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Operative Techniques in

Sports Medicine

Anterior Cruciate Ligament Functional Sports Asssessment

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The incidence of anterior cruciate ligament (ACL) patients has doubled in the past 5 years at Rush University Orthopaedics. Additionally, there has been a 3-fold increase in the number of anterior cruciate ligament injuries in patients younger than the age of 25 years of age during this 5-year period. Fortunately, approximately 80%-90% of these patients return to their sports at their previous level of play. However, with the increased incidence in tears, it is important for medical providers to assist the patients in determining the risk factors they may display when preparing to return to sport. There are very few published return to sport guidelines following anterior cruciate ligament reconstruction. Midwest Orthopaedics at Rush has developed a functional sports assessment (FSA) to evaluate anterior cruciate ligament injury risk factors on postoperative patients. The FSA factors include range-of-motion, strength, endurance, proprioception, power, core stability, ankle stability, and overall biomechanics and confidence. Although the FSA has not been proven reliable or valid, it is based on the other commonly used tasks in determining a patient's ability after anterior cruciate ligament surgery. It has been clinically relevant for the patient, therapist, athletic trainer, and physician in identifying weaknesses and risk factors at the 5-6 month time postoperative time period. This helps to guide the patient in what tasks he or she needs to be attentive to during the transition to return to sport to minimize reinjury. This article provides factors that were considered when developing the FSA, a detailed description of the FSA, and future considerations to improve the assessment for validity and reliability.

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The incidence of anterior cruciate ligament (ACL) injuries is 400,000-500,000 per year.[1] In the United States alone, anterior cruciate ligament reconstruction is performed in 175,000 patients.[2] The rehabilitation following anterior cruciate ligament reconstruction is critical in achieving a successful clinical outcome. There are variations of rehabilitation protocols but most are based in an accelerated program that facilitates early motion, recovery of strength, and return to previous level of function. The return to function often includes sport specific activities. This consists of running, jumping, landing, cutting, stopping, and starting and ability to tolerate any contact related to the sport they are returning to. For most of the patients, the procedure is successful but failure rates average 3% but has been reported as high as 10%-25%.[3] Considering the cost and time spent on an anterior cruciate ligament reconstruction in addition to the mental time away from activity, a discussion about safe return to sport is a very important topic.

The timeline in deciding when to return an athlete to sports after anterior cruciate ligament reconstruction can be controversial. It is important to use standardized outcome measure in research and clinical practice. However, objective guidelines are infrequently used to determine when an athlete is ready to safely return to sport. There are few valid and reliable outcome measures in the literature. Factors to consider can include

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range-of-motion (ROM), strength, pain, outcome scores, and functional performance. It is imperative that the dynamic component of the performance is considered to decrease the possibility of reinjury.

The objective of this article is to review the return to sport protocols in the literature as it relates to the Midwest Orthopaedics at Rush Functional Sports Assessment (FSA). The assessment was developed to assist the orthopedic physicians and physical therapists in determining the deficits and strengths of postoperative anterior cruciate ligament patients, as they are preparing to return to sport. It is used to clarify what tasks the athlete needs to focus on, to perform sport specific activities with minimal risk.

Our objective in creating the FSA was to evaluate as many modifiable ACL injury risk factors as possible whereas adhering to constraints that limit most physical therapy clinics. For the purpose of the FSA, the modifiable ACL injury risk factors were ROM in the lower extremities, strength and power symmetry of the lower extremities, quadriceps dominance, proprioception, endurance, core stability, ankle stability, overall quality of biomechanics with high-risk athletic movements, and confidence in the knee. Constraints placed on our approach to testing protocols were that the FSA needed to take 60 minutes or less to complete, use common equipment found in a PT clinic, be able to be performed in a small area (6 m × 3 m), use the movements in all 3 planes, be relevant, be reliable, provide immediate feedback that the patient can use to reduce their injury risk factors, and provide data that the patient's physician can use as a component in the return to play decision.

Patients are strongly encouraged to have met the criteria described below performing the FSA. Patients should allow at least 20 weeks since their date of surgery, have experience with lateral movement, pivoting, and plyometrics, report pain levels less than a 3/10 with activities of daily living and current exercises, be prepared to begin the transition back to their sport in the next month, and have a physician's clearance specifically for the FSA.

