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Commentary Open Access

Changes in the Uninvolved Limb during Rehabilitation Following ACL Reconstruction, and Recommendations for a Practical and Evidence-Based Functional Testing Battery

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Introduction

ACL reconstruction is a common orthopaedic procedure, for which physical therapy is a mainstay of the post-operative rehabilitation process. Our recent study described a pattern of improvement in the uninvolved limb that must be accounted for when measuring progress during post-operative rehabilitation; in addition we identified the tests within the functional test battery that demonstrated the most significant changes over time [1].

The ACL is crucial for knee stability and proprioception. Following ACL reconstruction (ACLR), patients typically have profound deficits in their abilities, and physical therapy helps to restore normal function. Especially since ACL injuries are common in younger people and athletes, restoration of function is a primary goal of treatment. Physical therapy and activity regimens have evolved over the last several decades with newer evidence, and current practices were previously summarized in an excellent review article [2].

As patients progress, physicians must decide when to allow return to play. There is a significant risk of re-injury following ACL reconstruction, and yet little evidence as to what tests can predict a successful outcome [3]. Early in rehabilitation, isokinetic strength measurements are often used to track progress. Patient-reported measures such as the International Knee Documentation Committee score (IKDC) or Knee Injury and Osteoarthritis Outcome Score (KOOS) are also often used. Investigators have found, however, that subjective measures such as the IKDC are not sufficiently correlated with rigorous objective testing, and these are not recommended alone as return-to-play criteria [4]. When isokinetic strength approaches that of the uninvolved limb, and the patient can perform basic activities without pain, many providers introduce functional tests to better simulate sports-like activities. In our practice, physical therapy is advanced at this point to include closed-chain and sport-specific exercises, and typically the functional test battery is performed at 6 months post-op; some portions of the testing battery may be performed earlier in an effort to identify deficits. Patients receive additional rounds of therapy and functional testing if performance is unsatisfactory at 6 months post-op.

Functional tests are increasingly important in return-to-play decisions, since they involve complex multi-joint motions that closely mimic sport. In an attempt to mimic the many motions and stresses involved with athletics, a wide variety of individual functional tests have been developed. It is assumed that patients who display persistent limb deficits are at higher risk for re-injury, and typically are recommended for additional therapy. Testing in the clinical setting, however, is time-consuming. Therefore, a practical testing battery should comprehensively challenge the injured limb, while limiting itself to tests that best demonstrate rehabilitation progress in the involved limb. The most thoroughly studied and widely used tests are the 4 hop tests: single leg hop, single leg triple hop, crossover triple hop, and 6-meter timed hop. Previous research has established the reliability of this testing battery [5-9]. Performance on these tests is correlated to self-reported ability in the post-op period, although no research has directly linked it to lower re-injury rates or successful return to play [10].

Typically, functional tests are scored using a measure known as the Limb Symmetry Index (LSI). The LSI is measured by dividing the injured limb's score by the uninjured limb's score, yielding a percentage. In this system, 100% indicates perfectly symmetric performance. LSI is considered a more appropriate measure than absolute limb ability, because it intrinsically uses the patient's own abilities as a baseline target. Symmetric limb ability has also been shown to be an indicator of successful return to function following ACLR, whereas biomechanical limb asymmetries have been correlated to failure of both objective and subjective return-to-play criteria [11-14]. Although no score threshold has been rigorously validated, most providers prefer an LSI of 90% before return to play.

