falling or stepping with the uninvolved leg is considered invalid, and the trial is not included in data collection if this occurs. This is consistent across all hop tests demonstrated. The test is then performed on the opposite leg after testing of the first leg is complete. Typically, 3 trials on each leg are conducted. This data are then used to obtain an average of distance jumped with each leg. A ratio—limb symmetry index—is then calculated by dividing the average distance traveled on the involved leg when compared with the uninvolved leg. This ratio provides clinicians an understanding of how well the involved leg is progressing and can determine readiness for return to sport.

For the triple leg hop for distance, ask the patient to again stand on 1 leg. Instruct the patient to jump as far as possible 3 times while only jumping and landing with the same leg. Measure the distance and record it. Again, test the opposite leg as well.

With the crossover hop for distance, ask the patient to again stand on 1 leg. Instruct the patient to jump as far as possible 3 times while only jumping and landing with the same leg. With each jump, the patient should land on the opposite side of the line from where they previously had been. Measure the distance and record and perform the next trial. Again, test the opposite leg as well.

We will now review isokinetic and isometric strength tests. Isokinetic testing represents obtaining a measurement of force output while at a fixed speed. The device demonstrated in this video is an isokinetic dynamometer, known as the Biodex System 4 (Biodex Medical Systems, Shirley, NY), although other brands of dynamometers may be used. The machine is arranged to test isolated knee flexion and extension. The machine will match the subject's output of force to move at a constant speed, thus being able to obtain a force output with speed as a controlled and fixed variable. Speeds of 300, 180, and 60 degrees per second are tested in an ACL return to play (RTP) battery.

Dynamometers, such as shown here, may not be readily available due to cost. Increased cost due to equipment needed in strength testing may not allow for inclusion of these tests in a RTP battery, but the hop tests alone may still be used.

There are also handheld and stationary-based isometric dynamometers on the market, with lower cost compared with the isokinetic dynamometers. These sensors detect force output by a single muscle group in Newtons. For isometric testing, outcomes can be measured by normalizing strength to body mass. Measures greater than 3.1 N*m/kg are predictive of self-reported high functionality.[6] Like testing of the isokinetic dynamometer, both the flexors and extensors of the knee joint can be tested, as well as other joints and muscle groups.

We will now introduce single and double leg vertical jumps on a force deck system. For the double leg jump, instruct the patient to stand on a force deck and perform a deep squat followed by a vertical jump to maximum height.

The force deck will be utilized to calculate several data points, including both propulsive forces, breaking forces, and vertical displacement.

For the single leg vertical jump, instruct the patient to stand on a force deck and perform a single leg deep squat followed by a vertical jump to maximum height. The force deck will then allow comparison of involved and noninvolved propulsion and breaking metrics.

We will now explain a drop jump landing task. In this task, have the patient start by standing on a box. The subject then jumps onto a force plate. This drop jump is followed by a double leg jump with a subsequent landing. The advantage of the drop jump task is in examining both involved and uninvolved limb braking capacity from a fixed gravitational force. It is of the author group's opinion that a ratio of involved to uninvolved peak braking forces in Newtons is the key metric in return to play decision making from this test.

The performance of these tasks has no increased risk for patients. However, the tests themselves are an imperfect method of determining return to sport. The calculated limb symmetry, or limb symmetry index (LSI), may not accurately reflect the patient's progress. For example, poor distance achieved on testing with both legs may yield a misleading high LSI. Additionally, LSI does not provide information for the biomechanics of limb movement.[3]

There still is a risk of reinjury to patients even with passing these tests, so patients must be informed and advised to delay return to sport when possible.

These tests do not test the ability of the patient and knee to react to external stimuli, which would simulate a more realistic sports setting—sport-specific testing should be still utilized. Patient fatigue as a factor of these tests has not been determined and the time between trials has not been standardized. Similarly patient warm-up prior to testing as a factor has not been determined and conceivably could affect these results.

