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Knee Joint Proprioception in Weight Bearing and Non-Weight Bearing Position in Arthroscopic Assisted Anterior Cruciate Ligament Reconstruction: A Cross-Sectional Study

Yamna Mazher[1], Marwa Muslim[2], Hassan Shahid Dar[3], Mahrukh Asif[4], Muhammad Tariq Shafi[5]

[1 5] Assistant Professor, University of Biological and Applied Sciences, Lahore, Pakistan
[2 4] Student, University of Biological and Applied Sciences, Lahore, Pakistan
[3] Orthopedic Surgeon, THQ, Kahna Nau, Lahore, Pakistan

Author`s Contribution

[1] Substantial contributions to the conception or design of the work for the acquisition, analysis or interpretation of data for the work, [1 4]Drafting the work or reviewing it critically for important intellectual content, [1-5]Final approval of the version to be published, Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Address of Correspondence

Name: Yamna Mazher
Email Id: yamnamazher@gmail.com
ORCID: 0000-0001-5152-5163

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A B S T R A C T

Background: Proprioception is the body's ability of sensing the position, movement, and alignment of its joints and limbs. The ACL is rich in proprioceptive fibers, an injury to this ligament, impairs knee function and neuromuscular control, leading to poor coordination. Incorporating proprioception assessment and training in ACL rehabilitation is essential for restoring function and preventing future injuries.

Objective: To determine knee joint proprioception in loaded and unloaded position among patients after arthroscopically assisted anterior cruciate ligament (ACL) reconstruction.

Methodology: A descriptive cross-sectional study was conducted at Ghurki Trust and Teaching Hospital (GTTH), targeting patients who had undergone surgical reconstruction of anterior cruciate ligament. The total study duration was six months, covering the period from June 2023 to December 2023. Using a non-probability purposive sampling technique, a total of 74 participants meeting the inclusion criteria were selected. A goniometer was utilized to evaluate joint position sense in both loaded and unloaded positions. The data was entered and analyzed using SPSS version 22.

Results: The result showed that the mean age of participants was 27.79 ± 5.03. Knee flexion in weight bearing position was 30 degrees and maximum range was 44 degree with mean of 34.89 ± 4.21 whereas minimum knee flexion in non-weight bearing was 30 degree and maximum was 45 degree with mean of 33.68 ± 4.35.

Conclusion: Statistically significant difference was found in knee joint proprioception between loaded and unloaded position among patient of ACL reconstruction.

Keywords: Anterior Cruciate Ligament, Knee Joint, Proprioception, Weight-Bearing

Introduction

Proprioception is defined as knowing the mechanical and spatial state of our body and its musculoskeletal components. It plays an important role in motor activities as well as our sense of ownership over our bodies.[1] It is the awareness of movement and position of the body. The capacity to distinguish between different limb movements based on joint position, force, and movement is known as proprioceptive acuity.[2] Impaired proprioception can lead to altered neuromuscular control and increased risk of re-injury,

so the proprioceptive deficits during rehabilitation must be addressed.[3]

ACL has significant influence on knee proprioception.[4] Ruffini endings and Golgi tendon organs (sensitive to static joint positioning) and Pacinian corpuscles (responsive to dynamic movement) account for as much as 2.5% of the total neural receptor network that make up the ACL.[5] For the lower extremities to move steadily, the anterior cruciate ligament (ACL) plays a critical role. By limiting forward translation of the tibia relative to the femur, this ligament primarily serves to maintain the knee joint stability and integrity. The "screw-home" action, which happens as the femur and tibia rotate as the knee reaches full extension, is another function of the ACL. A crucial aspect of typical human functioning is the somatosensory system, which includes proprioception.[6] A complete ACL rupture results in restricted joint movement, mechanical and functional instability in the anterolateral knee, muscle imbalances, atrophy, and compromised neuromuscular function. These alterations contribute to a loss of knee stability and performance. Consequently, ACL reconstruction surgery is commonly recommended, and when paired with proper rehabilitation, it is expected to enhance static stability and restore knee function through improved neuromuscular control.[7]

Female athletes may be more vulnerable to ACL injuries than male athletes in terms of risk variables.[8] Female athletes were 1.5 times more likely to suffer an ACL injury than male athletes. However, it has been noted that because men are more likely to engage in physical and athletic activities, they sustain injuries more frequently.[9] ACL injuries have been associated with both internal and external risk factors. Internal risk factors include gender, inherited genetic traits, anatomic variation (geometry of the femoral notch and tibial plateau), BMI, Hormonal status, neuromuscular deficits, and biomechanical abnormalities.[10, 11] While external factors are type of sport, playing environment, level of competition and equipment. ACL reconstruction is a surgical procedure that involves the use of a tissue graft to replace a torn or injured ACL. The tissue graft can come from the patient, or from a deceased donor. With arthroscopy, the surgeon may view within your joint without creating a big cut. Using pencil-thin surgical tools inserted through additional tiny incisions, surgeons can even heal some types of joint injury during arthroscopy.[12, 13]