The FSA consists of 9 different sections—a knee and ankle ROM assessment, single leg hop, triple hop, crossover triple hop, 6 m timed hop, single leg squatting, lateral jumping, and pivoting, 6 m straight line run with a change in direction, and a plyometric box jump assessment. The patient's test is recorded with 1-2 video cameras and the video is analyzed afterwards with the patient present to discuss deficits noted. Video footage is also analyzed by the test administrator afterwards for more comprehensive identification of deficits.

Patients are instructed to wear athletic clothing and shoes that they wear for their regular athletic activity and training. Patients that would be utilizing a brace when they return to their sport are instructed to wear their brace during testing. Patients are allowed to warm up utilizing any method with which they are comfortable and familiar.

ROM Assessment

The FSA ROM assessment consists of goniometric assessment of ankle dorsiflexion, knee flexion, and knee extension. The purpose of this ROM testing in the FSA is to identify significant ROM restrictions that would inhibit progressing with the remainder of the test. For the purposes of the FSA, the patient is expected to achieve 20° of ankle dorsiflexion bilaterally, symmetric knee extension, and 120° of knee flexion bilaterally.

Figure 1 Single Leg Squat Front View (Color version of figure is available online.)

Single Leg Hop

The single leg hop assessment requires the patient to stand on 1 leg and hop as far as possible, land on the same limb, and maintain their balance for 2 seconds. Inability to maintain balance invalidates that attempt. Measurements are then taken from the patient's heel to the nearest centimeter. This process is repeated, alternating between the unaffected and affected side until 3 measurements are taken on each leg.

Single-leg performance-based measures used to assess the combination of muscle strength and power, neuromuscular control, confidence in the repair knee, and the ability to tolerate loads related to sports-specific activities following surgical and rehabilitative interventions.[4-7] In our opinion, the 4 hop tests progress from the least difficult to the most

Figure 2 Single Leg Squat Side View (Color version of figure is available online.)

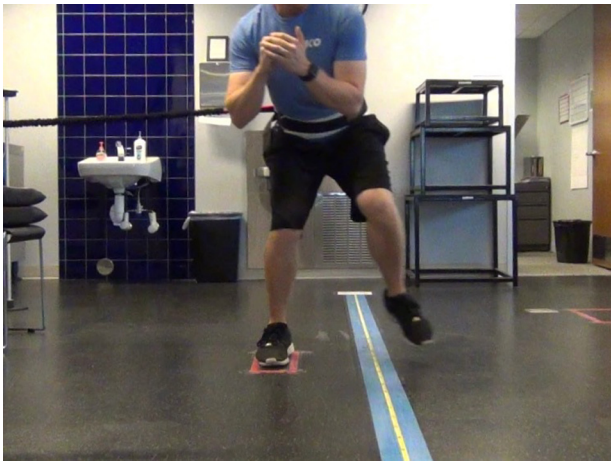

Figure 3 Lateral Bounding.

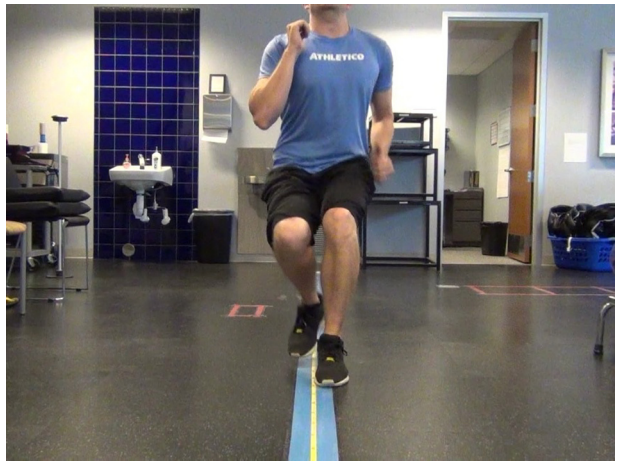

Figure 5 Decleration.

difficult. If an athlete is unable to perform the single hop for distance safely, they may not be able to continue with the rest of the FSA. Even though it is the least difficult portion of the test, it still requires adequate lower extremity strength, neuromuscular control, and balance to avoid knee valgus and compromising knee positions.

