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RESEARCH ARTICLE

Gait analysis among patients with quadriceps weakness after anterior cruciate ligament reconstruction post 9 months

Ansa Imran[1], Hufsa Tariq[1], Somia Faisal[1], Hafiz Muhammad Asim[1]

ABSTRACT

Background: One of the most frequent musculoskeletal injuries in young adults is anterior cruciate ligament (ACL) damage. Following ACL reconstruction, there have been reports of changes in the lower extremity joints' kinematics and kinetics, including decreased knee ROM during the stance and swing phases of walking and weakened knee joint flexor and extensor muscles.

Objective: To analyze the gait parameter among patients with Quadriceps weakness after Anterior Cruciate Ligament Reconstruction (ACLR) post 9 months**.**

Methods: A descriptive cross-sectional study was carried out on 143 soccer players with age range of 18-39 years, who had unilateral ACL rupture managed through arthroscopic-assisted ACLR Endo-button procedure post 9 months. Written informed consent from the participants was taken before data collection. Observational gait analysis (OGA) with 66 check-off option is used to identify the gait deviations among the patients.

Results: In ankle during the weight acceptance phase, inadequate dorsiflexion (36.4%) and plantar flexion (23.8%) were reported; during single limb support, early heel off was (4.2%) and inadequate dorsiflexion (44.1%) and during single limb advancement, toe drag was (18.2%) and inadequate dorsiflexion (65%). In knee during the weight acceptance phase, inadequate extension (59.4%) and flexion (16.1%) were reported; during single limb support.

Conclusion: OGA revealed gait deviations as inadequate dorsiflexion, inadequate extension, and inadequate flexion due to eccentric loss of quadriceps widely after ACL reconstruction post 9 months**.**

Keywords: Anterior cruciate ligament, Gait, Knee, Quadriceps avoidance.

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Introduction:

Among the most frequent musculoskeletal injuries, anterior cruciate ligament (ACL) tears usually affect young adults.(1) The most common knee injuries resulting from participation in sports are said to be ACL injuries.(2) In comparison to the general population, people under 30 years old experience ACL ruptures more frequently.(3) When the knee is considerably flexed, the ACL inhibits anterior tibial translation in relation to the femur, which plays a crucial role in knee joint biomechanics.(4)

Affiliations: [1]Lahore College of Physical Therapy, Lahore Medical and Dental College, Pakistan
Correspondence: Hufsa Tariq
Email: hufsatariq5@gmail.com
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Injuries to the ACL occur 0.41 per 1,000 hours of professional football play.(5) Knee morphology is one of the contributing factors which leads to ACL injury such as intercondylar notch, condylar shape, Q angle, poor tibiofemoral congruency and reduced ACL size.(6) Following an ACL injury, the individuals experience knee joint effusion, limited range of motion (ROM), aberrant patterns of gait, and decreased strength of quadriceps.(7) Conversely, decreased knee extension have been associated with weakness of quadriceps and the "Quadriceps-Avoidance" gait, both of which have been connected to decreased functional performance.(8)

When there is complete ACL rupture, one of the treatment options is reconstruction. Hamstring or quadriceps tendon graft is used for this purpose.(9,10) After ACL reconstruction (ACLR), the normal range of motion can be regained and the individual can perform his daily activities without any pain or problem. Muscle weakness occurs after 3 months of ACLR and sometimes post 6 months due to skeletal muscle fiber deficit. ACLR leads to cellular contractile dysfunction

which ultimately results in decrease muscular strength leading to quadriceps weakness.(11-13)

Knee joint is more sensitive for the kinematic changes than the other joints.(14-15) After ACLR, kinematic changes occur as the tibia is in internal position leading to abnormal loading of knee joint which initiates the degenerative changes and development of osteoarthritis (OA). There is more extension during stance phase and less extension during pre-swing and terminal stance phase of gait. The deficit in extension occurs due to quadriceps weakness.(16-19)

Hence, after ACL reconstruction during walking, alterations in lower extremity joint kinetics and kinematics have been documented.(20-23) Within the first year following surgery, patients with ACL reconstruction have also been found to have decreased knee ROM during the stance and swing phases of walking and deteriorating strength of the knee joint flexor and extensor muscles.(24-25) Moreover, weakness of quadriceps muscle increases after ACLR that contributes to knee osteoarthritis.(26) Many gait deviations will occur in weight acceptance phase, owing to quadriceps weakness as the eccentric control of quadriceps is required to control the knee flexion and is involved in shock absorption. But when there is quadriceps strength weakness, the shock absorption capability reduces leading to knee osteoarthritis.(27-28)

