,

Effect of ACL Reconstruction Using Peroneus Longus versus Hamstring Autografts on Body Balance

Lena Mahmoud Abo Alfotoh Elbadawy 1, Reda Sayed Ashour 1, Mohammed Refaat abdel shafy 2, Lamiaa Kottob Elsayyad 1

[1] Biomechanics Department, Faculty of Physical Therapy, Cairo University.

[2] Orthopedic Surgery, Faculty of Medicine, Cairo University.

*Corresponding author: Lena Mahmoud Abo Alfotoh Elbadawy. Email address: lena.elbadawy@hotmail.com.

Abstract

Background: The anterior cruciate ligament (ACL) is crucial for knee stability, with ACL injuries comprising about 50% of knee injuries. Donor site morbidity influences graft selection and rehabilitation, making graft choice essential.

Purpose: This study aimed to investigate the effect of ACL reconstruction using peroneus longus tendon (PLT) versus hamstring tendon (HT) autografts on static balance.

Subjects and Methods: Thirty-six patients with ACL injury were randomly assigned to PLT (n=18) or HT (n=18) groups. Static balance was evaluated by measuring single leg stance time before surgery and at three and six months after surgery. The IdFAI questionnaire excluded participants with functional ankle instability. All patients underwent a standardized six-month rehabilitation program aimed at reducing swelling, restoring motion, increasing strength, and safely returning to activity.

Results: The PLT group demonstrated significantly greater improvements in single leg stance time at both three and six months postoperatively compared to the HT group. Only the PLT group showed significant improvement from preoperative to six-month follow-up. Both groups consistently had shorter single leg stance times on the injured leg compared to the uninjured leg.

Conclusion: The PLT group showed greater improvements in static balance at three and six months postoperatively compared with the HT group. Both groups demonstrated improvement in static balance over time. Additionally, both groups showed a significant decrease in Single Leg Stance time on the affected side compared with the non-affected side at all measurement times.

Keywords: ACL Reconstruction; Hamstring Tendon; Peroneus Longus Tendon; Static Balance, postural control

INTRODUCTION

The anterior cruciate ligament (ACL) is an important ligamentous structure in the knee joint that promotes stability. ACL injuries contribute to approximately 50% of knee injuries [1]. The incidence of ACL ruptures is estimated to be between 30 and 78 per 100,000 people per year [2, 3]. The incidence of ACL ruptures varies depending on several factors, including age, sex, sport participation, and genetics. ACL ruptures are most common in young adults, particularly women. The risk of an ACL rupture has been reported as 2-8 times higher for women than for men [4]. A systematic review study found that the risk of ACL injury was highest in football, followed by soccer, basketball, and skiing [5]. Injuries of the ACL can be treated operatively by reconstructing the ligament with an allograft or an autograft, or conservatively with a knee brace and physical therapy. **There are several criteria to be considered when deciding on this aspect, like the patient's activity level,** fear of not being able to return to a previous level of sport ability**, age, and functional demand of the patient** [6].

Many different grafts have been used for ACL reconstruction, including hamstring tendon (HT), bone-patellar tendon-bone (BPTB), and recently, the peroneus longus tendon (PLT) graft. The BPTB graft is still regarded as the gold standard graft in reconstruction as BPTB biomechanical strength is like native ACL. BPTB allows early active safe rehabilitation without an increased risk of graft failure and has good long-term results [7]. However, Angthong et al. reported that BPTB has potential morbidity at the site of graft harvesting, including patellofemoral pain, loss of motion, and patellar fracture [8].

HT autograft provides better outcomes for pain severity and rehabilitation period than the patellar tendon autograft [9]. However, there are varying muscle diameters in several individuals that lead to inefficient performance or even graft failure [10]. Additionally, HT autograft may cause a significant decrease in strength at the original HT muscle site. If medial collateral ligament injury is present along with ACL injury, then harvesting the HT can lead to medial instability of the knee joint [11]. Recently, the PLT autograft has gained popularity due to its favorable tensile strength and reported positive functional outcomes [12]. However, its use in ACL reconstruction is controversial due to concerns regarding donor site morbidity [13,14].

Importantly, the success of ACL reconstruction heavily depends on a **structured rehabilitation program**, which plays a vital role in graft protection, reducing inflammation, restoring joint mobility, rebuilding muscle strength, and gradually reintroducing functional and sport-specific activities. Rehabilitation typically begins immediately post-surgery and spans several months, progressing through clearly defined phases with individualized goals. Early stages emphasize swelling control and range of motion, while later stages incorporate strength training, proprioception exercises, and dynamic balance drills essential for return-to-sport readiness.

Neglecting proper rehabilitation may result in suboptimal recovery, delayed return to activity, or re-injury [14].

The decision to return to play after the ACL injury is a complex one that is influenced by several factors, including the severity of the injury, the athlete's age and sport, and their risk of re-injury [15]. However, one factor that is becoming increasingly important in this decision is the athlete's postural stability and balance parameters [15]. A study by Werner et al. found that athletes with poor postural stability and balance parameters were more likely to suffer a re-injury within two years of returning to play after an ACL injury [15]. This suggests that improving postural stability and balance parameters may be an important part of the rehabilitation process for athletes who want to return to high-level sports after ACL injury.

