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The relationship between hamstring muscle morphology, physical activity, dynamic balance, and knee functions among post-operative anterior cruciate ligament reconstruction patients

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ABSTRACT

Introduction: Anterior cruciate ligament (ACL) injuries are common in pivot sports, particularly soccer and volleyball, with soccer accounting for the majority. ACL reconstruction often leads to morphological changes, and lower extremity balance plays a key role in knee function recovery. This study aimed to examine the relationship between hamstring muscle morphology and physical activity (GLTEQ), dynamic balance (Y-Balance Test), and knee function (KOOS) in post-ACL reconstruction patients.

Methods: This study employed a literature review method, sourcing articles from PubMed, Google Scholar, and the Journal of Sport Rehabilitation. Keywords included 'hamstring muscle morphology,' 'Godin Leisure-Time Exercise Questionnaire,' 'Y-Balance Test,' 'Knee Injury and Osteoarthritis Outcome Score,' and 'anterior cruciate ligament reconstruction.' Boolean operators 'AND' and 'OR' were used to refine the search.

Results: Subjects with ACLR showed reduced muscle volume and lower Y-Balance Test scores compared to healthy controls. They also scored significantly lower across all KOOS subscales ($p < 0.01$). The KOOS Sport and Recreation subscale was marginally associated with GLTEQ scores ($p = 0.057$). Additionally, GLTEQ scores were lower in the ACLR group than the modified GLTEQ scores in healthy participants ($p = 0.58$).

Conclusion: Hamstring muscle morphology was significantly associated with Y-Balance Test performance, while no significant relationship was found between KOOS or GLTEQ scores in post-ACL reconstruction patients.

Keywords: ACL reconstruction, activity, balance, hamstring, morphology.

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Introduction

ACL injury is a common knee injury among athletes, accounting for almost 64% of all knee injuries in the general population, and is rapidly becoming an orthopedic health concern. With an annual incidence of isolated ACL tears of 68.6 per 100,000 people, those injured may have to cease strenuous exercise, reduce thickness of their joints, or even have to undergo surgical ACL reconstruction to restore mechanical knee stability.[1]

ACL reconstruction surgery often involves the use of hamstring, patellar, peronei, quadriceps, tibialis anterior and posterior, and Achilles tendons. While these structures are used due to their similarity to the native ACL, all grafts have potential advantages and disadvantages. Semitendinosus (ST) and gracilis (G) are two of the most frequently used muscles for grafts in ACL reconstruction surgery. The use of ST and G muscles for grafts results in morphological changes on the operated side.[2–4]

Unfortunately, most patients experience chronic, bothersome knee symptoms that interfere with activities of daily living and inhibit the ability to exercise.[5] ACLR patients may experience instability, muscle weakness, and joint pain and may perceive a greater degree of disability, which collectively affects their return to previous activity levels, potentially impacting the ability to maintain a healthy and physically active lifestyle. Early ACLR is considered if additional injuries necessitate immediate or subacute repair. Delayed ACLR is an option for those with secondary injuries, recurrent instability, or unacceptable activity limitations.[6]

There has been a significant shift in the management of ACL tears in this population over the past few decades, with a paradigm shift from nonoperative or delayed surgery to earlier ACL reconstruction (ACLR) in younger patients.[7] In athletes undergoing ACLR, functional testing needs to be performed before returning to sport at three and six months. One such functional test is the Y-balance test (YBT). The Y-

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balance test is a dynamic balance test that requires subjects to maintain a single-leg stance while reaching as far as possible with the contralateral leg in three different directions of movement (i.e., anterior, posteromedial, and posterolateral). This test is used to assess dynamic balance impairments and is more time-efficient compared to the Star Excursion Balance Test.[8–11]

Furthermore, it has been widely used to assess postural stability in adolescents, runners, and patients with ankle sprains or ACL injuries and is known as a predictor of lower extremity injuries.[12] This test is measured twice in each direction while standing barefoot, where the highest measurement value is recorded and frequently used in clinical settings. This testing is also important for identifying a group of athletes prone to recurrent injury of the reconstructed ACL.[8,13]