To measure proprioception, researchers commonly use two methods that are Joint Position Sense (JPS) and Threshold to Detection of Passive Motion (TDPM). JPS assesses how accurately an individual can replicate a specific joint angle through either active or passive movement and Threshold to Detection of Passive Motion (TDPM), which measures the sensitivity to perceiving the initial phase of passive joint movement.[14] Goniometry is a standard tool for measuring joint range of motion. This study aimed to evaluate proprioception in both loaded and unloaded positions after ACL reconstruction, with the objective of establishing a theoretical basis for treating ACL injuries, addressing knee instability, and guiding rehabilitation.[15]

Methodology

From June to December 2023, a descriptive cross-sectional study was completed at the Lahore College of Physical Therapy, LMDC. Ghurki Trust and Teaching Hospital served as the data gathering place. Lahore College of Physical Therapy's Ethical Review Committee gave its approval to the study (Ref. No. LCPT/22254). Written consent was secured from all participants prior to the commencement of the study. The sample size was determined using Epitool software with a proportion of 0.104, a precision of 0.07, and a 95% confidence level. The sample size was n=74.[16] The sampling technique used was non probability convenient sampling.[17, 18] Seventy four patients aged 20-25 years, 8 weeks post-operative from unilateral arthroscopic ACL reconstruction and patient with score of more than 45 on Berg Balance Scale were included, while the exclusion criteria were recurrent ACL reconstruction, ACL injury accompanied by other ligament or meniscus damage, post-operative infection or complications, bilateral ACL reconstruction, poor balance, any joint disease and neuromuscular disorder. The evaluation of proprioception was carried out with the assistance of a goniometer in both loaded and unloaded positions.[19] It has demonstrated exceptional reliability and validity for measuring knee joint angles during both active and passive movements, with ICC values of 0.994 for active and passive flexion, and 0.978 and 0.987 for extension under active and passive conditions, indicating excellent reliability. In terms of validity, goniometer demonstrated strong performance in evaluating knee joint angles, with correlation coefficients (r) of 0.969 and 0.97 for active and passive flexion, respectively. For extension movements, the device showed moderate to high validity, reflected by r values of 0.751 and 0.892. These findings support the goniometer's effectiveness, reliability, and accuracy as a tool for joint angle assessment, making it a useful instrument for evaluating knee proprioception and function.[20] Knee joint proprioception was assessed using an active replication test. With their eyes closed, participants actively attempted to reproduce a reference position using the same limb. The reference angle of 30 degrees at the knee was initially set by the examiner through passive limb

movement. To ensure precise angle measurement, the goniometer was fixed to the lower limb with its pivot centered on the lateral aspect of the knee joint. One arm was oriented along the axis connecting the greater trochanter to the pivot point, while the opposite arm extended toward the lateral malleolus, maintaining alignment with the limb's anatomical landmarks. The assessment was performed while the subject was seated on a bed in a non-weight-bearing short-sitting position, legs hanging off the edge, and thigh fully supported. A blindfold was used to eliminate visual input. The examiner moved the knee from full extension to a predetermined angle of 30 degrees through passive movement. The participant then actively held this position for four seconds to identify the target angle before the joint was passively returned to its initial extended state. Five practice trials were provided, after which the participant was instructed to actively reproduce the predetermined joint angle using the same limb that had been previously positioned. The weight-bearing assessment was conducted in a unilateral stance on the ipsilateral leg, with minimal finger support for balance. The subject kept the contralateral foot off the ground while slowly flexing the ipsilateral knee until reaching the target angle of 30 degrees, at which point they were instructed to stop. Once the target angle was achieved, the individual sustained the posture for four seconds duration to enhance proprioceptive awareness of the knee joint. Afterward, they returned to a bilateral weight-bearing stance. This process was repeated five times for practice. Before the formal assessment, all subjects received an explanation and a practice session. The response position was determined by the angle at which the subject stopped, with three consecutive response angles recorded.[21]