While there is substantial research on the risks and potential complications associated with ACL reconstruction using PLT autograft [12,13,14], certain aspects of this procedure remain understudied. For instance, the impact of this graft on postural control and balance has not been extensively investigated. Previous research indicated that ACL reconstruction may be associated with a decline in postural control and balance [8]. On the contrary, other researchers recently found that ACL reconstruction can lead to improved postural control and balance [16]. Hence, this study aimed to investigate the effects of ACL reconstruction using PLT autografts versus HT autografts on static balance. **This research seeks to provide valuable insights for optimizing surgical and rehabilitation strategies, ultimately improving patient outcomes and minimizing donor site complications.**

MATERIALS AND METHODS

Study Design

This study involved a mixed repeated measure design, “Two-way design with one repeated factor” in which patients were assigned to two groups (hamstring and peroneus longus). Outcome measures were collected three times; preoperative, three-month postoperative, and six-month postoperative. This study was conducted under the Declaration of Helsinki's guidelines for human research and approved by the institutional review board at the Faculty of Physical Therapy, Cairo University with reference number [P.T.REC/012/005015].

Participants

Forty male patients with ACL injury were referred by two orthopedic surgeons. Of the 40 patients who were referred, 36 met the inclusion criteria that were verified by the principal researcher. The 36 patients (18 in the HT group and 18 in the PLT group) completed the six-month study duration (figure 1).

The inclusion criteria for this study were patients’ age ranging between 15 to 45 years and unilateral isolated ACL tear without any concomitant tear of other ligaments in the knee. Additionally, participants should have no evidence of meniscal repair and must have had bilateral healthy ankles before undergoing surgery. Patients were excluded from the study if they had a pre-existing ankle injury or ankle instability, any associated ligament injury, chondral damage, meniscal injury, fracture around the knee, or the presence of a pathologic condition in the lower extremity or an abnormal contralateral knee joint. Individuals with visible malalignments in the lower extremities or a history of previous surgery to the affected knee were also excluded [17].

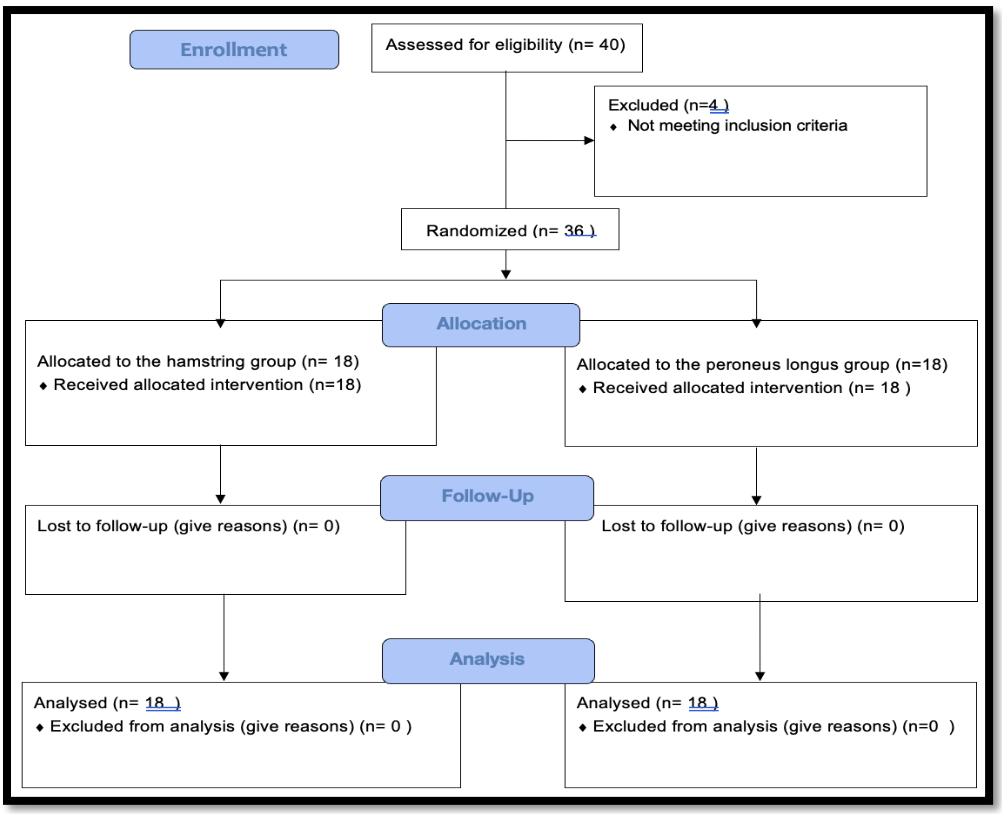

Figure (1): Flow chart for patients' enrollment

Measurement procedure

The nature of the study, aims, equipment, and procedures were explained to the participants before starting the measurements to be familiar with the study. The inclusion and exclusion criteria were verified. Each participant was asked to sign an informed consent of participation in the study. The recording data sheet was filled in for each participant.