It was reported that the people after early post-ACLR walk with tensed knees in the affected limb, which is demonstrated by decreased knee flexion angle and internal knee extension in the initial 50 percent of the stance phase of the gait cycle. This "stiffened knee" approach has a negative impact on force attenuation at the knee and accelerates the onset of posttraumatic arthritis.(29)

In most of the previous literature, only correlation between athletes' gait mechanics and symmetry in strength of the quadriceps in athletes after Anterior Cruciate Ligament Reconstruction has been reported but no conclusion was drawn regarding involved limb and related gait abnormalities specifically. Thus, this study aims to determine gait asymmetries due to quadriceps weakness in involved extremity. After anterior cruciate ligament reconstruction, the majority of the prior literature only reported a correlation between athletes' gait mechanics and symmetry in quadriceps strength, but no specific conclusions were made regarding the involved limb and associated gait abnormalities. Therefore, the purpose of this study was to identify gait asymmetries caused by quadriceps weakness in the affected extremity. A further benefit of this study is that it will enable clinicians' implement gait-specific training in rehabilitation to lessen post-operative gait asymmetries and to act as a manual for going back to work and being a contributing member of society.

Methods:

It was a descriptive cross-sectional study, a total of 143 participants were recruited from Bahria Town Football Academy, Model town Football Club, Lahore Football Academy, Fame Football Club and from Ghurki Trust and Teaching Hospital, Lahore. Non-probability convenience sampling was the approach used for sampling. The study took place between June 2020 and December 2020.

The Lahore College of Physical Therapy's ethical board gave the study their approval (LCPT/DPT/20/532). Through the World Health Organization Sample Size Calculator, sample size is determined. The estimated sample size was n=143 with 95% confidence interval, anticipated population proportion p=0.104 and absolute precision d=0.05.(30)

Adult soccer players with age range 18-39 years, who had unilateral ACL rupture, managed through arthroscopic-assisted ACL Reconstruction (ACLR) Endo-button procedure post 9 months, were included in this study. Whereas, athletes with restricted knee joint movement, patients who had any meniscectomy concomitant PCL injury, any spinal deformity (e.g., scoliosis), prior history of both knee surgeries, any history of recent ankle dislocation and ankle sprain and any other musculoskeletal injuries were not included in this study. Prior to data collection, participants' written informed consent was obtained.

Observational gait analysis (OGA) identifies the gait deviations. It is a full body gait analysis form of 176 check-off to determine gait deviations by observation. The abbreviated form JAKC OGA with 66 check-off option used to identify the gait deviations among the patients with quadriceps weakness after ACLR. Patient's gait was observed by videotaping from multiple views. JAKC-OGA form includes determination of stride length, walking speed and cadence. Once the deviations were documented, the deficits can be obtained.(31) Observational gait analysis has high validity of 0.94. Inter observer reliability is moderately high that is 0.76 while the intra observer reliability is also high as 0.89.(32) The Statistical

Package for Social Sciences SPSS version 26 was used for data entry and analysis. Data was presented using frequency tables, pie charts and bar charts.

Results:

There were 143 participants and their ages ranged from 22 to 38 years old. The mean age of these participants was 30.85, with a standard deviation (SD) of 3.98.

In figure 1 shows frequency of right and left limb anterior cruciate ligament reconstruction surgery.

During the gait cycle, 84 (58.7%) participants reported maximum ankle deviations during flat foot 58.7% (n=84) in initial contact phase whereas maximum participants i.e. 65% (n=93) had inadequate dorsiflexion during pre-swing to terminal swing phase as shown in table 1.

During the gait cycle, maximum deviations reported at calcaneus were excessive inversion by 18.4% (n=12) participants during mid-stance to terminal stance whereas maximum participants [18.9% (n=27)] had excessive inversion during pre-swing to terminal swing phase as shown in table 2.