Triple Hop

The triple hop assessment requires the patient to stand on 1 leg and hop 3 consecutive times on the same leg as far as possible, maintaining their balance for 2 seconds after the final jump. The patient is expected to maintain constant motion between the second and third jumps. Pausing for more than half of a second between the second and third jumps or demonstrating an inability to maintain balance invalidates that attempt. Measurements are then taken from the patient's heel to the nearest centimeter. This process is repeated, alternating between the unaffected and affected side until 3 measurements are taken on each leg.

The triple hop assesses strength and power symmetry, proprioception, ankle stability, and confidence in the knee. We believe, the triple hop is the next most difficult regarding the 4 hop tests. Hamilton et al[8] found that the triple hop for distance was a strong positive predictor of performance on clinical power and strength tests. These findings demonstrate that the triple hop is a strong predictor of lower limb muscular strength and power The triple hop has been shown to be a strong predictive test for strength and power symmetry when compared with the results of a Biodex System 3 Pro Dynamometer (Biodex Medical Systems, Shirley, NY) at angular velocities of 60°/s and 180°/s.[8]

Crossover Hop Test

The crossover hop assessment requires the patient to stand on 1 leg and hop 3 consecutive times on the same leg as far as possible, maintaining their balance for 2 seconds after the final jump. The patient is expected to jump medially over a line on the floor on their first jump, laterally over the line on their second jump, and medially over the line for their third jump. The patient is expected to maintain constant motion between the second and third jumps. Pausing for more than half of a second between the second and third jumps or demonstrating

Figure 4 Lateral Bounding.

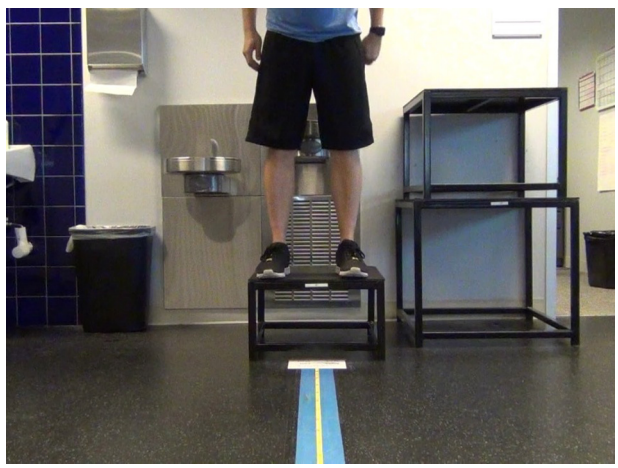

Figure 6 Box Jump Starting Position.

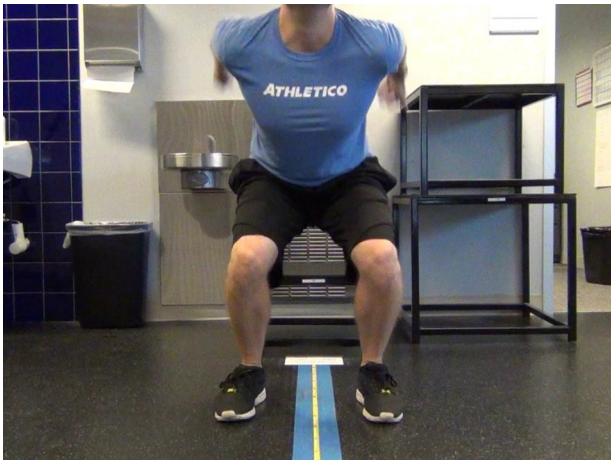

Figure 7 Box Jump Landing (Color version of figure is available online.)