The Identification of Functional Ankle Instability (IdFAI)

The IdFAI is a validated, self-reported measure that combines elements from previous tools, such as the Cumberland Ankle Instability Tool (CAIT) and the Ankle Instability Instrument (AII), to assess perceived ankle instability, history of ankle sprains, and episodes of "giving way" [18]. A total score of 11 or higher indicates the presence of ankle instability, while a score of 10 or lower suggests the absence of ankle instability [18]. This threshold has demonstrated good diagnostic accuracy, with strong sensitivity (85%) and specificity (82%) in classifying individuals with ankle instability [18]. In this study, the IdFAI was used as a screening tool to **exclude any participants with functional ankle instability**, thereby ensuring a homogeneous sample of individuals without clinically relevant instability symptoms. This approach enhanced the internal validity and reproducibility of the study findings.

Single Leg Stance test (SLS)

SLS is a reliable method of quantifying static balance ability and impairment of body proprioception, especially when performed in a static position [19]. The patient was asked to cross his arms over the chest and stand on the tested limb, with the other limb raised (figure 2). Each patient was asked to focus on a spot on the wall at eye level with eyes open during the test duration. The investigator was used a stopwatch to measure the duration of the patient's SLS. The stopwatch was started when the patient raised his foot off the floor. Time was ended when the patient either: (1) uncrossed his arms, (2) moved the raised foot toward or away from the standing limb or touched the floor, or (3) rotated the weight-bearing foot on the ground to maintain his balance. The procedure was repeated three times, and each time was recorded on the data collection sheet. The average of the three trials was recorded [19]. After another 2-minute rest, the same testing procedure was repeated for the other LL. Patients were assessed three times: preoperative, 3 months, and 6 months postoperative.

Figure (2): Single Leg Stance test; the patient crosses his arms over the chest and stands on the tested limb with the other limb raised.

Treatment procedure

Operative procedure

All patients underwent surgical procedures performed by one orthopedic surgeon. The patient was laid supine. An arthroscopic assessment of medial meniscus and ACL rupture was performed, followed by graft harvesting of either the ipsilateral peroneus longus or the hamstring tendon. PLT graft; tenodesis for the peroneus longus and peroneus brevis tendons was performed, and the PLT was stripped proximally with a tendon stripper to at least 5 cm from the fibular head to prevent peroneal nerve injury. This allowed for the harvesting of the PLT graft. The longitudinal skin incision was made at 2 to 3 cm (2 finger-breadths) above and 1 cm (1 finger-breadth) behind the lateral malleolus. To get the right graft size, a conventional technique for graft preparation was followed [20]. HT graft; a 3-cm incision made one fingerbreadth medial and two fingerbreadths distal to the tibial tubercle directly above the pes anserinus tendons is used to harvest the semitendinosus and gracilis tendons.

The intercondylar notch was then cleared of fibrous tissue to ease visualization during preparation of the tunnels, but some remaining ACL fibers were preserved as a reference for tunnel placement. The femoral tunnel and the tibial tunnel were then prepared independently. After drilling the tunnels, proceeded with the implantation of the tendon with graft fixation on the femoral side with a button (XO Button Conmed″, USA) and graft fixation on the tibial side with a bio-absorbable screw (Bioscrew., Conmed″, USA) after appropriate tensioning with a graft tensioner [20].

Postoperative rehabilitation protocol

All participants followed a structured rehabilitation protocol based on guidelines established by Logerstedt et al. (2017). The program was started immediately after the operation and lasted for six months. It was divided into six progressive phases, each with specific goals and clinical criteria for advancement. Phase I (0-2 weeks) focuses on protecting the graft, reducing swelling, and restoring knee mobility, with early strengthening exercises and partial weight bearing. Phase II (3-5 weeks) aims to restore knee flexion, normalize gait, and enhance strength through biking, stretches, and balance exercises. Phase III (6-8 weeks) continues ROM maintenance, strength progression, and introduces low-impact cardio and movement pattern exercises. Phase IV (9-12 weeks) advances sport-specific training and plyometrics, progressing from partial to full weight bearing. Phase V (3-5 months) focuses on interval running and plyometrics, with functional assessments to ensure readiness for sports. Each phase ensures a controlled recovery and gradual return to activity. Phase VI (6+ months) clears the participant for full sport-specific drills, including multi-plane plyometrics and agility, aiming for symmetrical performance and preventing re-injury [21].

Statistical analysis

All statistical measures were performed through the statistical package for social studies (SPSS) version 20 for Windows. Initially, data were screened for normality assumption using the Shapiro-Wilk test, homogeneity of variance, and presence of extreme scores. As the data revealed not to violate the normality and homogeneity assumptions, parametric calculations were conducted. This study involved three independent variables; the first one was the tested group “between-subjects factor” which had two levels; PLT group and HT group. The second one was the testing time “within-subject factor” which had three levels: pre, 3-month post, and 6-month post ACL reconstruction. The third one was the tested side, "within-subject factor" which had two levels: the affected and non-affected sides. Additionally, this study involved one dependent variable, the SLS time. Accordingly, 2x3x2 Mixed Design Analysis of Variance (ANOVA) was used for these comparisons with the alpha level of significance set at 0.05.