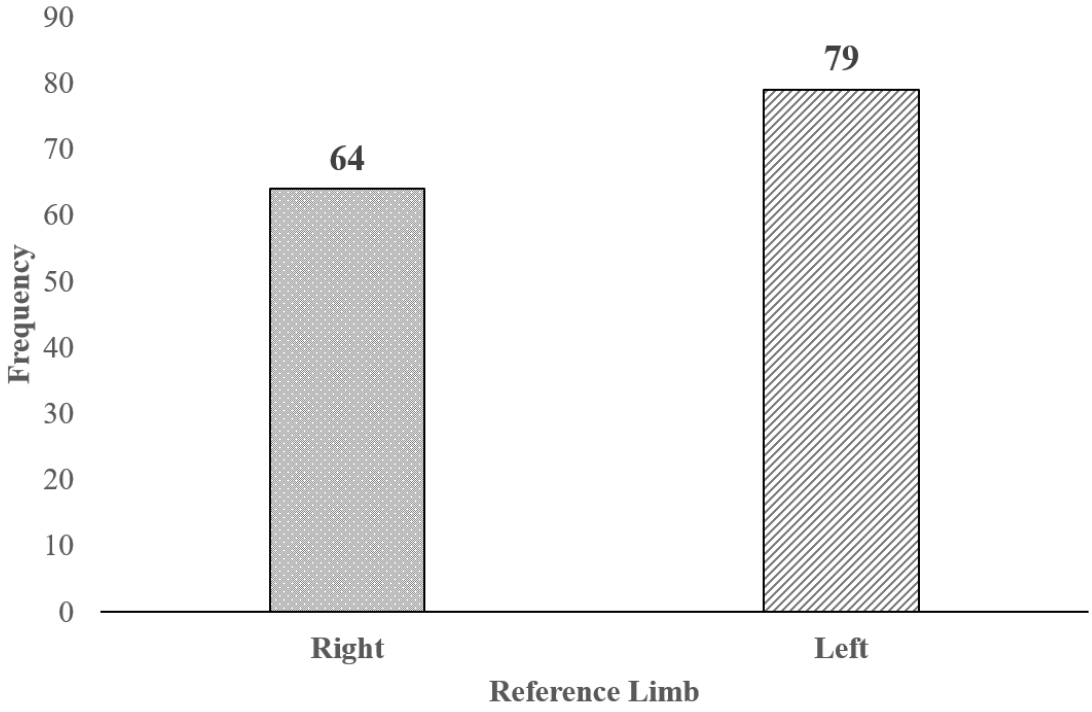

Figure 1: frequency of right and left limb anterior cruciate ligament reconstruction surgery

Table 1: Frequency of ankle deviations

Phase of gait cycle		Ankle deviations	n (%)
Weight acceptance	Initial contact	Flat foot	84 (58.7%)
		Inadequate dorsiflexion	52 (36.4%)
	Loading response	Foot slap	36 (25.5%)
		Inadequate plantar flexion	34 (23.8%)
Single limb support	Mid stance and terminal stance	Early heel off	6 (4.2%)
		Inadequate dorsiflexion	63 (44.1%)
Swing limb advancement	Pre swing to terminal swing	Toe drag	26 (18.2%)
		Inadequate dorsiflexion	93 (65%)

During the gait cycle, maximum deviations reported at knee were inadequate flexion 25.5% (n=36) at loading response, whereas in mid stance to terminal stance inadequate extension 39.9 % (n=57) was reported and during pre-swing to terminal swing phase inadequate flexion was 52.4% (n=75) as shown in table 3.

During the gait cycle, maximum deviations reported at thigh were inadequate flexion 57.3% (n=82) at initial contact, whereas; during pre-swing to terminal swing phase inadequate flexion was 46.2% (n=66) as shown in table 4.

Table 2: Frequency of calcaneal deviations

Phase of gait cycle		Calcaneal deviations	n (%)
Weight acceptance	Initial contact	Excessive inversion	5 (3.5%)
	Loading response	Excessive inversion	5 (3.5%)
Single limb support	Mid stance and terminal stance	Excessive inversion	12 (18.4%)
Swing limb advancement	Pre swing to terminal swing	Excessive inversion	27 (18.9%)