When using the limb symmetry index, a 90% cutoff is often used. Patients with an LSI greater than 90% are considered as passing.[1-3,5,6] For strength testing, a cutoff of 85% to 90% may be used, although there is no consensus, and it is of the author group's opinion that over 90% of strength testing as compared to normative, baseline, and/or contralateral side values should be obtained at minimum, and a target of 95% should be strived for, and it is becoming more of a standard in practice.[10]

Alternatively, isometric strength can be measured through normalizing strength to body mass, and isometric extension strength greater than 3.1 N*m/kg is predictive of self-reported high functionality.[6] Patients who fail to meet

these criteria may be subject to significant risk of knee reinjury.[2,6] Sport-specific testing should be conducted, along with psychological assessment of patient confidence in knee function and readiness in return to sport.[2] With all these factors considered, clinician evaluation still forms the backbone of patient assessment, and other factors and testing are supplemental. Passing a battery of tests that includes isokinetic, isometric, and hop tests has been shown to reduce risk of ACL reinjury by 75% to 84%.[4,6]

Overall, LSI demonstrates strong reliability. Research indicates that the hop tests have an excellent rank-order repeatability and the calculated LSI has a strong reliability, with intraclass coefficients ranging from 0.84 to 0.92.[1]

Furthermore, the hop tests are able to discriminate performance at intermediate and late stages of rehabilitation, and are indicator for the likelihood of return to sport.[5,8] However, only 2 hop tests may be needed in a test battery, as the maximum sensitivity was recorded at 62% when 2 hop tests were utilized.[1] The single hop for distance and the crossover hop for distance were found to have the lowest correlation, with a correlation of 0.56, as they may be testing different constructs and so use of these 2 hop tests may provide clinicians more information.[1]

Deficiency in strength on the isokinetic and isometric tasks have shown strong correlations with deficits in the single and triple leg hop for distances.[1] Another study found that a decreased hamstring to quadriceps ratio at 60°/s is correlated with a 4x increased risk in ACL graft rupture.[6]

Evidence regarding the single and double vertical jumps is unclear, due to variability in methodology and criterion validity. However, limited evidence suggests correlations between the single leg vertical jump and self-assessed difficulty in pivoting and cutting.[5,7] Drop jump testing has shown a high correlation with the single leg hop for distance task, so inclusion of both may not be necessary in a battery of tests.[7] It is of the author group's opinion that more literature is needed examining these jump tests due to this emerging technology.

This concludes our video on the use of strength and functionality tests in patients after ACL reconstruction.

Thank you.

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REFERENCES

1. Davies WT, Myer GD, Read PJ. Is it time we better understood the tests we are using for return to sport decision making following ACL reconstruction? a critical review of the hop tests. *Sports Med*. 2020;50(3):485-495.
2. Filbay SR, Grindem H. Evidence-based recommendations for the management of anterior cruciate ligament (ACL) rupture. *Best Pract Res Clin Rheumatol*. 2019;33(1):33-47.
3. Gokeler A, Welling W, Zaffagnini S, Seil R, Padua D. Development of a test battery to enhance safe return to sports after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2017;25(1):192-199.
4. Grindem H, Snyder-Mackler L, Moksnes H, Engebretsen L, Risberg MA. Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Oslo ACL cohort study. *Br J Sports Med*. 2016;50(13):804-808.
5. Hegedus EJ, McDonough S, Bleakley C, Cook CE, Baxter GD. Clinician-friendly lower extremity physical performance measures in athletes: a systematic review of measurement properties and correlation with injury, part 1. The tests for knee function including the hop tests. *Br J Sports Med*. 2015;49(10):642-648.
6. Kyritsis P, Bahr R, Landreau P, Miladi R, Witvrouw E. 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. *Br J Sports Med*. 2016;50(15):946-951.
7. Lee DW, Yang SJ, Cho SI, Lee JH, Kim JG. Single-leg vertical jump test as a functional test after anterior cruciate ligament reconstruction. *Knee*. 2018;25(6):1016-1026.
8. Narducci E, Waltz A, Gorski K, Leppla L, Donaldson M. The clinical utility of functional performance tests within one-year post-acl reconstruction: a systematic review. *Int J Sports Phys Ther*. 2011;6(4):333-342.
9. Petersen W, Zantop T. Return to play following ACL reconstruction: survey among experienced arthroscopic surgeons (AGA instructors). *Arch Orthop Trauma Surg*. 2013;133(7):969-977.
10. van Melick N, van Cingel RE, Brooijmans F, et al. Evidence-based clinical practice update: practice guidelines for anterior cruciate ligament rehabilitation based on a systematic review and multidisciplinary consensus. *Br J Sports Med*. 2016;50(24):1506-1515.