RESULTS

The Unpaired t-test was conducted to reveal the presence of any significant differences in the mean values of the patients' age, body mass, height, BMI, and the Identification of Functional Ankle Instability (IdFAI) score for both the affected and non-affected sides between the two groups. The test revealed no significant differences ($p > 0.05$) in the mean values of all measured variables between both groups (Table 1).

Table (1): The Unpaired t-test for demographic data and functional ankle instability of the Peroneus longus and Hamstring groups

	Peroneus group (n=18)	**Hamstring group (n=18)**	**Unpaired t-test**	
			t-value	**p-value**
Age (y)	23.11± 3.64	27.38± 4.80	-3.010	0.159
Mass (kg)	80.47± 8.26	78.72± 11.38	0.528	0.184
Height (m)	1.74± 0.071	1.75± 0.087	0.290	0.293
BMI (kg/m^2)	25.22± 2.76	24.12± 3.51	1.050	0.379
IdFAI score for the affected side	0.833± 2.007	0.611± 1.50	0.376	0.709
IdFAI for the non-affected side	1.055± 2.127	0.888± 1.529	0.270	0.789

*Significant at alpha level < 0.05, data are expressed as Mean ±SD, IdFAI=Identification of Functional Ankle Instability

2x3x2 Mixed Design ANOVA revealed significant effects for group ($F(1, 34) = 9.00$, $p = 0.005$), time ($F(1, 34) = 30.006$, $p < 0.001$) and side ($F(1, 34) = 40.301$, $p < 0.001$) for the SLS time. However, there was no significant interaction between the three independent variables: tested group, tested time, and tested side for the SEBT score ($F(1, 34) = 1.38$, $p = 0.259$).

Considering the group effect, the pairwise comparisons revealed no significant difference in the preoperative SLS time of the affected side between both groups ($p > 0.05$). However, significant increases in the 3-month and 6-month postoperative mean values of the SLS time were detected in the affected side of the PLT group compared with the HT group ($p < 0.05$) (Table 2).

Regarding the time effect, Post-hoc comparisons revealed no significant differences in the mean values of the SLS time of the affected side 3 months postoperatively in both groups compared with their preoperative values ($p > 0.05$). However, there was a significant improvement (increase) in the mean values of the SLS time of the affected side 6 months postoperatively in both groups compared with their 3-month postoperative values ($p < 0.05$). Moreover, there were significant improvements (increases) in the mean values of the SLS time of the affected side 6 months postoperatively in PLT group compared with their preoperative values ($p < 0.05$). While no significant difference in the mean values of the SLS time of the affected side 6 months postoperative in HT group compared with their preoperative values ($p > 0.05$) (Table 2).

For the side effect, the pairwise comparisons revealed a significant decrease in SLS time of the affected side compared with the non-affected side in the PLT group preoperatively and 6 months postoperatively ($p < 0.05$). However, no significant difference was detected between both sides of PLT group at 3 months postoperative ($p > 0.05$). Moreover, the HT group showed significant decreases in the SLS time of the affected side compared with the non-affected side preoperatively, at 3 months, and 6 months postoperatively ($p < 0.05$) (Table 3).

Table (2): Descriptive statistics and multiple pairwise comparison tests of the Single Leg Stance time score for the affected side preoperative, 3 months, and 6 months postoperative in the two groups.

Affected	**PLT group (M±SD)**		**HT group (M±SD)**		**Group effect (PLT versus HT)** MD (95% CI)	p-value
Pre	100.56±52.16		73.47± 39.92		27.09 (-4.38 to 58.54)	0.089
3 months	118.85± 74.92		74.22± 24.85		44.63 (6.81 to 82.435)	0.022*
6 months	177.50± 87.28		102.50± 19.19		75.00 (32.19 to 117.8)	0.001*
Time effect	**MD (95% CI)**	**p-value**	**MD (95% CI)**	**p-value**		
Pre-3 months	-18.29 (-41.50 to 4.92)	0.166	-0.75 (-23.96 to 22.46)	1.000		
Pre-6 months	-76.94 (109.84 to -44.04)	0.001*	-29.03 (-61.923 to 3.868)	0.099		
3 months- 6 months	-58.65 (-79.74to -37.56)	0.001*	-28.28 (-49.37 to -7.184)	0.006*		

*Significant at alpha level < 0.05, M: mean, SD: standard deviation, MD (95% CI): Mean difference (95% confidence interval), p: significance.

Table (3): Descriptive statistics and multiple pairwise comparison tests of the Single Leg Stance time score for the affected and non-affected sides preoperative, 3 months, and 6 months postoperative in the two groups.

	PLT group (M±SD)			HT group (M±SD)		
	Affected	Non-affected	Mean difference (p)	Affected	Non-affected	Mean difference (p)
Pre	100.56±52.16	169.15±126.58	-68.594 (0.001*)	73.47±39.92	120.29±10.89	-46.817 (0.015*)
3 months	118.85± 74.92	142.07± 31.95	-23.228 (0.052)	74.22±24.85	123.87± 9.28	-49.650 (0.001*)
6 months	177.50± 87.28	221.05± 95.11	-43.55 (0.013*)	102.50±19.19	149.94±53.08	-47.44 (0.003*)

*Significant at alpha level < 0.05, M: mean, SD: standard deviation, p: significance

DISCUSSION

The current study revealed a non-significant difference in the preoperative SLS time mean values of the affected side between the two tested groups ($p > 0.05$). However, significant increases in the 3-month and 6-month postoperative mean values of the SLS time were detected in the affected side of the PLT group compared with the HT group ($p < 0.05$). Given that both groups followed the same rehabilitation protocol, the observed differences in postoperative SLS time are less likely attributable to variations in rehabilitation strategies.