Table 3: frequency of knee deviations

Phase of gait cycle		Knee deviations	n (%)
Weight acceptance	Initial contact	Inadequate extension	23 (16.1%)
	Loading response	Inadequate flexion	36 (25.5%)
		Hyperextension	24 (16.8%)
		Extensor thrust	13 (9.1%)
Single limb support	Mid stance and terminal stance	Inadequate extension	57 (39.9%)
		Hyperextension	23 (16.1%)
		Extensor thrust	16 (11.2%)
Swing limb advancement	Pre swing to terminal swing	Inadequate flexion	75 (52.4%)
		Excessive flexion	26 (18.2%)
		Inadequate extension	59 (41.3%)
		Extensor thrust	25 (17.5%)

Table 4: Frequencies of hip deviations

Phase of gait cycle		Hip deviations	n (%)
Weight acceptance	Initial contact	Inadequate flexion	82 (57.3%)
	Loading response	Inadequate flexion	81 (56.6%)
Single limb support	Mid stance and terminal stance	Inadequate extension	37 (25.9%)
		Medial rotation	20 (14%)
		Adduction	6 (4.2%)
Swing limb advancement	Pre swing to terminal swing	Inadequate flexion	66 (46.2%)
		Lateral rotation	5 (3.5%)

Table 5: frequency of pelvis deviations

Phase of gait cycle		Pelvic deviations	n (%)
Single limb support	Mid stance and terminal stance	Contralateral drop more than 5°	1 (0.7%)
		Inadequate backward rotation	28 (19.6%)
Swing limb advancement	Pre swing to terminal swing	Ipsilateral drop more than 5°	2 (1.4%)
		Inadequate forward rotation	28 (19.6%)
		Excess forward rotation	10 (7%)
		Excess posterior tilt	5 (3.5%)

Table 6: Frequency of trunk deviations

Phase of gait cycle		Trunk deviations	n (%)
Single limb Support	Mid stance and terminal stance	Forward lean	55 (38.2%)
Swing limb advancement	Pre swing to terminal swing	Forward lean	5 (3.5%)

During the gait cycle, maximum deviations reported at pelvis were inadequate backward rotation 19.6% (n=28) at mid stance to terminal stance, whereas; during pre-swing to terminal swing phase inadequate forward rotation was 19.6% (n=28) as shown in table 5.

The frequency of trunk deviations were forward lean in 55(38.2%) participants at single limb support as presented in table 6.

Dicsussion:

The important findings of study indicate the Quadriceps weakness after ACLR led to many gait deviations in stance as well as in swing phase such as foot flat in ankle, inadequate extension in knee and inadequate flexion in hip during initial contact that suggest the loss of eccentric work of quadriceps. Moreover, from pre swing to terminal swing, there was inadequate dorsiflexion in ankle, inadequate flexion in knee, inadequate flexion in hip and forward leaning in trunk that highlight the loss of concentric work of quadriceps. This suggested that quadriceps weakness after ACL reconstruction results in many gait deviations due to both concentric and majorly eccentric loss of quadriceps. Earlier studies add credibility to the concept that quadriceps weakness partially explains the altered gait patterns seen in ACL damage patients.

Hossein et al conducted a study in 2021 which revealed that there was a strong positive correlation between the asymmetry of rectus femoris activity and biceps femoris activity. In the contact phase, the injured limb's quadriceps strength was substantially lower than the uninjured limb. This study's findings are congruent with current findings, which showed gait deviations as inadequate dorsiflexion, inadequate extension, inadequate flexion due to eccentric loss of quadriceps majorly after ACL reconstruction post 9 months whereas former study revealed a significant relationship between kinesiophobia and asymmetry in muscle activity and vGRF in different phases of the gait cycle.(33)

A study was conducted in 2020 by Nao aki et. al after anterior cruciate ligament restoration, gait asymmetries are linked to early-onset knee osteoarthritis (OA). During over-ground walking, when participants had full knee range of motion, trace or less knee effusion, greater than 80% quadriceps strength limb symmetry index, ability to hop on each leg without pain, and initiated running, 70 participants, grouped by sex and mechanism of injury (MOI), underwent biomechanical testing. Using mixed-model analysis of variance (α =.05), the bilateral knee kinetics, kinematics, and joint contact forces were compared. In conclusion, their findings imply that gait asymmetries exist for all sex and MOI groups 6 months following ACLR. Males who sustained non-contact injuries showed clinically significant under-loading of the affected limb, in contrast to individuals who sustained contact injuries. There was a less obvious pattern in women. Our research suggests that quadriceps