Original Study

Our study examined 122 patients in the ACLR rehabilitation period. All patients followed our standard rehabilitation protocol, and underwent our 12-test functional testing battery at multiple time points. Our data identified a consistent pattern of increasing ability in the uninvolved limb during rehabilitation, a pattern which providers should be cognizant of during testing. Patients in our study showed significant uninvolved limb improvements in the timed hop, retro step up, and single leg reach tests. Additionally, there were non-significant trends towards uninvolved limb improvement in all of the remaining tests. We attribute this increase to neuromuscular learning of the test itself, along with improved conditioning of the uninvolved limb, a view shared by other authors [15]. That being said, the involved limb improved to a significantly greater degree during rehabilitation, leading to the increased LSI scores that were observed. We believe the uninvolved limb, therefore, serves as an appropriate control for comparison with the involved limb. Crucially, the uninvolved limb's ability did not decrease, as this could undermine the legitimacy of LSI testing. Had the uninvolved limb's performance decreased, this could have suggested that LSI improvements merely reflected a worsened uninvolved limb, rather than true improvement in the involved limb. Given this pattern

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of improving ability in both limbs, we recommend that the LSI always be calculated using measurements of both limbs from the same date. LSI calculations based on uninvolved limb ability from a previous date - for instance, a benchmark obtained at the beginning of rehabilitation - will not account for improvements in uninvolved limb ability and may therefore overestimate improvements in the LSI.

Of the functional tests included in our analysis, we found six that both showed initial functional deficits, and demonstrated improvement in functional deficits during rehabilitation. Consistent with previous literature and clinical practice, we found that all 4 classic hop tests demonstrated significant improvement in functional deficits. In addition, they all showed average initial LSI below 90%, with 3 of the 4 (single leg hop, crossover triple hop, and timed hop) showing average improvement to over 90% by the final test. Additionally, we found that the retro step up and single leg squat tests also detected initial functional deficits with significant improvement to over 90% average LSI. Of all tests evaluated, the retro step up demonstrated the greatest improvement over time. We therefore believe that retro step up and single leg squat could be valuable additions to the four hop tests within a functional testing protocol, and that retro step up might be especially sensitive for detecting functional deficits.

A number of tests evaluated in our protocol may not be useful in helping to determine appropriate timing for return-to-play. These tests either did not show an initial LSI deficit below 90%, or did not show significant improvement over time. The single leg reach and the single-leg stork stance tests did not show an LSI below 90% at any point during testing. The core plank and single leg bridge tests do not produce an LSI measurement and therefore cannot be used to determine symmetry for return-to-play criteria.

An evidence-based testing protocol should include tests which are sensitive to functional deficits, which have established reliability, and which are validated as predictors of improved outcomes. Our study found six tests in our regimen that demonstrated improvement in initial functional deficits. Of these 6, the 4 hop tests have established reliability in previous literature, but the other 2 functional tests (retro step up, single leg squat) have not been studied in this regard. Given the ability of these two tests to detect functional deficits in our study, however, we believe these are appropriate tests for inclusion in a functional testing battery; reliability data on these tests should be a goal of future research.

The major limitation to both our study and other functional testing literature is a lack of validation between functional test scores and outcomes. Functional tests are intuitively appealing due to their close resemblance to actual athletic motions, and they have been correlated to self-reported outcome measures [16]. However, none of the functional tests, nor any other post-operative tests, have been directly correlated to successful return to play or decreased re-injury rates. As these are the ultimate goals of post-ACLR rehabilitation, this should be a priority of future studies. Our study could also benefit from correlating functional test performance with other testing methods such as outcomes instruments and strength testing. A more standardized testing schedule would also strengthen our study's methodology - however, this is difficult since the timing of functional testing is dependent on each patient's progress with therapy. Finally, it is possible that these results could change over time, and therefore following functional testing results over time may add valuable information for how best to use these tests.

Final Considerations

In conclusion, we recommend that return-to-play decision making should, at a minimum, include both functional testing and patient-reported measures. Specifically, we believe that functional test batteries should include the 4 hop tests, as well as a single leg squat and retro step up, and that 90% LSI is a reasonable threshold for return to play. LSI scores should be based on measurements from both limbs taken during the same testing session, and should not be calculated using limb scores from different dates. Further studies are needed to establish the reliability of the single leg hop and retro step up, and to better describe the relationship between improved functional test scores, successful return to play, and lower re-injury rates.

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