Journal of Surgery and Trauma. 2027; 15(x):xx-xx. https://jsurgery.bums.ac.ir

Letter to Editor

Open Access Publish Free

Graft Selection in ACL Reconstruction: Implications for Walking and Running Biomechanics

Ebrahim Piri[1]✉, AmirAli Jafarnezhadgero[1], Sara Kahnemooei[1], Makwan Jabar Ali[2]

[1] Department of Sports Biomechanics, Faculty of Educational Sciences and Psychology, University of Mohaghegh Ardabili, Ardabil, Iran

[2] Department of Physical Education, College of Physical Education and Sport Sciences, University of Halabja, Halabja, Kurdistan Region, Iraq

✉**Corresponding Author:** Tel: +989145384056; Email: ebrahimpiri@uma.ac.ir

Received: April 17, 2026 **Revised:** October 03,2026 **Accepted:** October 10,2026

Citation: Piri E, Jafarnezhadgero AA, Kahnemooei S, Jabar Ali M. Graft Selection in ACL Reconstruction: Implications for Walking and Running Biomechanics. J Surg Trauma. 2027;15(x):xx-xx. DOI:10.61882/jsurgtrauma.15.x.xx

Dear Editor,

Anterior cruciate ligament (ACL) injury is one of the most common ligamentous disruptions in sports, with reconstruction rates exceeding 200,000 annually worldwide [1]. While advances in fixation techniques and early mobilization protocols have markedly improved stability and short-term outcomes, deficits in symmetrical movement remain across graft types [2]. Subtle deviations in knee flexion, limb loading, and inter-limb coordination often persist years after surgery [3]. Restoration of mechanical integrity does not guarantee restoration of physiological function, emphasizing a crucial gap between structural success and biomechanical recovery. Choice of graft substantially affects donor-site morbidity, proprioceptive reintegration, and kinetic balance. Therefore, understanding graft specific biomechanical adaptations is important for interpreting postoperative locomotor recovery. This editorial synthesizes evidence on how graft type alters both biological integration and neuromuscular reorganization governing walking and running mechanics.

Graft Construction and Healing Biology

Each graft exhibits distinct histological and mechanical properties influencing healing and biomechanical expression:

BPTB Autograft: Comprises central patellar tendon secured via bone plugs. Allows rapid bone-to-bone integration, superior initial fixation [4]. However, anterior knee pain and extensor mechanism inhibition are frequent.

Hamstring Autograft (STG): Provides higher elasticity and less anterior knee morbidity. Soft-tissue-to-bone healing is slower, and donor-site weakness of medial hamstrings can persist [5].

Quadriceps Tendon Autograft: Larger cross-sectional area, adjustable thickness, and reduced harvest pain relative to BPTB. Healing includes a mixed bone–tendon interface [6]. However, long term biomechanical outcomes remain relatively under studied, representing a valuable opportunity for future longitudinal research.

Allograft: Variable mechanical reliability depending on processing (e.g., irradiation, freeze-drying). Facilitates faster operating time but often slower remodeling and impaired proprioception [7].

Biomechanical Consequences for Walking Patterns

Walking recovery depends on synchronization of quadriceps–hamstring activation. BTB grafts often cause diminished quadriceps torque, leading to compensatory hip extension strategies during stance [8]. Hamstring grafts may produce asymmetrical loading patterns because medial hamstring harvesting reduces restraint against tibial rotation [9]. Motion analysis studies illustrate that gait asymmetry persists even 12–24 months post reconstruction [10]. These alterations typically

[Downloaded from jsurgery.bums.ac.ir on 2026-11-05]

Copyright © 2027, Journal of Surgery and Trauma. This is an open access article distributed under the terms of the Creative Commons Attribution License (CC-By-NC4.0: https://creativecommons.org/licenses/by-nc/4.0/legalcode.en), which permits use, distribution, and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

include reduced stance phase knee flexion angles and decreased ground reaction force peaks. Electromyographic evidence suggests increased reliance on lateral stabilizing musculature. Together, these findings indicate that many patients achieve functional compensation rather than complete restoration of normal gait mechanics.

Running Mechanics and High-Demand Function

Running amplifies subtle gait discrepancies because of higher joint power demands. BTB reconstructions often show reduced knee extensor power generation and modified patellofemoral loading patterns [11]. Hamstring grafts demonstrate increased tibial rotation variability and altered hip to knee coordination during running tasks [12]. QT autografts appear to restore sagittal plane symmetry more rapidly than other grafts. However, the current evidence base is limited and mostly derived from small cohorts, highlighting the need for larger prospective studies [13]. Across graft types, elite athletes frequently display reduced stride efficiency and increased energetic cost for up to 18 months after surgery. Persistent biomechanical asymmetry may contribute to long term joint loading imbalance and increased risk of PTOA.