Leisure-time physical exercise is seen as an important component of public health intervention, having been related to an increased risk of cardiovascular disease and depressed symptoms. The Godin Leisure-Time Exercise Questionnaire (GLTEQ) is widely used to assess leisure-time physical activity. Godin scores vary from 0 to infinity and are calculated as a weighted sum of light, moderate, and strenuous exercise, with higher values indicating more physical activity participation. This strategy has been utilized to show a decrease in leisure-time physical activity after ACLR compared to healthy control groups. The GLTEQ's three domains provide a more comprehensive measure than variables containing only moderate and strenuous physical activity.[14,15]

Patient-reported outcome metrics are frequently used to assess the results of ACL restoration. The Knee Injury and Osteoarthritis Outcomes Score (KOOS) is a tool for measuring knee function in active persons with knee injuries. KOOS is a validated self-reported outcome measure comprised of 42 items over five subscales designed to investigate knee-related symptoms and function in active persons with knee injuries or osteoarthritis (OA). The subscales are added together, and the total is converted to a 0–100 scale, with lower scores indicating poorer results. [2,13,16,17] Patient-reported knee complaints vary with patient age and sex in adult populations; healthy adolescents and young adults are known to report good to excellent knee function when completing the KOOS questionnaire.[18]

The scarcity of literature and research addressing hamstring muscle morphology and physical activity with the Y-balance test and KOOS scores in post-ACLR patients, as well as the unclear relationship between the related variables, highlights the urgency of this literature review. Therefore, the purpose of this literature review was to investigate the relationship of hamstring muscle morphology (musculotendinous length, CSA, muscle volume) and self-reported physical activity using the GLTEQ with the Y-balance test and KOOS in post-ACLR patients.

Methods

This literature review used published research articles as secondary data sources. A literature search was conducted using the PEO framework: Patient (P) = post-ACL reconstruction patients, Exposure (E) = hamstring muscle morphology, and Outcome (O) = Y-balance Test and KOOS. The keywords used were "hamstring muscle morphology," "Godin Leisure-Time Exercise Questionnaire," "Y-balance test," "Knee Injury and Osteoarthritis Outcome Score (KOOS)," and "anterior cruciate ligament reconstruction," which were aligned with the research topic and content. The inclusion criteria were studies published in English that investigated the relationship between hamstring muscle morphology and the Godin Leisure-Time Exercise Questionnaire, Y-balance Test, and KOOS. Articles published more than 10 years ago were excluded. The search was conducted online through PubMed, Google Scholar, and the Journal of Sport Rehabilitation, which yielded 25 relevant articles. After applying the inclusion and exclusion criteria, 4 articles met the requirements for review.

Results

Nikose et al.[1]demonstrated a reduction in the volume and length of the semitendinosus (ST) and gracilis (G) tendons on the operated side compared to the contralateral limb in ACL-reconstructed patients. The ST tendon length was 8.13 ± 2.36 mm² on the operated side and 13.90 ± 3.96 mm² on the healthy side ($p < 0.01$), while the G tendon measured 3.16 ± 2.12 mm² vs. 5.19 ± 2.45 mm² ($p < 0.01$). Y-Balance Test (YBT) scores were also significantly lower in the operated limb (88.63 vs. 91.25). This study assessed three YBT variables: anterior reach, posterolateral reach, and composite scores, with standard deviations of 4.29, 5.69, and 2.96, and p-values of 0.04, 0.046, and 0.001, respectively.

Norte et al.[16,19] reported lower Godin Leisure-Time Exercise Questionnaire (GLTEQ) scores in ACLR patients compared to healthy individuals. Higher GLTEQ scores were associated with better KOOS sport and recreation subscale scores. In Norte et al.[2], the high physical activity group had a GLTEQ score of 98.2 ± 27.3, while the low activity group scored 46.6 ± 18.8 ($p < 0.001$). Norte et al.[4] also found significantly better outcomes in all KOOS subscales and GLTEQ scores in the healthy group ($p < 0.001$), with GLTEQ showing a significance level of $p = 0.011$.

Ezzat et al.[14] studied patients with sport-related intra-articular knee injuries, including 13% with grade 1–2 collateral ligament sprains and 54% with grade 3 ACL sprains. Comparing injured and uninjured groups, they found no significant differences in GLTEQ scores ($p = 0.58$), although all KOOS subscales showed significant differences ($p < 0.01$). Overall, the findings suggest a strong relationship between hamstring tendon morphology, physical activity levels, and functional outcomes following ACL reconstruction.