This finding suggests that the PLT graft, even with a standardized rehabilitation program, may inherently facilitate a more rapid recovery of static balance compared with the HT graft. This could be due to several factors. Firstly, **Physiologically**, the PL group might experience enhanced proprioceptive feedback and neuromuscular control in the ankle due to compensatory adaptations following tendon harvest, leading to improved SLS performance. The ankle involvement in PL harvest might stimulate a more robust proprioceptive feedback loop. The loss of the PL tendon might force the body to rely more heavily on other muscles and proprioceptive pathways to maintain ankle stability [22]. This could lead to the development of compensatory mechanisms that enhance proprioceptive feedback and improve overall neuromuscular control, leading to improved neuromuscular control and stability, benefiting both the ankle and the knee.

Secondly, the impact of hamstring donor site morbidity, such as muscle weakness or altered knee biomechanics, may hinder the HT group's recovery of static balance, even with a standardized rehabilitation approach [23, 24]. Additionally, Psychological factors may have contributed to the improved static balance in the PLT group. The experience of symptoms affecting both the knee and ankle could have increased patients' focus on their lower limbs and their drive to engage in rehabilitation, ultimately leading to better static balance [25].

To the best of our knowledge, a limited body of research directly compares static balance outcomes following ACL reconstruction utilizing PLT versus HT autografts. Consequently, a direct comparison of our findings with existing literature presents a notable challenge. However, by extrapolating from broader literature pertaining to PLT grafts and the trajectory of recovery post-ACL reconstruction, the current findings, which demonstrated improvements in static balance within the PLT group at both 3- and 6-month postoperative assessments in comparison to the HT group, are congruent with observed trends of functional enhancement following PLT graft utilization. While direct comparisons are limited, studies examining static balance outcomes associated with PLT grafts have generally indicated positive results concerning ankle stability and overall lower extremity function [26].

Regarding the time effect, the current study demonstrated a statistically significant improvement in SLS time between 3- and 6-month post-ACL reconstruction in both the PLT and HT autograft groups ($p < 0.05$). This finding aligns with the typical recovery trajectory following ACL reconstruction, as the graft undergoes further ligamentization and surrounding tissues continue to heal [27]. The progressive rehabilitation program, which emphasized strength training, proprioceptive exercises, and functional activities during this period, likely contributed to the observed gains [28]. Furthermore, reduced pain and swelling as well as improved neuromuscular adaptation, may have facilitated enhanced functional performance. These findings underscore the importance of continued rehabilitation beyond three months to maximize functional recovery following ACL reconstruction [29]. However, increased confidence and reduced fear of movement are likely contributing psychological factors to the observed improvements. As patients gain comfort with their recovering limb, they may be more inclined to challenge their balance and perform the SLS test with greater assurance and stability [30].

Moreover, the significant postoperative improvement in static balance observed in the PLT group, compared to the HT group, may be attributed to a combination of psychological and physiological factors. Psychologically, PLT patients may have developed greater awareness and motivation due to the dual impact on both the knee and ankle, which could have enhanced their engagement in rehabilitation and contributed to superior balance outcomes [25]. Physiologically, the harvest of the PLT may have triggered compensatory neuromuscular adaptations and increased reliance on proprioceptive mechanisms to maintain lower limb stability. These changes likely enhanced postural control and contributed to the observed improvements in static balance [22]. Together, these findings suggest a multifactorial recovery process, emphasizing the importance of addressing both psychological and physiological elements in rehabilitation strategies following ACL reconstruction.

The current study's observation of notable improvements in static balance postoperatively is strongly supported by a growing body of research examining static balance recovery following ACL reconstruction. [25,26,31,32,33]. Kotsifaki et al. (2023) reported significant improvements in SLS performance at six-month post-surgery, aligning with the current study findings of notable improvements [28].

Moreover, Fernandes et al. (2016), focusing on the relationship between proprioception and static balance, also found marked improvements in static postural control from three- to six-month post-reconstruction of the ACL [34]. In addition, Pk & Mm (2023), utilizing the Humac Balance System, reported statistically significant improvements in SLS balance on the affected leg, further reinforcing the observed pattern of improvement [25]. Notably, these studies employed diverse assessment tools, including force plates [28], a combination of clinical and instrumented assessments [34], and the Humac Balance System [35], yet consistently reported significant improvements in static balance. This convergence of findings across different methodologies and patient populations provides compelling evidence that static balance increases postoperatively, reinforcing the validity and clinical significance of the study's observations.

While the current study showed consistent improvement in static balance between three- and six-month post-ACL reconstruction, Myer et al. (2020) found inconsistent static balance gains, attributing this to individual variability and rehabilitation differences [36]. Betsch et al. (2022) reported no significant static balance changes in younger athletes, potentially due to age-related recovery patterns [37].

