



**EVALUATION OF FUNCTIONAL PERFORMANCE
TESTS IN INDIVIDUALS WHO HAVE RECEIVED ANTERIOR
CRUCIATE LIGAMENT RECONSTRUCTION WITH DIFFERENT
AUTOGRAFT METHODS – A MINI REVIEW**

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Abstract:

The anterior cruciate ligament (ACL), which contributes greatly to the stability of the knee, has a share of 50% in all ligament injuries. Because of this injury rate, ACL

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reconstruction procedures (ACLR) are one of the most common surgical procedures performed for the knee joint by orthopaedists. Some tests should be conducted in order to evaluate the success of the surgical procedure and for the return of patients to their daily life and sports activities. Otherwise, it is possible for graft failure and re-tear cases to occur. Many different functional performance tests are used for this purpose. This mini-review provides evidence for functional performance tests performed after ACL injury.

Keywords: ACL reconstruction; functional performance tests; autograft

1. Introduction

The anterior cruciate ligament (ACL) is one of the most important ligaments in maintaining knee stability and it controls anterior translation and excessive rotation of the tibia (Giuliani, Kilcoyne, and Rue, 2009). ACL, which has a 70% sports-related injury rate, is the most commonly injured ligament in the knee joint (Gianotti et al., 2009). Weakness of the knee extensors is a common disorder after ACL reconstruction (ACLR), which is the primary treatment option in patients who want to return to sports involving running and sudden changes of direction (Ageberg et al., 2008; Barber-Westin, Noyes 2011; Beischer et al., 2018; Keays et al., 2003; Schmitt et al., 2015; Thomeé et al., 2012; Toole et al., 2017; Guney-Deniz et al., 2020). The time to return to sports (RTS) following ACLR varies considerably among sources (Grassi et al., 2016). Various strength tests, functional tests, and self-report results of patients are generally evaluated 6 to 12 months after surgery to assess when the patient can safely return to sports (Grindem et al., 2016; Müller et al., 2015; Endut, Morley, and Tien, 2018). Most assessments use the non-operated leg for comparison and calculate a limb symmetry index (LSI) to indicate how much the operated leg has healed (Grindem et al., 2016; Müller et al., 2015; Endut, Morley and Tien, 2018). Criterion thresholds for acceptable recovery range are between 65% to 90% of the contralateral leg for the knee extensor strength levels of the tested leg (Grindem et al., 2016; Schmitt et al., 2015; Keays et al., 2003). A commonly used criterion for RTS decision is an LSI of 85% and above for both strength and jump performance (Noyes and Barber, 1991; Silva, Ribeiro and Oliveira, 2012).

Considering that the isokinetic dynamometer, which is one of the force measurement methods, is available in a few centres and less accessible, functional tests are often used instead of or as an alternative to a strength test. Although many functional tests have been used, one of the most frequently used is the single-leg hop test (SLHT) (Noyes and Barber, 1991; Engelen-van Melick et al., 2013). SLHTs, which are frequently used in post-ACLR rehabilitation processes and for RTS, are widely applied to evaluate the functional status of athletes, to reveal the asymmetries between the operated and non-operated limbs, and to follow the developments in the operated limb (Cournapeau, Klouche and Hardy, 2013; Hegedus et al., 2015; Logerstedt et al., 2010).

When all this information is evaluated, the aim of our study is to show the evaluation of single leg hop tests in patients who have undergone ACLR with different graft methods.

2. Material and Method

The research was conducted by using Google Academic, YÖK Thesis and Pub-Med databases. The studies to be included in the research were filtered as between 2010-2022. In the literature review, the keywords to be used in literature review were determined as ‘ACL, Reconstruction, Single leg hop tests, Hamstring tendon graft, Quadriceps tendon graft, Patellar tendon graft’. Studies the participants of which were patients who did not have concomitant meniscal, chondral, or other ligamentous injuries, who had a diagnosis of isolated ACL rupture in only one knee, who had undergone ACLR by Hamstring tendon (HT), Quadriceps tendon (QT), or Patellar tendon (PT) autograft method, who did not have a history of contralateral knee surgery or injury and who had ACLR at least 6 months ago were included in the study. Studies in which any exercise program was applied on the participants were excluded.

3. Results

Table 1: Review of literature studies evaluating SLHTs after ACLR

Author	Participant group	Comparison group	SLHT	Follow up	Outcome
Barford et al. (2019)	47 males, 22 females, HT Mean age: 14-45	Contralateral limb	SH	6 months	The subjects' SH was measured 6 and 12 months after ACLR with HT autograft technique, and LSI ratios were found to be >85 in most of the groups.
Herrington et al. (2021)	10 males, HT, 5 males, PT Mean age: 22.3 Athletes	Contralateral limb	SH and CH	7.8 months	After ACLR, isokinetic and isometric quadriceps strengths of professional football players, and SH and CH were evaluated and it was found that LSI ratios did not reach >90, but the difference between the two limbs was not in the risk range for re-injury.
Kehribar et al. (2022)	23 males, HT Mean age: 24.7 Athletes	16 males MAI ACLR technique Mean age: 27.6 Athletes	SH, TH, CH, MSTH and MRH	6 months	It was shown that postoperative 6-month LSI rates were in the range of <10% in athletes who underwent both HT and MAI ACLR techniques.
Karasel et al. (2010)	33 males, 5 females, PT Mean age: 27.6	Contralateral limb	SH, TH and CH	16.2 months	Mean performance scores of the ACL extremity were found to be greater than 85% of the intact extremity. All patients returned to their intense daily activities and sports activities in 6-12 months.