weakness may contribute to this reduction in knee flexion and may be is to be blamed for the increased risk of early arthorgenic alterations. Our findings underscore the need for interventions that go beyond typical strengthening and sport-specific training to address biomechanical asymmetries and gait abnormalities that commonly persist among even the most thoroughly rehabilitated patients. Although quadriceps femoris strength is widely used as a gauge for recovery progress in return to play standards, others have used a quadriceps index of at least 90% as a standard for eligibility to return to sports.(34-37) This study supports the prior research showing that patients' knees can resume regular activity when they have full range of motion, no effusion, and everyday activities are normal. These conditions were met by each participant in our study; they all exhibited normal ROM and knee function during routine activities. The group with a quadriceps index under 80%, however, displayed walking and running patterns that were akin to those of patients with ACL deficit. These changes raise the possibility that the entire range of motion, the absence of effusion, and high self-rating function scores may not be adequate conditions for "return to play."

The fact that the results of this study are restricted to walking, an activity with comparatively low demand, is one of its limitations. Higher-level return-to-sport tasks may offer more insight, but they cannot be made since they require more quadriceps strength. ACL and concurrent injury subgroup analyses are not part of this study. Prior research has suggested a connection between quadriceps strength and gait mechanics, but our data does not include preoperative or early postoperative rehabilitation time points.

Conclusion:

Observational gait analysis revealed gait deviations as inadequate dorsiflexion, inadequate extension, inadequate flexion due to eccentric loss of quadriceps, majorly after ACL reconstruction post 9 months.

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Conflict of interest: None to declare .

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References:

1. Balkanlı B, Arslan A. Magnetic Resonance Imaging for Acute Musculoskeletal Injuries of the Knee Joint in Coal Miners: A Retrospective Study. Indian Journal of Orthopaedics. 2023 Jan;57(1):102-9.
2. Rai SK, Gupta TP, Singh VB, Kale A, Vij V, Shaki O. Retrospective analysis and risk of progression of partial anterior cruciate ligament injuries in a young population. Archives of Orthopaedic and Trauma Surgery. 2022 Jul 2:1-9.
3. Nicholls M, Ingvarsson T, Briem K. Younger age increases the risk of sustaining multiple concomitant injuries with an ACL rupture. Knee Surgery, Sports Traumatology, Arthroscopy. 2021 Aug;29(8):2701-8.
4. Yao J, Yang B, Fan Y. Biomechanical Study on Injury and Treatment of Human Knee Joint. InBiomechanics of Injury and Prevention 2022 (pp. 285-304). Springer, Singapore.
5. Nitta CT, Baldan AR, Costa LP, Cohen M, Pagura JR, Arliani GG. Epidemiology of anterior cruciate ligament injury in soccer players in the brazilian championship. Acta Ortopédica Brasileira. 2021 Mar 10;29:45-8.
6. Bayer S, Meredith SJ, Wilson KW, Pauyo T, Byrne K, McDonough CM, Musahl V. Knee morphological risk factors for anterior cruciate ligament injury: a systematic review. JBJS. 2020 Apr 15;102(8):703-18.
7. Suh DK, Lee JH, Rhim HC, Cho IY, Han SB, Jang KM. Comparison of muscle strength and neuromuscular control up to 1 year after anterior cruciate ligament reconstruction between patients with dominant leg and non-dominant leg injuries. The Knee. 2021 Mar 1;29:15-25.
8. Pietrosimone B, Lepley AS, Kuenze C, Harkey MS, Hart JM, Blackburn JT, Norte G. Arthrogenic Muscle Inhibition Following Anterior Cruciate Ligament Injury. Journal of Sport Rehabilitation. 2022 Feb 14;1(aop):1-3.
9. Mouarbes D, Menetrey J, Marot V, Courtot L, Berard E, Cavaignac E. Anterior cruciate ligament reconstruction: a systematic review and meta-analysis of outcomes for quadriceps tendon autograft versus bone–patellar tendon–bone and

hamstring-tendon autografts. The American journal of sports medicine. 2019 Dec;47(14):3531-40.