Neurophysiological Perspective

Mechanoreceptor disruption during graft harvesting influences afferent input to the central sensorimotor system [14]. BTB graft harvest affects patellar tendon Golgi organ signaling, while hamstring harvest reduces muscle spindle sensitivity to tibial rotation. Functional MRI studies show altered cortical representation of the operated limb up to two years post-surgery [15]. These neural adaptations likely contribute to persistent movement asymmetry despite restoration of ligament stability.

Table 1. Comparative Overview of Common ACL Graft Types and Biomechanical Implications.

Graft Type	Mechanical Properties	Healing Mode	Donor-Site Effects	Biomechanical Influence on Gait/Running	Clinical Pros/Cons
Patellar Tendon [4]	High stiffness; direct bone plugging	Bone-to-bone, rapid	Anterior knee pain; quadriceps inhibition	Reduced knee extensor moment and altered patellofemoral loading during stance phase.	+Excellent fixation; −Higher anterior knee pain & hypoesthesia
Hamstring [5]	Moderate stiffness; good elasticity	Tendon-to-bone, gradual incorporation	Medial hamstring weakness; possible tibial IR increase	Greater limb-loading asymmetry and increased reliance on lateral hamstring activation	+Less anterior knee pain; −Slower graft integration
Quadriceps Tendon [6]	Largest cross-section; high tensile strength	Mixed bone/tendon interface	Mild anterior thigh soreness, transient hip–knee imbalance	Relatively normal sagittal knee flexion during gait with improved movement symmetry.	+Reduced anterior knee pain; −Limited long-term evidence
Allograft [7]	Depends on processing; potential stiffness loss	Slower revascularization	None (no donor-site morbidity)	Lower knee flexion moment and reduced proprioceptive feedback during locomotion.	+Lower surgical trauma; −Slower healing; higher failure rate in young athletes

Rehabilitation and Clinical Translation

Understanding these graft-dependent biomechanics enables customized therapy:

BTB: Progressive quadriceps loading, patellar mobilization, and eccentric knee extensor retraining [16].

HS: Emphasis on medial hamstring strength, proprioceptive retraining, and tibial rotation control drills [9].

QT: Hip-knee coordination exercises and dynamic quadriceps stretching to counter donor-site stiffness [17].

AL: Neuromuscular feedback training and delayed high-impact return due to slower graft

[Downloaded from jsurgery.bums.ac.ir on 2026-11-05]

incorporation [18].
Integrating gait analysis and symmetry based rehabilitation algorithms may further enhance restoration of functional locomotion after ACL reconstruction.

Limitations of Current Evidence

Comparison studies frequently employ heterogeneous rehabilitation protocols and small sample sizes. Few investigations simultaneously integrate kinetic, kinematic, and neural parameters. Additionally, standardized gait metrics such as symmetry index or limb loading ratio are not consistently reported, limiting meta analytic interpretation. Future research should adopt unified biomechanical outcome measures to improve comparability across graft types.

Future Directions

Integrative frameworks combining biomechanical simulation with biological modeling could predict graft-specific adaptations. Machine learning applied to motion analysis may help stratify patients by risk of dysfunctional gait or secondary injury. Combining biomarkers of tendon–bone healing with locomotor biomechanics may ultimately enable precision based graft selection tailored to individual movement demands and sporting activity.

Conclusion

Graft selection in ACL reconstruction extends beyond structural ligament repair and influences the neuromuscular reorganization of locomotion. Each graft presents distinct mechanical and sensory consequences that shape walking and running symmetry. Recognizing these graft specific biomechanical adaptations may help bridge the gap between surgical success and true functional recovery. Future integration of quantitative biomechanics with surgical biology may enable clinicians to reconstruct not only the ligament but also the movement patterns essential for long term joint health.

Conflict of Interest

The authors declare that they have no competing interests.

Declaration of generative (AI) in scientific writing:

We have not used any AI tools or technologies to prepare this manuscript.