Guney-Deniz et al. (2020)	18 males, 4 females, HT Mean age: 26.7 17 males, 5 females QT Mean age: 27.8 17 males, 4 females TAA (tibialis anterior allograft) Mean age: 26.4	20 control group Mean age: 28.7	SH	13.3, 13.1, 13.5 months	LSI findings were found to be 91.9% in the QT group, 91.2% in the TAA group, 95.3% in the HTA group and 94.6% in the control group.
Kılıçarslan et al. (2011)	22 males, 5 females PT Mean age: 22.85	Contralateral limb	SH	19.0 months	25 patients (92.6%) had a score of 90% or higher. Two patients (7.4%) had LSI values below 90%. One of these patients was a patient with graft failure.

4. Discussion and Conclusion

The most important criterion in evaluating the success of surgical treatment is the evaluation of RTS. Graft failure due to re-tear cases after reconstruction surgery or early return to high-energy sports can be prevented by the correct evaluation of the RTS period (Valke et al., 2020). One of the common methods of assessing the performance and RTS times of individuals with ACL failure is SLHTs. This functional test, which is an important indicator of strength and confidence, considers normal performance as the operated leg reaching 90% and above values of the unaffected leg. Different rates have been obtained in ACLR series applied with different grafts in literature (Lai et al., 2018). LSI is calculated using single leg hop for distance (SH). LSI is an easy assessment method that can be used to compare both legs in healthy, disabled individuals or individuals who have had any lower extremity operation. It is considered normal for healthy sedentary and athletes to have 10-15% difference between both legs. If the difference between the two lower extremities is more than 10% after ACLR, there is an assumption that the results are not sufficient in terms of muscle strength and jump tests (Palmieri-Smith and Lepley, 2015).

Barford et al. evaluated patients who underwent ACLR with hamstring autograft technique (HT) using SH at months 6 and 12, and found LSI rates as >85 in most of the participants. In the study, it was found that less than a third of the participants were able to regain their knee extensor muscle strength compared to the non-operated leg at the stage of resuming sports activities 6 months after the reconstruction, while less than half regained at the 12th month. As the main finding of the study, it was emphasized that SH performance ($\geq 85\%$ LSI) does not mean a satisfactory improvement in knee extensor muscle strength ($\geq 85\%$ LSI), and SH is not a proxy measure for knee extensor muscle strength for the operated leg after reconstruction. Retrospective studies on professional sports reveal that a large proportion of players return to sports at the same level after ACLR, while a significant proportion does not perform at the same level within 3 years after surgical repair (Barford et al., 2019). Herrington et al. presented the quadriceps

strength and jump performance data of a group of professional football players, all of whom received RTS permission after ACLR. The researchers found that although professional athletes were considered suitable for RTS, there were significant deficiencies in quadriceps muscle strength, muscle activation, and also jump test performance. It was hypothesized that there may be a link between these findings of the study and players who are unable to maintain their performance level or who develop secondary problems. Based on this hypothesis, the importance of regaining full quadriceps activation and strength before returning to unrestricted sports activity was emphasized (Herrington et al., 2013). Kehribar et al. compared post-operative 6-month performances of athletes on whom they applied MAI ACLR technique using adjustable cortical suspension and HT as ACLR technique. They used SLHT and LSI in different directions for evaluation in their study. The results of the study showed that there was a significant difference in SLHT between the operated side and the non-operated side in the HT graft group, while the results of SLHT and LSI were similar when both graft methods were compared. In order to compare the ACLR technique they applied with different techniques, the researchers emphasized the importance of evaluating isokinetic strength tests, electromyographic analyses and different performance components in addition to SLHT (Kehribar et al., 2022). Karasel et al. applied a modified accelerated rehabilitation program to patients who underwent ACLR with patellar tendon graft (PT), and used SH, triple leg (TH) and 90° medial rotation (MRH) hop for distance test for evaluation. As a result of functional tests, it was found that values on the operated side of 68.4% of the participants reached at least 85% of the values of the non-operated side (Karasel et al., 2010). Guney-Deniz et al. compared active joint position sense, muscle strength and knee functions in individuals who underwent ACLR with quadriceps tendon autograft (QT), HT, tibialis anterior allograft (TAA) and healthy individuals and found that LSI, which they evaluated with SH, was similar to the healthy control group (Guney-Deniz et al., 2020). Kılıçarslan et al. evaluated the duration of PT and RTS after ACLR with SH at postoperative 6 months in individuals who did active sports. As a result of SH, 25 (92.6%) of the participants had a value of $\geq 90\%$, and 2 (7.4%) had a value of $< 90\%$ (Kılıçarslan et al., 2011).

Although there are studies in the literature that use different functional performance tests, the most commonly preferred evaluation methods after ACLR are SH and LSI. Both tests have an important place in the evaluation of the individual's performance and in making the RTS decision.

Evaluation of SH and LSI after ACLR can be preferred for the decision of RTS in terms of requiring less equipment, being accessible and easy to implement. However, in case of the presence of advanced evaluation methods such as isokinetic force tests, electromyographic analyses etc., the multidimensional post-ACLR evaluation will facilitate the clinical decision-making process. It is imperative to conduct more detailed studies on the ACL, which has a high frequency of injury and surgery.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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