For the side effect, the current study revealed a significant decrease in SLS time on the affected side compared with the non-affected side in both PLT and HT groups. This finding was consistent across all time points (preoperative, three-month, and six-month postoperative) for the HT group and at preoperative and six-month postoperative time points for the PLT group ($p < 0.05$). This indicates a persistent asymmetry in static balance performance between the affected and non-affected limbs in both groups throughout the study period.

The preoperative side-to-side difference in both groups likely reflects the initial functional deficits from the ACL injury, leading to instability and impaired balance [24]. Postoperatively, complete static balance recovery was not achieved in either group, possibly due to factors like initial ACL injury, surgical trauma, and rehabilitation limitations [28]. Both groups may have experienced lingering proprioceptive deficits, impacting their ability to maintain static balance. Increased SLS time on the non-affected side due to the rehabilitation could contribute to the observed differences. Rehabilitation exercises targeting balance, coordination, and proprioception may improve SLS time on the non-affected side [37,38]. Thus, the observed side-to-side differences may be partially attributed to the enhancement, rather than absolute deficits in the affected limb.

The study revealed a significant side-to-side difference in SLS time at three months postoperatively in the HT group, while the PLT group showed no such difference. This disparity likely reflects distinct recovery dynamics between the two graft types. In the HT group, the continued imbalance may stem from persistent donor site morbidity—such as hamstring weakness or altered knee biomechanics—that disproportionately affects the affected side, delaying symmetrical balance restoration [26]. Conversely, the PLT group may have benefited from compensatory neuromuscular adaptations involving the ankle and surrounding musculature, which facilitated more balanced recovery between limbs [33]. Importantly, the absence of a significant difference in the PLT group does not necessarily indicate full recovery but rather a relative improvement in the affected limb that minimized asymmetry with the non-affected side. These findings suggest that PLT grafts may promote more rapid re-establishment of limb symmetry in static balance, potentially due to both physiological adaptations and differences in graft site morbidity.

The current study revealed a consistent pattern of static balance deficits, as evidenced by significantly decreased SLS time on the affected side compared with the non-affected side in both PLT and HT groups. This observation is supported by findings from Hewett et al. (2022) utilizing a force plate system, which demonstrated significant static balance deficits on the affected limb at three- and six-months post-ACL reconstruction, mirroring the current finding of decreased SLS time [27]. Therefore, while the current findings, in addition to these studies, indicate that *affected side static balance does not fully recover to match the non-affected side within the observed timeframe*, they also underscore the potential for rehabilitation interventions to mitigate these deficits and improve overall static balance outcomes.

On the contrary, the findings of the current study are opposed by those reported by Yılmaz et al. (2024). Utilizing the Biodex Stability System, researchers reported no significant differences in static balance between the affected and non-affected sides at six months postoperatively [41]. This discrepancy suggests that the choice of assessment tool may significantly influence the observed recovery patterns. The Biodex Stability System, which quantifies stability indices during SLS, may capture different aspects of static balance compared with our SLS time measurement, potentially explaining the divergent findings.

Furthermore, Johnson & Lee (2024), while focusing primarily on dynamic stability, included a component of SLS testing in their evaluation [39]. They observed improvements in both limbs over time but noted persistent deficits on the affected side compared with preoperative measures, rather than solely against the non-affected side resulting continue asymmetry. The improvements they noted in both limbs may have masked a true deficit when compared to the non-affected leg. Additionally, Pk & Mm (2023), utilizing the Humac Balance System, found improvements in static balance postoperatively; however, they found no difference between the affected and non-affected leg. This further emphasizes that the assessment tool used and the method of comparison can drastically change the outcome of the study [31].

Limitations

This study was limited to male participants aged 15 to 45 years, reducing generalizability to females and other age groups. It assessed only static balance using the SLS test, without evaluating dynamic balance or broader functional outcomes. Additionally, the follow-up period was restricted to six months, limiting insights into long-term recovery. Future studies should include female participants, assess dynamic balance and other functional outcomes, extend follow-up durations, and investigate the mechanisms behind graft-specific differences in balance recovery, such as proprioception and muscle strength.

Conclusion

The PLT group demonstrated greater improvements in static balance at three and six months postoperatively compared to the HT group. Both groups showed an overall improvement in balance over time and a consistent reduction in SLS time on the affected side.

References

1. Fernandes TL, Felix EC, Bessa F, Luna NM, Sugimoto D, Greve JM, et al. Evaluation of static and dynamic balance in athletes with anterior cruciate ligament injury - A controlled study. Clinics (Sao Paulo, Brazil). 2016;71(8):425–9.
2. Sanders TL, Maradit Kremers H, Bryan AJ, Larson DR, Dahm DL, Levy BA, et al. Incidence of anterior cruciate ligament tears and reconstruction: a 21-year population-based study. The American journal of sports medicine. 2016;44(6):1502-7.
3. Utoyo GA. ACL Reconstruction In Laxity Patient. Orthopaedic Journal of Sports Medicine. 2024;12(10 suppl3):2325967124S00377.
4. Devana SK, Solorzano C, Nwachukwu B, Jones KJ. Disparities in ACL reconstruction: the influence of gender and race on incidence, treatment , and outcomes. Current reviews in musculoskeletal medicine. 2022:1-9.
5. Bram J, Magee L, Mehta N, Patel N, Ganley T. Anterior Cruciate Ligament Injury Incidence in Adolescent Athletes: A Systematic Review and Meta-analysis. The American Journal of Sports Medicine. 2020;49.
6. Goetz G, De Villiers C, Sadoghi P, Geiger-Gritsch S. Allograft for Anterior Cruciate Ligament Reconstruction (ACLR): A Systematic Review and Meta-Analysis of Long-Term Comparative Effectiveness and Safety. Results of a

Health Technology Assessment. Arthroscopy, Sports Medicine, and Rehabilitation. 2020;2:e873 - e891.