References

1. Schlecht SH, Loflin BE, Carter AR, Hanna R, Shergill S, Wojtys EM. Sex differences in the physiological response to acute anterior cruciate ligament overuse. J Physiol. 2026;604(1):297-316. [DOI: 10.1113/JP289078]
2. Jackson GR, Wakefield R, Nuelle CW, DeFroda SF. A Review of the Biomechanical and Clinical Outcomes of Tibial-Sided Fixation for Anterior Cruciate Ligament Reconstruction. JBJS Reviews. 2026;14(2). [DOI: 10.2106/JBJS.RVW.25.00186]
3. Lawless AM, Ebert JR, Edwards PK, Malik SS, Davies PS, D'Alessandro PA. A semitendinosus with adjustable button graft construct in patients undergoing hamstring ACL reconstruction results in improved knee flexor strength symmetry and less donor site pain and morbidity: Outcomes from the DOSTAR randomized controlled trial. Knee Surg Sports Traumatol Arthrosc. 2026;34(2):484-93. [DOI: 10.1002/ksa.12698]
4. McCarty III LP, Bach Jr BR. Anatomy, biology and biomechanics of patellar tendon autograft anterior cruciate ligament reconstruction. Tech Orthop. 2005;20(4):342-52. [DOI: 10.1097/01.bto.0000190264.10914.fc]
5. Janssen RP, van der Wijk J, Fiedler A, Schmidt T, Sala HA, Scheffler SU. Remodelling of human hamstring autografts after anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc. 2011;19(8):1299-306. [DOI: 10.1007/s00167-011-1419-y]
6. Slone HS, Romine SE, Premkumar A, Xerogeanes JW. Quadriceps tendon autograft for anterior cruciate ligament reconstruction: a comprehensive review of biomechanical and clinical outcomes. J Knee Surg. 2015;28(3):191-8.
7. Nikolaou PK, Seaber AV, Glisson RR, Ribbeck BM, Bassett III FH. Anterior cruciate ligament allograft transplantation: Long-term function, histology, revascularization, and operative technique. Am J Sports Med. 1986;14(5):348-60. [DOI: 10.1177/036354658601400502]
8. Slater LV, Hart JM, Kelly AR, Kuenze CM. Progressive changes in walking kinematics and kinetics after anterior cruciate ligament injury and reconstruction: a review and meta-analysis. J Athl Train. 2017;52(9):847-60. [DOI: 10.4085/1062-6050-52.6.06
9. Jónasson G, Helgason A, Ingvarsson Þ, Kristjánsson AM, Briem K. The effect of tibial rotation on the contribution of medial and lateral hamstrings during isometric knee flexion. Sports health. 2016;8(2):161-6. [DOI: 10.1177/1941738115625039]

[Downloaded from jsurgery.bums.ac.ir on 2026-11-05]

10. Piri E, Jafarnezhadgero A, Dehghani M, Rezazadeh F, Enteshari-Moghaddam A. Running mechanics in individuals with anterior cruciate ligament reconstruction 6-12 months after surgery: A Systematic Review and Meta-Analysis. Journal of Sport Biomechanics. 2026;12(1):52-69. [DOI: 10.61882/JSportBiomech.12.1.52]
11. Schmitz HA. The effects of gait modification on musculoskeletal loading during running: Iowa State University; 2025; P. 24-36. [DOI: 10.31274/td-20251215-413]
12. Cherelstein RE, Kuenze CM, Walaszek MC, Brumfield ER, Lewis JN, Hughes GA, et al. Patients With a Quadriceps Tendon Autograft Demonstrate Greater Asymmetry in Landing Kinetics Than Patients With a Bone-Patellar Tendon-Bone Autograft 6 Months After Anterior Cruciate Ligament Reconstruction. Am J Sports Med. 2025;53(3):623-31. [DOI: 10.1177/03635465241310400]
13. Piri E, Jafarnezhadgero A, Dionisio VC. Effects of anterior cruciate ligament reconstruction on running biomechanics: a systematic review with meta-analysis of cross-sectional studies. Sport Sci Health. 2026;22(2):114. [DOI: 10.1007/s11332-026-01700-1]
14. Nyland J, Gamble C, Franklin T, Caborn DN. Permanent knee sensorimotor system changes following ACL injury and surgery. Knee Surg Sports Traumatol Arthrosc. 2017;25(5):1461-74. [DOI: 10.1007/s00167-017-4432-y]
15. Furstein JS. Sciatic Peripheral Nerve Blockade for Pain Control Following Hamstring Autograft Harvest in Adolescents: A Comparison of Two Techniques: Virginia Commonwealth University; 2016; P. 20-25. [DOI: 10.25772/6S5K-0756]
16. Pereira C. Patellar tendon quality and quadriceps strength in male athletes with a unilateral ACL injury or reconstruction. JYU Dissertations. 2025; P. 12-33. [URL:https://jyx.jyu.fi/jyx/Record/jyx_123456789_103182]
17. Vasquez B. The Effect of Biofeedback on Eccentric Knee Joint Power, Limb Stiffness, and Limb Stiffness Symmetry in ACLR Patients During Bilateral Landing: Virginia Tech; 2023; P. 13-33. [URL: http://hdl.handle.net/10919/115550]
18. Patel S, Amirhekmat A, Le R, Williams Iii RJ, Wang D. Osteochondral allograft transplantation in professional athletes: rehabilitation and return to play. Int J Sports Phys Ther. 2021;16(3):941. [DOI: 10.26603/001c.22085]

[Downloaded from jsurgery.bums.ac.ir on 2026-11-05]