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ASSESSMENT OF CORE STRENGTH AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION DURING SINGLE-LEG SQUATS

Original Research

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ABSTRACT

Background: Core strength plays a pivotal role in dynamic stability and efficient force transmission. Inadequate core and hip muscle strength often contribute to knee valgus, which increases the risk of non-contact anterior cruciate ligament (ACL) injuries. With ACL injuries being prevalent in team sports, there is a growing need for effective rehabilitation strategies. This study addresses a notable gap in understanding the relationship between core strength and single-leg squat (SLS) performance in patients post-ACL reconstruction, providing valuable insights to optimize rehabilitation practices.

Objective: To assess the impact of core strength on single-leg squat performance in individuals following ACL reconstruction.

Methods: A descriptive cross-sectional study design was employed, including 72 participants selected using non-probability convenient sampling. The study was conducted at Lahore Medical and Dental College over six months. Inclusion criteria included individuals aged 18-40 years with a history of unilateral ACL reconstruction, a stable graft, full knee range of motion, and completion of rehabilitation. Core strength was measured using the Plank Test, while SLS performance was graded using a three-point ordinal scale ("Good," "Fair," and "Poor"). SPSS version 24.0 was used for data analysis, and results were reported as mean, standard deviation, frequency, and percentages.

Results: The mean plank hold time was 51.58 seconds (SD = 30.47), with durations ranging from 7 to 130 seconds. SLS grading revealed 45.8% of participants performed in the “Good” category, 29.5% in “Fair,” and 25% in “Poor.” These findings demonstrate a positive association between core strength, as measured by plank hold time, and improved SLS performance.

Conclusion: Enhanced core strength significantly improves SLS performance in individuals post-ACL reconstruction. Incorporating core stability training into rehabilitation programs is critical for optimizing lower limb function and reducin g the risk of re-injury.

Keywords: Anterior cruciate ligament reconstruction, core stability, core strength, knee valgus, physical therapy, rehabilitation, single-leg squat.

INTRODUCTION

Core strength is recognized as the active regulation and stabilization of the lumbopelvic-hip region, facilitating the efficient transfer of force and energy between the upper and lower limbs during a wide range of physical activities, including sports, exercise, and daily functional movements (1). The core musculature comprises a complex network of muscles, including the abdominal muscles anteriorly, the paraspinal and gluteal muscles posteriorly, the diaphragm as the upper boundary, and the pelvic floor and hip girdle musculature as the lower framework (2). Core strength training is widely utilized to enhance physical performance, improve overall fitness in healthy individuals, reduce injury risks in athletes, and alleviate discomfort associated with lower back pain (3). Moreover, it has been shown to improve dynamic balance and coordination between the upper and lower extremity muscles (4).

The anterior cruciate ligament (ACL) plays a vital role in knee stability by connecting the femur and tibia, thereby preventing excessive forward translation of the tibia (5). Injuries to the ACL, particularly among athletes, are common and often necessitate surgical intervention in the form of ACL reconstruction (ACLR), which serves as the standard treatment to restore joint function and enable return to physical activity (6). A lack of core and hip muscle strength, particularly in the abductors and external rotators, contributes to the development of dynamic knee valgus, a biomechanical position that increases the risk of non-contact ACL injuries (7). ACL injuries are often linked to excessive flexion and abduction movements, with factors such as neuromuscular control, anatomical structure, hormonal influences, and biomechanical alignment playing significant roles in injury occurrence (16). Sports-related injuries account for a large proportion of ACL injuries, with 34.9% resulting from sports, 30.2% from industrial accidents, and 28.6% from traffic incidents (9). Notably, over 50% of ACL injuries in team-ball sports occur without direct contact, and females are at a higher risk of sustaining such injuries compared to males (10).

Despite advances in surgical techniques, approximately 37% of individuals undergoing ACL reconstruction fail to return to their previous level of physical activity, and the likelihood of re-injury post-reconstruction exceeds 30% (12, 13, 14). For athletes returning to sports following ACLR, there remains a 1 in 4 chance of sustaining a secondary injury, underscoring the need for effective rehabilitation strategies to mitigate these risks (15). The single-leg squat (SLS) is a widely used functional assessment tool to evaluate lower extremity alignment and detect movement pattern abnormalities in the trunk, pelvis, and legs (17). Its use is particularly significant in predicting knee injuries such as ACL tears and patellofemoral pain syndrome (18). The SLS is functionally relevant as the single-limb stance position frequently occurs in daily activities, including walking and running, as well as in sports like hockey, football, and skiing (2). Performance in weight-bearing activities such as the SLS is influenced by a combination of muscle strength, flexibility, and skeletal alignment, which are critical for movement efficiency and joint protection (20).