Discussion

Nikose et al.[1] found a significant relationship between hamstring muscle morphology and Y-balance test (YBT) scores. This aligns with previous studies by Rush et al., Sunner-Keklik et al., and Messer et al., which reported smaller volumes and cross-sectional areas of the biceps femoris, semitendinosus, and semimembranosus in injured limbs

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Table 1. Results summary of the relationship between hamstring muscle morphology and the Godin Leisure-Time Exercise Questionnaire with Y-balance test and KOOS questionnaire in post-ACL reconstruction patients

Author (Year)	Study Design	Population	Sample Size	Method	Results
Nikose et al. (2021)[1]	Prospective Cohort Study	Patients with unilateral primary ACLR	50	Isometric torque, isokinetic strength, and MRI	ST and G tendons in terms of volume and length of the operated limb for ACL reconstruction showed lower values compared to normal and significantly lower YBT scores in the ACL operated knee.
Norte et al. (2019)[19]	Cross-sectional	Patients with unilateral primary ACLR	77	KOOS subscales, and GLTEQ	No significant relationship between GLTEQ and KOOS.
Ezzat et al. (2017)[14]	Historical cohort study	Participants with a history of intra-articular knee injury, including ACL sprain.	100	KOOS and modified GLTEQ	No significant difference between all KOOS subscales with modified GLTEQ.
Norte et al. (2017)[16]	Cross-sectional	Patients with unilateral primary ACLR	72	GLTEQ, KOOS	Patients with ACLR had lower KOOS and GLTEQ scores compared to the healthy group.

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compared to uninjured ones.[20–23] Similarly, Dutaillis et al. observed reduced semitendinosus muscle size in limbs that underwent anterior cruciate ligament reconstruction (ACLR).[24] Nikose et al. also reported lower YBT scores on the operated side, consistent with Guzel et al., who found higher scores in healthy limbs.[25]

Norte et al.[16] observed lower Knee injury and Osteoarthritis Outcome Score (KOOS) and Global Rating of Leisure-Time Exercise Questionnaire (GLTEQ) scores in ACLR patients compared to healthy controls. Dejour et al. also noted reduced KOOS scores in patients awaiting surgery. These consistent findings suggest that deficits in hamstring morphology, possibly due to semitendinosus graft harvesting, affect YBT performance in ACLR patients, who often experience hamstring shortening that limits anterior reach. However, no significant relationship was found between KOOS and GLTEQ in this study. While GLTEQ is a validated tool, it may lack sensitivity to detect variations in activity intensity among ACLR patients, though it may still correlate with the KOOS sport and recreation subscale.[3]

The primary strength of this literature review lies in its comprehensive examination of the potential relationship between hamstring muscle morphology, the Godin Leisure-Time Exercise Questionnaire (GLTEQ), the Y-Balance Test, and the KOOS questionnaire in individuals undergoing anterior cruciate ligament (ACL) reconstruction. Moreover, the inclusion of studies with large sample sizes enhances the external validity and generalizability of the findings.

This study has some limitations to acknowledge. First, the potential for selection bias, as it did not incorporate formal validity assessments of the included articles. This may affect the overall reliability of the findings and their interpretation. Second, the limited number of eligible studies and restriction to English-language publications may have excluded relevant research, reducing the comprehensiveness and generalizability of the results. Despite these limitations, the review highlights the clinical relevance of hamstring muscle morphology in relation to post-operative quality of life and knee function in individuals following ACL reconstruction. The findings support the prioritization of targeted hamstring strengthening in rehabilitation protocols to enhance functional recovery and reduce the risk of re-injury.

Conclusions

This literature review highlights the association between reduced hamstring muscle morphology and lower physical activity levels with impaired balance and knee function in post-ACL reconstruction patients. These findings highlighted the importance of rehabilitation strategies focusing on hamstring strengthening and balance training to enhance knee stability and function. Further research is needed to clarify these relationships using validated assessments in ACLR populations.

Ethical Clearance

This review used publicly available articles; therefore, informed consent and ethical approval were not required.

Conflict of Interest

The authors declare no conflicts of interest, financial or otherwise, that could have influenced the research, manuscript preparation, or publication. All authors affirm that the study and manuscript were conducted with scientific integrity and free from external pressures or personal interests that might compromise objectivity.

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Author contributions

IKSR designed the study, collected data, and drafted the initial manuscript. IPGSA and GPK contributed to data collection and revised the manuscript.

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