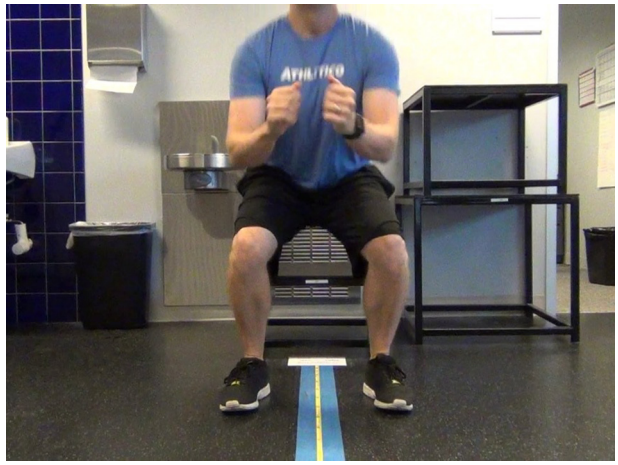

Figure 9 Box Jump Rebound Landing (Color version of figure is available online.)

an inability to maintain balance invalidates that attempt. Measurements are then taken from the patient's heel to the nearest centimeter. This process is repeated, alternating between the unaffected and affected side until 3 measurements are taken on each leg.

The last 2 hop tests performed are arguably the most apprehensive for the participant to perform.[9] The crossover hop is the most demanding hop test as it imposes forces in frontal and transverse planes, combined with multiple hops in the sagittal plane.[10] Side-to-side differences are minimized in these patients, likely indicating superior neuromuscular control, therefore increasing the probability of knee function within normal ranges at 1 year.[10] The crossover hop test most accurately identified patients with knee function within normal ranges.[10]

The 6-m Hop for Time

The 6 m hop for time assessment requires the patient to stand on 1 leg and hop along a 6 m line, utilizing only the leg being tested. Time for completion is done with Dartfish motion analysis software (Dartfish USA Inc), with timing beginning when the patient's toe is no longer in contact with the ground and ending when the foot lands over the 6 m mark. This process is repeated, alternating between the unaffected and affected side until 3 measurements are taken on each leg.

Logerstedt et al[10] demonstrates that the 6 m timed hop was the strongest independent predictor and had the highest discriminatory accuracy for self reported knee function 1 year after ACL reconstruction.[10] With a specificity of 90%, the 6 m timed hop test was the most useful test for identifying patients with self reported knee function below normal ranges at 1 year.[11] Previous work by Fitzgerald et al[5] has shown that the 6 m timed hop along with other variables can identify those with poor dynamic knee stability from those with good knee stability early after ACL injury. In those individuals with good dynamic knee stability, this test can also discriminate among those who did not successfully return to high-level sports from those who did.[11] Those individuals who can perform these hops tests with high limb symmetry demonstrate more confidence and less favoring of the un-involved limb during return to sport activities.

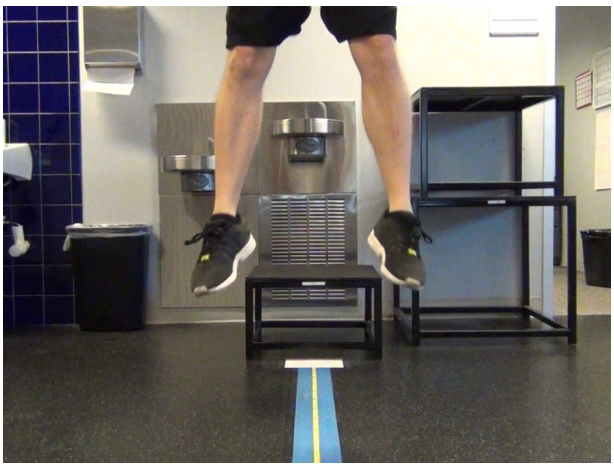

Figure 8 Box Jump Rebound (Color version of figure is available online.)