Within the context of ACLR rehabilitation, assessing core strength through functional tests such as the SLS and plank test provides valuable insights into muscle coordination and recovery progress. However, despite the prevalence of ACL injuries and the importance of core strength in functional recovery, there is limited research exploring the relationship between core strength and single-leg squat performance in individuals who have undergone ACL reconstruction, particularly within the Pakistani population. This significant gap in the literature highlights the need for further exploration of this topic to enhance understanding and inform rehabilitation strategies. Therefore, the objective of this study is to assess core strength and its impact on single-leg squat performance in individuals post-ACL reconstruction, providing valuable data to bridge this gap in knowledge and contribute to improved clinical outcomes.

METHODS

The study utilized a descriptive cross-sectional design conducted over a six-month period, from June 2023 to December 2023, following the formal approval of the research topic. Data collection was carried out at Ghurki Trust and Teaching Hospital (GTTH) using a non-probability purposive sampling technique. All eligible participants meeting the inclusion criteria within the study timeframe were included through a census approach, resulting in a total sample size of 72 participants (21). Inclusion criteria required participants to have a history of unilateral ACL injury and reconstruction (22), with completion of rehabilitation and medical clearance for all physical activities (22). Participants were aged between 18 and 40 years (23), had full knee range of motion and a stable graft (24), and had undergone reconstruction using a hamstring tendon autograft (25). Exclusion criteria ruled out individuals with multiple ACL

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reconstruction surgeries or recurrent knee problems (25), injuries to the trunk or lower extremities following surgery (25), or pain in any body region during testing that hindered test performance (23).

Before participation, informed consent was obtained from all individuals after explaining the study's purpose and procedures. Participants were provided a detailed description of the clinical testing, and their data was recorded accordingly. Core strength was assessed using the plank test (26). During the test, participants positioned themselves face down, supporting their bodies on their forearms and feet, ensuring a straight and neutral alignment of the legs and torso. Proper alignment was monitored using a wooden dowel placed lengthwise along the participant's back to provide proprioceptive feedback. Participants were instructed to maintain the plank position as long as possible. Improper form was corrected once through verbal feedback; if the participant failed to correct or reverted to improper form, the timer was stopped. The timer also ceased if participants voluntarily terminated the test due to fatigue.

The single-leg squat test (SLST) was used to evaluate dynamic movement and lower limb alignment. Participants stood on a 20-centimeter box with their arms extended forward while keeping the free leg positioned behind them to facilitate assessment of pelvic tilt and hip adduction. One of the investigators demonstrated the procedure to ensure clarity. Participants performed squats by flexing their knee to approximately 60 degrees in a controlled manner, at a pace of one squat every two seconds. Three practice attempts were allowed for each limb before the actual trials. Each limb underwent three trials, graded using a three-point ordinal scale: "good," "fair," or "poor." The grading criteria were based on the presence or absence of ipsilateral trunk leaning, pelvic tilt or rotation, hip adduction or internal rotation, dynamic knee valgus, and overall balance stability, following the methodology established by Crossley et al. A "poor" rating was assigned if one or more criteria were not met in all repetitions. A "fair" rating was given if one to three criteria were met, while a "good" rating required meeting at least four of the five criteria consistently.

The collected data were entered and analyzed using the Statistical Package for Social Sciences (SPSS version 24). Continuous variables were presented as mean and standard deviation, while categorical variables were expressed as frequency and percentages. Data visualization was achieved through graphs and charts. Ethical approval for the research was obtained from the ethical board of Lahore College of Physical Therapy (LCPT) with reference number DPT/ERB/12 dated 15-05-2023. Confidentiality of participants was maintained by securing data on a password-protected laptop, ensuring anonymity throughout the process.

To minimize observer bias and inter-rater variability during grading, standardized protocols and objective criteria were strictly followed throughout the assessment process. All investigators involved in grading were trained and calibrated using the same instructional guidelines and demonstrations to ensure consistency in evaluations. A pilot testing phase was conducted prior to data collection to align grading practices among the assessors. Furthermore, the assessments were video-recorded, allowing for independent review and cross-validation by multiple observers to enhance reliability. Discrepancies in grading were resolved through consensus among the investigators to ensure uniformity in the final ratings. These measures aimed to enhance the reliability and validity of the study outcomes.

RESULTS

The demographic and physical characteristics of the participants were thoroughly analyzed, highlighting important insights into the study population. Participants' ages ranged from 18 to 38 years, with a mean age of 26.49 years and a standard deviation of 5.151, representing a relatively young cohort. The gender distribution was predominantly male, with 93.1% (67 participants) being male and only 6.9% (5 participants) being female, indicating a significant gender imbalance. Participants' weights varied widely, ranging from 55 to 147 kilograms, with a mean weight of 77.08 kilograms and a standard deviation of 14.15, showing considerable variation in body mass. Height measurements ranged from 160 cm to 198.1 cm, with a mean height of 1.742 meters and a standard deviation of 7.26 cm. The Body Mass Index (BMI) ranged from 17.84 to 49.29, with a mean BMI of 25.45 and a standard deviation of 4.67, reflecting a broad spectrum of body composition among participants.