7. Chung K, Ham H, Kim S, Seo Y . Effect of Graft Choice for ACL Reconstruction on Clinical Outcomes in Combined ACL and MCL Injuries: Comparison Between Bone-Patellar Tendon-Bone and Hamstring Autografts. Stomatology. 2024;13(21):6316.
8. Angthong C, Chernchujit B, Apivatgaroon A, Chaijenkit K, Nualon P, Suchao-In K. The anterior cruciate ligament reconstruction with the peroneus longus tendon: a biomechanical and clinical evaluation of the donor ankle morbidity. J Med Assoc Thai. 2015;98(6):555-60.
9. Sadeghpour A, Ebrahimpour A, Attar B, Azizian Z . Comparison of patellar versus hamstring tendon autografts in arthroscopic anterior cruciate ligament reconstruction: A 6-month follow-up of a randomized clinical trial. Journal of research in medical sciences : the official journal of Isfahan University of Medical Sciences. 2017;22:105.
10. Fan L, Zhang L, Tang J, Xu Z, Fu W . Comparison of clinical outcomes between hamstring tendon autografts and hybrid grafts in ACL reconstruction: a systematic review and meta-analysis. Journal of Orthopaedic Surgery and Research. 2024;19(1).
11. Figueroa F, Figueroa D, Calvo R, Vaisman A, Espregueira-Mendes J. Graft choice in combined anterior cruciate ligament and medial collateral ligament reconstruction. EFORT open reviews. 2020;5(4):221–5.
12. Shi F-D, Hess DE, Zuo J-Z, et al. Peroneus longus tendon autograft is a safe and effective alternative for anterior cruciate ligament reconstruction. 1 J Knee Surg. 2019;32(8):804-11.
13. Kusumastutia AH, Rukmoyo T, Rhatomy S, Sakti YM. Anterior Cruciate Ligament Reconstruction with Peroneus Longus Tendon Autograft: Functional Outcome and Donor Site Morbidity. Orthopaedic Journal of Sports Medicine. 2020;8(Suppl 6):2325967120S00084.
14. Kumar VK, Narayanan SK, Vishal RB. A study on peroneus longus autograft for anterior cruciate

ligament reconstruction. International Journal of Research in Medical Sciences. 2019;7(12):7419.

15. Werner JL, Burland JP, Mattacola CG, Toonstra J, English RA, Howard JS. Decision to return to sport participation after anterior cruciate ligament reconstruction, part II: self-reported and functional performance outcomes. Journal of athletic training. 2018;53(5):464-74.
16. Sahoo PK, Sahu MM. (2021) Quantitative assessment of postural balance in patients with chronic anterior cruciate ligament injury- A controlled study. J Clin Orthop Trauma doi: 10.1016/j.jcot.2021.10164.
17. Keyhani S, Qoreishi M, Mousavi M, Ronaghi H, Soleymanha M. Peroneus Longus Tendon Autograft versus Hamstring Tendon Autograft in Anterior Cruciate Ligament Reconstruction: A Comparative Study with a Mean Follow-up of Two Years. PubMed. 2022;10(8):695–701.
18. Donahue M, Simon J, Docherty CL, Schrader J, Paranjape S. The Identification of Functional Ankle Instability: A Tool for Clinicians. Journal of Athletic Training. 2011;46(5):549–57.
19. Ponce-González J , Sanchis-Moysi J , Henríquez JJ , Arteaga-Ortiz R , Calbet J , Dorado C. A reliable unipedal stance test for the assessment of balance using a force platform. The Journal of sports medicine and physical fitness. 2014;54:108-17.
20. Abdelgaliel A, Abdelsalam M, El-Hefnawy M, Salama A. Comparison between Peroneus Longus and Hamstring Grafts for Anterior Cruciate Ligament Reconstruction. Zagazig University Medical Journal. 2023b;0(0):0. Available from: https://doi.org/10.21608/zumj.2023.247985.3003
21. Logerstedt DS, Scalzitti DA, Risberg MA, Engebretsen L, Webster KE, Feller J, et al. Knee Stability and Movement Coordination Impairments: Knee Ligament Sprain Revision 2017: Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability and Health from the Orthopaedic Section of the American Physical Therapy Association. Journal of Orthopaedic & Sports Physical

Therapy. 2017;47(11):A1-A47.