Single Leg Squat

The single leg squat assessment requires the patient to perform unilateral squatting from 0° of extension to 60° of flexion while holding the 15% of their body weight with their ipsilateral upper extremity. The patient is allowed to use a balance assist with 2 fingers of the contralateral upper extremity. 60° of knee flexion is measured with a goniometer with the patient in a squatted position and a chair with padding is set to make contact with the patient when 60° of flexion is achieved. Instructions are then given to the patient outlining expectations and potential cuing they may receive to address common deficits. Expectations are that the patient would perform the single leg squatting task for 2 minutes, bearing the weight on 1 leg, maintain constant motion, avoid hyperextension of the knee, avoid transferring weight to the chair behind them, maintain a position void of lateral trunk flexion, maintain a

position void of excessive forward trunk flexion (beyond parallel plane of tibia when viewed laterally), avoid the knee passing a vertical plane in anterior to their toes, maintain level hips when viewed anteriorly, and avoid a valgus knee angle. Cuing is given to correct form during testing to assess the patient's ability to perform this task correctly and gain insight for potential factors that may be hindering an ability to perform this task with correct form. This test is performed bilaterally (Figs. 1,2).

The purpose of the single leg squat test is to challenge the patient's endurance toward the beginning of the test to fatigue the quadriceps to properly assess what the patient's form might look like when the leg is tired (ie, the end of the game). In addition, the "single leg squat component is for the patient to demonstrate quadriceps and hip muscle endurance to maintaining the appropriate movement strategies."[11] The single leg squat test has been shown to be a reliable test per Ageberg et al,"medio-lateral knee motion assessed by visual inspection during the single-limb mini-squat was valid in 2-dimensional, showing a medially placed tibia and thigh, and knee valgus in individuals with a knee-medial-to-foot position compared with those with a knee-over-foot position. The actual movement, in 3-dimensional, was mainly exhibited as increased internal hip rotation. The inter-rater reliability of the observational clinical test was high. These results suggest that the single-limb mini-squat test provides a valid and reliable clinical method."[12]

Lateral Agility and Pivoting

The lateral agility and pivoting test requires the patient to jump laterally, anterolaterally, and posterolaterally against resistance for 90 seconds. A rectangle is outlined on the floor where the foot of patient's lower extremity being tested is outlined. This rectangle is used as a landing target for testing. A rectangle is used to encourage the patient to maintain a neutral foot and tibial rotation position regarding the camera being used to film the test and discourage premature rotation of the body as a whole before pivoting jumps. The rectangle is positioned at a distance from the wall equal to the amount of slack in the resistance bands used for testing. Lines are then placed directly lateral, 45° anterolateral, and 45° posterolateral to the landing goal at a distance equal to the patient's length from greater trochanter to the floor. A belt is placed around the patient's waist at anterior superior iliac spine level and resistance is attached equal to 15% of their of body weight. If exactly 15% is not possible because of the gaps in resistance cord resistance tiers, the closest weight to 5 lb (rounding down) is used. Expectations are that the patient would jump laterally, pivot posterolaterally, jump laterally, then pivot anterolaterally, repeating this process for 90 continuous seconds without stopping. The patient is expected to maintain constant motion, have at most one foot in contact with the ground at any given point of testing, rotate their body as a whole for pivoting tasks, avoid a valgus knee angle, display at least 30° of knee flexion with landings, and keep their foot in line with the landing target. Cuing is given to correct form during testing to assess the patient's ability to perform this task correctly and gain insight for potential factors that may be hindering an ability to perform this task with correct form. This test is performed bilaterally (Figs. 3,4).

The purpose of this test is to assess the patient's ability to maintain stable core, hip, and knee with push-off and landing during lateral movements such as changing directions when side-stepping or defending a player during a game. Sell et al[13] demonstrated, "jump direction significantly influenced knee biomechanics, suggesting that lateral jumps are the most dangerous of the stop-jumps." Therefore, anterolateral, lateral, and posterolateral jumps are included in our FSA to assess a risky movement that requires significant gluteal and quadriceps control to maintain proper knee stability without knee valgus. In addition, Queen et al's[14] research suggests that, "the crossover cut places an increased load on the lateral portion of the forefoot, whereas the side-cut task places an increased load on the medial portion of the forefoot and the acceleration task places increased load on the middle forefoot, the differences in loading patterns based on athletic task are important for understanding potential injury mechanisms" Therefore, with this information videotaped it allows the testers to provide patients with their specific risks and alternative ways of moving to avoid high-risk knee movement patterns that could cause another injury or ACL tear.