Table: Showing frequency among SLS grading among patients

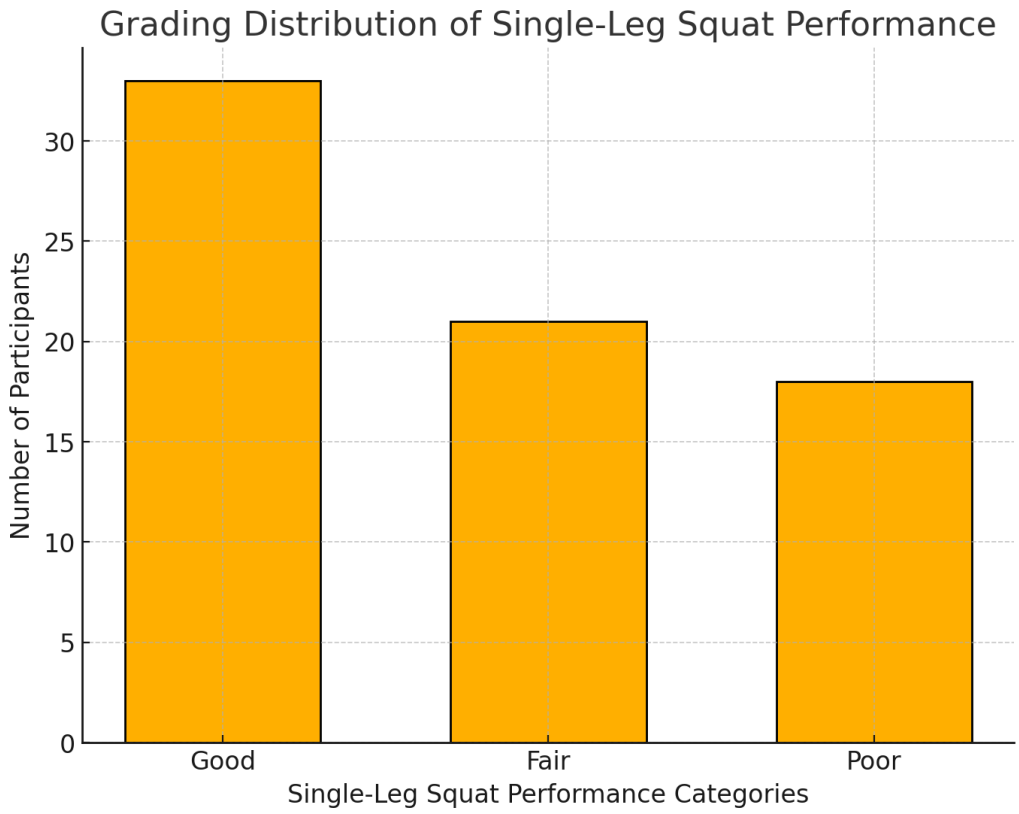
	Frequency	Percentage
Good	33	45.8
Fair	21	29.5
Poor	18	25.0

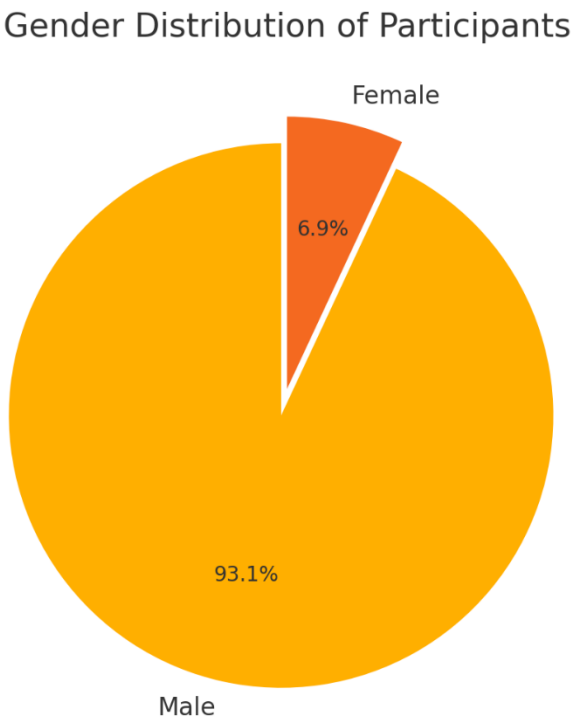
Core strength assessment using plank hold times revealed significant variability among participants. Plank hold durations ranged from a minimum of 7 seconds to a maximum of 130 seconds, with a mean hold time of 51.58 seconds and a standard deviation of 30.47, demonstrating a wide range of core strength and endurance levels within the sample. Performance in the single-leg squat test was graded across three categories: "Good," "Fair," and "Poor." Of the participants, 45.8% (33 individuals) achieved a "Good" grade, 29.5% (21 individuals) were rated as "Fair," and 25.0% (18 individuals) received a "Poor" grade. These findings indicate that nearly half of the participants demonstrated strong functional performance, while the remainder showed moderate to lower capabilities.