Results

The participant had mean age of 27.79 ± 5.03 years and a mean body weight 77.27 ± 8.81 kg. The mean height of participant was 5.67 ± 0.36 feet. Paired sample T test shows that the mean ± SD of knee flexion in weight bearing was 33.67 ± 4.214 and in non-weight bearing the mean ± SD was 34.89 ± 4.359. Accuracy in joint position sense was assessed through relative error, derived from the numerical difference between the target angle and the angle reproduced by the participant. A negative value denoted that the reproduced position exceeded flexion compared to the reference angle (indicating underestimation), while a positive value reflected greater extension than intended (representing overestimation). The median relative error was computed for both conditions. Due to the absence of a normal distribution within the dataset, a non-parametric method was applied for statistical analysis. The Mann-Whitney test was conducted to analyze differences in response angle errors and relative errors between the loaded and unloaded conditions. There was statistically significant difference found between the two joints position as p value was less than 0.05 as shown in Table 1. The results also indicated a significantly greater proprioceptive accuracy in the WB condition compared to NWB (Relative Error: NWB = -0.315˚, WB = -1.745˚; p = 0.006) as shown in table 2. Additionally, the coefficient of variation (C.V.) was lower in the WB condition (6.85%) compared to NWB (8.92%), suggesting greater consistency in proprioceptive responses during weight-bearing assessment as shown in table 3.

Table1: Comparison of loaded and unloaded positions response angle

	Loaded Position	Unloaded Position	p-value
Response Angle	Mean ± SD		0.04
	33.67 ± 4.214	34.89 ± 4.359	

Table2: Comparison of loaded and unloaded conditions relative error

	Loaded Position	Unloaded Bearing Position	p-value
Relative Error	-1.745˚	-0.315 ˚	0.006

Table3: Coefficient of variation of loaded and unloaded position (target knee joint position was 30 degrees of knee flexion)

	Loaded Position	Unloaded Position
Coefficient of variation	6.85%	8.92%

Discussion

The study aimed to evaluate knee proprioception in patients following ACL repair. A goniometer was utilized to measure proprioception in both loaded and unloaded conditions.

Barry C. Stillman and Joan M. McMeeken's study found that evaluating active knee joint position sense in a single-leg, weight-bearing stance, performed with closed eyes and limited hand support, yielded greater accuracy and reliability than assessments conducted in a supine, non-weight-bearing posture.[22]

Another study explored the impact of sensory impairments on proprioceptive and motor function in individuals following unilateral ACL reconstruction. Results indicated a reduced capacity for joint position awareness in the limb that had undergone surgical repair, an increased threshold for detecting passive knee motion, delayed hamstring muscle activation, and impaired performance in

postural control tasks. These results align with the findings of the present study.[23]

The study focused on evaluating joint position sense (JPS) in functional, weight-bearing scenarios following anterior cruciate ligament (ACL) reconstruction. Findings revealed no statistically significant differences in JPS between the surgically treated and unaffected knees of participants, nor between ACL-reconstructed individuals and healthy controls ($p \geq 0.05$). These outcomes remained consistent across flexion and extension movement tasks. The study concluded that, approximately 11 months post-operation, individuals with ACL reconstruction exhibited JPS comparable to that of uninjured individuals during weight-bearing assessments. However, these findings do not align with the results of the present study.[24]

A study examined knee joint repositioning sense in both loaded and unloaded conditions. Researchers also explored the potential relationship between knee displacement (KD) and joint repositioning sense. The findings revealed that proprioception was assessed more accurately in the WB or closed-chain condition compared to the NWB or open-chain condition. In other words, proprioceptive awareness was more effectively demonstrated under load-bearing, closed kinetic chain conditions, relative to unsupported, open-chain positioning.[25]

The study has several limitations. First, the number of repetitions in the testing may introduce testing effects, such as practice or fatigue, which could bias the results. Furthermore, the absence of preoperative joint position sense assessment makes it challenging to determine whether postoperative changes are a result of the intervention or influenced by other factors. Moreover, the study did not consider the duration between injury and surgery, a factor that may potentially impact the recovery process. Further studies with larger sample size should be conducted to improve statistical power. A longitudinal design would allow for better tracking of long-term outcomes, while data should be gathered from various settings to increase generalizability. More studies must be conducted including different knee surgical approaches, and further research on the effect of remnant volume and surgical timing during ACL reconstruction on proprioception recovery is necessary.

Conclusion

The study found that proprioception was more compromised in weight bearing position as balance requirements hindered assessment, and that there was a statistically significant difference between loaded and unloaded positions following ACL reconstruction. Its findings may enhance rehabilitation strategies, improving recovery outcomes and reducing reinjures risks.

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