10. Ajrawat, P., Dwyer, T., Whelan, D., Theodoropoulos, J., Murnaghan, L., Bhargava, M., Ogilvie-Harris, D. and Chahal, J., 2021. A comparison of quadriceps tendon autograft with bone-patellar tendon-bone autograft and hamstring tendon autograft for primary anterior cruciate ligament reconstruction: a systematic review and quantitative synthesis. *Clinical Journal of Sport Medicine*, *31*(4), pp.392-399.
11. Tourville TW, Voigt TB, Choquette RH, Failla MJ, Endres NK, Slauterbeck JR, Beynnon BD, Toth MJ. Skeletal muscle cellular contractile dysfunction after anterior cruciate ligament reconstruction contributes to quadriceps weakness at 6-month follow-up. Journal of Orthopaedic Research®. 2022 Mar;40(3):727-37.
12. Leszczynski EC, Kuenze C, Brazier B, Visker J, Ferguson DP. The effect of ACL reconstruction on involved and contralateral limb vastus lateralis morphology and histology: a pilot study. The Journal of Knee Surgery. 2021 Apr;34(05):533-7.
13. Peck BD, Brightwell CR, Johnson DL, Ireland ML, Noehren B, Fry CS. Anterior cruciate ligament tear promotes skeletal muscle myostatin expression, fibrogenic cell expansion, and a decline in muscle quality. The American journal of sports medicine. 2019 May;47(6):1385-95.
14. Gu W, Pandy MG. Direct validation of human knee-joint contact mechanics derived from subject-specific finite-element models of the tibiofemoral and patellofemoral joints. Journal of Biomechanical Engineering. 2020 Jul 1;142(7).
15. Sharifi M, Shirazi-Adl A, Marouane H. Sensitivity of the knee joint response, muscle forces and stability to variations in gait kinematics-kinetics. Journal of Biomechanics. 2020 Jan 23;99:109472.
16. Neal K, Williams JR, Alfayyadh A, Capin JJ, Khandha A, Manal K, Snyder-Mackler L, Buchanan TS. Knee joint biomechanics during gait improve from 3 to 6 months after anterior cruciate ligament reconstruction. Journal of Orthopaedic Research®. 2022 Jan 6.
17. Rothrauff BB, Fox MA, Murray RS, Winkler PW, Musahl V. Biomechanics of Instability and Its Relationship to OA. InEarly Osteoarthritis 2022 (pp. 85-102). Springer, Cham.
18. Fukunaga T, Johnson CD, Nicholas SJ, McHugh MP. Muscle hypotrophy, not inhibition, is responsible for quadriceps weakness during rehabilitation after anterior cruciate ligament reconstruction. Knee Surgery, Sports Traumatology, Arthroscopy. 2019 Feb;27(2):573-9.
19. Nuccio S, Del Vecchio A, Casolo A, Labanca L, Rocchi JE, Felici F, Macaluso A, Mariani PP, Falla D, Farina D, Sbriccoli P. Deficit in knee extension strength following anterior cruciate ligament reconstruction is explained by a reduced neural drive to the vasti muscles. The Journal of Physiology. 2021 Nov;599(22):5103-20.
20. Ma W, Pan CY, Diehl LH, Wittstein JR, Riboh JC, Toth AP, Amendola A, Faherty MS, Killelea C, Le DT, Sell TC. Altered lower extremity biomechanics following anterior cruciate ligament reconstruction during single-leg and double-leg stop-jump tasks: A bilateral total support moment analysis. Clinical Biomechanics. 2022 Jan 1;91:105533.
21. Burland JP, Lepley AS, Frechette L, Lepley LK. Protracted alterations in muscle activation strategies and knee mechanics in patients after Anterior Cruciate Ligament Reconstruction. Knee Surgery, Sports Traumatology, Arthroscopy. 2020 Dec;28(12):3766-72.
22. Shimizu T, Markes AR, Samaan MA, Tanaka MS, Souza RB, Li X, Ma CB. Patients with abnormal limb kinetics at 6 months after anterior cruciate ligament reconstruction have an increased risk of persistent medial meniscal abnormality at 3 years. Orthopaedic journal of sports medicine. 2020 Jan 23;8(1):2325967119895248.
23. Moore JM, Cessford K, Willmott AP, Raj D, Exell TA, Burbage J, Mullineaux DR. Lower limb biomechanics before and after anterior cruciate ligament reconstruction: A systematic review. Journal of Biomechanics. 2020 Jun 9;106:109828.
24. Cheng R, Wang Z, Wang C, Li F, Yao Y, Yu Y, Tsai TY. Biomechanics of human motion. InFrontiers in Orthopaedic Biomechanics 2020 (pp. 265-300). Springer, Singapore.
25. Larson D, Vu V, Ness BM, Wellsandt E, Morrison S. A Multi-Systems Approach to Human Movement after ACL Reconstruction: The Musculoskeletal System. International Journal of Sports Physical Therapy. 2022;17(1):27.