Table 2: Plank Hold Time Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Plank Hold	72	7	130	51.58	30.47

The relationship between core strength, as measured by plank hold times, and single-leg squat performance appeared positive, with the majority of participants achieving higher performance levels in both tests. The mean plank hold time of 51.58 seconds, coupled with 45.8% of participants receiving a "Good" grade in single-leg squat performance, suggests a positive association between core strength and lower limb functional capabilities. These results align with the study objective of examining core strength and functional performance in individuals following ACL reconstruction.





DISCUSSION

This study explored the relationship between core strength and single-leg squat biomechanics and functional outcomes in individuals following anterior cruciate ligament (ACL) reconstruction. The findings indicated a positive association between core strength, as measured by plank hold duration, and single-leg squat performance, demonstrating the significance of core stability in enhancing functional movement post-ACL reconstruction. These results emphasize the importance of targeted core strengthening exercises in rehabilitation programs to improve dynamic balance, coordination, and lower extremity function, ultimately reducing the risk of re-injury and enhancing recovery outcomes. The positive relationship observed between plank hold performance and single-leg squat outcomes aligns with the broader understanding of the role of core strength in maintaining dynamic balance and influencing lower extremity kinematics during functional tasks. However, these findings contrast with prior studies that reported a lack of significant correlation between plank hold duration and specific kinematic measures such as the knee frontal plane projection angle during single-leg squats, underscoring the complexity of the interplay between core strength, neuromuscular control, and biomechanical function (2). This discrepancy highlights the multifaceted nature of core stability and its impact on functional movements, suggesting that other factors, such as muscle activation patterns and joint proprioception, may also play critical roles.

In agreement with this study's findings, previous research on core-stability training in patients post-ACL reconstruction demonstrated improvements in dynamic balance, coordination, and gait patterns, supporting the integration of core-focused exercises into rehabilitation protocols (5). Another study examining core stability tests and their relationship to single-leg squat performance in active females complemented the current findings by emphasizing that deficits in core stability could influence neuromuscular control in the lumbopelvic-hip complex, thereby affecting lower extremity alignment and movement. These collective findings underscore the critical importance of incorporating dynamic core stability exercises into rehabilitation programs to address deficits that may predispose individuals to improper movement patterns and potential re-injury. Gender differences in core strength and lower extremity function, as observed in prior studies, provide additional context to the current findings. Research highlighting significantly lower core strength in females compared to males reinforces the need for tailored rehabilitation strategies to address gender-specific vulnerabilities. While this study did not explicitly focus on gender disparities, the predominantly male sample limits the generalizability of the findings to a more diverse population. Future research exploring gender-specific interventions may provide further clarity on optimizing rehabilitation outcomes (27).

The strengths of this study lie in its use of objective measures, such as the plank test and single-leg squat assessment, to evaluate core strength and functional performance. The inclusion of a standardized grading system for single-leg squat performance enhances the reliability of the results. However, the study is not without limitations. The small proportion of female participants resulted in an imbalance in gender representation, potentially influencing the applicability of the findings across different populations. Additionally, while the study successfully highlighted a positive relationship between core strength and single-leg squat performance, the lack of

advanced biomechanical analysis, such as motion capture or electromyography, limits the ability to explore the precise mechanisms underlying this relationship (28). Despite these limitations, this study contributes valuable insights into the role of core strength in functional recovery following ACL reconstruction. It provides a foundation for developing targeted rehabilitation protocols that incorporate core strengthening exercises to improve single-leg squat performance, enhance lower extremity function, and reduce injury risks. Future research should aim to include a more diverse population, employ advanced biomechanical tools, and explore additional factors influencing the relationship between core strength and functional outcomes to further refine rehabilitation strategies for individuals recovering from ACL reconstruction.

CONCLUSION

The findings of this study highlight that individuals who have undergone anterior cruciate ligament reconstruction and possess enhanced core strength demonstrate better performance in single-leg squat activities. This emphasizes the integral role of core stability in improving lower limb function and movement efficiency. The results support the incorporation of core strength training into rehabilitation and fitness programs as a key strategy to optimize functional recovery, enhance dynamic balance, and minimize the risk of re-injury or improper movement patterns. These insights contribute to advancing rehabilitation protocols for individuals recovering from ACL reconstruction.

AUTHOR CONTRIBUTIONS

Author	Contribution
Fatima Ali	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Rabia Rahim	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Misha	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Waqas Waheed	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Salwa Atta*	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published

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