Deceleration and Change in Direction

The deceleration test requires the patient to take 4-5 steps anteriorly, accelerating with each step, come to a sudden stop, and change direction to a backpedal. Expectations are that the patient would build speed with each step until the change in direction. At the change in direction, the patient is to land and push-off with the tested lower extremity when transitioning from an anterior run to a backpedal without any assistance from the contralateral lower extremity. When the patient returns to the starting point, they transition back to an anterior run, repeating this process until 5 trials have been completed on each lower extremity. The patient is instructed to run at a speed that is as fast as they are comfortable with, building speed with each repetition. Expectations are that the patient would maintain constant motion during testing, change direction unilaterally, display knee flexion during their change of direction, maintain level hips when viewed anteriorly, and maintain a neutral hip, knee, and ankle alignment during their transition from anterior to posterior movement. Cuing is given to correct form during testing to assess the patient's ability to perform this task correctly and gain insight for potential factors that may be hindering an ability to perform this task with correct form (Fig. 5).

This test is performed to assess hip and knee stability during quick direction changes which frequently occur in a sports setting. The test is videotaped to slowly assess patients' neuromuscular control of hip internal rotation, knee valgus, trendelenburg, trunk flexion (lateral or forward), and patients' confidence when asked to change direction while only placing weight on postsurgical leg. Research has suggested that poor

single leg landing mechanics correlate with poor knee mechanics and increased risk for noncontact anterior cruciate ligament injuries.[15] Additional research is required to test the validity and reliability of deceleration testing in the ACLR patient.

Box Jump Landing to Vertical Jump

The box jump landing to vertical jump test requires the patient to jump anterior from a 12 in plyometric box to a line that is set one half of their height away, land, immediately jump vertically with a maximum effort vertical jump, and land. Expectations are that the patient would make ground contact at the same time with both lower extremities, display at least 30° of knee flexion at both landings, land with their hip, knee, and ankle in neutral alignment, display a stance width that is shoulder width, and display symmetrical weight distribution when viewed anteriorly. This test is repeated until 5 successful trials are completed. Cuing is given among each trial in an effort to correct form and gain insight for potential factors that may be hindering an ability to perform this task with correct form (Figs. 6-9).

Box jumps are performed to assess plyometric control of hips and knees during first and second landings. Landing mechanics are viewed from an anterior and sagittal perspective to assess squat form and valgus knee loading as many studies have shown that "quadriceps force coupled with a valgus load increases the ACL force up to 100% compared with valgus loads without a quadriceps force."[16] Therefore, the box jump is able to assess quadriceps force and knee valgus that might put patient at higher risk for ACL re-tear. Padua et al[17] found that assessing box jumps can provide tester with additional information to separate patients into high and low-risk subgroups of re-tearing anterior cruciate ligament. This indicates that the box test jump is a specific screening tool to determine anterior cruciate ligament injury risk in elite-youth soccer athletes.

Conclusions

The evidence to support "return to sport" testing is limited. However, the need to identify when postoperative anterior cruciate ligament patients are ready to return to their chosen sport with minimal risk factors is a growing concern. This is in part caused by the growing number of ACL tears in the general population and particularly in younger than 25 years of age population. Additionally, the demand for return to a high-level of activity after anterior cruciate ligament surgery is mandatory for many high school, college ,and professional athletes. The Midwest Orthopaedics at Rush FSA was developed to clinically assess patients who are 20 weeks or more after anterior cruciate ligament reconstruction. The assessment identifies lower extremity ROM, strength, proprioception, endurance, core stability, ankle stability, and assesses the overall quality of biomechanics. The tasks used in the assessment were commonly used protocols that have been considered in the literature. Although the validity and reliability of these protocols are limited, they have been found to be strong predictors of strength, performance, neuromuscular control, power, and high-risk or low-risk for re-tears.

Despite limited evidence to fully support the FSA as a reliable and valid tool, it has been clinically relevant in identifying risk factors and weaknesses for the patient, physical therapist, athletic trainer, and physician to concentrate on, when preparing to return to sport.

Additional studies would be beneficial to standardize the FSA and other similar assessments to develop a valid and reliable tool for postoperative anterior cruciate ligament return to sport testing.

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