26. Wang LJ, Zeng N, Yan ZP, Li JT, Ni GX. Post-traumatic osteoarthritis following ACL injury. Arthritis research & therapy. 2020 Dec;22(1):1-8.

27. Arab F, Quddus N, Khan SA, Alghadir AH, Khan M. Association of eccentric quadriceps torque with pain, physical function, and extension lag in women with grade≤ II knee osteoarthritis: An observational study. Medicine. 2022 Aug 8;101(31).

28. Ahmadi M, Yalfani A. Interlimb Asymmetry of Vertical Ground Reaction Force as a Risk Factor for Re-injury and Knee Osteoarthritis Following Anterior Cruciate Ligament Reconstruction: A Systematic Review. Journal of Research in Orthopedic Science. 2022 Feb 10;9(1):15-24.

29. Arhos EK, Capin JJ, Buchanan TS, Snyder-Mackler L. Quadriceps strength symmetry does not modify gait mechanics after anterior cruciate ligament reconstruction, rehabilitation, and return-to-sport training. The American Journal of Sports Medicine. 2021 Feb;49(2):417-25.

30. Longu, U. G., Nagal, K., Salvatore, G., Cella, E., Candela, V., Cappelli, F., Ciccozzi, M. & Denaro, V. 2021. Epidemiology of Anterior Cruciate Ligament Reconstruction Surgery in Italy: A 15-Year Nationwide Registry Study. Journal of clinical medicine, 10, 223.

31. Middleton A, Fritz SL, Lusardi M. Walking speed: the functional vital sign. Journal of aging and physical activity. 2015 Apr 1;23(2):314-22.

32. McGinley JL, Goldie PA, Greenwood KM, Olney SJ. Accuracy and reliability of observational gait analysis data: judgments of push-off in gait after stroke. Physical Therapy. 2003 Feb 1;83(2):146-60.

33. Tajdini H, Letafatkar A, Brewer BW, Hosseinzadeh M. Association between kinesiophobia and gait asymmetry after ACL reconstruction: Implications for prevention of reinjury. International Journal of Environmental Research and Public Health. 2021 Mar 22;18(6):3264.

34. Ito N, Capin JJ, Arhos EK, Khandha A, Buchanan TS, Snyder-Mackler L. Sex and mechanism of injury influence knee joint loading symmetry during gait 6 months after ACLR. Journal of Orthopaedic Research®. 2021 May;39(5):1123-32.

35. Capin JJ, Zarzycki R, Arundale A, Cummer K, Snyder-Mackler L. Report of the primary outcomes for gait mechanics in men of the ACL-SPORTS trial: secondary prevention with and without perturbation training does not restore gait symmetry in men 1 or 2 years after ACL reconstruction. Clinical Orthopaedics and Related Research®. 2017 Oct;475(10):2513-22.

36. Capin JJ, Khandha A, Zarzycki R, Arundale AJ, Ziegler ML, Manal K, Buchanan TS, Snyder-Mackler L. Gait mechanics and tibiofemoral loading in men of the ACL-SPORTS randomized control trial. Journal of Orthopaedic Research®. 2018 Sep;36(9):2364-72.

37. Capin JJ, Zarzycki R, Ito N, Khandha A, Dix C, Manal K, Buchanan TS, Snyder-Mackler L. Gait mechanics in women of the ACL-SPORTS randomized control trial: interlimb symmetry improves over time regardless of treatment group. Journal of Orthopaedic Research®. 2019 Aug;37(8):1743-53.

Authors Contribution:

Imran A: Conception and design, literature search, collection, and assembly of data.

Tariq H: Drafting the article and statistical expertise, article writing, final approval and guarantor of article.

Faisal S: Drafting the article and critical revisions of article.

Asim HM: Analysis and interpretation, content writing.