22. Nakagawa L, Hoffman M. Performance in Static, Dynamic, and Clinical Tests of Postural Control in Individuals With Recurrent Ankle Sprains. Journal of Sport Rehabilitation. 2004;13(3).
23. Herzog MM, Marshall SW, Lund JL, Pate V, Mack CD, Spang JT. (2018). Trends in Incidence of ACL Reconstruction and Concomitant Procedures Among Commercially Insured Individuals in the United States, 2002-2014. Sports Health , 10 (6), 523-531.
24. Hospodar SJ, Miller MD. Controversies in ACL reconstruction: bone patellar tendon-bone anterior cruciate ligament reconstruction remains gold standard. Sports Medicine and Arthroscopy Review. 2009;17(4):242-6.
25. Wikstrom EA, Song K, Pietrosimone BG, Blackburn JT, Padua DA. Visual Utilization during postural control in anterior cruciate ligament– deficient and –Reconstructed patients: Systematic Reviews and Meta-Analyses. Archives of Physical Medicine and Rehabilitation. 2017;98(10):2052–65.
26. Hagen M, Vanrenterghem J, Van Den Borne Y, Diaz MA, Verschueren S, Robinson MA, Smeets A. Hamstrings and quadriceps weaknesses following anterior cruciate ligament reconstruction persist up to 6 months after Return-to-Sport: an angle-specific strength analysis. International Journal of Sports Physical Therapy. 2025;20(2).
27. Hewett TE, Myer GD, Ford KR, Paterno MV, Quatman CE. Mechanisms, prediction, and prevention of ACL injuries: Cut risk with three sharpened and validated tools. Journal of orthopaedic research : official publication of the Orthopaedic Research Society. 2016;34(11):1843–55.
28. Kotsifaki A, Tsiridis E, Papadopoulos PE. "Psychological factors influencing functional recovery after anterior cruciate ligament reconstruction: A systematic review.". Journal of Orthopaedic & Sports Physical Therapy. 2021;51(5):300-10.
29. Grindem H, Snyder-Mackler L, Moksnes H , et al Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the

,

Delaware-Oslo ACL cohort study British Journal of Sports Medicine 2016; 50: 804-808.

30. Ageberg E, Roos EM. The association between knee confidence and muscle power, hop performance, and postural orientation in people with anterior cruciate ligament injury. Journal of Orthopaedic & Sports Physical Therapy. 2016;46
31. Pk S, Mm S. Analysis of Postural Control following Anterior Cruciate Ligament Reconstruction with Ipsilateral Peroneus Longus Tendon Graft. Malaysian Orthopaedic Journal. 2023;17(1):133–41.
32. Yao S, Fu BS, Yung PSH. Graft healing after anterior cruciate ligament reconstruction (ACLR). Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology. 2021;25:8–15.
33. Paço M, Peysson M, Dumont E, Correia M, Quialheiro A, Chaves P. The Effect of Physiotherapy on Arthrogenic Muscle Inhibition After ACL Injury or Reconstruction: A Systematic Review. Life (Basel, Switzerland). 2024; 14 (12), 1586.
34. Fernandes TL, Felix EC, Bessa F, Luna NM, Sugimoto D, Greve JM, et al. Evaluation of static and dynamic balance in athletes with anterior cruciate ligament injury - A controlled study. Clinics (Sao Paulo, Brazil). 2016; 71 (8), 425–429.
35. Attalin B, Sagnard T, Laboute E, Forestier N, Rémy-Néris O, Picot B. Proprioceptive Reweighting and Postural Control are Impaired Among Elite Athletes Following Anterior Cruciate Ligament Reconstruction. International journal of sports physical therapy. 2024; 19 (11), 1314–1323.
36. Mayer SW, Queen RM, Taylor D, Moorman III CT, Toth AP, Garrett Jr WE, Butler RJ. Functional testing differences in anterior cruciate ligament reconstruction patients released versus not released to return to sport. The American journal of sports medicine. 2015;43(7):1648-55.
37. Betsch M, Darwich A, Chang J, Whelan D, Ogilvie-Harris D, Chahal J, Theodoropoulos J. Wide Variability in Return-to-Sport Criteria used by Team Physicians After Anterior Cruciate Ligament Reconstruction in

Elite Athletes-A Qualitative Study. Arthroscopy, sports medicine, and rehabilitation . 2022; 4 (5), e1759–e1766.

38. Bettariga F, Maestroni L, Martorelli L, Jarvis P, Turner A, Bishop C. (2022). The Effects of a Unilateral Strength and Power Training Intervention on Inter-Limb Asymmetry and Physical Performance in Male Amateur Soccer Players. Journal of Science in Sport and Exercise. 5.
39. Johnston W, Dolan K, Reid N, Coughlan GF, Caulfield B. Investigating the effects of maximal anaerobic fatigue on dynamic postural control using the YBalance Test. Journal of Science and Medicine in Sport. 2018;21(1):103–8.
40. Griffin LY, Albohm MJ, Arendt EA, Bahr R, Beynnon BD, DeMaio M, et al. Understanding and preventing noncontact anterior cruciate ligament injuries: A review of the Hunt Valley II Meeting, January 2005. American Journal of Sports Medicine. 2006;34(9):1512-32.
41. Yılmaz O, Soylu Y, Erkmen N, Kaplan T, Batalik L. Effects of proprioceptive training on sports performance: a systematic review. BMC sports science, medicine & rehabilitation. 2024; 16 (1), 149.